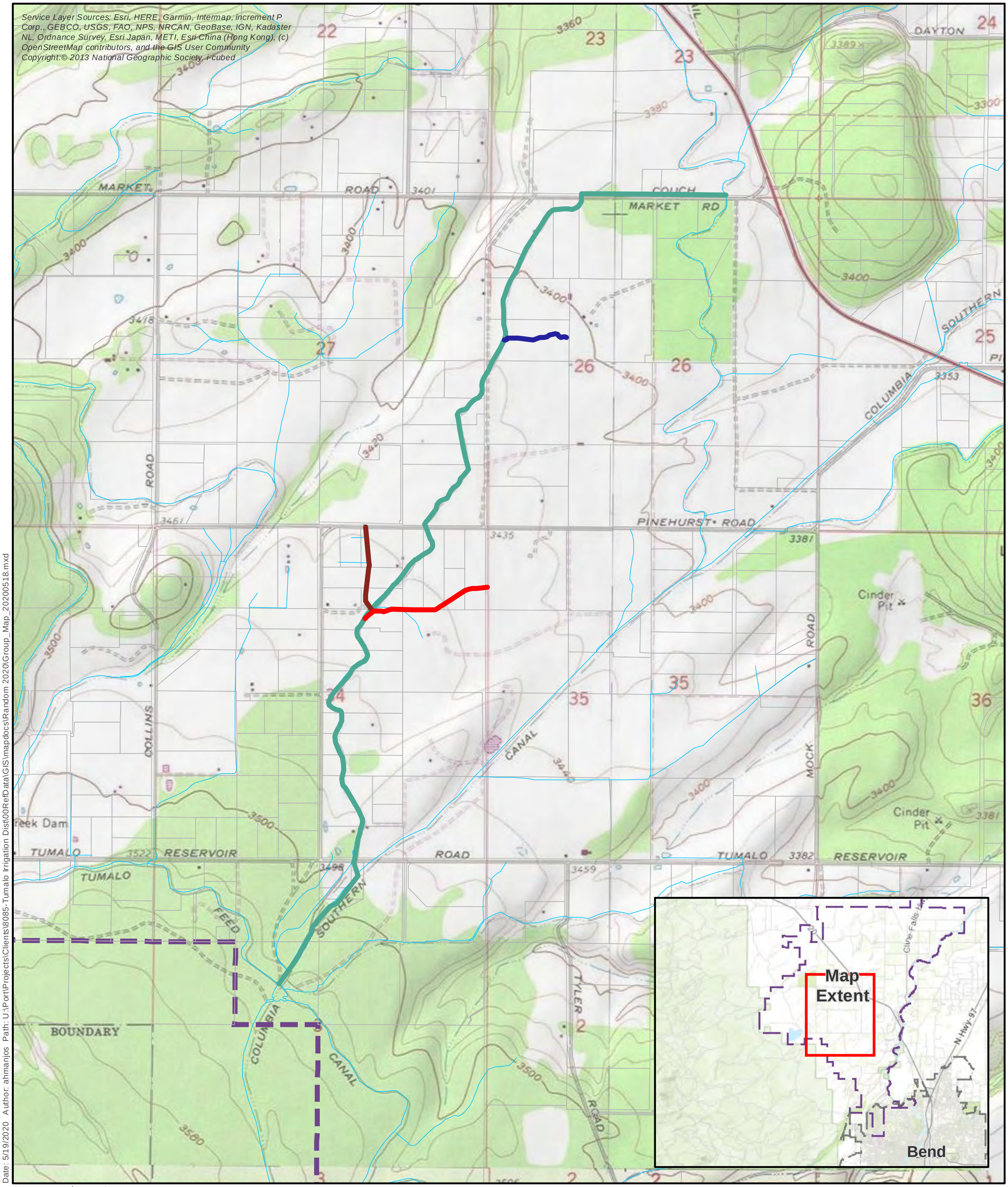
Attachment 1 - Site Map



Source: Deschutes County, Tumalo Irrigation District

Canal
Tax Lot
Service Area Boundary
Allen
Allen sub Lateral
Existing Pipe, PVC 8"
Allen sub Lateral

Reference Map

0 500 1,000 2,000 Feet
1 inch = 2,000 feet

Tumalo Irrigation District

WILLIAMS Becky S * WRD

From:	Lauren Reese <lauren@integratedwatersolutions.net>
Sent:	Thursday, June 04, 2020 2:43 PM
To:	WILLIAMS Becky S * WRD; 'Ken Rieck'; 'Chris Schull'
Cc:	WRD_DL_waterprojects
Subject:	RE: Deschutes Basin Flow Restoration - Group 3: Application completeness
Attachments:	TID-Deschutes-Basin-Flow-Restoration_ver05282020-submitted_rev.pdf; Attachment 3 - Matching Funds Documentation.pdf; Attachment 2 - Property Access Documentation Revised06042020.pdf; Attachment 1 - Site Map.pdf
Follow Up Flag:	Follow up
Flag Status:	Completed
Categories:	Hold

Dear Ms. Williams:

Thank you for the opportunity to provide more information and clarification. Below and attached you will find additional information and explanation to your questions:

1. After working with a landowner, a portion of this pipeline was consolidated into one pipeline rather than three portions that were originally described in the grant application. We simplified the language to clarify that this project is to pipe the Allen lateral as well as its two sublaterals. The text in the application is revised, as well as Attachment 1 – Site Map for clarification.
2. The properties listed in the table on Question 3 are all the tax lots that will have construction and disturbance activities. Those 3 tax lots are served by TID but they will have zero construction activity on them their existing system starts on the neighboring property. Thus, they are not listed in the table.
3. All land owners were recently notified about the project on April 20, 2020. I have revised Attachment 2 to include a sample of the letter that was sent out as well as the table that lists each landowner it was sent to.
4. We apologize for the omission. We have now checked both 14 (a) and (b) – and have included water right information for certificates 74146 and 74147.
5. We are currently applying for the OWEB Restoration Grant. I have included a screenshot of our in-progress application with a budget value OWEB contribution of $250,000 in a revised Attachment 3. Our application is due on July 27, 2020. We can also send confirmation # after our application is submitted.

Thank you for your consideration of the revised information above and attached. The only attachments revised were 1 – 3; I have included those as separate files. Please let me know if you would rather me submit all attachments in one PDF file as we did previously.

I can be made immediately available for any further clarifications or information needs.

Thank you,

From: WILLIAMS Becky S * WRD <Becky.S.Williams@oregon.gov>
Sent: Thursday, June 4, 2020 8:08 AM
To: Lauren Reese <lauren@integratedwatersolutions.net>; 'Ken Rieck' <ken@tumalo.org>; 'Chris Schull' <chris@tumalo.org>
Cc: WRD_DL_waterprojects <WRD_DL_waterprojects@oregon.gov>
Subject: Deschutes Basin Flow Restoration – Group 3: Application completeness

Dear Applicant,

Deschutes Basin Flow Restoration – Group 3

Thank you for submitting your Water Project Grant and Loan application. The Oregon Water Resources Department (Department) conducts an eligibility and completeness review for each application submitted for 2020 Water Project Grants and Loans funding opportunity (OAR 690-093-0060).

As a result of application completeness review, we identified the following missing element(s):

1. Section V, Question #2: Requirement to submit a Site Map

   The two site maps included as Attachment #1, both show the following pipelines: Allen lateral, Allen sub-lateral, and the **MacGinnis** Lateral. However, the Project description (see Section IV and VI, Question #5) reference the Allen Lateral, the Allen sub-lateral, and the **Columbia Southern lateral**. There is no mention of work being conducted on the MacGinnis Lateral in the application, nor does the Columbia Southern Lateral show up on the site plan.

   Request:
   Please address the above described discrepancy between the Project description (Sections IV and VI, Question #5) and the site maps.

2. Section V, Question #3

   The properties <u>17S 11E 03A0 01300</u>, <u>17S 11E 03A0 01500</u>, <u>17S 11E 03A0 00500</u> are shown on the Site Map with the Allen Lateral. The properties are not listed on the Table in Question #3.

   Request:
   Please address the above described discrepancy between the properties not listed on the Table in Question #3 and the site maps.

3. Section V, Question #4. Landowner Agreement

   For this funding opportunity there are specific statutory and regulatory requirements of ORS 541.666(4) and OAR 690-093-0070(1)(d) requiring evidence that landowners are aware of and agree to the proposal and are aware that monitoring information is a public record.

   The application includes a letter from Attorney Mark Reinecke attesting that, the existence and scope of the Carey Act irrigation canal easements, includes conversion of the irrigation canal to a pipeline within the scope of [the] easement. The Department will accept this legal opinion as sufficient to meet part of the landowner criteria for this funding opportunity.

   The application states that landowners are aware that monitoring, as part of the grant, is a matter of public record. However, no documentation was found to verify how or when landowners had been informed of the project and that any monitoring would be a matter of public record, and that the information had been provided to the entire list of property owners listed in Question #3.

   Request:
   Please provide verification describing how and when property owners have been informed that monitoring is a public record, or other evidence that they are aware of this requirement. This documentation should provide verification that all property owners listed in Question #3 were informed.

4. Section VI, Question #14 asks the applicant to "*Identify any water rights needed to <u>implement the proposed project</u> below. Check **all** of the following that apply and provide the information requested:*"

   Only option "a." is checked in the application form, indicating that the proposed project requires a new water right. The applicant states that an, "Allocation of Conserved Water transfer is required". This corresponds with the project description and is correct. However, "b" or "c" should have also been checked and the water rights involved in this project listed. Since the project proposed to utilize the Allocation of Conserved Water program, one must have water rights in order to conserve water, as part of the Allocation of Conserved Water program. Therefore, all involved water rights used for this project must be listed.

   Request:
   Please complete Question #14 to identify all current water rights which will be involved in this project.

5. Section IX Match Fund documentation and Attachment #3.
   The attachment showing the intention to apply for the OWEB grant shows the application deadline but does not show the dollar amount being sought.

   Request:
   Please provide verification of the amount of funding that the Tumalo Irrigation District is seeking in OWEB funding.

In order to maintain application eligibility please resubmit the entire application by email, ensuring that the above-mentioned item(s) are addressed. Please note, no additional revisions or attachments may be added to the application beyond the above-mentioned items(s)

In order to maintain application eligibility please email the above-mentioned item(s) to WRD_DL_waterprojects@oregon.gov no later than **5:00 pm on June 5, 2020**. If the information listed above is not received by the deadline the application will be deemed incomplete and it will not be forwarded to the Technical Review Team for scoring and ranking. If you have any questions about the please contact WRD_DL_waterprojects@oregon.gov.

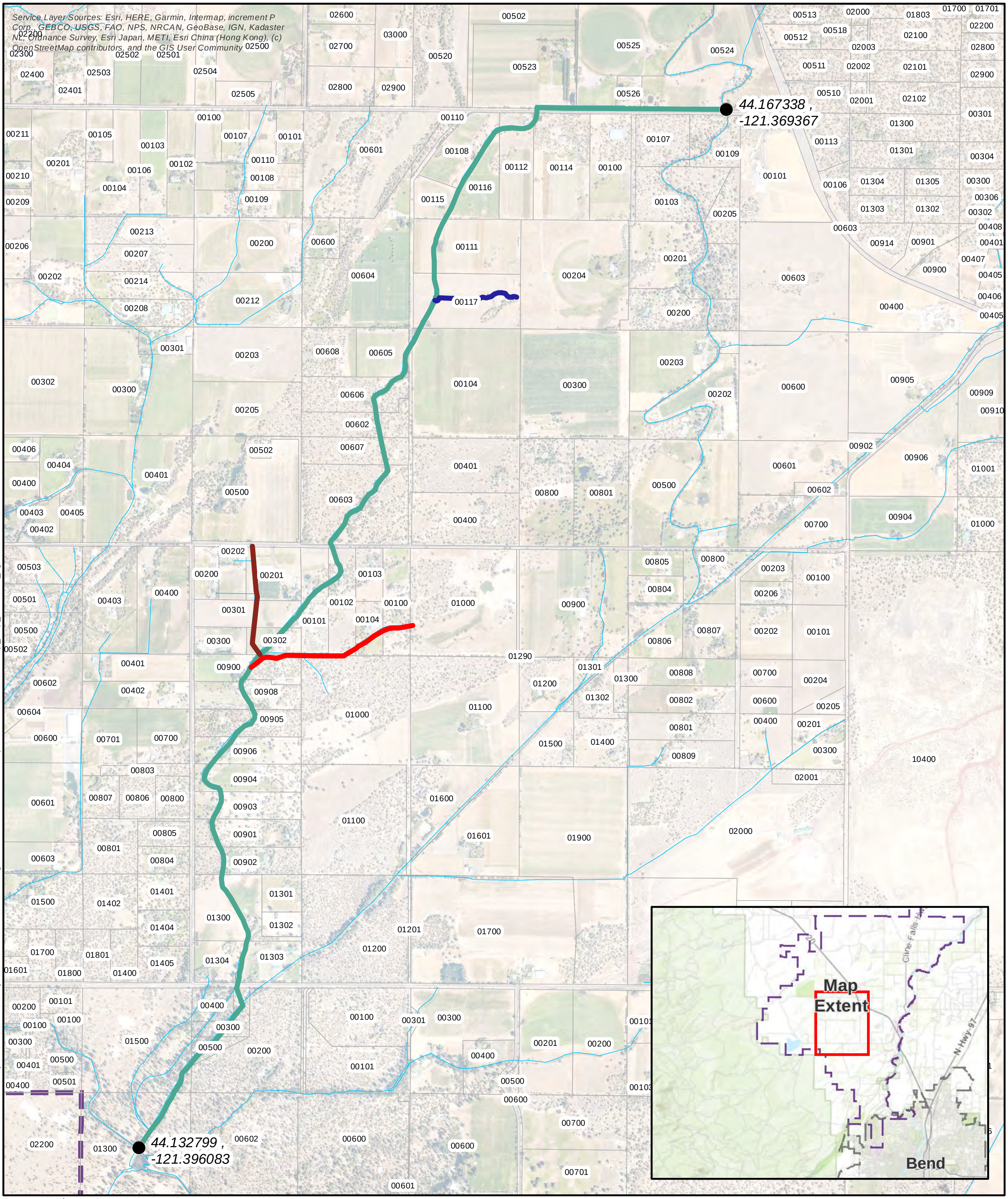
Thank you,
Becky

Rebecca Williams (she/her/hers)
GRANT PROGRAM COORDINATOR
Director's Office
Oregon Water Resources Department
725 Summer Street NE, Suite A Salem, OR 97301 | Phone 503-986-0869

OREGON WATER RESOURCES DEPARTMENT

Integrity | Service | Technical Excellence | Teamwork | Forward-Looking

Attachment 1 - Site Map



Source: Deshutes County,
Tumalo Irrigation District

Canal
Tax Lot
Service Area Boundary
Allen
Allen sub Lateral
Existing Pipe, PVC 8"
Allen sub Lateral

0 500 1,000 2,000 Feet
1 inch = 1,536 feet

Reference Map

Tumalo
Irrigation District

BRYANT
LOVLIEN
& JARVIS
EST. 1915
ATTORNEYS AT LAW

ATTORNEYS

Neil R. Bryant
Sharon R. Smith
John D. Sorlie
Mark G. Reinecke
Melissa P. Lande
Paul J. Taylor
Jeremy M. Green
Melinda Thomas
Heather J. Hansen
Garrett Chrostek
Danielle Lordi
Alan R. Dale
Lindsay E. Gardner

May 14, 2018

Becky Williams
Oregon Water Resources Department
725 Summer Street, NE, Suite A
Salem, OR 97301

RE: Grant Application for Tumalo Irrigation District Phase VI Piping Project
Areas Affected by the Piping Project and Legal Authority for Activities in those Areas

Dear Becky:

Pursuant to your request, the purpose of this letter is to provide the Oregon Water Resources Department ("Department") with information about the areas affected by Tumalo Irrigation District's ("Tumalo") Phase VI piping project grant application and the sources of Tumalo's legal authority for operations, maintenance, and improvement of its canals and laterals in the affected areas.

Tumalo is an Oregon irrigation district organized and existing under Oregon Revised Statutes, Chapter 545. For nearly 120 years, Tumalo has been a steward of critical water resources in Central Oregon. It holds certificated water rights-including rights to live flow and storage water-in a trust relationship with its patrons, and delivers water proportionately to patrons who hold water rights within Tumalo's boundaries.

Tumalo's easement rights with respect to its canals and laterals in the affected areas originate from the Carey Act (Law of August 18, 1894, Ch. 301, § 4, 28 Stat. 422 (1894), 43 USCA § 641 (2000)) which encouraged settlement of the western United States by allowing private companies to erect irrigation systems. The Carey Act process utilized two contracts, one between the State of Oregon and the contractor who developed the system and one between the contractor and the entryman, also known as the settlor.

The related federal Right of Way Act of 1891 states:

> 'The right of way through the public lands and reservations of the United States is granted to any canal ditch company, irrigation or drainage district formed for the purpose of irrigation or drainage, and duly organized under the laws of any State or Territory, and which shall have filed, or may hereafter file, with the Secretary of the Interior a copy of its articles of incorporation or, if not a private corporation, a copy of the law under which the same is formed and

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591 SW Mill View Way, Bend, OR 97702 | P 541.382.4331 | F 541.389.3386 | bljlawyers.com

due proof of its organization under the same, to the extent of the ground occupied by the water of any reservoir and of any canals and laterals and fifty feet on each side of the marginal limits thereof, and, upon presentation of satisfactory showing by the applicant, such additional rights of way as the Secretary of the Interior may deem necessary for the proper operation and maintenance of said reservoirs, canals, and laterals; also the right to take from the public lands adjacent to the line of the canal or ditch, material, earth, and stone necessary for the construction of such canal or ditch. . .".

43 U.S. Code Section 946.

The existence and scope of Carey Act irrigation canal easements have been confirmed in Federal Court for the District of Oregon where Judge Ann Aiken ruled that the irrigation district in that case possessed irrigation rights of way pursuant to the Carey Act and related federal and state statutes and "conversion of [an] irrigation canal to a pipeline is encompassed within the scope of [the] easement." S*walley Irrigation District v. Gary Clement Alvis, et al,* U.S. Dist. Ct. for Oregon, Civ. No. 04-1721-AA (2008).

Oregon law provides additional support for Tumalo's right to pipe its canals. The Carey Act contract between the State of Oregon and the Contractor often anticipated that the Contractor (subsequently the Irrigation District) would promulgate rules and regulations to manage the system. ORS 545.221 (c) authorizes districts to "Establish equitable bylaws, rules and regulations for the administration of the district and for the distribution and use of water among the landowners." Tumalo maintains such written rules and regulations.

Also, pursuant to ORS 545-221(1)(d), Oregon irrigation districts including Tumalo are authorized "to perform all acts necessary to fully carry out the purposes of the Irrigation District Law." Tumalo enacts policies to maintain and improve its delivery system to ensure its ability to provide water for its patrons while achieving compliance with state and federal laws. Finally, pursuant to ORS 545.287, irrigation districts in Oregon are authorized to construct, repair and maintain irrigation system improvements.

A copy of the Carey Act map for Tumalo Irrigation District is enclosed. The affected areas for Tumalo's Phase VI piping project include the following:

1. Tumalo Feed Canal
2. Tumalo owned laterals
    a. The Highline Lateral
    b. The Rock Springs Lateral
    c. The Steele Lateral
    d. The Lacy Lateral
    e. The Gill Lateral
    f. The Parkhurst Lateral

g. The Two Rivers Lateral

To summarize, the canals and laterals Tumalo Irrigation District seeks to pipe with grant funds provided by the State of Oregon and others are located within easements granted to Tumalo through federal and state legislation and related contracts. The *Swalley* federal court case confirmed that such canals and laterals can be piped even if the owner of the dominant estate objects.

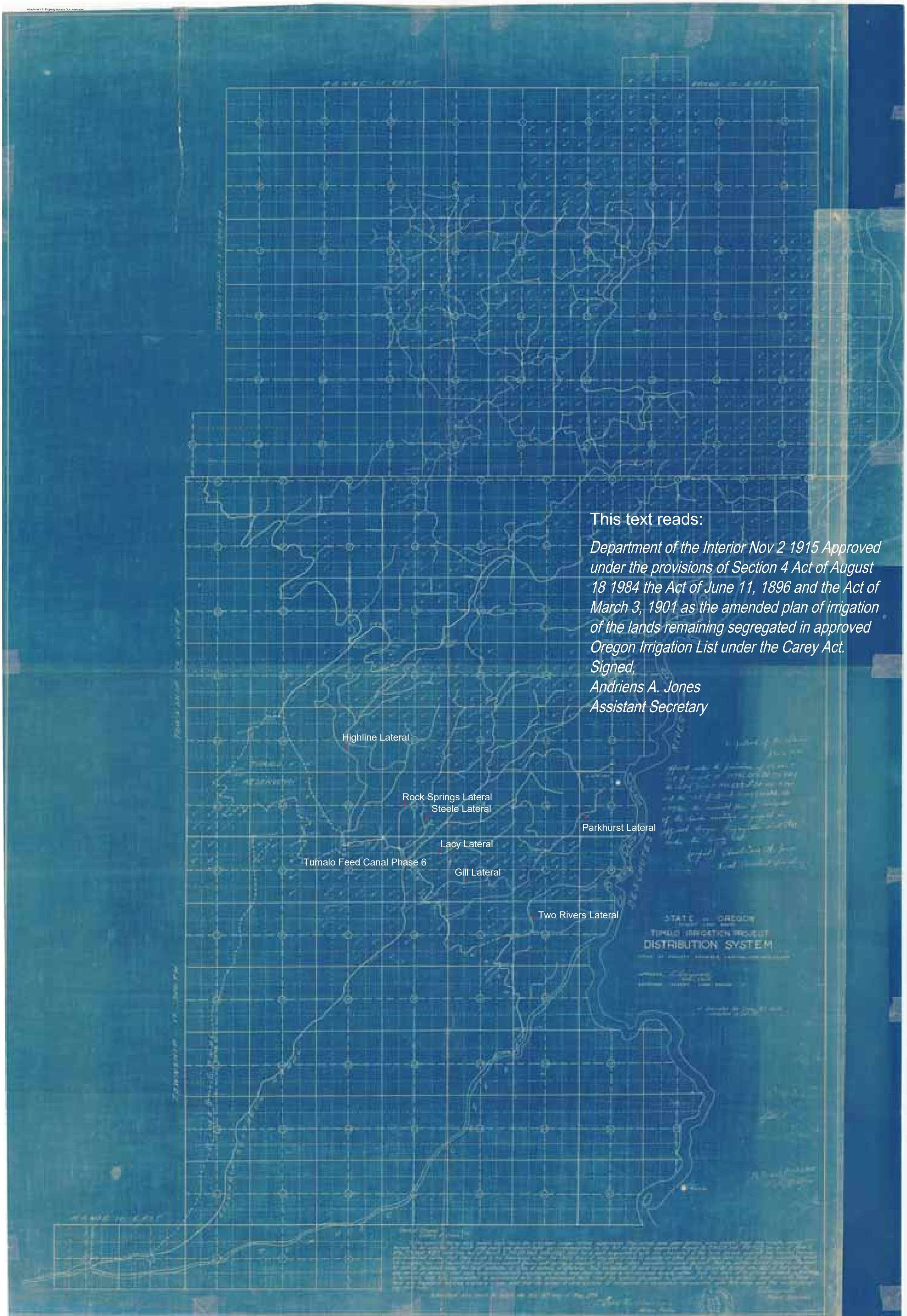
If you need any additional information, please let me know.

Sincerely,

Mark Reinecke

MARK G. REINECKE
Attorney for Tumalo Irrigation District

Enclosure
cc: Doug Woodcock
Tumalo Irrigation District


This text reads:
Department of the Interior Nov 2 1915 Approved under the provisions of Section 4 Act of August 18 1984 the Act of June 11, 1896 and the Act of March 3, 1901 as the amended plan of irrigation of the lands remaining segregated in approved Oregon Irrigation List under the Carey Act.
Signed,
Andriens A. Jones
Assistant Secretary
Highline Lateral
Rock Springs Lateral
Steele Lateral
Parkhurst Lateral
Lacy Lateral
Tumalo Feed Canal Phase 6
Gill Lateral
Two Rivers Lateral
STATE OF OREGON
TUMALO IRRIGATION PROJECT
DISTRIBUTION SYSTEM

The following letter was sent to landowners at these tax-lots on April 20, 2020. The letter clearly states that all or part of the project will occur on or adjacent to their property and that all grant monitoring information obtained on their property during this phase of piping will be public record.

Tax Map No. (e.g. 12S06W-12714)	**Tax Lot No.** (e.g. 100)	**Ownership Type (✓ One)**	**Property Owner of Record**
17S 11E 03A0	300	☐Public ☒Private	PETERSON, THOMAS & CLAUDIA
17S 11E 03A0	400	☐Public ☒Private	PETERSON, THOMAS & CLAUDIA
16S 11E 3400	1300	☐Public ☒Private	DE PERSIO, EDWARD & PAMELA
16S 11E 3400	1303	☐Public ☒Private	CAMPBELL REV TRUST, MARY BETH
16S 11E 3400	1304	☐Public ☒Private	PATTEE, BRIAN SCOTT & LISA STANO
16S 11E 3400	902	☐Public ☒Private	CALLEN, PAUL & BEVERLY
16S 11E 3400	901	☐Public ☒Private	MARTIN TRUST, CHARLES & SUSAN
16S 11E 3400	903	☐Public ☒Private	DINGERSON, ANN & KEVIN CORKERY
16S 11E 3400	904	☐Public ☒Private	MILLS, MAX E. & LORI A.
16S 11E 3400	906	☐Public ☒Private	REYNOLDS, MARK E.
16S 11E 3400	905	☐Public ☒Private	SCHWAB, GENEVIEVE L.
16S 11E 3400	908	☐Public ☒Private	WHITELAW, WILLIAM & ELOISE
16S 11E 3400	900	☐Public ☒Private	BARNES & COLE REV TRUST, EDWARD & JENNIFER
16S 11E 3400	1000	☐Public ☒Private	COLEMAN, NANCY D.
16S 11E 3400	104	☐Public ☒Private	NAUER, CHRISTIAN & LEAH KING & ZELIA FLANNERY
16S 11E 3400	100	☐Public ☒Private	MILLER, RONALD & DANAE BENNETT
16S 11E 3500	1000	☐Public ☒Private	PLEASANCE LIVING TRUST

Tax Map No. (e.g. 12S06W-12714)	**Tax Lot No.** (e.g. 100)	**Ownership Type (✓ One)**	**Property Owner of Record**
16S 11E 3400	302	☐Public ☒Private	VEZINA FAMILY TRUST
16S 11E 3400	301	☐Public ☒Private	KRUEGER REV LIVING TRUST, KEITH & REBECCA
16S 11E 3400	201	☐Public ☒Private	HANSEN, DAVID & HOLLY
16S 11E 3400	102	☐Public ☒Private	MAYER JR., PETER CARL
16S 11E 3400	101	☐Public ☒Private	PARKER, DAREN & WARNER, LYNN
16S 11E 2700	603	☐Public ☒Private	POWELL, KATHY
16S 11E 2700	606	☐Public ☒Private	HAMPTON REV. TRUST, JAMES
16S 11E 2700	607	☐Public ☒Private	KOEHLER FAMILY LLC
16S 11E 2700	602	☐Public ☒Private	KOEHLER FAMILY LLC
16S 11E 2700	605	☐Public ☒Private	ROLA REV TRUST, JEFFREY
16S 11E 2600	104	☐Public ☒Private	KOEHLER FAMILY LLC
16S 11E 2600	117	☐Public ☒Private	LEMON TRUST B, LEO W.
16S 11E 2600	111	☐Public ☒Private	MALONEY REV TRUST, MICHAEL & LINDA
16S 11E 2600	115	☐Public ☒Private	CLACK, ALLAN D.
16S 11E 2600	116	☐Public ☒Private	MOREHEN REV. TRUST, PATRICIA E.
16S 11E 2600	108	☐Public ☒Private	VAUGHN, BRYAN & GINA
16S 11E 2600	114	☐Public ☒Private	SMITH, EMILY
16S 11E 2600	112	☐Public ☒Private	SMITH, MICHAEL & BLOCKLEY, AMANDA
16S 11E 2300	523	☐Public ☒Private	MCCORMICK, WILLIAM P.
16S 11E 2300	525	☐Public ☒Private	SMITH, DEBRA D. & DALE A.

Tax Map No. (e.g. 12S06W-12714)	**Tax Lot No.** (e.g. 100)	**Ownership Type (✓ One)**	**Property Owner of Record**
16S 11E 2300	524	☐Public ☒Private	SMITH, RACHELLE DIANNE
16S 11E 2300	526	☐Public ☒Private	SMITH, DEBRA D. & DALE A.

TUMALO IRRIGATION DISTRICT

Wednesday, April 15, 2020

Paul Martin & Beverley Dee Callen
[redacted]

Re **Tumalo Irrigation District Piping**
Group 3 / Allen Lateral

Dear Paul and Beverley,

I hope this finds you well. As you may know Tumalo Irrigation District (TID) is in the process of planning Group 3 / Allen Lateral of the Tumalo Irrigation piping project that will begin in the fall of 2020.

Now that TID feels confident that the funding has solidified for this project, it is time for TID to start the design process. For those of you who own properties on the canals or will be impacted by the piping project over the next couple of weeks you will be seeing a surveyor accessing TID's easement on your properties.
After we have gathered this information it will be used in the design of the District's plans to pipe the Allen Lateral.
The District will set up a meeting to discuss the piping project at some point this summer at the Tumalo Community Church. TID will have a preliminary set of plans available for viewing during that meeting.

As part of the project may take place on or adjacent to your property, I would like to inform you that all grant monitoring information obtained on your property during this phase of piping will be public record.

Thank you

Chris Schull
District Watermaster

Office of Management and Budget (OMB) Fact Sheet

Summary Watershed Plan-Environmental Assessment Document For Tumalo Irrigation District – Irrigation Modernization Project Upper Deschutes Basin Subwatersheds: Buckhorn Canyon, Bull Creek, Lower Tumalo Creek, Laidlaw Butte-Deschutes River, Overturf Butte-Deschutes River, and Deep Canyon Dam-Deep Canyon Deschutes County, Oregon Oregon 2nd Congressional District	
Authorization	Public Law 83-566 Stat. 666 as amended (16 U.S.C. Section 1001 et. Seq.) 1954
Lead Sponsor	Deschutes Basin Board of Control and Tumalo Irrigation District (co-sponsor)
Proposed Action	The Tumalo Irrigation District (TID) – Irrigation Modernization Project is a large agricultural water conveyance efficiency project. The proposed action would modernize up to 1.9 miles of TID's irrigation canals and 66.9 miles of laterals.
Purpose and Need	The purpose of this project is to improve water conservation, water delivery reliability, and public safety on 68.8 miles of District-owned canals and laterals. Implementation of the proposed action would meet Public Law 83-566 Authorized Project Purpose (v), Agricultural Water Management, through irrigation water conservation, water quality improvement, and more reliable agricultural water supply. Federal action is needed to address the following watershed problems and resource concerns: water loss in District conveyance systems, water delivery and operations inefficiencies, instream flow for fish and aquatic habitat, and risks to public safety from open irrigation canals. Implementation of the proposed action would ensure agricultural production is maintained in an area undergoing rapid urbanization where public safety and environmental concerns necessitate federal action. The proposed action addresses seepage and evaporation loss and provides better-managed water diversions for farm use, increased agricultural production, improved streamflow for fish, aquatic, and riparian habitat, and increased public safety. These measures would serve to stretch the supply of water by increasing the reliability and efficiency of water delivered for irrigation while permanently reducing the amount of water diverted, and legally protecting saved water instream.
Description of the Preferred Alternative	Under the Preferred Alternative, 1.9 miles of canals and 66.9 miles of laterals in the TID system would be converted to high-density polyethylene (HDPE) gravity-pressurized buried pipe.
Project Measures	Under the Preferred Alternative, project sponsors would replace canals and laterals with HDPE pipe. Additionally, existing turnouts would be upgraded to pressurized delivery systems with additional turnouts added, and three pressure-reducing valves (PRV) would be installed to alleviate high pressures within the system. Construction of the Preferred Alternative would occur in seven project groups over the course of 11 years.

Resource Information

Subwatersheds	12-digit Hydrologic Unit Code	Latitude and Longitude	Subwatershed Size
Buckhorn Canyon	170703010804	44.248873, -121.356289	13,809 acres
Bull Creek	170703010603	44.190339, -121.420120	32,153 acres
Lower Tumalo Creek	170703010502	44.065108, -121.415720	17,238 acres

<table>
<tr><td>Laidlaw Butte-Deschutes River</td><td>170703010802</td><td>44.151316, -121.329905</td><td>42,749 acres</td></tr>
<tr><td>Overturf Butte-Deschutes River</td><td>170703010406</td><td>44.027097, -121.367571</td><td>31,374 acres</td></tr>
<tr><td>Deep Canyon Dam-Deep Canyon</td><td>170703010604</td><td>44.235075, -121.452157</td><td>31,928 acres</td></tr>
<tr><td>Subwatershed Total Size</td><td colspan="3">169,251 acres</td></tr>
<tr><td>Tumalo Irrigation District Size</td><td colspan="3">27,964 acres</td></tr>
<tr><td>Climate and Topography</td><td colspan="3">The Project is located in the rain shadow of the Cascade Mountain range. TID's annual average precipitation is 10-14 inches. The average high temperature for July is 82 degrees Fahrenheit, and the average low temperature for December is 23 degrees Fahrenheit. The land within TID is slightly undulating with an average elevation of 3,200 feet above mean sea level.</td></tr>
<tr><td rowspan="4">Land Use Tumalo Irrigation District (total 27,964 acres)</td><td colspan="2">Use</td><td>Acres</td></tr>
<tr><td colspan="2">Agriculture (irrigated acres)</td><td>7,417</td></tr>
<tr><td colspan="2">Developed</td><td>2,622</td></tr>
<tr><td colspan="2">Undeveloped</td><td>17,925</td></tr>
<tr><td rowspan="4">Land Ownership Tumalo Irrigation District (total 27,964 acres)</td><td colspan="2">Owner</td><td>Percentage</td></tr>
<tr><td colspan="2">Private</td><td>77% (21,530 acres)</td></tr>
<tr><td colspan="2">State-Local</td><td>7% (1,923 acres)</td></tr>
<tr><td colspan="2">Federal</td><td>16% (4,511 acres)</td></tr>
<tr><td>Population and Demographics</td><td colspan="3">The Preferred Alternative would occur within Deschutes County, Oregon. The population of Deschutes County was 166,622, or 56 people per square mile, in 2015. The population growth rate of the county between 2005 and 2015 was 14 percent. The population of the State of Oregon grew by about 8 percent in the same period.</td></tr>
<tr><td rowspan="4">Population and Demographics</td><td></td><td>Deschutes County</td><td>Oregon</td></tr>
<tr><td>Population 2015</td><td>166,622</td><td>3,939,233</td></tr>
<tr><td>Unemployment Rate</td><td>4.1%</td><td>4.1%</td></tr>
<tr><td>Median Household Income</td><td>$51,223</td><td>$51,243</td></tr>
<tr><td>Relevant Resource Concerns</td><td colspan="3">Resource concerns identified through scoping are water conservation and quality, groundwater, aquatic and fish resources, soil and geologic resources, visual resources, cultural resources, recreation, socioeconomics, wetlands, terrestrial wildlife, and vegetation resources.</td></tr>
<tr><td colspan="4">Alternatives</td></tr>
<tr><td>Alternatives Considered</td><td colspan="3">Eleven alternatives were considered; nine were eliminated from full analysis due to inconsistency with the purpose and need for action or due to cost, logistics, existing</td></tr>
</table>

	technology, social, or environmental reasons. The No Action Alternative, Canal Lining Alternative, and HDPE Pressurized Piping Alternative were analyzed in full.
No Action Alternative	Under the No Action Alternative, construction activities associated with the project would not occur and TID would continue to operate and maintain its existing canals and pipe system in their current condition. The need for the project would still exist; however, the District would only modernize its infrastructure on a project-by-project basis as public and public interest funding became available. This funding is not reasonably certain to be available under a project-by-project approach at the large scale necessary to modernize the District's infrastructure.
Proposed Action	Two action alternatives were considered. Under the Canal Lining Alternative, TID would line 65.1 miles of open canals and laterals with a geomembrane covered by shotcrete. Under the HDPE Pressurized Piping Alternative, TID would replace 1.9 miles of canals and 66.9 miles of laterals with gravity-pressurized HDPE buried pipe. The HDPE Pressurized Piping Alternative has been identified as the National Economic Development (NED) alternative and is also the Preferred Alternative.

Project Costs	**PL 83-566 Funds**		**Other Funds**		**Total**	
Construction	67%	$24,900,000	33%	$12,529,200	$37,429,200	86%
Engineering	75%	$1,332,700	25%	$444,100	$1,776,800	4%
SUBTOTAL COSTS	67%	$26,232,700	33%	$12,973,300	$39,206,000	90%
Technical Assistance	98%	$2,764,000	2%	$50,000	$2,814,000	6%
Relocation	Not Applicable					
Real Property Rights	Not Applicable					
Permitting	0%	$0	100%	$128,900	$128,900	0%
Project Administration	67%	$785,000	33%	$392,100	$1,177,100	3%
Annual Operation and Maintenance (O&M)	Not Applicable					
TOTAL COSTS	**69%**	**$29,781,700**	**31%**	**$13,544,300**	**$43,326,000**	**100%**

Mitigation, Minimization, and Avoidance Measures	Approximately 1,610 acres of land along open canals and laterals, which could provide seasonal wetland characteristics, would be converted to upland vegetation. Project canals and laterals are not considered jurisdictional wetlands by state or federal agencies. The wetland characteristics that could occur in the open canals and laterals have low function and the loss would be more than offset by gains in water quality and habitat function in the project area's natural riverine systems. The National Wetland Inventory (NWI) geographic information systems data (USFWS 2016) shows about 23 wetland features to sporadically occur adjacent to canals and laterals within the area of potential effect; however, these wetland features have not been field verified. Wetland determinations and/or delineations of areas adjacent to canals and laterals in areas where work would occur will be conducted prior to implementation of construction of each project group, and wetlands will be avoided to the extent practicable. Surveys for cultural resources have been completed for Project Group 1. In this portion of the project, archaeological resources have not been found and effects to aboveground resources have been addressed through completion of a Historic American Engineering Report. For Project Groups 2-7, cultural resource surveys and consultation between NRCS and the Oregon State Historic Preservation Office (SHPO) for compliance with Section 106 of the National Historic Preservation Act (NHPA) will be completed nearer to initiation of construction. Mitigation measures such as historical reports, brochures, interpretive signs,

	and content on the District's website will be identified prior to construction and completed concurrent with or after construction. For all project groups, ground disturbances would be limited to only those areas necessary and within rights-of-way to minimize effects on soil, vegetation, and land use. Construction activities would be confined to existing rights-of-way to avoid effects on agricultural lands. Where roads or access routes do not currently allow construction access, temporary access routes would be selected in a manner to minimize effects on vegetation and avoid the removal of trees and erosion. Stormwater best management practices would be employed during and after construction, and construction schedules would be determined to minimize disturbance to wildlife and the public. After construction, disturbed areas would be graded and replanted with a mix of native grasses and forbs to reduce the risk of erosion and spread of noxious weeds.						
Project Benefits							
Project Benefits	Implementation of the Preferred Alternative would improve water delivery reliability for TID's patrons, conserve 48 cubic feet per second of water for instream uses, reduce TID's operation and maintenance costs, reduce electricity costs from pumping, and improve public safety.						
Number of Direct Beneficiaries	TID serves 667 patrons, who would benefit from the project.						
Other Beneficial Effects-Physical Terms	Implementation of the Preferred Alternative would have minor to moderate, long-term, beneficial effects on agricultural water availability, water quality, and fish and wildlife habitat.						
Damage Reduction Benefits	**Project Group***						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Other - Reduced O&M	$5,000	$30,600	$9,300	$21,800	$19,300	$29,600	$11,000
Other - Power Cost Savings	$700	$49,500	$25,400	$58,400	$31,400	$133,100	$27,000
Other - Social Value of Carbon (Avoided Carbon Emissions)	$0	$19,200	$9,800	$23,900	$12,600	$53,600	$10,500
Water Conservation	$199,900	$170,000	$91,100	$101,000	$70,200	$279,500	$75,600
Total Quantified Benefits	$205,600	$269,300	$135,600	$205,100	$133,500	$495,800	$124,100
Benefit to Cost Ratio	1.00	1.34	1.28	1.69	1.36	1.41	2.67

*Project Group refers to groupings of canals and laterals that would undergo construction during the same period. Canals and laterals under each project group are as follows:
1. Tumalo Feed Canal, Kerns
2. Tumalo Res. Feed, Steele, Rock Springs, Highline, 2 Rivers, Parkhurst, Gill, Lacy
3. Allen, Allen Sublateral West, Allen Sublateral South, McGinnis Ditch
4. West Branch Columbia So. West, Beasley, Spaulding, N. Spaulding
5. Couch, West Couch, West Couch Sublateral East, Chambers (Lafores) Ditch, East Couch, Gainsforth
6. North Columbia So. West, Jewett, Conarn East, Putnam, West Branch Columbia So. East, Conarn, Phiffer, Hooker Creek, Hammond, North Hammond, Columbia Southern TFC to PRV, Columbia Southern PRV to Tail, North Columbia So. East
7. Hillburner, Gerking, Kickbush, West Branch Columbia So. South, Flannery Ditch, Tellin Ditch

Period of Analysis							
Project Group	1	2	3	4	5	6	7
Installation Period (years)	2	2	1	1	1	3	1

Project Life	100 years for each project group

Funding Schedule

Year—Project Group		PL 83-566	Other Funds	Total
2018, 2019	--1	$5,179,100	$1,756,800	$6,935,900
2020, 2021	--2	$5,505,300	$1,703,900	$7,209,200
2022	--3	$3,019,600	$943,600	$3,963,200
2023	--4	$3,559,400	$1,108,700	$4,668,100
2024	--5	$2,965,700	$927,200	$3,892,900
2025, 2026, 2027	--6	$9,287,200	$5,357,100	$14,644,300
2028	--7	$265,400	$1,747,000	$2,012,400

Environmental Effects

In portions of the project area where canals are considered historic features under Section 106 of the National Historic Preservation Act (NHPA), conversion of the canals would be mitigated through implementation of measures in consultation with the Oregon State Historic Preservation Office (SHPO). Consultation has been completed for Project Group 1. For Project Groups 2-7, cultural resource surveys and consultation between NRCS and SHPO for compliance with Section 106 of the NHPA will be completed nearer to initiation of construction in order to achieve no effects greater than moderate in intensity. Effects to below-ground archaeological resources are not anticipated for Project Groups 2-7, as surveys for Project Group 1 found no archaeological resources. Areas of potential ground disturbance for Project Groups 2-7 would be surveyed closer to construction and effects to archaeological resources will be avoided to the extent practicable in consultation with SHPO. As there would be no known effects to below-ground cultural resources, and changes to historic resources would not diminish resource integrity, effects to cultural resources would be negligible to moderate, for each project group.

Effects to aquatic species would result from the application of legal and permanent protection to conserved water seasonally released from Crescent Lake Dam that was previously volunteered by the District. Further, additional flows would be seasonally protected instream in Tumalo Creek. Three federally-listed species may occur in the area potentially affected by the project; bull trout, steelhead, and Oregon spotted frog. There would be no effect from the proposed action on bull trout or steelhead due to the timing of increased streamflow resulting from project actions and the location of bull trout and steelhead populations being at the very downstream end of where effects could be detectable. Any effects to Oregon spotted frog would be entirely beneficial. Overall, the presence (and legal protection) of conserved water from the proposed action would serve to benefit aquatic species and their habitat, thus the effects of the project on all aquatic species would be minor to moderate, and beneficial in the long term.

The proposed action will result in a total of approximately 200,000 cubic yards of soil disturbance during the 11-year construction period of the Preferred Alternative. Soil disturbances would be minor, as these effects would be short-term and localized to small portions of the larger project area over an 11-year construction period. Effects would be further minimized through implementation of soil stabilization measures, such as the preservation of vegetation when possible and re-vegetating disturbed areas after construction.

The Preferred Alternative would have a negligible effect on land use, as property ownership and existing use of land would not change. It is anticipated that the proposed action will encourage and promote agricultural sustainability in the watershed through improved irrigation water reliability.

As the proposed action would eliminate drowning risk from open canals, the project would have minor, and long-term effects on public safety; these effects would be entirely beneficial.

Effects to recreation from the proposed action would be minor in the short-term, as construction may temporarily preclude or limit dispersed and dedicated recreational opportunities during project construction. After construction, effects to both river- and land-based recreation would be negligible as the project would create visual and water level changes but would not change the quality of the recreational experience in a quantifiable way.

Of the 27,964 acres within the TID boundary, construction of the Preferred Alternative would temporarily disturb a total of approximately 167 acres of vegetation. Since the project would be completed over an 11-year construction period, only a portion of these effects would be evident at any one time. Long-term vegetation changes would occur over less than 1 percent of the District. Further, mitigation measures such as seeding all exposed areas with native grasses and forbs would be implemented. At project completion, about 44 acres of previously-open canals and laterals would be converted to upland vegetation over the buried pipes. Since effects to vegetation would be localized, would occur over a relatively small area, and all disturbed vegetated areas would be revegetated, effects to vegetation would be minor.

Overall, the visual change from canal to buried pipe would be expected to have a minor effect because there would be short-term visual changes during construction, and the long-term effects would be a vegetated corridor that would blend in with the natural landscape following revegetation.

Effects on surface water hydrology and water quality would vary in intensity depending on the stream reach, and none would be adverse. The following waterbodies would experience minor to moderate, long-term beneficial effects to hydrology and water quality: Crescent Creek, the Little Deschutes River, Tumalo Creek, and the Deschutes River downstream from the confluence with the Little Deschutes River (RM 192.5) to Lake Billy Chinook (RM 120). Because all effects to surface water resources would be beneficial, there would be no adverse effects to surface water resources. Since the reduction in seepage to groundwater realized from the piped canals would be reduced by increased groundwater recharge via improved streamflows upgradient from the proposed action, effects to groundwater would be negligible.

Effects to wetlands, floodplains, and riparian areas would be minor, as there are no wetland features in the canals or laterals, effects to any adjacent wetlands would be avoided or mitigated, and riparian and wetland areas downstream of the project would benefit from the protection and addition of instream flows.

Effects to terrestrial wildlife would be minor because there would be small, localized changes in wildlife populations and their habitats due to construction disturbance; however, these changes would be of little consequence to any populations or their habitats due to abundance of species and their habitat in the area. As project groups would be constructed sequentially over an 11-year period, terrestrial wildlife would have ample time to adjust and find new water sources and habitats as open canals are converted to buried pipe.

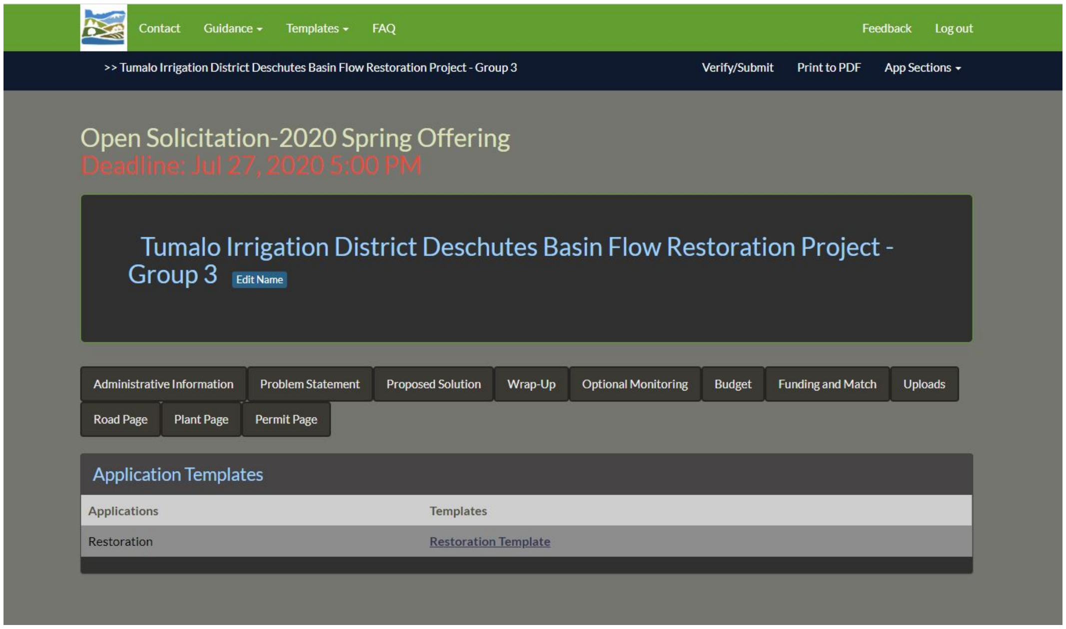
There would be no effects from the proposed action to designated Wild and Scenic rivers.

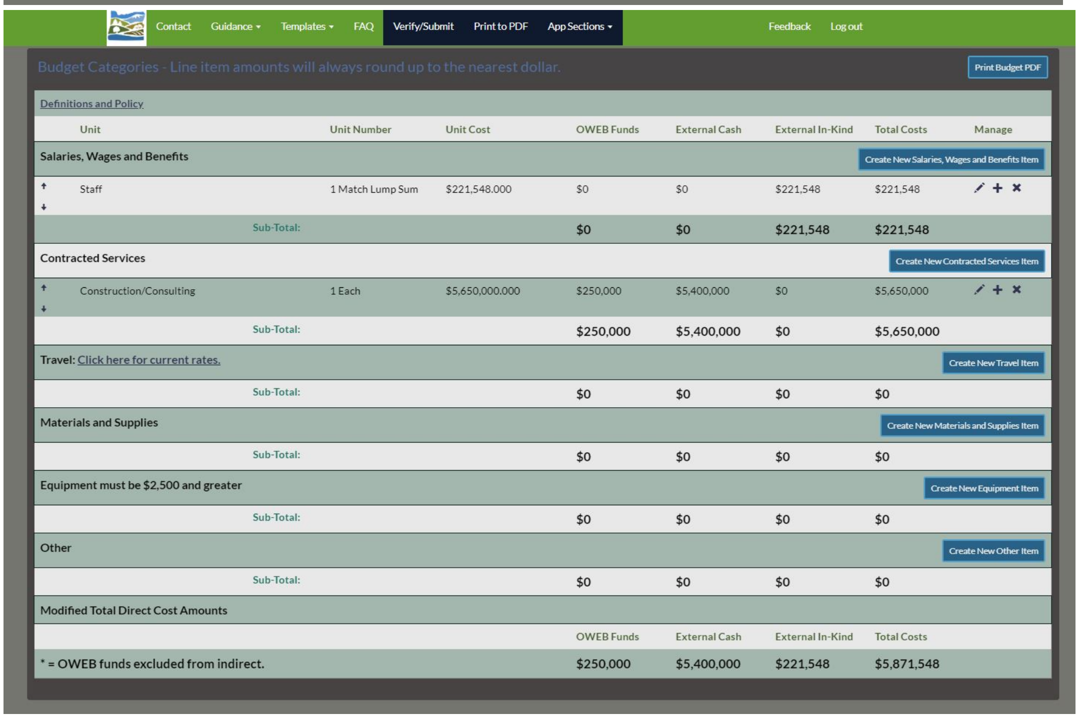
Major Conclusions	Implementation of the Preferred Alternative would improve water delivery reliability for farmers, reduce water loss to seepage and evaporation in District infrastructure, enhance fish and aquatic habitat through greater instream flows, and improve public safety while supporting agriculture and improving the environmental quality of rivers and tributaries in the area of potential effect.
Areas of Controversy	There have been no areas of controversy identified.
Issues to be Resolved	None
Evidence of Unusual Congressional or Local Interest	Comments on the Plan-EA and/or Preliminary Investigative Report were received from one state representative (Knute Buehler, District 54), one municipality (City of Bend), four state agencies through the Regional Solutions Program/Oregon Governor's Office (Oregon Department of Environmental Quality, Oregon Department of Transportation, Oregon Department of Fish and Wildlife, and Oregon Water Resources Department), two federal agencies (United States Fish and Wildlife Service and United States Forest Service-Deschutes National Forest), and local non-governmental organizations and individuals.

Compliance	Is this report in compliance with executive orders, public laws, and other statues governing the formulation of water resource projects? Yes _X_ No____

Tumalo Irrigation District

Pictured below are screenshots from the OWEB portal showing our draft application in process and is due on July 27, 2020.





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Budget Categories - Line item amounts will always round up to the nearest dollar.

Print Budget PDF

Definitions and Policy

Unit	Unit Number	Unit Cost	OWEB Funds	External Cash	External In-Kind	Total Costs	Manage
Salaries, Wages and Benefits							Create New Salaries, Wages and Benefits Item
Staff	1 Match Lump Sum	$221,548.000	$0	$0	$221,548	$221,548	
Sub-Total:			$0	$0	$221,548	$221,548	
Contracted Services							Create New Contracted Services Item
Construction/Consulting	1 Each	$5,650,000.000	$250,000	$5,400,000	$0	$5,650,000	
Sub-Total:			$250,000	$5,400,000	$0	$5,650,000	
Travel: Click here for current rates.							Create New Travel Item
Sub-Total:			$0	$0	$0	$0	
Materials and Supplies							Create New Materials and Supplies Item
Sub-Total:			$0	$0	$0	$0	
Equipment must be $2,500 and greater							Create New Equipment Item
Sub-Total:			$0	$0	$0	$0	
Other							Create New Other Item
Sub-Total:			$0	$0	$0	$0	
Modified Total Direct Cost Amounts							
			OWEB Funds	External Cash	External In-Kind	Total Costs	
* = OWEB funds excluded from indirect.			$250,000	$5,400,000	$221,548	$5,871,548	

Tumalo Irrigation District
Irrigation Modernization Project

Watershed Plan-Environmental Assessment

August, 2018

United States Department of Agriculture, Natural Resources Conservation Service – Lead Federal Agency in cooperation with the Deschutes Basin Board of Control and Tumalo Irrigation District

Prepared by Farmers Conservation Alliance

Watershed Plan-Environmental Assessment for the Tumalo Irrigation District - Irrigation Modernization Project

Lead Agency: United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Oregon

Sponsoring Local Organization (SLO): Deschutes Basin Board of Control (DBBC) (lead sponsor) and Tumalo Irrigation District (TID) (co-sponsor)

Authority: This Watershed Plan-Environmental Assessment (Plan-EA) has been prepared under the Authority of the Watershed Protection and Flood Prevention Act of 1954 (Public Law 83-566). The Plan-EA has been prepared in accordance with the National Environmental Policy Act (NEPA) of 1969, Public Law 91-190, as amended (42 United States Code [U.S.C.] 43221 et seq.).

Abstract: This document is intended to fulfill requirements of the NEPA and to be considered for authorization of Public Law 83-566 funding of the Tumalo Irrigation District – Irrigation Modernization Project (Project). The Project seeks to improve water conservation, water delivery reliability, and public safety on up to 68.8 miles of canals and laterals in Oregon's Deschutes Basin. The Project would include converting 68.8 miles of TID's canals and laterals to a buried and pressurized pipeline. Total estimated Project costs are $43,326,000, of which $13,544,300 would be paid by the sponsors and other non-federal funding sources. The estimated amount to be paid through NRCS Public Law 83-566 funds is $29,781,700.

Watershed Agreement
between the
Deschutes Basin Board of Control
(Referred to herein as the lead sponsor)
and the
Tumalo Irrigation District
(Referred to herein as the co-sponsor)
and the
U.S. Department of Agriculture,
Natural Resources Conservation Service
(Referred to herein as NRCS)

Whereas, application has heretofore been made to the Secretary of Agriculture by the sponsors for assistance in preparing a plan for works of improvement for the Tumalo Irrigation District - Irrigation Modernization Project, State of Oregon, under the authority of the Watershed Protection and Flood Prevention Act, as amended (16 U.S.C. Sections 1001 to 1008, 1010, and 1012); and

Whereas, the responsibility for administration of the Watershed Protection and Flood Prevention Act, has been assigned by the Secretary of Agriculture to NRCS; and

Whereas, there has been developed through the cooperative efforts of the sponsors and NRCS a watershed project plan and environmental assessment for works of improvement for the Tumalo Irrigation District - Irrigation Modernization Project, State of Oregon, hereinafter referred to as the watershed project plan or plan, which plan is annexed to and made a part of this agreement.

Now, therefore, in view of the foregoing considerations, the Secretary of Agriculture, through NRCS, and the sponsors hereby agree on this watershed project plan and that the works of improvement for this project will be installed, operated, and maintained in accordance with the terms, conditions, and stipulations provided for in this plan and including the following:

1. Term. The term of this agreement is for the installation period and evaluated life of the project (100 years) and does not commit NRCS to assistance of any kind beyond the end of the evaluated life.

2. Costs. The costs shown in this plan are preliminary estimates. Final costs to be borne by the parties hereto will be the actual costs incurred in the installation of works of improvement.

3. Real Property. The sponsors will acquire such real property as will be needed in connection with the works of improvement. The amounts and percentages of the real property acquisition costs to be borne by the sponsors and NRCS are as shown in the cost-share table in Section 5 hereof.

The sponsors agree that all land acquired for measures, other than land treatment practices, with financial or credit assistance under this agreement will not be sold or otherwise disposed of for the evaluated life of the project except to a public agency that will continue to maintain and operate the development in accordance with the operation and maintenance (O&M) agreement.

4. Uniform Relocation Assistance and Real Property Acquisition Policies Act. The sponsors hereby agree to comply with all of the policies and procedures of the Uniform Relocation Assistance and Real Property Acquisition Policies Act (42 U.S.C. Section 4601 et seq. as further implemented through regulations in 49 Code of Federal Regulations [CFR] Part 24 and 7 CFR Part 21) when acquiring real property interests for this federally assisted project. If the sponsors are legally unable to comply with the real property acquisition requirements, it agrees that, before any federal financial assistance is furnished, it will provide a statement to that effect, supported by an opinion of the chief legal officer of the state containing a full discussion of the facts and law involved. This statement may be accepted as constituting compliance.

5. Cost-share for Watershed Project Plans. The following table will be used to show cost-share percentages and amounts for watershed project plan implementation.

Cost-share Table for Watershed Operation or Rehabilitation Projects					
	NRCS		Sponsors		Total
Works of Improvement	**Percent**	**Cost**	**Percent**	**Cost**	**Cost**
Cost-Sharable Items[1/]					
Agricultural Water Management	67%	$24,900,000	33%	$12,529,200	$37,429,200
Sponsors Engineering Costs	75%	$1,332,700	25%	$444,100	$1,776,800
Subtotal: Cost-Sharable Costs	67%	$26,232,700	33%	$12,973,300	$39,206,000
Non-Cost-Sharable Items[2/]					
NRCS Technical Assistance/Engineering	98%	$2,764,000	2%	$50,000	$2,814,000
Project Administration[3/]	67%	$785,000	33%	$392,100	$1,177,100
Permits	0%	$0	100%	$128,900	$128,900
Subtotal: Non-Cost-Share Costs	86%	$3,549,000	14%	$571,100	$4,120,000
Total:	**69%**	**$29,781,700**	**31%**	**$13,544,300**	**$43,326,000**

Installation costs explanatory notes:

1. The cost-share rate is the percentage of the average cost of installing the practice in the selected plan for the evaluation unit. During project implementation, the actual cost-share rate must not exceed the rate of assistance for similar practices and measures under existing national programs.
2. If actual non-cost-sharable item expenditures vary from these figures, the responsible party will bear the change.
3. The sponsors and NRCS will each bear the costs of project administration that each incurs. Sponsors costs for project administration include relocation assistance advisory service.

6. Land Treatment Agreements. The sponsors will obtain agreements from owners of not less than 50 percent of the land above each multiple-purpose and floodwater-retarding structure. These agreements must provide that the owners will carry out farm or ranch conservation plans on their land. The sponsors will ensure that 50 percent of the land upstream of any retention reservoir site is adequately protected before construction of the dam. The sponsors will provide assistance to landowners and operators to ensure the installation of the land treatment measures shown in the watershed project plan. The sponsors will encourage landowners and operators to continue to operate and maintain the land treatment measures after the long-term contracts expire, for the protection and improvement of the watershed.

7. Floodplain Management. Before construction of any project for flood prevention, the sponsors must agree to participate in and comply with applicable federal floodplain management and flood insurance programs. The sponsors are required to have development controls in place below low and significant hazard dams prior to NRCS or the sponsors entering into a construction contract.

8. Water and Mineral Rights. The sponsors will acquire or provide assurance that landowners or resource users have acquired such water, mineral, or other natural resources rights pursuant to State law as may be needed in the installation and operation of the works of improvement.

9. Permits. The sponsors will obtain and bear the cost for all necessary federal, state, and local permits required by law, ordinance, or regulation for installation of the works of improvement.

10. Natural Resources Conservation Service Assistance. This agreement is not a fund-obligating document. Financial and other assistance to be furnished by NRCS in carrying out the plan is contingent upon the fulfillment of applicable laws and regulations and the availability of appropriations for this purpose.

11. Additional Agreements. A separate agreement will be entered into between NRCS and the sponsors before either party initiates work involving funds of the other party. Such agreements will set forth in detail the financial and working arrangements and other conditions that are applicable to the specific works of improvement.

12. Amendments. This plan may be amended or revised only by mutual agreement of the parties hereto, except that NRCS may deauthorize or terminate funding at any time it determines that the sponsors have failed to comply with the conditions of this agreement or when the program funding or authority expires. In this case, NRCS must promptly notify the sponsors in writing of the determination and the reasons for the deauthorization of project funding, together with the effective date. Payments made to the sponsors or recoveries by NRCS must be in accordance with the legal rights and liabilities of the parties when project funding has been deauthorized. An amendment to incorporate changes affecting a specific measure may be made by mutual agreement between NRCS and the sponsors having specific responsibilities for the measure involved.

13. Prohibitions. No member of or delegate to Congress, or resident commissioner, may be admitted to any share or part of this plan or to any benefit that may arise therefrom; but this provision may not be construed to extend to this agreement if made with a corporation for its general benefit.

14. Operation and Maintenance (O&M). The sponsors will be responsible for the operation, maintenance, and any needed replacement of the works of improvement by actually performing the work or arranging for such work, in accordance with an O&M agreement. An O&M agreement will be entered into before federal funds are obligated and will continue for the project life (100 years). Although the sponsors' responsibility to the Federal Government for O&M ends when the O&M agreement expires upon completion of the evaluated life of measures covered by the agreement, the sponsors acknowledge that continued liabilities and responsibilities associated with works of improvement may exist beyond the evaluated life.

15. Emergency Action Plan. Prior to construction, the sponsors must prepare an emergency action plan (EAP) for each dam or similar structure where failure may cause loss of life or as required by state and local regulations. The EAP must meet the minimum content specified in NRCS Title 180, National Operation and Maintenance Manual, Part 500, Subpart F, Section 500.52, and meet applicable State agency dam safety requirements. NRCS will determine that an EAP is prepared prior to the execution of fund obligating documents for construction of the structure. EAPs must be reviewed and updated by the sponsors annually.

16. Nondiscrimination Provisions. In accordance with federal civil rights law and USDA civil rights regulations and policies, the USDA, its agencies, offices, employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at How to File a Program Discrimination Complaint and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.

By signing this agreement, the recipient assures the USDA that the program or activities provided for under this agreement will be conducted in compliance with all applicable federal civil rights laws, rules, regulations, and policies.

17. Certification Regarding Drug-Free Workplace Requirements (7 CFR Part 3021). By signing this Watershed Agreement, the sponsors are providing the certification set out below. If it is later determined that the sponsors knowingly rendered a false certification, or otherwise violated the requirements of the Drug-Free Workplace Act, NRCS, in addition to any other remedies available to the Federal Government, may take action authorized under the Drug-Free Workplace Act.

Controlled substance means a controlled substance in schedules I through V of the Controlled Substances Act (21 U.S.C. Section 812) and as further defined by regulation (21 CFR Sections 1308.11 through 1308.15);

Conviction means a finding of guilt (including a plea of *nolo contendere*) or imposition of sentence, or both, by any judicial body charged with the responsibility to determine violations of the federal or state criminal drug statutes;

Criminal drug statute means a federal or non-federal criminal statute involving the manufacturing, distribution, dispensing, use, or possession of any controlled substance;

Employee means the employee of a grantee directly engaged in the performance of work under a grant, including (i) all direct charge employees, (ii) all indirect charge employees unless their impact or involvement is insignificant to the performance of the grant, and (iii) temporary personnel and consultants who are directly engaged in the performance of work under the grant and who are on the grantee's payroll. This definition does not include workers not on the payroll of the grantee (e.g., volunteers, even if used to meet a matching requirement, consultants or independent contractors not on the grantees' payroll, or employees of subrecipients or subcontractors in covered workplaces).

Certification:

A. The sponsors certify that they will or will continue to provide a drug-free workplace by—

(1) Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of such prohibition.

(2) Establishing an ongoing drug-free awareness program to inform employees about—
   (a) The danger of drug abuse in the workplace.
   (b) The grantee's policy of maintaining a drug-free workplace.
   (c) Any available drug counseling, rehabilitation, and employee assistance programs.
   (d) The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace.

(3) Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (1).

(4) Notifying the employee in the statement required by paragraph (1) that, as a condition of employment under the grant, the employee must—
   (a) Abide by the terms of the statement; and

(b) Notify the employer in writing of his or her conviction for a violation of a criminal drug statute occurring in the workplace no later than 5 calendar days after such conviction.

(5) Notifying NRCS in writing, within 10 calendar days after receiving notice under paragraph (4)(b) from an employee or otherwise receiving actual notice of such conviction. Employers of convicted employees must provide notice, including position title, to every grant officer or other designee on whose grant activity the convicted employee was working, unless the federal agency has designated a central point for the receipt of such notices. Notice must include the identification numbers of each affected grant.

(6) Taking one of the following actions, within 30 calendar days of receiving notice under paragraph (4)(b), with respect to any employee who is so convicted—

(a) Taking appropriate personnel action against such an employee, up to and including termination, consistent with the requirements of the Rehabilitation Act of 1973, as amended; or

(b) Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a federal, state, or local health, law enforcement, or other appropriate agency.

(7) Making a good faith effort to continue to maintain a drug-free workplace through implementation of paragraphs (1), (2), (3), (4), (5), and (6).

B. The sponsors may provide a list of the sites for the performance of work done in connection with a specific project or other agreement.

C. Agencies will keep the original of all disclosure reports in the official files of the agency.

18. Certification Regarding Lobbying (7 CFR Part 3018)

A. The sponsors certify to the best of their knowledge and belief, that—

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the sponsors, to any person for influencing or attempting to influence an officer or employee of an agency, Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any federal grant, the making of any federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this federal contract, grant, loan, or cooperative agreement, the undersigned must complete and submit Standard Form LLL, “Disclosure Form to Report Lobbying,” in accordance with its instructions.

(3) The sponsors must require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients must certify and disclose accordingly.

B. This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by 31 U.S.C. Section 1352. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

19. Certification Regarding Debarment, Suspension, and Other Responsibility Matters—Primary Covered Transactions (7 CFR Part 3017).

A. The sponsors certify to the best of their knowledge and belief, that they and their principals—

(1) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any federal department or agency;
(2) Have not within a 3-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (federal, state, or local) transaction or contract under a public transaction; violation of federal or state antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;
(3) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (federal, state, or local) with commission of any of the offenses enumerated in paragraph A(2) of this certification; and
(4) Have not within a 3-year period preceding this application/proposal had one or more public transactions (federal, state, or local) terminated for cause or default.

B. Where the primary sponsors are unable to certify to any of the statements in this certification, such prospective participant must attach an explanation to this agreement.

20. Clean Air and Water Certification.

(Applicable if this agreement exceeds $100,000, or a facility to be used has been subject of a conviction under the Clean Air Act (42 U.S.C. Section 7413(c)) or the Federal Water Pollution Control Act (33 U.S.C. Section 1319(c)) and is listed by EPA, or is not otherwise exempt.)

A. The project sponsoring organizations signatory to this agreement certify as follows:

(1) Any facility to be utilized in the performance of this proposed agreement is (____), is not (_x_) listed on the U.S. Environmental Protection Agency List of Violating Facilities.
(2) To promptly notify NRCS-State administrative officer prior to the signing of this agreement by NRCS, of the receipt of any communication from the Director, Office of Federal Activities, U.S. Environmental Protection Agency, indicating that any facility which is proposed for use under this agreement is under consideration to be listed on the Environmental Protection Agency List of Violating Facilities.
(3) To include substantially this certification, including this subparagraph, in every nonexempt subagreement.

B. The project sponsoring organizations signatory to this agreement agree as follows:

(1) To comply with all the requirements of Section 114 of the Clean Air Act as amended (42 U.S.C. Section 7414) and Section 308 of the Federal Water Pollution Control Act (33 U.S.C. Section 1318), respectively, relating to inspection, monitoring, entry, reports, and information, as well as other requirements specified in Section 114 and Section 308 of the Air Act and the Water Act, issued there under before the signing of this agreement by NRCS.

(2) That no portion of the work required by this agreement will be performed in facilities listed on the USEPA List of Violating Facilities on the date when this agreement was signed by NRCS unless and until the EPA eliminates the name of such facility or facilities from such listing.

(3) To use their best efforts to comply with clean air standards and clean water standards at the facilities in which the agreement is being performed.

(4) To insert the substance of the provisions of this clause in any nonexempt subagreement.

C. The terms used in this clause have the following meanings:

(1) The term “Air Act” means the Clean Air Act, as amended (42 U.S.C. Section 7401 et seq.).

(2) The term “Water Act” means Federal Water Pollution Control Act, as amended (33 U.S.C. Section 1251 et seq.).

(3) The term “clean air standards” means any enforceable rules, regulations, guidelines, standards, limitations, orders, controls, prohibitions, or other requirements which are contained in, issued under, or otherwise adopted pursuant to the Air Act or Executive Order 11738, an applicable implementation plan as described in Section 110 of the Air Act (42 U.S.C. Section 7414) or an approved implementation procedure under Section 112 of the Air Act (42 U.S.C. Section 7412).

(4) The term “clean water standards” means any enforceable limitation, control, condition, prohibition, standards, or other requirement which is promulgated pursuant to the Water Act or contained in a permit issued to a discharger by the Environmental Protection Agency or by a State under an approved program, as authorized by Section 402 of the Water Act (33 U.S.C. Section 1342), or by a local government to assure compliance with pretreatment regulations as required by Section 307 of the Water Act (33 U.S.C. Section 1317).

(5) The term “facility” means any building, plant, installation, structure, mine, vessel, or other floating craft, location or site of operations, owned, leased, or supervised by a sponsor, to be utilized in the performance of an agreement or subagreement. Where a location or site of operations contains or includes more than one building, plant, installation, or structure, the entire location will be deemed to be a facility except where the Director, Office of Federal Activities, Environmental Protection Agency, determines that independent facilities are collocated in one geographical area.

21. Assurances and Compliance.

As a condition of the grant or cooperative agreement, the sponsors assure and certify that it is in compliance with and will comply in the course of the agreement with all applicable laws, regulations, executive orders, and other generally applicable requirements, including those set out below which are hereby incorporated in this agreement by reference, and such other statutory provisions as a specifically set forth herein.

State, Local, and Indian Tribal Governments: Office of Management and Budget (OMB) Circular Nos. A-87, A-102, A-129, and A-133; and 7 CFR Parts 3015, 3016, 3017, 3018, 3021, and 3052.

Nonprofit Organizations, Hospitals, Institutions of Higher Learning: OMB Circular Nos. A-110, A-122, A-129, and A-133; and 7 CFR Parts 3015, 3017, 3018, 3019, 3021 and 3052.

22. Examination of Records.

The sponsors must give NRCS or the Comptroller General, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to this agreement, and retain all records related to this agreement for a period of three years after completion of the terms of this agreement in accordance with the applicable OMB Circular.

23. Signatures

DESCHUTES BASIN BOARD OF CONTROL

The signing of this plan was authorized by a resolution by the DBBC governing body and adopted at an official meeting held on

AUGUST 15, 2018 at [MADRAS], Oregon.

By:

Date: 8/15/18

Mike Britton, Chairman
Deschutes Basin Board of Control
c/o: DBBC Chair
2024 NW Beech Street
Madras, OR 97741

TUMALO IRRIGATION DISTRICT

The signing of this plan was authorized by a resolution by the TID governing body and adopted at an official meeting held on

8-15, 2018 at [TUMALO], Oregon.

By:

Date: 8-15

Kenneth B. Rieck, District Manager and Secretary to the Board
Tumalo Irrigation District
64697 Cook Avenue
Bend, OR 97703

USDA-NATURAL RESOURCES CONSERVATION SERVICE

Approved by:

Date: 08/16/18

Ron Alvarado, State Conservationist
Natural Resources Conservation Service
1201 NE Lloyd Blvd
Suite 900
Portland, OR 97232

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Summary Watershed Plan-Environmental Assessment Document For Tumalo Irrigation District – Irrigation Modernization Project Upper Deschutes Basin Subwatersheds: Buckhorn Canyon, Bull Creek, Lower Tumalo Creek, Laidlaw Butte-Deschutes River, Overturf Butte-Deschutes River, and Deep Canyon Dam-Deep Canyon Deschutes County, Oregon Oregon 2nd Congressional District	
Authorization	Public Law 83-566 Stat. 666 as amended (16 U.S.C. Section 1001 et. Seq.) 1954
Lead Sponsor	Deschutes Basin Board of Control and Tumalo Irrigation District (co-sponsor)
Proposed Action	The Tumalo Irrigation District (TID) – Irrigation Modernization Project is a large agricultural water conveyance efficiency project. The proposed action would modernize up to 1.9 miles of TID's irrigation canals and 66.9 miles of laterals.
Purpose and Need	The purpose of this project is to improve water conservation, water delivery reliability, and public safety on 68.8 miles of District-owned canals and laterals. Implementation of the proposed action would meet Public Law 83-566 Authorized Project Purpose (v), Agricultural Water Management, through irrigation water conservation, water quality improvement, and more reliable agricultural water supply. Federal action is needed to address the following watershed problems and resource concerns: water loss in District conveyance systems, water delivery and operations inefficiencies, instream flow for fish and aquatic habitat, and risks to public safety from open irrigation canals. Implementation of the proposed action would ensure agricultural production is maintained in an area undergoing rapid urbanization where public safety and environmental concerns necessitate federal action. The proposed action addresses seepage and evaporation loss and provides better-managed water diversions for farm use, increased agricultural production, improved streamflow for fish, aquatic, and riparian habitat, and increased public safety. These measures would serve to stretch the supply of water by increasing the reliability and efficiency of water delivered for irrigation while permanently reducing the amount of water diverted, and legally protecting saved water instream.
Description of the Preferred Alternative	Under the Preferred Alternative, 1.9 miles of canals and 66.9 miles of laterals in the TID system would be converted to high-density polyethylene (HDPE) gravity-pressurized buried pipe.
Project Measures	Under the Preferred Alternative, project sponsors would replace canals and laterals with HDPE pipe. Additionally, existing turnouts would be upgraded to pressurized delivery systems with additional turnouts added, and three pressure-reducing valves (PRV) would be installed to alleviate high pressures within the system. Construction of the Preferred Alternative would occur in seven project groups over the course of 11 years.

Resource Information

Subwatersheds	12-digit Hydrologic Unit Code	Latitude and Longitude	Subwatershed Size
Buckhorn Canyon	170703010804	44.248873, -121.356289	13,809 acres
Bull Creek	170703010603	44.190339, -121.420120	32,153 acres
Lower Tumalo Creek	170703010502	44.065108, -121.415720	17,238 acres

Laidlaw Butte-Deschutes River	170703010802	44.151316, -121.329905	42,749 acres
Overturf Butte-Deschutes River	170703010406	44.027097, -121.367571	31,374 acres
Deep Canyon Dam-Deep Canyon	170703010604	44.235075, -121.452157	31,928 acres
Subwatershed Total Size	169,251 acres		
Tumalo Irrigation District Size	27,964 acres		
Climate and Topography	The Project is located in the rain shadow of the Cascade Mountain range. TID's annual average precipitation is 10-14 inches. The average high temperature for July is 82 degrees Fahrenheit, and the average low temperature for December is 23 degrees Fahrenheit. The land within TID is slightly undulating with an average elevation of 3,200 feet above mean sea level.		
Land Use Tumalo Irrigation District (total 27,964 acres)	Use	Acres	
	Agriculture (irrigated acres)	7,417	
	Developed	2,622	
	Undeveloped	17,925	
Land Ownership Tumalo Irrigation District (total 27,964 acres)	Owner	Percentage	
	Private	77% (21,530 acres)	
	State-Local	7% (1,923 acres)	
	Federal	16% (4,511 acres)	
Population and Demographics	The Preferred Alternative would occur within Deschutes County, Oregon. The population of Deschutes County was 166,622, or 56 people per square mile, in 2015. The population growth rate of the county between 2005 and 2015 was 14 percent. The population of the State of Oregon grew by about 8 percent in the same period.		
Population and Demographics		Deschutes County	Oregon
	Population 2015	166,622	3,939,233
	Unemployment Rate	4.1%	4.1%
	Median Household Income	$51,223	$51,243
Relevant Resource Concerns	Resource concerns identified through scoping are water conservation and quality, groundwater, aquatic and fish resources, soil and geologic resources, visual resources, cultural resources, recreation, socioeconomics, wetlands, terrestrial wildlife, and vegetation resources.		
Alternatives			
Alternatives Considered	Eleven alternatives were considered; nine were eliminated from full analysis due to inconsistency with the purpose and need for action or due to cost, logistics, existing		

	technology, social, or environmental reasons. The No Action Alternative, Canal Lining Alternative, and HDPE Pressurized Piping Alternative were analyzed in full.
No Action Alternative	Under the No Action Alternative, construction activities associated with the project would not occur and TID would continue to operate and maintain its existing canals and pipe system in their current condition. The need for the project would still exist; however, the District would only modernize its infrastructure on a project-by-project basis as public and public interest funding became available. This funding is not reasonably certain to be available under a project-by-project approach at the large scale necessary to modernize the District's infrastructure.
Proposed Action	Two action alternatives were considered. Under the Canal Lining Alternative, TID would line 65.1 miles of open canals and laterals with a geomembrane covered by shotcrete. Under the HDPE Pressurized Piping Alternative, TID would replace 1.9 miles of canals and 66.9 miles of laterals with gravity-pressurized HDPE buried pipe. The HDPE Pressurized Piping Alternative has been identified as the National Economic Development (NED) alternative and is also the Preferred Alternative.

Project Costs	**PL 83-566 Funds**		**Other Funds**		**Total**	
Construction	67%	$24,900,000	33%	$12,529,200	$37,429,200	86%
Engineering	75%	$1,332,700	25%	$444,100	$1,776,800	4%
SUBTOTAL COSTS	67%	$26,232,700	33%	$12,973,300	$39,206,000	90%
Technical Assistance	98%	$2,764,000	2%	$50,000	$2,814,000	6%
Relocation	Not Applicable					
Real Property Rights	Not Applicable					
Permitting	0%	$0	100%	$128,900	$128,900	0%
Project Administration	67%	$785,000	33%	$392,100	$1,177,100	3%
Annual Operation and Maintenance (O&M)	Not Applicable					
TOTAL COSTS	**69%**	**$29,781,700**	**31%**	**$13,544,300**	**$43,326,000**	**100%**

Mitigation, Minimization, and Avoidance Measures	Approximately 1,610 acres of land along open canals and laterals, which could provide seasonal wetland characteristics, would be converted to upland vegetation. Project canals and laterals are not considered jurisdictional wetlands by state or federal agencies. The wetland characteristics that could occur in the open canals and laterals have low function and the loss would be more than offset by gains in water quality and habitat function in the project area's natural riverine systems. The National Wetland Inventory (NWI) geographic information systems data (USFWS 2016) shows about 23 wetland features to sporadically occur adjacent to canals and laterals within the area of potential effect; however, these wetland features have not been field verified. Wetland determinations and/or delineations of areas adjacent to canals and laterals in areas where work would occur will be conducted prior to implementation of construction of each project group, and wetlands will be avoided to the extent practicable. Surveys for cultural resources have been completed for Project Group 1. In this portion of the project, archaeological resources have not been found and effects to aboveground resources have been addressed through completion of a Historic American Engineering Report. For Project Groups 2-7, cultural resource surveys and consultation between NRCS and the Oregon State Historic Preservation Office (SHPO) for compliance with Section 106 of the National Historic Preservation Act (NHPA) will be completed nearer to initiation of construction. Mitigation measures such as historical reports, brochures, interpretive signs,

	and content on the District's website will be identified prior to construction and completed concurrent with or after construction. For all project groups, ground disturbances would be limited to only those areas necessary and within rights-of-way to minimize effects on soil, vegetation, and land use. Construction activities would be confined to existing rights-of-way to avoid effects on agricultural lands. Where roads or access routes do not currently allow construction access, temporary access routes would be selected in a manner to minimize effects on vegetation and avoid the removal of trees and erosion. Stormwater best management practices would be employed during and after construction, and construction schedules would be determined to minimize disturbance to wildlife and the public. After construction, disturbed areas would be graded and replanted with a mix of native grasses and forbs to reduce the risk of erosion and spread of noxious weeds.						
Project Benefits							
Project Benefits	Implementation of the Preferred Alternative would improve water delivery reliability for TID's patrons, conserve 48 cubic feet per second of water for instream uses, reduce TID's operation and maintenance costs, reduce electricity costs from pumping, and improve public safety.						
Number of Direct Beneficiaries	TID serves 667 patrons, who would benefit from the project.						
Other Beneficial Effects-Physical Terms	Implementation of the Preferred Alternative would have minor to moderate, long-term, beneficial effects on agricultural water availability, water quality, and fish and wildlife habitat.						
Damage Reduction Benefits	**Project Group***						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Other - Reduced O&M	$5,000	$30,600	$9,300	$21,800	$19,300	$29,600	$11,000
Other - Power Cost Savings	$700	$49,500	$25,400	$58,400	$31,400	$133,100	$27,000
Other - Social Value of Carbon (Avoided Carbon Emissions)	$0	$19,200	$9,800	$23,900	$12,600	$53,600	$10,500
Water Conservation	$199,900	$170,000	$91,100	$101,000	$70,200	$279,500	$75,600
Total Quantified Benefits	$205,600	$269,300	$135,600	$205,100	$133,500	$495,800	$124,100
Benefit to Cost Ratio	1.00	1.34	1.28	1.69	1.36	1.41	2.67

*Project Group refers to groupings of canals and laterals that would undergo construction during the same period. Canals and laterals under each project group are as follows:
1. Tumalo Feed Canal, Kerns
2. Tumalo Res. Feed, Steele, Rock Springs, Highline, 2 Rivers, Parkhurst, Gill, Lacy
3. Allen, Allen Sublateral West, Allen Sublateral South, McGinnis Ditch
4. West Branch Columbia So. West, Beasley, Spaulding, N. Spaulding
5. Couch, West Couch, West Couch Sublateral East, Chambers (Lafores) Ditch, East Couch, Gainsforth
6. North Columbia So. West, Jewett, Conarn East, Putnam, West Branch Columbia So. East, Conarn, Phiffer, Hooker Creek, Hammond, North Hammond, Columbia Southern TFC to PRV, Columbia Southern PRV to Tail, North Columbia So. East
7. Hillburner, Gerking, Kickbush, West Branch Columbia So. South, Flannery Ditch, Tellin Ditch

Period of Analysis							
Project Group	1	2	3	4	5	6	7
Installation Period (years)	2	2	1	1	1	3	1

Project Life	100 years for each project group

Funding Schedule			
Year—Project Group	**PL 83-566**	**Other Funds**	**Total**
2018, 2019 --1	$5,179,100	$1,756,800	$6,935,900
2020, 2021 --2	$5,505,300	$1,703,900	$7,209,200
2022 --3	$3,019,600	$943,600	$3,963,200
2023 --4	$3,559,400	$1,108,700	$4,668,100
2024 --5	$2,965,700	$927,200	$3,892,900
2025, 2026, 2027 --6	$9,287,200	$5,357,100	$14,644,300
2028 --7	$265,400	$1,747,000	$2,012,400

Environmental Effects

In portions of the project area where canals are considered historic features under Section 106 of the National Historic Preservation Act (NHPA), conversion of the canals would be mitigated through implementation of measures in consultation with the Oregon State Historic Preservation Office (SHPO). Consultation has been completed for Project Group 1. For Project Groups 2-7, cultural resource surveys and consultation between NRCS and SHPO for compliance with Section 106 of the NHPA will be completed nearer to initiation of construction in order to achieve no effects greater than moderate in intensity. Effects to below-ground archaeological resources are not anticipated for Project Groups 2-7, as surveys for Project Group 1 found no archaeological resources. Areas of potential ground disturbance for Project Groups 2-7 would be surveyed closer to construction and effects to archaeological resources will be avoided to the extent practicable in consultation with SHPO. As there would be no known effects to below-ground cultural resources, and changes to historic resources would not diminish resource integrity, effects to cultural resources would be negligible to moderate, for each project group.

Effects to aquatic species would result from the application of legal and permanent protection to conserved water seasonally released from Crescent Lake Dam that was previously volunteered by the District. Further, additional flows would be seasonally protected instream in Tumalo Creek. Three federally-listed species may occur in the area potentially affected by the project; bull trout, steelhead, and Oregon spotted frog. There would be no effect from the proposed action on bull trout or steelhead due to the timing of increased streamflow resulting from project actions and the location of bull trout and steelhead populations being at the very downstream end of where effects could be detectable. Any effects to Oregon spotted frog would be entirely beneficial. Overall, the presence (and legal protection) of conserved water from the proposed action would serve to benefit aquatic species and their habitat, thus the effects of the project on all aquatic species would be minor to moderate, and beneficial in the long term.

The proposed action will result in a total of approximately 200,000 cubic yards of soil disturbance during the 11-year construction period of the Preferred Alternative. Soil disturbances would be minor, as these effects would be short-term and localized to small portions of the larger project area over an 11-year construction period. Effects would be further minimized through implementation of soil stabilization measures, such as the preservation of vegetation when possible and re-vegetating disturbed areas after construction.

The Preferred Alternative would have a negligible effect on land use, as property ownership and existing use of land would not change. It is anticipated that the proposed action will encourage and promote agricultural sustainability in the watershed through improved irrigation water reliability.

As the proposed action would eliminate drowning risk from open canals, the project would have minor, and long-term effects on public safety; these effects would be entirely beneficial.

Effects to recreation from the proposed action would be minor in the short-term, as construction may temporarily preclude or limit dispersed and dedicated recreational opportunities during project construction. After construction, effects to both river- and land-based recreation would be negligible as the project would create visual and water level changes but would not change the quality of the recreational experience in a quantifiable way.

Of the 27,964 acres within the TID boundary, construction of the Preferred Alternative would temporarily disturb a total of approximately 167 acres of vegetation. Since the project would be completed over an 11-year construction period, only a portion of these effects would be evident at any one time. Long-term vegetation changes would occur over less than 1 percent of the District. Further, mitigation measures such as seeding all exposed areas with native grasses and forbs would be implemented. At project completion, about 44 acres of previously-open canals and laterals would be converted to upland vegetation over the buried pipes. Since effects to vegetation would be localized, would occur over a relatively small area, and all disturbed vegetated areas would be revegetated, effects to vegetation would be minor.

Overall, the visual change from canal to buried pipe would be expected to have a minor effect because there would be short-term visual changes during construction, and the long-term effects would be a vegetated corridor that would blend in with the natural landscape following revegetation.

Effects on surface water hydrology and water quality would vary in intensity depending on the stream reach, and none would be adverse. The following waterbodies would experience minor to moderate, long-term beneficial effects to hydrology and water quality: Crescent Creek, the Little Deschutes River, Tumalo Creek, and the Deschutes River downstream from the confluence with the Little Deschutes River (RM 192.5) to Lake Billy Chinook (RM 120). Because all effects to surface water resources would be beneficial, there would be no adverse effects to surface water resources. Since the reduction in seepage to groundwater realized from the piped canals would be reduced by increased groundwater recharge via improved streamflows upgradient from the proposed action, effects to groundwater would be negligible.

Effects to wetlands, floodplains, and riparian areas would be minor, as there are no wetland features in the canals or laterals, effects to any adjacent wetlands would be avoided or mitigated, and riparian and wetland areas downstream of the project would benefit from the protection and addition of instream flows.

Effects to terrestrial wildlife would be minor because there would be small, localized changes in wildlife populations and their habitats due to construction disturbance; however, these changes would be of little consequence to any populations or their habitats due to abundance of species and their habitat in the area. As project groups would be constructed sequentially over an 11-year period, terrestrial wildlife would have ample time to adjust and find new water sources and habitats as open canals are converted to buried pipe.

There would be no effects from the proposed action to designated Wild and Scenic rivers.

Major Conclusions	Implementation of the Preferred Alternative would improve water delivery reliability for farmers, reduce water loss to seepage and evaporation in District infrastructure, enhance fish and aquatic habitat through greater instream flows, and improve public safety while supporting agriculture and improving the environmental quality of rivers and tributaries in the area of potential effect.
Areas of Controversy	There have been no areas of controversy identified.
Issues to be Resolved	None
Evidence of Unusual Congressional or Local Interest	Comments on the Plan-EA and/or Preliminary Investigative Report were received from one state representative (Knute Buehler, District 54), one municipality (City of Bend), four state agencies through the Regional Solutions Program/Oregon Governor's Office (Oregon Department of Environmental Quality, Oregon Department of Transportation, Oregon Department of Fish and Wildlife, and Oregon Water Resources Department), two federal agencies (United States Fish and Wildlife Service and United States Forest Service-Deschutes National Forest), and local non-governmental organizations and individuals.

Compliance	Is this report in compliance with executive orders, public laws, and other statues governing the formulation of water resource projects? Yes _X_ No____

1 Introduction

Aging infrastructure, growing populations, shifting rural economies, and changing climate conditions have increased pressure on water resources across the western United States (U.S.). Within the Deschutes Basin, irrigated agriculture is the primary out-of-stream water use and relies on up to 100-year-old infrastructure to divert, store, and deliver water to farms and ranches across the region. The need to minimize system water losses is an ongoing concern of the Tumalo Irrigation District (herein referred to as TID or the District).

In recent years, water resources have been a community focus within the Deschutes Basin. In response, TID has been pursuing a water conservation program to provide a permanent solution to system-wide water losses since the mid-1990s. Although some improvements have been made, aging and outdated infrastructure continues to contribute to water delivery insecurity for out-of-stream users and limit streamflow, affecting water quality and aquatic habitat along the Deschutes River and its tributaries. Irrigation canals and laterals in the District have become a public safety risk and require increasing maintenance. Aging infrastructure also affects the financial stability of TID and its patrons, as the District must find new approaches to fund growing maintenance needs.

Approximately 30 percent of the water diverted through TID's canals and laterals[1] currently seeps into the area's porous, volcanic soil, or evaporates, prior to reaching farms. The District has a higher diversion rate than their on-farm delivery rate to account for the losses in the distribution system. If the distribution system were more efficient, the District would divert less water and leave more water instream in the Deschutes River and its tributaries. Patrons would continue receiving their water rights, supporting local agriculture and the local economy. Improving irrigation infrastructure offers an opportunity to improve water conservation, increase water delivery reliability to farms, reduce O&M costs for farmers and the District, enhance streamflow and habitat conditions for fish and aquatic species in the Deschutes Basin, and reduce risks to public safety from open irrigation canals.

The Deschutes Basin Board of Control (DBBC) is the lead sponsor for the TID Irrigation Modernization Project (herein referred to as the project or proposed action), which is intended to improve water conservation, water delivery reliability, and public safety for District-owned canals and laterals. The District operates and maintains over 77 miles of main canals and laterals; of these, approximately 8.2 miles are piped and the rest are unlined, open channels dug into volcanic soils and rock (Figure 1-1). The proposed action would modernize up to 68.8 miles of canals and laterals in order to conserve up to 48 cubic feet per second (cfs) of water, equivalent to 15,115 acre-feet of water throughout the entire irrigation season. Modernization would allow the District to provide more reliable water deliveries to patrons; enhance instream flow, water quality, and aquatic habitat; provide financial and operational benefits to the District and its patrons; and improve public safety. Specific details regarding the District's proposed action are further described in this document and in the System Improvement Plan (SIP) (TID 2017).

[1] "Laterals" refer to smaller canals that branch off from main canals.

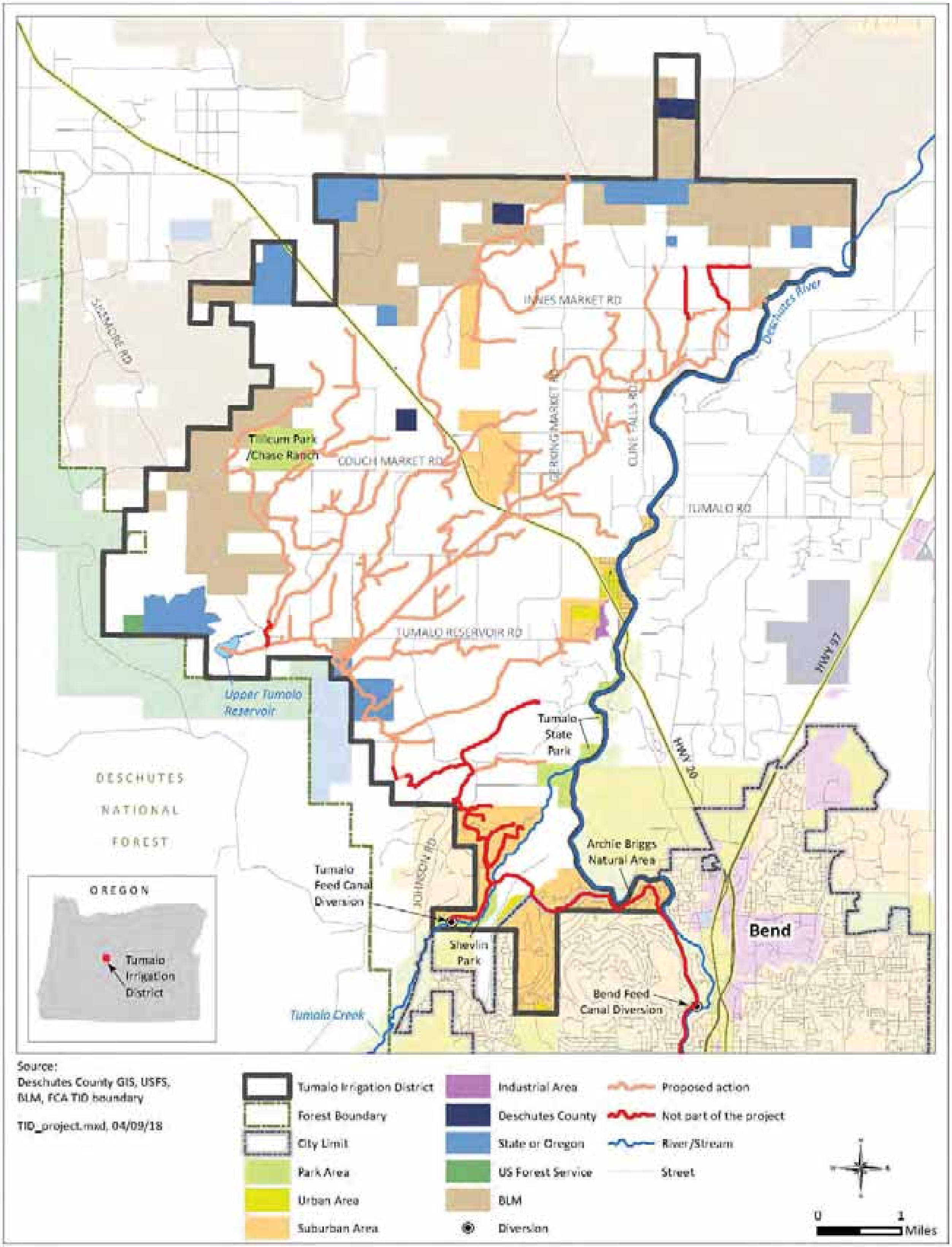


Figure 1-1. Location of the Tumalo Irrigation District – Irrigation Modernization Project.

1.1 General Setting

The District is located in Central Oregon, in the northern half of Deschutes County. The District is situated northwest of the City of Bend, west of the Deschutes River, and falls within six subwatersheds that comprise the TID Watershed Planning Area (Figure 1-2; Table 1-1). The entire District is approximately 28,000 acres; within that, there are 7,417 acres currently irrigated by 667 patrons. Of these 7,417 acres, 7,002 irrigated acres would be served by infrastructure included in the proposed action (TID 2017). The District is about 15 miles long (north to south) and 8 miles wide (east to west).

The Watershed Planning Area is 169,251 acres and is located within the Upper Deschutes watershed (4th field Hydrologic Unit Code [HUC]: 17070301) and within Deschutes County. Within the Upper Deschutes watershed, portions of the Deschutes River are referenced as the upper Deschutes River (from River Mile [RM] 226 to RM 164.8) and the middle Deschutes River (from RM 164.8 to RM 120). This reference point divides the river based on its hydrograph, which is influenced by reservoir operations and irrigation diversions. Current reservoir management in the upper Deschutes watershed leads to low winter flows and high summer flows in the upper Deschutes River. Six irrigation districts divert water from the Deschutes River at the City of Bend during the spring, summer, and fall, leading to lower flows in the middle Deschutes River.

There are several designated National Wild and Scenic Rivers (Public Law 90-542; 16 U.S.C. 1271 et seq.) in the general area. These include the Deschutes River from Wickiup Reservoir (RM 226.8) to the Bend Urban Growth Boundary (approximately RM 172) and from Cline Falls (RM 140) to the upper end of Lake Billy Chinook (RM 120). The 10-mile segment of Crescent Creek downstream from Crescent Lake (RM 30) is also designated as a National Wild and Scenic River. In addition, there are about 61.7 miles of waterways in the general area that are designated through the Oregon Wild and Scenic Rivers Act (Oregon Revised Statute [ORS] 390.826) as Oregon Scenic Waterways.

1.2 Current Infrastructure

The District has two primary points of diversion. The District's primary water right is on Tumalo Creek, a tributary of the Deschutes River that is fed by snowmelt and precipitation. The District diverts water at the Tumalo Diversion Dam, located on Tumalo Creek at RM 2.5, approximately 0.5 mile downstream from Shevlin Park.

The District also maintains supplemental storage rights in Crescent Lake, as Tumalo Creek flows are insufficient to meet the District's water rights throughout the irrigation season. Water flows from Crescent Lake via Crescent Creek to the Little Deschutes River, which then flows to the Deschutes River. The District diverts this water from the Deschutes River at Steidl Dam (RM 166) in Bend, Oregon (TID 2017). Steidl Dam was built in 1922 and was rehabilitated in 1975. The District is the only irrigation district that withdraws water from this location. Both of TID's diversions have powered head gates, fish passage, and agency-compliant fish screens to protect upstream and downstream migrating fish.

District infrastructure includes approximately 8.2 miles of pipe and 68.8 miles of canals, laterals, and ditches. Water at the Tumalo Diversion Dam enters the Tumalo Feed Canal (TFC), a dual-pipe conveyance system, and is transported approximately 4,000 feet to the convergence with the Bend Feed Canal (BFC), which transports water from the Steidl Dam diversion on the Deschutes River. The BFC is fully piped for 5 miles. It consists of a combination of 72-inch-diameter reinforced concrete pipe that was installed in the 1970s and 84-inch-diameter high-density polyethylene (HDPE) pipe that was installed by the District over the last 15 years (TID 2017).

From the convergence of the BFC and the TFC, the water is conveyed in a combination of pipes and canals until it reaches the Tumalo Reservoir. The TFC is approximately 60 percent piped, consisting predominantly of HDPE pipe except for steel pipe at siphon locations; reinforced, dual-barrel concrete pipes from the intake for approximately 2,967 linear feet downstream of the TFC diversion; and a segment of steel-reinforced polyethylene pipe (TID 2017).

Below the piped section of the TFC, the water continues into an unlined canal for approximately 2.5 miles to a junction known as the Division. Here, the open, unlined Columbia Southern Lateral carries water into the District in a northeasterly direction. The Tumalo Reservoir Feed continues to Tumalo Reservoir, which feeds the Couch Lateral. The District stores and releases water from Tumalo Reservoir to meet changes in demand further down in the system. Numerous open laterals stem from the TFC and the Columbia Southern Lateral (Figure 1-1).

Elevations in the District fall approximately 370 feet between the diversions and the northern limit of the District. Patron turnouts from District canals and laterals are gate-regulated and weir-measured by TID field staff; approximately 10 patrons are currently being served by the existing pressurized pipelines.

The District's distribution system does not discharge to any natural waterbodies. Due to the age of the District's distribution system and porous nature of the underlying soils, the District's system loses approximately 48 cfs of water through seepage and evaporation. The District must divert more water than needed by farms in order to account for the loss in the distribution system. Water loss associated with specific canals and laterals is detailed in the SIP (Appendix D).

1.3 Watershed Planning Area

The District's service area and the TID Irrigation Modernization Project are located in six subwatersheds: Buckhorn Canyon, Bull Creek, Lower Tumalo Creek, Laidlaw Butte-Deschutes River, Overturf Butte-Deschutes River, and Deep Canyon Dam-Deep Canyon (Table 1-1; Figure 1-2), which cover a total of 169,251 acres. These six subwatersheds comprise the TID Watershed Planning Area. They are located within the Upper Deschutes watershed (HUC 17070301).

Table 1-1. Tumalo Irrigation District Watershed Planning Area.

12-Digit Hydrologic Unit Code	Name	Area (acres)
170703010804	Buckhorn Canyon	13,809
170703010603	Bull Creek	32,153
170703010502	Lower Tumalo Creek	17,238
170703010802	Laidlaw Butte-Deschutes River	42,749
170703010406	Overturf Butte-Deschutes River	31,374
170703010604	Deep Canyon Dam-Deep Canyon	31,928
	Total	**169,251**

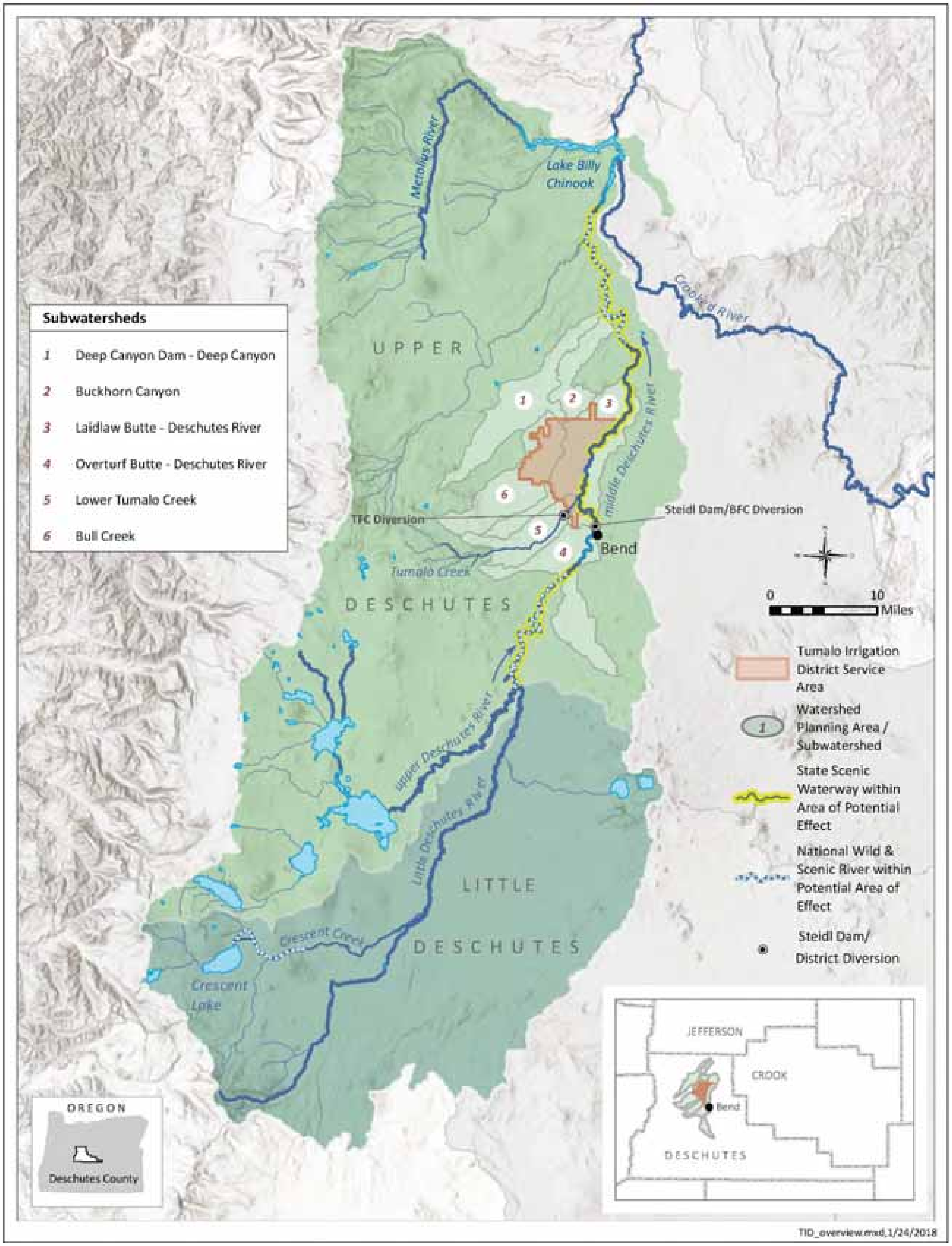


Figure 1-2. The Six Subwatersheds Comprising the Tumalo Irrigation District Watershed Planning Area.

1.4 Project Area

The “project area” for the TID Irrigation Modernization Project is the area where construction activities would occur to modernize up to 68.8 miles of the District’s canals and laterals. All construction activities would occur entirely within the District's existing rights-of-way (ROW), which were granted under the Carey Desert Land Act of 1894 (Carey Act). The District’s ROW under the Carey Act extends 50 feet on each side of the canal from the toe of the bank for a total easement width of 100 feet plus the width of the canal.

The “area of potential effect” for the TID Irrigation Modernization Project is the area that would be affected by implementation of the proposed action. Unlike the project area, the area of potential effect is not a single defined boundary; it varies depending on the resource affected. For example, the area of potential effect on water resources would include waterbodies upstream and downstream of the District’s diversions that are several miles away from any construction. Conversely, the area of potential effect on public safety would be identical to the boundaries of the project area.

1.5 Decision Framework

This Draft Watershed Plan-Environmental Assessment (Plan-EA) has been prepared to assess and disclose the potential effects of the proposed actions. The Plan-EA is required to apply for federal funding through the Watershed Protection and Flood Prevention Program, Public Law 83-566, authorized by Congress in 1954 (herein referred to as PL 83-566). This program is managed by the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). Through this program, NRCS provides technical and financial assistance to states, local governments, and Tribes (project sponsors) to plan and implement authorized watershed project plans for the purpose of watershed protection; flood mitigation; water quality improvements; soil erosion reduction; rural, municipal, and industrial water supply; irrigation; water management; sediment control; fish and wildlife enhancement; and hydropower. NRCS is the lead federal agency for this Plan-EA and is responsible for review and issuance of a decision in accordance with the National Environmental Policy Act (NEPA).

NEPA requires that Environmental Impact Statements (EISs) are completed for projects utilizing federal funds and that significantly affect the quality of the human environment. When a proposed project is not likely to result in significant impacts requiring an EIS, but the activity has not been categorically excluded from NEPA, an agency can prepare an EA to assist them in determining whether there is a need for an EIS (See 40 Code of Federal Regulations [CFR] 1501.4, 1508.9; 7 CFR 650.8.).

For purposes of NEPA compliance, the intent of this Plan-EA is to provide a programmatic platform for the implementation of the proposed action. The DBBC and TID are partnered with NRCS to implement the Irrigation Modernization Project within the TID Watershed Planning Area under the watershed authority of the PL 83-566 program. This approach provides a programmatic analysis to which those site-specific actions may tier, reducing the regulatory burden of acquiring approval for each individual project in a streamlined fashion that is responsive to the NEPA framework.

Tiering is a staged approach to NEPA as described in the Council on Environmental Quality's (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (40 CFR 1500 – 1508). Broad programs and issues are described in initial analyses, while site-specific proposals and impacts are described in subsequent site-specific studies. The tiered process permits the lead agency to focus on issues that are ripe for decision, and exclude from consideration issues already decided or not yet ripe. Tiering eliminates repetitive discussions of the same issues through incorporating by reference the general discussions.

NRCS has determined the need for a Plan-EA to implement the proposed action under PL 83-566 watershed authority. Due to the broad spatial scale of this analysis, and the multi-year project group approach, this Plan-EA does not identify the specific details associated with the engineering design and construction activities that would be required to implement the proposed action. Instead, this document intends to present an analysis in sufficient detail to allow implementation of a proposed action within the designated project area with minimal additional NEPA analysis.

The proposed action is planned to be completed in seven project groups[2]. Consistent with the tiering process as described above, prior to the implementation of each project group, an onsite Environmental Evaluation (EE) review would occur utilizing the Form NRCS-CPA-52, "Environmental Evaluation Worksheet." The EE process would determine if that particular project group meets applicable project specifications, and whether the site-specific environmental effects are consistent with those as described and developed in this Plan-EA. This process provides information for the Responsible Federal Official (RFO) to determine if the proposed action has been adequately analyzed, and if the conditions and environmental effects described in the Plan-EA are still valid. Where the impacts of the narrower project specific action are identified and analyzed in the broader NEPA document, no further analysis would occur and the Plan-EA would be used for purposes of the pending action.

If it is determined that the Plan-EA is not sufficiently comprehensive, not adequate to support further decisions, or if resource concerns or effects have not been adequately evaluated through the programmatic approach, a separate site-specific supplemental EA would be prepared. Furthermore, as part of the tiering process, agency consultation (e.g., Section 404 of the Clean Water Act [CWA] and Section 106 of the National Historic Preservation Act [NHPA]) would be completed for each individual project group before implementation of the project group, as appropriate.

This Plan-EA has been prepared in accordance with applicable CEQ regulations for implementing NEPA (40 CFR 1500–1508), USDA's NEPA regulations (7 CFR Part 650), NRCS Title 190 General Manual Part 410, and NRCS National Environmental Compliance Handbook Title 190 Part 610 (May 2016). The Plan-EA also meets the guidelines of the 2015 NRCS National Watershed Program Manual (NWPM) and the 2014 NRCS National Watershed Program Handbook (NWPH). This Plan-EA serves to fulfill the NEPA and NRCS environmental review requirements of the proposed action.

[2] Project Group refers to groupings of canals and laterals that would undergo construction during the same period. The project groups identified in the SIP are not identical to the project groups identified in the Plan-EA.

2 Purpose and Need for Action

The purpose of this project is to improve water conservation, water delivery reliability, and public safety on up to 68.8 miles of District-owned canals and laterals.

Federal action is needed to accelerate and provide certainty to address the following watershed problems and resource concerns: water loss in District conveyance systems, water delivery and operations inefficiencies, instream flow for fish and aquatic habitat, and risks to public safety from open irrigation canals. The District has begun to address these concerns over the past two decades as funding opportunities have allowed. These funding opportunities are not reasonably certain to occur if the District continues to follow their current approach. Federal action would enable the District to follow a strategic, comprehensive approach to securing additional funding and addressing these issues, which are discussed below in more depth.

2.1 Watershed Problems and Resource Concerns

2.1.1 Water Loss in District Conveyance Systems

Conserving water is a key goal of the District; it has already invested in multiple large piping projects and used the State of Oregon's Allocation of Conserved Water Program to protect the water conserved instream. Currently, the District's remaining antiquated canal infrastructure loses approximately 48 cfs (approximately 15,115 acre-feet annually) of water to seepage through the porous underlying soils, evaporation, and other conveyance inefficiencies. During past drought conditions, the District has had to curtail deliveries by up to 75 percent due to a lack of water. If the District's distribution system did not lose so much water to seepage and evaporation, less would need to be diverted and more water could stay instream. Details of water losses and demands can be found in the District's SIP [TID 2017; Appendix D].

2.1.2 Water Delivery and Operations Inefficiencies

In addition to seepage and evaporation losses, it can take days to recharge[3] open canals and laterals after the District reduces its diversions, further affecting the reliability of water deliveries for patrons. When the District increases its diversion rate again to increase the water level in the canal, the ends of the District's laterals remain dry as the system recharges. During these periods, the District cannot always fully meet its obligations to deliver water to its patrons due to conveyance inefficiencies. The District's canals and laterals do not transport and deliver water as precisely, accurately, or efficiently as a modernized system would.

The District's antiquated canal and laterals make it difficult to deliver the correct amount of water to patrons at the correct time, particularly early and late in the irrigation season. During these periods, the District's water rights require it to divert water at a reduced rate. At these reduced flow rates, the canals and laterals are more sensitive to small changes in streamflows at the diversion or deliveries at

[3] After the winter season when the canals are dry, it takes the District a few days at the beginning of the irrigation season to wet the perimeter of the canals, which allows for the swelling of clays, a decrease in the permeability of the canal soil, and therefore a more efficient system to send water flows to patron turnouts. This process is referred to by the District as recharging the canals.

each point-of-delivery. The reduced flow rates in the open canal and laterals make it much more challenging for the District to deliver the amount of water that patrons need when they need it. For example, a point-of-delivery near the end of a lateral may receive no water in the morning and excess water in the evening. The District also has to pass excess water, known as carry water, to ensure that the appropriate amount of water reaches all points-of-delivery based on patrons' needs and water rights. When patrons' demands subside, this excess water is spilled onto non-productive lands at the ends of the conveyance system; the water does not return to any waterways. This excess water is another example of the inefficiencies in the current conveyance system.

Operating and maintaining the District's open canals and laterals requires staff to clean ditches and canals, clean debris from trash racks, and adjust flows to patrons. The District's current operations budget is approximately $946,000 annually (see Figure 5-2), or over $12,000 per mile of the system. The District now serves small-sized parcels through a canal and lateral system originally designed for larger parcels. Approximately 54 percent of TID's accounts are now 5-acre or smaller parcels. These accounts represent only 15 percent of the irrigated area of the District (TID 2017). District staff invest proportionally more time to manage water delivery for these smaller-sized parcels than they would for larger parcels; smaller deliveries on an unpressurized canal and lateral system are more sensitive to fluctuations in system operations due to changes in streamflows, diversion amounts, or other patrons' deliveries.

2.1.3 Instream Flow for Fish and Aquatic Habitat

The Deschutes River and its tributaries experience low streamflows every year due to the storage and diversion of water for agricultural use. Resource agencies have identified streamflow as a primary concern in Tumalo Creek, Crescent Creek, the Little Deschutes River, and the Deschutes River (UDWC 2014). Reservoir operations lead to low winter streamflows and high summer streamflows in Crescent Creek, the Little Deschutes River, and the Deschutes River upstream from TID's BFC diversion. The combined diversions of the seven major irrigation districts and the cities that divert water in or near the City of Bend lead to low spring, summer, and fall streamflows in the Deschutes River downstream from TID's BFC diversion and in Tumalo Creek downstream from TID's TFC diversion.

The Deschutes River and its tributaries support many fish, bird, and wildlife species. Among these include several sensitive species such as steelhead trout, redband trout, and Chinook salmon, as well as the Oregon spotted frog and bull trout listed as 'threatened' under the Endangered Species Act. Low streamflows in the Deschutes River and its tributaries limit habitat for many of these species. Reduced habitat associated with low streamflows increases competition between populations, which often favors non-native brown trout over native redband trout, and can concentrate fish populations and increase susceptibility to predators and disease.

Tumalo Creek, Crescent Creek, the Little Deschutes River, and the Deschutes River are listed as impaired waterways under Section 303(d) of the CWA (the "Clean Water Act" became the common name with the 1972 amendments to the Federal Water Pollution Control Act of 1948) because they do not meet one or more of the State of Oregon's water quality standards for salmon and trout, as well as other beneficial uses. Water management along the entire length of the Deschutes River affects temperature, dissolved oxygen, pH, and other water quality parameters, which in turn affects habitat conditions.

Low streamflows in late fall, winter, and early spring associated with upstream reservoir storage limits riparian vegetation in Crescent Creek and the Deschutes River (RDG 2005). Low streamflows along these reaches can expose the channel bed and river banks, facilitating increased erosion and fine sediment delivery following freeze-thaw processes and increased spring streamflow (RDG 2005). The opposite is seen in Tumalo Creek as winter flows are maintained in their near-natural state but summer flows are severely limited downstream from the TFC diversion. Because streamflow is strongly correlated with critical physical and biological characteristics of a river, it influences the functions of associated riparian areas (National Research Council 2002).

As riparian areas become hydrologically disconnected from their adjacent stream due to consistently low streamflows, they lose many of their ecological functions. Reestablishing a more natural hydrologic regime in these reaches allows the river channel to supply water to riparian areas via infiltration through channel banks, thus enhancing riparian function by facilitating processes such as hyporheic exchange, physical and chemical transformations, and supporting riparian plant communities and aquatic habitat (National Research Council 2002).

2.1.4 Risks to Public Safety

Open canals pose a risk to public safety during the irrigation season. In addition to multiple instances of injury, several drowning deaths have occurred in adjacent districts' canals in 1996, 1997, and 2004 (Flowers 2004). The District's location in a partly urbanized area heightens the potential for an accident, as the canals pass through urban areas, rural residences, private lands, and irrigated fields.

During the summer, water depths in the District's canals range between 2 to 6 feet, with velocities up to 5 feet per second in places. These conditions make it difficult for a healthy, strong adult to stand in or climb out of a canal without assistance. A child or non/weak-swimmer would have an even higher risk of drowning in a canal with these attributes. If a person or animal falls into a District canal, they could have serious difficulty gaining hold on the banks in order to climb out due to the volume and speed of the moving water. Barriers or fences at the top banks of the canals are not currently installed.

Deschutes County was the second fastest growing county in Oregon in 2015 based on the Oregon Population Report (PSU 2015). Public safety risks associated with open canals will continue to grow as urbanization expands into previously rural areas such as TID's service area.

2.2 Watershed and Resource Opportunities

The following list of resource opportunities would be realized through the implementation of the project. Quantification of these opportunities is provided in other sections of this Plan-EA.

- Provide a more reliable source of irrigation water to TID patrons by enabling TID to better deliver the amount of water that patrons need when they need it. Piping open canals and laterals eliminates the need for carry water[4] so that more water is available for patrons and further reduces the need to spill excess water as the system becomes on demand. Either piping or lining open canals would improve operational efficiencies to ensure that patrons receive the water they need at the time that they need it. A modern conveyance system would reduce the District's diversion rate while fulfilling patron water rights.

- Improve streamflows, water quality, and habitat availability in Tumalo Creek downstream from the TFC Diversion, Crescent Creek downstream from Crescent Lake, the Little Deschutes River downstream from Crescent Creek, and the Deschutes River downstream from the Little Deschutes River by legally protecting conserved water instream under the State of Oregon's Allocation of Conserved Water Program (described below).
- Reduce the operations and maintenance costs involved in delivering irrigation water to TID patrons.
- Minimize the potential for injury and loss of life associated with the open TID canals.
- Reduce energy costs by removing the need for most patrons' individual pumps. Currently, TID patrons use individual pumps to pressurize water from their private ditch or pond. Cumulatively, these individual pumps serving farms across the District use approximately 6 million kilowatt hours per year with electricity costs of approximately $584,000 per year.

2.2.1 Using the State of Oregon's Allocation of Conserved Water Program

The District has determined that implementation of the proposed action could conserve up to 48 cfs that is currently lost through seepage and evaporation (TID 2017). The District would use the State of Oregon's Allocation of Conserved Water Program (Oregon Revised Statute [ORS] 537.470) to legally protect the water conserved by the project as instream flow. The Conserved Water Program allows water users to create new water rights for water saved as the result of an efficiency project (see OWRD 2017 and Appendix E for more information about the Conserved Water Program). New instream water rights created through the program are permanently protected instream and unavailable for other uses. The District anticipates that 100 percent of the project would be funded through PL 83-566 and other public or public-interest funding sources. With this anticipated funding, the District would allocate 100 percent of the conserved water instream.[5]

Through the Conserved Water Program, the Oregon Water Resources Department (OWRD) would issue a new water right certificate to the District with the original priority date reflecting the reduced quantity of water being used with the improved technology. An additional certificate would then be issued to the State of Oregon for the instream water right. The water allocated instream through the

[4] Lining canals would still require the District to utilize carry water.

[5] The District would potentially invest up to 5% of the cost of any project group from its own funds to facilitate project implementation, only if needed, due to unforeseen circumstances. For example, the District would invest its own funds in materials if public funds were not yet available and doing so would ensure that project construction could occur on schedule. If the District were to invest its own funds in a project group, the District would apply for an amount of conserved water created through that project group in proportion to the amount of public and public-interest funding invested in that project group (i.e. between 95% and 100% of the water saved by that project group). The District would not apply to create new water rights for out-of-stream uses through any project group.

program would be legally protected against any out-of-stream use; the District would no longer be able to divert the water.

The water allocated for instream use would be shared between Crescent Creek and Tumalo Creek. Water allocated to instream water rights in Crescent Creek would be released outside of the irrigation season from Crescent Lake Dam. Water allocated to instream water rights in Tumalo Creek would bypass the TFC diversion and remain instream. Streamflow and habitat conditions along Crescent Creek, the Little Deschutes River, the Deschutes River, and Tumalo Creek would benefit from increased streamflows. OWRD would continue to measure streamflows in each of these water bodies at existing permanent stream gauging stations and diversions into TID's system to ensure that the water conserved by the project remains instream.

Section 6.10 and its subsections describe a volume of water to be conserved and allocated instream following the completion of the proposed action. These sections also describe the rates, timing, and sources for this allocation. These rates, timing, and sources are estimates based on prior conserved water applications that were associated with similar projects in TID and that have already completed the State of Oregon's administrative process for the allocation of conserved water (see Oregon Administrative Rules 690-018-0050). The State of Oregon's administrative process will determine the final volumes, rates, timing, and sources of water allocated instream for each conserved water application.

3 Scope of the Plan-EA

The scoping process followed the general procedures consistent with NRCS guidance and PL 83-566 requirements. Both NRCS procedures and NEPA regulations (40 CFR 1500–1508) require that NRCS use scoping early in the planning process to identify issues, concerns, and potential effects that require detailed analysis.

Using input obtained during scoping, NRCS refined the TID Irrigation Modernization Project to focus on relevant resource concerns and issues, as well as eliminated those that are not relevant from further detailed study. Relevant resource concerns are carried forward for further study and discussion.

3.1 Agency, Tribal and Public Outreach

Federal, state, and local agencies and representatives, as well as non-governmental organizations (NGOs), received an invitation to the scoping period of the Plan-EA. Advertisements announcing the scoping period and the associated scoping meeting were placed in two local and regional newspapers in addition to multiple online locations including NRCS website, the District's website, and DBBC's website. In addition, the scoping meetings were featured by KTVZ Channel 21 and KBND News.

Tribal consultation was conducted in accordance with the NHPA of 1966 and Executive Order (EO) 13175, *Consultation and Coordination with Indian Tribal Governments*, to maintain NRCS' government-to-government relationship between Native villages and tribes. NRCS sent a letter to the Confederated Tribes of Warm Springs (CTWS) requesting input and notifying them of the scoping process. Confederated Tribes of Warm Springs responded and requested that they be consulted during the planning phase of the TID Irrigation Modernization Project.

3.2 Scoping Meeting

A scoping meeting was held on Thursday, July 6, 2017 at the Tumalo Community Church Meeting Room, 64671 Bruce Avenue in Bend, Oregon. Presenters at the meeting included Tom Makowski, NRCS; Kenneth B. Rieck, Manager of TID; Margi Hoffmann, Farmers Conservation Alliance (FCA); and Bridget Moran, U.S. Fish and Wildlife Service (USFWS). The presentations covered the financial assistance available through PL 83-566, the purpose and need of the project, the Watershed Plan-EA process, and how the public could get involved. After the presentations, attendees asked questions and provided comments for the public record. The meeting was attended by 76 people, excluding staff from TID, NRCS, USFWS, and FCA.

3.3 Scoping Comments

Scoping comments were accepted from June 16, 2017, to July 24, 2017. Comments were submitted via the following methods:

- At the public meeting on July 6, 2017
- Email, wsp@tumalo.org or margi.hoffman@fcasolutions.org
- Mail, Farmers Conservation Alliance, Attention Watershed Plan-EA, 11 3rd Street Suite #101, Hood River, OR 97031
- Phone, Farmers Conservation Alliance, 541-716-6085

Comments generally supported the TID Irrigation Modernization Project. Comments included these items:

- Importance of instream flows for the health of the Deschutes River, its tributaries, and the associated fish, aquatic species, and general wildlife
- Request to permanently commit 100 percent of water conserved through the project instream
- Amount of water conserved by the project, mechanism by which water would be conserved, and how the conserved water would be distributed in the area of potential effect
- Whether conserved water would be used for groundwater mitigation credits
- Request to include an analysis of the efficient use of dollars, quantifying the public cost per cfs of water conserved
- Request to work with farmers to adopt on-farm water conservation measures as a result of pressurized delivery
- Importance of preparing for the potential effects of climate change
- Concern for wildlife along the canals and laterals

- Concern for private ponds and associated wildlife
- Concern for groundwater, aquifer recharge, and water availability for private wells
- Concern for vegetation along the canals and laterals, especially mature trees
- Removal cost of and responsibility for trees that do not survive the project
- Concern for property values of the adjacent landowners
- Request to avoid any new irrigation on previously unirrigated land
- Cost effectiveness and engineering considerations of a top-down versus bottom-up piping design
- Effect of water meters and measuring water use
- Effect of the project cost on District water rates
- Effect on maintenance and access roads along canals
- Recreation possibilities and potential trail network
- Trail development and proximity to private homes
- Effect on patron deliveries including amount of water and timing
- Ability of patrons to lease their water to other users or for other purposes
- Relation of the project to hydroelectric development
- Effect on Tumalo Reservoir management and infrastructure
- Relation of the project to the floodplain

Federal, state, Tribal, and local agency consultation and other public participation activities are further described in Section 7 of the Plan-EA.

3.4 Identification of Resource Concerns

Resource concerns identified through scoping comments include water resources (water conservation, water quality, groundwater, and wild and scenic rivers), aquatic and fish resources, soil and geologic resources, visual resources, cultural resources, recreation, socioeconomics, wetlands, terrestrial wildlife, and vegetation resources. Table 3-1 provides a summary of resource concerns and their relevancy to the proposed action. Resource items determined not relevant have been eliminated from detailed study, and those resources determined relevant have been carried forward for analysis.

Table 3-1. Summary of Resource Concerns for the Tumalo Irrigation District – Irrigation Modernization Project.

Resource	Relevant to the Proposed Action? Yes	No	Justification
Air			
Air Quality		X	Review of Oregon Department of Environmental Quality air quality data indicates that the entire project area is in attainment for all criteria pollutants. Emissions from equipment associated with implementation of proposed action activities would occur; however, such emissions are considered negligible when compared to background levels and the application of best management practices.
Geology and Soils			
Erosion	X		Soil disturbance during construction could contribute to erosion.
Landslides	X		There are some areas of low to moderate landslide risk within the project area.
Prime Farmlands	X		Prime farmlands occur in the project area and could be affected by the project.
Human Environment			
Archaeological Resources	X		Archaeological resources have not been found in the portions of the project area that have been surveyed to date. Additional archaeological surveys would be completed for the remaining portions of the project area.
Environmental Justice		X	The proposed action would not disproportionally affect any racial, socioeconomic, or environmental justice groups, and would comply with Executive Order 12898.
Historical Resources	X		Historical resources are known to occur in the project area. Consultation with the State Historic Preservation Office is required for compliance with Section 106.
Land Use	X		While no effects on property ownership would occur, construction activities would temporarily affect traffic and agricultural land use would be indirectly affected.
National Parks and Monuments		X	No National Parks or Monuments occur in the project area.

Resource	Relevant to the Proposed Action?		Justification
	Yes	No	
Noise		X	The project is located in agricultural areas where heavy equipment use is commonplace. Therefore, noise in the project area is anticipated to be consistent with existing background levels. Effects associated with noise were considered, but eliminated from detailed analysis because the potential for any additional noise-related effects is low.
Parklands	X		Construction activities would temporarily affect recreation activities in the southeast corner of Tillicum Park.
Public Safety	X		Implementation of the proposed action would affect the risk of drowning in open canals depending upon the alternative selected.
Recreation Trails	X		Construction activities would temporarily affect recreational use of Twin Bridges Scenic Bikeway and Tillicum Park.
Visual Resources	X		Visual resources of the project area would be affected by project construction where open canals would be altered.
Socioeconomics			
Local and Regional Economy	X		The proposed action involves an expenditure of public funds, which could affect the local and regional economy. An evaluation of the effects of providing NRCS funding is included.
National Economic Development (NED)	X		A NED analysis has been completed as required by the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.
Vegetation			
Invasive Species/Noxious Weeds	X		Construction activities could spread noxious weeds and/or create conditions for them to establish.
Mature Trees	X		Direct and indirect effects to mature trees could occur.
Special Status/Threatened or Endangered Species	X		The project area has rights-of-way through BLM land that is an Area of Critical Environmental Concern for Peck's milkvetch, a Federal Species of Concern; however, the species has not been observed in the project area to date.
Water			
Coastal Zones		X	No coastal zones occur within or near the project area.

Resource	Relevant to the Proposed Action?		Justification
	Yes	No	
Coral Reefs		X	No coral reefs occur within or near the project area.
Conserved Water	X		Water conserved by the proposed action would not be diverted and would remain in Tumalo Creek or Crescent Creek and would be allocated to instream uses.
Floodplain Management		X	The proposed action does not occur in the 100-year floodplain as represented by the Federal Emergency Management Agency's Flood Insurance Rate Maps (FEMA 2013), and the proposed action would not directly or indirectly support floodplain development; as such, effects on the floodplain are not further considered or addressed.
Groundwater Mitigation Credits		X	The proposed action would not create groundwater mitigation credits.
Groundwater Quality		X	Groundwater quality would not be affected by the proposed action.
Groundwater Quantity, Aquifer Recharge	X		Reduced seepage from canals and increased instream flows could affect groundwater quantity and aquifer recharge.
Hydroelectric Development		X	The proposed action does not consider developing hydroelectric facilities and cannot use the existing authorization of PL 83-566 funding for such development.
Hydrology	X		Reduced seepage could affect hydrology. The proposed action would allocate conserved water instream.
Private Water Features and Ponds		X	The proposed action would not remove or modify private water features and ponds.
Public Water Supply		X	The proposed action would not affect public water supply.
Regional Water Resources Plans	X		Implementation of the proposed action would allocate more water instream and reduce District diversion flow rates. Changes to District operations and management plans of the District's water resources would likely occur.
Surface Water Quality	X		Implementation of the proposed action could result in long-term effects by increasing river flows.
Tumalo Reservoir		X	Implementation of the proposed action does not change Tumalo Reservoir operations and maintenance activities; as such, they are not further considered or addressed.
Water Leasing	X		Implementation of the proposed action would remove leasing limitations for patrons.

Resource	Relevant to the Proposed Action?		Justification
	Yes	No	
Water Rights	X		Transfers of water rights would occur under the Allocation of Conserved Water Program.
Wild and Scenic Rivers	X		Stretches of the Deschutes River upstream and downstream from TID's diversion, as well as a stretch of Crescent Creek, are a designated Wild and Scenic River and would be indirectly affected by the proposed action.
Wetlands and Riparian Areas			
Wetlands and Riparian Areas	X		Wetlands and riparian areas could be indirectly affected.
Fish and Wildlife			
Bald and Golden Eagle Protection Act	X		Habitat for bald eagles could occur in the project area. Two golden eagle nests are known to occur near project area.
Endangered Species	X		The proposed action would not affect the yellow-billed cuckoo, northern spotted owl, endangered gray wolf, or their designated critical habitat due to species habitat preferences and ranges. These species would not be carried forward for consideration and analysis in this Plan-EA. Oregon spotted frog and bull trout or their habitats are known to occur in waterways that could be affected by the project.
Essential Fish Habitat		X	The Magnuson-Stevens Act established requirements for including Essential Fish Habitat (EFH) descriptions in federal fishery management plans, and requires federal agencies to consult with National Marine Fisheries Service (NMFS) on activities that may adversely affect EFH (Pub. L. No. 104-297). EFH can include all streams, lakes, ponds, wetlands, and other viable waterbodies, and most of the habitat historically accessible to salmon necessary for spawning, breeding, feeding, or growth to maturity. As the project would not affect EFH, consultation under the Magnuson Stevens Act is not required.
Fish and Fish Habitat	X		The proposed action could affect fish habitat within the area of potential effect.
General Wildlife and Wildlife Habitat	X		Construction and operation of project components could affect wildlife within the area of potential effect.
Migratory Bird Treaty Act species	X		Construction and operation of project components could affect migratory birds.

4 Affected Environment

The following sections describe the existing ecological, physical, biological, economic, and social environment of areas that would be affected by the proposed action. The project area is defined in Section 1.4 and is a single, defined boundary. The area of potential effect varies for each resource based on the relevant expected effects of the proposed action.

4.1 Cultural Resources

Cultural resources are defined as physical or other expressions of human activity or occupation. Historic properties are defined as any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion on the National Register of Historic Places. The term "historic properties" includes traditional cultural properties and archaeological sites. Section 106 of the NHPA requires federal agencies to take into account the potential effects of a project on historic properties. The area of potential effect for cultural resources is identical to the project area.

4.1.1 Irrigation Development in Central Oregon

At the turn of the twentieth century, Central Oregon, known then as the Deschutes country, was one of the most remote regions in the nation. Settlers were enticed with opportunities to capitalize on the Deschutes River, promising lands for agriculture, and immense pine forests. Two major factors contributed to the settlement and agricultural development of Central Oregon: the arrival in 1900 of the Columbia Southern railroad, and the State of Oregon's acceptance in 1901 of the 1894 federal Carey Act that encouraged states to pursue development of arid lands (NPS 2015). In exchange for up to 1 million acres of federal land, states made up to 160 acres available to settlers who agreed to improve and cultivate the land. The Carey Act enabled states to issue irrigation contracts to private developers who were expected to design and build irrigation projects, as well as recruit settlers to farm the new areas. The State would issue a water right to the private developer for a particular project, but the State would not be responsible for financing or construction. If an irrigation project failed, the State reassigned the contract to another development company. While limited irrigation in Central Oregon had begun before these changes, the Carey Act helped spur the creation of more irrigation companies and investment in large-scale irrigation projects (NPS 2017).

4.1.2 Archaeological Resources

Archaeological surveys were conducted for the District's Highline/Couch laterals in 2006 (parts of Project Group 2 and 5) and the TFC in 2017 (Project Group 1). The canal and laterals were empty at the time of the surveys, allowing an examination of the canal banks and the full length and width of the ROW. No archaeological resources were found (Stuemke 2006 and 2017). Archaeological surveys for areas affected by other project groups (Project Groups 2 through 7) would be completed closer to their implementation date. An overview of Central Oregon's prehistoric cultural history and Euro-American history can be found in Appendix E.

4.1.3 Historical Resources

Construction of the TID system began in 1900, with other substantial building phases occurring in 1903, 1913-1914, and 1922-1923. Originally known as the Tumalo Project, the irrigation system has encouraged and accompanied settlement and agricultural development in the upper Deschutes

Basin. Over time, the District made improvements to failing structures, installed required fish screens, and piped critical segments of canal for public safety and water conservation. Portions of the original system are still in use today.

Based on its significance as one of the earliest Carey Act irrigation enterprises in Oregon's upper Deschutes Basin, the State Historic Preservation Office (SHPO) concurred with the U.S. Bureau of Reclamation (Reclamation) in 1997 that TID is considered eligible for listing in the National Register of Historic Places (Reclamation 2010). Eight features of the system were evaluated for the National Register as contributing or potentially contributing features. These features include the Tumalo Diversion Dam, TFC, Columbia Southern Canal, Bend Diversion Dam, BFC, Tumalo Reservoir, Tumalo Dam and Control House, and Bull Creek Dam and Bridge. These features of the District are documented in Historic American Engineering Record No. OR-151 (HAER) (Luttrell and Pfaff 2006).

Two features that would be affected by the proposed action, the TFC (Project Group 1) and the Columbia Southern Canal (Project Group 6), are described below in more detail with information from the HAER (Luttrell and Pfaff 2006).

4.1.3.1 Tumalo Feed Canal

The TFC was constructed from 1913 to 1914. As originally built, the canal extended 7.2 miles overland from Tumalo Creek, running northwesterly along the southwestern edge of TID to the reservoir on Bull Flat. The canal consisted of a 14-foot-wide open ditch with a water depth of 4 feet. It had three state-of-the-art metal flumes collectively totaling 6,381 feet in length, each 10 feet wide by five feet deep, elevated on wooden trestles set on concrete piers. All structures appurtenant to the TFC, such as drops, canal crossings, and turnouts were constructed of concrete.

Beginning with a rehabilitation program in 1974, substantial changes have occurred to the canal structures to correct conveyance losses or replace aged components. The TFC was rehabilitated in 1974 with 2,755 feet of 54-inch diameter concrete-pipe siphon. In 1998, 3,000 feet of new pipeline were installed in the canal. The Klippel and Weber flumes, two original wooden trestle flumes, were replaced with siphons in 2000. Flume replacement features included concrete inlet and outlet structures and buried steel pipeline. Likewise, the adjacent twin flumes downstream from the Klippel Siphon have also been removed. The Pauly Lateral Canal is presently served by a newer concrete delivery.

4.1.3.2 Columbia Southern Canal

The construction of the Columbia Southern Canal was initiated by the Three Sisters Irrigation Company in 1900. Starting eight miles upstream of Shevlin Park, the unlined and open canal diverted water from Tumalo Creek for 8.5 miles to the intersection with the TFC and an associated settling pond. The Columbia Southern Canal south of the pond is no longer used by the District. The pond also directly supplies water into the Tumalo Reservoir Feed Canal and the Lacey Lateral Canal. After leaving the pond, the Columbia Southern Canal continues northward to its diversion into the West Branch Columbia Southern Canal. Both the West Branch Drop and the Gerking Flume are situated along the West Branch Columbia Southern Canal. Although an original feature of the canal, the Gerking Flume has been periodically rehabilitated during its lifetime.

The HAER found that as the oldest project feature, the Columbia Southern Canal represents a contributing element if it retains sufficient physical integrity. To date, the Columbia Southern Canal has not been thoroughly surveyed (Luttrell and Pfaff 2006).

4.2 Fish and Aquatic Resources

The area of potential effect for fish and aquatic resources includes waterbodies that could be affected by the project (Table 4-1). These waterbodies include Crescent Lake, Crescent Creek (RM 30 - 0), the Little Deschutes River (RM 57 - 0), the Deschutes River (RM 192.5 - 120), and Tumalo Creek (RM 2.5 - 0). These waterbodies are included in the area of potential effect because the increased water in these sections of stream following completion of the project, would indirectly affect fish and aquatic resources.

Table 4-1. Waterbodies Included in the Area of Potential Effect for Fish and Aquatic Resources.

Waterbody No.	Name	Reach	Size	Tributary To
1	Crescent Lake	N/A	86,900 acre-feet	N/A
2	Crescent Creek	Crescent Lake Dam (RM 30) to the mouth (RM 0)	30 miles	Little Deschutes River
3	Little Deschutes River	Crescent Creek (RM 57) to the mouth (RM 0)	57 miles	Deschutes River
4	Deschutes River	Little Deschutes River (RM 192.5) to the Bend Feed Canal diversion at Steidl Dam (RM 166)	26.5 miles	Columbia River
5	Deschutes River	Bend Feed Canal diversion at Steidl Dam (RM 166) to Lake Billy Chinook (RM 120)	46 miles	Columbia River
6	Tumalo Creek	Tumalo Feed Canal diversion (RM 2.5) to its confluence with the Deschutes River (RM 0)	2.5 miles	Deschutes River

Notes:
N/A: Not Applicable

4.2.1 General Fish and Aquatic Species

The District's canals do not support game fish, salmonids, or threatened and endangered aquatic species. Fish screens compliant with Oregon Department of Fish and Wildlife (ODFW) standards were installed on the BFC diversion in 2004 and on the TFC diversion in 2006. These fish screens separate water diverted for consumptive use from water left instream. They prevent any fish from entering the District's irrigation conveyance system.

There are 18 species of fish documented in the area of potential effect (Table 4-2). All 18 of these fish species are potentially present in the Deschutes River from Steelhead Falls (RM 128) to Lake Billy Chinook (RM 120). The summer steelhead, Chinook salmon, and sockeye salmon in this reach are part of a re-introduction effort that began in 2009 to mitigate for blockage of fish passage around the Pelton Round Butte Dam Complex (ODFW and CTWS 2008). Chinook and sockeye salmon are unable to navigate Steelhead Falls at RM 128, which creates the uppermost distribution limit for salmon in the Deschutes River. Summer steelhead are able to pass upstream of Steelhead Falls but are unable to navigate upstream of Big Falls at RM 132. Big Falls is considered the uppermost limit of anadromous fish distribution (ODFW 1996).

Table 4-2. Fish Species within the Area of Potential Effect for the Tumalo Irrigation District – Irrigation Modernization Project.

Fish Species	Scientific Name	Origin
Bridgelip sucker	*Catastomus columbianus*	indigenous
Brook trout	*Salvelinus fontinalis*	introduced
Brown bullhead catfish	*Ictalurus nebulosus*	introduced
Brown trout	*Salmo trutta*	introduced
Bull trout	*Salvelinus confluentus*	indigenous
Chinook salmon	*Oncorhynchus tshawyscha*	indigenous
Chiselmouth	*Acrocheilus alutaceus*	indigenous
Largescale sucker	*Catastomus macrocheilus*	indigenous
Longnose dace	*Rhinichthys cataractae*	indigenous
Mountain whitefish	*Prosopium williamsoni*	indigenous
Northern pike minnow	*Ptychocheilus oregonensis*	indigenous
Rainbow trout	*Oncorhynchus mykiss*	introduced
Redband trout	*Oncorhynchus mykiss*	indigenous
Sculpin spp.	*Cottus* spp.	indigenous
Sockeye salmon / Kokanee	*Oncorhynchus nerka*	indigenous
Summer Steelhead	*Oncorhynchus mykiss*	indigenous
Three-spined stickleback	*Gasterosteus aculeatus*	introduced
Tui chub	*Gila (Siphateles) bicolor*	introduced

Notes:
Adapted from Starcevich 2016

Redband trout and mountain whitefish are indigenous species that are found in the entire area of potential effect including Crescent Creek, the Little Deschutes River, the Deschutes River, and Tumalo Creek. Brown trout, eastern brook, and tui chub trout are introduced species that are also found throughout the area of potential effect. Brown trout were introduced to the Deschutes Basin by state and federal agencies in the early 1900s. In Tumalo Creek, redband trout, brown trout, and eastern brook trout are the most abundant species (Starcevich 2016). Brown bullhead catfish and three-spined stickleback are distributed in the Deschutes River and the Little Deschutes River. Sculpin spp. has also been found within the area of potential effect (Starcevich 2016). Longnose dace, chiselmouth, largescale sucker, bridgelip sucker, and northern pike minnow are found in the Deschutes River between Lake Billy Chinook and Big Falls. All of these species are indigenous to the Deschutes River.

Rainbow trout is a managed species that has been stocked in the Deschutes River and its lakes and tributaries for over 100 years. In the 1990s, ODFW adopted the Wild Fish Policy and stopped stocking rivers with hatchery rainbow trout to protect populations of native redband trout (ODFW 1996). Rainbow trout are still found in areas of the Deschutes River and within the area of potential effect.

Between 2012 and 2014, Carrasco and Moberly found fish assemblages in the middle Deschutes River (RM 164.8 - 120) to include mountain whitefish, redband trout, brown bullhead, mottled sculpin, brown trout, tui chub, and bridgelip sucker. Mountain whitefish, redband trout, and brown trout were found to be the dominant species (Carrasco and Moberly 2014). This species assemblage is similar to the species that ODFW found in an electrofishing occupancy study (Starcevich 2016).

Historically, the Deschutes River had relatively consistent streamflows seasonally and annually (see Section 4.10.2). The steady streamflows created fish habitat with cold, clear water, and consistent hydrology. Since the late 1800s, changes to Deschutes River surface water flows, construction of fish passage barriers, and water management has created a very different aquatic environment with resulting changes to the fish species assemblages.

Elevated water temperatures in the middle Deschutes River negatively affect salmonid growth and survival (Recsetar et al. 2012). Availability of cold-water refugia for temperature-sensitive fish species is of key importance when water temperatures in the main streams rise above acceptable standards. Water temperatures out of the normal range for fish can increase physiologic stress, increase susceptibility to predators, and influence growth rates, feeding, metabolism, and development. Water temperature changes to the area of potential effect are provided in Section 4.10.3.1.

Other aquatic species potentially found in the project area include Oregon spotted frog (see Section 4.2.2), bullfrog, western toad, Pacific treefrog, and long-toed salamander. The western toad, Pacific treefrog, and long-toed salamander are native to Oregon and may be present in open irrigation canals and adjacent banks where there is suitable vegetation (S. Wray, personal communication, November 17, 2017). The bullfrog is considered an invasive species that was introduced to Oregon in the early 1900s. Bullfrogs are voracious predators that eat any animal they can swallow. With the exception of the Oregon spotted frog listed as vulnerable, all of these amphibians are listed as species of least concern by the International Union for Conservation of Nature (IUCN 2017).

4.2.2 Federally Listed Fish and Aquatic Species

A list of species protected under the Endangered Species Act of 1973 (ESA; 16 U.S.C. 1531 et seq.), as amended in 1988, that have the potential to occur within the area of potential effect was obtained using the USFWS Environmental Conservation Online System Information for Planning and Conservation. Federally listed fish and aquatic species that are known to occur in the area of potential effect are Oregon spotted frog, steelhead, and bull trout (USFWS 2017).

USFWS lists Oregon spotted frog as threatened under the ESA. The Oregon spotted frog and its designated critical habitat occurs upstream of the BFC within the area of potential effect for aquatic resources, primarily in the area of Crescent Creek and the Little Deschutes River (Figure 4-1). USFWS has identified primary constituent elements (PCEs) for Oregon spotted frog critical habitat (81 *Federal Register* 29335, 2016). PCEs represent biological and physical features that are essential to the conservation of a species, and they describe habitat components that support one or more life stages of the species. PCEs for Oregon spotted frog generally describe areas that have appropriate water depths and refuge from predators, aquatic connectivity, and absence of non-native predators. A detailed list of Oregon spotted frog Critical Habitat PCEs is provided in Appendix E.2.

USFWS also lists bull trout as threatened under the ESA, and critical habitat is designated. The PCEs for bull trout describe habitat that has aquatic connectivity, complex habitat structure, water temperatures ranging from 2 degrees Celsius (°C) to 15 °C, natural variability in streamflows, a sufficient food base, absence of non-native predatory and competing fish (70 *Federal Register* 56211, 2005). A detailed list of Critical Habitat PCEs for bull trout is provided in Appendix E.2. Although critical habitat for threatened bull trout has been designated downstream of the TFC diversion and within the area of potential effects to aquatic resources in the Deschutes River from Big Falls (RM 132) to Lake Billy Chinook (RM 120) (Figure 4-2), recent electrofishing for an occupancy study did not find evidence of bull trout in this section of the Deschutes River (Starcevich 2016).

Steelhead populations are listed as threatened under ESA and are present within the area affected by the project (see Section 4.2.1). However, the population in the Deschutes River (Middle Columbia River steelhead) is classified as a non-essential experimental population (NEP) under section 10(j) of ESA and critical habitat is not designated (76 *Federal Register* 28715, 2011). Because of this classification, and because the NEP is located outside of a National Wildlife Refuge System and a National Park System, the population is treated as “proposed for listing” under ESA section 7 (76 *Federal Register* 28715, 2011; 81 *Federal Register* 33416, 2016).

4.2.3 State Listed Species

The ODFW maintains a list of native wildlife species in Oregon that have been determined to be either “threatened” or “endangered” according to criteria set forth by Oregon Administrative Rule [OAR] 635-100-0105 (ODFW 2017a). There are no threatened, endangered, or candidate aquatic species known to occur within the irrigation canals or any other areas where work associated with the proposed action would occur.

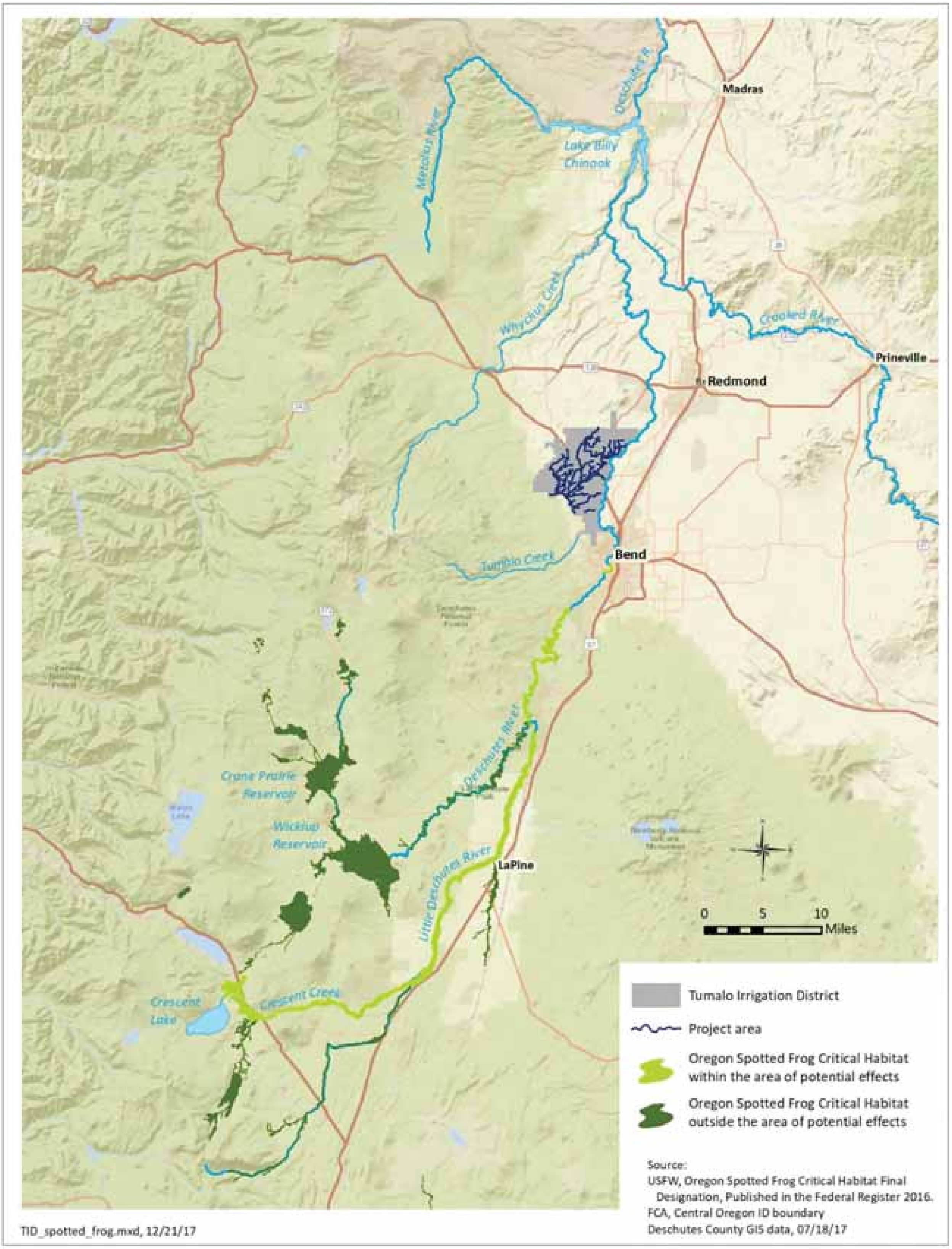


Figure 4-1. Oregon Spotted Frog Critical Habitat near the Tumalo Irrigation District.

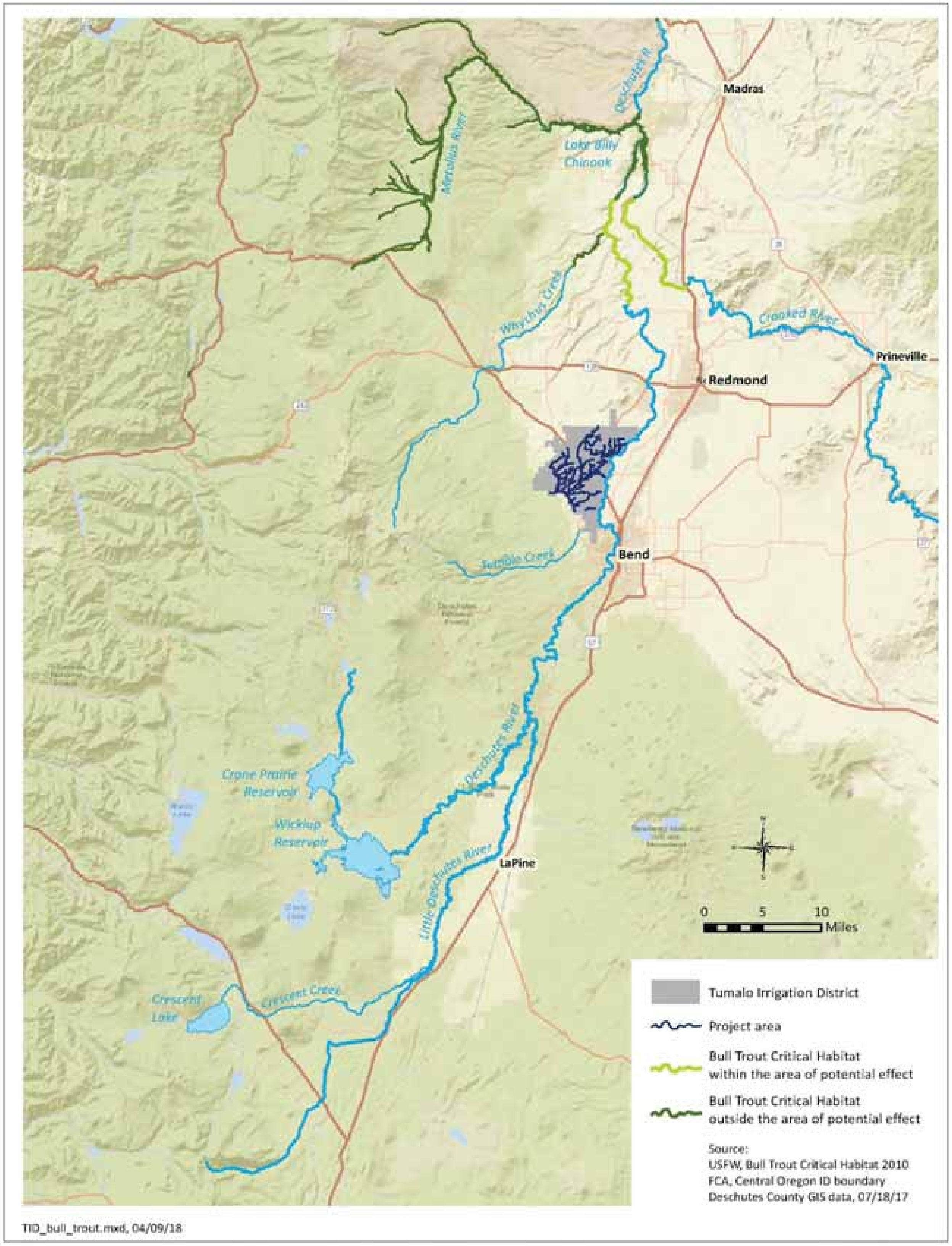


Figure 4-2. Bull Trout Critical Habitat near the Tumalo Irrigation District.

4.3 Geology and Soils

Effects on geology and soil resources as a result of the proposed action are not expected to extend beyond the project area; therefore, the area of potential effect is bound by the limits of the project area.

4.3.1 Geology

The project area is located within the Deschutes-Columbia Plateau, which is part of the larger Columbia Plateau. The Deschutes-Columbia Plateau was formed by periodic fissure eruptions of lava during the Miocene epoch, which filled a subsiding basin. The Deschutes Formation is a result of these basalt flows that erupted from vents and fissures (Lite and Gannett 2012). The permeability of the Deschutes Formation is variable within the Deschutes Basin. In areas where the underlying rock formation consists of fine-grained sedimentary deposits, dense lava flows, and pyroclastic flows, the ability of water to penetrate the layer is low. In areas with coarse-gained, unconsolidated sediments, vesicular rock, and brecciated lava flows that contain holes and cracks, water is able to move through easily (Lite and Gannett 2012). These layers of volcanic rock influence hydrology because many stream reaches lose water to the underlying aquifers or gain water through springs, both of which are created by these layers of volcanic rock.

The project area is located at the interface of the Cascade Range and High Lava Plains physiographic provinces (Orr et al. 1992) and more specifically, just east of the High Cascade subprovince. The High Cascades were primarily formed 2 to 4 million years ago during the Pliocene and Pleistocene Epochs, and they changed the landscape of the Deschutes Basin. This volcanic activity resulted in complex assemblages of vents, lava flows, pyroclastic deposits, and volcanically derived sedimentary deposits. The peaks in the High Cascades that lie to the west of TID are Jefferson, Three Fingered Jack, Washington, the Three Sisters, Broken Top, Mt. Mazama, and Bachelor. Over the last 2 to 4 million years, erosion, sedimentation, and volcanic activity deposited more layers of alluvium, ash, and andesite over areas of the Deschutes Formation. The geologic units found in the area of potential effect include basaltic to andesitic lava from the Pliocene and Miocene epochs, areas of sand and gravel deposits, as well as alluvium from the Pleistocene and some small areas of tuff deposits (Sherrod et al. 2004).

Geologic formations along TID's two primary diversion canals, the BFC and TFC, include basalt, volcanic ash tuff, cinder deposits, and sand and gravel deposits. Geology along the Columbia Southern Canal and its laterals are primarily sand and gravel deposits and basalt. The Highline and Couch Laterals and their sub-laterals overtop either basalt or sand and gravel deposits. Figure 4-3 presents a general geologic map of the District.

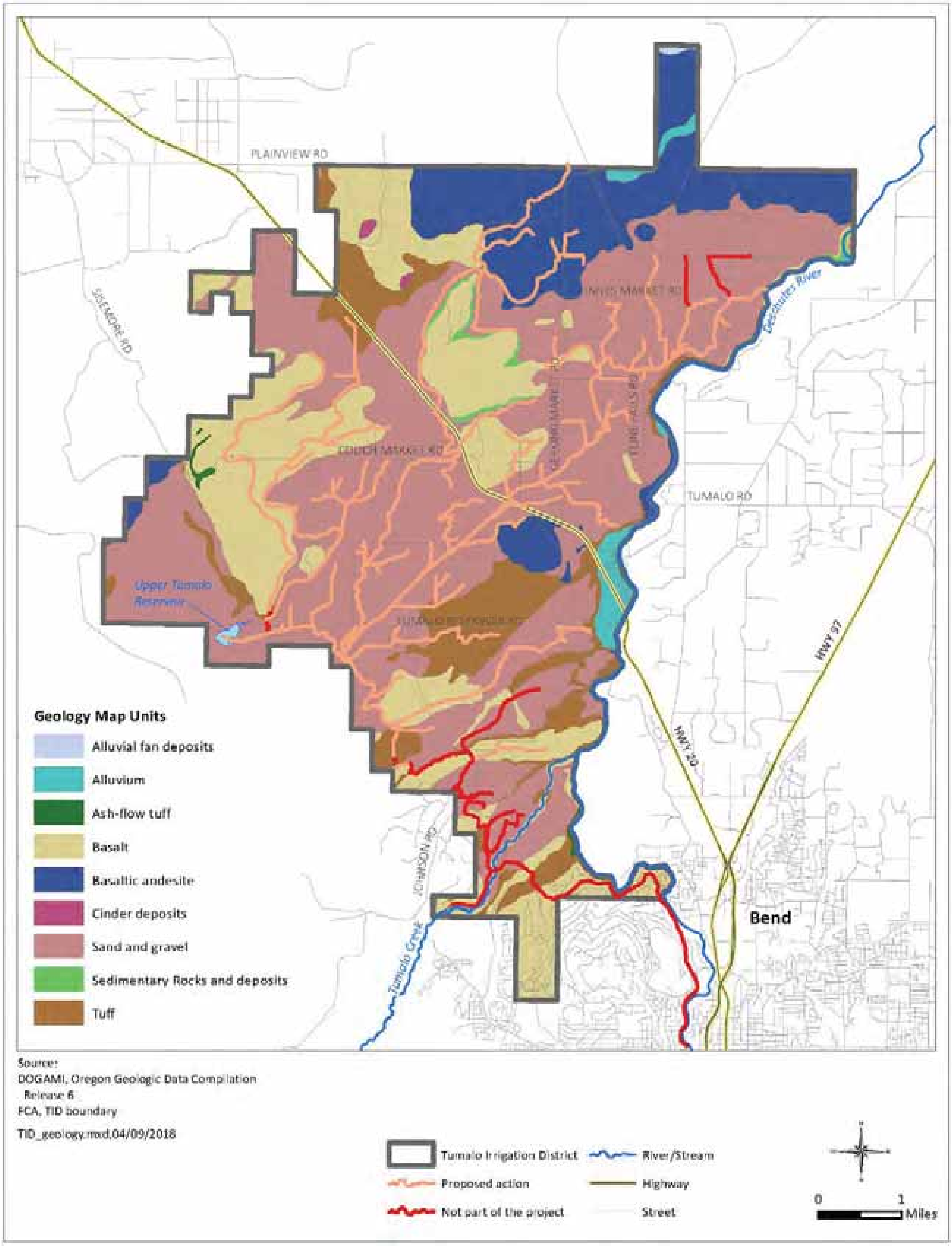


Figure 4-3. Geologic Formations in the Tumalo Irrigation District.

Geologic hazards in the project area include the potential liquefaction of soil that may occur during an earthquake. Areas that are susceptible to liquefaction include wet or low-lying areas or unconsolidated sediments. In portions of the project area with basalt formations, liquefaction susceptibility is generally low. Areas of the project area primarily overlain with gravel and sand deposits are more susceptible to liquefaction. There are some mapped areas with a low to moderate landslide risk within the project area (Burns et al. 2016). Areas with moderate landslide risk within the project area include Highline Canal, Lacy and Parkhurst Laterals off the TFC, the West Branch Canal, the Beasely Lateral of the West Branch, and the Hillburner Lateral of the Columbia Southern Canal (Burns et al. 2016). Additionally, there are areas of high landslide risk; these areas are primarily along the eastern border of the District paralleling the Deschutes River and are not crossed by the project area.

4.3.2 Soils

The underlying material of District lands is generally basalt and andesite, with areas of alluvium and volcanic ash deposits. Soil surface layers consisting of sandy loam and Tumalo sandy loam is the most common soil in the District (NRCS 2015b). Much of the Tumalo sandy loam occurs in areas between mounds and ridges of outcropping lava, which are characteristic of the upland plains east of the Cascades. Tumalo sandy loam has a slightly developed profile, meaning the subsoil is slightly finer in texture and more compact than the surface soil and has a weakly developed structural aggregate. They are very loose and are sensitive to lateral soil movement and erosion. Soil displacement of topsoil layers can adversely affect soil fertility and productivity. The sandy loam soils are moderately deep and well drained. This type of soil has high seepage rates for canal conveyed water and for ponds. The low available water capacity and high permeability requires the careful management of sprinkler irrigation to avoid deep percolation losses while providing adequate soil moisture for crop use. These soils are also subject to wind erosion without adequate cover.

The parent materials for Tumalo sandy loam soils are primarily derived from ash and pumice deposited from past volcanic eruptions. Pumice and ash tephras were expelled during eruptions like that of Mt. Mazama and the other High Cascade mountains. The ash and pumice deposits fell on previously developed soils. Almost all of the bedrock materials beneath the soils are extrusive volcanic rocks (NRCS 2015). Litter and duff on the soil surface is also found in variable depths throughout the District, primarily as a function of the aspect and plant association on which a given soil profile is located. Surface litter and duff is a primary component of the productivity of the soils present within the area. Underlying glacial or volcanic materials within the District affect the subsurface flow of water and influence the availability and content of nutrients within the soil profile. Hydric soil materials line the open canals and laterals in some areas of the District. NRCS defines hydric soils as soils permanently or seasonally saturated by water to develop anaerobic conditions. Hydric soils were added to reduce seepage and do not reflect the natural profile of soils surrounding the project area. Figure 4-4 and Figure 4-5 present existing soil types within the District.

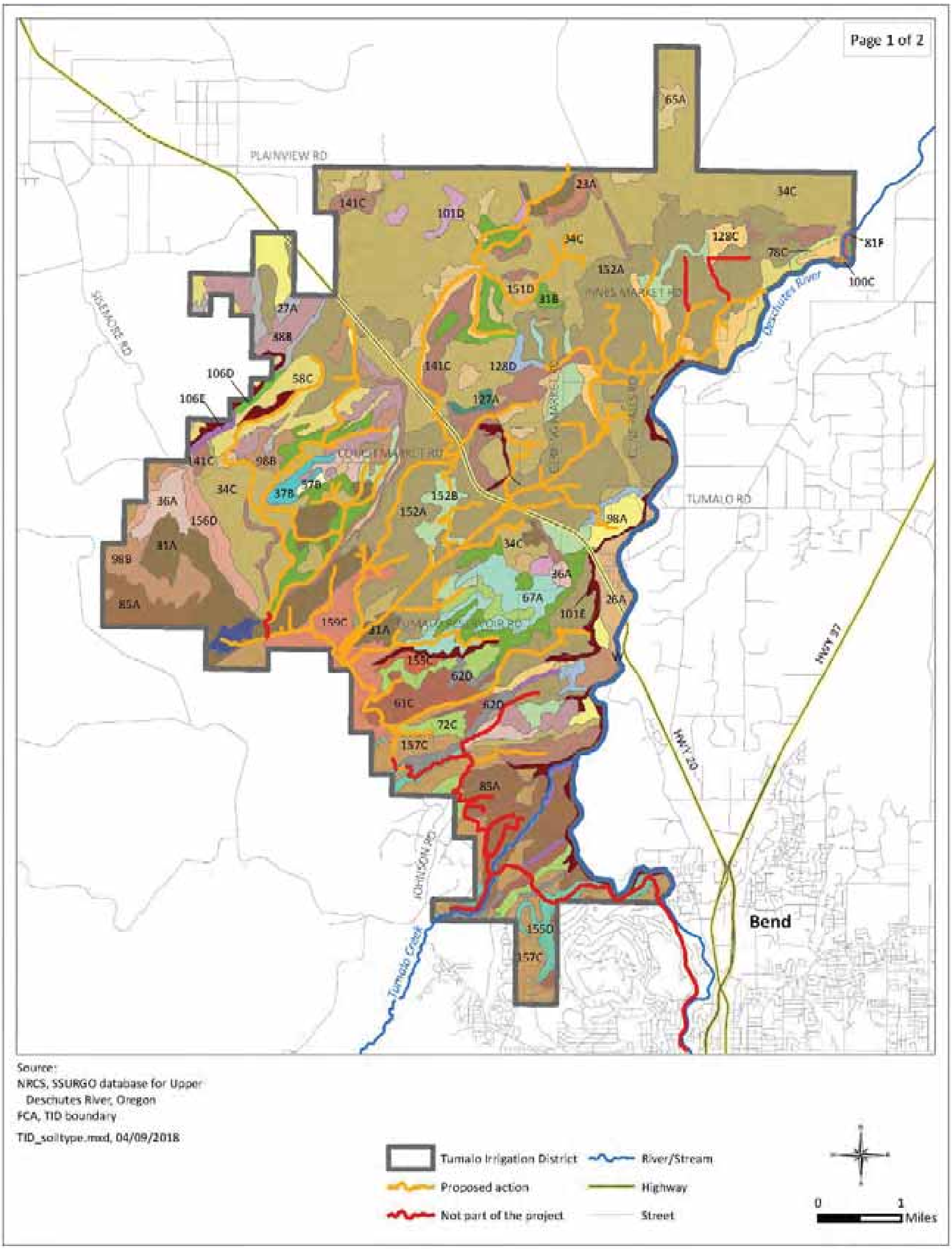


Figure 4-4. General Soil Types in Tumalo Irrigation District.

NRCS Map Unit Descriptions

Map Unit Symbol	Map Unit Name
23A	Buckbert sandy loam, 0 to 3 percent slopes
26A	Clinefalls sandy loam, 0 to 3 percent slopes
27A	Clovkamp loamy sand, 0 to 3 percent slopes
31A	Deschutes sandy loam, 0 to 3 percent slopes
31B	Deschutes sandy loam, 3 to 8 percent slopes
34C	Deschutes-Stukel complex, 0 to 15 percent slopes
36A	Deskamp loamy sand, 0 to 3 percent slopes
37B	Deskamp sandy loam, 3 to 8 percent slopes
38B	Deskamp-Gosney complex, 0 to 8 percent slopes
57B	Gosney stony loamy sand, 3 to 8 percent slopes
58C	Gosney-Rock outcrop-Deskamp complex, 0 to 15 percent slopes
61C	Henkle-Fryrear-Lava flow s complex, 0 to 15 percent slopes
62D	Henkle-Lava flow s-Fryrear complex, 15 to 50 percent slopes
65A	Houstake sandy loam, 0 to 3 percent slopes
67A	Houstake sandy loam, very gravelly substratum, 0 to 3 percent slopes
72C	Laidlaw sandy loam, 0 to 15 percent slopes
78C	Lickskillet-Deschutes complex, 0 to 15 percent slopes
81F	Lickskillet-Rock outcrop complex, 45 to 80 percent slopes
85A	Lundgren sandy loam, 0 to 3 percent slopes
98A	Plainview sandy loam, 0 to 3 percent slopes
98B	Plainview sandy loam, 3 to 8 percent slopes
100C	Redcliff-Lickskillet complex, 0 to 15 percent slopes
101D	Redcliff-Lickskillet-Rock outcrop complex, 15 to 30 percent south slopes
101E	Redcliff-Lickskillet-Rock outcrop complex, 30 to 50 percent south slopes
106D	Redslide-Lickskillet complex, 15 to 30 percent north slopes
106E	Redslide-Lickskillet complex, 30 to 50 percent north slopes
127A	Statz sandy loam, 0 to 3 percent slopes
128C	Statz-Deschutes complex, 0 to 15 percent slopes
128D	Statz-Deschutes complex, 15 to 30 percent slopes
141C	Stukel-Deschutes-Rock outcrop complex, 0 to 15 percent slopes
151D	Tetherow-Clovkamp complex, 8 to 50 percent slopes
152A	Tumalo sandy loam, 0 to 3 percent slopes
152B	Tumalo sandy loam, 3 to 8 percent slopes
155C	Wanoga sandy loam, 0 to 15 percent slopes
155D	Wanoga sandy loam, 15 to 30 percent slopes
156D	Wanoga-Fremkle-Henkle complex, 15 to 30 percent slopes
157C	Wanoga-Fremkle-Rock outcrop complex, 0 to 15 percent slopes
159C	Wilt sandy loam, 0 to 15 percent slopes
W	Water

Source:
NRCS, SSURGO database for Upper Deschutes River, Oregon

TID_soiltypelegend.mxd, 08/09/17

Figure 4-5. Legend for General Soil Types in Tumalo Irrigation District.

4.3.2.1 Farmland Classification

NRCS developed technical soil groups related to any environmental concerns that are associated with a particular soil type and a soil's rating for agricultural commodity production (NRCS 2015b). Using the NRCS soil mapping tool, the following soil groupings within TID were identified: prime farmland, farmland of statewide importance, and non-prime farmland.

Prime Farmland: Land designated with a prime farmland soil group has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. NRCS has developed further classifications under prime farmland as follows:

- Prime farmland if irrigated
- Prime farmland if irrigated and drained
- Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated and the product of soil erodibility (I) times (x) the climate factor (C) does not exceed 60

Farmland of Statewide Importance: Land that does not meet the criteria for prime farmland is considered "farmland of statewide importance." This land has characteristics that nearly meet prime farmland requirements and, when managed appropriately, can produce economically high crop yields.

Over 84 percent of the District is considered either farmland of statewide importance or prime farmland if irrigated. Table 4-3 presents the area and fraction of the District that are classified under each respective soil grouping. Figure 4-6 presents these soil groupings in map form.

Table 4-3. NRCS Classification of Farmlands within the Tumalo Irrigation District.

Farm Class	Area (acres)	Area (%)
Farmland of Statewide Importance	14,238	51
Non-Prime Farmland	1,694	6
Prime Farmland If Irrigated	12,032	43
Grand Total	**27,964**	**100**

4.3.2.2 Erosion Susceptibility

Erosion hazards include areas covered by soils with a high susceptibility to erosion as classified by NRCS. NRCS determines the erosion hazard class of an area by considering slope and select soil properties that may include cohesion, drainage, and the organic content of the soil. Within TID, approximately 84 percent of the soils are classified with a high erosion potential. Figure 4-7 presents the areas within TID with a high erosion potential.

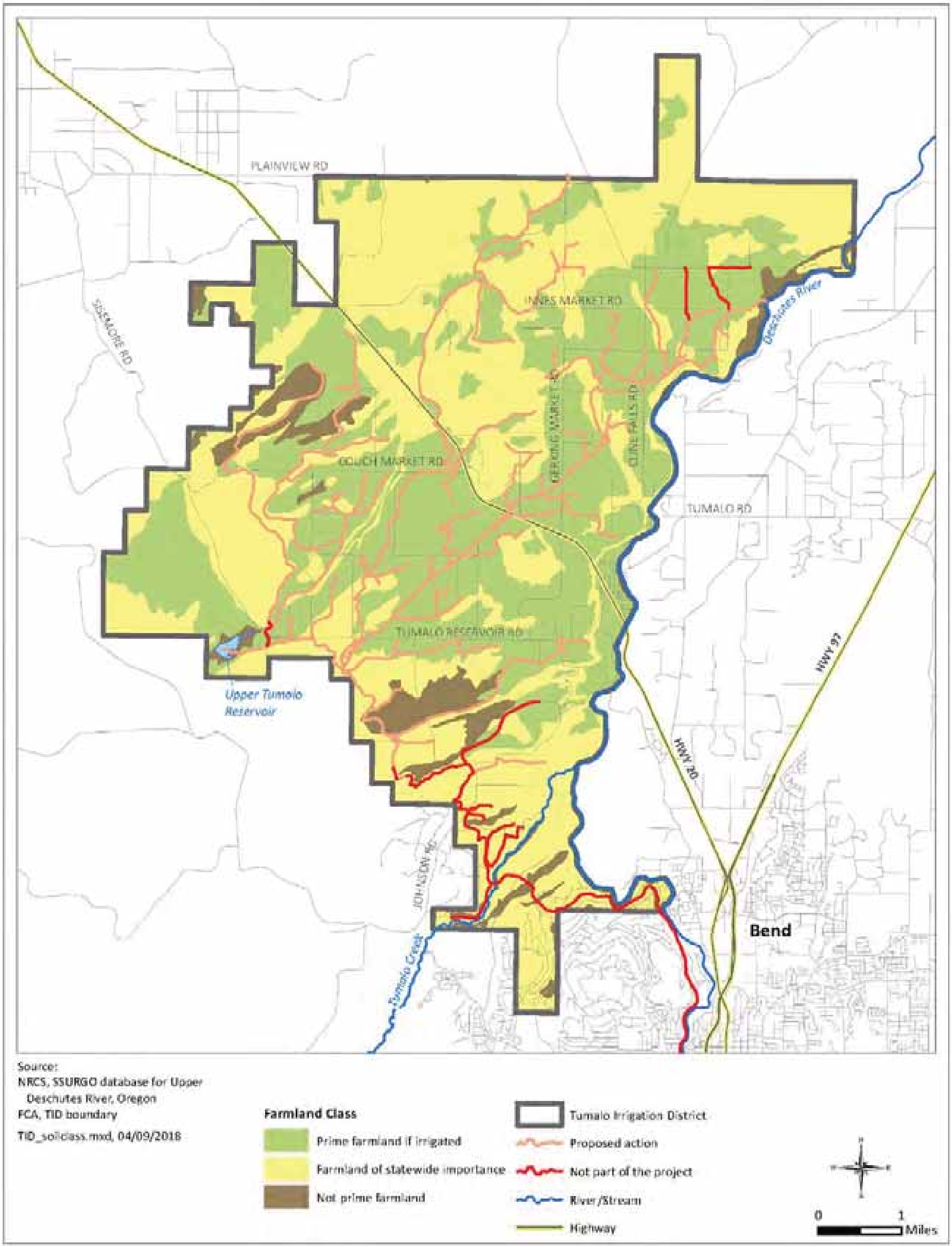


Figure 4-6. NRCS Classification of Farmlands within the Tumalo Irrigation District.

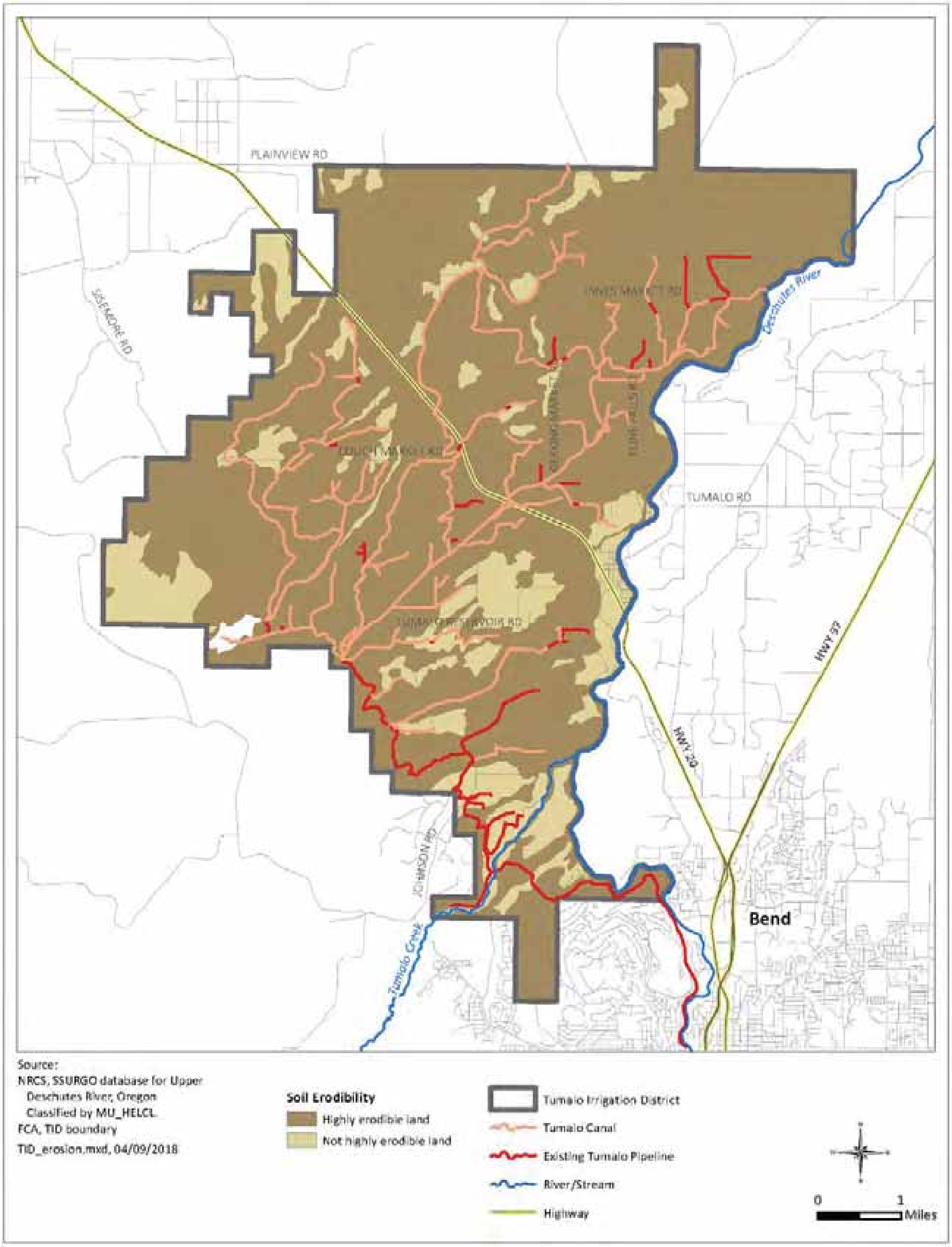


Figure 4-7. Erosion Potential of Soils in the Tumalo Irrigation District.

4.4 Land Use

Effects on land use are expected to extend beyond the project area to include all land served by the District.

4.4.1 ROW Land Use

Land use within the ROW consists of the conveyance of irrigation water as well as O&M of the irrigation system. However, in certain areas throughout the District there is informal and formal use of the ROW for recreation (see Section 4.6).

4.4.2 District Land Use

Land uses adjacent to TID's ROW are primarily irrigated land and land left undeveloped. Data from TID's SIP and the National Land Cover Dataset and corresponding land cover classes were used to indicate the land use. Table 4-4 shows the percentages of land uses within the District and that the project area crosses. Land use is also represented in land cover data shown in Figure 4-8.

Table 4-4. Land Use within Tumalo Irrigation District and Crossed by the Project Area.

Land Use Type	Area within TID (acres)	Percent Area of TID	Percentage of Total Proposed Action Length Crossing the Area[5]
Agriculture[1] (irrigated acres)[2]	7,417	27%	31%
Developed[3]	2,622	9%	11%
Undeveloped[4]	17,925	64%	58%
Total	**27,964**	**100%**	**100%**

Notes:

1. The NLCD data classified 5,983 acres as agriculture. Because more precise and current data on irrigated acres were available through the District, 7,417 acres was used to more accurately portray agricultural land use. The difference between these two numbers was taken out of the acres shown as Undeveloped Land.
2. Irrigated acres in the Tumalo Irrigation District (TID 2017). The proposed action would only affect 7,002 of the total irrigated acres.
3. Developed open space, high, medium, and low intensity development within TID; the project area only runs adjacent to low intensity and developed open space.
4. Shrub/scrub, barren land, evergreen forest, herbaceous, open water, woody wetlands
5. These numbers are approximate; in multiple areas, lengths of proposed action are simultaneously adjacent to both undeveloped land and agricultural land, but only one land use category could be considered in the calculations.

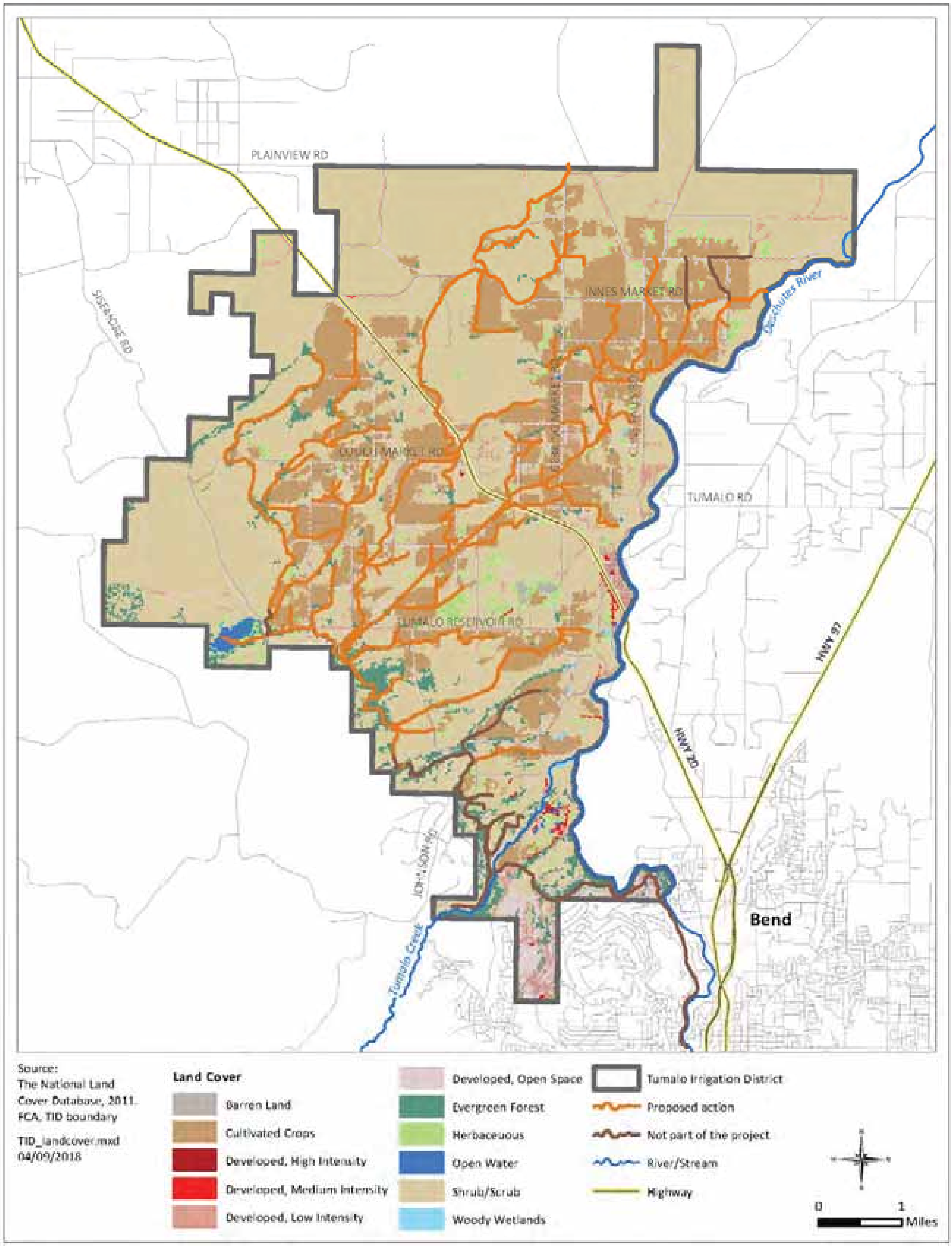


Figure 4-8. Land Cover in the Tumalo Irrigation District.

The primary crops grown on agricultural land within TID are hay, alfalfa, pasture, grains, and specialty crops. The majority of TID patrons irrigate parcels smaller than five acres. Farmers typically get two to three cuttings per year of hay and pasture grass (TID 2017). The agricultural land is primarily zoned as Exclusive Farm Use (EFU). The EFU designation is meant to maintain the agricultural economy of the state as well as assure the adequate provision of healthy food. The county is required to inventory and protect farmlands under Statewide Goal 3, Agricultural Land, ORS 215, and OAR 660-033. The EFU designation serves to accomplish Statewide Goal 3 and the Deschutes County Comprehensive Plan Goal 1. In 1992, Deschutes County identified seven EFU subzones based on the average number of acres irrigated. The District includes lands within both the Sisters/Cloverdale Subzone and Tumalo/Bend/Redmond Subzone. Parcels within the subzones must retain at minimum a specific number of irrigated acres per the type of farmland (Deschutes County 2010). As Bend, Redmond, and other towns in the region have grown and farmers have faced rising challenges of water shortages and drought, there has been increasing pressure on the conversion of agricultural lands.

4.4.3 District Land Ownership

The District's ROW is primarily adjacent to privately owned land (Table 4-5 and Figure 4-9). A small number of canals and laterals cross public land that is managed by the State of Oregon, Bureau of Land Management (BLM), and Bend Parks and Recreation District. Project activities would not occur on or affect lands owned by the U.S. Forest Service, National Park Service (NPS), Oregon Department of Parks and Recreation, Deschutes County, or other entities. Therefore, these lands are not discussed further.

Table 4-5. Land Ownership within the Tumalo Irrigation District.

Land Owner	Area within TID (acres)	Percentage of TID	Percentage of Total Proposed Action Length Crossing the Area
Private	21,530	77%	89%
U.S. Forest Service	45	.2%	0%
State of Oregon	1,219	4.4%	3%
U.S. Department of the Interior Bureau of Land Management	4,466	16%	7%
Oregon Department of Parks and Recreation	178	.6%	0%
Bend Parks and Recreation District	345	1.2%	1%
Deschutes County	181	.6%	0%
Total	**27,964**	**100%**	**100%**

The project area crosses the BLM's Peck's milkvetch Area of Critical Environmental Concern (ACEC), land that has been left undeveloped and is managed to not impair Peck's milkvetch habitat and populations (BLM 2005). Additionally, the project area crosses BLM land with an informal trail running alongside the Tumalo Reservoir Feed lateral. Land falling within the BLM Peck's milkvetch

ACEC and additional BLM parcels crossed by TID's system are managed according to the BLM, Upper Deschutes Record of Decision and Resource Management Plan (BLM 2005). The project area also crosses Tillicum Regional Park/Chase Ranch, which is owned and managed by Bend Parks and Recreation District. An additional parcel crossed by the project is owned by the State of Oregon but not under any current management plan.

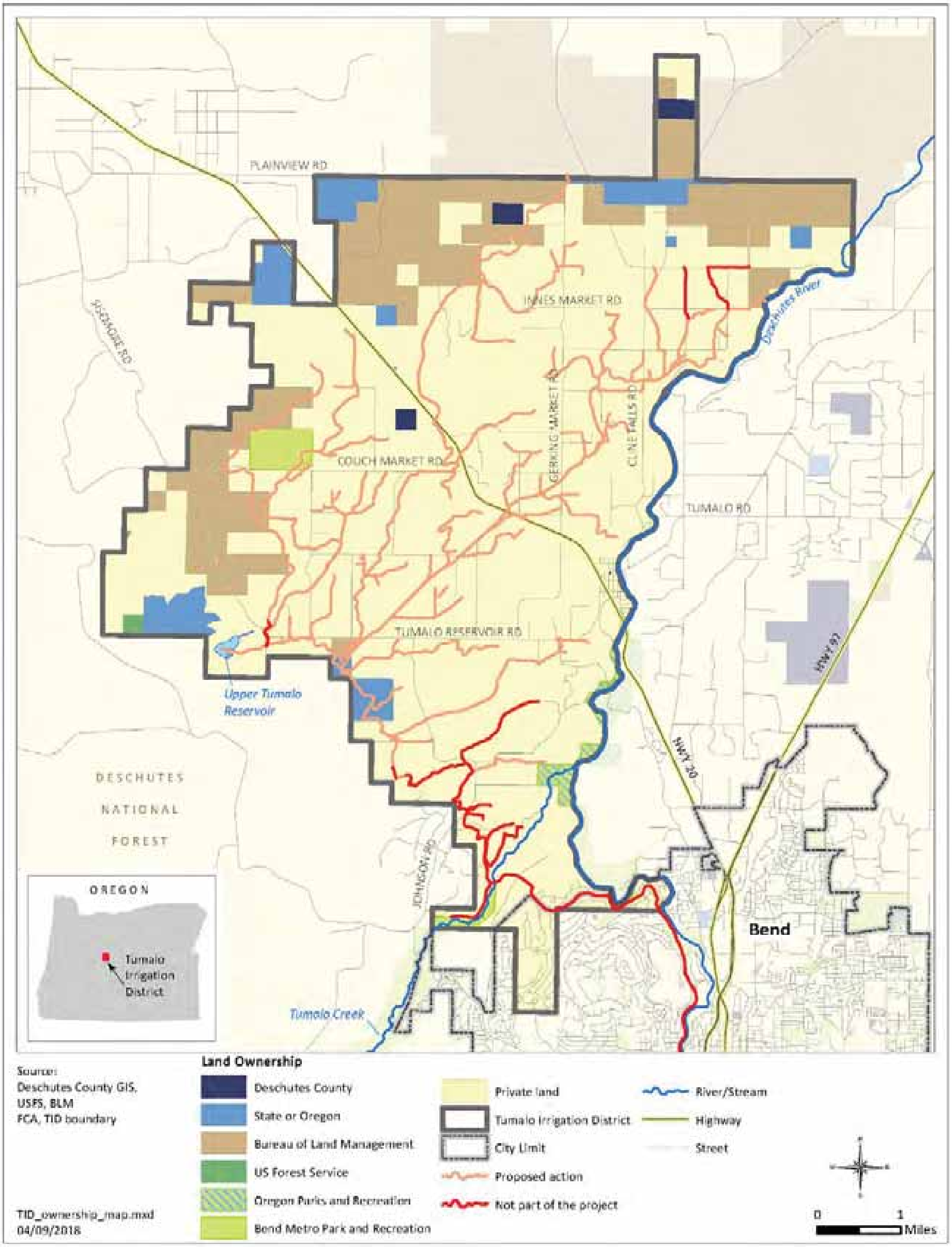


Figure 4-9. Land Ownership within Tumalo Irrigation District.

4.5 Public Safety

Effects to public safety are not expected to extend beyond the limits of the project area; therefore, the area of potential effect and project area are identical.

The District has approximately 65.1 miles of open canals that are accessible to the public. These canals pose a risk to public safety when they carry water. During the summer months when irrigation water is flowing at peak volume in the canals, water depths range between 2 to 6 feet and velocities range up to 5 feet per second. These conditions result in areas of deep, swift water that can make it difficult for a child or non-swimmer to get to safety and can result in tragic outcomes. In addition to multiple instances of injury, several drowning deaths have occurred in neighboring districts' canals in 1996, 1997, and 2004 (Flowers 2004). The District canals' route through urban areas, rural residential areas, and private lands heightens the potential for accidents.

4.6 Recreation

The area of potential effect for recreation includes the project area and waterbodies that could be affected by the project (see Table 4-1 in Section 4.2 for the list of waterbodies and their associated river miles). In 2015, visitors spent $660.2 million in Deschutes County, the fourth highest amount among Oregon counties (Dean Runyan Associates 2015). Recreation opportunities within TID include trails and parks. Rivers in the surface water area of potential effect, as described in Section 4.10.2, are used for a variety of recreation activities. The District's canals and laterals do not contain fish due to functioning fish screens at the District's diversions on Tumalo Creek and the Deschutes River. Use of the canals and laterals to fish, swim, float, or pursue any other activities that are not a function of the District is prohibited.

4.6.1 Trail and Bikeway Activities

The Deschutes River Trail, operated by Bend Park and Recreation District (BPRD), is a popular walking, hiking, and biking trail. In 2002, TID partnered with BPRD to allow expansion of the trail system along the piped section of the BFC (BPRD 2017a).

The District's maintenance roads are used regularly by hikers, bikers, runners, and horseback riders where the ROW is not fenced by property owners. While using the maintenance roads, the trail users have views of the irrigation canals and the surrounding area. Although the District does not prohibit public use of the maintenance road, users are technically trespassing on District or private land. The exception is on maintenance roads included in the Bend Urban Trails Plan joint-use agreement between TID and BPRD. An informal trail on BLM land runs along the Tumalo Reservoir Feed lateral, with the potential of BLM building a new trailhead in the near future.

Biking also occurs on public roads that intersect the project area. Twin Bridges Scenic Bikeway is a popular bike route with a high volume of traffic. This Bikeway is a 36-mile loop that begins at Drake Park in Bend. The route passes through Shevlin Park, the community of Tumalo, and to the east of Tumalo Reservoir (Deschutes County 2017a). The Bikeway crosses TID's canals and laterals that would be modernized under the proposed action at multiple points (see Figure 4-10).

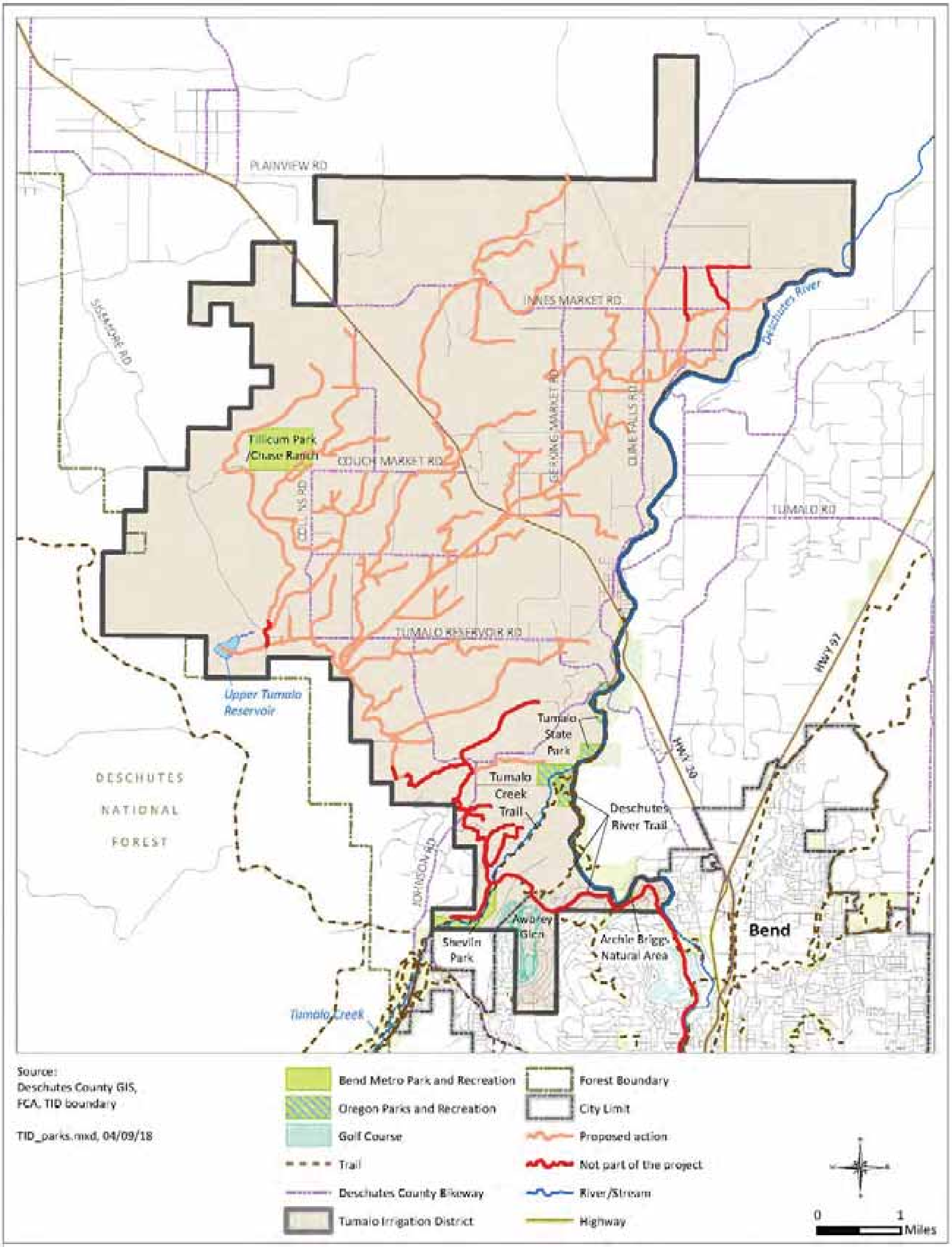


Figure 4-10. Recreation Including Parks, Trails, and Bikeways in the Tumalo Irrigation District.

4.6.2 Park Activities

Three parks are adjacent to the project area: Shevlin Park, Tumalo State Park, and Tillicum Regional Park/Chase Ranch. Tumalo State Park is bisected by the Deschutes River and is a popular area for wading, swimming, and inner-tubing (OPRD 2017). The western side of the park falls within TID; no canals or laterals that are included with the proposed action pass through the park. Shevlin Park is a 652-acre regional park with a small section falling within TID's boundaries. Tumalo Creek flows through the park, which is used for hiking, biking, events, and other recreational activities (BPRD 2017b). The Tumalo Diversion Dam is located 0.5 mile downstream from the park. Tillicum Regional Park/Chase Ranch is managed by BPRD. A house onsite is rented to BPRD employees. There are no established walking trails, but people use the Park to walk their dogs as well as fly drones and model planes (S. Sulia, personal communication, July 5, 2017). Laterals that would be modernized under the proposed action (i.e., the West Couch Lateral, Highline Lateral, and Chambers Ditch) are located within the southeast section of Tillicum Regional Park/Chase Ranch.

4.6.3 River Activities

Waterbodies downstream of the District's diversions include the Deschutes River and Tumalo Creek. These stretches of river provide opportunities for many types of recreational activities including rafting, kayaking, floating, stand up paddle boarding, and fishing. Two stretches of river within the area of potential effect are designated through the Oregon Scenic Waterways Act (Oregon Revised Statute [ORS] 390.826) as Recreational River Areas: (1) the Deschutes River from the northern Urban Growth Boundary of the City of Bend at approximately river mile 161 downstream to Tumalo State Park at approximately river mile 158; (2) the Deschutes River from Harper Bridge (RM 190.6) to the intersection of the Deschutes National Forest boundary at RM 184.8. These two scenic waterway reaches have been designated Recreation River Areas due to their accessibility and are managed to allow for compatible recreational uses (see Section 4.13 for further discussion). Tumalo Reservoir, located within TID, has been closed to recreation and public access since 1988 (Rieck 2016).

4.7 Socioeconomic Resources

The area of potential effect for socioeconomics is Deschutes County. The area of potential effect includes the communities of Bend, Redmond, and Tumalo (Figure 4-11).

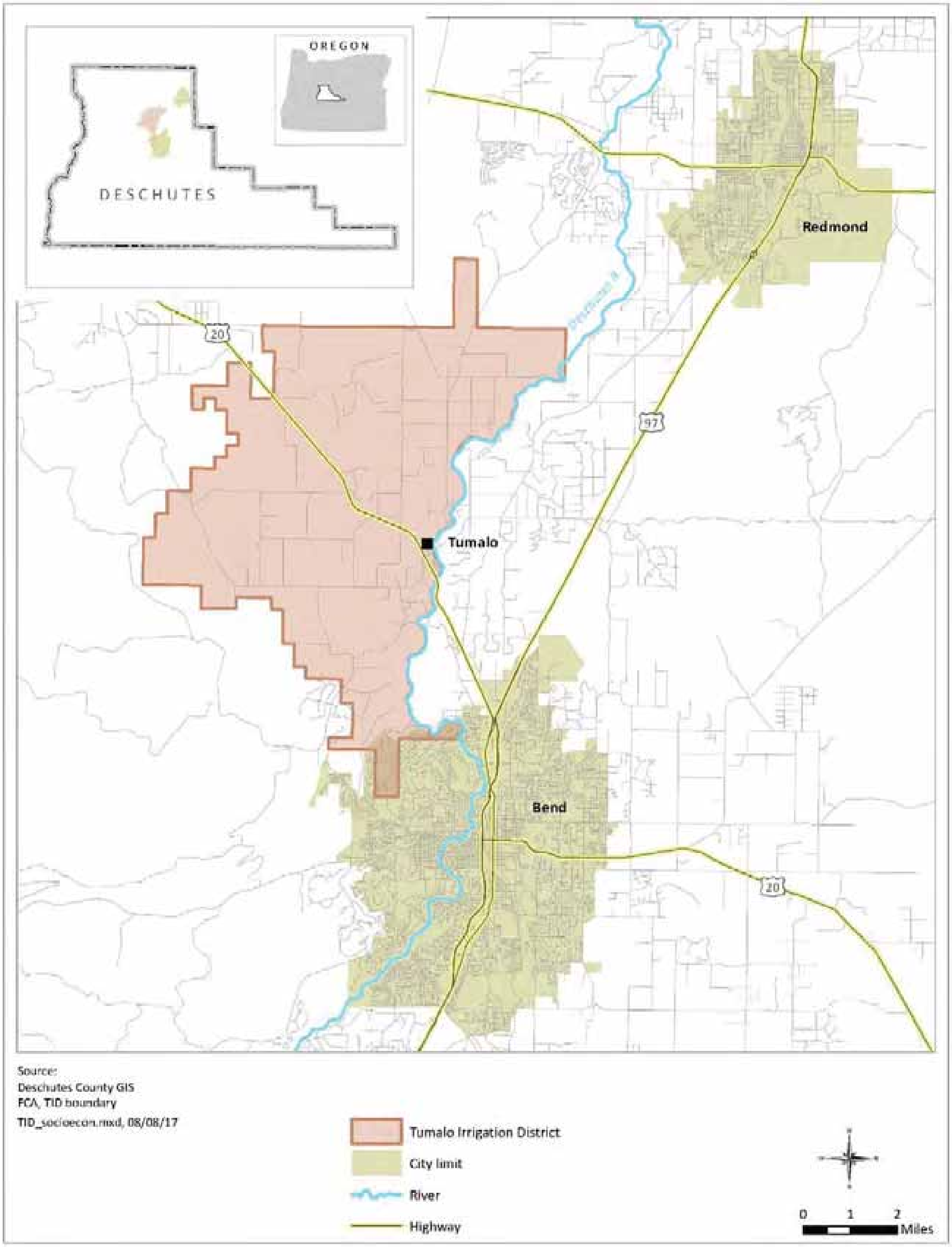


Figure 4-11. Location of the Tumalo Irrigation District within the Socioeconomic Area of Potential Effect.

4.7.1 Population

Generally, the area of potential effect has seen consistent growth over the past 10 years (2005 to 2015). The county has grown by 14 percent between 2005 and 2015, while the state had a growth rate of 8 percent during the same period of time (U.S. Census Bureau 2015). Table 4-6 shows population estimates for Deschutes County; the nearby communities of Redmond, Bend, and Tumalo; and the State of Oregon. The Oregon Office of Economic Analysis estimates that Deschutes County could reach a population of 241,223 by 2040.

Table 4-6. Population Characteristics by City, County, and State.

Area	Year 2005 Population (number of people)[1]	Year 2015 Population (number of people)[2]	Population Growth Rate 2005 to 2015	Year 2015 Population per Square Mile (number of people)
County				
Deschutes County	143,490	166,622	14%	56
Cities and Towns				
Redmond	20,010	27,450	37%	1,635
Bend	70,330	87,017	24%	2615
Tumalo	393[3]	538	37%	314
State				
Oregon	3,631,440	3,939,233	8%	40

Notes:
Sources: 1. U.S. Census Bureau 2005; 2. U.S. Census Bureau 2015; 3. U.S. Census Bureau 2010. Data for the population in 2005 was unavailable for Tumalo; population estimate shown is from 2010.

Ethnicity and race are shown for the area of potential effect in Table 4-7. Deschutes County is predominantly white with all other races accounting for less than 13 percent of the population. Deschutes County contains a lesser percent of persons identifying as Hispanic or Latino than the state and national average. In Deschutes County, the percent of persons identifying as American Indian or Alaska Native exceed the state percentage and is similar to the national level.

Table 4-7. Race by County, State, and U.S., 2015.

Population Criteria	Unit	Deschutes County	Oregon (State)	United States
Total Population		166,622	3,939,233	316,515,021
White	Number	146,449	3,043,010	197,258,278
	Percent	87.9%	77.2%	62.3%
African American	Number	734	69,105	38,785,726
	Percent	0.4%	1.8%	12.2%
Hispanic or Latino	Number	12,831	485,646	54,232,205
	Percent	7.7%	12.3%	17.1%
Asian	Number	1,969	154,496	16,054,074
	Percent	1.2%	3.9%	5.1%
American Indian or Alaska Native	Number	890	36,347	2,078,613
	Percent	0.5%	0.9%	0.7%
Native Hawaiian or Pacific Islander	Number	166	14,334	499,531
	Percent	0.1%	0.4%	0.2%
Identified Two or more races	Number	3,558	130,767	6,968,165
	Percent	2.1%	3.3%	2.2%
Some Other Race Alone	Number	25	5,528	638,429
	Percent	0.0%	0.1%	0.2%

Notes:
Source: U.S. Census Bureau 2015

4.7.2 Area Employment and Income

The economy within the area of potential effect is described by employment/unemployment numbers, employment by industry, income, and agricultural activity. Table 4-8 summarizes employment by industry classification. Educational services, health care and social assistance provides the highest number of employment positions throughout the county.

Table 4-9 demonstrates the labor force characteristics for Deschutes County and Oregon in 2017. Unemployment is lower in Deschutes County than the state average.

Table 4-8. Employment by Industry and Percent Employment Rates in the Project Area, 2015.

	Oregon		Deschutes County	
Employment Sectors	**Number of People**	**Percent of Oregon Employment**	**Number of People**	**Percent of County Employment**
Agriculture, forestry, fishing and hunting, and mining	60,535	3.4%	2,330	3.1%
Construction	99,157	5.5%	5,306	7.1%
Manufacturing	204,094	11.4%	6,403	8.6%
Wholesale trade	51,908	2.9%	1,358	1.8%
Retail Trade	215,805	12.1%	9,619	12.9%
Transportation, warehousing, and utilities	73,724	4.1%	2,013	2.7%
Information	33,058	1.8%	2,159	2.9%
Finance and insurance, real estate, rental, and leasing	102,145	5.7%	4,327	5.8%
Professional, scientific, management, and administrative and waste management services	190,080	10.6%	8,554	11.5%
Educational services, health care, and social assistance	413,562	23.1%	15,472	20.7%
Arts, entertainment, recreation, accommodation, and food services	176,909	9.9%	10,046	13.5%
Other services (except public administration)	88,177	4.9%	4,450	6.0%
Public administration	80,653	4.5%	2,562	3.4%
Total Employed- all sectors	**1,789,807**	**100%**	**74,599**	**100%**

Notes:
Source: U.S. Census Bureau 2015

Table 4-9. Labor Force Characteristics of Deschutes County Compared to the State of Oregon, 2017.

Indicator	**Deschutes County**	**Oregon (State)**
Labor Force	93,444	2,104,077
Employed	89,625	2,017,292
Unemployed	3,820	86,786
Unemployment Rate	4.1%	4.1%

Notes:
Source: USBLS 2017

Household income and persons living below the poverty level are summarized in Table 4-10. Information is presented for two income indicators: median household income and per capita income. Income in Deschutes County is the same as median income in the State of Oregon; however, both are comparable to the median income in the U.S. The percent of persons living below poverty in Deschutes County is similar to that of the U.S. but slightly lower than the state.

Table 4-10. Income and Poverty Rates in Deschutes County as Compared to the State of Oregon, 2015.

Indicator	Deschutes County	Oregon (State)	United States
Median Household Income	$51,223	$51,243	$53,889
Per Capita Income	$29,158	$27,684	$28,930
Persons in Poverty	14.6%	16.5%	15.5%

Notes:
Source: U.S. Census Bureau 2015

4.7.3 Agricultural Statistics

Table 4-11 presents summarized agricultural information for Deschutes County from the 2012 USDA Census of Agriculture (USDA 2012) and the 2007 USDA Census of Agriculture (USDA 2007). The top crop item produced in the county by acreage is forage (defined as all hay and haylage, grass silage, and greenchop).

Table 4-11. Agricultural Statistics Associated with Deschutes County.

Agricultural Statistic	2012	2007	Percent Change
Number of Farms	1,283	1,405	-9.5%
Land in Farms (acres)	131,036	129,369	1.3%
Average Size of Farm (acres)	102	92	9.8%
Median Size of Farm (acres)	20	20	0%
Market value of products sold	$20,570,000	$19,759,000	3.9%
Crop Sales	$11,127,000	$9,051,000	18.7%
Livestock Sales	$9,442,000	$10,708,000	-13.4%
Average per Farm	$16,033	$14,063	12.2%

Notes:
Source: USDA 2012, USDA 2007

4.8 Vegetation

Effects on vegetation resources are not expected to extend beyond the project area; therefore, the area of potential effect for these resources is bound by the limits of the project area.

4.8.1 Ecoregion

The area of potential effect and majority of the proposed project area lies primarily in the Deschutes River Valley level four ecoregion, a part of the larger level three Blue Mountains ecoregion. The Deschutes River Valley ecoregion is a broad, intermountain sagebrush-grassland. The climate in this ecoregion has a marine influence and is not as arid as the botanically similar level four High Lava Plains ecoregion to the southeast. Because of the proximity of the Cascade Mountains ecoregion to the west, stream density and water availability are high. As a result, human population density is much higher than in some nearby ecoregions (Thorson et al. 2003).

A smaller section of the proposed project area lies in the level four Ponderosa Pine/Bitterbrush Woodland ecoregion 9d, a part of the level three Eastern Cascades Slopes and Foothills ecoregion 9. The Pine/Bitterbush Woodland ecoregion is in the rain shadow of the Cascade Range. Compared to ecoregions to the west, it experiences more extreme temperatures and receives less precipitation. The topography includes undulating volcanic plateaus and canyons. Within the ecoregion, the frigid soils are often derived from ash and are well drained. Unlike the Pumice Plateau ecoregion to the south, lodgepole pine does not have a strong population presence.

4.8.2 Vegetation Communities

Over the past 100 years, land use has changed much of the vegetation within the District. Urban development, roads, irrigated agriculture, land management, and livestock grazing are the primary causes of changes to the plant community. The introduction of cheatgrass has also threatened the survival and diversity of native perennial grasses and forbs while increasing the risk of severe hot wild fire in the proposed project area. Due to the exclusion of fire, dense stands of small diameter juniper, sage, and bitterbrush cover vast areas of lands once dominated by large diameter juniper and grasses.

The common natural vegetation found within TID's ROW are ponderosa pine, western juniper, big sagebrush and low sagebrush, rabbit brush, wild rye and bunch grasses, some species of wildflowers, and other plant species commonly found in the dry Central Oregon steppe environment; other shrubs found in the area include bitterbrush, Idaho fescue, Sandberg bluegrass, and cheatgrass (Table 4-12). Figure 4-12 and Figure 4-13 provides a visual example of typical vegetation surrounding a canal.

Table 4-12. Common Vegetation within Tumalo Irrigation District's ROW.

Vegetation Species	Scientific Name
Big sagebrush	*Artemisia tridentata*
Bitterbrush	*Pseudoroegneria spicata*
Black cottonwood	*Populus balsamifera*
Bulrush	*Scirpus* spp.
Idaho fescue	*Festuca idahoensis*
Low sagebrush	*Artemisia arbuscula*
Ponderosa pine	*Pinus ponderosa*
Rabbit brush	*Ericameria nauseosa*
Sandberg bluegrass	*Poa sandbergii*
Western juniper	*Juniperus occidentalis*

Notes:
Source: Franklin and Dyrness 1988

Source: Reclamation 2010.

Figure 4-12. A Canal and Maintenance Road during Irrigation Season.

Source: Reclamation 2010

Figure 4-13. An Example of Typical Vegetation on the Margin of a Lateral during the Off-Irrigation Season When Canals and Laterals are Dewatered.

In some areas, a fringe of opportunistic hydrophytic (water-loving) plants has formed along the margins of the top of the canal bank represented predominately by bulrush, black cottonwood, and willow. Occurring sporadically, it is a few feet wide in scattered locations and does not function as a habitat type due in part to infrastructure maintenance activities. The District's infrastructure is maintained during the off-season by grading and clearing, and no vegetation is allowed to develop within the canals.

4.8.3 Special Status Species

No ESA endangered, threatened, species of concern, or candidate plant species or their designated critical habitats, or Oregon special status species are known to occur within the project area. There are three special status species with potential to occur in Deschutes County: federal candidate whitebark pine, Oregon threatened pumice grape-fern, and federal species of concern and Oregon threatened Peck's milkvetch. Both whitebark pine and pumice grape fern typically occur in subalpine and timberline zones. Based on the USFWS Information for Planning and Conservation database, District and elemental observations, the Oregon Department of Agriculture (ODA) identification of species population centers, and the elevation and plant communities these two generally inhabit, it is unlikely that the pumice grape-fern and whitebark pine would occur within the project area. Therefore, these two special status plant species will not be discussed further.

Peck's milkvetch occurs in sagebrush-juniper woodlands, ponderosa pine forests, and lodgepole pine forests, preferring sandy soils with minimal organic matter and pumice, in varying amounts, from Mt. Mazama's eruption. In Oregon, Peck's milkvetch is broadly grouped by the ODA into three population centers: barren pumice flats near Chemult (60 miles south of the project area), east of

Chiloquin in open ponderosa pine stands (100 miles south of the project area), and in Deschutes County between Sisters and Bend (within the area of potential effect) (ODA 2017b). As discussed in Section 4.4, the project area crosses the BLM Peck's Milkvetch ACEC. The District has not documented any Peck's milkvetch where the project area and the ACEC overlap.

4.8.4 Invasive Species–Noxious Weeds

The Oregon State Weed Board defines a noxious weed as a terrestrial, aquatic, or marine plant that is a top priority for action to be taken by weed control programs and the greatest public menace (ORS 569.615). Certain noxious weeds are so pervasive that they have been classified by ORS 569.350 to be a menace to public welfare (ODA 2017a). The Deschutes County Noxious Weed Program has an active eradication program and provides financial and technical support to private landowners, which would include patrons of TID (Deschutes County 2017b).

Table 4-13 lists the noxious weeds known to occur in the project area (E. Keith, personal communication, July 12, 2017). The District has recently started herbicide application in problem areas of the ROW (K. Rieck, personal communication, June 27, 2017).

Table 4-13. Invasive Species-Noxious Weeds Known to Occur in the Area of Potential Effect.

Vegetation Species	Scientific Name	Deschutes County Noxious Weed Rating[1]
Spotted knapweed	*Centaurea stoebe*	B
Diffuse knapweed	*Centaurea diffusa*	B
Yellow flag iris	*Iris pseudacorus*	B
Bull thistle	*Cirsium vulgare*	C
Common mullein	*Verbascum thapsus*	C
Russian thistle	*Salsola* spp.	B
Kochia	*Kochia scoparia*	B
Cheatgrass	*Bromus tectorum*	C
Poison hemlock	*Conium maculatum*	B
Ribbon grass	*Phalaris arundinacea* var. *picta*	B
Reed canary grass	*Phalaris arundinacea*	C

Notes:

1. The Deschutes County Noxious Weed Policy and Classification System designates three weed categories. "A" designated weeds are of highest priority for control and are subject to intensive eradication, containment, or control measures using county resources. "B" designated weeds have a limited distribution; intensive containment control and monitoring by landowners is required, and support from the County is provided when resources allow. "C" designated weeds are the lowest priority for control. They have a widespread distribution; landowner control and monitoring are recommended.

4.9 Visual Resources

Effects on visual resources as a result of the proposed action are expected to extend beyond the project area to include adjacent lands from which the proposed action can be viewed. Canals and laterals that would be modernized under the proposed action pass through irrigated crop and pasture land with farm equipment as a common feature of the landscape. Interspersed with the irrigated land is uncultivated agriculture land as well as forest land with ponderosa pines and western juniper. Some of the canals and laterals can be seen by nearby residences. Canals and laterals in the project area can also be seen from public road crossings as shown in Figure 4-14 to Figure 4-18, and from public lands.

The District's irrigation season typically is from April through mid-October. During this time the District's canals and laterals carry water. Outside of the irrigation season, typically from mid-October through March, TID's canals and laterals do not carry water and are typically dry. The District provides "stock runs," water delivered through the system to fill patrons' ponds used for livestock, three times outside of the irrigation season. Although the canals are not naturally formed waterways, some viewers may consider them water features during the irrigation season.

Figure 4-14. View of Couch Lateral Looking East from Bridge along Sisemore Road in 2017.

Source: Reclamation 2010.

Figure 4-15. View of Couch Lateral Dewatered outside of the Irrigation Season.

Figure 4-16. View of Columbia Southern Lateral near the Intersection of Pinehurst Road and Highway 20 in 2017.

Figure 4-17. View of West Branch Lateral Looking Southwest where it Crosses Pinehurst Road in 2017.

Figure 4-18. View of West Branch Lateral Crossing Pinehurst Road Looking Northeast in 2017.

4.10 Water Resources

The area of potential effect for surface water includes waterbodies that could be affected by the project (see Table 4-1 in Section 4.2 for the list of waterbodies and their associated river miles). These waterbodies include Crescent Lake, Crescent Creek, the Little Deschutes River, the Deschutes River, and Tumalo Creek. The upstream end of Lake Billy Chinook, at the confluence of the Deschutes, Crooked, and Metolius Rivers, serves as the downstream boundary of the area of potential effect. The area of potential effect for groundwater is limited to the upper Deschutes Basin.

The District primarily obtains water from Tumalo Creek at the TFC. It also obtains supplemental stored water from Crescent Lake, which is in the Cascade Range about 84 miles upstream from Bend on the Deschutes River. Crescent Lake relies on annual snowmelt and precipitation for inflow. The lake was constructed as a rock crib dam in the 1920s, but was rebuilt between 1954 and 1957 by Reclamation. Crescent Lake has a usable storage capacity of 86,900 acre-feet. Water from Crescent Lake is released throughout the year; during the irrigation season, it is released as necessary to supply the District's water rights. The water is conveyed through Crescent Creek, the Little Deschutes River, and the Deschutes River to the District's BFC diversion (RM 166) in Bend. It experiences an 18 percent conveyance loss from Crescent Creek to Benham Falls and an additional 7 percent conveyance loss from Benham Falls to the City of Bend before it enters the BFC pipeline at the BFC diversion. TID staff control diversion rates at the BFC diversion. In addition to stored water rights, the District also retains a 9.5 cfs live flow water right in the Deschutes River that is subject to diversion at the BFC intake. The District does not discharge to natural waterbodies at the terminal ends of its system.

The proposed action could affect water releases from Crescent Lake and streamflow in Crescent Creek, the Little Deschutes River, and the Deschutes River. The proposed action could also affect streamflow in Tumalo Creek downstream from the TFC diversion.

4.10.1 Water Rights

The District provides irrigation water to approximately 7,417 acres using two diversions. Of this total current irrigated acreage, 7,002 acres would be affected by the project. The District holds water rights with priority dates between 1900 and 1913. These rights have all been adjudicated and certificated. The District's primary water right is on Tumalo Creek, a tributary of the Deschutes River. The District holds other water rights on Crater Creek, Little Crater Creek, and Three Springs Branches – seasonal streams that are diverted into the upper reaches of Tumalo Creek. The District holds supplemental live-flow rights from the Deschutes River, a tributary to the Columbia River. The District also holds supplemental storage rights from Crescent Lake. These rights are delivered through Crescent Creek, the Little Deschutes, and the Deschutes River.

The beneficial uses allowed under the District's water rights are livestock, irrigation, industrial, and storage uses. Water right transfers associated with canal piping projects over the past 20 years have modified some of the District's water rights, allocating water rights to instream use. These conservation projects piped over 36,000 feet of canal, conserving 11.2 cfs of water in Tumalo Creek and 2,825 acre-feet in Crescent Lake. During the peak irrigation season, the District's water rights allow it to divert up to 207 cfs of water from Tumalo Creek, or a combination of Tumalo Creek and the Deschutes River supplemental rights. The District rarely exceeds a combined diversion total of 178 cfs as a result of previous conservation projects.

In 1987, the Oregon legislature passed the Instream Water Rights Act and created the statutory framework necessary to establish instream water rights. OWRD holds these rights in trust for the public, but they can be purchased, leased, or gifted to the state by anyone within Oregon looking to either obtain water rights for their property, lease their water rights instream, or gift their water rights to the state for permanent instream use (Golden and Aylward 2006; OAR 690-077). OWRD regulates instream rights based on a rate, duty, and priority date in the same manner that they regulate traditional water rights. Oregon's Allocation of Conserved Water Program (OAR 690-018) is one method to create instream water rights in Oregon. Several reaches in the area of potential effect, including Crescent Creek, the Deschutes River, and Tumalo Creek, have instream water rights that serve as preliminary streamflow restoration targets (Appendix E.7).

4.10.2 Surface Water Hydrology

Historically, the spring-fed Deschutes River had relatively consistent streamflows seasonally and annually (DRC 2012). Hydrological conditions and channel morphology have changed with the construction and operation of reservoirs, dams, and diversions on the river and its tributaries. Water is now managed for irrigation use, resulting in lower flows downstream from reservoirs during the winter months, higher flows downstream from reservoirs during the summer months, and lower flows downstream from irrigation diversions during the spring, summer, and fall.

Over the past 15 years, streamflows in the Deschutes River and Tumalo Creek have increased in response to collaborative restoration efforts by the irrigation districts and their partners. July median streamflow in the Deschutes River at North Canal Dam (RM 164.8) more than tripled from 2002 to 2012, from 47 cfs to 158 cfs (Mork 2016). In response to a reduction in instream leases and water voluntarily left instream by irrigation districts, July median streamflow dropped in 2013 to 129 cfs. It has steadily crept upward since 2013 to a 2015 July median flow of 136 cfs (Mork 2016). Streamflow restoration efforts by the District and its partners have yielded similar results in Tumalo Creek. July median daily average streamflow in the creek increased from 5 cfs in 2001 to a high of 58 cfs in 2012, averaging between 12 to 15 cfs (Mork 2016). OWRD measures this streamflow at stream gauging stations and ensures that leases, transfers, and conserved water remain instream.

The upper Deschutes Basin has experienced a general drying trend for several decades (Gannett and Lite 2013) and is susceptible to future changes in precipitation and the amount and timing of spring runoff (Shelton and Fridirici 2001). Models suggest that increased rain and a decrease in snowpack combined with an accelerated rate of spring snowmelt will influence the future water supply in the area; these changes will make managing the water supply more difficult (Shelton and Fridirici 2001; Reclamation 2016). This trend has potential for a decrease in annual mean streamflow as well as decreases in groundwater discharge to spring-fed streams (Gannett and Lite 2013).

The following sections summarize surface water hydrology in each waterbody. Graphs are provided to display the historic daily[6] average baseline streamflow and the modified daily average baseline streamflow. The historic daily average baseline streamflow involves available data from water years[7] prior to recent agreements between the District and local environmental groups. The modified daily average baseline streamflow involves data from water years following the recent agreements. Figure 4-19 presents the waterbodies included in the surface water hydrology area of potential effect.

[6] The daily average streamflow is the mean streamflow over a whole day.
[7] A water year is defined as the 12-month period from October 1 for any given year through September 30 of the following year.

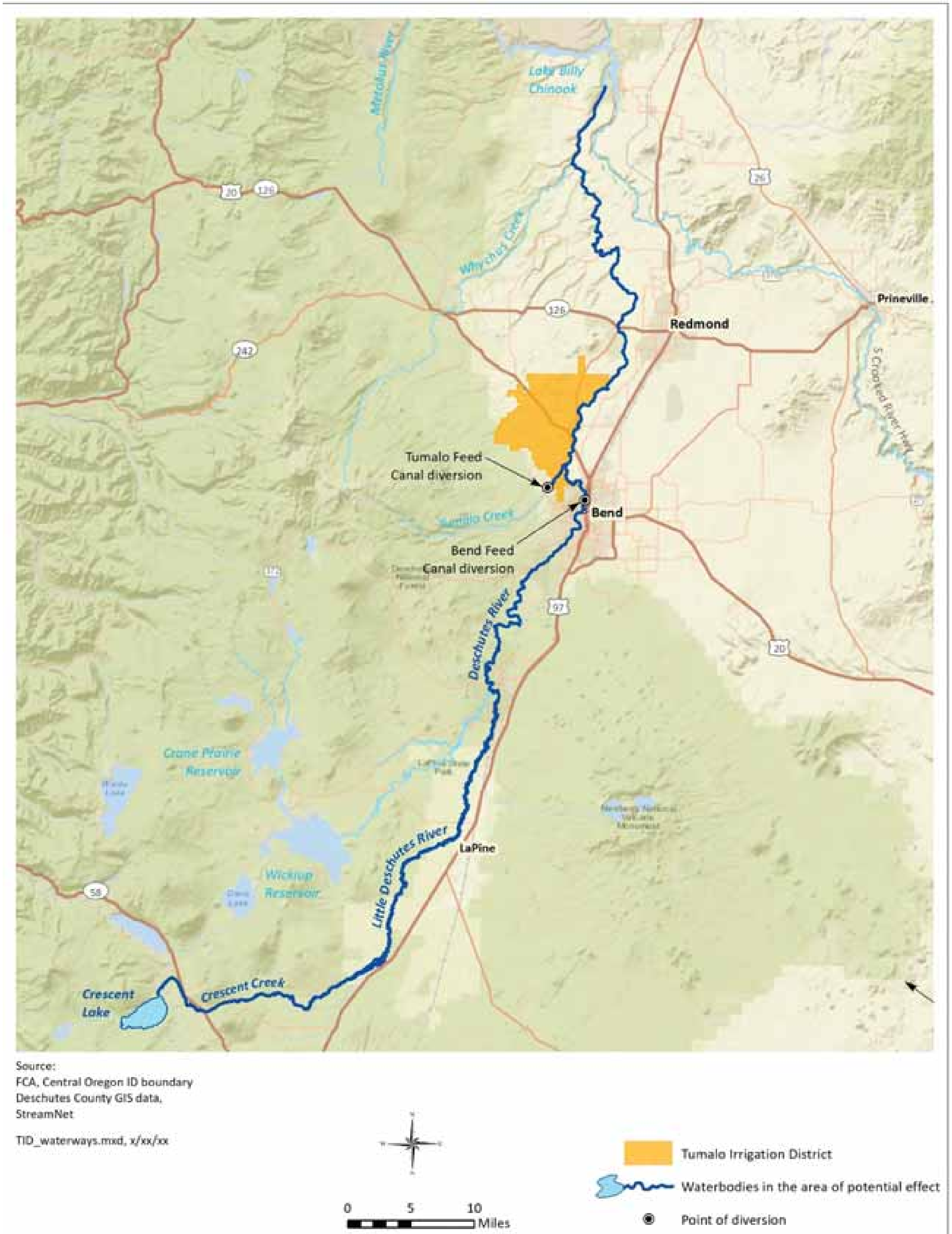


Figure 4-19. Waterbodies Included in the Area of Potential Effect for Surface Water Resources.

4.10.2.1 Crescent Lake

The proposed action may affect operations of Crescent Lake. Crescent Lake, upstream from the City of Bend on Crescent Creek, relies on annual snowmelt and precipitation for inflow. The District stores water in Crescent Lake to meet irrigation demands and releases water from the lake throughout the year. During the irrigation season, TID releases water as necessary to supply the District's water rights. The water is conveyed through Crescent Creek, the Little Deschutes River, and the Deschutes River to the District's BFC diversion in Bend.

4.10.2.2 Crescent Creek, Crescent Lake Dam (RM 30) to the mouth (RM 0)

The proposed action may affect streamflow rates in Crescent Creek. Releases from Crescent Lake control streamflow in Crescent Creek. Crescent Creek streamflow varies within and between years depending on reservoir operations and climate conditions (Figure 4-20). Outside of the irrigation season, the District has historically released at least 5 cfs from Crescent Lake into Crescent Creek under an informal agreement with OWRD to increase streamflow and improve aquatic resources (OWRD 2005). Any future flow restoration activities, including instream transfers and allocation of conserved water, are additive to the 5 cfs established in the 2005 agreement and released outside of the irrigation season to improve aquatic resources and their habitat (OWRD 2005).

In 2016, TID agreed to voluntarily release additional streamflow from Crescent Lake outside the irrigation season to benefit Oregon spotted frog populations in Crescent Creek (Center for Biological Diversity, et al. v. U.S. Bureau of Reclamation and Arnold Irrigation District, et al. 2016). Under this Stipulated Settlement Agreement with the Center for Biological Diversity,[8] TID agreed to maintain a minimum of 20 cfs in Crescent Creek outside the irrigation season. These conditions have been maintained since the expiration of the Settlement Agreement in compliance with the 2017 Biological Opinion (BiOp) for Bureau of Reclamation dam operations (Reclamation 2017). Water releases exceeding the formerly agreed upon 5 cfs are not legally protected instream.

Crescent Creek downstream of Crescent Lake has instream water rights that serve as preliminary streamflow restoration targets (Appendix E.6). Water right certificate #73234 is a junior water right (October 11, 1990) for the flows shown below in Table 4-14 and providing a target for the flows that are needed for fish migration, spawning, egg incubation, fry emergence, and juvenile rearing between the Crescent Lake (RM 30) to the mouth of Crescent Creek (RM 0).

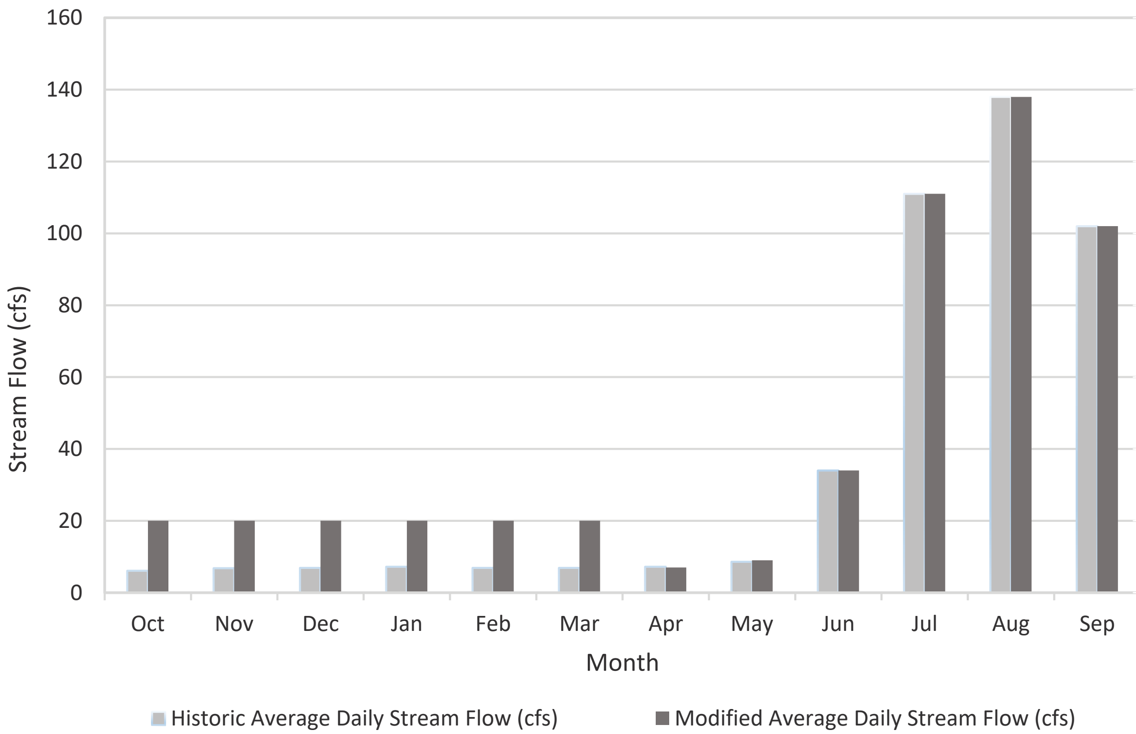
Table 4-14. Target Streamflows in Crescent Creek based on Certificate #73234

Instream Rates (cfs)											
Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
75	75	125	125	125	75	50	50	50	50	108	125

Daily average streamflow in Crescent Creek from 1984 to 2017 is shown in Figure 4-20 below.

[8] In addition to TID interim operation adjustments to Crescent Lake dam and reservoir, this Stipulated Settlement Agreement prompted interim operation adjustments for Districts operating Wickiup and Crane Prairie dams and reservoirs and a completion of the consultation and biological opinion by USFWS on effects of such operations on Oregon spotted frogs (Reclamation 2017).

Streamflows from 1984 to 2014 are noted on the figure as "historic average daily streamflow." Streamflows in 2016 and 2017 are representative of conditions after implementation of the Stipulated Settlement Agreement, and are called "modified average daily streamflow.



Note:

Data for historic streamflows represent the 1984 through 2014 water years. Data for the modified streamflows represent October 2016 through September 2017. Average streamflows represent the 50 percent exceedance streamflows.

Figure 4-20. Historic and Modified Daily Average Streamflows in Crescent Creek downstream from Crescent Lake at OWRD Gauge No. 14060000.

4.10.2.3 Little Deschutes River, Crescent Creek (RM 57) to the mouth (RM 0)

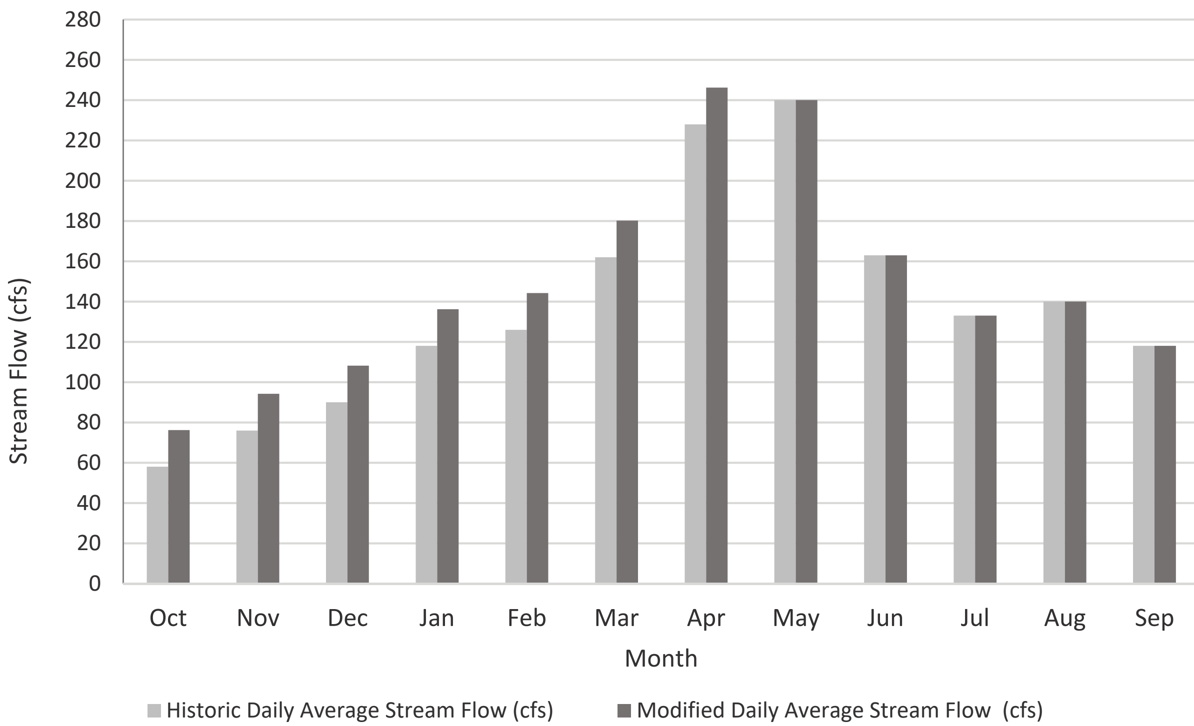
The Little Deschutes River is a free-flowing tributary to the Deschutes River. It enters the Deschutes River at RM 192.5. Precipitation, snowmelt, and releases from Crescent Lake affect streamflow in the Little Deschutes River from Crescent Creek (RM 57) to the mouth (RM 0). Streamflow in this reach varies seasonally depending on upstream reservoir operations and irrigation demands.

This reach of the Little Deschutes River has instream water rights that serve as preliminary streamflow restoration targets (Appendix E.6). Water right certificate #73226 is a junior water right (October 11, 1990) for the flows shown below in Table 4-15 to support fish migration, spawning, egg incubation, fry emergence, and juvenile rearing between the mouth of the Crescent Creek (RM 57) to the mouth (RM 0).

Table 4-15. Target Streamflows in the Little Deschutes River based on Certificate #73226

Instream Rates (cfs)											
Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
200	200	236	240	240	200	126	74.5	92.2	116	164	196

Figure 4-21 displays the Little Deschutes' historic daily average baseline streamflow (1984 to 2014) and the modified daily average baseline streamflow (October 2016 to September 2017) representing the requirements of the Stipulated Settlement Agreement in place, shown by month and measured in cfs. Streamflows from 1984 to 2014 represent historical baseline conditions. Streamflows in 2016 and 2017 represent modified baseline conditions.



Note:
Data for historic streamflows represent the 1984 through 2014 water years. Data for the modified streamflows represent October 2016 through September 2017. Average streamflows represent the 50 percent exceedance streamflows.

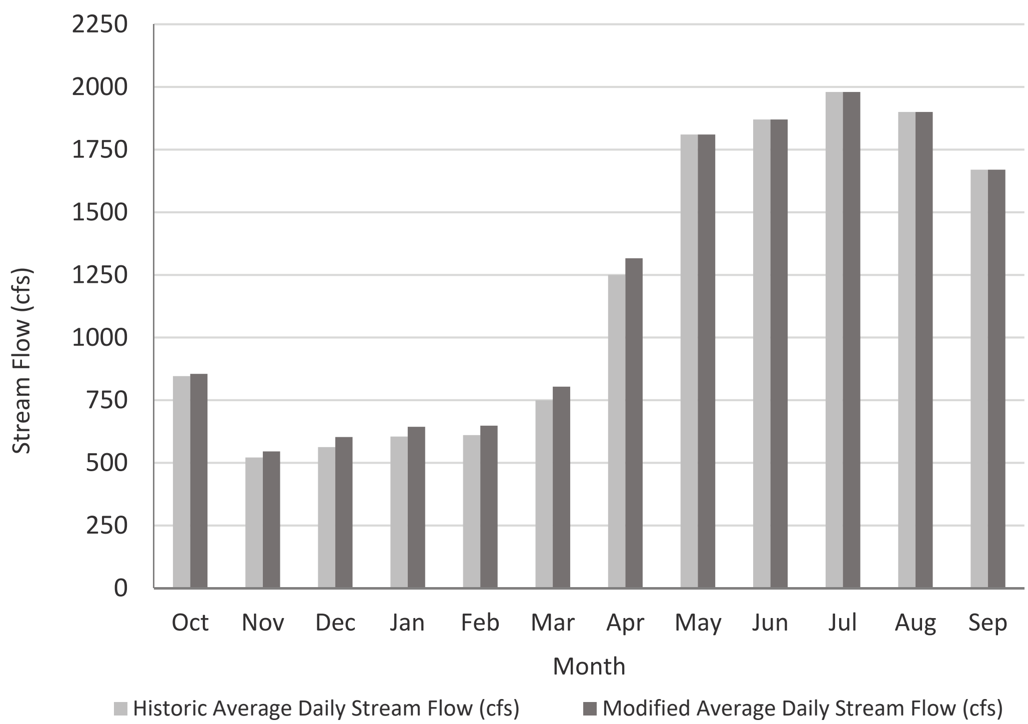
Figure 4-21. Historic and Modified Daily Average Streamflows in the Little Deschutes River at La Pine, Oregon, at OWRD Gauge No. 1406300.

4.10.2.4 Deschutes River, Little Deschutes River (RM 192.5) to the BFC diversion at Steidl Dam (RM 166)

Reservoir releases, tributary inflows, irrigation diversions, and groundwater interactions drive streamflow in this reach of the Deschutes River. Crane Prairie Reservoir, Wickiup Reservoir, and Crescent Lake store water upstream from this reach. Their operations decrease winter streamflow and increase summer streamflow from unregulated conditions (Figure 4-22). Water released from Crescent Lake during the irrigation season is conveyed through Crescent Creek, the Little Deschutes River, and the Deschutes River until it is diverted at the BFC diversion at Steidl Dam (RM 166). A portion of the streamflow enters into the groundwater aquifer through the porous volcanic riverbed and banks upstream from the City of Bend. OWRD accounts for these losses when accounting for dam releases, water available for diversion, and water protected instream.

This reach of the Deschutes River has instream water rights that serve as preliminary streamflow restoration targets (Appendix E.6). Water right certificate #59777 is a junior water right (November 3, 1983) for a year round flow of 400 cfs and provides a target for what flows are needed for fish, wildlife, their habitat quality, or recreation between the mouth of the Little Deschutes River (RM 192.5) to the mouth of the Spring River (RM 190.4). Water right certificate #59778 is a junior water right (November 3, 1983) for a year round flow of 660 cfs to support aquatic life and minimize pollution between the mouth of Spring River (RM 190.4) to North Canal Dam (RM 164.8).

Figure 4-22 displays the Deschutes River at Benham Falls' historic daily average baseline streamflow (1984 to 2014) and the modified daily average baseline streamflow (October 2016 to September 2017) representing the requirements of the Stipulated Settlement Agreement in place, shown by month and measured in cfs. Streamflows from 1984 to 2014 represent historical baseline conditions. Streamflows in 2016 and 2017 represent modified baseline conditions.



Note:
Data for historic streamflows represent the 1984 through 2014 water years. Data for the modified streamflows represent October 2016 through September 2017. Average streamflows represent the 50 percent exceedance streamflows.

Figure 4-22. Historic and Modified Average Daily Streamflows in the Deschutes River at Benham Falls at OWRD Gauge No. 14064500.

4.10.2.5 Tumalo Creek TFC diversion (RM 2.5) to the mouth (RM 0)

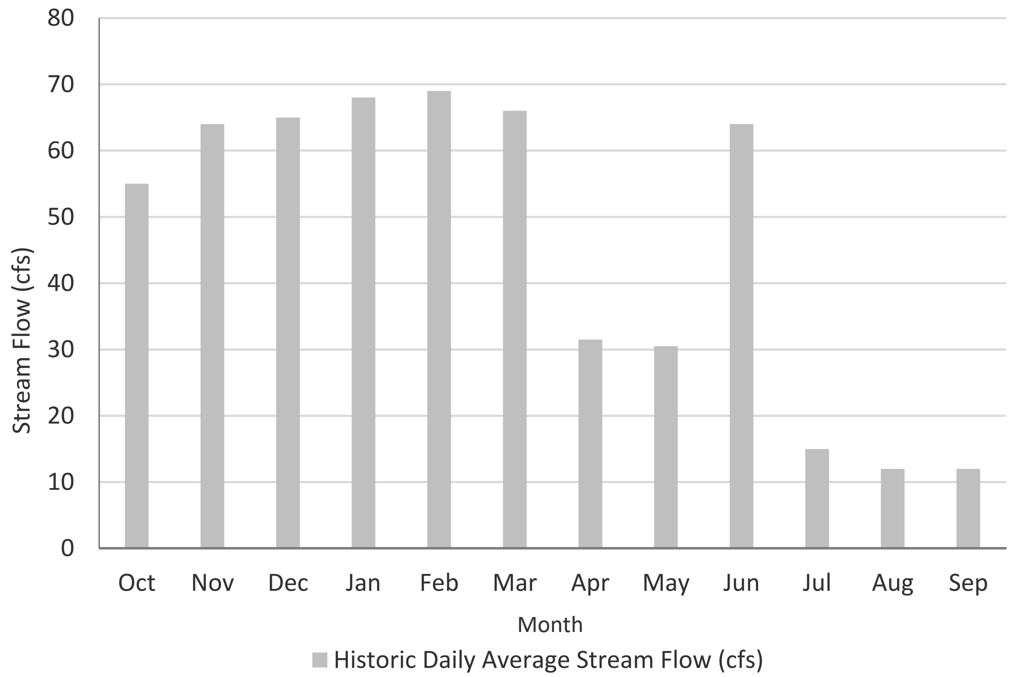
The hydrology of Tumalo Creek is largely influenced by snowmelt, precipitation, and groundwater discharge from springs. Tumalo Creek and its tributaries (Bottle Creek, Bridge Creek, Happy Valley Creek, Middle Fork, North Fork, Rock Creek, South Fork, and Spring Creek) are unusual in the area due to their response to rain-on-snow events, which result in large increases of streamflow. Streamflow upstream from the TFC diversion (RM 2.5) typically peaks at 200 to 300 cfs during the spring due to snowmelt. During the irrigation season, the District's diversions influence streamflow in Tumalo Creek downstream from the TFC diversion (RM 2.5).

This reach of the Tumalo Creek has instream water rights that serve as preliminary streamflow restoration targets (Appendix E.6). Water right certificate #73222 is a junior water right (October 11, 1990) for the flows shown below in Table 4-16 to support fish migration, spawning, egg incubation, fry emergence, and juvenile rearing from the South Fork Tumalo Creek to the mouth of Tumalo Creek.

Table 4-16. Target Streamflows in Tumalo Creek Based on Certificate #73222

Instream Rates (cfs)											
Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
47	47	68.7	76.6	82	47	32	32	47	65.3	47	47

Historically, the District diverted up to all of the water from the creek to meet peak irrigation demands in most years. The District and its partners' extensive investments in conservation have permanently increased streamflow in the creek. Currently, the District typically maintains at least 10 to 12 cfs downstream from this diversion during the irrigation season in order to operate its fish screen and passage structures (Figure 4-23). This streamflow is typically present but not legally protected instream. Water allocated to instream water rights in Tumalo Creek are legally protected from the TFC diversion (RM 2.5) to the mouth (RM 0) and then into the Deschutes River to Lake Billy Chinook (RM 120).



Note:
Data for historic streamflows represent the 1998 through 2016 water years. Average streamflows represent the 50 percent exceedance streamflows.

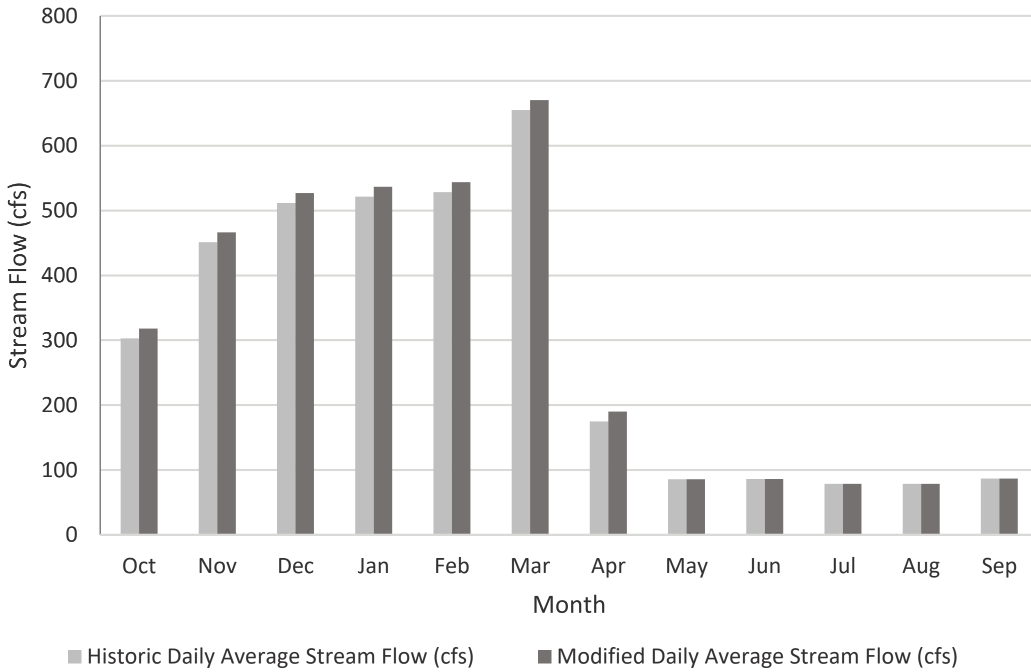
Figure 4-23. Historic Daily Average Streamflows in Tumalo Creek Downstream from the Tumalo Feed Canal Diversion at OWRD Gauge No. 14073520.

4.10.2.6 Deschutes River, BFC diversion at Steidl Dam (RM 166) to Lake Billy Chinook (RM 120)

Central Oregon, Arnold, Lone Pine, North Unit, and Swalley Irrigation Districts divert water from the Deschutes River at the City of Bend. These irrigation diversions influence streamflow patterns in the Deschutes River downstream from the City of Bend (Figure 4-24). Historically, these irrigation districts maintained a minimum of 30 cfs instream in this reach under a voluntary agreement. Extensive conservation efforts by the irrigation districts and their partners starting in the 2000s have enhanced streamflow during the irrigation season. Currently, the irrigation districts maintain approximately 130 cfs downstream from their diversions at the City of Bend during the summer irrigation season.

This reach of the Deschutes River has instream water rights that serve as preliminary streamflow restoration targets (Appendix E.6). The ODFW has a pending water right requesting a year round flow of 250 cfs and providing a target for what flows are needed for fish, wildlife, their habitat quality, or recreation between the North Canal Dam (RM 164.8) to Round Butte Reservoir (Lake Billy Chinook; RM 120).

Figure 4-24 displays the historic daily average baseline streamflow and the modified daily average baseline streamflow representing the requirements of the Stipulated Settlement Agreement in place, downstream from the City of Bend. Streamflows from 1984 to 2014 represent historical baseline conditions. Streamflows in 2016 and 2017 represent modified baseline conditions.



Note:
Data for historic streamflows represent the 1984 through 2014 water years. Data for the modified streamflows represent October 2016 through September 2017. Average streamflows represent the 50 percent exceedance streamflows.

Figure 4-24. Historic and Modified Daily Average Streamflows in Deschutes River Downstream from the City of Bend at OWRD Gauge No. 14070500.

4.10.3 Surface Water Quality

The Oregon Department of Environmental Quality (ODEQ) maintains a list of all surface waters in the state that are considered impaired because they do not meet water quality standards under Section 303(d) of the CWA (33 United States Code [U.S.C.] 1251 et seq.) The 2012 303(d) list is effective for CWA purposes. The Deschutes River and its tributaries in the area of potential effect are included on Oregon's 303(d) list for not meeting water quality standards for temperature, dissolved oxygen, pH, sedimentation, turbidity, and/or chlorophyll a (Table 4-17).

Water management in the Deschutes Basin has altered seasonal streamflow patterns, increasing streamflows above historic levels in some reaches and decreasing streamflows below historical levels in other reaches. Low flows affect water quality in the Deschutes River by exacerbating temperature and dissolved oxygen problems. The following sections describe existing 303(d)-listed impairments in the surface water area of potential effect. Oregon Department of Environmental Quality is required to develop total maximum daily loads (TMDLs) for rivers and streams in the Upper Deschutes and Little Deschutes basins (these impairments may extend upstream or downstream of the reaches included in Table 4-17).

Table 4-17. Impaired Waterbodies in the Surface Water Area of Potential Effect.

Waterbody No.	Name	Area of Potential Effect	Parameters Included on Oregon's 303(d) List
1	Crescent Creek	Crescent Lake Dam (RM 30) to the mouth (RM 0)	Temperature
2	Little Deschutes River	Crescent Creek (RM 57) to the mouth (RM 0)	Temperature Dissolved oxygen
3	Deschutes River	Little Deschutes River (RM 192.5) to the Bend Feed Canal diversion at Steidl Dam (RM 166)	Temperature Dissolved oxygen Chlorophyll a pH Sedimentation Turbidity
4	Deschutes River	Bend Feed Canal diversion at Steidl Dam (RM 166) to Lake Billy Chinook (RM 120)	Temperature Dissolved oxygen
5	Tumalo Creek	Tumalo Feed Canal diversion (RM 2.5) to the mouth (RM 0)	Temperature

Notes:
Source: ODEQ 2012

4.10.3.1 Temperature

Crescent Creek, Little Deschutes River, Deschutes River, and Tumalo Creek do not meet stream temperature criteria within the area of potential effect (Table 4-17). The temperature criterion that applies throughout the area of potential effect is 18 °C (64.4 degrees Fahrenheit [°F]), which is designed to protect salmon and trout rearing and migration. There is an additional criterion designed to protect bull trout spawning and juvenile rearing that currently applies in Crescent Creek above RM 11. This criterion is 12 °C (53.6 °F). Elevated stream temperatures affect aquatic species including native fish by exacerbating conditions that cause stress and disease, raise their metabolism, and reduce growth rates. Low streamflows, reduced streamside vegetation, and widened channels can all contribute to elevated stream temperatures.

4.10.3.2 Dissolved Oxygen

In the area of potential effect, all of the Little Deschutes River and the Deschutes River waters do not meet Oregon's standards for dissolved oxygen during trout spawning season from January 1 to May 15 (Table 4-17; ODEQ 2012). Year-round, dissolved oxygen levels in the Little Deschutes and in a portion of the area of potential effect in the Deschutes River (RM 192.5-171.7) are not high enough to meet Oregon's standards either (ODEQ 2012). Low dissolved oxygen levels can affect aquatic life by reducing habitat quality and quantity, changing behavior, or reducing growth rates. Excess nutrient inputs, associated algae growth and die-off, and elevated stream temperatures can all contribute to lower dissolved oxygen levels.

4.10.3.3 pH

pH is a measure of the acidity or alkalinity of a waterbody. Within the area of potential effect, the most downstream 2.2 miles of the Deschutes River between the Little Deschutes River (RM 192.5) and the BFC diversion (RM 166) and all the Deschutes River from the BFC diversion (RM 166) to Lake Billy Chinook (RM 120) exceed Oregon's pH standard with higher, or more alkaline, pH values

(ODEQ 2012; Table 4-17). Higher pH can affect aquatic life by changing the solubility or biological availability of chemicals in the water.

4.10.3.4 Sedimentation

Sedimentation refers to deposits of silt, sand, or other small particles in a river. In the area of potential effect, 21 miles of the Deschutes River between the Little Deschutes River (RM 192.5) and the BFC diversion (RM 166) do not meet Oregon's standards for sedimentation (ODEQ 2012; Table 4-17). The Oregon Department of Environmental Quality set this standard to protect resident fish and aquatic life and salmonid fish spawning and rearing in the river. In the Deschutes River, lower winter flows and higher summer flows have contributed to increased bank erosion. Increased bank erosion contributes to increased sediment in the river. The river carries this sediment downstream and deposits it along the riverbed. Deposited sediment can affect fish and aquatic life by reducing the quantity and quality of available habitat.

4.10.3.5 Turbidity

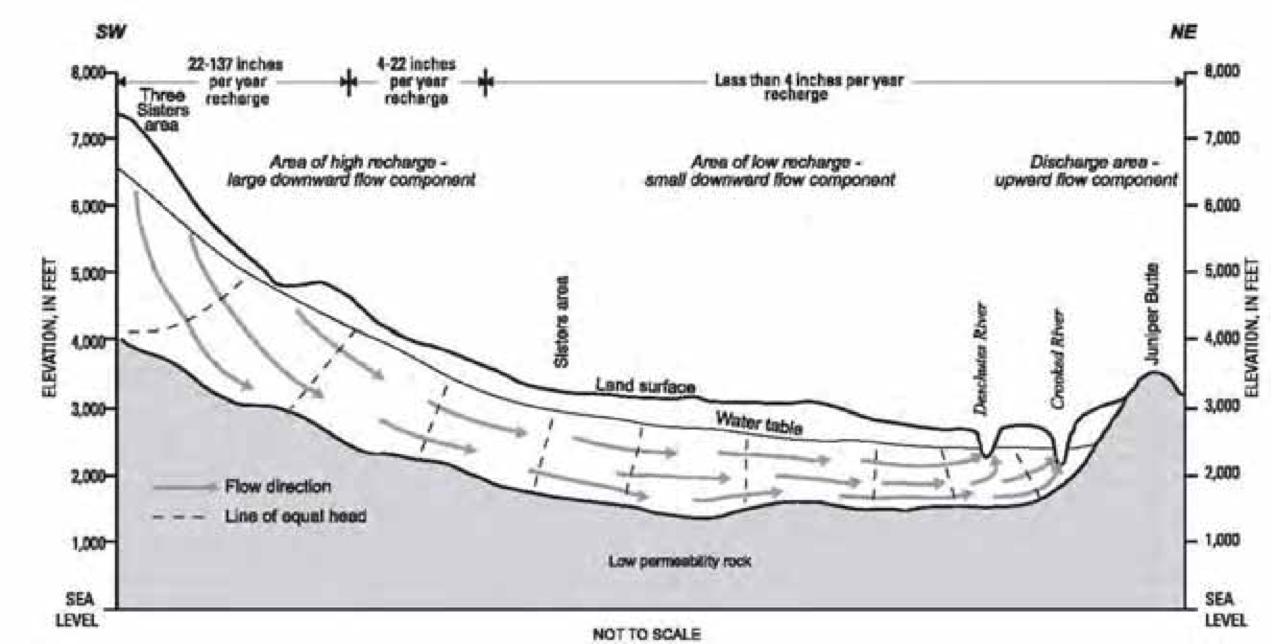
Turbidity is a measure of water cloudiness. Within the area of potential effect, 21 miles of the Deschutes River between the Little Deschutes River (RM 192.5) and the BFC diversion (RM 166) do not meet Oregon's turbidity standard during the spring and summer (ODEQ 2012; Table 4-17). This standard is set to protect aesthetics, resident fish and aquatic life, and water supply in the river. Suspended sediment, algae, and other suspended or dissolved materials contribute to increased turbidity.

4.10.3.6 Chlorophyll a

Chlorophyll a is a specific type of chlorophyll that is measured to evaluate the amount of algae in a waterbody. Monitoring chlorophyll levels is a direct way of tracking algal growth; surface waters that have high chlorophyll conditions are typically in correlation with high levels of nutrients, commonly phosphorus and nitrogen. In the area of potential effect, 21 miles of the Deschutes River between the Little Deschutes River (RM 192.5) and the BFC diversion (RM 166) do not meet Oregon's standards during the summer (ODEQ 2012; Table 4-17). The Oregon Department of Environmental Quality set this standard to protect multiple uses in the river, including resident fish and aquatic life. High chlorophyll a indicates excess algal growth in the river. Excess algae often contribute to low dissolved oxygen concentrations. Excess algae grown can be caused by both natural influences and nutrient inputs (from sources such as fertilizer or leaking septic tanks) into the waterbody.

4.10.4 Groundwater

The area of potential effect for groundwater is limited to the upper Deschutes Basin. The area of potential effect is bounded on the north by Jefferson Creek, the Metolius River, the Deschutes River, and Trout Creek; the east by the geological change between the Deschutes Formation and the much less permeable John Day Formation; on the south by the drainage divides between the Deschutes Basin and the Fort Rock and Klamath Basins; and on the west by the Cascade Mountain Range. Previous groundwater studies define the upper Deschutes Basin and provide context for groundwater within the area of potential effect (Gannett et al. 2001, Gannett and Lite 2013, Figure 4-25).



Source: Gannett et al. 2001

Notes:

Flow generally moves east then north before discharging to the streams along the edge of the Cascade Range or the streams and rivers near the confluence of the Metolius, Deschutes, and Crooked Rivers

Figure 4-25. Precipitation Recharge in a Deschutes Basin Regional Aquifer.

Within the upper Deschutes Basin, precipitation in the Cascade Range provides 3,500 cfs of annual groundwater recharge. Inflows from outside the upper Deschutes provide an additional 850 cfs of recharge. Canal leakage across the region provides approximately 411 cfs of additional recharge based on 2008 data (Gannett et al. 2001; Gannett and Lite 2013, Gannett et al. 2017). Subsequent canal lining and piping projects have further reduced canal leakage.

Groundwater generally flows east and then north through the basin. Approximately half of this groundwater discharges into streams through springs along the edge of the Cascade Mountains. The remainder of this groundwater discharges into streams and rivers near the confluence of the Metolius, Deschutes, and Crooked Rivers (Gannett et al. 2001; Figure 4-25).

Due to the porous geology of the area, groundwater levels and stream discharge are associated with movement of water between surface and groundwater sytems. The rivers, streams, and irrigation canals in the Upper Deschutes watershed all show seepage losses indicative of the area’s permeable geology (Gannett et al. 2001). A loss assessment study in 2016 measured 48 cfs of peak-season loss in TID’s canals due to seepage and evaporation (TID 2017). The water that is lost as canal seepage from the District's canal and laterals likely enters the regional groundwater system that discharges near or into Lake Billy Chinook. The groundwater flows in the area are generally parallel to Tumalo Creek; as a result, the canal seepage does not return to Tumalo Creek and does not become available to other water users in Tumalo Creek (OWRD 2005).

Cascade Range aquifers in the upper Deschutes Basin have experienced a general drying trend since the 1950s. Climate oscillations remain the primary driver of these declines (Gannett et al. 2001;

Gannett et al. 2003). A U.S. Geological Survey study between 1997 and 2008 investigated the influence of canal lining, groundwater pumping, and climate on water level trends in the region. The study found an approximate 5- to 14-foot decline in groundwater levels in the central part of the region, which includes the proposed project area (Gannett and Lite 2013). The study found that 60 to 70 percent of the measured decline was associated with climate variations, 20 to 30 percent of the measured decline was associated with increased groundwater pumping, and 10 percent was associated with canal lining and piping (Gannett and Lite 2013). At the basin-scale, natural fluctuations in groundwater discharge largely mask the effects of development on discharge from the regional aquifer (Gannett et al. 2001).

4.11 Wetlands and Riparian Areas

The area of potential effect for wetlands and riparian areas consists of the project area and the wetlands and riparian areas adjacent to the following 162 miles of rivers and streams: Crescent Lake, Crescent Creek from Crescent Lake Dam (RM 30) to the mouth (RM 0), the Little Deschutes River from the confluence with Crescent Creek (RM 57) to the mouth (RM 0), the Deschutes River downstream of the confluence with the Little Deschutes River (RM 192.5), and Tumalo Creek downstream from the TFC diversion (see Figure 4-19).

Wetlands perform a number of valuable functions including water storage, water filtration, and biological productivity. They can also support complex food chains that provide sources of nutrients to plants and animals and specialized habitat for a wide variety of aquatic and terrestrial species. Wetlands in the area of potential effect may be subject to federal or state regulations depending on their characteristics. Within the State of Oregon, wetlands are managed under two laws, the CWA, and Oregon Removal-Fill Law. The U.S. Army Corps of Engineers (USACE) administers Section 404 of the CWA with the oversight of the U.S. Environmental Protection Agency (USEPA). This law regulates the dredge or fill of wetlands over which the USACE has jurisdiction (or “jurisdictional wetlands”).

Section 404 of the CWA defines wetlands as “those areas inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions” (USACE 1986).

Oregon Department of State Lands (ODSL) implements the Removal-Fill Law (ORS 196.800-990), which regulates the removal or fill of material in wetlands or waterways, requiring any person who plans to “remove or fill” material within “waters of the state” to obtain a permit from ODSL.

Per the Oregon Removal-Fill statute OR 141-085-0515(9), an irrigation ditch is not jurisdictional under Oregon Removal-Fill permitting if it meets both of the following (ODSL 2013):

- The ditch is operated and maintained for the primary purpose of irrigation; and
- The ditch is dewatered outside of the irrigation season except for isolated puddles in low areas.

Language provided in the 1986, Final Rule for Regulatory Programs of the Corps of Engineers (1986 Final Rule) identified that irrigation ditches are generally not considered Waters of the United States for the purpose of determining CWA Section 404(f)(1)(C) applicability. However, EPA reserved the, "right to determine on a case-by-case basis if any of these waters are "Waters of the United States…" including, "…irrigation ditches excavated on dry land…" (USACE 1986). In 2006, a "significant nexus" jurisdiction standard from Rapanos v. United States (547 U.S. 715 2006) was established which has been used to determine if identified waters are Waters of the United States.

In 2015, the Clean Water Rule: Definition of "Waters of the United States" (2015 Final Rule) (USEPA 2015) was published and provided clear exclusions for certain types of ditches; however, the U.S. Court of Appeals for the Sixth Circuit stayed the 2015 Final Rule nationwide pending further action of the court. This reinstated the "significant nexus" jurisdiction standard from Rapanos v. United States.

Water typically flows through the canals and laterals in the project area during the irrigation season, between April and mid-October. Water may also occasionally flow through these canals outside of the irrigation season for stock water deliveries or be present as standing water following rain or snow events. Wetland plants are sometimes found along the banks of irrigation canals and laterals within the project area, as the hydrology provided by the canals and laterals can create favorable growing conditions during a portion of the year. Hydrophytic plants found along these open canals and laterals include black cottonwood, bulrush, and others (Table 4-18). Although some canals and laterals may have hydrology and vegetation indicative of a wetland, they only contain water during the irrigation season and do not meet functional criteria of wetlands, nor are they regulated as wetlands by ODSL or USACE. These canals and laterals meet exemptions under the Oregon Removal-Fill Law for specific agricultural activities in wetlands and other waters of the state.

The National Wetland Inventory (NWI) geographic information systems data (USFWS 2016) shows that about 23 wetland features sporadically occur adjacent to canals and laterals within the area of potential effect; however, these have not been field verified.

Wetland plants and habitat functions in these areas are further limited by routine canal maintenance activities and dewatering outside of the irrigation season.

Table 4-18. Wetland Plant Species within the Area of Potential Effect.

Wetland Plant Species	Scientific Name
Alder species	*Alnus* spp.
Aspen species	*Populus* spp.
Black cottonwood	*Populus balsamifera*
Willow species	*Salix* spp.
Bulrush species	*Scirpus* spp.
Ragwort species	*Senecio* spp.
Sedge species	*Carex* spp.

Notes: Source: RDG 2005

Wetlands are found within and sporadically adjacent to the 162 miles of river (see Section 4.10) downstream of existing diversions within the area of potential effect. Wetlands include the streams and reservoirs themselves (Crescent Creek, Little Deschutes River, Deschutes River, and Tumalo Creek, and Crescent Lake) and depressional wetlands adjacent to affected waterbodies. These depressional wetlands generally occur in low-lying areas.

Riparian areas are transition zones between waterbodies and adjacent upland areas that support hydrophytic vegetation that is dependent upon the hydrology of the waterbody. Riparian areas as defined by Section 404 of the CWA are “areas next to or substantially influenced by water. These may include areas adjacent to rivers, lakes, or estuaries.” (USEPA 2015).

Riparian areas are typically associated with high water tables due to the close proximity to aquatic ecosystems, certain soil characteristics, and a range of vegetation that requires free water or conditions that are moister than normal (Oakley et al. 1985). These zones are transitional between aquatic and upland zones and have a variety of vegetation ranging from grasses, to sedges, to willows, alder, and aspen with minimal conifer encroachment.

Riparian areas of varying size and quality occur adjacent to natural waterbodies in the area of potential effect. Low late fall, winter, and early spring streamflows associated with upstream reservoir storage limits riparian vegetation in Crescent Creek and the Deschutes River (RDG 2005). Low streamflows along these reaches can expose the channel bed and river banks, facilitating increased erosion and fine sediment delivery following freeze-thaw processes and increased spring streamflows (RDG 2005). In Tumalo Creek, winter flows are maintained in their near-natural state but summer flows are severely limited downstream from the TFC diversion. Because streamflow is strongly correlated with critical physical and biological characteristics of the river, it influences the functions of associated riparian areas (National Research Council 2002). As riparian areas become hydrologically disconnected from their adjacent stream channels, they lose many of their ecological functions.

4.12 Wildlife Resources

Effects on wildlife including threatened and endangered species as a result of the proposed action are not expected to extend beyond the project area; therefore, the area of potential effect is defined as the project area when considering wildlife resources.

4.12.1 General Wildlife

A suite of terrestrial wildlife species has the potential to occur in the project area. Generally, wildlife present consists of habitat generalists or edge species with the ability to adapt or exploit the urban environment. These species are tolerant to fragmentation, disturbance, and urbanization, and include species such as deer, coyote, skunk, grey squirrel, raccoon, and red-tailed hawk (Blair 1996; Ditchkoff et al. 2006; McKinney 2002; and Shochat et al. 2006).

Wildlife within the project area may use the canal and lateral system as a water source and dispersal corridor. Additionally, where not cleared, vegetation along canals and laterals can provide food, cover, and breeding sites for many wildlife species throughout the year. However, given the fragmented, disturbed nature of habitat and continued urbanization and biotic homogenization, habitat within the project area likely supports less species diversity and a greater percentage of exotic flora and fauna than native, intact, undisturbed habitat types support.

Table 4-19 lists wildlife species commonly seen within the project area.

Table 4-19. Wildlife Species Likely to Occur within the Tumalo Irrigation District – Irrigation Modernization Project Area.

Wildlife Species	Scientific Name
Bat	*Vespertilionidae* spp.
Coyote	*Canis latrans*
Desert horned lizard	*Phrynosoma platyrhinos*
Golden mantled ground squirrel	*Spermophilus lateralis*
Mule deer	*Odocoileus hemionus*
Northern flicker	*Colaptes auratus*
Osprey	*Pandion haliaetus*
Pygmy rabbit	*Brachylagus idahoensis*
Pygmy short-horned lizard	*Phrynosoma douglasii*
Raccoon	*Procyon lotor*
Red-tailed hawk	*Buteo jamaicensis*
Rufous hummingbird	*Selasphorus rufus*
Turkey vulture	*Cathartes aura*
Western gray squirrel	*Sciurus griseus*
Western rattlesnake	*Crotalus viridus*
Western skink	*Eumeces skiltonianus*
Yellow pine chipmunk	*Eutamias amoenus*

Notes:
Source: ODFW 2017b

4.12.2 MBTA/BGEPA Species

Bird species listed in Table 4-20 potentially occur within the project area and are protected under the Migratory Bird Treaty Act (MBTA) or the Bald and Golden Eagle Protection Act (BGEPA). Although migratory birds are known to occur in the project area and its vicinity, limited habitat is provided within the project area and TID's ROW due to maintenance activities that remove vegetation on an annual basis.

Table 4-20. MBTA/BGEPA Species Potentially Occurring within the Project Area.

MBTA/BGEPA Species	Scientific Name
Bald eagle	*Haliaeetus leucocephalus*
Brewer's sparrow	*Spizella breweri*
Calliope hummingbird	*Stellula calliope*
Cassin's finch	*Carpodacus cassinii*
Eared grebe	*Podiceps nigricollis*
Flammulated owl	*Otus flammeolus*
Fox sparrow	*Passerella iliaca*
Golden eagle	*Aquila chrysaetos*
Green-tailed towhee	*Pipilo chlorurus*
Lewis's woodpecker	*Melanerpes lewis*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Olive-sided flycatcher	*Cantopus cooperi*
Peregrine falcon	*Falco peregrinus*
Pinyon jay	*Gymnorhinus cyanocephalus*
Rufous hummingbird	*Selasphorus rufus*
Sage thrasher	*Oreoscoptes montanus*
Short-eared owl	*Asio flammeus*
Swainson's hawk	*Buteo swainsoni*
Western grebe	*Aechmophorus occidentalis*
White-headed woodpecker	*Picoides albolavatus*
Williamson's sapsucker	*Sphyrapicus thyroidus*
Willow flycatcher	*Empidonax traillii*

Notes:
Source: USFWS 2017

The USFWS maintains a database of known golden and bald eagle nesting sites. Two golden eagle nesting sites are known within the TID service area. No known bald eagle nests occur within the project area although it is possible that a nest could be located near irrigation ponds and/or a proposed pipeline (J. Cordova, personal communication, August 23, 2017).

4.12.3 Federally Listed Species

The USFWS maintains a list of wildlife species protected under the ESA that may occur in Deschutes County (USFWS 2017). As noted previously, no species or federally designated critical habitat occurs within the project area or area of potential effect with the exception of Oregon spotted frog, steelhead, and bull trout, which are discussed in Section 4.2.3.

4.12.4 State Listed Species

The ODFW maintains a list of native wildlife species in Oregon that have been determined to be either threatened or endangered according to criteria set forth by rule (OAR 635-100-0105) (ODFW 2017a). There are no state-listed terrestrial species known to occur within the irrigation canals or any other areas where work associated with the proposed action would occur.

4.13 Wild and Scenic Rivers

There are several waterways federally designated as Wild and Scenic Rivers (Public Law 90-542; 16 U.S.C. 1271 et seq.) that may be affected by the proposed action. Ten miles of Crescent Creek, from Crescent Lake (RM 30) to the west section line of Section 13, T24S, R7E (approximately RM 20) is classified as “Recreation” with the Outstandingly Remarkable Value of Scenery. The Deschutes River from Wickiup Reservoir (RM 226.8) to the Bend Urban Growth boundary at the southwest corner of Section 13, T18S, R11E (approximately RM 172) is classified as both “Scenic” and “Recreation” with Outstandingly Remarkable Values including: Cultural, Fish, Geologic, Historic, Recreation, Scenery, Wildlife, and Botany. However, only the section from the Deschutes River’s confluence with the Little Deschutes River (RM 192.5) downstream to RM 172 is located in the area of potential effect. In addition, the Deschutes River from Odin Falls (RM 139.9) to the upper end of Lake Billy Chinook (RM 120) is classified as “Scenic” with its Outstandingly Remarkable Values including: Cultural, Fish, Geologic, Recreation, Scenery, Wildlife, Hydrology, Botanical/Ecological, and Wilderness.

In addition to federally designated Wild and Scenic Rivers, several waterways in the area of potential effect are designated through the Oregon Wild and Scenic Rivers Act (Oregon Revised Statute [ORS] 390.826) as Oregon Scenic River Waterways. These locations, with specific exclusions and classifications, are detailed in Table 4-21.

Table 4-21. Waterbodies in the Area of Potential Effect designated as Oregon Scenic River Waterways.

Waterbody No.	River	Classification	Reach
1.	Upper Deschutes River	Scenic River Area[1]	From the Deschutes National Forest boundary in Section 20, T19S, R11E (approximately RM 184.8) to the Bend Urban Growth Boundary (approximately RM 172)
2.	Upper Deschutes River	River Community Area[2]	From RM 172 to RM 171
3.	Upper Deschutes River	Recreational River Area[3]	From RM 190.6 to approximately RM 184.8
4.	Middle Deschutes River	Scenic River Area	From Deschutes Market Road (approximately RM 157) to the south boundary of the Wilderness Study Area (approximately RM 131), with the exception of the Clines Falls Dam and powerhouse between State Highway 126 Bridge (RM 144.9) and RM 144 and the Crooked River Ranch River Community Area (RM 129.9 to RM 131.5)
5.	Middle Deschutes River	River Community Area	From RM 164 to approximately RM 161; from RM 129.9 to RM 131.5; and from RM 124.3 to RM 125.25
6.	Middle Deschutes River	Recreational River Area	From the northern Bend Urban Growth Boundary (RM 161) to Tumalo State Park (RM 158)
7.	Middle Deschutes River	Natural River Area[4]	From the south boundary of the Wilderness Study Area as approximately RM 131 to Lake Billy Chinook (RM 120), with the exception of RM 129.9 to RM 131.5.

Notes:
1. Those designated scenic waterways or segments with related adjacent lands and shorelines, are still largely primitive and largely undeveloped except for agriculture and grazing, but accessible in places by roads. These classified areas will be administered to maintain or enhance their high scenic quality, recreational value, fishery, and wildlife habitat, while preserving their largely undeveloped character and allowing continuing agricultural uses.
2. Those designated areas of a scenic waterway where density of structures or other developments already exist and provide for precludes application of a more restrictive classification.
3. Those designated scenic waterways that are readily accessible by road or railroad, that allow a wide range of compatible river-oriented public outdoor recreation opportunities, to the extent that these do not impair substantially the natural beauty of the scenic waterway or diminish its esthetic, fish and wildlife, scientific and recreational values.
4. Those designated scenic waterways that are generally inaccessible except by trail or the river, with related adjacent lands and shorelines essentially primitive. These classified scenic waterways will be administered to preserve their natural, wild, and primitive condition, essentially unaltered by the effects of man, while allowing compatible recreational uses, other compatible existing uses, and protection of fish and wildlife.

5 Alternatives

5.1 Formulation Process

In order to determine the most viable alternatives to meet the project's purpose and need, TID considered the needs of the water users, goals for conservation and restoration, resources and funding available, and the current status of the District's previous improvements. The comments received during the scoping period and Draft Plan-EA review period were incorporated into the alternatives formulation process. Alternatives considered during project development but eliminated from the detailed study were evaluated based on the criteria in USDA's Guidance for Conducting Analysis under the Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies and Federal Water and Resource Investments (USDA 2017). Pursuant to this guidance, alternatives that become "unreasonable due to cost, logistics, existing technology, social or environmental reasons," or general inability to address the purpose and need for action, may be removed from consideration. The alternatives eliminated from detailed study are discussed in Section 5.2. Three separate alternatives were selected for further consideration and are presented in Section 5.3.

5.2 Alternatives Eliminated from Detailed Study

Nine alternatives were considered but eliminated from detailed study. The following six of these alternatives were eliminated due to logistics, social or environmental reasons, or inability to meet the purpose and need of the project:

- Piping outside the ROW
- Conversion to dryland farming
- Fallowing farm fields through transfer or leasing
- Voluntary duty reduction
- On-farm efficiency upgrades
- Private lateral piping

Three alternatives were eliminated due to costs: steel pressurized piping, polyvinyl chloride (PVC) pressurized piping, and the exclusive or partial use of groundwater for irrigation. These alternatives were evaluated with respect to capital and ongoing annual costs over a 100-year period of analysis. The evaluation was based on seven individual project groups, which represent canals and laterals that would undergo construction during the same period. The cost analysis indicated that the District would have to replace steel and PVC piping at least once during the 100-year analysis period for each project group. These piping alternatives were eliminated as a result of these replacement costs. The partial use of groundwater was eliminated due to the logistics of acquiring groundwater rights and ongoing annual electricity costs that would increase the District's annual operating costs by 17 percent.

These are described in more detail below and Table 5-1 presents the net present value of the steel piping, PVC piping, and partial groundwater use alternatives and the HDPE Piping Alternative evaluated in the SIP for each of the seven project groups.

5.2.1 Pipeline Realignment

Pipeline realignment would convert the District's system to pipes. However, instead of following the same path of the existing canals and laterals, in some cases the pipes would be laid in a new alignment (or path across the landscape). New alignments would be selected to continue to serve all patrons but, when possible, would take a more direct route to decrease the length of piping needed. Approximately 89 percent of land adjacent to TID's current system is privately owned. Realignment would require acquiring new easements or ROW across these private lands, which have been divided into smaller parcels with many different owners over time. Depending on the proposed alignment, a ROW across public land could potentially be necessary.

New easements would disrupt prime farmland and residential living areas, and the easements would be difficult to secure from enough landowners to be feasible. Pipeline realignment outside the existing ROW would require the irrigation district to pay market price for the easements and negotiate with multiple landowners, which would be a complex, expensive, and time-consuming process. Pipeline realignment would meet the sponsors' objectives; however, this alternative was eliminated from further study due to legal costs, logistical complexity, and social effects to adjacent landowners.

5.2.2 Conversion to Dryland Farming

The lack of rainfall through the growing season coupled with hot temperatures and desiccating winds, as well as generally shallow and well to excessively drained soils with low storage potentials, generally less than five inches, makes dryland farming infeasible within the District. This is supported by William Renwick's "Changes in Deschutes County Irrigated Agriculture Since 1950" (Renwick 1975). In his report, Renwick described the formation of irrigation districts after new farmers found dryland farming to be impossible and concluded, "The calculated net irrigation requirements vary with annual and monthly fluctuation in precipitation, but it is evident that irrigation is necessary for raising the area's major crops."

In these dryland farming systems where rainfall is 10-15 inches per year, a fallow every other year is necessary. In TID, production would substantially decrease if dryland farming were entertained and farmers could potentially sell their land due to the development pressure Deschutes County is experiencing. Dryland farming would be inconsistent with ensuring agricultural production is maintained in an area undergoing rapid urbanization. Dryland farming would meet the sponsors' objectives to improve water conservation. This alternative was eliminated because it would not meet the objectives to improve water delivery reliability and public safety for District-owned canal and lateral infrastructure, and it would be inconsistent with public policy supporting agricultural land use.

5.2.3 Fallowing Farm Fields

Fallowing farm fields includes permanently transferring or temporarily leasing water rights from irrigated lands or otherwise not using water rights appurtenant to irrigated lands. Fallowing farm fields would use less irrigation water within the District and would therefore allow more water to be kept instream for fish, wildlife, and habitat. This water would be legally protected instream if the associated water rights were leased or transferred instream. Fallowing farm fields would exacerbate the water conveyance challenges that the District already experiences (see Section 2.1.1 and Section 2.1.2) because it would affect flow rates across the District and water reliability to certain patrons.

Fallowing farm fields would meet the sponsors' objective to conserve water, but this alternative would not improve water delivery reliability and public safety for District-owned canal and lateral infrastructure. Fallowing farm fields was eliminated from further study as it would not meet the purpose and need to improve water delivery reliability and public safety for District-owned canal and lateral infrastructure, and it would be contrary to public policy supporting and maintaining existing agricultural land uses (see Section 4.4.2).

5.2.4 Voluntary Duty Reduction

Duty reduction refers to patrons voluntarily accepting less than their full water delivery rate from the District. A reduction in duty could allow the District to divert less water, which would leave more water instream. This water would not be permanently protected instream through a new instream water right.

Because this alternative would be voluntary and at the discretion of individual landowners, there would be no certainty that water would be saved and that streamflow would be restored. If duty reductions by patrons were substantial enough, they could exacerbate the water conveyance challenges that the District already experiences in its open canals and laterals, which would be similar to the challenges associated with fallowing farm fields (see Section 5.2.3). The District would also have logistical challenges in working with many individual landowners to encourage adoption of this alternative.

Voluntary duty reduction was eliminated from further study because of the logistical challenges, the potential to exacerbate water conveyance challenges in the District, and because it would not meet the purpose and need to improve water delivery reliability and public safety for District-owned canal and lateral infrastructure.

5.2.5 On-Farm Efficiency Upgrades

The on-farm efficiency upgrades alternative refers to TID patrons upgrading their on-farm infrastructure to use irrigation technologies that provide a more precise application of water. These technologies can have greater application efficiencies. On-farm infrastructure is distinct from District canals and laterals because it is owned and operated by patrons. Once delivered by the District and arriving on-farm, water can either be released to flow over the land for flood irrigation or stored in a holding pond for sprinkler irrigation systems. The typical on-farm systems include center-pivots, wheel-lines, hand-lines, K-lines, drip systems, and flood irrigation. Each irrigation practice has a different irrigation efficiency (i.e., its ability to deliver the irrigation water to the crop root system across the full field being irrigated). Farms within the District primarily use pump and sprinkler systems. On average, the irrigation efficiency of farms within TID is estimated at 70 percent (TID 2017).

This alternative would meet the objective of conserving water; however, it would be logistically challenging for the District to implement at a large scale. Implementing on-farm efficiency upgrades to achieve water savings at the scale of modernizing District infrastructure would require voluntary participation from many individual landowners. Because the District does not have responsibility for or authority over on-farm irrigation infrastructure, there would be no guarantee that individual landowners would participate. However, the proposed action does not preclude landowners' otherwise upgrading their on-farm infrastructure or receiving assistance to do so through other programs.

Project sponsors must have the legal authority and resources to carry out, operate, and maintain works of improvement (Public Law 83-566 Section 2 and Section 4(3)). Because TID lacks the statutory authority or responsibility to carry out, operate, and maintain on-farm infrastructure owned by TID patrons, on-farm efficiency upgrades are not within the scope of actions that TID can entertain as the Project Sponsor. Therefore, consistent with PL 83-566 authorities under which this plan is being prepared, this alternative was not qualified as a stand-alone alternative or as an additional measure added to an alternative under consideration; as such, it was not fully analyzed in this plan.

On-farm efficiency upgrades were eliminated from further study because of the logistical challenges and because they would not meet the purpose and need to improve water delivery reliability and public safety for District-owned canal and lateral infrastructure.

5.2.6 Piping Private Laterals

Piping private laterals refers to converting from patron-owned, open laterals to piped laterals from the District's point of delivery to the point of use on-farm. Private laterals are owned and operated by patrons; the District does not have responsibility for the operation or maintenance of private laterals.

Similar to on-farm efficiency upgrades, piping private laterals would meet the objective of conserving water; however, it would be logistically challenging for the District to implement at a large scale for the same reasons as on-farm efficiency upgrades (see Section 5.2.5). Piping private laterals was eliminated from further study because of these logistical challenges and because it would not meet the purpose and need to improve water delivery reliability and public safety for District-owned canal and lateral infrastructure.

5.2.7 Piping with Steel or Polyvinyl Chloride

Under the piping alternative, the District would install pipe in the remaining 1.9 miles of canals and 66.9 miles of laterals. The lengths, diameters, and range of pressure ratings used for the piping alternative were estimated based on the engineering analysis completed in the TID SIP.

5.2.7.1 Steel Piping

Under the steel piping alternative, spiral welded steel pipe would be installed in 68.8 miles of canals and laterals. Spiral welded steel was selected that conforms to requirements of the American Water Works Association C200 standard. Steel pipe conforming to American Water Works Association C200 was selected because it is considered an industry consensus standard and is a prominent guide for the manufacture of steel pipe for water and wastewater applications in North America (Bambie and Keil 2013).

Steel pipe typically has a design life of 50 years under irrigation water delivery applications (M. Thalacker, personal communication, November 8, 2017). Pipe diameters of the spiral welded steel pipe would range in size from 6 to 84 inches and pressure ratings designed to accommodate a range for pressures from up to 997 to 1,111 pounds per square inch (psi), depending on the pipe diameter and thickness. Unlike HDPE, steel pipe cannot be shaped to conform into canal alignments; therefore, additional elbows would be required. Capital costs were estimated based on the lengths and diameters quantified and the additional elbows required. These costs were also estimated with constant dollars as per the Economic and Environmental Principles and Guidelines (P&G) for Water and Related Land Resources Implementation Studies. Annual operating costs associated with the steel piping alternative were estimated based on TID's current operating budget and assumed that equipment, maintenance, and labor costs would decrease. Assuming a design life of 50 years, capital costs, replacement costs, and annual operations and maintenance costs for the steel piping alternative were estimated. The cost for each project group associated with the steel piping alternative range from $8,308,000 to $38,764,000 over 100 years. Based on this cost, the steel piping alternative was eliminated from further study (see Appendix D for cost details).

5.2.7.2 Polyvinyl Chloride Piping

Under the PVC piping alternative, 66.9 miles of the delivery system would be piped with PVC and 1.9 miles would be piped with HDPE. PVC would be installed for pipe diameters from 6 inches up to 54 inches, and HDPE would be installed in diameters from 63 to 84 inches because PVC pipe is only manufactured in diameters up to 54 inches. Schedule 41 PVC was selected for this alternative, which can accommodate working pressures up to 100 psi, and the HDPE pipe would accommodate working pressures up to 100 psi.

The lifespan of a piping system depends on many different factors. Proper installation and operation of the piping system are key to achieving a long service life. Assuming a piping system is ideally installed and operated, the main factor affecting the pipe's service life is the number and magnitude of surge/water hammer events the system experiences. Surge/water hammer events are caused by valve operations, changing irrigation demand in the system, pump startup and shutdown, quick hydropower turbine shutdowns due to power failures, and any other factors causing fast changes in the piping system flow rate (B. Cronin, personal communication, July 27, 2018).

The USDA-NRCS practice standard lifespan for irrigation pipeline is 20 years (NRCS n.d.). This lifespan is based on long-term experience with primarily PVC pipe irrigation system installations (B. Cronin, personal communication, July 27, 2018). The Plastics Pipe Institute's online software indicates that with the average number of surge/water hammer events expected in a pipeline network, the lifespan of a typical 24-inch, 125 psi pressure rated PVC pipe would be 14 years with a safety factor of two (Plastics Pipe Institute 2015). PVC is also more prone to failure under freezing conditions, and the TID system is used to deliver water several times during the winter for livestock. During these periods, the PVC pipe system would be more likely to freeze and potentially rupture and fail. PVC piping has been installed in irrigation districts in the Deschutes Basin and experienced premature failure, especially in Districts where stock water is delivered during the winter (M. Thalacker, personal communication, November 8, 2017). Considering all of the information above, a PVC design life of 33 years was assumed for purposes of this analysis.

In assessing PVC as a potential piping material, other factors were taken into consideration. PVC joints have a higher potential to leak, which would result in additional replacement costs. In terms of earthquake resiliency, pipe material such as HDPE has been shown to be more resilient in both lab tests (Oliphant et al. 2012; Cornell University et al. 2009) and in seismic events in places such as New Zealand and Japan (Ballantyne 2013).

The annual O&M costs associated with the PVC piping alternative are expected to be the same as the steel piping alternative. The capital costs were estimated based on the lengths and diameters of the PVC piping. Capital costs also account for additional elbow fittings that will be necessary to conform the PVC pipe into the existing canal alignments. These costs reflect constant dollars as per the P&G. Assuming a design life of 33 years and taking into consideration the estimated capital costs, replacement costs, and annual O&M costs, the net present value for each project group ranged between $4,940,000 to $24,391,000 (2018 dollars) over 100 years (see Appendix D for cost details). Although PVC piping would meet the sponsors' objectives, the PVC alternative was eliminated based on the availability of a more resilient and longer lasting material that would achieve the sponsors' objectives at a lower cost across the lifespan of the project (see Appendix D for cost details).

5.2.8 Exclusive or Partial Use of Groundwater

The exclusive or partial use of groundwater in place of surface water for irrigation was also initially considered as possible alternatives under the proposed action. To use groundwater in the Deschutes Basin, the District would have to apply for groundwater rights under OWRD's Deschutes Basin Groundwater Mitigation (DBGM) program pursuant to OAR 690-505-0500. The DBGM program is part of OWRD's goal to limit groundwater use by imposing restrictions to new users obtaining groundwater rights. Under the DBGM program, only 32.98 cfs are available, and it is unlikely the District could obtain rights to all the remaining water (S Henderson, personal communication, August 14, 2017). Given that only 32.98 cfs is available under this program, the District's exclusive use of groundwater to entirely replace their use of surface water is not feasible.

The partial use of groundwater would utilize the remaining groundwater available under the DBGM program where the District would transfer 32.98 cfs of their surface water rights to groundwater rights. Laterals in the northwestern portion of the TID delivery system would be selected for the conversion to groundwater use, which include the Beasley, North Spaulding, Spaulding, West Branch Columbia Southern East and West, Couch, East Couch, West Couch, Gainsforth, and Chambers Ditch laterals. These account for 23.5 miles of the delivery system and serve approximately 1,900 irrigated acres and 119 points of delivery to individual users. Assuming the application rate of 7.48 gallons per minute per acre that was used in the TID SIP, groundwater would need to meet a demand of 14,365 gallons per minute or 32.1 cfs over the irrigation season for the portion of the District that would be converted to groundwater use. The District would decommission the laterals and corresponding 119 points-of-diversion and construct 119 individual wells. Based on the average well depth of existing wells in the District, the constructed wells were assumed to have a well depth of 267 feet. The remaining 45 miles of the delivery system would be replaced with HDPE pipe.

Capital costs were estimated based on the well construction costs for the 119 wells and HDPE piping costs for the remaining 45 miles of the delivery system. These costs reflect constant dollars as per the P&G. Annual O&M costs associated with partial groundwater use are expected to be higher than O&M costs associated with piping due to the increased energy requirements to pump groundwater. A design life of 50 years for each well was selected based on well design guidance provided in the NRCS Engineering Handbook (NRCS 2010). Based on common engineering experience, each well pump was assumed to have a design life of 25 years. Assuming a design life of 50 and 25 years for the well and well pumps, respectively, capital costs, replacement costs, and annual operations and maintenance costs for the partial use of groundwater alternative for each project group were estimated to range from $4,278,000 to $19,811,000 over 100 years. Based on this cost and the logistical constraints associated with obtaining groundwater rights, partial use of groundwater was eliminated from further study (see Appendix D for cost details).

Table 5-1. Net Present Value of Alternatives Considered for the Tumalo Irrigation District – Irrigation Modernization Project.

Project Groups	Alternative			
	HDPE Piping	PVC & HDPE Piping	Steel Piping	Groundwater and & HDPE Piping
1	$7,468,000	$7,305,000	$8,308,000	$7,468,000
2	$12,178,000	$15,045,000	$25,736,000	$12,178,000
3	$5,295,000	$6,688,000	$11,428,000	$5,295,000
4	$8,500,000	$10,158,000	$18,149,000	$11,573,000
5	$7,405,000	$9,117,000	$16,643,000	$11,191,000
6	$19,346,000	$24,391,000	$38,764,000	$19,811,000
7	$4,278,000	$4,940,000	$8,102,000	$4,278,000

Notes:

1. Costs presented were rounded to the nearest $1,000.
2. The costs presented for HDPE piping reflect the initial estimate quantified in the SIP; therefore, these costs do not match the HDPE costs presented elsewhere in the document.

5.3 Alternatives Description

Of the several project alternatives that were considered for the TID Irrigation Modernization Project, three were selected for further evaluation:

- No Action (Future without Project): Improvements to existing open canals and laterals occur as funding becomes available and are not reasonably certain to occur;
- Canal Lining Alternative: Line existing open canals and laterals with polyethylene geocomposite covered with shotcrete; and
- High-Density Polyethylene Pressurized Piping Alternative (or the “HDPE Piping Alternative”): Replace the existing canals and laterals with a closed conduit HDPE pressurized pipeline system.

These alternatives are discussed further in the following sections and include only TID-owned infrastructure.

5.3.1 No Action (Future without Project)

Under the No Action Alternative, the District would continue to operate and maintain its existing canal, lateral, and pipe system in its current condition. This alternative assumes that modernization of the District's system to meet the purposes and needs of the Project would not be reasonably certain to occur. Under this alternative, the District would only modernize its infrastructure on a project-by-project basis as public and public interest funding became available. This funding is not reasonably certain to be available under a project-by-project approach at the large scale necessary to modernize the District's infrastructure.

Without PL 83-566 funding, neither the Canal Lining nor the HDPE Piping Alternative would occur in the foreseeable future. Therefore, for the purposes of this Plan-EA, the No Action Alternative is a near-term continuation of the District's standard operation procedures. Instream flows would not be enhanced for fish, and energy use and cost would remain high. Without pressurized water, the current individual on-farm pumps would continue to require an estimated 6 million kilowatt hours per year. Agriculture in the area would continue to be susceptible to inconsistent water supply and increased production costs.

The No Action Alternative contributes to the sponsors' objectives as follows:

- <u>Improve water conservation</u>: This alternative continues existing water loss in the District's system of 48 cfs (approximately 15,115 acre-feet of water throughout the entire irrigation season) from canal seepage and evaporation.
- <u>Increase water delivery reliability to farms</u>: This alternative maintains existing operations and infrastructure and would only improve irrigation water delivery reliability if the District secures additional funding sources. Effects on the District's water supply from potential regulations and changes in precipitation patterns could force farmers to fallow fields or discontinue irrigated agriculture.
- <u>Reduce O&M costs:</u> This alternative maintains existing energy use and associated costs for farmers. The use of individual pumps requires an energy use of over 6 million kilowatt hours per year across the District at a cost of up to $584,400 per year. This energy use emits approximately 4,600 metric tons of carbon emissions per year. District canal and maintenance costs would remain the same as District personnel would have to continue timely system maintenance that include removal of debris and foreign material that hinder system operation and perform repairs to the banks and slopes of the open canal and lateral system. This alternative would limit the reduction of O&M costs for the District until individual projects are completed.
- <u>Enhance streamflow and habitat conditions for fish and aquatic species</u>: The District would allocate conserved water instream incrementally as projects are completed. This alternative would affect streamflow and habitat conditions along Crescent Creek, the Little Deschutes River, the Deschutes River, and Tumalo Creek as projects are completed, however these benefits are not reasonably certain to occur.

- Improve public safety: This alternative would not reduce the drowning risks associated with open canals.

5.3.2 Canal Lining Alternative

The Canal Lining Alternative involves the installation of an impervious system to cover 65.1 miles of canals and laterals; current piping in the system would not be replaced with lined canals. Materials typically employed include geomembranes, rubber liners, shotcrete, and/or similar materials. This alternative would require reshaping the current canals to a trapezoidal form, while sub-grade preparation, installation of the liner, and applying a coating for protection. Five representative cross sections of the existing system were identified to size the trapezoid cross sections and are described in further detail in Section 5.3.2.1. Construction of the Canal Lining Alternative would occur in seven project groups[9] over the course of 11 years.

Canals and laterals identified for lining would be accessed from TID's existing maintenance roads when possible. Existing maintenance roads and overland access routes commonly used for O&M would require few, if any, improvements for use during construction.

Temporary overland travel routes within TID's existing ROW would be necessary to access certain canals and laterals associated with the proposed action that do not have established maintenance roads. To facilitate restoration, temporary travel routes would be left in their natural condition with only minimal altering when necessary to allow travel during construction. The most direct route possible would be used to access the construction area. Any work needed to create equipment access would occur prior or concurrently with lining.

Vegetation clearing prior to construction, reseeding, and vegetation management of TID's ROW during construction would be completed according to TID's current vegetation management practices and NRCS Oregon and Washington Guide for Conservation Seedings and Plantings (NRCS 2000). During construction, clearing of vegetation would be minimized to the extent practicable with locations for vehicle and equipment access, staging, and storage selected to avoid trees and other slow-growing vegetation. Trees would only be removed if they pose a safety threat to construction crews working in the canal or lateral trench. Following construction, all disturbed areas would be reseeded with consultation with NRCS and weeds would be managed per the protocol laid out in NRCS Oregon and Washington Guide for Conservations Seedings and Plantings (NRCS 2000). Weeds would be controlled within the ROW using hand pulling during the first year after reseeding, and a combination of hand pulling and herbicide application in the second year if weeds become problematic. In regards to operations and maintenance over the life of the proposed action, TID would remove volunteer and dead trees when necessary (K. Rieck, personal communication, June 27, 2017).

Fences would need to be installed along dangerous sections or areas that are easily accessible by public in order to increase public safety and reduce District liability. These fences would be chosen to prevent the public from nearing the edge or entering canal and would be standard chain link with

[9] Project Group refers to groupings of canals and laterals that would undergo construction during the same period.

3-wire barbed wire cap per NRCS guidelines. In canals with depths greater than 2.5 feet, safety ladders would be installed every 750 feet.

During the irrigation season from April to October, maintenance work would be performed on an as-needed basis. Operation procedures regarding patron deliveries would remain the same as current procedures. During the winter months, outside of the irrigation season, TID would perform system component maintenance including patron valve battery changes, meter maintenance, valve repairs, and repairs to cracks and leaks in the lining throughout the canal and lateral system.

The Canal Lining Alternative contributes to the sponsors' objectives as follows:

- Improve water conservation: This alternative would reduce water loss from canal seepage by approximately 43 cfs (approximately 13,604 acre-feet of water throughout the entire irrigation season) through installing impervious materials between the porous soil and water flowing in the system. Water loss in an open, lined system is estimated to be 10 percent based on studies of canal lining (Swihart and Haynes 2002), compared to up to 30 percent loss in the current, unlined system. Lined canals are vulnerable to tears or cracks in the lining and when torn or cracked, leakage from lined canals is similar to that from unlined canals.
- Increase water delivery reliability to farms: Modernizing the system would improve irrigation water delivery reliability for 7,002 acres of irrigated land. This alternative would improve operational efficiencies to ensure that patrons receive the water they need at the time that they need it.
- Reduce O&M costs: This alternative is anticipated to increase O&M costs for the District by $52,800 per year over the life of the project. Canal lining has a varying lifespan as short as 40 years and can require extensive maintenance to continue operating at high efficiency (Swihart, J. & Haynes, J. 2002). In addition, this alternative maintains existing energy use and associated costs for farmers. The use of individual pumps requires an energy use of over 6 million kilowatt hours per year across the District at a cost of up to $584,400 per year. This energy use emits approximately 4,600 metric tons of carbon emissions per year.
- Enhance streamflow and habitat conditions for fish and aquatic species: This alternative would enhance streamflow and habitat conditions for fish and aquatic species by creating instream water rights through the State of Oregon's Allocation of Conserved Water Program. Under this alternative, the District would conserve approximately 43 cfs and legally reduce its water right by the amount of conserved water. The District would fully fund this alternative through public and public interest sources. Under this funding model, the District would allocate and legally protect 100 percent of the conserved water instream through Oregon's Allocation of Conserved Water Program (ORS 537.470). The District would allocate the conserved water instream incrementally following completion of each project group. Streamflow and habitat conditions along Crescent Creek, the Little Deschutes River, the Deschutes River, and Tumalo Creek would benefit incrementally.
- Improve public safety: Without fences, this alternative would not reduce the drowning risks associated with open canals and laterals. Lining the canals and laterals would increase the

water velocity and make the sides slippery and more difficult for people in the water to grasp and climb out. Fences would need to be installed along dangerous sections or areas that are easily accessible by public in order to increase public safety and reduce District liability. Safety ladders would have to be installed within canals to provide the opportunity for escape. The cost analysis of this alternative includes fencing and safety ladders in the total construction cost.

The estimated total project cost for the Canal Lining Alternative over the 100-year period of analysis is $84,334,900. The total average annual project cost amortized over 100 years at 2.75 percent would be $3,197,700. O&M is estimated to increase from the current amount by $52,800 per year.

5.3.2.1 Project-Specific Components

The District would implement the Canal Lining Alternative over seven different project groups (Figure 5-1). Upon completion of all seven project groups, TID would have lined 65.1 miles of open canals and laterals. Five different, representative cross sections were identified in TID's existing delivery system and used to define five trapezoidal cross sections for canal lining.

The delivery laterals would require a trapezoidal channel with a base width ranging from 1 to 4 feet and a top width ranging from 5 to 20 feet, respectively. The TFC channel would have a base width of 4 feet and a top width of 28 feet. Side slopes would be 2 horizontal to 1 vertical. This configuration allows for 1 foot of freeboard in the channel. The cross-sectional area of the laterals would range from about 3 to 48 square feet and the TFC would be about 96 square feet.

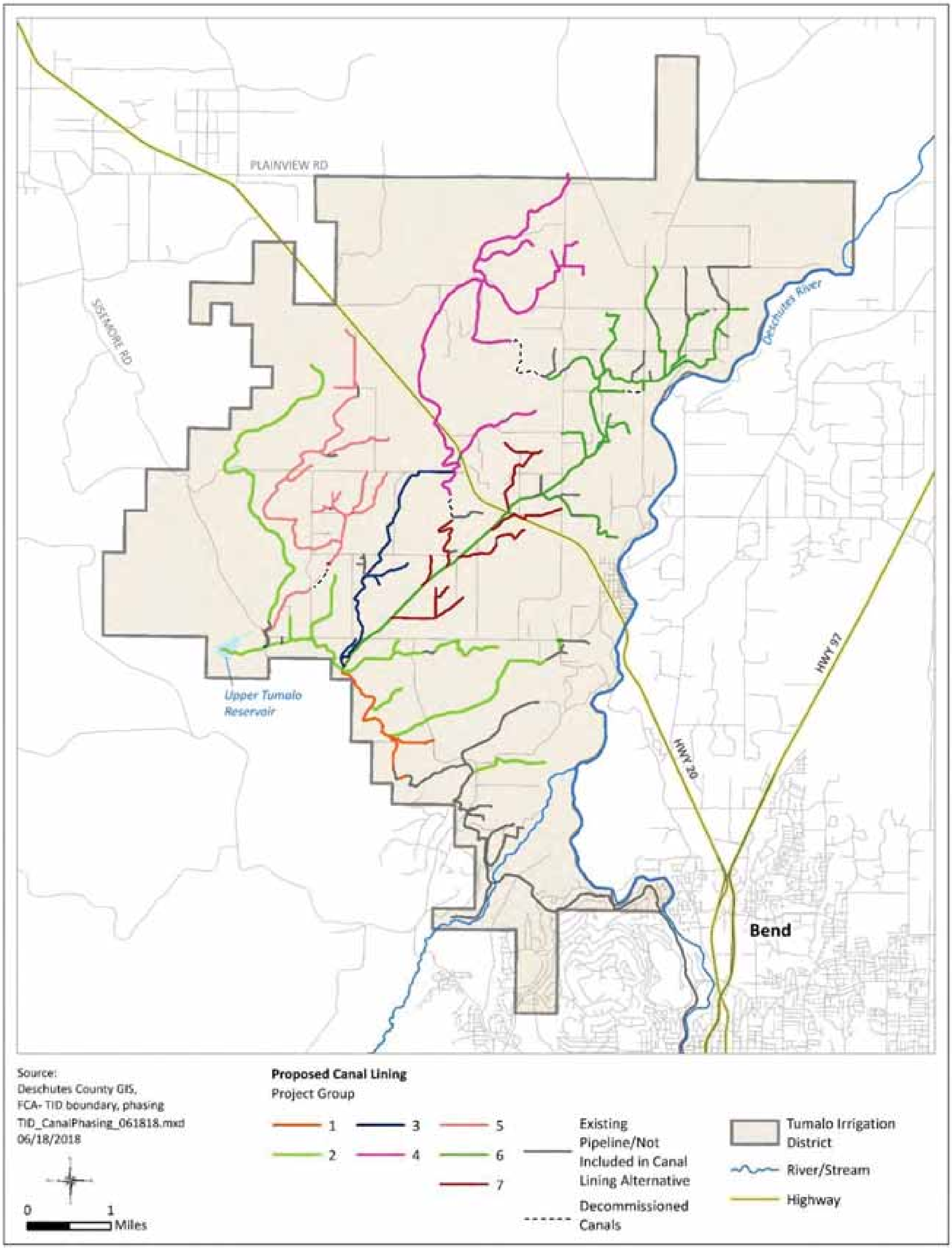


Figure 5-1. Project Groups of the Canal Lining Alternative for Tumalo Irrigation District - Irrigation Modernization Project.

5.3.3 HDPE Piping Alternative

In the HDPE Piping Alternative, the District would install HDPE pipe over 68.8 miles[10]: 1.9 miles of canals and 66.9 miles of laterals. The remaining un-piped segment of the TFC would be piped with 84-inch solid wall HDPE. The remaining portions of the delivery system would be pressurized with HDPE single walled pipe. Pipe size, based on hydraulic modeling, would range in diameter from 6 to 84 inches (TID 2017). Construction of the HDPE Piping Alternative would occur in seven project groups over the course of 11 years.

Construction of the piping and pressurization alternative would include: mobilization and staging of construction equipment, delivery of piping to construction areas, excavation of trenches, fusing of pipelines, placement of pipe, compaction of backfill, and restoration and reseeding of the disturbed areas. In some locations, construction access would need to be created prior to bringing pipes or equipment into construction areas. This could include removal of vegetation within the construction area. Appropriately sized construction equipment would be used to minimize disturbance in the construction area.

Installation of the pipeline would most likely require some borrow or fill material as well as storage areas for pipe, other materials, and construction equipment. These areas have not yet been identified. Areas that have been previously disturbed and are accessible through existing access routes would be selected.

Canals and laterals identified for piping would be accessed from TID's existing maintenance roads when possible. Existing maintenance roads and overland access routes commonly used for O&M would require few, if any, improvements for use during construction.

Temporary overland travel routes within TID's existing ROW would be necessary to access certain canals and laterals associated with the proposed action that do not have established maintenance roads. To facilitate restoration, temporary travel routes would be left in their natural condition, with only minimal altering when necessary to allow travel during construction. The most direct route possible would be used to access the construction area. Any work needed to create equipment access would occur prior or concurrently with piping.

Vegetation clearing prior to construction, reseeding, and vegetation management of TID's ROW during construction would be completed according to TID's current vegetation management practices and NRCS Oregon and Washington Guide for Conservation Seedings and Plantings (NRCS 2000). During construction, clearing of vegetation would be minimized to the extent practicable with locations for vehicle and equipment access, staging, and storage selected to avoid trees and other slow-growing vegetation. Trees would only be removed if they pose a safety threat to construction crews working in the canal or lateral trench. After construction, all disturbed areas would be reseeded with consultation with NRCS and weeds would be managed per the protocol laid out in NRCS Oregon and Washington Guide for Conservations Seedings and Plantings (NRCS

[10] Throughout the Plan-EA, the HDPE Piping Alternative refers to piping 68.8 miles of canals and laterals, while the Canal Lining Alternative refers to lining 65.1 miles of currently open canals and laterals. The difference in lengths between the two alternatives is due to the two data sets used.

2000). Weeds would be controlled within the ROW using hand pulling during the first year after reseeding, and a combination of hand pulling and herbicide application in the second year if weeds become problematic. In regards to operations and maintenance over the life of the proposed action, TID would remove volunteer and dead trees when necessary (K. Rieck, personal communication, June 27, 2017).

O&M under the HDPE Piping Alternative would consist of an ongoing pipe inspection program that would systematically cover inspection of the entire system over a period of several years (most likely a 10-year cycle). During the irrigation season from April to mid-October, work would be performed on an as-needed basis. During the winter months, outside of the irrigation season, TID would perform system component maintenance including patron valve battery changes, meter maintenance, patron and District operational valve maintenance, air and vacuum valve maintenance, pressure reducing station filter maintenance, and valve repairs.

The HDPE Piping Alternative contributes to the sponsors' objectives as follows:

- Improve water conservation: This alternative would reduce water loss from canal seepage and evaporation by 48 cfs (approximately 15,115 acre-feet of water throughout the entire irrigation season) through installing pressurized HDPE pipe for all open canals and laterals.
- Increase water delivery reliability to farms: Modernizing the system would improve irrigation water delivery reliability for 7,002 acres of irrigated land. This alternative would improve operational efficiencies to ensure that patrons receive the water they need at the time that they need it. A piped and pressurized system greatly increases conveyance efficiency, allowing existing carry water to be available for patrons and further reducing the need to spill excess water as the system becomes on demand.
- Reduce O&M costs: HDPE pipes are UV resistant, water hammer resistant, and have high tensile strength. During installation HDPE pipes are welded together, and therefore the need for expensive fittings and thrust blocks are minimized. HDPE pipe is easy to install, bendable, retains its properties between -220°F and 180°F, and has a design life of 100 years. Because HDPE pipe requires less O&M than an open system, TID would direct its attention to telemetry for measurement and system adjustments from Crescent Lake to optimize water conservation. In addition, a pressurized pipeline allows for the elimination of individual pumps serving farms across the District and the conservation of approximately 4 million kilowatt hours per year. It would reduce patron pumping costs by approximately $325,500 per year and reduce carbon emissions by approximately 2,300 metric tons per year.
- Enhance streamflow and habitat conditions for fish and aquatic species: This alternative would enhance streamflow and habitat conditions for fish and aquatic species by creating instream water rights through the State of Oregon's Allocation of Conserved Water Program. Under this alternative, the District would conserve 48 cfs and legally reduce its water right by the amount of conserved water. The District would fully fund this alternative through public and public interest sources. Under this funding model, the District would allocate and legally protect 100 percent of the conserved water instream through Oregon's Allocation of Conserved Water Program. The District would allocate the conserved water

instream incrementally following completion of each project group. Streamflow and habitat conditions along Crescent Creek, the Little Deschutes River, the Deschutes River, and Tumalo Creek would benefit incrementally.

- Improve public safety: Converting open canals and laterals to buried pipe would eliminate the risk of drowning.

The estimated total project cost for the HDPE Piping Alternative over the 100-year period of analysis is $43,326,000. The total average annual project cost amortized over 100 years at 2.75 percent is $1,128,400. Over the lifetime of the project, O&M is estimated to decrease by $126,600 per year.

5.3.3.1 Project–Specific Components

The District would implement the HDPE Piping Alternative over the seven different project groups (Figure 5-2). Upon completion of all seven project groups, TID would replace 1.9 miles of canals and 66.9 miles of laterals in its system with gravity-pressurized buried pipe. The open portion of the TFC would be piped with 84-inch solid wall HDPE. The remaining portions of the delivery system would be pressurized with HDPE single walled pipe. Pipe required based on hydraulic modeling would range in diameter from 6 to 84 inches (TID 2017).

Under this alternative, 543 existing turnouts would be upgraded to pressurized delivery systems. Currently numerous TID turnouts are shared by patrons. In order to provide pressurization benefits and better water management, the majority of these existing shared turnouts would be converted to individual turnouts by the addition of approximately 119 new turnouts. Modifications to each turnout would include an appropriately sized tee from the mainline or lateral, a pressure relief valve, a gear-actuated plug valve, a magnetic meter, a combination air and vacuum relief valve, and associated hardware and spool pipe segments (TID 2017). Three pressure-reducing valves (PRV) would also be installed as part of the proposed action to alleviate high pressures within the system.

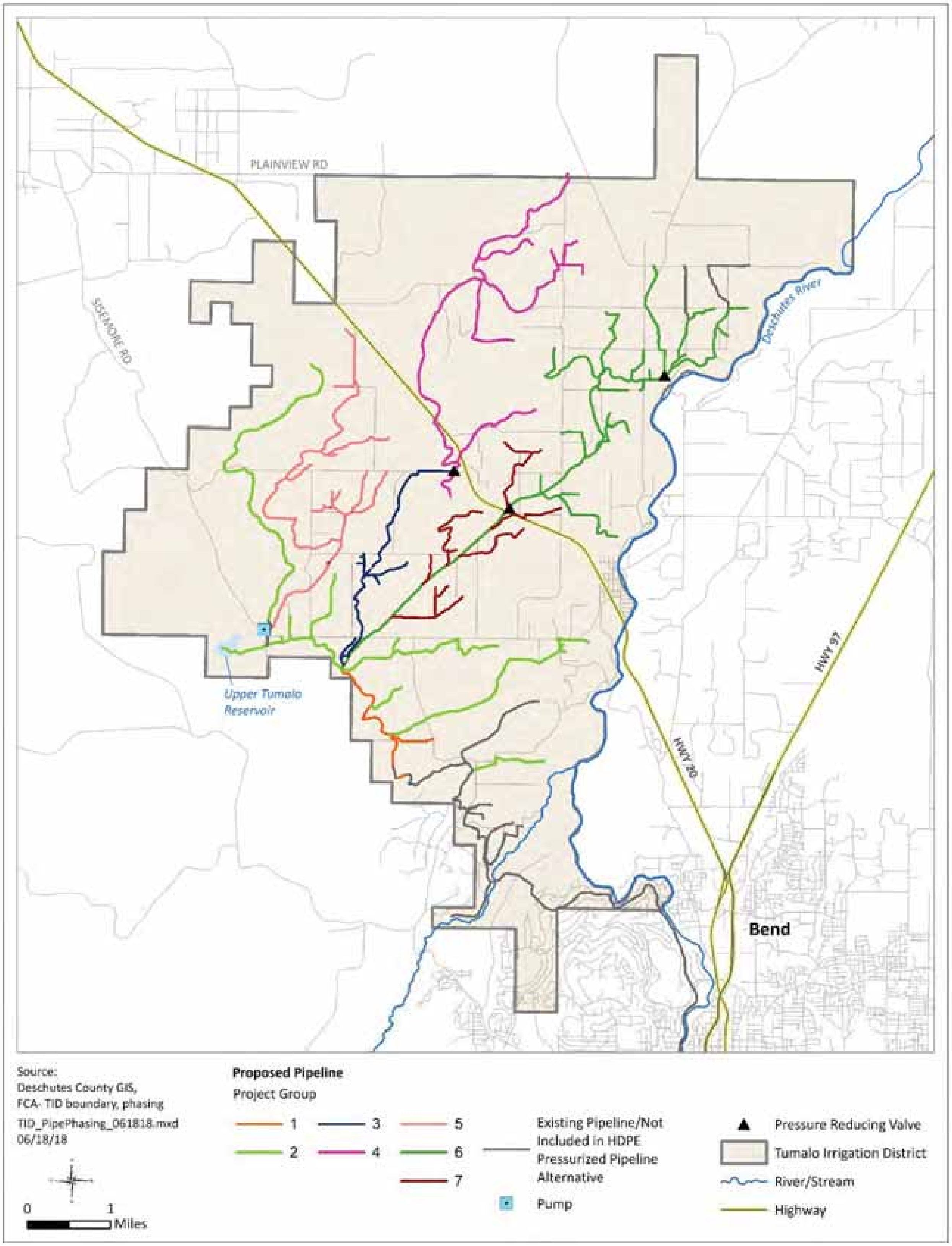


Figure 5-2. Project Groups of the HDPE Piping Alternative for Tumalo Irrigation District - Irrigation Modernization Project.

5.4 Summary and Comparison of Alternatives

Table 5-2 compares the No Action/Future without Project (Alternative 1), the Canal Lining Alternative (Alternative 2), and the HDPE Piping Alternative (Alternative 3). The table summarizes measures addressed as well as environmental, social, cultural, and economic effects.

Table 5-2. Summary and Comparison of Alternative Plans

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
Measures to address	Habitat for fish and wildlife	Instream flows and habitat would not be improved.	Allocation of conserved water to instream flows would improve water quality and enhance habitat.	Allocation of conserved water to instream flows would improve water quality and enhance habitat.
	Public safety	Canals and laterals would be left open and drowning would remain a risk.	The lined canal would have steeper concrete side slopes and faster water velocities than the existing canal. Canals and laterals would be left open and fencing would be installed along dangerous sections. Drowning would remain a risk.	Drowning risk would be eliminated.
	Water delivery reliability for agriculture	Water delivery reliability for agriculture would not be improved as infrastructure and operations would not change.	Water delivery reliability for agriculture would improve for irrigators within the District.	Water delivery reliability for agriculture would improve for irrigators within the District. Pressurized water would be available to irrigators when they need it.
Installation Costs	NRCS Contribution	$0	$64,410,000	$29,781,700
	SLO Contribution	$0	$19,924,900	$13,544,300
	Total	$0	$84,334,900	$43,326,000
NED Account	**Project Group 1[1]**			
	Average Annual Cost Installation OM&R[2] Other Direct Costs[3] Total	 $0 $0 $0 $0	 $196,600 $2,200 $5,000 $203,800	 $199,800 $0 $5,200 $205,000
	Annual Benefits[4]	$0	$177,400	$205,600
	Annual Costs[5]	$0	$203,800	$205,000
	Annual Net Benefits[6]	$0	-$26,400	$600
	Annual Remaining Flood Damage	N/A	N/A	N/A

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
	Project Group 2[1]			
NED Account	Average Annual Cost			
	Installation	$0	$692,000	$198,300
	OM&R[2]	$0	$12,700	$0
	Other Direct Cost[3]	$0	$4,500	$2,400
	Total	$0	$709,200	$200,700
	Annual Benefits[4]	$0	$148,400	$269,300
	Annual Costs[5]	$0	$709,200	$200,700
	Annual Net Benefits[6]	$0	-$560,800	$68,600
	Annual Remaining Flood Damage	N/A	N/A	N/A
	Project Group 3[1]			
NED Account	Average Annual Cost			
	Installation	$0	$304,500	$104,700
	OM&R[2]	$0	$4,100	$0
	Other Direct Costs[3]	$0	$2,400	$1,300
	Total	$0	$311,000	$106,000
	Annual Benefits[4]	$0	$79,600	$135,600
	Annual Costs[5]	$0	$311,000	$106,000
	Annual Net Benefits[6]	$0	-$231,400	$29,600
	Annual Remaining Flood Damage	N/A	N/A	N/A
	Project Group 4[1]			

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
NED Account	Average Annual Cost			
	Installation	$0	$544,300	$120,100
	OM&R[2]	$0	$9,000	$0
	Other Direct Costs[3]	$0	$2,700	$1,400
	Total	$0	$556,000	$121,500
	Annual Benefits[4]	$0	$88,200	$205,100
	Annual Costs[5]	$0	$556,000	$121,500
	Annual Net Benefits[6]	$0	-$467,800	$83,600
	Annual Remaining Flood Damage	N/A	N/A	N/A
	Project Group 5[1]			
NED Account	Average Annual Cost			
	Installation	$0	$447,800	$97,400
	OM&R[2]	$0	$8,100	$0
	Other Direct Costs[3]	$0	$2,000	$1,000
	Total	$0	$457,900	$98,400
	Annual Benefits[4]	$0	$61,200	$133,500
	Annual Costs[5]	$0	$457,900	$98,400
	Annual Net Benefits[6]	$0	-$396,700	$35,100
	Annual Remaining Flood Damage	N/A	N/A	N/A
	Project Group 6[1]			
NED Account	Average Annual Cost			
	Installation	$0	$840,500	$346,300
	OM&R[2]	$0	$14,300	$0
	Other Direct Costs[3]	$0	$8,100	$4,100
	Total	$0	$862,900	$350,400
	Annual Benefits[4]	$0	$243,400	$495,800

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
	Annual Costs[5]	$0	$862,900	$350,400
	Annual Net Benefits[6]	$0	-$619,500	$145,400
	Annual Remaining Flood Damage	N/A	N/A	N/A
	Project Group 7[1]			
NED Account	Average Annual Cost			
	Installation	$0	$92,200	$45,200
	OM&R[2]	$0	$2,400	$0
	Other Direct Costs[3]	$0	$2,300	$1,200
	Total	$0	$96,900	$46,400
	Annual Benefits[4]	$0	$65,800	$124,100
	Annual Costs[5]	$0	$96,900	$46,400
	Annual Net Benefits[6]	$0	-$31,100	$77,700
	Annual Remaining Flood Damage	N/A	N/A	N/A

Notes:

1. All Costs and Benefits presented in the table for the HDPE Alternative and Canal Lining Alternative are included as a change from the No Action Alternative. Costs and Benefits for the No Action Alternative are shown as $0 to represent there would be no change to the existing costs and benefits.
2. OM&R costs for the HDPE Alternative are included in the annual benefits row, as they would decrease and therefore be a benefit to the District.
3. Other Direct Costs for the Canal Lining Alternative consist of increased groundwater pumping costs associated with reduced recharge in the basin and increased carbon costs. Other Direct Costs for the HDPE Alternative consist of increased groundwater pumping costs associated with reduced recharge in the basin.
4. For the HDPE Piping Alternative, quantified benefits include instream flow benefits, reduced OM&R costs, reduced carbon outputs, and reduced energy costs from pumping. For the Canal Lining Alternative quantified benefits include instream flow.
5. For the HDPE Piping Alternative, costs include annualized installation costs and increased groundwater pumping costs associated with reduced recharge in the basin. For the Canal Lining Alternative, costs include annualized installation costs, increased groundwater pumping costs associated with reduced recharge in the basin, increased carbon costs, and increased OM&R costs.
6. Annual Net Benefits shown for the HDPE Piping Alternative and Canal Lining Alternative are the additional net benefits compared to the No Action Alternative.

Watershed Plan Element	**Item or Concern**	**No Action Alternative**	**Alternative 2 Canal Lining**	**Alternative 3 HDPE Piping (NED Recommended)**
Environmental Quality (EQ) Account	**Geology and Soils**			
	Geology	No effect	No effect	No effect
	Erosion	Minor effects from ongoing erosion of canals and laterals.	Negligible short-term effects during construction.	Negligible short-term effects during construction.
	Prime Farmlands	No effect	Minor short-term effects during construction.	Minor short-term effects during construction.
Environmental Quality (EQ) Account	**Water**			
	Surface- Water Quality	No effect	Potential to improve 162 miles of stream 303d listed for temperature, dissolved oxygen, Chlorophyll a, pH, sedimentation, or turbidity.	Potential to improve 162 miles of stream 303d listed for temperature, dissolved oxygen, Chlorophyll a, pH, sedimentation, or turbidity. Potential to improve irrigation water quality delivered to patrons by preventing contaminants in agricultural tailwater, such as herbicides and pesticides, from entering the District's canals and laterals.
	Surface- Water Quantity	No effect	Allocation of conserved water to instream water rights of approximately 43 cfs to be legally protected within 162 river miles.	Allocation of conserved water to instream water rights of approximately 48 cfs to be legally protected within 162 river miles. As sections of the District become piped, the conveyance system would convert into an on-demand system allowing water to remain instream (not diverted) when not being utilized by patrons.
	Groundwater- Quantity	No effect	Reduction to recharge by approximately 13,500 acre-feet. Recharge through cracks and tears would continue to occur.	Reduction to recharge by approximately 15,000 acre-feet.
	Regional Water Resources Plan	No effect	Allocation of conserved water to instream water rights aligns with goals and objectives of regional water resources plans.	Allocation of conserved water to instream water rights aligns with goals and objectives of regional water resources plans.

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
	Conserved Water	No effect	Potential to conserve approximately 43 cfs currently lost through seepage in conveyance canals and laterals.	Potential to conserve approximately 48 cfs currently lost through seepage and evaporation in conveyance canals and laterals.
	Water Rights	No effect District will continue to struggle in supplying patrons their full water rights due to conveyance inefficiencies.	Allocation of conserved water to instream water rights of approximately 43 cfs through Oregon's Allocation of Conserved Water Program. District would have an efficient conveyance system to supply patrons their full water rights.	Allocation of conserved water to instream water rights of approximately 48 cfs through Oregon's Allocation of Conserved Water Program. District would have an efficient conveyance system to supply patrons their full water rights.
	Water Leasing	No effect	Potential for reduction in instream leasing limitations for patrons.	Removal of instream leasing limitations for patrons.
	Wild and Scenic Rivers	No effect	There would be no direct effects to the 146.5 river miles of designated Wild and Scenic Rivers and State Scenic Waterways located within the area of potential effect. A reduced District diversion rate and the allocation of instream water rights would have indirect effects by restoring the designated waterways to a more natural hydrologic regime.	There would be no direct effects to the 146.5 river miles of designated Wild and Scenic Rivers and State Scenic Waterways located within the area of potential effect. A reduced District diversion rate and the allocation of instream water rights would have indirect effects by restoring the designated waterways to a more natural hydrologic regime.
	Wetland and Riparian Areas			

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
Environmental Quality (EQ) Account	Wetlands	No effect	Project canals and laterals are not considered jurisdictional wetlands by state or federal agencies. The National Wetland Inventory (NWI) geographic information systems data (USFWS 2016) shows that about 23 wetland features sporadically occur adjacent to canals and laterals within the area of potential effect; however, these features have not been field verified. Wetland determinations and/or delineations of areas adjacent to canals in areas where work would occur will be conducted prior to implementation of construction of each project group, and wetlands will be avoided to the extent practicable. Wetland habitat adjacent to stream reaches downstream of Crescent Lake Dam and TID's diversions would experience additional flows, which will enhance wetlands along 162 miles of rivers through allocation of instream water rights and reduced diverted water at District diversions.	Project canals and laterals are not considered jurisdictional wetlands by state or federal agencies. The National Wetland Inventory (NWI) geographic information systems data (USFWS 2016) shows that about 23 wetland features sporadically occur adjacent to canals and laterals within the area of potential effect; however, these features have not been field verified. Wetland determinations and/or delineations of areas adjacent to canals in areas where work would occur will be conducted prior to implementation of construction of each project group, and wetlands will be avoided to the extent practicable. Wetland habitat adjacent to stream reaches downstream of Crescent Lake Dam and TID's diversions would experience additional flows, which would enhance wetlands along 162 miles of rivers through allocation of instream water rights and reduced diverted water at District diversions.
	Riparian Areas	No effect	Reduction of available water to riparian plants found along canals and laterals in project area. Effects will be offset by the benefits and enhancement to riparian areas along 162 miles of river through instream water right transfers and reduction of diverted water at District diversions.	Reduction of available water to riparian plants found along canals and laterals in project area. Effects will be offset by the benefits and enhancement to riparian areas along 162 miles of river through instream water right transfers and reduction of diverted water at District diversions.
	Fish and Wildlife			

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
Environmental Quality (EQ) Account	Bald and Golden Eagle Protection Act	No effect	No effect; best management practices would include operating outside the USFWS-approved buffer distances. If operating within the recommended buffer distance, the District would operate outside of the nesting season.	No effect; best management practices would include operating outside the USFWS-approved buffer distances. If operating within the recommended buffer distance, the District would operate outside of the nesting season.
	Terrestrial Endangered and Threatened Species	No effect.	No effect.	No effect.
	Fish and Fish Habitat	No effect.	Minor to moderate, long-term effects due to 162 miles of improved stream fishery.	Minor to moderate, long-term effects due to 162 miles of improved stream fishery.
	Aquatic Endangered and Threatened Species	No effect.	No effect to bull trout. Minor beneficial effects to steelhead and Oregon spotted frog.	No effect to bull trout. Minor beneficial effects to steelhead and Oregon spotted frog.
	General Wildlife and Wildlife Habitat	No effect.	The newly lined canal would have steeper concrete side slopes and faster water velocities than the existing canal, posing a drowning risk to large mammals. Fencing along the canals would alter the land use patterns of wildlife. Lining of canals would remove available water to riparian vegetation, thus potential for reduced habitat. This risk would be mitigated by reseeding with native vegetation.	Piping of canals would remove available water to riparian vegetation, thus potential for reduced habitat. This risk would be mitigated by reseeding with native vegetation.
	Migratory Bird Treaty Act Species	No effect	No effect; the District is operating outside the primary nesting period for migratory birds of concern (April 15 through July 15) and raptors (April through July).	No effect; the District is operating outside the primary nesting period for migratory birds of concern (April 15 through July 15) and raptors (April through July).
Environmental Quality (EQ) Account	**Vegetation**			
	General vegetation	No effect	Minor, short-term effects to approximately 150 acres of vegetation due to construction.	Minor, short-term effects to approximately 161 acres of vegetation due to construction.

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
	Invasive Species	No effect	Negligible effects due to construction.	Minor, long-term effects resulting from decreased transport of invasive species through canals.
	Special Status Species	No effect	Negligible effects expected. Surveys would be completed prior to construction in the BLM Peck's milkvetch ACEC. If surveys detect plants within the project area, there would be negligible long-term effects based upon proposed mitigation measures.	Negligible effects expected. Surveys would be completed prior to construction in the BLM Peck's milkvetch ACEC. If surveys detect plants within the project area, there would be negligible long-term effects based upon proposed mitigation measures.
Environmental Quality (EQ) Account	**Human Environment**			
	Land Use	No effect	No direct effect. Long-term, indirect effects would occur due to the support of current agricultural land use and existing zoning designations.	No direct effect. Long-term, indirect effects would occur due to the support of current agricultural land use and existing zoning designations.
	Recreation	No effect	Negligible to minor, short-term, effects during construction. Moderate long-term effects due to the loss of hiking and biking use of the ROW from safety fencing installed.	Negligible to minor, short-term, effects during construction.
	Historic, Cultural, and Scientific Resources	No effect	Long-term effects on historic properties require consultation with State Historic Preservation Office and appropriate mitigation measures, which would be identified prior to construction and completed concurrent with or after construction. Mitigation would limit effects to moderate.	Long-term effects on historic properties require consultation with State Historic Preservation Office and appropriate mitigation measures, which would be identified prior to construction and completed concurrent with or after construction. Mitigation would limit effects to moderate.
Other Social Effects Account	Visual Resources	No effect.	Minor, short-term effects due to construction activities. Moderate, long-term effects due to the change in appearance from new fences and concrete.	Minor, short-term effects due to construction activities. Minor, long-term effects due to the change in appearance from open canals and riparian plants to buried pipe with upland vegetation.

Watershed Plan Element	Item or Concern	No Action Alternative	Alternative 2 Canal Lining	Alternative 3 HDPE Piping (NED Recommended)
	Tribal, religious, sacred, or cultural site	No effect.	The project area would be surveyed prior to construction to avoid effects on archaeological resources.	The project area would be surveyed prior to construction to avoid effects on archaeological resources.
Regional Economic Development Account	Local jobs during construction	N/A	100	50
	Annual jobs from recreation	N/A	Magnitude/direction of recreation visitation impacts not known, so no Regional Economic Development (RED) benefits quantified.	Magnitude/direction of recreation visitation impacts not known, so no RED benefits quantified.
	Other Economic Sector Jobs	120	120	130
	Beneficial Effects Annualized (Millions, 2017$)			
	Region	$3.6	$5.4	$4.2
	Rest of Nation	N/A[1]	N/A	N/A
	Adverse Effects Annualized (Millions, 2017$)[2]			
	Region	$0.9	$0.9	$0.8
	Rest of Nation	$0	$3.0	$1.1

1. Not applicable
2. Note that this includes only the direct costs (no indirect/induced costs are included). Also, total RED effects at the regional level may be minimal as changes in OM&R costs may largely result in income transfers between individuals (i.e., OM&R savings may be offset by reduced District wages and construction sector income), which would reduce changes in net regional income.

6 Environmental Consequences

This section evaluates the environmental consequences of the No Action Alternative, HDPE Piping Alternative, and Canal Lining Alternative. The effects of the three alternatives were evaluated with respect to each resource discussed in Section 4. When considering each resource, the intensity and duration of effects were evaluated using either a quantitative or a qualitative approach. The intensity of an effect was classified as either negligible, minor, moderate, or major. The duration of an effect was classified as temporary, short-term, or long-term, where the period of an effect is dependent on the resource. Table E-1 in Appendix E presents the intensity threshold matrix used to categorize and define the range of expected effects.

6.1 Cultural Resources

The area of potential effects for archaeological and historical resources is described in Section 4.1.

Pursuant to the NHPA of 1966, as amended, federal agencies must take into account the potential effect of an undertaking on historical properties, which refers to cultural resources listed in, or eligible for listing in, the National Register of Historic Places. Recommendations of eligibility require consultation with the Oregon SHPO, and a determination of effects must be agreed upon by the consulting parties. Any finding of “historic properties adversely affected” would require that the consulting parties enter into a Memorandum of Agreement requiring a method of treatment for the adverse effect that is acceptable to all of the consulting parties. Adverse effects could include physical destruction; alteration through repair or maintenance; removal from original location; neglect; visual, audible, or atmospheric changes; transfer, lease, or sale. The Memorandum of Agreement would stipulate that the treatment would be successfully completed prior to the initiation of project construction. The purpose of the Memorandum of Agreement is to ensure effects on cultural resources as a result of system modification are successfully mitigated and are not classified as major.

The District signed a Memorandum of Agreement with SHPO in 2006 to meet Section 106 requirements for a previous project. The Memorandum of Agreement applied to the TFC (Project Group 1) and the Highline/Couch laterals (parts of Project Groups 2 and 5). It was determined by SHPO that piping these segments would have an adverse effect on historical resources. The Memorandum of Agreement accepted the HAER documentation as mitigation for the effects of piping the TFC and Highline/Couch laterals, provided the terms of the agreement are fulfilled. The HAER determined that several features of the District were eligible for listing on the National Register of Historic Places, including the TFC and the Columbia Southern Canal. Both the TFC and Columbia Southern Canal are part of the proposed action.

A tiered EA approach is being used to meet Section 106 requirements for the remaining portions of the proposed action. This approach involves consultation with SHPO to address resource concerns related to the entire project, while site-specific issues and effects are addressed in subsequent site-specific studies nearer to their implementation date. The tiered approach would complete site-specific archaeological and historical resource surveys on a schedule that would align with the proposed action’s 11-year installation period.

The District and NRCS are in consultation with SHPO about mitigation for the proposed action's adverse effects on cultural resources. Mitigation measures under consideration include informational signing at trailheads or publicly significant locations, development of an informational brochure for interpretative use, and historical information for the District's website. These measures would be completed concurrently with or after construction.

6.1.1 No Action (Future without Project)

6.1.1.1 Archaeological Resources

Under the No Action Alternative, the canal and laterals would remain open. Until the canal and laterals are modernized, there would be no opportunity to disturb archaeological resources. O&M activities would continue and may potentially increase in frequency and intensity as the water conveyance system deteriorates over time. Eventually, system failures may cause disturbances that could inadvertently affect archaeological resources.

6.1.1.2 Historical Resources

The District would not utilize PL 83-566 funding to modernize canals and laterals. Until the canal and laterals are modernized, there would be no effects on historical resources other than O&M activities.

6.1.2 Canal Lining Alternative

Reshaping the District's canal and laterals to a trapezoidal form and lining with geomembranes, rubber liners, shotcrete, and/or similar materials would alter the design, materials, and workmanship of TID's infrastructure, which has the potential to adversely affect cultural and historical resources.

6.1.2.1 Archaeological Resources

No archaeological resources were found during surveys that covered the TFC (Project Group 1) and the Highline/Couch laterals (parts of Project Groups 2 and 5) of the Canal Lining Alternative (Stuemke 2006 and 2017). Following the tiered EA approach, site-specific archaeological surveys would be competed for each project group prior to construction for areas not already surveyed. All construction would take place in previously disturbed areas. An Inadvertent Discovery Plan would be followed if archaeological resources were discovered during project excavation, as described below.

6.1.2.2 Historical Resources

The 2006 Memorandum of Agreement with SHPO would apply to the TFC (Project Group 1) and the Highline/Couch laterals (parts of Project Groups 2 and 5). Surveys for historical resources in the remaining portions of the Canal Lining Alternative would be completed prior to construction, and mitigation measures such as those listed above would be identified in consultation with SHPO prior to construction. Mitigation measures would be completed concurrently with or after construction. An Inadvertent Discovery Plan would be followed if historical or cultural resources were discovered during project excavation, as described below.

Overall, the effects on potential cultural resources from the Canal Lining Alternative would be moderate and long-term in intensity because mitigation for each project group would be completed in consultation with SHPO.

6.1.3 HDPE Piping Alternative

Converting the District's canal and laterals to buried pipe would alter the design, materials, and workmanship of TID's infrastructure, which has the potential to adversely affect cultural and historical resources.

6.1.3.1 Archaeological Resources

No archaeological resources were found during surveys that covered the TFC (Project Group 1) and the Highline/Couch laterals (parts of Project Groups 2 and 5) of the HDPE Piping Alternative (Stuemke 2006 and 2017). Following the tiered EA approach, site-specific archaeological surveys would be competed for each project group prior to construction for areas not already surveyed. All construction would take place in previously disturbed areas. An Inadvertent Discovery Plan would be followed if archaeological resources were discovered during project excavation, as described below.

6.1.3.2 Historical Resources

The 2006 Memorandum of Agreement with SHPO would apply to the TFC (Project Group 1) and the Highline/Couch laterals (parts of Project Groups 2 and 5). Surveys for historical resources in the remaining portions of the HDPE Piping Alternative would be completed prior to construction and mitigation measures such as those listed above would be identified in consultation with SHPO prior to construction. Mitigation measures would be completed concurrently with or after construction. An Inadvertent Discovery Plan would be followed if historical or cultural resources were discovered during project excavation, as described below.

Overall, the effects on potential cultural resources from the HDPE Piping Alternative would be moderate and long-term in intensity because mitigation for each project group would be completed in consultation with SHPO.

6.1.4 Compliance and Best Management Practices

Effects on cultural resources would be minimized by implementing the following practices under both alternatives unless otherwise specified:

- Based on the 2006 Memorandum of Agreement, the HAER documentation would be sufficient mitigation for piping the TFC (Project Group 1) and the Highline/Couch laterals (parts of Project Groups 2 and 5). Since the Canal Lining Alternative involves different modifications but would have a similar overall effect on historical integrity, it is expected the HAER would also be sufficient mitigation for lining the TFC and the Highline/Couch laterals. If the HAER is not sufficient mitigation for these portions, additional mitigation would be agreed upon with SHPO, NRCS, and the District prior to construction.

- Following the tiered EA approach, site-specific archaeological and historical resource surveys would be completed for the remaining portions of either alternative closer to their implementation date.
- Further consultation resulting in a Memorandum of Agreement would be completed between SHPO, NRCS, and the District for either alternative. The Memorandum of Agreement would address cultural resource concerns related to the entire proposed action and agree to appropriate mitigation measures for all features found to be eligible for inclusion on the National Register of Historic Places. Mitigation measures would be completed concurrently with or after construction. By incorporating these mitigation measures that have been accepted by SHPO, the mitigation efforts would successfully mitigate effects to cultural resources.
- An Inadvertent Discovery Plan would be followed if archaeological or historical materials, including human remains, were encountered during construction. The plan would require construction to stop accordingly, consultation with SHPO and NRCS cultural resources staff, and notification to appropriate Tribes. Continuation of construction would occur in accordance with applicable guidance and law.

6.2 Fish and Aquatic Resources

The areas of potential effect for fish and aquatic resources are discussed in Section 4.2.

6.2.1 No Action (Future without Project)

6.2.1.1 General Fish and Aquatic Species

The No Action Alternative would have no effect on fish and aquatic species in the project area and in the area of potential effect. The District would continue to divert water from Tumalo Creek and the Deschutes River for consumptive use at the current rate. The project area canals and laterals would continue to leak water. The same amount of water would continue to be stored in Crescent Lake and routed along Crescent Creek, the Little Deschutes River, and the Deschutes River to the BFC. The same amount of water would also be diverted from Tumalo Creek at the TFC diversion. The reduced flow in the area of potential effect would continue to reduce the potential fish habitat and compromise water quality for fish and aquatic species.

6.2.1.2 Federally Listed Fish and Aquatic Species

Oregon spotted frog, steelhead, and bull trout populations would continue to be managed by state and federal agencies in the No Action Alternative. Habitat would likely not change substantially from its current state.

6.2.2 Canal Lining Alternative

6.2.2.1 General Fish Species

The Canal Lining Alternative is expected to conserve approximately 43 cfs of water that would be partitioned between Crescent Lake (approximately 38 percent) during the non-irrigation season and Tumalo Creek (approximately 62 percent) during the irrigation season. These allocations by source and by season are estimates based on conserved water applications associated with similar projects completed in TID that have already completed the State of Oregon's administrative process for the allocation of conserved water (see OAR 690-018).

The conserved water allocations between Crescent and Tumalo Creeks may change following a thorough review of the application by OWRD who may order a different allocation to avoid affecting other water users at either source.

See Sections 4.10.2 and 6.10.3 for detailed discussion about conserved water and allocation.

As a result of the Canal Lining Alternative, the protection of conserved water below Crescent Creek Dam during the non-irrigation season may affect the affected river reaches differently depending on average instream flow. In the following reaches, the conserved water protected instream would have minor, long-term effects on fish species:

- Crescent Creek: Crescent Lake Dam (RM 30) to mouth (RM 0)
- Little Deschutes River: Crescent Creek (RM 57) to the mouth (RM 0)
- Upper Deschutes River: Little Deschutes River (RM 192.5) to the BFC diversion at Steidl Dam (RM 166)

Because conserved water from Crescent Lake Dam released into this reach would legally and permanently protect instream flow that was previously voluntarily protected by the District (see Section 4.10.2.2 for discussion about the 2016 Stipulated Settlement Agreement and continued compliance with the 2017 BiOp [Reclamation 2017]), the habitat available to fish is expected to remain. The passing of protected, conserved water from the upper Deschutes into the middle Deschutes below Steidl Dam to Lake Billy Chinook (RM 120), however, would have negligible effects on fish species because instream flow during the non-irrigation season is already above restorative targets set by ODFW (see Section 4.10.2.6).

In Tumalo Creek (TFC diversion [RM 2.5] to the mouth [RM 0]), conserved water would be allocated during the irrigation season. At this time, the District already commits 10 to 12 cfs of water below the TFC diversion to operate its fish screen and passage structures. In addition to this water, the Canal Lining Alternative would add and protect approximately 27 cfs. This action would have moderate, long-term effects on fish species because enhanced streamflows would increase the amount of habitat available to fish species in this reach, especially during the summer months when streamflows are low.

The Canal Lining Alternative would also have minor, long-term effects on fish species in the middle Deschutes River from the confluence with Tumalo Creek (RM 160) to Lake Billy Chinook (RM 120). The enhanced streamflows would increase the amount of habitat available to fish species in this reach, especially during the irrigation season when streamflows are low and when the ODFW restorative instream water target is rarely met (see Sections 4.10.2.6 and 6.10.2.2).

6.2.2.2 General Aquatic Species

Lining the canals and laterals with concrete would remove the limited amount of habitat available for bullfrog, western toad, Pacific treefrog, and long-toed salamander available in canals and laterals.

The habitat that would be lost is not considered critical to the long-term survival of these species (S. Wray, personal communication, November 17, 2017).

The Canal Lining Alternative would have minor, long-term effects on aquatic species on the following reaches because legally protecting the instream flow provided by the 2016 Stipulated Settlement Agreement and continued with the 2017 BiOp (Section 4.10.2.2) during the non-irrigation season would ensure that habitat available for aquatic species would remain:

- Crescent Creek: Crescent Lake Dam (RM 30) to mouth (RM 0)
- Little Deschutes River: Crescent Creek (RM 57) to the mouth (RM 0)
- Upper Deschutes River: Little Deschutes River (RM 192.5) to the BFC diversion at Steidl Dam (RM 166)

Increased streamflows in the following reaches during the irrigation season would result in minor, long-term effects on aquatic species because habitat available for species would be enhanced:

- Tumalo Creek: TFC diversion (RM 2.5) to the mouth (RM 0)
- Middle Deschutes: confluence of Tumalo Creek (RM 160) to Lake Billy Chinook (RM 120)

6.2.2.3 Federally Listed Fish and Aquatic Species

The Canal Lining Alternative may have minor, beneficial effects to federally listed fish and aquatic species. Within the affected project area, the federally listed Oregon spotted frog occurs in Crescent Creek, Little Deschutes River, and upper Deschutes River. Conserved water released from Crescent Lake Dam as a result of the Canal Lining Alternative would provide legal protections for water that has been released by the District since 2016 due to an interim agreement (see Section 4.10.2.2). This protective action would ensure the long-term benefit of Oregon spotted frog and their critical habitat (see Appendix E.9 for a letter of concurrence from USFWS). All PCEs of the Oregon spotted frog critical habitat would benefit from the Canal Lining Alternative (see Appendix E, Table E-2 of this Plan-EA). This action is consistent with the recommendations of USFWS Oregon Spotted Frog Biological Opinion (Reclamation 2017, pp. 128, 129, and 160).

The Middle Columbia River steelhead population can potentially access the Deschutes River as far upstream as Big Falls (RM 132, Section 4.2.1). Due to the magnitude of increased flow in this reach, as a result of the Canal Lining Alternative, there would be no effect on this population.

Increased instream flow during the irrigation season, as a result of the Canal Lining Alternative, would not affect bull trout in the middle Deschutes River. Bull trout forage in the middle Deschutes River upstream as far as Big Falls (roughly 30 miles downstream of Bend) during the winter, and are believed to be absent from that river reach the rest of the year. Therefore, because of the timing and magnitude of this increased flow during the irrigation season summer months, there would be no effect on bull trout populations.

6.2.3 HDPE Piping Alternative

6.2.3.1 General Fish Species

The HDPE Piping Alternative would have no direct effects on fish species in the project area. Although the HDPE Piping Alternative is expected to conserve 48 cfs rather than 43 cfs as described in the Canal Lining Alternative, the indirect effects on fish species within the area of potential effect would be qualitatively the same as those effects described above.

As in the Canal Lining Alternative, conserved water generated by the HDPE Piping Alternative would be allocated between Crescent Lake (approximately 38 percent) during the non-irrigation season and Tumalo Creek (approximately 62 percent) during the irrigation season. See Section 4.10.2 and 6.10.3 for detailed discussion about conserved water and allocation.

6.2.3.2 General Aquatic Species

The HDPE Piping Alternative would result in minor, direct effects on aquatic species. Replacing the canals and laterals with pipe would remove the limited amount of habitat available for bullfrog, western toad, Pacific treefrog, and long-toed salamander in the canals and laterals. The habitat that would be lost is not considered critical to the long-term survival of these species (S. Wray, personal communication, November 17, 2017).

The HDPE Piping Alternative would have minor, long term-effects on aquatic species in reaches affected by the project. The effects would be the same as described in the Canal Lining Alternative.

6.2.3.3 Federally Listed Fish and Aquatic Species

The HDPE Piping Alternative may have minor, beneficial effects to federally listed fish and aquatic species. The effects on the Oregon spotted frog, bull trout, and steelhead would be the same as described in the Canal Lining Alternative.

6.2.4 Compliance and Best Management Practices

The ESA establishes a national program for the conservation of threatened and endangered species, and the preservation of the ecosystems on which they depend. The ESA is administered by the USFWS for wildlife and freshwater species and by NMFS for marine and anadromous species. The ESA defines procedures for listing species, designating critical habitat for listed species, and preparing recovery plans. It also specifies prohibited actions and exceptions. Section 7 of the ESA, called "Interagency Cooperation," is the mechanism by which federal agencies ensure the actions they take, including those they fund or authorize, do not jeopardize the existence of any listed species. Under Section 7 of the ESA, federal agencies must consult with USFWS when any action the agency carries out, funds, or authorizes (such as through a permit) may affect a listed endangered or threatened species.

Implementation of the HDPE Piping Alternative or the Canal Lining Alternative may have minor, long-term effects on federally listed species. Section 7 consultation under the ESA with USFWS is complete (see Appendix E.9 for a letter of concurrence from USFWS).

Although the Middle Columbia River steelhead population is potentially present in the Deschutes River as far upstream as Big Falls (RM 132), this populations is classified as a NEP under section 10(j) of ESA (76 *Federal Register* 28715, 2011). Because the NEP is located outside a National Wildlife Refuge or National Park, and because implementation of the HDPE Piping Alternative or the Canal Lining Alternative is an entirely beneficial action, not likely to jeopardize the continued existence of the species, consultation with NMFS is not necessary (76 *Federal Register* 28715, 2011; 81 *Federal Register* 33416, 2016).

6.3 Geology and Soils

The area of potential effect for geology and soils is discussed in Section 4.3.

6.3.1 No Action (Future without Project)

Under the No Action Alternative, continued operation of the canal system would have minor effects on erosion and soils. Ongoing erosion of canals and laterals, as well as any erosion that might be occurring on farms that use flood irrigation, would persist.

6.3.2 Canal Lining Alternative

6.3.2.1 Geology

Protection of unique geological features and the siting of project components in relation to potential geologic hazards are considered when evaluating potential effects of the Canal Lining Alternative on geological resources. The implementation of the Canal Lining Alternative would not alter underlying lithology or geologic formations in the area of potential effect; therefore, no effects to geological resources are expected to occur.

6.3.2.2 Soils

Construction of the Canal Lining Alternative would include grading the existing trench, as described in Section 5.3.2, and disturbance of soils adjacent to canals to anchor the geomembrane. The volume of soil disturbed would vary for each canal depending upon its size. Based on top width, canals were grouped into five different classes. Applying assumptions for the canal depth, channel steepness, and anchor berm dimensions (Swihart and Haynes 2002), the maximum volume of soil that would be disturbed under the Canal Lining Alternative was estimated to be 189,965 cubic yards (see Appendix E for detailed calculations). After construction, soil layers would be permanently disturbed. The hydric soils lining the canals were placed when the delivery system was originally built; therefore, this soil profile is not representative of pre-development conditions. The Canal Lining Alternative would not affect any soil profiles existing prior to the construction of the original delivery system.

Following construction, areas disturbed by construction would be covered by soil and replanted. Overall, minor, short-term effects on soil resources are anticipated because proposed soil stabilization measures would be in place and the effect occurs over a large contiguous area over time.

Farmland Classification

Under the Canal Lining Alternative, construction would result in the temporary disturbance of approximately 156 acres of the project area that are classified as prime farmlands if irrigated and/or farmlands of state importance. These lands are currently not being cultivated; therefore, no farmlands would be removed from production as a result of the Canal Lining Alternative.

No long-term effects would be expected to any federal or state-level farmland designations. Minor short-term effects on agriculturally important soils would be expected during construction, but adherence to best management practices (BMPs) would minimize these effects.

Erosion Susceptibility

Erosion resulting from precipitation events may occur in disturbed and cleared areas within the project area. The National Pollutant Discharge Elimination System program, implemented by ODEQ, would require a 1200-C General Construction Stormwater Permit (1200-C Permit) for construction activities including clearing, grading, excavation, materials or equipment staging and stockpiling that would disturb one or more acres of land and have the potential to discharge into a public waterbody. Since none of the areas within the project discharge to a public waterbody, a 1200-C Permit would not be required.

Construction BMPs would be implemented to minimize soil erosion; therefore, no effects on soils would be anticipated. BMPs could include installing silt fencing, straw wattles, or geotextile filters; applying water to disturbed soil to prevent wind erosion; and revegetating disturbed areas as soon as possible after disturbance, as appropriate.

Vegetation clearing, soil disturbances, and grading that would be completed during construction for the Canal Lining Alternative would have negligible and short-term effects on soils. BMPs would be implemented during construction to reduce these effects.

6.3.3 HDPE Piping Alternative

6.3.3.1 Geology

Protection of unique geological features and the siting of project components in relation to potential geologic hazards are considered when evaluating potential effects of the HDPE Piping Alternative on geological resources. The implementation of the HDPE Piping Alternative would not alter underlying lithology or geologic formations in the area of potential effect; therefore, no effects to geological resources are expected to occur.

6.3.3.2 Soils

Construction activities would include excavation of existing soils, placement of the pipe, and burial of the pipe with the excavated soil material. The volume of soil disturbed would vary for each canal and lateral, depending on its width, its depth, and the diameter of the proposed pipe that would be installed. Using the designed pipe diameters that were determined in the SIP and applying general assumptions for the depth and width of excavation that would be required, the maximum volume of soil that would be disturbed under the HDPE Piping Alternative was estimated to be 174,028 cubic yards (see Appendix E for detailed calculations).

The hydric soils lining the canals were placed when the delivery system was originally built; therefore, this soil profile is not representative of pre-development conditions. The HDPE Piping Alternative would not affect any soil profiles existing prior to the construction of the original delivery system. After construction, soil layers would be permanently disturbed and the pipe would be permanently buried in the path of the pipeline. Areas disturbed by construction would be covered by soil and replanted. Overall, minor, short-term effects on soil resources are anticipated because proposed soil stabilization measures would be in place and the effect occurs over a large contiguous area over time.

Farmland Classification

Under the HDPE Piping Alternative, the installation of buried pipelines would result in the temporary disturbance of approximately 156 acres of the project area that are classified as prime farmlands if irrigated and farmlands of state importance. These lands are currently not being cultivated; therefore, no farmlands would be removed from production as a result of the HDPE Piping Alternative.

TID's open delivery system would be converted to a gravity-pressurized system. Increased system efficiencies may increase crop production, which is particularly important in the 43 percent of District land that is classified as prime farmland if irrigated. In addition, piping the canal and laterals prevents sediment and other contaminants, such as herbicides and pesticides, from entering the water supply for TID's patrons. As a result, soil quality could improve with reduced pollutants in the irrigation water.

No long-term effect would be expected to any federal or state-level farmland designations. Minor, short-term effects on agriculturally important soils would be expected during construction, but adherence to BMPs would minimize these effects. There would be a minor, long-term effect on farmlands due to improved irrigation water quantity.

Erosion Susceptibility

Compliance measures that would be implemented during construction of the HDPE Piping Alternative to reduce effects on soils are described as follows. Erosion resulting from precipitation events may occur in disturbed and cleared areas within the project area. The National Pollutant Discharge Elimination System program, implemented by ODEQ, would require a 1200-C General Construction Stormwater Permit (1200-C Permit) for construction activities such as clearing, grading, excavation, materials or equipment staging and stockpiling that would disturb one or more acres of land and have the potential to discharge into a public waterbody. All of the seven project groups of the HDPE Piping Alternative would disturb at least 5 acres, but none of the project groups discharges to a public waterbody; therefore, a 1200-C Permit would not be required.

During construction, existing maintenance roads would provide access to most of the project area. Given that the pipe segments would be installed in 50- or 100-foot lengths, the District may use temporary travel routes within its existing ROW. The use of temporary travel routes would result in soil compaction and temporary increases in construction-related erosion and stormwater runoff. However, these effects would be largely mitigated by the implementation of erosion control measures. Proper design of the temporary travel routes, the implementation of adequate controls for any stormwater runoff, and other BMPs would reduce erosion and potential effects on soils.

Construction BMPs would be implemented to minimize soil erosion; therefore, no effects on soils would be anticipated. BMPs could include installing silt fencing, straw wattles, or geotextile filters; applying water to disturbed soil to prevent wind erosion; and revegetating disturbed areas as soon as possible after disturbance, as appropriate.

Vegetation clearing, soil disturbances, and grading that would be completed during construction for the HDPE Piping Alternative would have negligible and short-term effects on soils. BMPs would be implemented during construction to reduce these effects. Soil erosion over the long-term would be greatly reduced where buried pipeline would replace open canals. Reduced on-farm soil erosion and reduced deep percolation losses could also occur depending on management decisions.

6.3.4 Compliance and Best Management Practices

The following BMPs would be implemented as part of both the Canal Lining Alternative and the HDPE Piping Alternative (unless stated otherwise) to reduce effects on soils:

- Ground disturbances would be limited to only those areas necessary to safely implement both the Canal Lining Alternative and the HDPE Piping Alternative.
- Work would be confined within the existing ROW whenever possible to preserve existing vegetation and private property. The ROW would be clearly marked in the field prior to construction.
- Construction limits would be clearly flagged onsite to avoid unnecessary plant loss or ground disturbance.
- Work crews would carry spill cleanup kits, and, in times of burn bans or wildfire concerns, each crew would have a fire suppression kit.
- Project construction activities would be conducted in accordance with the project’s spill prevention and cleanup plan.

6.4 Land Use

The area of potential effect and project area for land use is discussed in Section 4.4.

6.4.1 No Action (Future without Project)

Under the No Action Alternative, irrigated agriculture producers would continue to face increasing water supply uncertainty. Water supplies would continue to be unreliable, and agriculture producers would likely continue to irrigate fewer acres of land or grow different crops. Compounded with anticipated population increases and associated developmental pressures, agricultural lands would continue to be increasingly vulnerable to transitioning to a different land use.

The No Action Alternative would not have a direct effect on land use within the ROW. The District's canals and laterals would continue to operate as an open system.

6.4.2 Canal Lining Alternative

6.4.2.1 Agricultural Land Use

There would be no direct effect on agricultural use during or after construction of the Canal Lining Alternative. Increased water delivery reliability and improved control over water delivery would have long-term indirect effects on agricultural land use because water uncertainty would be reduced for farmers. Water supply uncertainty and ongoing drought can limit the type of crops grown as farmers choose drought resistant species or convert more-water-intensive crops to less-water-intensive crops.

Increasing water delivery reliability could decrease the developmental pressures to convert agricultural land (that was not being planted or producing low yields due to water scarcity) to other uses. This alternative would support current zoning designations and state land use goals (discussed below in the HDPE Piping Alternative).

6.4.2.2 ROW Land Use

There would be no effect on TID's ROW; it would continue to be used for the conveyance of irrigation water and O&M. There would be no changes in property ownership. During O&M of the system, the District's ditch walkers would continue to be present in the ROW to ensure there are no blockages or other issues. Over the 100-year analysis of the project, the ROW would see increased levels of human traffic and disturbance every 40 years when the canal lining would be replaced. District staff and ditch riders would continue to be present in the ROW, with the potential of becoming increasingly present as the system ages and requires more maintenance.

The District's ROW that passes through the Peck's milkvetch ACEC was granted through the Carey Act, which predates BLM management of the land. The BLM has been consulted regarding the proposed project (see Section 7 of the Plan-EA).

6.4.3 HDPE Piping Alternative

6.4.3.1 Agricultural Land Use

There would be no direct effect to agricultural use during or after construction of the alternative. Construction would not cause any interruption to water deliveries or long-term change in the agricultural land use. Increased water delivery reliability would have long-term indirect effects on agricultural land use, as it would reduce water uncertainty for farmers. Water supply uncertainty and ongoing drought can limit the type of crops grown as farmers choose drought resistant species or convert more water intensive crops to less water intensive crops. Implementation of the HDPE Piping Alternative would allow for more diversity in the types of crops grown in the District because of water supply security.

Reducing pumping costs and increasing the reliability of water delivery could decrease pressure to convert agricultural land to other uses. This alternative would support current zoning designations and State land use goals because the resulting certainty of agricultural water would assure that the minimum irrigated acre requirements for parcels within EFU subzones would be met. Implementation of the HDPE Piping Alternative would also similarly promote Statewide Planning Goal 3: to maintain agricultural lands (Oregon Department of Land Conservation and Development 2010). Increased water supply security would allow irrigated farmland to be protected and not have to be removed from production due to water scarcity.

6.4.3.2 ROW Land Use

Effects to ROW land use under the HDPE Piping Alternative are similar to those discussed under the Canal Lining Alternative except for the level of human traffic. During O&M of the system, there would be a decrease in the presence of District staff in the ROW, as they no longer need to patrol the open canals or laterals. The HDPE Piping Alternative would only require construction once (at the beginning) of the 100-year period of analysis. There would be no subsequent construction and related increases in human traffic.

6.4.4 Compliance and Best Management Practices

The following BMPs would be implemented as part of both the Canal Lining Alternative and HDPE Piping Alternative (unless otherwise indicated) to reduce effects on land use:

- Standard construction safety procedures and traffic control measures would be employed to reduce the risk of collisions between construction vehicles and other vehicles, pedestrians, or bicyclists while construction is ongoing.
- Traffic control measures would be coordinated by the construction contractor with the Oregon Department of Transportation, the Deschutes County Sheriff, and local emergency services before working in the U.S. Highway 20 ROW.
- Lane closures on roadways would be avoided during peak travel periods where possible to reduce potential traffic delays from construction vehicles.
- The condition of roadways and work zones would be communicated to travelers via the District's website or other communication channels.
- Adjacent landowners would be provided a construction schedule prior to beginning construction.

6.5 Public Safety

The area of potential effect for public safety is discussed in Section 4.5.

6.5.1 No Action (Future without Project)

The District would not pipe the remaining canal and laterals with funding from PL 83-566. Under the No Action Alternative, the canals and laterals would remain open. The No Action Alternative would provide no immediate or foreseeable changes to the current delivery infrastructure. The risk of drowning could increase as urban and suburban areas grow and surround more of the District.

6.5.2 Canal Lining Alternative

The Canal Lining Alternative would install fencing along dangerous sections or areas that are easily accessible by public in order to increase public safety and reduce District liability. These fences would be chosen to prevent the public from nearing the edge or entering the canal and would be a standard chain link with 3-wire barbed wire cap per NRCS guidelines. In canals with depths greater than 2 feet, safety ladders would be installed every 750 feet.

The risk of drowning would be reduced but not eliminated. If someone were to fall into the lined canal, escape would be more difficult than in an unlined canal due to increased water velocity and the removal of all adjacent vegetation. This alternative would have minor, long-term effects on public safety.

6.5.3 HDPE Piping Alternative

The HDPE Piping Alternative would eliminate the drowning risk from open canals. This would result in minor, long-term effects on public safety since the possibility of a more serious accident would be eliminated. While not identified as a resource concern, the HDPE Piping Alternative would also eliminate any potential flooding risk from canal overflow, and the durability of the HDPE pipe would increase seismic resiliency.

6.5.4 Compliance and Best Management Practices

The following BMPs would be implemented as part of both the Canal Lining Alternative and the HDPE Piping Alternative to reduce effects to public safety:

- Roadway lane closures would be avoided during peak travel periods where possible to reduce potential traffic and pedestrian safety issues.
- Ground disturbances would be limited to only those areas necessary to safely implement the action.
- Work would be confined within the existing ROW whenever possible to preserve existing vegetation and private property. The ROW would be clearly marked in the field prior to construction.
- Work crews would carry spill cleanup kits, and in times of burn bans or wildfire concerns, each crew would have a fire suppression kit.

The following BMPs would only be implemented as part of the Canal Lining Alternative to reduce effects to public safety:

- A standard chain link fence with 3-wire barbed wire cap would be chosen per NRCS guidelines.

- Safety ladders would be installed every 750 feet in canals with depths greater than 2 feet.

6.6 Recreation Resources

The area of potential effect for recreation resources is discussed in Section 4.6.

6.6.1 No Action (Future without Project)

The No Action Alternative would have no effect on recreation resources in the area of potential effect.

6.6.2 Canal Lining Alternative

Construction of the Canal Lining Alternative would have minor, short-term effects for trail, bikeway, and Tillicum Park recreational users because of reroutes or delays during construction. Visitors would still be able to use the park during construction; however, their experience could be affected by visible construction activities and localized noise disruption. These effects would be minor and short-term because construction would occur over a discrete period.

Over the 100-year lifespan of the project these construction effects would occur every 40 years during replacement and repair of the lining. After construction there would be long-term, moderate effects to recreation, as newly installed fencing along canals and laterals would prevent the informal use of ROW for activities such as hiking and biking.

During construction, recreational activities along and on the river would not be affected. After construction, river activities, including recreational fishing, would be indirectly affected by an increase in streamflows from the allocation of conserved water. Overall, there would be a negligible, long-term effect to recreational resources because effects would be localized in scope and would not alter any existing recreational uses.

6.6.3 HDPE Piping Alternative

Construction of the HDPE Piping Alternative would have similar minor, short-term effects on trail, bikeway, and Tillicum Park recreational users as the Canal Lining Alternative. There would be no loss of user days during the construction period. Effects due to construction would only occur once during the 100-year period of analysis for each individual Project Group.

In the long-term, recreational use of Tillicum Park and the informal recreational use of the ROW for walking would not change; however, recreationists would have views of a vegetated corridor rather than either open water or an empty canal, depending on the season. This effect is considered in the NED but does not have a monetized value.

Effects to river recreation are the same as those under the Canal Lining Alternative, discussed above. Overall, there would be a negligible, long-term effect to recreational resources because effects would be localized in scope and would not alter any existing recreational uses.

6.6.4 Compliance and Best Management Practices

The following BMPs would be implemented as part of both the Canal Lining Alternative and the HDPE Piping Alternative (unless otherwise indicated) to reduce effects on recreation resources:

- Roadway lane closures would be avoided during peak travel periods where possible to reduce potential traffic delays from construction vehicles.
- The condition of roadways, work zones, and maintenance roads would be communicated to travelers via the District's website, or other communication channels.
- Standard construction safety procedures and traffic control measures would be employed to reduce the risk of collisions between construction vehicles and other vehicles, pedestrians, or bicyclists while construction is ongoing.

6.7 Socioeconomic Resources

The area of potential effect for socioeconomics is discussed in Section 4.7. To estimate the total economic impacts of the three alternatives, in terms of jobs and income supported, this analysis uses a 2015 IMPLAN economic impact model of Deschutes County.

6.7.1 No Action (Future without Project)

For the No Action Alternative, the total economic activity supported by TID agricultural production is estimated at approximately 120 jobs and $3.6 million in average annualized income. Approximately 100 of those jobs would be in agriculture with an additional 20 jobs in other economic sectors. Approximately $1.9 million would be agricultural income and an additional $1.7 million would be income in other sectors benefiting from agricultural expenditures and income.

6.7.2 Canal Lining Alternative

Implementation of the Canal Lining Alternative would have a minor, short-term effect on employment and income in Deschutes County from construction activities.

6.7.2.1 Regional Economic Development

The Canal Lining Alternative construction expenditures of approximately $85.6 million (incurred every 40 years) would support construction sector jobs and income. These expenditures would also provide economic ripple effects that increase jobs and income in other economic sectors in Deschutes County. Economic ripple effects would result from the construction sector spending on labor, materials, and services. This spending would spur increased sales and economic activity in other sectors (such as hardware stores and construction equipment businesses supplying construction businesses). Impacts of construction sector spending in these other sectors are known as indirect impacts. As household incomes rise from the construction and the indirectly impacted economic sectors, household spending would also increase and generate increased economic activity in sectors such as retail, wholesale trade, personal services industries, and real estate (known as induced impacts). Total job and income impacts of the economic activity supported by the proposed project are the sum of the direct impacts (construction sector) and the indirect/induced impacts (in other economic sectors).

The $85.6 million in construction expenditure is spread over 11 years, supporting approximately 100 jobs annually and $4.5 million in average annual income (annualized over 111 years[11] this equates to approximately $1.8 million in annualized average income benefits). Of these impacts, during the 11-year construction period, approximately 60 jobs and $3.2 million in annual average income are in the construction sector (direct impacts), while the remaining 40 jobs and $1.3 million in annual income are in other sectors.

After construction is complete, the Canal Lining Alternative would result in minimal changes in basin pumping costs and increased District OM&R costs (approximately $60,000 per year). As discussed above, changes in OM&R may have minimal regional economic development effects (i.e., changes in OM&R expenditures may largely result in an income transfer between TID patrons, TID staff, and the local construction/repair sector), so effects of this change in expenditure are not quantified in this regional economic development analysis.

No changes to agricultural production are expected in the Canal Lining Alternative. To the extent that increased streamflows enhance recreation and support additional recreation visitation and spending in Deschutes County, the long-term regional economic impact would be much larger.

6.7.2.2 National Economic Development Benefits

A National Economic Development (NED) benefit cost analysis has been performed to evaluate the benefits of the Canal Lining Alternative (see Appendix D). This evaluation includes identification of the No Action Alternative economic damages, and estimation of the NED benefits of the alternatives to the identified problems. The analysis uses NRCS guidelines for the evaluation of NED benefits as outlined in the Economic and Environmental Principles and Guidelines for Water Related Land Resources Implementation Studies, and NRCS Natural Resources Economics Handbook.

6.7.3 HDPE Piping Alternative

Implementation of the HDPE Piping Alternative would have a minor, short-term effect on employment and income in Deschutes County from construction activities, and a moderate, long-term effect on agricultural production and related farm household income in the County.

6.7.3.1 Regional Economic Development

The HDPE Piping Alternative construction expenditures of nearly $43.3 million would support construction sector jobs and income. These changes would also provide economic ripple effects that increase jobs and income in other economic sectors in Deschutes County (these effects are described in the Canal Lining Alternative).

[11] Note that each project has a 100-year life but that since construction takes 11 years, benefits extend out to year 110 and therefore, the analysis period for all project groups is 111 years.

The $43.3 million in construction expenditure is spread over 11 years, supporting approximately 50 jobs annually and $2.3 million in average annual income (annualized over 111 years this equates to approximately $0.6 million in annualized average income benefits). Of these impacts, approximately 30 jobs and $1.6 million in annual income would be in the construction sector (direct impacts), while the remaining 20 jobs and $0.7 million in annual income would be in other sectors.

The HDPE Pressurized Piping Alternative may also result in increased farm productivity (increased yields), but these effects are not quantified due to limited data. The HDPE Pressurized Piping Alternative would also result in slightly lower OM&R expenses for TID. However, the effects on District wages and employment are expected to be minimal. Reduced OM&R and pumping costs may largely result in an income transfer between TID patrons, TID staff, and the local construction, repair, and electricity sectors. As such, regional economic development effects are expected to be limited for this reduced expenditure (i.e., less than the rounding margin of error) so effects are not quantified in this regional economic development analysis. To the extent that increased streamflows enhance recreation and support additional recreation visitation and spending in Deschutes County, the long-term regional economic impact would be much larger.

6.7.3.2 National Economic Development Benefits

A NED benefit cost analysis has been performed to evaluate the benefits of the HDPE Piping Alternative (see Appendix D). This process is described in the Canal Lining Alternative.

6.8 Vegetation

The area of potential effect for vegetation is discussed in Section 4.8.

6.8.1 No Action (Future without Project)

Under the No Action Alternative, vegetation associated with the network of open irrigation canals and laterals would persist, and adjacent native upland vegetation would remain in its current condition.

6.8.2 Canal Lining Alternative

6.8.2.1 General Vegetation

Construction of the Canal Lining Alternative would involve grading the existing trench to the specifications described in Section 5.3.2, disturbance of lands adjacent to canals for construction equipment access and anchoring of the geomembrane, and use of the existing ROW for movement and staging of construction equipment and materials. During construction, herbaceous, shrub, and woody vegetation along the canals and laterals within the ROW would be temporarily disturbed through activities such as clearing, crushing, and digging. It is expected that all access would be possible with existing maintenance roads.

Construction activities would temporarily disturb approximately 150 acres of existing vegetation within the 27,964-acre District boundary. Potential vegetation disturbance along canals and laterals is described in Table 6-1 and Table 6-2. Opportunistic riparian vegetation that is located along canals and laterals would be permanently removed (see Section 6.11.2.2 for further discussion).

Table 6-1. Potential Vegetation Disturbance along Canals and Laterals under the Canal Lining Alternative.

System Element	Proposed Lining (feet)	Total Width of Disturbance Adjacent to the System (feet)	Additional Width of Disturbance on Side of Canal/Lateral Maintenance Road (feet)	Total Disturbed Vegetation Area (acres)
Canals	12,715	14	15	9
Laterals	331,167	10	8	140
			Total	**149**

Table 6-2. Potential Vegetation Disturbance along Turnouts under the Canal Lining Alternative.

System Element	Units	Disturbance Width (feet)	Disturbance Length (feet)	Total Disturbed Vegetation Area (acres)
Turnouts	490	10	10	1

After construction, areas disturbed by construction and areas where the geomembrane has been anchored and covered by soil would be replanted with native grasses and forbs with NRCS's guidance. Some trees that are dependent upon the canal for seepage may not survive the construction of this Alternative.

Over the project's life, vegetation within the ROW would be maintained according to TID's vegetation management program and NRCS Oregon and Washington Guide for Conservation Seedings and Plantings (NRCS 2000). Trees would not be allowed to establish above the areas where the geomembrane is anchored. After 40 years, the expected lifespan of the canal lining, vegetation would be disturbed again during the replacement process. Similar short-term construction effects would be expected.

Implementation of the Canal Lining Alternative would have a minor, long-term effect on vegetation because disturbance occurs over less than one percent of the District and measures designed to minimize effects on vegetation, such as clearly flagging construction areas, would be implemented (additional measures are identified in Sections 6.8.4 and 8.4).

6.8.2.2 Invasive Species - Noxious Weeds

During construction, exposed soils would create temporarily susceptible areas where weeds could establish themselves. The movement of construction vehicles could provide opportunities to transport weeds to new locations. During construction, the contractor would utilize BMPs such as avoiding unnecessary ground disturbances and using erosion control measures that are free of weeds and weed seeds.

After construction, weeds would be managed according to the protocol in NRCS Oregon and Washington Guide for Conservation Seedings and Plantings (NRCS 2000). Weeds would be controlled within the ROW using hand pulling during the first year after reseeding and a combination of hand pulling and herbicide application in the second year if weeds become problematic. Implementation of the Canal Lining Alternative would have a negligible effect on noxious weeds because the spread of noxious weeds during construction would be controlled through BMPs.

6.8.2.3 Special Status Species

Currently no special status species occur within the project area; therefore, no effects are expected. Prior to beginning construction within the ROW that crosses the Peck's milkvetch ACEC, a pre-construction survey for Peck's milkvetch would be completed and any subsequent action or mitigation necessary would occur in consultation with BLM. Additional mitigation within the Peck's milkvetch ACEC to minimize project effects would include potting, care, and replanting during the appropriate planting window for individual plants that would have been directly affected by the project.

While there is potential for the species to be present, there have been no observations by the District of Peck's milkvetch in their ROW. Implementation of the Canal Lining Alternative would result in potentially more O&M of the system, and therefore higher disturbance in the ROW. Any potential plants that may occur in the future are anticipated to be limited in number and potential project effects would not affect the ecological integrity of the population. As such, a negligible, long-term effect would be expected.

6.8.3 HDPE Piping Alternative

6.8.3.1 General Vegetation

Construction of the HDPE Piping Alternative would involve trenching for pipe placement primarily in existing canals, disturbance of lands adjacent to canals for construction equipment access, and use of the existing ROW for movement and staging of construction equipment and materials. Figure 6-1 shows vegetation along the TFC during the irrigation season, before a previous piping project.

Source: Deschutes River Conservancy 2012

Figure 6-1. The Tumalo Feed Canal before a Previous Piping Project.

During construction, existing maintenance roads within the ROW would provide access to most of the project area. Figure 6-2 is illustrative of typical construction activities associated with replacing open irrigation canals with pipeline. Given that the pipe segments would be installed in 50- or 100-foot lengths, some temporary travel routes within the ROW would be necessary along canals and laterals that are not accessible by existing roads.

Figure 6-2. An Example of Construction on a Tumalo Irrigation District Lateral using an Existing Maintenance Road.

Temporary travel routes would be selected to minimize effects on vegetation and avoid tree removal. Selection of construction areas adjacent to canals and travel routes would consider existing vegetation and avoid mature trees to the extent practicable. Pruning would occur entirely within TID's Carey Act ROW and would not exceed what is required for equipment clearance.

During construction, herbaceous, shrub, and woody vegetation along the canals, laterals, turnouts, and within the ROW would be temporarily disturbed through activities such as clearing, crushing, and digging. These activities would temporarily disturb approximately 161 acres of existing vegetation within the 27,964-acre District boundary. Potential vegetation disturbance along canals and laterals is described in Table 6-3 and Table 6-4. Opportunistic riparian vegetation that is located along canals and laterals would be permanently removed (see Section 6.11 for further discussion).

Table 6-3. Potential Vegetation Disturbance along Canals and Laterals under the HDPE Piping Alternative.

System Element	Proposed Piping (feet)	Total Width of Disturbance Adjacent to the System (feet)	Additional Width of Disturbance Adjacent to Maintenance Roads (feet)	Subtotal Disturbed Vegetation Area (acres)
Canals	9,852	16	15	7
Laterals	353,293	10	8	149
			Total	**156**

Table 6-4. Potential Turnout Vegetation Disturbance under the HDPE Piping Alternative.

System Element	Units	Disturbance Width (feet)	Disturbance Length (feet)	Total Disturbed Vegetation Area (acres)
Turnouts	663	10	30	5

After construction, the project alignment would be re-contoured and planted with a seed mix of native grasses and forbs. Planting would be done in consultation with NRCS. Vegetation within the ROW would return to the historic upland habitat. Figure 6-3, Figure 6-4, and Figure 6-5 show examples of vegetation along the BFC and TFC post-installation for similar piping projects. Some trees that are dependent upon the canal for water may not survive the construction of the HDPE Piping Alternative. Prior experience with piping in TID has shown that with active irrigation by the property owner, 70 to 80 percent of the well-established trees within the project area would survive after piping (20 to 30 percent of the trees that do not normally survive in such a location without the canal did not survive after piping). The District would remove trees in the ROW that do not survive piping for the two years following construction at adjacent landowners' requests and during maintenance season.

In the long-term, at least 41 acres of vegetation would be gained because open canals and laterals would be piped and then covered with topsoil and seeded. Over the project's life, vegetation within the ROW would be maintained according to TID's vegetation management program and NRCS Oregon and Washington Guide for Conservation Seedings and Plantings (NRCS 2000). Trees would not be allowed to establish above the buried pipe because roots may interfere with future maintenance.

Implementation of the HDPE Piping Alternative would have a minor, long-term effect on vegetation because disturbances occurs over less than one percent of the District, and mitigation measures designed to minimize effects to vegetation, such as re-vegetating with native grasses and forbs in consultation with NRCS, would be implemented (other measures are identified in Sections 6.8.4 and 8.4). Additionally, the conversion of open canals to buried pipes with new vegetation seeded on top would add 41 acres of native vegetation to the project area.

Figure 6-3. A Section of the Bend Feed Canal after a Piping Project.

Source: Reclamation 2010.

Figure 6-4. A Section of the Bend Feed Canal Approximately Four Months after a Piping Project.

Source: Deschutes River Conservancy 2013

Figure 6-5. A Section of the Tumalo Feed Canal after a Piping Project.

6.8.3.2 Invasive Species - Noxious Weeds

Construction activities and temporary effects would be similar to those described under the Canal Lining Alternative, as would post construction weed management. After construction, the closed system no longer presents opportunities for aquatic noxious weeds to grow or spread to other areas of the District.

Implementation of the HDPE Piping Alternative would have a minor, long-term effect on noxious weeds. The spread of noxious weeds during construction would be controlled through BMPs, and the conversion to a piped system would reduce the spread of noxious weeds through the open canal system.

6.8.3.3 Special Status Species

Construction activities and effects on Special Status Species are the same as those discussed above for the Canal Lining Alternative. However, implementation of the HDPE Piping Alternative would result in less O&M of the system, and therefore less disturbance of the ROW in the BLM Peck's milkvetch ACEC.

6.8.4 Compliance and Best Management Practices

To reduce the disruption to existing vegetation and minimize the spread of noxious weeds as a result of the construction of either the Canal Lining or HDPE Piping Alternative, the following BMPs that have been utilized and successful in previous piping projects would be implemented (applicable to both alternatives unless identified otherwise):

- Prior to construction that crosses the Peck's milkvetch ACEC, a survey would be completed for Peck's milkvetch. If plants were detected, individual plants affected by construction would be excavated, potted, cared for, and replanted during the appropriate planting window. Surveys and mitigation would be done in consultation with BLM.
- Construction limits would be clearly flagged onsite to avoid unnecessary plant loss or ground disturbance.
- Ground disturbances would be limited to only those areas necessary to safely implement either alternative.
- Work would be confined within the existing ROW whenever possible to preserve existing vegetation and private property. The ROW would be clearly marked in the field prior to construction.
- Temporary travel routes for the HDPE Piping Alternative would be selected and utilized to minimize effects on vegetation and avoid the removal of trees.
- After construction, under the HDPE Piping Alternative, the project area would be re-contoured and planted with a seed mix of native grasses and forbs. Planting would be done in consultation with NRCS.
- After construction and re-seeding, vegetation within the ROW would be maintained according to TID's vegetation management program and NRCS Oregon and Washington's Guide for Conservation Seedings and Plantings (NRCS 2000).

6.9 Visual Resources

The area of potential effect for visual resources is defined in Section 4.9. Effects on visual resources occur when project activities visually standout from the existing landscape or introduce disruptive visual characteristics. The visibility of the activity or modification and the sensitivity of the viewer influence the magnitude of the effect. For example, there would be less effect from an action surrounded by thick vegetation or an action that blends into the landscape. This visual analysis was based on evaluations of aerial and ground-based photographs of the proposed project sites and preliminary design information.

Visual effects were assessed based on the potential of the proposed action to alter scenic resources or to degrade the visual character of the project area. The evaluation of temporary or short-term visual effects considered whether construction activities could substantially degrade the existing visual character or quality of the site or surrounding area. The evaluation also considered the duration over which any such changes would occur. Because of their short-term nature, construction activities occurring in an area for less than one year are typically considered to have a less-than-major effect on visual quality.

Actions with long-term visual effects, such as constructing new or altered structures, grading roads, removing trees, and introducing new sources of light and glare, can permanently alter the landscape in a manner that could affect the existing visual character or quality of the area, depending on the perspective of the viewer. Since damaging scenic resources such as trees, rock outcroppings, and other features typically constitute a long-term effect, the potential for project implementation to damage scenic resources was evaluated solely as a long-term effect and differentiated from construction-related effects.

6.9.1 No Action (Future without Project)

Under the No Action Alternative, TID would not modernize the remaining canals and laterals with funding from PL 83-566. The canals and laterals would remain open and unlined. There would be no changes to visual resources, and local residents and visitors would continue to see open canals and laterals as they now exist from public and private viewpoints. Open canals and laterals would hold water during the irrigation season from April through mid-October.

6.9.2 Canal Lining Alternative

Under the Canal Lining Alternative, construction activities, including use of heavy equipment within the ROW would be visible to residents, motorists, and recreationists in the area. Vegetation would be cleared within TID's ROW in some areas where access for construction equipment is necessary, and disturbance to existing mature trees would be minimized to the extent possible. During construction, there would be minor, short-term effects to visual resources because the construction activities would draw attention to the setting. However, similar large equipment is used for agricultural production and in the maintenance of canals and is therefore a common feature in the landscape. Construction would follow the BMPs listed below in Section 6.9.4 to minimize any visual disruptions.

Following construction, the impervious lining would eliminate water seepage along the canals and laterals, and as a result, vegetation species dependent on moist or saturated soils would not occur along the banks of the canals and laterals. Riparian vegetation would no longer be part of the viewshed. In addition, the Canal Lining Alternative would involve reshaping the canals and laterals into trapezoidal channels with sloping sides and a flat bottom. Depending on the specific materials and design used, shotcrete or other lining material may extend several feet above the water line or extend over the bank and be visible. These attributes could change viewers' experiences of the canals and laterals from a more stream-like to a more industrial appearance when the canals are full, or empty and snow-free. Additionally, chain link fence topped with barbed wire would be installed along the canals and laterals for public safety. These fences would stand out from the existing landscape features because of their height and they would disrupt a direct, unimpeded view of the canal.

After construction, disturbed areas including the banks of the lined canals and laterals would be planted with a seed mix of native grasses and forbs in consultation with NRCS. As these plantings mature, the lined canals and laterals would blend into the surrounding landscape. Trees that were not removed during construction would also be part of the vegetated corridor. The open, lined canal and laterals would continue to hold water during the irrigation season from April through mid-October.

Overall, the visual change from earthen, unlined canals to lined, trapezoidal canals with fencing is expected to have a moderate, long-term effect on visual resources.

6.9.3 HDPE Piping Alternative

Under the HDPE Piping Alternative, construction activities, including use of heavy equipment within the ROW and pipe laying, would be visible to residents, motorists, and recreationists in the area. Vegetation would be cleared within TID's ROW in some areas where pipe is laid or access for construction equipment is necessary and disturbance to existing mature trees would be minimized to the extent possible. There would be minor, short-term effects to visual resources because the construction activities would draw attention to the setting. However, similar large equipment is used for agricultural production and in the maintenance of canals and is therefore a common feature in the landscape. Construction would follow the BMPs discussed below to minimize any visual disruptions.

After construction, areas adjacent to the canal would be restored to near prior contours. The area over the pipe would be graded to blend with the side of the canal. Disturbed areas, including the newly buried pipes, would be planted with a seed mix of native grasses and forbs in consultation with NRCS. Recreationists would have views of a vegetated corridor rather than either open water or an empty canal, depending on the season. Disturbance to existing mature trees during construction would be minimized to the extent possible, and these trees would be part of the vegetated corridor. The visual loss of waterways for recreationists and property owners could not be monetized because of insufficient data; a further discussion can be found in the NED (Appendix D).

Overall, the visual change from canal to buried pipe would be expected to have a minor, long-term effect because the revegetated corridor would blend in with the natural landscape following revegetation.

6.9.4 Compliance and Best Management Practices

The following BMPs would be implemented as part of both the Lining and HDPE Piping Alternative (unless noted otherwise) to reduce effects to visual resources:

- The construction would occur during the daytime to minimize disturbance to any recreationists, landowners, or other individuals in the vicinity of the construction area.
- Ground disturbances would be limited to only those areas necessary to safely implement the alternatives.
- Work would be confined within the existing ROW whenever possible to preserve existing vegetation and private property. The ROW would be clearly marked in the field prior to construction.
- Construction limits would be clearly flagged onsite to avoid unnecessary plant loss or ground disturbance.
- Temporary travel routes would be selected and utilized to minimize effects to vegetation and avoid the removal of trees.
- Selection of construction areas adjacent to canals and travel routes would consider existing vegetation and avoid mature trees to the extent practicable.
- Pruning would be entirely within TID's ROW and would not exceed what is required for equipment clearance.
- During construction, the contractor would use erosion control measures that are free of weeds and weed seeds.
- Immediately after construction, areas with disturbed soils including newly covered pipes (under the HDPE Piping Alternative) would be planted with a seed mix of native grasses and forbs.

6.10 Water Resources

The areas of potential effect for water resources are discussed in Section 4.10.

6.10.1 No Action (Future without Project)

Under the No Action Alternative, the canal and laterals would remain open. This section discusses the future of the project area and area of potential effect without a full system modernization implementation and completion in relation to water resources.

6.10.1.1 Surface Water Rights

Under the No Action Alternative, TID would not create instream water rights through Oregon's Allocation of Conserved Water Program. The District would not permanently reduce its water right or permanently protect water instream in Tumalo Creek, Crescent Creek, the Little Deschutes River, or the Deschutes River. A portion of the water diverted at the TFC and BFC diversions would continue to seep into the ground before reaching any farms.

6.10.1.2 Surface Water Hydrology

The No Action Alternative would not be reasonably certain to convert the District's open canal and laterals to a modernized system. Water diverted into TID's canals and laterals would continue to seep through the porous volcanic substrate. The District would continue to experience delivery shortages during most years. The No Action Alternative effects on the surface water hydrology are described in the following sections.

Crescent Lake

There would be no effect on water resources within Crescent Lake.

Crescent Creek, Crescent Lake Dam (RM 30) to the Mouth (RM 0)

There would be no effect on water resources in Crescent Creek. Any voluntary releases from Crescent Lake for fish and wildlife would not be permanently and legally protected instream under an instream water right.

Little Deschutes River, Crescent Creek (RM 57) to the Mouth (RM 0)

There would be no effect on water resources within the Little Deschutes River from the confluence with Crescent Creek (RM 57) to the mouth (RM 0). Any voluntary releases from Crescent Lake for fish and wildlife would not be permanently and legally protected instream under an instream water right.

Deschutes River, Little Deschutes River (RM 192.5) to the BFC Diversion at Steidl Dam (RM 166)

There would be no effect on water resources in the Deschutes River from the confluence with the Little Deschutes River (RM 192.5) to the BFC diversion at Steidl Dam (RM 166). Any voluntary releases from Crescent Lake for fish and wildlife would not be permanently and legally protected instream under an instream water right.

Tumalo Creek, TFC diversion (RM 2.5) to the Mouth (RM 0)

There would be no effect on water resources in Tumalo Creek from the TFC diversion (RM 2.5) to the mouth (RM 0). The District would continue to maintain at least 10-12 cfs downstream from the TFC diversion during the irrigation season. Instream water rights in the creek would not change.

Deschutes River, BFC Diversion at Steidl Dam (RM 166) to Lake Billy Chinook (RM 120)

There would be no effect on water resources in the Deschutes River from Steidl Dam (RM 166) to the confluence with Tumalo Creek (RM 160), and subsequently to Lake Billy Chinook (RM 120).

Any voluntary releases from Crescent Lake for fish and wildlife would not be permanently and legally protected instream under an instream water right. The District would continue to divert water from the BFC in a volume that accounts for seepage loss. No additional water would be protected instream downstream from the TFC diversion on Tumalo Creek.

6.10.1.3 Surface Water Quality

There would be no effect on surface water quality in the area of potential effect. The Deschutes River and its tributaries in the area of potential effect would continue to be included on Oregon's 303(d) list for not meeting temperature, dissolved oxygen, pH, sedimentation, turbidity, and/or chlorophyll a water quality standards (Table 4-17).

The irrigation canal and lateral system would continue to collect irrigation tailwater, subsequently delivering contaminates, such as herbicides and pesticides, to patrons down gradient in the system. This concern is especially relevant to a patron dairy producer and farms that sell food products to the local farmers' markets.

6.10.1.4 Groundwater

There would be no effect on groundwater in the project area or the area of potential effect.

6.10.2 Canal Lining Alternative

This section discusses the environmental consequences of implementation of the Canal Lining Alternative. Included and discussed below are the effects to surface water and groundwater present in the project area and the area of potential effect.

6.10.2.1 Surface Water Rights

Following construction, TID would create permanent instream water rights for Tumalo Creek, Crescent Creek, the Little Deschutes River, and the Deschutes River through Oregon's Allocation of Conserved Water Program (ORS 537.470).

The amount of water allocated instream would be determined based on the amount of water conserved through implementation of the Canal Lining Alternative. The District has identified that implementation of the Canal Lining Alternative would conserve approximately 43 cfs. The District would allocate 100 percent of the conserved water created for instream use. The District would allocate the conserved water instream incrementally following completion of each project group of the Canal Lining Alternative.

Following the precedent of previous Allocation of Conserved Water applications by the District, an estimated 38 percent (approximately 16 cfs) of the conserved water would be allocated to Crescent Creek and 62 percent (approximately 27 cfs) would be allocated to Tumalo Creek. These allocations by source and by season are estimates based on conserved water applications associated with similar, completed projects in TID that have already completed the State of Oregon's administrative process for the allocation of conserved water (see OAR 690-018). These allocations may change following a thorough review of the application by OWRD who may order a different allocation in an attempt to avoid affecting other water users at either source. The instream water rights created as an effect of the Canal Lining Alternative would carry the same priority dates as TID's water rights. The District would permanently reduce its own water rights by corresponding rates and volumes, permanently reducing the rates of diversion at the TFC diversion and the BFC diversion.

In Crescent Creek, the conserved water would be permanently protected instream from the Crescent Lake Dam (RM 30) to the mouth (RM 0), the Little Deschutes River from the confluence with Crescent Creek (RM 57.3) to the mouth (RM 0), and the Deschutes River from the confluence with the Little Deschutes River (RM 192.5) to Lake Billy Chinook (RM 120). This conserved water would be stored in and released from Crescent Lake.

In Tumalo Creek, the conserved water would be permanently protected instream from the District's TFC diversion (RM 2.5) to the confluence with the Deschutes River and in the Deschutes River from Tumalo Creek (RM 160) to Lake Billy Chinook (RM 120).

Following construction, completion of each project group of the Canal Lining Alternative would directly affect TID patrons by ensuring delivery of existing water rights throughout the irrigation season. Implementation of the Canal Lining Alternative would improve water supplies for both patrons and instream uses; therefore, minor, long-term effects would occur.

6.10.2.2 Surface Water Hydrology

Environmental effects on surface water hydrology from implementation of the Canal Lining Alternative would vary throughout the area of potential effect. All environmental effects to surface water hydrology are assumed beneficial. Transferring surface water rights for instream conservation would have an overall minor, long-term effect in the area of potential effect. Effects on individual reaches are identified below.

Crescent Lake

Implementation of the Canal Lining Alternative would have minor, long-term effects on Crescent Lake. At capacity, the volume of water held in Crescent Lake currently is 86,900 acre-feet. The Canal Lining Alternative would allocate 4,949 acre-feet of water in Crescent Lake to instream use through Oregon's Allocation of Conserved Water Program. The District currently releases this water from Crescent Lake, diverts it, and loses it through canal and lateral seepage. Implementation of the Canal Lining Alternative would allow the District to use less stored water over the irrigation season. Irrigation season releases from Crescent Lake Dam would decrease accordingly. The State would determine its desired timing for the release of this 4,949 acre-feet from Crescent Lake during the fall, winter, and spring. As a result, this alternative may affect reservoir elevations within the lake during any given year.

Crescent Creek, Crescent Lake Dam (RM 30) to the Mouth (RM 0)

Implementation of the Canal Lining Alternative would have minor, long-term effects on Crescent Creek. The Canal Lining Alternative would affect Crescent Creek from Crescent Lake Dam (RM 30) to the mouth (RM 0). The Canal Lining Alternative would create 4,949 acre-feet of instream water rights in this reach through Oregon's Allocation of Conserved Water Program. The conserved water would be incrementally protected instream following completion of each project group, protecting

4,949 acre-feet of streamflow outside of the irrigation season. The conserved water would legally protect 16 cfs instream against appropriation out of the irrigation season. ODFW has an instream water right for this reach (varies seasonally from 50 cfs in late summer to 125 cfs in late winter), which is not met outside the irrigation season. Therefore, this permanent flow would assist in meeting these junior water rights.

Summer releases from the Crescent Lake Dam would also decrease, as the District would require less water following implementation of the Canal Lining Alternative. This would reduce summer flows within this section of Crescent Creek and return it to a more natural hydrologic regime.

Little Deschutes River, Crescent Creek (RM 57) to the Mouth (RM 0)

Implementation of the Canal Lining Alternative would have minor, long-term effects on the Little Deschutes River. The Canal Lining Alternative would affect Little Deschutes River from the confluence with Crescent Creek (RM 57) to the mouth (RM 0). The Canal Lining Alternative would create 4,059 acre-feet of instream water rights in this reach through Oregon's Allocation of Conserved Water Program (after accounting for an 18 percent channel loss from Crescent Creek to Benham Falls, as required by OWRD). The conserved water would be incrementally protected instream following completion of each project group, protecting 4,059 acre-feet of streamflow in this reach outside of the irrigation season. The conserved water would legally protect 13.5 cfs instream against appropriation outside of the irrigation season. ODFW has an instream water right for this reach (varies seasonally from 74.5 cfs in late summer to 240 cfs in early spring), which is rarely met. Therefore, this permanent flow would assist in meeting these junior water rights outside of the irrigation season.

Summer releases from the Crescent Lake Dam would also decrease, as the District would require less water following implementation of the Canal Lining Alternative. This would reduce summer flows within these sections of Crescent Creek, the Little Deschutes River, and the Deschutes River and return it to a more natural hydrologic regime.

Deschutes River, Little Deschutes River (RM 192.5) to the BFC Diversion at Steidl Dam (RM 166)

Implementation of the Canal Lining Alternative would have minor, long-term effects on the Deschutes River. The Canal Lining Alternative would affect the Deschutes River from the confluence with the Little Deschutes River (RM 192.5) to the BFC diversion at Steidl Dam (RM 166). The Canal Lining Alternative would create 3,775 acre-feet of instream water rights in this reach through Oregon's Allocation of Conserved Water Program (after accounting for a 7 percent channel loss between Benham Falls and Bend as required by OWRD). The conserved water would be incrementally protected instream following completion of each project group, protecting 3,775 acre-feet of streamflow outside of the irrigation season. The conserved water would legally protect 12.5 cfs instream against appropriation outside of the irrigation season. ODFW has an instream water right for this reach, which is not always met outside of the irrigation season. Therefore, this permanent flow would assist in meeting these junior water rights.

Summer releases from the Crescent Lake Dam would also decrease, as the District would require less water following implementation of the Canal Lining Alternative. This would reduce summer flows within this section of the Deschutes River and return it to a more natural hydrologic regime.

Tumalo Creek, TFC diversion (RM 2.5) to the Mouth (RM 0)

Implementation of the Canal Lining Alternative would have moderate, long-term effects on Tumalo Creek. The Canal Lining Alternative would affect Tumalo Creek downstream from the TFC diversion. The Canal Lining Alternative would create up to 27 cfs of instream water rights in this reach through Oregon's Allocation of Conserved Water Program. The conserved water would be incrementally protected instream following completion of each project group, increasing streamflows in this reach during the irrigation season. The conserved water would be legally protected instream and unavailable for appropriation. In addition, the Canal Lining Alternative's reduced demand in the BFC would leave additional capacity that would allow for trades between the Deschutes River and Tumalo Creek. The ODFW has an instream water right for Tumalo Creek, which is rarely met during the irrigation season. These additional streamflows would assist in meeting these junior instream water rights.

Deschutes River, BFC Diversion at Steidl Dam (RM 166) to Lake Billy Chinook (RM 120)

The Canal Lining Alternative would have a minor, long-term effect on the Deschutes River from Steidl Dam (RM 166) to Lake Billy Chinook (RM 120) outside of the irrigation season. As described above, the Canal Lining Alternative would create 3,775 acre-feet of instream water rights in this reach through Oregon's Allocation of Conserved Water Program. The conserved water would be incrementally protected instream following completion of each project group, protecting 3,775 acre-feet of streamflow in this reach outside of the irrigation season. The conserved water would legally protect 12.5 cfs instream against appropriation outside of the irrigation season.

In addition, the Canal Lining Alternative would have a minor, long-term effect on the Deschutes River from the confluence with Tumalo Creek (RM 160) to Lake Billy Chinook (RM 120) during the irrigation season. The Canal Lining Alternative would create up to 27 cfs of instream water rights in this reach through Oregon's Allocation of Conserved Water Program.

The historic daily average streamflow in this reach varies between 85.5 cfs to 391.5 cfs during the irrigation season. The ODFW has a pending instream water right for 250 cfs in this reach, which is rarely met during the irrigation season. Therefore, this additional flow would assist in meeting these junior water rights.

6.10.2.3 Surface Water Quality

Implementation of the Canal Lining Alternative would have a moderate, long-term effect on water quality within the area of potential effect due to improved streamflows as described below. The Canal Lining Alternative would provide permanent instream rights in Crescent Creek, the Little Deschutes River, the Deschutes River, and Tumalo Creek in addition to a potential increase in the inactive storage capacity of Crescent Lake Reservoir. This protected streamflow would affect water quality in streams and rivers within the area of potential effect. These streams currently do not meet water quality standards under Section 303(d) of the CWA (33 U.S.C. 1251 et seq.) See Section 4.12.2 for a more detailed description of these impaired reaches.

Increasing streamflows in Tumalo Creek would decrease water temperatures in the Deschutes River past the confluence (Park and Foged 2009; Mork 2016). This decrease in water temperature past the confluence may have an indirect effect on other water quality components including dissolved oxygen, pH, and chlorophyll a.

Implementation of the Canal Lining Alternative would contribute to increased streamflows in Crescent Creek downstream from Crescent Lake Dam. It would contribute to improved streambank stability, sedimentation, and scour below Crescent Lake. Restoring wetlands and riparian function along most of the study reach would help address many of the identified resource concerns. Developing a riparian corridor that is healthy, resilient, and diverse would improve stream stability, expand aquatic and riparian habitat, and positively influence stream temperature and other water quality parameters including sedimentation, chlorophyll a, pH, and dissolved oxygen. This change would occur because as water enters a wetland it slows down and moves around wetland plants, and much of the suspended sediment drops out and settles to the wetland floor. Plant roots and microorganisms on plant stems in the soil absorb excess nutrients that can cause excess algae growth that is harmful to fish and other aquatic life.

The irrigation canal and lateral system would continue to collect irrigation tailwater, subsequently delivering contaminates, such as herbicides and pesticides, to patrons down gradient in the system. This concern is especially relevant to a patron dairy producer and farms that sell food products to the local farmers' markets.

Implementation of the Canal Lining Alternative would be expected to have a moderate, long-term effect on water quality for waterbodies that are 303(d) listed and in the area of potential effect.

6.10.2.4 Groundwater

No groundwater resources would be extracted or consumptively used as part of the Canal Lining Alternative; however, lining of irrigation canals and laterals may affect groundwater hydrology associated with canal leakage. Following construction, reduction in canal leakage is expected to result in reduced groundwater recharge during the irrigation season. A seepage loss assessment performed in 2016 calculated water loss at a rate of 48 cfs throughout the entire District (TID 2017). This estimate included evaporation, so it is anticipated that the entire 48 cfs does not contribute to the aquifer. Prior studies have found that canal lining and piping has a relatively small effect on groundwater recharge in the upper Deschutes Basin (Gannett and Lite 2013; Gannett et al. 2001; Gannett et al. 2003).

Extrapolating from a prior study (Gannett and Lite 2013), the average relationship between canal recharge and groundwater levels in the central part of the Deschutes Basin is approximately 1 foot of groundwater elevation drop per 377,000 acre-feet of reduced canal recharge. The Canal Lining Alternative would reduce canal seepage, and associated groundwater recharge, by up to approximately 13,604 acre-feet annually in this part of the Deschutes Basin. On average, for this part of the Deschutes Basin, this decrease in recharge translates into a decreased groundwater elevation of approximately 0.036 feet annually. An important caveat is that localized effects on groundwater from implementation of the Canal Lining Alternative would differ throughout the area of potential effect. Over the course of 50 years, this annual drop results in a cumulative decreased average groundwater elevation of 2 feet.

As described in Section 4.10.3, changes in canal and lateral seepage account for only a small portion of changes in groundwater recharge in this part of the Deschutes Basin. Climate remains the primary factor affecting groundwater levels in the region. The U.S. Geological Survey estimated that the combined effects of climate and groundwater pumping accounted for approximately 90 percent of the observed decrease in groundwater levels in the region, and canal piping and lining accounted for 10 percent of that decrease (Gannett and Lite 2013).

It is also important to note that, over time, the lining of the canal will often tear and breakdown. This would allow leakage of canal water to recharge the groundwater system.

Water conserved through the Canal Lining Alternative would be allocated instream to Crescent Creek and Tumalo Creek. OWRD calculates an 18 percent channel loss from Crescent Creek Gauging Station No. 14060000 to Benham Falls Gauging State No. 14064500 on the Deschutes River and a 7 percent channel loss from Benham Falls to the City of Bend on the Deschutes River (Figure 6-6; OWRD 2005). The additional groundwater recharge created through increased streamflows associated with the Canal Lining Alternative would enter regional groundwater system upgradient from the proposed action. It would reduce any effects of canal piping and lining on regional groundwater recharge. Based on this information, the Canal Lining Alternative's effects on groundwater would be negligable and long-term.

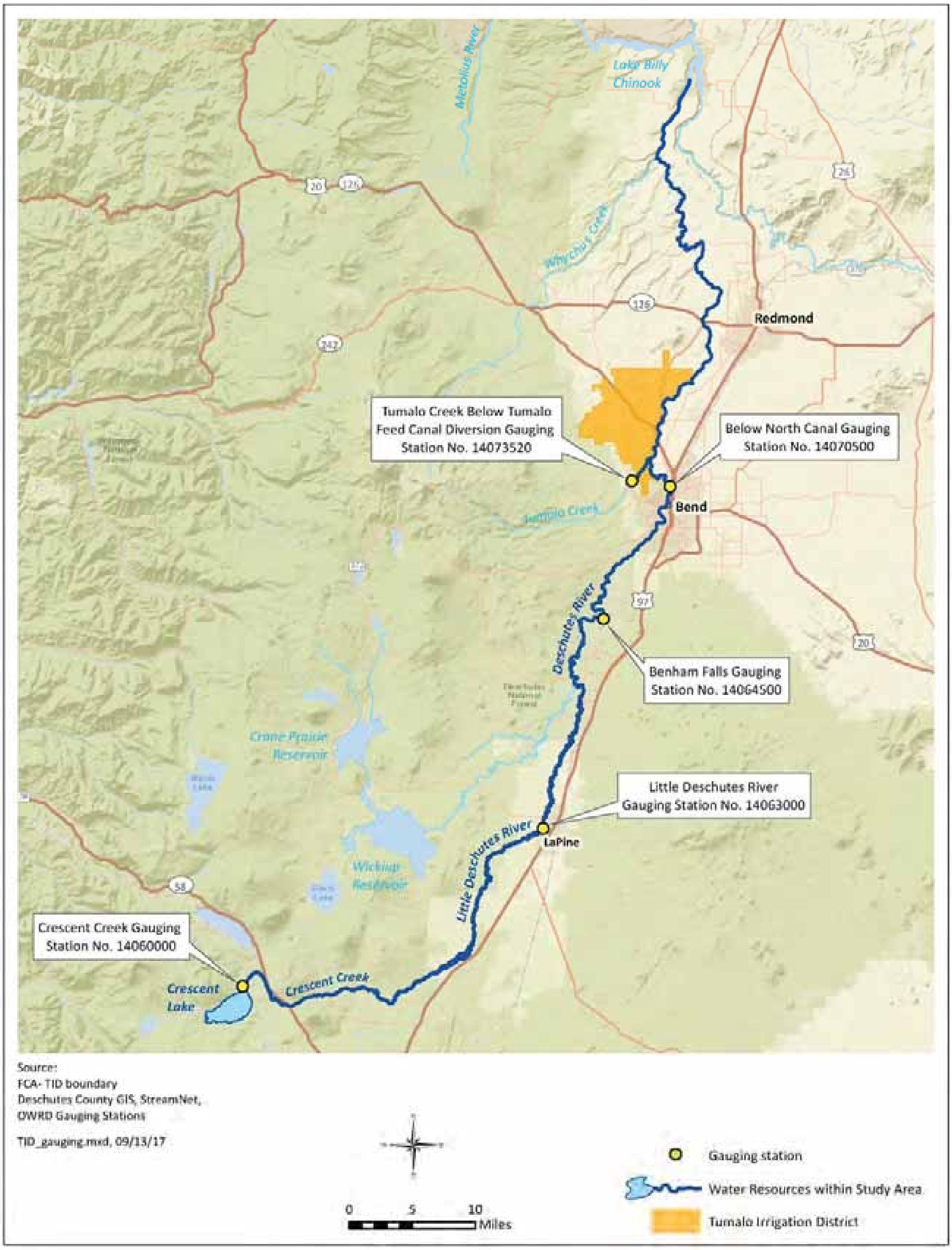


Figure 6-6. Location of Gauging Stations No. 14060000, 14063000, and 14064500 within the Tumalo Irrigation District Area of Potential Effect.

6.10.3 HDPE Piping Alternative

This section discusses the environmental consequences of implementation of the HDPE Piping Alternative. Included and discussed below are the effects to surface water and groundwater present in the project area and the area of potential effect.

6.10.3.1 Surface Water Rights

Following construction, TID would create permanent instream water rights in Tumalo Creek, Crescent Creek, the Little Deschutes River, and the Deschutes River through Oregon's Allocation of Conserved Water Program (ORS 537.470). Storage rights in Crescent Lake are discussed below.

The amount of water allocated instream would be determined based on the amount of water conserved through implementation of the HDPE Piping Alternative. The District has identified that the HDPE Piping Alternative would conserve 48 cfs. Under this alternative, the District would legally reduce their water right by the amount of conserved water. Correspondingly, the District would allocate and legally protect 100 percent of the conserved water instream through Oregon's Allocation of Conserved Water Program. The District would allocate the conserved water instream incrementally following completion of each project group of the HDPE Piping Alternative.

Following the precedent of previous Allocation of Conserved Water applications by the District, an estimated 38 percent (approximately 18 cfs) of the conserved water would be allocated to Crescent Creek, and 62 percent (approximately 30 cfs) would be allocated to Tumalo Creek. These allocations by source and by season are estimates based on conserved water applications associated with similar, completed projects in TID that have already completed the State of Oregon's administrative process for the allocation of conserved water (see OAR 690-18). These allocations may change following a thorough review of the application by OWRD who may order a different allocation in an attempt to avoid affecting other water users at either source. The instream water rights created as an effect of the HDPE Piping Alternative would carry the same priority dates as TID's water rights. The District would permanently reduce its own water rights by corresponding rates and volumes, permanently reducing the rates of diversion at the TFC diversion and the BFC diversion.

In Crescent Creek, the conserved water would be permanently protected instream from the Crescent Lake Dam (RM 30) to the mouth (RM 0), the Little Deschutes River from the confluence with Crescent Creek (RM 57.3) to the mouth (RM 0), and the Deschutes River from the confluence with the Little Deschutes River (RM 192.5) to Lake Billy Chinook (RM 120). This conserved water would be stored in and released from Crescent Lake.

In Tumalo Creek, the conserved water would be permanently protected instream from the District's TFC diversion (RM 2.5) to the confluence with the Deschutes River and in the Deschutes River from Tumalo Creek (RM 160) to Lake Billy Chinook (RM 120).

Following construction, completion of each project group of this alternative would directly affect TID patrons by ensuring delivery of existing water rights throughout the irrigation season. As sections of the District become piped, the conveyance system would convert into an on-demand system allowing water to remain instream when not being utilized. Implementation of the HDPE

Piping Alternative would improve water supplies for both patrons and instream uses; therefore, minor, long-term effects would occur.

6.10.3.2 Surface Water Hydrology

Environmental effects on surface water hydrology from implementation of the HDPE Piping Alternative would occur at different extents for different locations throughout the area of potential effect. All environmental effects within surface water hydrology are assumed to be beneficial. Transferring surface water rights for instream conservation would have an overall minor, long-term effect in the area of potential effect. Effects on individual reaches are identified below.

Crescent Lake

Implementation of the HDPE Piping Alternative would have minor, long-term effects on Crescent Lake. The volume of water held in Crescent Lake currently averages 86,900 acre-feet. The HDPE Piping Alternative would allocate a projected 5,499 acre-feet of water in Crescent Lake to instream use through Oregon's Allocation of Conserved Water Program. The District currently releases this water from Crescent Lake, diverts it, and loses it through canal and lateral seepage. Implementation of the HDPE Piping Alternative would allow the District to use less stored water over the irrigation season. Irrigation season releases from Crescent Lake Dam would decrease accordingly. The State would determine its desired timing for the release of this 5,499 acre-feet from Crescent Lake during the fall, winter, and spring. As a result, this alternative may affect reservoir elevations within the lake during any given year.

Crescent Creek, Crescent Lake Dam (RM 30) to the Mouth (RM 0)

Implementation of the HDPE Piping Alternative would have minor, long-term effects on Crescent Creek. The HDPE Piping Alternative would affect Crescent Creek from Crescent Lake Dam (RM 30) to the mouth (RM 0). The HDPE Piping Alternative would create a projected 5,499 acre-feet of instream water rights in this reach through Oregon's Allocation of Conserved Water Program. The conserved water would be incrementally protected instream following completion of each project group, protecting 5,499 acre-feet of streamflow outside the irrigation season. Under the 2016 Stipulated Settlement Agreement, TID releases a minimum of 20 cfs into Crescent Creek outside the irrigation season. Although these conditions have been maintained since the expiration of the Agreement in compliance with the 2017 BiOp for Reclamation dam operations (see Section 4.10.2.2), that water is not legally protected against diversion (Reclamation 2017). If managed as a flat release rate, the conserved water generated through the HDPE Piping Alternative would permanently and legally protect up to 18 cfs instream against appropriation outside the irrigation season in addition to 5 cfs that TID releases through an informal agreement with OWRD (see Section 4.10.2.2). ODFW has an instream water right for this reach (the quantity varies seasonally from 50 cfs in late summer to 125 cfs in late winter), which is not met outside the irrigation season. Therefore, this protected flow would assist in meeting these junior water rights. Summer releases from the Crescent Lake Dam would also decrease, as the District would require less water following implementation of the HDPE Piping Alternative. This would reduce summer flows within this section of Crescent Creek and return it to a more natural hydrologic regime.

Little Deschutes River, Crescent Creek (RM 57) to the Mouth (RM 0)

Implementation of the HDPE Piping Alternative would have minor, long-term effects on the Little Deschutes River. The HDPE Piping Alternative would affect the Little Deschutes River from the confluence with Crescent Creek (RM 57) to the mouth (RM 0). The HDPE Piping Alternative would create a projected 4,509 acre-feet of instream water rights in this reach through Oregon's Allocation of Conserved Water Program (after accounting for an 18 percent channel loss from Crescent Creek to Benham Falls, as required by OWRD). Although the District currently releases water instream from Crescent Lake Dam into Crescent Creek that flows into the Little Deschutes during the non-irrigation season in compliance with the 2017 BiOp, this water is not legally protected (Reclamation 2017). The conserved water generated through the HDPE Piping Alternative would be incrementally protected instream following completion of each project group. If managed as a flat release rate, the conserved water would legally and permanently protect 15 cfs instream against appropriation outside the irrigation season. ODFW has an instream water right for this reach (the quantity varies seasonally from 74.5 cfs in late summer to 240 cfs in early spring), which is rarely met. Therefore, this protected flow would assist in meeting these junior water rights outside the irrigation season.

Summer releases from the Crescent Lake Dam would also decrease, as the District would require less water following implementation of the HDPE Piping Alternative. This would reduce summer flows within this section of the Little Deschutes River and return it to a more natural hydrologic regime.

Deschutes River, Little Deschutes River (RM 192.5) to the BFC Diversion at Steidl Dam (RM 166)

Implementation of the HDPE Piping Alternative would have minor, long-term effects on the Deschutes River. The HDPE Piping Alternative would affect the Deschutes River from the confluence with the Little Deschutes River (RM 192.5) to the BFC diversion at Steidl Dam (RM 166). The HDPE Piping Alternative would create a projected 4,194 acre-feet of instream water rights in this reach through Oregon's Allocation of Conserved Water Program (after accounting for a 7 percent channel loss between Benham Falls and Bend as required by OWRD). In this reach, any water instream as a result of the District's releases outside the irrigation season in compliance with the 2017 BiOp is not legally protected. The conserved water generated through the HDPE Piping Alternative would be incrementally protected instream following completion of each project group, legally protecting a projected 4,194 acre-feet of streamflow outside of the irrigation season and permanently protecting flows created under the conditions of the 2016 Stipulated Settlement Agreement. ODFW has an instream water right for this reach, which is not always met outside of the irrigation season. Therefore, these protected instream water rights would assist in meeting the desired flows under this junior water right.

Summer releases from the Crescent Lake Dam would also decrease, as the District would require less water following implementation of the HDPE Piping Alternative. This would reduce summer flows within this section of the Deschutes River and return it to a more natural hydrologic regime.

Tumalo Creek, TFC diversion (RM 2.5) to the Mouth (RM 0)

Implementation of the HDPE Piping Alternative would have moderate, long-term effects on Tumalo Creek. The HDPE Piping Alternative would affect Tumalo Creek downstream from the TFC diversion. The HDPE Piping Alternative would create a projected 30 cfs of instream water rights in this reach through Oregon's Allocation of Conserved Water Program. The conserved water would be incrementally protected instream following completion of each project group, increasing streamflows in this reach during the irrigation season. The conserved water would be legally protected instream and unavailable for appropriation. In addition, the HDPE Piping Alternative's reduced demand in the BFC would leave additional capacity that would allow for trades between the Deschutes River and Tumalo Creek. The ODFW has an instream water right for Tumalo Creek, which is rarely met during the irrigation season. These additional streamflows would assist in meeting these junior water rights.

As project groups of the District become piped, the conveyance system would convert into an on-demand system allowing water to remain instream (not be diverted at the TFC diversion) when not being utilized.

Deschutes River, BFC Diversion at Steidl Dam (RM 166) to Lake Billy Chinook (RM 120)

The HDPE Piping Alternative would have a minor, long-term effect on the Deschutes River from Steidl Dam (RM 166) to Lake Billy Chinook (RM 120) outside of the irrigation season. As described in Section 6.10.2.1, the HDPE Piping Alternative would create a projected 4,194 acre-feet instream water rights in this reach through Oregon's Allocation of Conserved Water Program. The conserved water would be incrementally protected instream following completion of each project group, legally protecting up to 4,194 acre-feet of streamflow in this reach outside the irrigation season.

As project groups of the District become piped, the conveyance system would convert into an on-demand system during the irrigation season. An on-demand system allows the District to divert only the water that patrons need and leave the remainder instream.

In addition, the HDPE Piping Alternative would have a minor, long-term effect on the Deschutes River from the confluence with Tumalo Creek (RM 160) to Lake Billy Chinook (RM 120) during the irrigation season. The HDPE Piping Alternative would create a projected 30 cfs of instream water rights in this reach through Oregon's Allocation of Conserved Water Program. The conserved water would be incrementally protected instream following completion of each project group, protecting up to 30 cfs of streamflow during the irrigation season (see Table E-14 in Appendix E.6 for projected flows following these conservation projects). The conserved water would be unavailable for appropriation.

The pre-project, daily average streamflow in this reach varies between 85.5 cfs to 391.5 cfs during the irrigation season. ODFW has a pending instream water right for 250 cfs in this reach, which is rarely met during the irrigation season. Therefore, this additional flow would assist in meeting these junior water rights.

6.10.3.3 Surface Water Quality

Implementation of the HDPE Piping Alternative would have a moderate, long-term effect on water quality within the area of potential effect due to improved streamflows as described below. The HDPE Piping Alternative would provide permanent instream rights in Crescent Creek, the Little Deschutes River, the Deschutes River, and Tumalo Creek in addition to a potential increase in the inactive storage capacity of Crescent Lake Reservoir. This protected streamflow would affect water quality in streams and rivers within the area of potential effect. These streams currently do not meet water quality standards under Section 303(d) of the CWA (33 U.S.C. 1251 et seq.) See Section 4.12.2 for a more detailed description of these impaired reaches.

Increasing streamflows in Tumalo Creek would decrease water temperatures in the Deschutes River past the confluence (Park and Foged 2009; Mork 2016). This decrease in water temperature past the confluence may have an indirect effect on other water quality components including dissolved oxygen, pH, and chlorophyll a.

Implementation of the HDPE Piping Alternative would protect streamflows in Crescent Creek downstream from Crescent Lake Dam. This protection would ensure continued improvement to streambank stability, sedimentation, and scouring below Crescent Lake. Restoring wetlands and riparian function along most of the study reach would help resolve many of the identified resource concerns. Developing a riparian corridor that is healthy, resilient, and diverse would improve stream stability, expand aquatic and riparian habitat, and positively influence stream temperature and other water quality parameters including sedimentation, chlorophyll a, pH, and dissolved oxygen. This change would occur because as water enters a wetland it slows down and moves around wetland plants, and much of the suspended sediment drops out and settles to the wetland floor. Plant roots and microorganisms on plant stems in the soil absorb excess nutrients that can cause excess algae growth that is harmful to fish and other aquatic life.

Implementation of HDPE Piping Alternative would prevent the system from collecting irrigation tailwater, such as herbicides and pesticides, thus improving the water quality delivered to patrons. Water quality is especially relevant to a patron dairy producer and farms that sell food products to the local farmers' markets.

The HDPE Piping Alternative is expected to have a moderate, long-term effect on water quality for waterbodies that are 303(d) listed and in the area of potential effect.

6.10.3.4 Groundwater

No groundwater resources would be extracted or consumptively used as part of the HDPE Piping Alternative; however, piping of irrigation canals and laterals may affect groundwater hydrology associated with canal leakage. Following construction, reduction in canal leakage is expected to result in reduced groundwater recharge during the irrigation season. A seepage loss assessment performed in 2016 calculated water loss at a rate of 48 cfs throughout the entire District (TID 2017). This estimate includes evaporation, so it is anticipated that the entire 48 cfs does not contribute to the aquifer. Prior studies have found that canal lining and piping has a relatively small effect on groundwater recharge in the upper Deschutes Basin (Gannett and Lite 2013; Gannett et al. 2001; Gannett et al. 2003).

Extrapolating from a prior study (Gannett and Lite 2013), the average relationship between canal recharge and groundwater levels in the central part of the Deschutes Basin is approximately 1 foot of groundwater elevation drop per 377,000 acre-feet of reduced canal recharge. The HDPE Piping Alternative would reduce canal seepage, and associated groundwater recharge, by up to approximately 15,115 acre-feet annually in this part of the Deschutes Basin. On average, for this part of the Deschutes Basin, this decrease in recharge translates into a decreased groundwater elevation of approximately 0.040 feet annually. An important caveat is that localized effects on groundwater from implementation of the proposed project would differ throughout the area of potential effect. Over the course of 50 years, this annual drop results in a cumulative decreased average groundwater elevation of 2 feet.

As described in Section 4.10.3, changes in canal and lateral seepage account for only a small portion of changes in groundwater recharge in this part of the Deschutes Basin. Climate remains the primary factor affecting groundwater levels in the region. The U.S. Geological Survey estimated that the combined effects of climate and groundwater pumping accounted for approximately 90 percent of the observed decrease in groundwater levels in the region, and canal piping and lining accounted for 10 percent of that decrease (Gannett and Lite 2013).

Water conserved through the HDPE Piping Alternative would be allocated instream to Crescent Creek and Tumalo Creek. OWRD calculates an 18 percent channel loss from Crescent Creek Gauging Station No. 14060000 to Benham Falls Gauging State No. 14064500 on the Deschutes River and a 7 percent channel loss from Benham Falls to the City of Bend on the Deschutes River (OWRD 2005). The additional groundwater recharge created through increased streamflows associated with the HDPE Piping Alternative would enter regional groundwater system upgradient from the proposed action. It would reduce any effects of canal piping and lining on regional groundater recharge. Based on this information, the effects on groundwater would be negligable and long-term.

6.10.4 Compliance and Best Management Practices

The following compliance measures and BMPs would be implemented to mitigate any effects on water resources resulting from either the Canal Lining Alternative or the HDPE Piping Alternative (unless otherwise noted):

- Proper erosion control.
- Allocation of the conserved water to permanent instream water rights in Tumalo Creek, Crescent Creek, the Little Deschutes River, and the Deschutes River through Oregon's Allocation of Conserved Water Program (ORS 537.470).

6.11 Wetlands and Riparian Areas

The area of potential effect for wetlands and riparian areas are discussed in Section 4.11.

6.11.1 No Action (Future without Project)

This section discusses the future of the project area and area of potential effect without project implementation and completion in relation to wetlands and riparian areas. Under the No Action Alternative, the District's canals and laterals would remain open. The District's open canal and laterals would continue to lose 48 cfs through seepage.

6.11.1.1 Wetlands

The No Action Alternative would have no effect to any wetland features or sporadic hydrophytic vegetation occurring adjacent to District canals and laterals. It would also not provide a more natural hydrograph to support wetlands adjacent to the 162 miles of waterbodies downstream of Project diversions. Conditions that have allowed hydrophytic plants to opportunistically grow along the open canals and laterals would continue.

6.11.1.2 Riparian Areas

This alternative would not enhance flows and benefit riparian areas in the area of potential effect. Low streamflows during the late fall, winter, and early spring in Crescent Creek, the Little Deschutes River, and low streamflows during the late spring, summer, and early fall in Tumalo Creek downstream from the TFC diversion would continue to limit riparian vegetation growth and establishment.

6.11.2 Canal Lining Alternative

This section discusses the potential environmental consequences to wetlands and riparian areas under the Canal Lining Alternative. Following construction, approximately 43 cfs currently lost through seepage during the irrigation season would instead remain instream (see Section 6.10.2). Eliminating canal seepage would have direct effects on hydrophytic plants opportunistically growing in and along the canals and laterals, on wetlands adjacent to the canal and laterals, and indirect effects on riparian areas adjacent to natural waterbodies downstream of the District's diversions.

6.11.2.1 Wetlands

Although canals and laterals may have hydrology and vegetation indicative of a wetland in places, District operations meet exemptions under the Oregon Removal-Fill Law for specific agricultural activities in wetlands and other waters of the state (S. Kelly, personal communication, November 2016). Based on a review of the NWI geographic information systems data (USFWS 2016), there are no wetland features within project canals or laterals. Hydrophytic vegetation grows opportunistically along the canals and laterals in some areas. Further, approximately 23 wetland features are shown in the NWI data to occur near or adjacent to project canals or laterals; however, these have not been field verified. Consultation with USACE and ODSL would be completed prior to construction, and measures would be taken as required to identify and mitigate impacts to potential jurisdictional wetlands and Waters of the United States.

The Canal Lining Alternative could have direct effects on hydrophytic vegetation and wetlands adjacent to irrigation canals and laterals in the project area.

Hydrophytic vegetation or wetlands in some areas directly adjacent to the canals could be removed or buried during excavation, fill, placement of lining materials, or other construction activity; however, wetlands would be avoided to the extent practicable. After completion of canal lining, seepage losses would be eliminated along with the saturated soils necessary for hydrophytic plant growth along some canals. This could also limit water availability to wetlands adjacent to the canals or laterals if they are dependent upon canal seepage for hydrology.

The Canal Lining Alternative would have no effect on privately owned and operated excavated water storage ponds that occur in the project area.

Because the effects of this alternative could directly affect or reduce water availability to wetlands and hydrophytic vegetation occurring in places near or adjacent to the 65.1 miles of open canal and laterals in the project area, minor effects are assumed to occur to wetland habitat along canals and laterals within the project area. However, these effects would be offset by gains in water quality and habitat function in the 162 miles of natural riverine systems downstream of Crescent Lake and TID's diversions (in the project's area of potential effects) as a result of increased instream flows that contribute towards a more natural hydrologic regime and improved hydrologic connectivity with wetland vegetation. Based on the information provided above, the Canal Lining Alternative would have a minor effect on wetlands in the short-term and a negligible-to-minor effect on wetlands in the long-term.

6.11.2.2 Riparian Areas

Changes in a stream's hydrologic regime alter streambank structure, sediment transport dynamics, and hydrologic connectivity with riparian vegetation (National Research Council 2002). This alternative would provide improved habitat function within the 162 miles of rivers and streams in the study area by protecting winter flows downstream of Crescent Lake and providing additional irrigation season flows in Tumalo Creek that are more similar to the natural hydrograph. Reduced bank erosion along the rivers and streams in the study area could occur if riparian vegetation became more established along stream channels and functionality of the riparian areas increases.

Restablishing a more natural hydrologic regime in these reaches could allow the river channel to supply water to riparian areas via infiltration through channel banks. This change would enhance riparian function by facilitating processes such as surface and groundwater exchange, physical and chemical transformations, and supporting riparian plant communities. Based on the information provided above, the Canal Lining Alternative would have a minor effect on riparian areas in the short-term and a negligible-to-minor effect on riparian areas in the long-term as instream conservation is implemented.

6.11.3 HDPE Piping Alternative

This section discusses the potential environmental consequences to wetlands and riparian areas from implementation of the HDPE Piping Alternative. Following construction, 48 cfs that is currently diverted and lost through seepage and evaporation would instead remain instream (see Section 6.10.3). Eliminating canal seepage would have direct effects on hydrophytic plants opportunistically growing in and along the canals and laterals, and on wetlands adjacent to the canals and laterals.

This would also have indirect effects on riparian areas adjacent to natural waterbodies downstream of Crescent Lake and the District's TFC diversion. Permanently protecting flows in Crescent Creek created under the conditions of the 2016 Stipulated Settlement Agreement and increasing flows to Tumalo Creek downstream of the TFC diversion, could allow for enhancement to streamside vegetation.

6.11.3.1 Wetlands

Although canals and laterals may have hydrology and vegetation indicative of a wetland in places, operations by the District meet exemptions under the Oregon Removal-Fill Law for specific agricultural activities in wetlands and other waters of the state (S. Kelly, personal communication, November 2016). Hydrophytic vegetation grows opportunistically along the canals and laterals in some areas. Based on a review of the NWI geographic information systems data (USFWS 2016), there are no wetland features within project canals or laterals. Further, approximately 23 wetland features are shown in the NWI data to occur near or adjacent to project canals or laterals; however, these have not been field verified. Consultation with USACE and ODSL will be completed prior to construction, and measures will be taken as required to identify and mitigate impacts to potential jurisdictional wetlands and Waters of the United States.

Hydrophytic vegetation or wetlands in some areas directly adjacent to the canals could be removed or buried during excavation, fill, placement of lining materials, or other construction activity; however, wetlands would be avoided to the extent practicable. The District would follow appropriate reclamation procedures in order to revegetate disturbed areas as uplands. Figure 6-1 through Figure 6-5 demonstrate the before and after effects of a previous TFC piping project on hydrophytic vegetation. After completion of pipe installation, seepage losses would be eliminated along with the saturated soils necessary for opportunistic hydrophytic plant growth along some canals. This could also limit water availability to wetlands adjacent to the canals or laterals if they are dependent upon canal seepage for hydrology.

The HDPE Piping Alternative would have no effect on excavated water storage ponds that occur in the project area.

Because the effects of this alternative could reduce water availability to wetlands and hydrophytic vegetation occurring in places near or adjacent to the 65.1 miles of open canal and laterals in the project area, minor effects are assumed to occur to wetland habitat along canals and laterals within the project area. However, these effects would be offset by gains in water quality and habitat function in the 162 miles of natural riverine systems downstream of TID's diversions in the project's area of potential effects as a result of protection and addition of instream flows that contribute towards a more natural hydrologic regime and increasing hydrologic connectivity with wetland vegetation. Based on the information provided above, the HDPE Piping Alternative would have a minor effect on wetlands in the short-term and a negligible-to-minor effect on wetlands in the long-term.

6.11.3.2 Riparian Areas

Changes in a stream's hydrologic regime alter streambank structure, sediment transport dynamics, and hydrologic connectivity with riparian vegetation (National Research Council 2002). This alternative would continue to provide improved habitat function within the 162 miles of rivers and streams in the study area by protecting winter flows downstream of Crescent Lake and providing additional irrigation-season flows that are more similar to the natural hydrograph in Tumalo Creek. Reduced bank erosion along the rivers and streams in the study area could occur as riparian vegetation becames more established along stream channels and riparian area functionality increases.

Restablishing a more natural hydrologic regime in these reaches could allow the river channel to supply water to riparian areas via infiltration through channel banks. This change would enhance riparian function by facilitating processes such as surface and groundwater exchange, physical and chemical transformations, and supporting riparian plant communities. Based on the information provided above, the HDPE Piping Alternative would have a minor effect on riparian areas in the short-term and a negligible-to-minor effect on riparian areas in the long-term as instream conservation is implemented.

6.11.4 Compliance and Best Management Practices

The replacement of an open channel with a pipe or the lining of an open channel is considered an irrigation exemption under the USACE Regulatory Guidance Letter No. 07-02 Exemption for Construction or Maintenance of Irrigation Ditches and Maintenance of Drainage under Section 404 Part 323.4(a)(3) of the CWA. Under this exemption, no Nationwide Permit is required for the disturbance to wetlands within the project area. Coordination and consultation with USACE will occur prior to project implementation to ensure the project meets exemption criteria.

Executive Order 11988 requires federal agencies to avoid to the extent possible the long- and short-term effects associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. Canals and laterals in both the Canal Lining Alternative and the HDPE Piping Alternative are not located within the 100-year floodplain and would be compliant with EO 11988. In addition, wetlands found along canals and laterals in the Canal Lining Alternative and the HDPE Piping Alternative are classified by NRCS as being either excavated by humans or created or modified by a human-created barrier; therefore, both the Canal Lining Alternative and the HDPE Piping Alternative would be compliant with EO 11990 regarding the protection of wetlands.

The following BMPs would be implemented to mitigate any effects on wetlands and riparian areas resulting from either the Canal Lining Alternative or the HDPE Piping Alternative (unless otherwise noted):

- Following project implementation, appropriate reclamation procedures would be followed in order to revegetate disturbed areas as uplands while controlling noxious weeds.
- Work would be confined within the existing ROW whenever possible to preserve existing vegetation and private property. The ROW would be clearly marked in the field prior to construction.
- Construction limits would be clearly flagged onsite to avoid unnecessary plant loss or ground disturbance.

- Disturbance of jurisdictional wetlands would be avoided during construction.

6.12 Wildlife Resources

The area of potential effect for wildlife resources is discussed in Section 4.12.

6.12.1 No Action (Future without Project)

The No Action Alternative would have no effect on wildlife in the project area.

6.12.2 Canal Lining Alternative

6.12.2.1 Wildlife

Effects on terrestrial wildlife communities resulting from implementation of the Canal Lining Alternative would be direct and indirect as well as short-term and long-term. During construction, terrestrial wildlife could experience noise disturbance due to the operation of heavy equipment, habitat removal due to cutting of trees and other vegetation removal, or injury due to collision with construction equipment or habitat removal. Canals in the Canal Lining Alternative are located in agricultural areas where use of heavy equipment is commonplace. Therefore, most wildlife in the area is accustomed to noise in the area and these disturbances are anticipated to be minor.

The canal and laterals within the project area provide seasonal artificial wetland and elements of riparian habitat across the landscape as well as a source of drinking water for wildlife. As canal and lateral systems are lined and fenced, habitats are expected to shift from artificial wetlands to uplands; and the distribution patterns of wildlife within the area would change. The fence and barbed wire cap would alter the land use patterns of large ungulates by removing their access to these water sources and the vegetation they support. Densities of smaller species dependent on these habitats could decrease locally and shift to other more suitable habitat in the area as vegetation removal would occur. However, this alternative would have no effect on excavated water storage ponds that occur in the project area. These ponds would still allow for summer water and habitat availablilty to wildlife. The newly lined canal would also have steeper concrete side slopes and faster water velocities than the existing canal. This could pose a drowning risk to large mammals.

Wintering or migrating birds would be minimally affected by construction disturbance because they have the flexibility to move away from disturbances to other suitable areas. There is no expected direct effect to breeding migratory songbirds or waterbirds as construction activities would occur outside the nesting season.

The District is working with USFWS to ensure minimal disturbance to bald or golden eagles nesting near the project area. The critical nesting period for bald and golden eagles is January 1 through August 31. Two golden eagle nests are located near the project area, and, although no bald eagle nests are documented, it is possible that a bald eagle nest could be located near a proposed pipeline or irrigation pond (Cordova 2017). Site visits with a USFWS biologist confirmed that the locations of the golden eagle nests are a substantial distance from any planned construction activity. The District would continue to work with USFWS to ensure that appropriate buffers are maintained between construction activities and active nests or that construction in areas with known nests is avoided during the critical nesting period.

Although implementation of the Canal Lining Alternative would remove habitat adjacent to open canals, project implementation would provide increased instream flows in Crescent Creek, the Deschutes River, and Tumalo Creek, which would enhance riparian habitat in these reaches. Riparian areas in stream reaches with improved streamflows would provide more consistent access to water for hydrophytic plants. Enhanced riparian habitat could provide improved terrestrial wildlife habitat.

Overall, the Canal Lining Alternative would have a minor, long-term effect on general wildlife in the area of potential effect.

6.12.2.2 Threatened and Endangered Species

The Canal Lining Alternative would have no effect on threatened or endangered terrestrial species. As noted in Section 4.12.3 and Section 4.12.4, no terrestrial species or federally designated critical habitat occurs within the project area or area of potential effect.

6.12.3 HDPE Piping Alternative

6.12.3.1 Wildlife

Effects on terrestrial wildlife communities resulting from implementation of the HDPE Piping Alternative would be direct and indirect as well as short-term and long-term. During construction, terrestrial wildlife could experience noise disturbance due to the operation of heavy equipment, habitat removal due to cutting of trees and other vegetation removal, or injury due to collision with construction equipment or habitat removal. Canals in the HDPE Piping Alternative are located in agricultural areas where use of heavy equipment is commonplace, therefore most wildlife in the area are accustomed to noise in the area and these disturbances are anticipated to be minor.

The canal and laterals within the project area provide seasonal artificial wetland and elements of riparian habitat across the landscape, as well as a source of drinking water for wildlife. As canal and lateral systems are piped and habitats shift from artificial wetlands to uplands, the distribution patterns of wildlife within the area could change. Large ungulates could alter their land use patterns in response to removal of these water sources and the vegetation they support. Densities of smaller species dependent on these habitats could decrease locally and shift to other more suitable habitat in the area. However, this alternative would have no effect on excavated water storage ponds that occur in the project area and this would still allow for summer water and habitat availablilty to wildlife. Wintering or migrating birds would be minimally affected by construction disturbance because they have the flexibility to move away from disturbances to other suitable areas. There is no expected direct effect to breeding migratory songbirds or waterbirds as construction activities would occur outside the nesting season.

The District is working with USFWS to ensure minimal disturbance to bald or golden eagles nesting near the project area. The critical nesting period for bald and golden eagles is January 1 through August 31. Two golden eagle nests are located near the project area and although no bald eagle nests are documented, it is possible that a bald eagle nest could be located near a proposed pipeline or irrigation pond (Cordova 2017). Site visits with a USFWS biologist confirmed that the locations of the golden eagle nests are a substantial distance from any planned construction activity. The District would continue to work with USFWS to ensure that appropriate buffers are maintained between construction activities and active nests or that construction in areas with known nests is avoided during the critical nesting period.

Although implementation of the HDPE Piping Alternative would remove habitat adjacent to open canals, project implementation would protect and provide additional instream flows in Crescent Creek, Little Deschutes River, Deschutes River, and Tumalo Creek (see Section 4.10.2 and 6.10.3 for allocation of conserved water). Protection of these instream flows would enable continued enhancement of riparian habitat in these reaches. Riparian areas in stream reaches with improved streamflows would experience more consistent access to water for hydrophytic plants. Enhanced riparian habitat would provide improvement to terrestrial wildlife habitat.

Construction activities would cause short-term negligible effects on wildlife due to increased human presence and noise. However, piping of irrigation canals would potentially reduce human presence through the project area; fewer trips to maintain ditches and headgates would be necessary. This change would result in fewer human-wildlife conflicts and improve seclusion for wildlife. In addition, the HDPE Piping Alternative could remove barriers to movement of ungulates and other terrestrial wildlife within the project area as open canals are converted to buried pipelines. Although some species may use canals as a water source, canals and laterals can have adverse effects on wildlife due to risk of drowning and the barrier that they create to terrestrial movement (Beier et al. 2008). As this alternative would be implemented over time, ungulates and other terrestrial wildlife would have ample time to adjust and find new water sources.

Overall, the HDPE Piping Alternative would have a minor, long-term effect on general wildlife in the area of potential effect.

6.12.3.2 Threatened and Endangered Species

The HDPE Piping Alternative would have no effect on threatened or endangered terrestrial species. As noted in Section 4.12.4, no terrestrial species or federally designated critical habitat occurs within the project area or area of potential effect.

6.12.4 Compliance and Best Management Practices

Bald and golden eagles typically use the same nest sites year after year. The District is working with a USFWS biologist to determine the most recent locations of active nests and how to best operate within the project area that would minimize any potential effects. BMPs that would be implemented for both the Lining and HDPE Piping Alternative would include project construction outside the USFWS-approved buffer distances. If construction occurs within the recommended buffer distance, the District would avoid the nesting season.

Project construction would occur outside the primary nesting period for migratory birds of concern (April 15 through July 15) and raptors (April through July). For rare occasions where construction of either alternative would occur during the primary nesting period, construction would occur outside of the recommended buffer distance of any known nests. Should an active nest be found, construction would be paused and a consultation with a local USFWS biologist would occur to determine the following steps.

To mitigate for loss of functional habitat, the District would complete timely and appropriate revegetation of the construction area. Seed mixes would consist of native vegetation and would be approved by the local Soil and Water Conservation District or NRCS. In addition, the District would limit the construction footprint to the smallest area practicable.

Under both the Canal Lining and HDPE Piping Alternatives, there would be potential for wildlife to be trapped in dewatered trenches left open overnight during construction periods. To avoid this, ramps of size deemed appropriate by a USFWS biologist would be placed in trenches. These ramps would be strong enough to allow large animals to escape.

The Canal Lining Alternative would install a standard chain link fence with 3-wire barbed wire cap, chosen per NRCS guidelines. This would limit wildlife access to the canals and would reduce the potential for wildlife to fall into the canals and drown.

6.13 Wild and Scenic Rivers

The area of potential effect for Wild and Scenic Rivers is discussed in Section 4.13.

6.13.1 No Action Alternative (Future without Project)

The No Action Alternative would have no effect on designated Wild and Scenic Rivers or State Scenic Waterways in the area of potential effect.

6.13.2 Canal Lining Alternative

There would be no direct effects to designated Wild and Scenic Rivers and State Scenic Waterways following implementation of the Canal Lining Alternative. Increased streamflows (discussed in Section 6.10.2) as a result of water conservation in the designated river sections are consistent with the Outstanding Remarkable Values (ORV) in each area. Adverse effects are not expected in the Wild and Scenic River areas or in the State Scenic Waterways; therefore, consultation is not warranted.

6.13.3 HDPE Piping Alternative

There would be no direct effects to designated Wild and Scenic Rivers and State Scenic Waterways following implementation of the HDPE Piping Alternative. Increased streamflows (discussed in Section 6.10.3) in the designated river sections as a result of water conservation are consistent with the ORVs in each area. Adverse effects are not expected in the Wild and Scenic River areas or in the State Scenic Waterways and therefore, consultation is not warranted.

6.13.4 Compliance and Best Management Practices

The following compliance measures and BMPs would be implemented to mitigate any effects on Wild and Scenic River areas or State Scenic Waterways resulting from either the Canal Lining Alternative or the HDPE Piping Alternative (unless otherwise noted):

- Ground disturbances would be limited to only those areas necessary to safely implement both the Canal Lining Alternative and the HDPE Piping Alternative.
- Work would be confined within the existing ROW whenever possible to preserve existing vegetation and private property. The ROW would be clearly marked in the field prior to construction.
- Construction limits would be clearly flagged onsite to avoid unnecessary plant loss or ground disturbance.
- Work crews would carry spill cleanup kits, and, in times of burn bans or wildfire concerns, each crew would have a fire suppression kit.
- Project construction activities would be conducted in accordance with the project's spill prevention and cleanup plan.
- Allocation of the conserved water to permanent instream water rights in Tumalo Creek, Crescent Creek, the Little Deschutes River, and the Deschutes River through Oregon's Allocation of Conserved Water Program (ORS 537.470).

6.14 Cumulative Effects

This section includes a description of past, current, reasonably foreseeable future actions, and cumulative effects organized by resource and then by alternative. The cumulative effects are assumed to be the same for the Canal Lining and HDPE Piping alternatives except where stated differently.

6.14.1 Past Actions

Past actions considered in this analysis include land development activities related to irrigated agriculture (consisting of construction of the canal system, previous piping projects, and diversions), urban and suburban development, industrial land and water uses, commercial development, water diversions for non-agricultural uses, and transportation infrastructure. The nature and extent of these past actions and how they have influenced the existing environment are described for each resource in Section 4.

The first documented canal in the TID system was dug in 1883 and diverted water from Tumalo Creek to provide water to surrounding farms and ranches for crops and livestock. The TID system was formalized in 1902 and reorganized as an irrigation district under Oregon State law; it assumed the name "Tumalo Irrigation District" in 1922. Seven other irrigation districts were developed within the Deschutes River subbasin during this timeframe, collectively altering the hydrology of the

Deschutes River and the Little Deschutes River. Over time there has been increasing pressure to reduce the effects of irrigation needs on the natural water cycle in the Deschutes River basin.

6.14.2 Current and Reasonably Foreseeable Future Actions

Current actions are those projects, developments, and other actions that are presently underway, because they are either under construction or occurring on an ongoing basis. Reasonably foreseeable future actions generally include those actions formally proposed or planned, or highly likely to occur based on available information. Various sources including local, state, and federal agency websites and city and county staff were consulted to obtain information about current and potential future development in the project area. The following sections describe these current actions and reasonable foreseeable future actions.

6.14.2.1 Land Use and Development

Ongoing agricultural activities, including farming and grazing in the project area, are not expected to change from current conditions. Land use development in the project area is managed according to the Deschutes County Comprehensive Plan and Deschutes County zoning regulations and is implemented by Deschutes County Planning Department. Land development activities are expected to continue into the future. These activities would include agricultural, residential, commercial, and industrial land uses, as well as maintenance of public lands for their intended uses.

6.14.2.2 Habitat Conservation Plan

The District, other irrigation districts in the Deschutes Basin, state and federal agencies, local municipalities, and environmental groups are collaborating to develop a multi-species Habitat Conservation Plan (HCP) for the upper Deschutes Basin for listed species and those that may become listed during the 20- to 50-year life of the HCP, including the Oregon spotted frog, bull trout, chinook salmon, steelhead salmon, and sockeye salmon. The plan is planned for completion in 2019. The HCP is still in draft form; covered activities will likely include:

- Storage and release of irrigation water from:
    - Crane Prairie Reservoir
    - Wickiup Reservoir
    - Crescent Lake Reservoir
    - Prineville Reservoir
    - Ochoco Reservoir
- Diversion of irrigation water
- Conveyance and delivery of irrigation water
- Irrigation return flows
- Existing hydropower
- City of Prineville water use activities

6.14.2.3 Deschutes Basin Irrigation District Modernization

Other irrigation districts in the Deschutes Basin are working to modernize their infrastructure, and would implement projects similar to that proposed by TID in this Plan-EA. Districts most likely to obtain necessary funding and permitting to begin work in the next 2 years are Central Oregon Irrigation District (COID) and Swalley Irrigation District (SID). Modernization of SID's irrigation infrastructure would involve piping approximately 16.6 miles of canals over the course of 7 years starting in 2019 if funding is made available. Modernization of COID's Pilot Butte Canal system would involve a total of 174 miles of canals over the course of 11 years starting in 2019 if funding is made available.

If all proposed projects are constructed, these two districts would cumulatively convert approximately 191 miles of open canals and ditches to piped systems and conserve 172 cfs of water that would otherwise be lost to seepage and evaporation in the Deschutes Basin over the course of 11 years.

6.14.3 Cumulative Effects by Resource

Cumulative effects are considered for each resource using the intensity threshold matrix (Appendix E) in combination with past, present, and reasonably foreseeable future actions.

6.14.3.1 Cultural Resources

Cultural resources in the project area have likely been affected due to past, present, and ongoing development activities such as agriculture, land development, forestry, and any other ground disturbing projects. Like the proposed action, other reasonably foreseeable future actions in the vicinity of the project area have the potential to disturb previously undiscovered cultural resources. The proposed action would likely have moderate cumulative effects on historic properties because any potential effects on historic canal structures would be completed in compliance with the NHPA, and any previously undiscovered archaeological resources would be managed as directed by SHPO. Mitigation measures for reasonably foreseeable future projects would likely be similar to those identified for the proposed action that would minimize effects on cultural resources. Cumulative effects on cultural resources from the proposed action in combination with other past, present, and reasonably foreseeable projects are therefore considered moderate.

6.14.3.2 Fish and Aquatic Species

Past actions including road construction, road maintenance, and urban and suburban development projects would have minor effects on fish in combination with the proposed action. The potential effects from these past projects in TID and the Deschutes Basin, such as sediment entering waterbodies or aquatic habitat disturbance, would be temporary and likely complete before construction of the proposed action.

Because TID's irrigation diversions are screened and the conveyance systems do not provide fish habitat, they do not have a direct effect on fish and aquatic species in the irrigation infrastructure itself. Irrigation diversions and reservoir operations are responsible for most of the past and ongoing direct and indirect effects related to water availability and seasonality on fish communities and associated riverine habitat in the area of potential effect.

Ongoing land use activities in the project area are not expected to change from current conditions. Future land developments and irrigation district modernization projects may cause indirect effects on fish, such as sediment inputs or aquatic habitat disturbance, and could potentially affect waters within the same watershed as the proposed action. However, reasonably foreseeable future actions are all proposed for improving aquatic habitat conditions. These actions include the HCP and installation of other irrigation modernization programs in the Deschutes Basin.

The cumulative effects of the HCP implementation and the proposed action would be negligible in Crescent Creek, as current flows in Crescent Creek are consistent with those anticipated from the proposed action and the HCP. No saved water from COID and SID projects would be returned instream to Crescent Creek. Because Tumalo Creek is not included in the HCP and TID is the only irrigation district to divert water from this waterbody, there would be no cumulative effects due to future foreseeable projects in this reach. Increased streamflow in Tumalo Creek as a result of TID's project implementation would affect streamflow in the middle Deschutes River downstream of Tumalo Creek. Other foreseeable projects may also increase streamflow in the middle Deschutes, and therefore, would result in cumulative increases in streamflow in the middle Deschutes River downstream of the confluence with Tumalo Creek during the irrigation season.

Implementation of the proposed action, when combined with other future actions, is anticipated to have a minor cumulative effect on aquatic species. Implementation of other irrigation modernization programs could have an additive effect on the amount of water conserved, and therefore would provide additional flexibility in managing water rights in the Deschutes Basin.

6.14.3.3 Geology and Soils

Past, ongoing, and future actions in the surrounding area that effect the geology and soils include agricultural uses, land development, and water management activities, as discussed above. The amount of soil affected by the proposed action is small compared to the area affected by other past, present, and reasonably foreseeable future actions in the area; the proposed action would have minor, cumulative effects on geology and soils.

6.14.3.4 Land Use

The project area has been substantially altered over the past century by a variety of human activities, including agricultural development, livestock grazing, urban and suburban development, and road construction. Implementation of the proposed action would support existing land uses, as would implementation of future actions, including the HCP and additional irrigation district modernization. Since these actions would collectively support existing land uses, implementation of the proposed action would have negligible cumulative effects on land use.

6.14.3.5 Public Safety

Past and ongoing operation of agricultural equipment and vehicle traffic in the project area would continue to create risks to public safety, but these risks are not expected to change from current conditions. Implementation of additional irrigation modernization would improve public safety by eliminating the risk of drowning in open canals. In combination with past, present, and reasonably foreseeable future actions, the proposed action is anticipated to have minor cumulative effects on public safety.

6.14.3.6 Recreation

In general, canals in the proposed action do not support any recreational pursuits; however, increased streamflows resulting from implementation of the proposed action would have a negligible indirect effect on recreation in areas away from these canals. A potential future project to include an informal trail on BLM land would run along the Tumalo Reservoir Feed lateral and include a new trailhead in the near future.

Past, ongoing, and future land uses and developments in the project area would be expected to support recreation in the same way that it is currently supported. Effects on recreation from the proposed action would be negligible, and since other actions are anticipated to be negligible, the cumulative effects on recreational resources are expected to be negligible.

6.14.3.7 Socioeconomic Resources

Past actions, including agricultural development, other land development, and recently completed projects, have had minor effects on socioeconomics. There are no other known future projects that would affect socioeconomic resources in the area of potential effect. Since the effects on socioeconomics from the proposed action are considered minor, the cumulative effects on socioeconomics from the proposed action in combination with other past, present, and reasonably foreseeable projects are also considered minor.

6.14.3.8 Vegetation

Agricultural activities, livestock grazing, vegetation control along roads, and urban and suburban development are responsible for most of the past and ongoing effects on vegetation in the project area and in the region. Livestock grazing can introduce and spread weed species, degrade native vegetation communities, and trample riparian and wetland areas. In addition, vegetation control activities generally include herbicide applications to control vegetation and noxious weeds, and mechanically cutting vegetation. The amount of vegetation that would be affected by the proposed action is small compared to the area affected by past and ongoing agricultural activities, livestock grazing, vegetation control along roads, and other utility corridors in the area. In addition, these past actions are not expected to change measurably from current conditions, resulting in minor additional cumulative effects.

6.14.3.9 Visual Resources

Past land use actions have changed the visual character of the project area. Agricultural and urbanization associated activities have altered the visual resources in the region by removing native vegetation, adding new infrastructure, and creating increased human activity within the landscape. Agricultural and urban land uses are anticipated to continue and become more prominent as the region is one of the fastest growing in the state and nation. There would be minor effects on the rural agricultural visual character of the landscape in the project area, resulting in minor cumulative effects when combined with other past, present, and reasonably foreseeable future actions.

6.14.3.10 Water Resources

Past actions over the last 120 years that have affected water resources include urban and agricultural development, road construction, road maintenance, and other irrigation projects. Since the early 1990s, there has been increasing interest in conserving water in the Deschutes River. The District and other Deschutes area irrigation districts have implemented various water conservation projects. These efforts have included piping existing irrigation canals, on-farm conservation, water management changes, and changes to crop production.

After over 20 years of conservation efforts, the District has completed several water conservation and pressurized pipe projects. These include the installation of HDPE pipe in approximately 5 miles of the BFC, an additional 4.2 miles of the TFC, and in several laterals stemming from the TFC and the Columbia Southern Canal. Projects completed by TID and other districts in the region have greatly benefitted stakeholders throughout the basin.

Ongoing and reasonably foreseeable future actions that could affect water resources include the implementation of the HCP and irrigation modernization in other irrigation districts that divert water from the Deschutes River.

Cumulative effects to surface water resources from the proposed project and other past, present, and reasonably foreseeable future actions are expected to be negligible in Crescent Creek and the Little Deschutes River. Current stream flows in Crescent Creek and the Little Deschutes River are consistent with those anticipated from the proposed project and the HCP, and irrigation modernization in other irrigation districts will not affect Crescent Creek and the Little Deschutes River.

Cumulative effects to surface water resources from the proposed project and other past, present, and reasonably foreseeable future actions are expected to be minor (seasonal increase) in the Deschutes River downstream from the confluence with the Little Deschutes River. The HCP and irrigation modernization in other irrigation districts may seasonally increase stream flows outside of the irrigation season (mid-October to March) to benefit aquatic species. This seasonal increase will be attenuated by tributary and groundwater inputs downstream.

The proposed project would increase surface flows in Tumalo Creek; however, the HCP and future projects with SID and COID would not, and therefore TID's project would not have a cumulative effect on water resources in that reach. Flows added to Tumalo Creek as a result of project implementation would have a minor cumulative effect (seasonal increase) on streamflow in the Deschutes River downstream from its confluence with Tumalo Creek. This cumulative effect would only occur during the irrigation season (April to mid-October) with restored flows from implementation of TID and other irrigation districts' projects.

Seepage from TID's canals most likely percolates to shallow aquifers, where it is extracted for groundwater consumption or ultimately discharges into the Deschutes River (Gannett et al. 2017). The piping of canals and laterals associated with reasonably foreseeable future actions in other irrigation districts would occur on the eastern side of the Deschutes River, and TID's canals are on the western side of the river. These reasonably foreseeable future actions are not expected to affect groundwater in TID's project area. However, cumulative effects on groundwater may occur at the wider basin scale. With the potential implementation of SID and COID irrigation modernization projects, groundwater levels are expected to decline 0.6 feet and 5 feet, respectively, over the course of 50 years. In total, these cumulative effects, with TID, could affect groundwater levels in parts of the greater Deschutes Basin by up to 7.6 feet in 50 years.

Groundwater levels in the Deschutes Basin are influenced by a combination of factors, including but not limited to climate, canal and lateral leakage, and pumping (Gannett and Lite 2013, Gannett et al. 2017). Removing leakage from canal and laterals in the Deschutes Basin through piping or lining project is estimated to have contributed to up to 10 percent of the observed decline in groundwater levels in some parts of the basin (Gannett and Lite 2013, Gannett et al. 2017). Although this number varies spatially, climate generally has the largest impact on groundwater recharge (Gannett et al. 2017). The implementation of the proposed action and other past, present, and reasonably foreseeable future actions is anticipated to have a minor cumulative effect on water resources, as implementation of other irrigation modernization programs could reduce groundwater infiltration via leaky canals and increase the amount of water that is conserved in the Deschutes Basin.

Water quality could be affected by nonpoint source pollution such as erosion and runoff associated with ongoing and reasonably foreseeable construction and land development activities. The proposed action would be constructed at a time when there was no water in the canal system or immediately adjacent to the system if there is water in the canals. The proposed action and reasonably foreseeable future actions are anticipated to increase stream flow in waterbodies in the area of potential effect, helping to meet local partners' objectives for water quality enhancement and having a minor cumulative effect on water resources.

6.14.3.11 Wetlands and Riparian Areas

Past actions that have affected wetlands, riparian areas, and floodplains consist of the construction of irrigation infrastructure, including existing canals, piping, and associated infrastructure, and operational and maintenance activities. Leakage from the canal and laterals has contributed to localized artificial wetlands adjacent to the project area as described in Section 4.11. Potential project area wetland cumulative effects could result if other projects and actions were to affect wetland functions (i.e., water quality, hydrology, and wildlife habitat). The reasonably foreseeable future actions in the project area that could have wetland effects include agricultural activities, vegetation control along roads and utility corridors, and urban and suburban development. These activities are also responsible for past and ongoing project area wetland effects. Because wetland impacts from implementation of the proposed action would be minimal and localized, and because the project would protect streamflow in Crescent Creek and add additional streamflow in Tumalo Creek, which would benefit downstream riparian wetlands, the cumulative effect of the proposed action and other past, present, and reasonably foreseeable future projects on wetlands would be minor.

Current maintenance and use of agricultural infrastructure, livestock grazing, and development are expected to continue in the project area. Changes to wetland and riparian area vegetation caused by the proposed action would be relatively minor compared to other activities in the area; cumulative effects on vegetation from the proposed action in combination with other past, present, and reasonably foreseeable projects are considered minor.

6.14.3.12 Wildlife

Agriculture, urban, and suburban development have affected wildlife and wildlife habitat in the project area since the late 1800s. Agricultural activities have substantially altered the habitat in the region by removing native vegetation communities in some areas and diverting streamflow. Livestock grazing occurs in much of the region around the area of potential effect and can result in the introduction and spread of weed species, the degradation of native habitat, and trampling of riparian and wetland areas. Some native habitats have been replaced with disturbance-tolerant or introduced species assemblages that may support different wildlife than previously existed. These ongoing activities would continue to affect wildlife and wildlife habitat in the project area.

Some wildlife currently use open canals and laterals as a water source. Implementation of the proposed action would cause wildlife to find other water sources, as they did prior to installation of the canals. Since other past, present, and reasonably foreseeable future actions would have different effects on wildlife, and effects of the proposed action on wildlife would happen over a period of time in which animals would be able to adapt, the cumulative effect on wildlife from implementation of the proposed action would be minor.

In addition, vegetation control activities, including herbicide applications to control noxious weeds and mechanical cutting of vegetation, are ongoing actions that contribute to wildlife habitat changes. The amount of wildlife habitat that would be affected by the proposed action is small compared to the area affected by past and ongoing agricultural activities, livestock grazing, vegetation control, and urban and suburban development in the area. In addition, the intensity of these ongoing actions is not expected to change measurably in the future, resulting in minor additional cumulative effects.

6.14.3.13 Wild and Scenic Rivers

Sections of Crescent Creek and the Deschutes River have been designated under the National Wild and Scenic River Act, and a section of the Deschutes River is designated as an Oregon State Scenic Waterway. These past actions aimed to protect these designated sections from changes that generally alter their scenic, recreational, and ecological qualities. Changes to the current and future management of these sections, which are located within the area of potential effects of the proposed action, are expected to be negligible. These wild and scenic sections will continue to be managed by federal and state agencies consistent with their designations.

7 Consultation, Coordination, and Public Participation

The District and its partners planned and conducted numerous agency coordination and public involvement activities throughout the development of the Plan-EA. These activities included public meetings, informational sessions, presentations, press announcements, and frequent correspondence with federal, state, and local resource agencies; agriculture interests; and other interest groups and individuals. The project development process was designed to work collaboratively with partners, agencies, tribes, and stakeholders to ensure transparency and cooperation towards a solution that fits within the framework of the purpose and need for action.

7.1 Preliminary Investigative Report and Public Scoping

A Preliminary Investigative Report (PIR) (FCA 2017) was prepared to provide sponsors, local partners, agencies, and the public with information to evaluate the goals and objectives of the project. During the development of the PIR, project sponsors conducted initial consultation with natural resource agencies and stakeholders in the Deschutes Basin.

Announcements for the Public Scoping Meeting and Scoping Comment Period

- NRCS public notice (June 16, 2017): https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/newsroom/pnotice/?cid=nrcseprd1333640
- These public notices were also published in the Capital Press Ag Weekly Newspaper and the Bend Bulletin. Ads were published in the Capital Press once a week for 3 weeks; ads were published in the Bend Bulletin twice a week for 3 weeks.
- NRCS press release (June 19, 2017): https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/newsroom/releases/?cid=NRCSEPRD1334010
- KTVZ Channel 21 news story (June 19, 2017): http://www.ktvz.com/news/irrigation-district-canal-piping-plans-up-for-public-input/551703403
- TID website announcement (June 20, 2017): http://tumalo.org/tumalo-irrigation-district-irrigation-modernization-project/
- TID letter mailed to all patrons (June 21, 2017)
- DBBC Facebook post (June 21, 2017)
- Bend Bulletin article (June 26, 2017): http://www.bendbulletin.com/localstate/5400420-151/change-coming-to-central-oregon-irrigation-districts
- NRCS letter to Confederated Tribes of Warm Springs for invitation to public scoping meetings and offer to set up consultation with the Tribes, signed by NRCS State Conservationist (June 30, 2017)
- Bend Bulletin guest column (July 6, 2017) by Craig Horrell, Central Oregon Irrigation District Manager: http://www.bendbulletin.com/opinion/5427265-151/guest-column-watershed-plan-needs-public-involvement?referrer=section
- KBND News article (July 6, 2017): http://kbnd.com/kbnd-news/local-news-feed/312557
- FCA Facebook post (July 6, 2017)
- TID website request for comments (July 7, 2017): http://tumalo.org/get-involved/
- NRCS Oregon Twitter post (July 10, 2017)
- DBBC Facebook post (July 20, 2017)

A website was launched on June 16, 2017 to inform the public and share project information. Oregonwatershedplans.org includes the following information:

- Overview of NRCS PL 83-566 funding program
- Overview of NEPA and Watershed Plan-EA public participation process
- Frequently Asked Questions about the Watershed Plan-EA process
- Background on the District, the Draft Plan-EA and appendices, the PIR and appendices, and presentations and handouts from public meetings
- Contact information and how to submit public comments
- Email signup option for more information; subscribers receive updates over the course of the project development

Public Information Session / Environmental Stakeholder Meeting

- June 22, 2017 at 6:00 p.m. at Trinity Episcopal Church, 469 NW Wall Street, Bend, OR 97701
- Members of the public were invited to hear an overview of NRCS PL 83-566 funding program, NEPA and the Watershed Plan-EA process, and an overview of the proposed project scope and water conservation need. Attendees were given an opportunity to ask questions and were given the oregonwatershedplans.org website for more information about how they could participate in the Watershed Plan-EA process.
- Presenters: Margi Hoffmann, Farmers Conservation Alliance

TID Public Scoping Meeting

- July 6, 2017 from 5:30 p.m. to 6:30 p.m. at Tumalo Community Church Meeting Room, 64671 Bruce Avenue, Bend, OR 97703
- Participants had an opportunity to learn more about the proposed irrigation improvements and discuss their comments, ideas, and concerns.
- Presenters:
  - Tom Makowski, Natural Resources Conservation Service
  - Kenneth B. Rieck, Manager, Tumalo Irrigation District
  - Margi Hoffmann, Farmers Conservation Alliance
  - Bridget Moran, United States Fish and Wildlife Service

Basin Study Work Group Steering Committee Meeting (Open to the Public)

- July 13, 2017 at Deschutes Services Building, 1300 NW Wall Street, Bend, OR 97701

- Participants were informed about the PL 83-566 funding opportunity and the proposed irrigation improvements, and were given information on how to submit comments for the public record.
- Presenter: Brett Golden, Farmers Conservation Alliance

Tumalo Irrigation District Board Meetings (Open to the Public)

Board meeting minutes that relate to PL 83-566 funding, watershed plan, and public participation:

- May 9, 2017
  - Congressional approval of Federal PL 83-566 funding was discussed in addition to the District's need for a Watershed Plan-EA to access funding.
  - A resolution was discussed that stated the Board was committed to developing State and private funding to match Federal PL 83-566 funds for Fiscal Year 2017-2018 for up to $5 million. All board members signed the resolution and it was approved unanimously. See Appendix E for a copy of the resolution.
- June 13, 2017
  - The Board heard an update on PL 83-566 funds and potential sources of matching funds.
  - The upcoming public meeting on July 6, 2017 was discussed; invitations to attend the meeting would be mailed to every water patron in the District.
  - The District is in the process of applying for groundwater mitigation credits from the State for the water that is being released from Crescent Lake for the Oregon spotted frog during the winter months. If the application is approved, the income could be used as a source of funds for matching the PL 83-566 grant.[12]
  - District Manager Rieck directed design to begin for Project Group 1 (or referred to by the District and original SIP as Phase IV B and V) of canal piping in order to be prepared when PL 83-566 funds become available, at which time the District would pipe the canal as far as funds allow.
- July 11, 2017
  - The Board was briefed on the results of the public scoping meeting that was held on July 6, 2017. District Manager Rieck stated that comments could be submitted during the public scoping period and that more information could be found at oregonwatershedplans.org.
  - District Manager Rieck stated that a second meeting would be held in order to receive comments that would be incorporated into the Watershed Plan. The District has a goal of completing the Watershed Plan by the end of September 2017.
- May 8, 2018

[12] Water for groundwater mitigation credits would only come from water associated with projects not funded by PL 83-566.

- The Board was briefed on the progress of the Watershed Plan-EA and signed a resolution that concomitant to 100 percent public funding, TID would legally protect 100 percent of conserved water from the project through Oregon's Allocation of Conserved Water Program. See Appendix E for a copy of the resolution.

Informational Materials Available to the Public

- PIR and Appendices, made available prior to public scoping meetings.
- Four-page public handouts, made available prior to public scoping meetings.
- Meeting presentation slides, made available after public scoping meetings.

7.2 List of Persons and Agencies Consulted

The following lists include persons and agencies with a vested interest in the Plan-EA or those consulted during the planning process. This includes agencies that provided formal or required consultation or individuals who were conferred with and who provided substantial input. Coordination with state and local agencies has been ongoing since project inception.

Local entities that have land ownership or a shared resource within the District include:

- Bend Parks and Recreation District
- City of Bend
- Deschutes County

Agencies that have been involved with the project include the following state and federal resource agencies:

- Business Oregon
- Oregon Department of Energy (ODOE)
- Oregon Department of Environmental Quality (ODEQ)
- Oregon Department of Fish and Wildlife (ODFW)
- Oregon Department of State Lands (ODSL)
- Oregon Governor's Office
- Oregon Water Resources Department (OWRD)
- Oregon Watershed Enhancement Board (OWEB)
- State Historic Preservation Office (SHPO)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Army Corps of Engineers (USACE)
- U.S. Bureau of Land Management (BLM)

Tribes that have been consulted regarding the TID Irrigation Modernization Project include:

- Confederated Tribes of Warm Springs (CTWS)

Other stakeholders for this project include:

- TID patrons
- Adjacent landowners
- Upper Deschutes Watershed Council (UDWC)
- Deschutes River Conservancy (DRC)
- Central Oregon Land Watch
- WaterWatch of Oregon
- Trout Unlimited
- Coalition for the Deschutes
- Interested public

Table 7-1 describes communications with agency personnel that were consulted during development of the Plan-EA.

Table 7-1. Agency Consultation and Communication Record.

Date	Contact, Agency	Communication
October 21, 2016	Bridget Moran, USFWS	• Overview of PL 83-566 Watershed Planning Program • Overview of Tumalo, Swalley, and Central Oregon Irrigation Districts proposed System Improvement Plans • Discussion of basin-wide fish and wildlife concerns/needs
November 6, 2016	Kyle Gorman, OWRD	• Overview of PL 83-566 Watershed Planning Program • Overview of Tumalo, Swalley, and Central Oregon Irrigation Districts proposed System Improvement Plans • Discussion of basin-wide fish and wildlife concerns/needs
December 2, 2016	Brett Hodgson, ODFW	• Overview of PL 83-566 Watershed Planning Program • Overview of Tumalo, Swalley, and Central Oregon Irrigation Districts proposed System Improvement Plans • Discussion of basin-wide fish and wildlife concerns/needs

Date	Contact, Agency	Communication
January 6, 2017	Greg Ciannella, OWEB	• Overview of PL 83-566 Watershed Planning Program • Overview of Tumalo, Swalley, and Central Oregon Irrigation Districts proposed System Improvement Plans • Discussion of basin-wide fish and wildlife concerns/needs
January 27, 2017	Kyle Gorman, OWRD	• Overview of PL 83-566 Watershed Planning Program • Overview of Tumalo, Swalley, and Central Oregon Irrigation Districts proposed System Improvement Plans • Discussion of basin-wide fish and wildlife concerns/needs
June 14, 2017	Bridget Moran, USFWS	• Overview of Endangered Species Act
June 23, 2017	Bridget Moran, USFWS	• Overview of Watershed Planning process for Tumalo, Swalley, and Central Oregon Irrigation Districts • Overview of Preliminary Investigative Reports • Overview of the Public Scoping meetings on July 6, 2017 (Tumalo and Swalley) and July 10, 2017 (Central Oregon)
July 6, 2017	Bridget Moran, USFWS Tom Makowski, NRCS Annette Liebe, Oregon Governor's Office Rob DelMar, ODOE Kelly Hill, ODEQ Kyle Gorman, OWRD Ian Johnson, Oregon SHPO Jessica Gabriel, Oregon SHPO Tom DiCorcia, Business Oregon Brett Hodgson, ODFW	• Overview of the Watershed Planning process for Tumalo, Swalley, and Central Oregon Irrigation Districts • Overview of Preliminary Investigative Reports • Overview of public participation website – oregonwatershedplans.org • Overview of Public Participation meetings July 6, 2017 (Tumalo & Swalley) and July 10, 2017 (Central Oregon)
July 2017	Eric Nigg, ODEQ	• Overview of the Watershed Planning process for Tumalo, Swalley, and Central Oregon Irrigation Districts • Overview of Preliminary Investigative Reports • Overview of public participation website – oregonwatershedplans.org • Overview of Public Participation meetings July 6, 2017 (Tumalo & Swalley) and July 10, 2017 (Central Oregon)
July 11, 2017	Annette Liebe, Oregon Governor's Office	• Update on Tumalo, Swalley, and Central Oregon Irrigation District Watershed Plans
July 20, 2017	Paul Henson, State Supervisor, USFWS Bridget Moran, USFWS	• Letter from NRCS to USFWS requesting PL 83-566 Section 12 consultation

Date	Contact, Agency	Communication
July 20, 2017	Bridget Moran, USFWS	• Overview of Watershed Planning process next steps for Tumalo, Swalley, and Central Oregon Irrigation Districts • Habitat Conservation Plan process and next steps
August 11, 2017	Teal Purrington, BLM Alice Beals, OPRD	• Overview of the Watershed Planning process for Tumalo, Swalley, and Central Oregon Irrigation Districts and public agency managed lands falling within the project area
August 14, 2017	Sasha Sulia, BPRD	• Overview of the Watershed Planning process for Tumalo, Swalley, and Central Oregon Irrigation Districts and public agency managed lands falling within the project area
August 17, 2017	Nancy Pustis, ODSL	• Overview of the Watershed Planning process for Tumalo, Swalley, and Central Oregon Irrigation Districts and public agency managed lands falling within the project area
August 29, 2017	Jerry Cordova, USFWS	• Discussion of eagle habitat and construction mitigation for Tumalo, Swalley, and Central Oregon Irrigation Districts
September 5, 2017	Teal Purrington, BLM Jamie Rhoades, BLM	• Discussion of ROW crossing BLM land
September 19, 2017	Anita Andazola, USACE	• Email exchange between NRCS about upcoming Plan-EA
October 5, 2017	Annette Liebe, Oregon Governor's Office Kyle Gorman, OWRD Ami Keiffer, Business Oregon Tom Rowley, Business Oregon Bridget Moran, USFWS	• Update on Habitat Conservation Plan process • Update on Basin Study Work Group process • Update on PL 83-566 Watershed Plans for Tumalo, Swalley, and Central Oregon Irrigation Districts • Update on NHPA Section 106 & ESA Section 7 compliance
March 20, 2018	Anita Andazola, USACE	• Email from NRCS about upcoming release of the Plan-EA and uploading the document to USACE site.
June 19, 2018	Bridget Moran, USFWS	• Discussion of instream flow in Crescent Creek on Oregon spotted frog • Identified need to review of the effects of instream flow in the Deschutes Basin on Oregon spotted frog and bull trout
June 26, 2018	Bridget Moran, USFWS Jennifer O'Reilly, USFWS Gary Diridoni, NRCS	• Discussion about NEPA and ESA Section 7 compliance • Discussion about initiating information consultation with USFWS through biological assessment letter

Date	Contact, Agency	Communication
July 10, 2018	Gary Diridoni, NRCS Tom Makowski, NRCS Kevin Conroy, NRCS Shawn Big Knife, NRCS Kathy Ferge, NRCS Bobby Brunoe, CTWS Brad Houslet, CTWS Bridget Moran, USFWS	• Consultation regarding TID Irrigation Modernization Project and Plan-EA
July 13, 2018	Anita Andazola, USACE	• Email from NRCS requesting any comments on the Plan-EA • USACE will determine jurisdiction and/or eligibility for exemption during project implementation

7.3 Review of the Draft Plan-EA

NRCS published the proposed Draft Plan-EA on oregonwatershedplans.org on April 16, 2018 for a 30-day comment period ending on May 22, 2018. During the comment period, NRCS hosted a public outreach meeting on May 8, 2018. Specific public outreach activities for the Draft Plan-EA included:

- NRCS Public Notice (April 16, 2018): https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/newsroom/pnotice/?cid=nrcseprd1395633
- NRCS News Release (April 16, 2018): https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/newsroom/releases/?cid=NRCSEPRD1395629
- KTVZ News story (April 16, 2018): http://www.ktvz.com/news/tumalo-irrigation-canal-piping-draft-plan-released/730396341
- FCA email to stakeholder list (April 16, 2018)
- TID website announcement (April 17, 2018): http://tumalo.org/public-meeting-scheduled-for-tumalo-watershed-plan/
- Capital Press article (April 17, 2018): http://www.capitalpress.com/Water/20180417/piping-to-save-water-in-tumalo-irrigation-district
- Bend Bulletin article (April 22, 2018): http://www.bendbulletin.com/localstate/6176950-151/piping-project-coming-to-tumalo
- TID letter to patrons and owners of adjacent properties (April 23, 2018)

- Bend Bulletin public notice (May 4, 2018)
- FCA email to stakeholder list (May 7, 2018)
- Public outreach meeting (May 8, 2018) from 6:00 – 7:30 PM at Cascades Academy 19860 Tumalo Reservoir Road, Bend, OR 97703
- FCA email to stakeholder list (May 21, 2018)

NRCS conducted government-to-government consultation with the CTWS. NRCS sent an initial letter to the CTWS Tribal Historic Preservation Officer outlining the project and initial planning. NRCS sent a consultation letter and provided the CTWS Tribal Historic Preservation Officer with a hard copy of the Draft Plan-EA. NRCS staff met with the CTWS staff on July 10, 2018.

Comments on the Draft Plan-EA were submitted in person at the public meeting, by email to wsp@tumalo.org, online at oregonwatershedplans.org, and by mail to Farmers Conservation Alliance, Tumalo Watershed Plan, 11 3rd St, Suite 101, Hood River, OR 97031.

NRCS received 57 comments on the proposed Draft Plan-EA. Comments were received from the following agencies and public entities: City of Bend; Oregon Department of Transportation, Oregon Department of Environmental Quality, Oregon Department of Fish and Wildlife, Oregon Water Resources Department through the Regional Solutions Program on behalf of the Governor's Office; and USFWS. Comments were also received from Central Oregon Land Watch, Coalition for the Deschutes, Deschutes Redbands Trout Unlimited Chapter, League of Women Voters of Deschutes County, Trout Unlimited, Water Watch of Oregon, and the general public.

NRCS has reviewed all public comments and has made changes, as appropriate, to the final Plan-EA based on those comments and internal review. Each comment received consideration in the development of the final rule. According to the NEPA Handbook 6.9.2.1, substantive comments do one or more of the following:

- Question, with reasonable basis, the accuracy of information in the EIS or EA.
- Question, with reasonable basis, the adequacy of, methodology for, or assumptions used for the environmental analysis.
- Present new information relevant to the analysis.
- Present reasonable alternatives other than those analyzed in the EIS or EA.
- Cause changes or revisions in one or more of the alternatives.

A summary of substantive and/or recurring comments received on the Draft Plan-EA are listed below. For a full list of comments and responses, see Appendix A.

- Effect on local groundwater levels and private wells from reduced groundwater recharge

- Effect on cold springs along the middle Deschutes River from reduced groundwater recharge
- Concern over methodology for allocation of conserved water between Tumalo Creek and Crescent Creek
- Request to further consider other alternatives such as on-farm efficiency upgrades, private lateral piping, voluntary duty reduction, leasing, and transfers
- Request that water conserved from the project be in addition to existing water placed instream by the District
- Request that duty rates do not increase above current average (3.5 acre-feet/acre per year)
- Request that all water saved by the proposed project be protected instream and verified by a third party
- Effect on wildlife along the canal and laterals from piping
- Effect on trees and vegetation along the canal and laterals from piping, especially mature ponderosa pines
- Effect on property values from piping the canal and laterals

8 Preferred Alternative

8.1 Selection of the Preferred Alternative

The project sponsors selected the HDPE Piping Alternative as the Preferred Alternative based on its ability to meet the purpose and needs for the project and provide the most environmental and social benefits. The Preferred Alternative is the only alternative that meets the SLOs' purpose and needs and meets the NED benefit cost ratio.

8.2 Rationale for the Preferred Alternative

The TID Irrigation Modernization Project is a large agricultural water efficiency project focused on Tumalo Creek, Crescent Creek, the Little Deschutes River, and the Deschutes River. The project would address natural resource concerns by improving water conservation, improving water delivery reliability to farms, reducing O&M costs, enhancing streamflow and habitat conditions for fish and aquatic species in the Deschutes Basin, and improving public safety. Implementation of the Preferred Alternative would accomplish these purposes through piping and pressurizing 68.8 miles of TID's canal and lateral system.

NRCS PL 83-566 funds can be applied to projects that meet any of the eight authorized project purposes outlined in Sections 3 and 4 of that law. The Preferred Alternative meets one of these eight purposes: Agricultural Water Management (Purpose 5) through irrigation water conservation, water quality improvement, and agricultural water supply; fish and wildlife habitats would be conserved and improved through associated increases in streamflow.

8.3 Measures to be Installed

TID would replace 1.9 miles of the TFC and 66.9 miles of laterals in its system with gravity-pressurized buried pipe. The un-piped portion of the TFC would be piped with 84-inch HDPE. The remaining open portions of the delivery system would be pressurized with HDPE single-walled pipe. Pipe size, determined through hydraulic modeling, would range in diameter from 6 to 84 inches (TID 2017).

Under this alternative, 543 existing turnouts would be upgraded to pressurized delivery systems. Currently numerous TID existing turnouts are shared by patrons. In order to provide pressurization benefits and better water management, the majority of these shared turnouts would be converted to individual turnouts by the addition of approximately 119 new turnouts. The pressure of water deliveries can vary depending on the demands of other patrons and overall diversion flow into the system. On-farm piping, fittings, and other appurtenances for each patron may not be rated to accommodate these pressure fluctuations; therefore, a pressure relief valve was included for each upgrade and new turnout. Each turnout would also include an appropriately sized tee from the mainline or lateral, a gear-actuated plug valve, a magnetic meter, a combination air and vacuum relief valve, and associated hardware and spool pipe segments (TID 2017). Three pressure-reducing valves would also be installed as part of the Preferred Alternative to alleviate high pressures across the system. The improvements described above would be broken into seven project groups as summarized in Table 8-1. At the time the SIP was finalized, the number assigned to each group reflected the sequential order that each project group would be completed. Since the completion of the SIP, TID has decided to combine project groups; the naming of project groups in the Plan-EA reflect those combinations and are therefore different than those in the SIP.

Table 8-1. Summary of the Tumalo Irrigation District Canals and Laterals that would be Piped under the Preferred Alternative for the Tumalo Irrigation District—Irrigation Modernization Project.

Project Group	Canal(s) and/or Lateral(s) in Project Group	Project Components					
		Flow (gpm)	Diameter (in)	Pressure Rating Index	Length of Piping (feet)	Upgraded Turnouts	Pressure Reducing Valves
1	Tumalo Feed Canal	47,106-50,545	84	N/A	12,716	10	N/A
	Kerns	224	6	32.5			
2	Tumalo Res. Feed	299-11,473	6	32.5	81,596	127	N/A
	Steele	301-774	6-10	32.5			
	Rock Springs	288-333	6	32.5			
	Highline	800-3,756	6-24	17-32.5			
	2 Rivers	-	6-12	32.5			
	Parkhurst	672-2,761	6-18	21-32.5			
	Gill	0	6	32.5			
	Lacy	52-1,734	6-12	26-32.5			
3	Allen	7,698-11,492	28-34	26-32.5	25,519	46	N/A
	Allen Sublateral West	290-316	6	32.5			
	Allen Sublateral South	183-247	6	32.5			
	McGinnis Ditch	147-312	6	32.5			
4	West Branch Columbia So. West	4,771-7,535	6-28	26-32.5	61,551	91	1
	Beasley	153-687	6-8	26-32.5			
	Spaulding	1,671-3,226	6-20	19-26			
	N. Spaulding	142	6	19-32.5			
5	Couch	103-5,976	6-26	32.5	55,950	89	N/A
	West Couch	696-3,416	6-20	15.5-32.5			
	West Couch Sublateral East	384-1,166	6-10	26-32.5			
	Chambers (Lafores) Ditch	52-322	6	32.5			

Project Group	Canal(s) and/or Lateral(s) in Project Group	Project Components					
		Flow (gpm)	Diameter (in)	Pressure Rating Index	Length of Piping (feet)	Upgraded Turnouts	Pressure Reducing Valves
	East Couch	202-672	6-16	32.5			
	Gainsforth	161-282	6	32.5			
6	North Columbia So. West	334-2,615	6-16	32.5	90,163	221	2
	Jewett	880-2,256	10-16	26-32.5			
	Conarn East	75	6	26			
	Putnam	1,297-1,757	6-14	21-32.5			
	West Branch Columbia So. East	37-1,193	6-12	26			
	Conarn	85-355	6	26			
	Phiffer	302-1,679	6-12	32.5			
	Hooker Creek	888-1,260	10-12	32.5			
	Hammond	368-1,808	6-14	26-32.5			
	North Hammond	300-710	6-8	32.5			
	Columbia Southern TFC to PRV	18,555-33,899	48-63	21-32.5			
	Columbia Southern PRV to Tail	10,280-17,760	6-42	26-32.5			
	North Columbia So. East	37-1,794	6-24	32.5			
7	Hillburner	338-676	6-24	32.5	35,650	79	N/A
	Gerking	75-494	6-8	19-21			
	Kickbush	461-574	6-8	21			
	West Branch Columbia So. South	561-1,215	6-8	26			
	Flannery Ditch	162-452	6-12	26			
	Tellin Ditch	202-589	6	32.5			
				Total Quantity	**363,145**	**663**	**3**

Construction of the HDPE Piping Alternative would include mobilization and staging of construction equipment, delivery of pipe to construction areas, excavation of trenches, fusing of pipelines, placement of pipe, compaction of backfill, and restoration and reseeding of the disturbed areas. In some locations, construction access would need to be created prior to bringing pipes or equipment into construction areas. This could include removal of vegetation within the construction area. Appropriately sized construction equipment would be used to minimize disturbance in the construction area. Borrow material would most likely be needed to backfill the canal surrounding the pipeline, assuming little to no material is available from prior canal dredging activities.

Construction would generally occur during the off-irrigation season (mid-October to March) with the majority of construction taking place during the first quarter of each calendar year. Project Group 1 construction could begin as early as the last few months of 2018.

Implementation of this project would be one component of a broader natural resource management effort by TID and other organizations in the area. In 2016, the State of Oregon approved TID's Water Management and Conservation Plan (Tumalo Irrigation District and Black Rock Consulting 2016). TID identified piping irrigation canals and providing pressurized water as integral parts of reaching the Deschutes River Conservancy's goal of 250 cfs for the Deschutes River. The Deschutes River Conservancy's goal is based on the ODFW pending instream water right for 250 cfs in the Middle Deschutes reach, where flows are rarely met during the irrigation season. Therefore, this additional flow from the Preferred Alternative would assist in meeting these junior water rights. Additionally, through its membership with seven other irrigation districts in the DBBC, TID is working to coordinate assets and resources to improve patron services, conserve water, and enhance river conditions for wildlife and recreation throughout the Deschutes Basin. Other DBBC districts are concurrently pursuing system modernization through piping and pressurization and are collaborating with state and federal agencies, local municipalities, and environmental groups to develop a multispecies HCP. The HCP is planned for completion in 2019.

8.4 Minimization, Avoidance, and Compensatory Mitigation Measures

Project design features and BMPs that would be applied during construction to avoid and minimize effects on environmental and social resources are described below.

8.4.1 Pre-Construction

- Adjacent landowners would be provided a construction schedule prior to beginning construction.
- Ground disturbances would be limited to only those areas necessary to safely implement the Preferred Alternative.
- Work would be confined within the existing ROW whenever possible to preserve existing vegetation and private property. The ROW would be clearly marked in the field prior to construction.

- Within the ROW that crosses the Peck's milkvetch ACEC, a survey would be completed for Peck's milkvetch. If plants were detected, ndividual plants affected by construction would be excavated, potted, cared for, and replanted during the appropriate planting window. Surveys and mitigation would be done in consultation with BLM.
- Construction limits would be clearly flagged onsite to avoid unnecessary plant loss or ground disturbance.
- Disturbance of jurisdictional wetlands would be avoided during construction.
- Appropriate erosion control measures would be utilized.
- The condition of roadways and work zones would be communicated to travelers via the District's website or other communication channels.
- Site-specific archaeological and historical resource surveys would be completed prior to construction.

8.4.2 Construction

- Stormwater and erosion BMPs would be implemented as appropriate.
- Construction would generally occur during the daytime and in the winter months to minimize disturbance to recreationists, landowners, or other individuals in the vicinity of the project area.
- Construction would occur primarily outside the USFWS-approved buffer distances for any known bald and golden eagle nests. If operating within the recommended buffer distance, the District would operate outside of the nesting season.
- Should an active bald or golden eagle nest be found during construction, construction would be paused and a consultation with a local USFWS biologist would occur to determine the following steps.
- Construction would occur primarily outside the primary nesting period for migratory birds of concern (April 15 through July 15) and raptors (April through July). For rare occasions where construction would occur during the primary nesting period, construction work would operate outside of the recommended buffer distance of any known nests. Should an active nest be found, construction would be paused and consultation with a local USFWS biologist would occur to determine the following steps.
- In appropriate cases and under consultation with ODFW, ramps would be placed in pipeline trenches to avoid the potential of wildlife becoming trapped overnight.
- Appropriate emission control devices would be required for all construction equipment.
- Work crews would carry spill cleanup kits, and in times of burn bans or wildfire concerns, each crew would have a fire suppression kit.

- Project construction activities would be conducted in accordance with the project's spill prevention and cleanup plan.
- Temporary travel routes would be selected and utilized to minimize effects on vegetation and avoid the removal of trees.
- Selection of construction areas adjacent to canals and travel routes would consider existing vegetation and avoid mature trees to the extent practicable.
- Pruning would be entirely within TID's ROW and would not exceed what is required for equipment clearance.
- During construction, the contractor would use erosion control measures that are free of weeds and weed seeds.
- When needed, water or other dust suppressants would be used on unpaved roads and areas of ground disturbance to minimize dust and any effects on air quality.
- Standard construction safety procedures and traffic control measures would be employed to reduce the risk of collisions between construction vehicles and other vehicles, pedestrians, or bicyclists while construction is ongoing.
- Traffic control measures would be coordinated by the construction contractor with the Oregon Department of Transportation, the Deschutes County Sheriff, and local emergency services prior to working in the U.S. Highway 20 ROW.
- Lane closures on roadways would be avoided during peak travel periods where possible to reduce potential traffic delays from construction vehicles.
- The condition of roadways and work zones would be communicated to travelers via the District's website, or other communication channels.
- Immediately after construction, areas with disturbed soils and newly covered pipes would be planted with a seed mix of native grasses and forbs. Vegetation within the ROW would be maintained according to TID's vegetation management program and NRCS Oregon and Washington's Guide for Conservation Seedings and Plantings (NRCS 2000).
- After construction, areas adjacent to the canal would be restored to near prior contours in order to blend with the surrounding landscape.
- Following completion of individual project groups, conserved water would be allocated to permanent instream water rights in Tumalo Creek, Crescent Creek, the Little Deschutes River, and the Deschutes River through Oregon's Allocation of Conserved Water Program (ORS 537.470).
- Further consultation resulting in a Memorandum of Agreement would be completed between SHPO, NRCS, and the District, addressing cultural resource concerns and agreed upon mitigation measures for all features found to be eligible for inclusion on the National

Register of Historic Places. Mitigation measures would be completed concurrently with or after construction.

- Mitigation measures under consideration for effects on cultural resources include informational signing at trailheads or publicly significant locations, development of an informational brochure for interpretative use, and historical information for the District's website.
- An Inadvertent Discovery Plan would be followed if archaeological or historical materials, including human remains, are encountered during construction. The plan would require construction to stop accordingly, consultation with SHPO and NRCS cultural resources staff, and notification to appropriate Tribes. Continuation of construction would occur in accordance with applicable guidance and law.

8.4.3 Operations and Maintenance

- Vegetation within the ROW would be maintained according to TID's vegetation management program and NRCS Oregon and Washington's Guide for Conservation Seedings and Plantings (NRCS 2000).
- Weeds would be controlled within the ROW using hand pulling during the first year after reseeding, and a combination of hand pulling and spot spraying in the second year if weeds become problematic. Thereafter, weeds would be managed per county standards.
- At adjacent landowner's requests and during maintenance season, the District would remove trees in the ROW that do not survive piping for two years following construction.

8.5 Land Rights and Easements

The Preferred Alternative and construction activities would be located entirely within the District's ROW, which were granted under the Carey Act. The District's ROW under the Carey Act extends 50 feet on each side of the canal from the toe of the bank for a total easement width of 100 feet plus the width of the canal.

8.6 Permits and Compliance

As discussed in Section 8.3, the Preferred Alternative would be implemented in project groups. Permitting specific to each project group would be conducted at the time that funding is available for implementation. Prior to implementing each project group, NRCS would complete an onsite EE utilizing NRCS-CPA-52 form. This process would determine if that project group meets the applicable project specifications and other conditions as developed in this EA and assess the environmental effects of any alternatives to the project group. If it is determined that there are significant issues or concerns, or if resource concerns have not been adequately evaluated through the programmatic approach in this EA, a separate analysis and appropriate agency consultation would be prepared as necessary.

Further, TID would acquire all necessary permits prior to construction. These may include the following:

8.6.1 Local and County

- **Deschutes County Planning**: Under OAR Chapter 340, Division 18, a Land Use Compatibility Statement would be submitted for county approval prior to construction.
- **Deschutes County Floodplain Administrator**: All work would be outside of the 100-year floodplain; no permitting requirement has been identified.

8.6.2 State

- **Department of Environmental Quality**: The National Pollutant Discharge Elimination System program, implemented by ODEQ, would require a permit for construction activities including clearing, grading, excavation, and materials and equipment staging and stockpiling that would disturb one or more acres of land and have the potential to discharge into a public waterbody. The seven project groups under the Preferred Alternative would each disturb more than 5 acres but none of them discharges into a public waterbody.
- **Oregon Water Resources Department**: To change the place of use, character of use, and/or point of diversion/appropriation of a water right, a water right transfer application must be approved by OWRD. The District would apply for an Allocation of Conserved Water associated with the Preferred Alternative under ORS 537.
- **Department of State Lands**: A wetland fill permit from ODSL would not be required for work in existing canals and laterals. Prior to initiation of construction of each project group, a wetland determination and/or delineation would be conducted, and wetlands would be avoided to the extent practicable. If jurisdictional wetlands occur in areas outside of canals where work will be done, a wetland fill permit from ODSL would be obtained.
- **Oregon Fish Passage Law:** Since August 2001, the owner or operator of an artificial obstruction located in waters in which native migratory fish are currently or were historically present must address fish passage requirements prior to certain trigger events, such as the construction, installation, replacement, extension, or repair of culverts, roads, or any other hydraulic facilities. Laws regarding fish passage are found in ORS 509.580 through ORS 509.910 and in OAR 635, Division 412. TID's irrigation diversions have functioning fish screens and provide both upstream and downstream fish passage; no fish are present within existing canals and laterals, therefore no additional consultation, or permitting is required.
- **Oregon Department of Transportation:** The District would apply for all pertinent construction permits as required by ODOT prior to beginning construction.

8.6.3 Federal

- **Bureau of Land Management:** No permitting is necessary due to the ownership seniority of TID's Carey Act ROW over BLM. Consultation will occur as it relates to Peck's milkvetch conservation prior to construction.
- **National Historic Preservation Act Section 106**: Pursuant to 36 CFR Part 800 of the NHPA (1966, as amended in 2000), and the regulations of the Advisory Council on Historic

Preservation implementing Section 106 of the NHPA (54 U.S.C. 306108), federal agencies must take into account the potential effect of an undertaking on "historic properties," which refers to cultural resources listed in or eligible for listing in the National Register of Historic Places. Consultation with SHPO to fulfill Section 106 obligations would be completed for each project group prior to implementation.

- **Clean Water Act:**
  - **Section 404**: Under Section 404(f)(1)(C) of the CWA, discharges of dredged or fill material associated with construction or maintenance of irrigation ditches, or the maintenance (but not construction) of drainage ditches, are not prohibited by or otherwise subject to regulation under Section 404. Discharges of dredged or fill material associated with siphons, pumps, headgates, wingwalls, weirs, diversion structures, and such other facilities as are appurtenant to and functionally related to irrigation ditches are included in the exemption for irrigation ditches. Under 33 CFR 323.4(a)(1)(iii)(C)(1)(i), "[c]onstruction and maintenance of upland (dryland) facilities such as ditching and tiling, incidental to the planting, cultivating, protecting, or harvesting of crops, involve no discharge of dredged or fill material into waters of the U.S., and as such never require a Section 404 permit." The construction and maintenance of irrigation ditches and maintenance of drainage ditches may require the construction and/or maintenance of a farm road. Subsection 404(f)(1)(E) exemption for discharges of dredged or fill material associated with the construction or maintenance of farm roads applies where such related farm roads are constructed and maintained in accordance with BMPs. However, in 33 CFR 323.4(a)(6) and 40 CFR 232.3(c)(6), there must be assurance that flow and circulation patterns and chemical and biological characteristics of waters of the U.S. are not impaired, that the reach of the waters of the U.S. is not reduced, and that any adverse effect on the aquatic environment would be otherwise minimized. Prior to construction activities, coordination and consultation with USACE will occur and measures taken as required to identify and mitigate impacts to potential jurisdictional wetlands and waters of the United States.
  - **Section 401**: Implemented by ODEQ, see above.

- **Farmland Protection Policy Act:** The Farmland Protection Policy Act (7 U.S.C. 4201 *et seq.*) directs federal agencies to identify and quantify adverse impacts of federal programs on farmlands. The Act's purpose is to minimize the number of federal programs that contribute to the unnecessary and irreversible conversion of agricultural land to nonagricultural uses. The project occurs primarily in EFU zones; however, all work would be done within TID's easements and ROW. The project would support agricultural productivity and the intention of the Act.

- **Endangered Species Act:** The ESA establishes a national program for the conservation of threatened and endangered species and the preservation of the ecosystems on which they depend. The ESA is administered by the USFWS for wildlife and freshwater species, and by NMFS for marine and anadromous species. The ESA defines procedures for listing species, designating critical habitat for listed species, and preparing recovery plans. It also specifies prohibited actions and exceptions. Section 7 of the ESA, called "Interagency Cooperation," is the mechanism by which federal agencies ensure the actions they take, including those they fund or authorize, do not jeopardize the existence of any listed species. Under Section 7 of the ESA, federal agencies must consult with USFWS when any action the agency carries out, funds, or authorizes (such as through a permit) *may affect* a listed endangered or threatened species.

- Due to the magnitude and timing of increased instream flow in the Deschutes River in relation to the life history of bull trout populations located in the Deschutes River, these populations and associated critical habitat would not be affected by implementation of either action alternative under consideration. It has been determined, however, that implementation of either action alternative could affect, but is not likely to adversely affect, Oregon spotted frog because of entirely beneficial actions. Informal consultation with USFWS under ESA section 7 has been initiated and a letter of concurrence with these determinations has been received by the Service (see Appendix E.9 of this Plan-EA).

- The Middle Columbia River steelhead population, present in the Deschutes River upstream from the Pelton Round Butte Dam complex, is classified as a non-essential experimental population under section 10(j) of ESA. Because this population is located outside of a National Wildlife Refuge System and a National Park System, the action alternatives would not likely jeopardize the continued existence of the species, and the action alternatives are entirely beneficial, the population is treated as "proposed for listing". NRCS, therefore, has determined that engagement with NMFS to obtain a conference report is not necessary (76 *Federal Register* 28715, 2011; 81 *Federal Register* 33416, 2016).

- **Magnuson Stevens Act:** The Magnuson-Stevens Act established requirements for including Essential Fish Habitat (EFH) descriptions in federal fishery management plans, and requires federal agencies to consult with NMFS on activities that may adversely affect EFH (Pub. L. No. 104-297). EFH can include all streams, lakes, ponds, wetlands, and other viable waterbodies, and most of the habitat historically accessible to salmon necessary for spawning, breeding, feeding, or growth to maturity. As the project would not affect EFH, consultation under the Magnuson Stevens Act is not required.

- **Safe Drinking Water Act**: Since the project would have no direct or indirect discharge to groundwater, permitting under the Safe Drinking Water Act is not required.

- **Migratory Bird Treaty Act:** The MBTA implements various treaties and conventions between the US and other countries, including Canada, Japan, Mexico, and the former Soviet Union, for the protection of migratory birds (16 U.S.C. 703–712). Under the Act, taking, killing, or possessing migratory birds, or taking, destroying, or possessing their eggs or nests, is unlawful. The Act classifies most species of birds as migratory, except for upland and nonnative birds such as pheasant, chukar, gray partridge, house sparrow, European starling, and rock dove.

- **Bald and Golden Eagle Protection Act**: The BGEPA prohibits the taking or possessing of and commerce in bald and golden eagles, with limited exceptions (16 U.S.C. 668–668d). The Act only covers international acts of acts in "wanton disregard" of the safety of bald or golden eagles. Two potential golden eagle nests are known to occur within 660 feet of the project area and requirements of the Act would be implemented appropriately.

8.7 Costs

Table 8-2 presents the total project cost of $43,326,000 for the Preferred Alternative. PL 83-566 funds would provide $29,781,700 of the total project cost where the remainder of the cost, $13,544,300, would be contributed by other, non-federal funds. Table 8-3 itemizes the costs for each project feature and distributes the costs between the sponsors and NRCS for each cost item.

- Construction cost accounts for all material, labor, and equipment necessary for the installation of pipe associated with the Preferred Alternative. These costs were estimated based on costs for similar installations at irrigation districts in central Oregon. Construction costs were estimated using the best available information about the project without having detailed design information.
- Engineering costs were estimated as a percentage of the cost of construction. The percentage applied for engineering costs depends on the scale of the particular pipe installation.
- The costs presented are planning level estimates and do not reflect final costs. Detailed designs and construction cost estimates would be completed prior to initiating the project. Final construction costs would only reflect the time and materials to perform the work.

8.8 Installation and Financing

The following sub-sections present the installation and financing of the Preferred Alternative. This section outlines a framework for implementing the Preferred Alternative; the sequence of installation; responsibilities of NRCS and the sponsors; contracting; real property and relocations; financing; and conditions for providing assistance.

8.8.1 Framework for Carrying out the Plan

The TID Irrigation Modernization Project would be implemented in a planned sequence as discussed in the following Section 8.8.2. The responsibilities of NRCS and the sponsors for the project are outlined in Section 8.8.3. No cost-shared on-farm measures are involved with this project; therefore, the responsibilities of individual participants do not need to be discussed. No preconditions are anticipated for installing the project.

8.8.2 Planned Sequence of Installation

The District would obtain all approvals and permits for the project prior to the start of construction. The project would be implemented in seven project groups as presented in Table 8-1. It is expected that Project Group 1 would occur over two years, Project Group 2 would occur over two years, and Project Group 6 would occur over three years. Project Groups 3-5 are each expected to be constructed over one year. The entire project (all seven project groups) would be completed over an 11-year period commencing in 2018 and ending in 2028.

8.8.3 Responsibilities

NRCS is responsible for leading the planning efforts, providing engineering design and construction oversight assistance, and certifying completion of the project. The District would be responsible for engineering design, project administration, environmental permitting, contracting, and construction implementation. The District has the needed authorities as an irrigation district organized under ORS 545 and has agreed to exercise those authorities to implement the actions described in the Plan-EA.

8.8.4 Contracting

The piping and pressurization of the delivery system would be completed using NRCS funding mechanisms. The District would be primarily responsible for overseeing and administering the construction of the project in coordination with NRCS.

8.8.5 Real Property and Relocations

Real property acquisition or relocations would not be required for the Preferred Alternative. All construction would be completed under TID's existing ROW as described in Section 8.5.

8.8.6 Financing

NRCS would provide 69 percent of the total project cost for the Preferred Alternative through PL 83-566 funding. The District is responsible for funding the remaining 31 percent of the costs, including funds that are not eligible under the National Watershed Program. Table A in the NED presents annual installation costs of each project group and the proportion of funding provided through PL 83-566 funding and other funding sources.

The District has a strong history of securing public and private funding through grants, loans, and patron assessments. According to TID's District Manager (K. Rieck, personal communication, July 25, 2017), nearly all funding is expected to be provided through grants (private or non-federal public). If necessary, approximately 31 percent of the project would be financed in this manner. If financing is required, TID expects to apply for funding through the ODEQ Clean Water State Revolving Fund. The District expects that funding from this source would be at an interest rate of 2.5 percent with a 0.5 percent annual fee paid on the remaining loan balance. These financing costs are not included in the NED analysis.

O&M costs after project completion would be provided through TID's revenues. O&M costs would not increase due to the project and would be budgeted on an annual basis.

NRCS reserves the authority and right to discontinue or reduce program benefits based on changes in agency priorities, funding availability, or TID's failure to fulfill the provisions of their agreement.

8.8.7 Conditions for Providing Assistance

Conditions for TID to receive program funds for the proposed project include TID completing a Final Watershed Plan-Environmental Assessment and NRCS issuing a Finding of No Significant Impact.

8.9 Operation, Maintenance, and Replacement

The District would be responsible for the O&M of the project for the 100 years of its design life. Prior to construction, NRCS and TID would make a separate O&M agreement based on NRCS's National Operation and Maintenance Manual. The agreement would continue through the design life of the project and could be modified with NRCS's approval.

Project sponsors and NRCS would make annual inspections of project measures to assure the quality of ongoing operations and maintenance. The District would be in charge of scheduling operations and maintenance inspections and responsible for any necessary work. The District's O&M would consist of an ongoing pipe inspection program that would systematically inspect the entire system over a period of several years (most likely a 10-year cycle).

The proposed system would continue its current operation schedule of April to mid-October, during which work would be performed on an as-needed basis. Outside of that period, TID would perform system component maintenance including valve battery changes, magnetic meter maintenance, District operational valve maintenance, air and vacuum valve maintenance, pressure reducing station filter maintenance, and valve repairs. The District would expand their current vegetation and weed management to include the areas on top of the newly piped system. All procedures would be followed as specified in the O&M agreement between project sponsors and NRCS.

8.10 Economic and Structural Tables

A summary of the economic analysis of the Preferred Alternative (NED Alternative), Canal Lining Alternative, and No Action Alternative is provided in Section 5.4. The full NED Analysis can be found in Appendix D. The Preferred Alternative would result in varying average annual benefits, costs, and benefit-cost ratios depending on the Project Group being implemented. Average annual benefits would range from $124,100 to $495,800; average annual costs would be between $46,400 and $350,400; and benefit-cost ratios fall between 1.00 and 2.67. Additionally, Appendix D contains an incremental analysis of the benefits and costs of completing each additional increment of the Preferred Alternative. The costs and benefits associated with each individual project group are gone into more detail in the following tables in this section. Table 8-2 (NWPM 506.11, Economic Table 1) presents the projected installation costs and the percentages of costs to be shared by the sponsors and NRCS for each project group.

Table 8-2. Economic Table 1—Estimated Installation Cost of the HDPE Piping Alternative, Water Resource Project Measures, Deschutes Watershed, Oregon, 2017$.[1,2]

Works of Improvement	Unit	Number			Estimated Cost (dollars)						
					Public Law 83-566 Funds			Other Funds			Total
		Federal land[3]	Non-Federal land	Total	Federal land NRCS[4]	Non-Federal land NRCS	Total	Federal land	Non-Federal land	Total	
Project Group 1	Feet	0	12,716	12,716	$0	$5,179,000	$5,179,100	$0	$1,757,000	$1,756,800	$6,935,900
Project Group 2	Feet	11,660	69,936	81,596	$787,000	$4,719,000	$5,505,300	$243,000	$1,460,000	$1,703,900	$7,209,200
Project Group 3	Feet	2,193	23,326	25,519	$260,000	$2,760,000	$3,019,600	$81,000	$862,000	$943,600	$3,963,200
Project Group 4	Feet	9,634	51,917	61,551	$557,000	$3,002,000	$3,559,400	$174,000	$935,000	$1,108,700	$4,668,100
Project Group 5	Feet	1,620	54,330	55,950	$86,000	$2,880,000	$2,965,700	$27,000	$900,000	$927,200	$3,892,900
Project Group 6	Feet	436	89,727	90,163	$45,000	$9,242,000	$9,287,200	$26,000	$5,331,000	$5,357,100	$14,644,300
Project Group 7	Feet	0	35,650	35,650	$0	$265,000	$265,400	$0	$1,747,000	$1,747,000	$2,012,400
Total project	Feet	25,544	337,601	363,145	$1,735,000	$28,047,000	$29,781,700	$551,000	$12,992,000	$13,544,300	$43,326,000

Notes: Totals may not sum due to rounding

Prepared: June 2018

1. Price base: 2017 dollars.
2. Project cost as identified in the Tumalo Irrigation District System Improvement Plan prepared by Black Rock Consulting, 2016, updated to 2017 dollars and including an additional three percent project administration cost and eight percent technical assistance cost as well as permitting costs.
3. The Project would cross BLM land; however, BLM is not assisting in the installation of the works of improvement.
4. Federal agency responsible for assisting in installation of works of improvement.

Table 8-3 (NWPM Economic Table 2, 506.12), presents the project's cost distribution across project groups as well as the proportion of PL 83-566 funding and other funding sources. The average annual NED costs are shown in Table 8-4 (NWPM 506.18, Economic Table 4).

Table 8-3. Economic Table 2 —Estimated HDPE Piping Alternative Cost Distribution, Water Resource Project Measures, Deschutes Watershed, Oregon, 2017$.[1,2]

Works of Improvement	Installation Costs—PL 83-566 Funds				Installation Cost—Other Funds				Total Installation Costs
Piping	**Construction**	**Engineering**	**Project Admin[3]**	**Total PL 83-566**	**Construction**	**Engineering**	**Project Admin[3]**	**Total Other**	
Project Group 1	$4,748,100	$150,000	$281,000	$5,179,100	$1,582,700	$50,000	$124,100	$1,756,800	$6,935,900
Project Group 2	$4,605,600	$251,700	$648,000	$5,505,300	$1,535,200	$83,900	$84,800	$1,703,900	$7,209,200
Project Group 3	$2,540,900	$123,700	$355,000	$3,019,600	$846,900	$41,200	$55,500	$943,600	$3,963,200
Project Group 4	$2,972,600	$167,800	$419,000	$3,559,400	$990,900	$55,900	$61,900	$1,108,700	$4,668,100
Project Group 5	$2,459,800	$156,900	$349,000	$2,965,700	$820,000	$52,300	$54,900	$927,200	$3,892,900
Project Group 6	$7,573,000	$397,200	$1,317,000	$9,287,200	$5,072,900	$132,300	$151,900	$5,357,100	$14,644,300
Project Group 7	$0	$85,400	$180,000	$265,400	$1,680,600	$28,500	$37,900	$1,747,000	$2,012,400
TOTAL COSTS	$24,900,000	$1,332,700	$3,549,000	$29,781,700	$12,529,200	$444,100	$571,000	$13,544,300	$43,326,000

Notes: Totals may not sum due to rounding. Prepared: June 2018

1. Price base: 2017 dollars.
2. Project cost as identified in the Tumalo Irrigation District System Improvement Plan prepared by Black Rock Consulting, 2016, updated to 2017 dollars and including an additional 3 percent project administration cost and 8 percent technical assistance cost. Of total estimated costs presented in the System Improvement Plan, Black Rock Consulting estimated 75 percent is for construction and 25 percent for engineering.
3. Project Admin includes project administration, technical assistance costs, and permitting costs.

Table 8-4. Economic Table 4—Estimated Average Annual NED Costs, Deschutes Watershed, Oregon, 2017$.[1]

Works of Improvement[2]	Project Outlays (Amortization of Installation Cost)	Other Direct Costs[3] (Increased Pumping Costs Elsewhere in Basin from Reduced GW Recharge)	Total Cost
Project Group 1	$199,800	$5,200	$205,000
Project Group 2	$198,300	$2,400	$200,700
Project Group 3	$104,700	$1,300	$106,000
Project Group 4	$120,100	$1,400	$121,500
Project Group 5	$97,400	$1,000	$98,400
Project Group 6	$346,300	$4,100	$350,400
Project Group 7	$45,200	$1,200	$46,400
Total	**$1,111,800**	**$16,600**	**$1,128,400**

Notes: Totals may not sum due to rounding. Prepared: June 2018

1. Price base: 2017 dollars, amortized over 100 years at a discount rate of 2.75 percent.
2. Project groups would be completed over the course of one to three years each, such that Group 1 is completed in Year 1 and Group 7 is completed in Year 11.
3. Other direct costs include the uncompensated economic losses due to changes in resource use or associated with installation, operation, or replacement of project structures. For Project Groups 2 -7, other direct costs are presented for increased pumping costs elsewhere in the basin from reduced groundwater recharge (i.e. seepage from unlined canals). For Project Group 1, other direct costs include the cost of increased carbon emissions associated with increased groundwater pumping energy use (in all other project groups, total groundwater energy use declines so carbon is a benefit). This does not include operations, maintenance, and repair costs because these decline under the HDPE Piping Alternative, so these are presented as a benefit.

The Preferred Alternative damage reduction benefits included agricultural yields, power cost savings, reduced O&M costs, improved fish and wildlife habitat and avoided carbon emissions. Table 8-5 (NWPM 506.20, Economic Table 5a) presents the average annual watershed protection damage reduction benefits across all project groups.

Table 8-5. Economic Table 5a—Estimated Average Annual Watershed Protection Damage Reduction Benefits Tumalo Irrigation District 2017 Watershed Plan, Deschutes Watershed, Oregon, 2017$.[1]

	Damage Reduction Benefit, Average Annual	
Item	**Agricultural- related**	**Non-Agricultural- related**
Project Group 1		
On-Site Damage Reduction Benefits		
Other - Reduced O&M	$5,000	
Other - Power Cost Savings	$700	
Subtotal	$5,700	
Off-Site Damage Reduction Benefits		
Water Conservation		$199,900
Subtotal		$199,900
Total Quantified Benefits	$5,700	$199,900
Project Group 2		
On-Site Damage Reduction Benefits		
Other - Reduced O&M	$30,600	
Other - Power Cost Savings	$49,500	
Subtotal	$80,100	
Off-Site Damage Reduction Benefits		
Other - Social Value of Carbon (Avoided Carbon Emissions)[2]		$19,200
Water Conservation		$170,000
Subtotal		$189,200
Total Quantified Benefits	$80,100	$189,200
Project Group 3		
On-Site Damage Reduction Benefits		
Other - Reduced O&M	$9,300	
Other - Power Cost Savings	$25,400	

	Damage Reduction Benefit, Average Annual	
Item	**Agricultural- related**	**Non-Agricultural- related**
Subtotal	$34,700	
Off-Site Damage Reduction Benefits		
Other - Social Value of Carbon (Avoided Carbon Emissions)[2]		$9,800
Water Conservation		$91,100
Subtotal		$100,900
Total Quantified Benefits	$34,700	$100,900
Project Group 4		
On-Site Damage Reduction Benefits		
Other - Reduced O&M	$21,800	
Other - Power Cost Savings	$58,400	
Subtotal	$80,200	
Off-Site Damage Reduction Benefits		
Other - Social Value of Carbon (Avoided Carbon Emissions)[2]		$23,900
Water Conservation		$101,000
Subtotal		$124,900
Total Quantified Benefits	$80,200	$124,900
Project Group 5		
On-Site Damage Reduction Benefits		
Other - Reduced O&M	$19,300	
Other - Power Cost Savings	$31,400	
Subtotal	$50,700	
Off-Site Damage Reduction Benefits		
Other - Social Value of Carbon (Avoided Carbon Emissions)[2]		$12,600
Water Conservation		$70,200

	Damage Reduction Benefit, Average Annual	
Item	**Agricultural- related**	**Non-Agricultural- related**
Subtotal		$82,800
Total Quantified Benefits	$50,700	$82,800
Project Group 6		
On-Site Damage Reduction Benefits		
Other - Reduced O&M	$29,600	
Other - Power Cost Savings	$133,100	
Subtotal	$162,700	
Off-Site Damage Reduction Benefits		
Other - Social Value of Carbon (Avoided Carbon Emissions)[2]		$53,600
Water Conservation		$279,500
Subtotal		$333,100
Total Quantified Benefits	$162,700	$333,100
Project Group 7		
On-Site Damage Reduction Benefits		
Other - Reduced O&M	$11,000	
Other - Power Cost Savings	$27,000	
Subtotal	$38,000	
Off-Site Damage Reduction Benefits		
Other - Social Value of Carbon (Avoided Carbon Emissions)[2]		$10,500
Water Conservation		$75,600
Subtotal		$86,100
Total Quantified Benefits	$38,000	$86,100

Notes: Totals may not sum due to rounding. Prepared: June 2018

1. Price base: 2017 dollars amortized over 100 years at a discount rate of 2.75 percent.
2. These benefits would also accrue to local residents, but the majority of the value would be experienced outside the proposed project area.

Using the resulting benefits and costs from the previous two tables, Table 8-6 (NWPM 506.21, Economic Table 6) presents a comparison of the NED average annual benefits and average annual costs.

Table 8-6. Economic Table 6— Comparison of Average Annual NED Costs and Benefits, Tumalo Irrigation District 2017 Watershed Plan, Deschutes Watershed, Oregon, 2017$.[1]

Works of Improvement	Agriculture-related		Non-agricultural		Average Annual Benefits	Average Annual Cost[2]	Benefit Cost Ratio
	Reduced O&M	Power Cost Savings	Carbon Value	Instream Flow Value			
Project Group 1	$5,000	$700	$0	$199,900	$205,600	$205,000	1.00
Project Group 2	$30,600	$49,500	$19,200	$170,000	$269,300	$200,700	1.34
Project Group 3	$9,300	$25,400	$9,800	$91,100	$135,600	$106,000	1.28
Project Group 4	$21,800	$58,400	$23,900	$101,000	$205,100	$121,500	1.69
Project Group 5	$19,300	$31,400	$12,600	$70,200	$133,500	$98,400	1.36
Project Group 6	$29,600	$133,100	$53,600	$279,500	$495,800	$350,400	1.41
Project Group 7	$11,000	$27,000	$10,500	$75,600	$124,100	$46,400	2.67
Total	$126,600	$325,500	$129,600	$987,300	$1,569,000	$1,128,400	1.39

Notes: Totals may not sum due to rounding. Prepared: June 2018

1. Price base: 2017 dollars amortized over 100 years at a discount rate of 2.75 percent.
2. From Economic Table 4.

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10 List of Preparers

Under the direction of NRCS, the Plan-EA was primarily developed by FCA and its subcontractor Highland Economics. The staff responsible for preparation of the Plan-EA is included in Table 10-1.

Table 10-1. List of Preparers.

Name	Title	Education	Professional Experience	Area Responsible For
FCA Watershed Plan-EA Team				
Kristin Alligood	Program Specialist	Ph.D. Biology B.A. Neuroscience	4 years	Fish and Aquatic Species, Vegetation, Cumulative Effects
Mattie Bossler	Staff Engineer	B.S. Environmental Resource Engineering	5 years	Alternatives, Geology and Soils
Raija Bushnell	Program Specialist	M.P.A. Natural Resource Policy M.S.E.S Natural Resource Management B.A. Political Science	4 years	Land Use, Recreation, Vegetation, Alternatives
Brett Golden	Program Manager	M.E.M Environmental Management A.B. Environmental and Evolutionary Biology	11 years	General
Kate Hart	Program Specialist	M.S. Earth Science B.S. Earth Science	3 years	Geology and Soils, Alternatives, General GIS
David McKay	Program Specialist	M.P.A. Environmental Policy B.A. Political Science	3 years	Purpose and Need, Visual, Cultural Resources, Public Scoping
Amanda Schroeder	Program Specialist	B.S. Natural Resource Management	3 years	Water Resources, Wetlands, Wildlife, Socioeconomics, Alternatives, Wild and Scenic Rivers, General GIS
Alexis Vaivoda	Program Specialist	M.S. Environmental Science B.S. Biology	16 years	Fish and Aquatic Species, Cultural Resources, Public Safety, General

Name	Title	Education	Professional Experience	Area Responsible For
NRCS – Oregon				
Gary Diridoni	Natural Resource Specialist	Fisheries Management Graduate Certificate B.S. Wildlife Management B.S. Interdisciplinary Studies, Ecosystem Conservation	15 years	General
Tom Makowski	Assistant State Conservationist-Watershed Resources and Planning	Ph.D. Rural Sociology M.S. Social Psychology B.S. Recreation Resource Management	30 years	General
Lakeitha Ruffin	Agricultural Economist	M.S. Agricultural Economics B.S. Agricultural Economics	8 years	Economic and Socioeconomic Analysis, Alternative Analysis, Overall Watershed Planning
Employees from Firms Under Contract with FCA				
Company	**Name**	**Education**	**Professional Experience**	**Area of Responsibility**
Highland Economics	Barbara Wyse	M.S. Environmental and Natural Resource Economics B.A. Environmental Sciences and Policy	13 years	Economic Analysis
Highland Economics	Travis Greenwalt	M.B.A. B.S. Business Finance and Management	14 years	Economic Analysis
ERM	Sandy Slayton	M.A. Ecology B.A. Environmental Science	15 years	General

11 Distribution List

A Notice of Availability for the Draft Plan-EA was distributed to federal, state, and local agencies, community representatives, and area NGOs. The agencies, representatives and organizations on the mailing list include the following:

- Bend Parks and Recreation
- Business Oregon
- Bureau of Reclamation (Reclamation)
- Central Oregon Land Watch
- City of Bend
- Coalition for the Deschutes
- Deschutes County
- Deschutes River Conservancy (DRC)
- National Oceanic and Atmospheric Administration (NOAA) Fisheries
- Oregon Department of Agriculture (ODA)
- Oregon Department of Energy (ODOE)
- Oregon Department of Environmental Quality (ODEQ)
- Oregon Department of Fish and Wildlife (ODFW)
- Oregon Department of State Lands (ODSL)
- Oregon Governor's Office
- Oregon Water Resources Department (OWRD)
- Oregon Watershed Enhancement Board (OWEB)
- State Historic Preservation Office (SHPO)
- Trout Unlimited
- U.S. Army Corps of Engineers (USACE)
- U.S. Bureau of Land Management (BLM)
- U.S. Department of Agriculture, U.S. Forest Service (USFS), Deschutes National Forest
- U.S. Fish and Wildlife Service (USFWS)
- Upper Deschutes Watershed Council (UDWC)
- WaterWatch of Oregon

In accordance with EO 13175, Consultation and Coordination with Indian Tribal Governments, NRCS contacted CTWS regarding the availability of the Draft Plan-EA.

The names of private stakeholders and members of the public who received notice of the Draft Plan-EA are not listed for privacy.

12 Acronyms, Abbreviations, and Short-forms

°C	degrees Celsius
°F	degrees Fahrenheit
ACEC	Area of Critical Environmental Concern
BFC	Bend Feed Canal
BGEPA	Bald and Golden Eagle Protection Act
BLM	Bureau of Land Management
BMP	best management practice
BPRD	Bend Parks and Recreation District
Carey Act	Carey Desert Land Act of 1894, governing irrigation rights-of-way
CEQ	Council on Environmental Quality
cfs	cubic feet per second
CFR	Code of Federal Regulations
COID	Central Oregon Irrigation District
CTWS	Confederated Tribes of Warm Springs
CWA	Clean Water Act
DBBC	Deschutes Basin Board of Control
DBGM	Deschutes Basin Groundwater Mitigation
District	Tumalo Irrigation District
DRC	Deschutes River Conservancy
EA	Environmental Assessment
EE	Environmental Evaluation
EFU	Exclusive Farm Use
EIS	Environmental Impact Statement
EO	Executive Order
EQ	Environmental Quality
ESA	Endangered Species Act
FCA	Farmers Conservation Alliance
FEMA	Federal Emergency Management Agency
HAER	Historic American Engineering Record No. OR-151
HCP	Habitat Conservation Plan
HDPE	high-density polyethylene

HUC	Hydrologic Unit Code
MBTA	Migratory Bird Treaty Act
N/A	Not Applicable
NEPA	National Environmental Policy Act
NED	National Economic Development
NGO	non-governmental organization
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NWI	National Wetland Inventory
NWPH	National Watershed Program Handbook
NWPM	National Watershed Program Manual
O&M	operation and maintenance
OAR	Oregon Administrative Rule
ODA	Oregon Department of Agriculture
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ODOE	Oregon Department of Energy
ODSL	Oregon Department of State Lands
OMB	Office of Management and Budget
OM&R	operation, maintenance, and replacement
ORS	Oregon Revised Statute
ORV	Outstanding Remarkable Value
OWEB	Oregon Watershed Enhancement Board
OWRD	Oregon Water Resources Department
P&G	Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
PCE	Primary Constituent Element
PIR	Preliminary Investigative Report
PL 83-566	Watershed Protection and Flood Prevention Program, Public Law 83-566
Plan-EA	Watershed Plan-Environmental Assessment

Project	Tumalo Irrigation District Irrigation Modernization Project
psi	pound per square inch
PVC	Polyvinyl Chloride
Reclamation	United States Bureau of Reclamation
RED	Regional Economic Development
RFO	Responsible Federal Official
RM	River Mile
ROW	rights-of-way
SHPO	State Historic Preservation Office
SID	Swalley Irrigation District
SIP	System Improvement Plan
SLO	Sponsoring Local Organization
TFC	Tumalo Feed Canal
TID	Tumalo Irrigation District
TMDL	total maximum daily load
UDWC	Upper Deschutes Watershed Council
USACE	United States Army Corps of Engineers
USBLS	United States Bureau of Labor Statistics
U.S.C.	United States Code
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
U.S./US	United States

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14 Appendix A-E

Appendices are provided in a separate document.

Appendix A. Comments and Responses
Appendix B. Project Maps
Appendix C. Supporting Maps
Appendix D. Investigations and Analysis Reports
Appendix E. Other Supporting Information

Finding of No Significant Impact
For
Tuma/a Irrigation District Irrigation Modernization Project
Deschutes County, Oregon

I. Introduction

The Tumalo Irrigation District Irrigation Modernization Project is a federally-assisted action authorized for planning under Public Law 83-566, the Watershed Protection and Flood Prevention Act. This act authorizes the Natural Resources Conservation Service to provide technical and financial assistance to local project sponsors. The local sponsors of the Project are the Tuma lo Irrigation District (TID) and the Deschutes Basin Board of Control.

An environmental assessment (Plan-EA), attached and incorporated by reference into this finding, was undertaken in conjunction with the development of the watershed plan. The assessment was conducted in consultation with local, State, and Tribal Governments; Federal agencies; and interested organizations and individuals. Data developed during the assessment are available for public review at the following location:

U.S. Department of Agriculture
Natural Resources Conservation Service
1201 NE Lloyd Blvd; Suite 900
Portland, Oregon 97232

II. Recommended Action

The proposed action under consideration would modernize up to 1.9 miles of Tl D's irrigation canals and 66.9 miles of laterals as part of an agricultural water conveyance efficiency project. The purpose of this project is to improve water conservation, water delivery reliability, and public safety. Implementation of the Preferred Alternative would improve water delivery reliability for Tl D's patrons, conserve water for instream uses, reduce Tl D's operation and maintenance costs, reduce electricity costs from pumping, and improve public safety.

I must determine if the agency's Preferred Alternative will or will not be a major Federal action significantly affecting the quality of the human environment. The Plan-EA accompanying this finding has provided the analysis needed to assess the significance of the potential impacts from the selected alternative. The decision on which alternative is to be implemented and the significance of that alternative's impacts are discussed under part IV ofthis finding.

111. Alternatives

All alternatives brought forward through the assessment process were analyzed for four criteria: completeness, effectiveness, efficiency, and acceptability; and against the following five factors: satisfaction of purpose and need statement, relative costs, technological feasibility, logistics, and social and environmental consequences. Eleven alternatives were considered; nine were eliminated from full analysis due to inconsistency with the purpose and need for action or due to cost, logistics, existing technology, social, or environmental reasons as described in Section 5 of the Plan-EA.

The No Action Alternative, and two Action Alternatives were analyzed in full.

> No Action Alternative– construction activities associated with the project would not occur and TID would continue to operate and maintain its existing canals and pipe system in their current condition. The need for the project would still exist; however, TID would only modernize its infrastructure on a project-by-project basis as public interest and funding became available. This funding is not reasonably certain to be available under a project-by-project approach at the large scale necessary to modernize the TID's infrastructure.
>
> Canal Lining Action Alternative— TID would line 65.2 miles of open canals and laterals with a geomembrane covered by shotcrete.
>
> HDPE Pressurized Piping Alternative— TID would replace 1.9 miles of canals and 66.9 miles of laterals with gravity-pressurized HDPE buried pipe.

Based on the evaluation in the Plan-EA, I have identified the HDPE Pressurized Piping as the agency's Preferred Alternative. I have considered that the Preferred Alternative meets the four criteria and five factors listed above and is the most practical means of improving water conservation, water delivery reliability, and public safety on 68.8 miles of District-owned canals and laterals. No significant adverse environmental impacts will result from installation of the measures, it is the project sponsor's Preferred Alternative, and it has been identified as the National Economic Development Alternative.

In accordance with the Council on Environmental Quality's (CEQ) "40 Most Asked Questions" guidance on National Environmental Policy Act (NEPA), Question 37(a), NRCS has considered "which factors were weighed most heavily in the determination" when choosing the agency's Preferred Alternative to implement. Based on the Plan-EA, potential impacts to soil, water, plants, fish and wildlife, and human resources were heavily considered in the decision. As a result, the agency's Preferred Alternative would result in short and long term beneficial impacts to the environmental resources potentially impacted by the Preferred Alternative.

IV. Effects of the Recommended Action- Finding of No Significant Impact

To determine the significance of the action analyzed in this Plan-EA, the agency is required by NEPA regulations at 40 CFR Section 1508.27 and NRCS regulations at 7 CFR Part 650 to consider the context and intensity of the proposed action. Upon review of the NEPA criteria for significant effects and based on the analysis in the Plan-EA, I have determined that the action to be selected, the Preferred Alternative, would not have a significant effect upon the quality of the human environment. Therefore, preparation of an environmental impact statement (EIS) on the final action is not required under Section 102(2)(c) of NEPA, CEQ implementing regulations (40 CFR Part 1500-1508, Section 1508.13), or NRCS environmental review procedures (7 CFR Part 650). This finding is based on the following factors from CEQ's implementing regulations at 40 CFR Section 1508.27 and from NRCS regulations at 7 CFR Part 650: The environmental impacts of constructing the Preferred Alternative are not significant for the following reasons:

1) The Plan-EA evaluated both beneficial and adverse impacts of the Preferred Alternative. It is anticipated that the Preferred Alternative will result in long-term beneficial impacts for environmental resources (i.e., soil, water, animals, plants, and human resources). As a result of the analysis (discussed in detail in the Plan-EA Section 4 Affected Environment and incorporated by reference), the Preferred Alternative does not result in significant impacts to the human environment, particularly when focusing on the significant adverse impacts which NEPA is intended to help decision makers avoid, minimize, or mitigate.

2) The Preferred Alternative does not significantly affect public health or safety. The direct and indirect effects associated with the implementation of the Preferred Alternative are anticipated to provide long term beneficial impacts to improve natural ecosystem functions and mitigate public safety risks. Specifically, water, fish and wildlife, plants, soil, and human resource issues will be improved and protected through selection of the Preferred Alternative.

3) As analyzed in Section 6 of the Plan-EA, there are no anticipated significant effects to historic or cultural resources, fish and aquatic resources, geology and soils, land use, public safety, recreation, socioeconomic resources, vegetation, visual resources, water resources, wetland and riparian areas, wildlife resources, or wild and scenic rivers from selection of the Preferred Alternative. NRCS regulations (7 CFR Part 650) and policy (Title 420, General Manual, Part 401), require that NRCS identify, assess, and minimize or mitigate effects to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas. In accordance with these requirements, avoidance, minimization or mitigation has been incorporated into the Plan-EA Section 6 and 8.4. Unlike the No Action Alternative, the Preferred Alternative is expected to reduce environmental risks associated with past, present, and future actions.

4) The effects on the human environment are not considered controversial for the Preferred Alternative. There are no impacts associated with the proposed action that would be considered controversial.

5) The Preferred Alternative is not considered highly uncertain and does not involve unique or unknown risks.

6) The Preferred Alternative will not establish a precedent for future actions with significant effects, nor does it represent a decision in principle about future considerations.

7) Particularly when focusing on the significant adverse impacts which NEPA is intended to help decision makers avoid, minimize, or mitigate, the Preferred Alternative does not result in significant adverse cumulative impacts to the environment as discussed in Section 6.14 of the Plan-EA.

8) The Preferred Alternative will not cause the loss or destruction of significant cultural or historical resources as addressed in Section 6.1 of the Plan-EA. NRCS follows the procedures developed in accordance with a nationwide programmatic agreement between NRCS, the Advisory Council on Historic Preservation, and the National Conference of State Historic Preservation Officers, which called for NRCS to develop consultation agreements with State historic preservation officers and federally recognized Tribes (or their designated Tribal historic preservation officers). These consultation agreements focus historic preservation reviews on resources and locations that are of special regional concern to these parties.

9) The Preferred Alternative will not adversely affect endangered or threatened species, or designated critical habitat, as discussed in section 6.2, and 6.12 of the Plan-EA. NRCS has concluded that the Preferred Alternative either has no effect on threatened and endangered species or will not likely adversely affect threatened and endangered species due to entirely beneficial effects. The U.S. Fish and Wildlife Service, which has jurisdiction over these species, has reviewed our conclusions and is in the process of concurring with our determination.

   Three federally-listed species and their critical habitat may occur in the area potentially affected by the project; bull trout, Oregon spotted frog, and middle Columbia River steelhead. There would be no effect from the Proposed Action on bull trout and steelhead due to the timing of increased streamflow resulting from project actions and the location of the populations being at the very downstream end of where effects could be detectable.

Any effects to Oregon spotted frog and its critical habitat would be entirely beneficial. Overall, the presence (and legal protection) of conserved water from the Proposed Action would serve to benefit aquatic species and their habitat, thus the effects of the project on all aquatic species would be minor to moderate, and beneficial in the long term. Informal consultation with U.S. Fish and Wildlife Service was initiated over project effects in accordance with Section 7(A)(2) of the Endangered Species Act of 1973, as amended, requesting U.S. Fish and Wildlife Service concur with our determination that the Project may affect but not likely adversely affect Oregon spotted frog due to entirely beneficial effects.

10) The Preferred Alternative does not violate Federal, State, or local law requirements imposed for protection of the environment as noted in Section 8.6 of the Plan-EA. The major laws identified with the selection of the Preferred Alternative include the Clean Water Act, Endangered Species Act, National Historic Preservation Act, Bald and Golden Eagle Protection Act, and Migratory Bird Treaty Act. The Preferred Alternative is consistent with the requirements of these laws.

V. Consultation- Public Participation

NRCS announced the public scoping process on June 16, 2017 through a public notice and subsequent news release. Advertisements announcing the scoping period and associated scoping meeting were placed in two local and regional newspapers. TID posted a notice on their website and mailed a notice to their patrons. A project website, oregonwatershedplans.org, was launched to inform the public and share information.

The scoping process followed the general procedures consistent with NRCS guidance and PL 83-566 requirements. A scoping meeting was held July 6, 2017 in Bend, Oregon. During the scoping period, 212 comments regarding the project were received. These comments were received from 195 individuals, 14 non-governmental organizations, one state agency (Oregon Department of Environmental Quality), and two federal agencies (U.S. Fish and Wildlife Service and U.S. Forest Service).

Specific consultation was conducted with the State Historic Preservation Office and with the Confederated Tribes of Warm Springs to maintain the NRCS' government-to-government relationship between Native tribes.

The Plan-EA was transmitted to all participating and interested agencies, groups, and individuals for review and comment from April 16, 2018 to May 22, 2018. A public meeting was held on May 8, 2018, in Bend, Oregon to obtain public input for the plan and environmental evaluation. During the review period 57 comments regarding the project were received. These comments were received from 48 individuals, six non-governmental organizations, one municipality (City of Bend), four state agencies on behalf of the Regional Solutions Program and the Oregon Governor's Office (Oregon Department of Transportation, Oregon Department of Environmental Quality, Oregon Department of Fish and Wildlife, Oregon Water Resources Department), and one federal agency (U.S. Fish and Wildlife Service). Although U.S. Army Corps of Engineers did not provide comment on the plan, U.S. Army Corps of Engineers provided guidance that the U.S. Army Corps of Engineers will defer to commenting and consulting on the implementation stage of proposed projects rather than on the Plan-EA (Anita Andazola, 7/13/2018).

VI. Conclusion

To best meet the purpose and need of the proposed action, the HDPE alternative has been selected as the Preferred Alternative for implementation based upon best meeting the purpose and need while maximizing net economic benefits and is also the Preferred Alternative of the sponsors. The Plan-EA accompanying this finding has provided the analysis needed to assess the significance of the potential impacts from the Preferred Alternative. The decision on which alternative is to be implemented and the significance of that alternative's impacts are summarized from the Plan-EA in the Effects of the Recommended Action of this finding. Based upon a review of the Watershed Plan-EA and supporting documents, the Preferred Alternative is not a major Federal action significantly affecting the quality of the human environment. I have determined that implementing the Preferred Alternative will not significantly affect the quality of the human and/or natural environment, individually or cumulatively with other actions in the area. No environmental effects meet the definition of significance in context or intensity as defined at 40 CFR 1508.27. Therefore, an environmental impact statement is not required for the Project. This finding is based on consideration of the context and intensity of impacts as summarized in the Tumalo Irrigation District Irrigation Modernization Project Plan-EA. With these findings, NRCS therefore has decided to implement the Preferred Alternative.

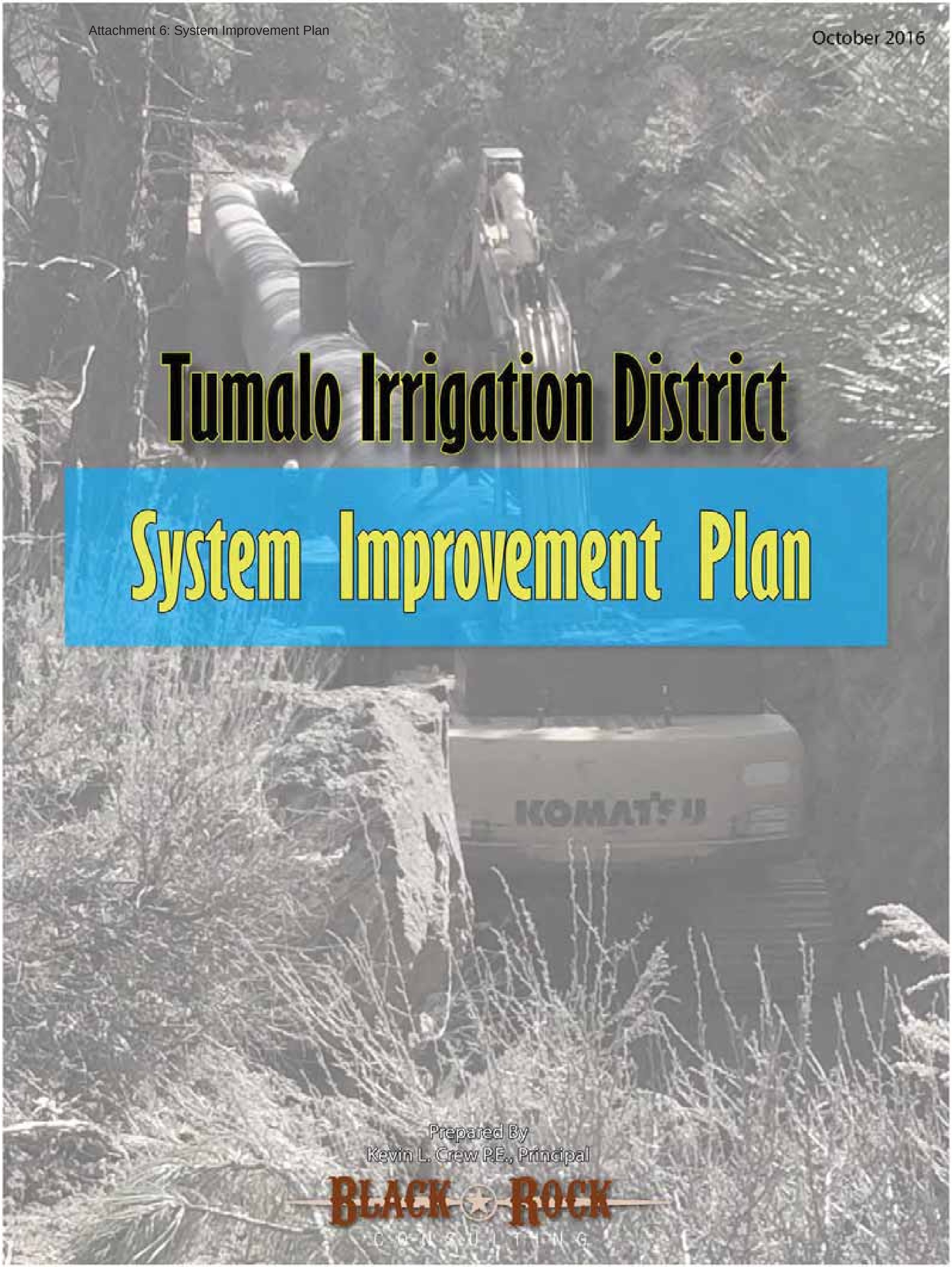
Ronald Alvarado (signature) 08/10/18 (date)

Ronald Alvarado, State Conservationist

October 2016

Tumalo Irrigation District

System Improvement Plan



Prepared By
Kevin L. Crew P.E., Principal
BLACK ROCK
CONSULTING

Table of Contents

Executive Summary

This study was funded by the Tumalo Irrigation District in partnership with the City of Bend and authorized February, 2015 through a Consultant Services Agreement by and between the Tumalo Irrigation District (TID) and Black Rock Consulting (BRC). Additionally, a grant through the Energy Trust of Oregon via Farmers Conservation Alliance was utilized to perform an evaluation of system seepage losses, LIDAR imagery, and base files for use in hydraulic modeling. The purpose of this System Improvement Plan (SIP) was to develop a well-considered evaluation of the District's primary and secondary canal systems, a mitigation plan for the seepage losses, and consideration of resulting pressurized deliveries. System piping was the primary method proposed for such mitigation.

In July and August of 2016, two meetings were held with District staff to confirm approach on the SIP. Data requests were fulfilled by the District. The District also determined that it planned to provide patron delivery pressurization where possible. The District determined that a value of 7.48 GPM/Acre should be used for hydraulic modeling and pipe sizing purposes. Lastly, that the cost estimating in this SIP should provide District flexibility, therefore should provide logical project groups including seepage loss and cost of mitigation (through piping) information.

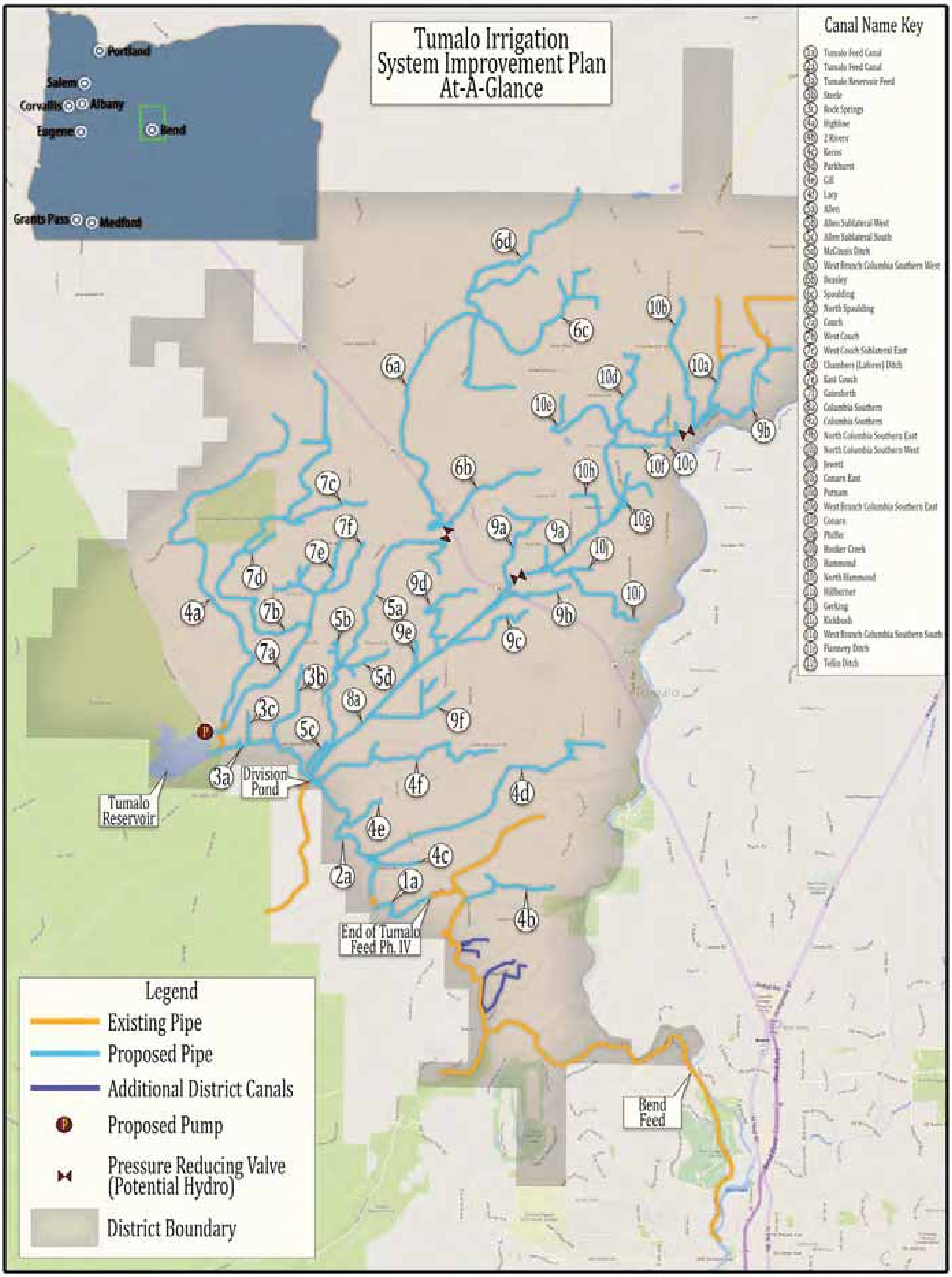
The District's approximate 7,417 acres are served by two primary diversion canals – the Tumalo Feed Canal and the Bend Feed Canal. The unpiped portions of the primary canal and laterals were evaluated for seepage loss using state-of-the-art measurement equipment and it was found that approximately 50.4 CFS were being lost at the time of measurements. It was also determined that approximately 53 CFS might be conserved if the system were completely piped and Tumalo Reservoir lined (assuming certificated peak flows of 7.48 GPM/Acre delivered). For the purposes of this SIP, 50 CFS was held as the total potential conservation attributed to piping projects.

The District chose to consider pressurization to patron deliveries as a priority for its SIP. Given this approach, where pressure reduction was required, pressure sustaining downstream was incorporated. This approach resulted in hydroelectric power potential estimated at 1.5 mWh and an estimated reduction of 4.0 mWh in patron pumping per season. A total of three pressure reducing stations combined with hydroelectric power potential were evaluated in the SIP.

A Pipe manufacturer/vendor was contacted to provide budgetary pipe cost information for pipe delivered to Central Oregon. This information was used to develop reconnaissance-level cost estimates to design and construct the entire piped system to all patron and private delivery points. The cost estimates were evaluated and broken into grouped cost elements. An At-A-Glance Map and summary tables are provided below indicating the summary results of this System Improvement Plan.

Section 1

System Summary At-A-Glance


Tumalo Irrigation
System Improvement Plan
At-A-Glance
Canal Name Key
Tumalo Feed Canal
Tumalo Feed Canal
Tumalo Reservoir Feed
Steele
Rock Springs
Highline
2 Rivers
Kerns
Parkhurst
Gill
Lacy
Allen
Allen Sublateral West
Allen Sublateral South
McGinnis Ditch
West Branch Columbia Southern West
Beasley
Spaulding
North Spaulding
Couch
West Couch
West Couch Sublateral East
Chambers (Lafores) Ditch
East Couch
Gainsforth
Columbia Southern
Columbia Southern
North Columbia Southern East
North Columbia Southern West
Jewett
Conars East
Putnam
West Branch Columbia Southern East
Conars
Phifer
Hooker Creek
Hammond
North Hammond
Hillburner
Gerking
Kickbush
West Branch Columbia Southern South
Flannery Ditch
Tellis Ditch
Portland
Salem
Corvallis
Albany
Eugene
Bend
Grants Pass
Medford
Tumalo Reservoir
Division Pond
End of Tumalo Feed Ph. IV
Bend Feed
Legend
Existing Pipe
Proposed Pipe
Additional District Canals
Proposed Pump
Pressure Reducing Valve (Potential Hydro)
District Boundary

AT A GLANCE - MAIN CANAL AND LATERAL PIPING						
PROJECT GROUP	CANAL/LATERAL	EST. WATER CONSERVATION (CFS)	EST. ENERGY CONSERVATION (KWH/YR)	EST. ENERGY PRODUCTION (KWH)	LENGTH PIPED (FT)	RECON-ESTIMATED COST
1 &2	Tumalo Feed Canal	11.1	6,307		13,446	$11,671,470
3	Tumalo Res. Feed	0.2	56,214		17,308	$2,913,083
3	Steele					
3	Rock Springs					
4	Highline	7.8	501,009		67,150	$3,079,404
4	2 Rivers					
4	Kerns					
4	Parkhurst					
4	Gill					
4	Lacy					
5	Allen	4.2	294,751		25,518	$3,495,568
5	Allen Sublateral West					
5	Allen Sublateral South					
5	McGinnis Ditch					
6	West Branch Columbia So. West	4.8	694,616	209,467	61,551	$3,868,267
6	Beasley					
6	Spaulding					
6	N. Spaulding					
7	Couch	3.5	383,475		55,950	$3,338,263
7	West Couch					
7	West Couch Sublateral East					
7	Chambers (Lafores) Ditch					
7	East Couch					
7	Gainsforth					
8	Columbia Southern TFC to PRV	2	420,029	1,166,762	14,978	$5,468,931
9	Columbia Southern PRV to Tail	4.5	1,120,365	162,263	30,491	$4,433,245
9	North Columbia So. East		526,185			
10	North Columbia So. West	7.9	Incl. in C.S. Lower		44,696	$2,547,536
10	Jewett					
10	Conarn East					
10	Putnam					
10	West Branch Columbia So. East					
10	Conarn					
10	Phiffer					
10	Hooker Creek					
10	Hammond					
10	North Hammond					
11	Hillburner	4.1	Incl. in C.S. Upper		35,650	$1,481,684
11	Gerking					
11	Kickbush					
11	West Branch Columbia So. South					
11	Flannery Ditch					
11	Tellin Ditch					
	TOTAL=	**50**	**4,002,951**	**1,538,492**	**366,740**	**$42,297,451**

Section 2

Project Description and Overview

2.0 Authorization and Funding

This study was funded by the Tumalo Irrigation District in partnership with the City of Bend and authorized February, 2015 through a Consultant Services Agreement by and between the Tumalo Irrigation District (TID) and Black Rock Consulting (BRC). Additionally, a grant through the Energy Trust of Oregon via Farmers Conservation Alliance was utilized to perform an evaluation of system seepage losses, LIDAR imagery, and base files for use in hydraulic modeling.

2.1 Purpose

The Tumalo Irrigation District was founded in 1914 by its predecessor. The District has a rich history of diligently finding ways to irrigate the arid region. The Tumalo Irrigation District area was originally conceived as a much larger District with the idea that as much as 40,000 acres may be irrigated within it. The less than hospitable climate, over-estimated runoff volumes, and porous volcanic substrate began to change the size and shape of the irrigated District. When the large Bull Run Reservoir was unable to hold water upon its completion, the District was restructured into the 7,417 currently irrigated acres and a geographic area of approximately 45 Square Miles. The District boundary is approximately 15 miles long (north to south) and 8 miles wide and serves approximately 667 delivery accounts. The District is oriented generally from Bend northerly toward Sisters, Oregon and is bifurcated by Highway 20. Its offices are located in Tumalo, Oregon approximately 8 miles north of Bend, Oregon.

The District operates and maintains over 77-miles of main canal and laterals, including existing piped segments. The volcanic nature of the Central Oregon geology presents fractured basalt, cinder and varied substrates that results in a propensity for seepage losses in many areas of the TID Canal system. The District recognized the issues with its "leaky" system and concern for minimizing losses has been an ongoing concern of the District. Starting in the mid 1990s, TID has aggressively pursued a water conservation program to provide a permanent solution to system-wide water losses.

The purpose of this System Improvement Plan (SIP) is to develop a well-considered evaluation of the District's primary and secondary canal systems, a mitigation plan for the seepage losses, and consideration of resulting pressurized deliveries. Consistent with its existing modernization program, well under way, system piping is to be the primary method proposed for such mitigation.

The plan will become a key element of the District's planning documents and is expected to become the basis for future phased construction of the District's conveyance system.

2.2 Scope of Services

Black Rock Consulting (hereinafter "BRC") was employed to provide the following services and deliverables in conjunction with this plan:

Kickoff Meeting –

BRC met with District staff and management on two separate occasions to confirm approach to the study. BRC developed a list of questions to review with District staff. At these meetings BRC requested documents for major system elements that affected system hydraulic modeling, requested a copy of the District Water Conservation Plan, and requested water diversion and water right information, and associated operational input from the District.

BRC discussed seepage loss information with the District and discussed the ongoing loss assessment program implemented by BRC within the District.

BRC inquired about energy dissipation approach preferences of the District (i.e hydroelectric power generation and pressurized delivery preferences).

Review of Materials -

BRC reviewed materials obtained form the District following the kick-off meetings to insure that required materials for moving the study forward were obtained or readily supplemented during the study to develop the deliverables indicated below. Data gaps that were found during the meeting process were identified and resolved with District staff.

Coordination -

BRC coordinated with the TID staff at various project milestones to confirm that the System Improvement Plan continued to be developed in accordance with the direction of TID.

Seepage Loss Study -

BRC coordinated the development of a seepage loss study with TID staff. The seepage loss study identified a program of seepage loss measurements for the TID system to support loss assumptions to be used in the SIP and to assist with water conservation estimates and system implementation phasing development.

Review of Provided Flow Data -

BRC provided a thorough review of diversion data and on-farm delivery rates (per water right certificates) to insure a clear understanding of delivery approach. BRC coordinated with the District to insure rates used in system evaluation and modeling were as directed by the District.

TID SIP Base Map Development -

In conjunction with TID mapping staff, BRC, TID, and FireWhat? developed an SIP primary and secondary canal and lateral system base map. The base map was populated with the TID primary and secondary canal system in its existing state.

TID SIP Improvement Map Development -

BRC (with TID input) developed a proposed primary and secondary system piping overlay on the base map. To the extent possible, existing mapping obtained as described above was used for this purpose. This map included an aerial underlay as available and as practical to manage file size.

TID SIP Hydraulic Model -

BRC confirmed approach regarding system pressurization with TID. Following the agreed approach discussed with TID and following delivery of basic system control and elevation information from FireWhat?, BRC then modeled the primary and secondary system elements (i.e. primary and secondary system canals and laterals) with EPANET hydraulic modeling software. Flow assumptions were based upon the rates agreed with TID staff. From iterations of model runs, BRC developed system elements including piping, pressure reducing elements; i.e. prv stations, hydroelectric power plant locations, primary system valving points, etc. Pipe materials and diameters were determined during this analysis.

TID SIP Phasing Approach -

In conjunction with the system model and upon review with TID, BRC developed a system improvement cost estimate that was broken down by District lateral elements. This will allow the District flexibility in implementation development and design decisions based upon funding availability and other critical considerations.

TID SIP Conservation Table -

BRC developed a table indicating water conservation estimates based upon historic diversions, desired delivery rates within a fully piped system, and also corroborated by the loss assessment program results.

Final SIP Mapping -

In conjunction with TID staff, BRC developed a final SIP map indicating primary and secondary canal system elements, indications of existing and proposed piping, and other key system elements.

Reconnaissance-Level Cost Estimate -

BRC coordinated with a reputable material vendor and developed reconnaissance-level cost estimating for the proposed piping system and pressure regulation necessary to appropriately operate the pressurized system.

SIP Reporting -

BRC compiled the results of the SIP study into this System Improvement Plan draft report for review and comment by TID. Comments received were incorporated as appropriate into the Final SIP Report. The report includes mapping, and summarizes all findings for elements identified above.

2.3 Goals and Objectives – District Meeting(s)

As indicated in the scope, Black Rock Consulting met with District staff on two occasions in July and August of 2016. Black Rock Consulting and District staff discussed key project parameters required to establish the approach for the SIP.

The meetings were attended by:

Kenneth B. Rieck, District Manager
Robert Varco, District Operations
Kevin L. Crew, Principal, Black Rock Consulting
District Field Staff (Prior to LAP Measurements)

Key agenda items addressed were as summarized below:

1) Data Needs: District Water Right Certificates, District's Water Management and Conservation Plan, District's Most Recent Irrigated Acre Accounting (Direct River Points of Delivery and Primary Diversion).

   Over the two meetings held, these materials were provided to Black Rock Consulting and/or BRC was directed as to where to obtain the information.

2) What are the plans for piping and pressurization of the District?

   The District has a significant amount of piping already in place in its Bend Feed Canal and its Tumalo Feed Canal. Some minor other piping has been performed in the District. Currently, these existing piped system segments operate largely under open channel and gravity flow regimes, however as laterals are piped, significant pressurization can occur in the District.

   The District plans to fully pipe its system. The District also wishes to prioritize pressurization of patron deliveries over hydroelectric power generation potential. Where pressure reduction in the system is required, the hydraulic model will reflect pressure sustaining downstream of the pressure reducing station (or possibly PRV/Hydroelectric Power Plant) to insure patrons downstream of pressure reduction have the benefit of pressurization and pumping cost reduction or elimination.

3) Given that water rights would dictate a delivery of 13.86 GPM/Acre for peak delivery flow rate to the District's irrigated properties, what flow rate should be used in the model for peak flow rates?

   The model should use 7.48 GPM/Acre for normal delivery modeling at 5 FT/S velocities or less in system elements per NRCS guidelines. It must also be confirmed that one additional condition will work within the proposed systems: An uncommon high flow rate of 9 GPM/Acre with allowance for velocities to exceed 5 FT/S under these conditions. This would insure that the system will operate satisfactorily under future scenarios if additional irrigated lands were attributed to the canal system, and to address climate change scenarios.

4) Black Rock Consulting indicated that it planned to break the canal piping cost estimates into lateral by lateral estimates, and the remaining primary canal estimate to provide the District with a high level of flexibility in project financial planning and implementation packaging.

   The District agreed with this approach.

Section 3

Existing System

3.0 Existing System Description (Refer to Figure 3.0.1 below)

Please refer to Figure 3.0.1 below regarding the existing District Delivery System that indicates the District service territory boundary, measurement points and the primary canal system.
Tumalo Irrigation Districts primary source of water is Tumalo Creek where water is diverted just below Shevlin Park into the Tumalo Feed Canal. The Tumalo Feed Canal diverts water through powered head-gates and through a compliant fish screen. The Tumalo Feed Canal diversion also includes fish passage as of 2012.

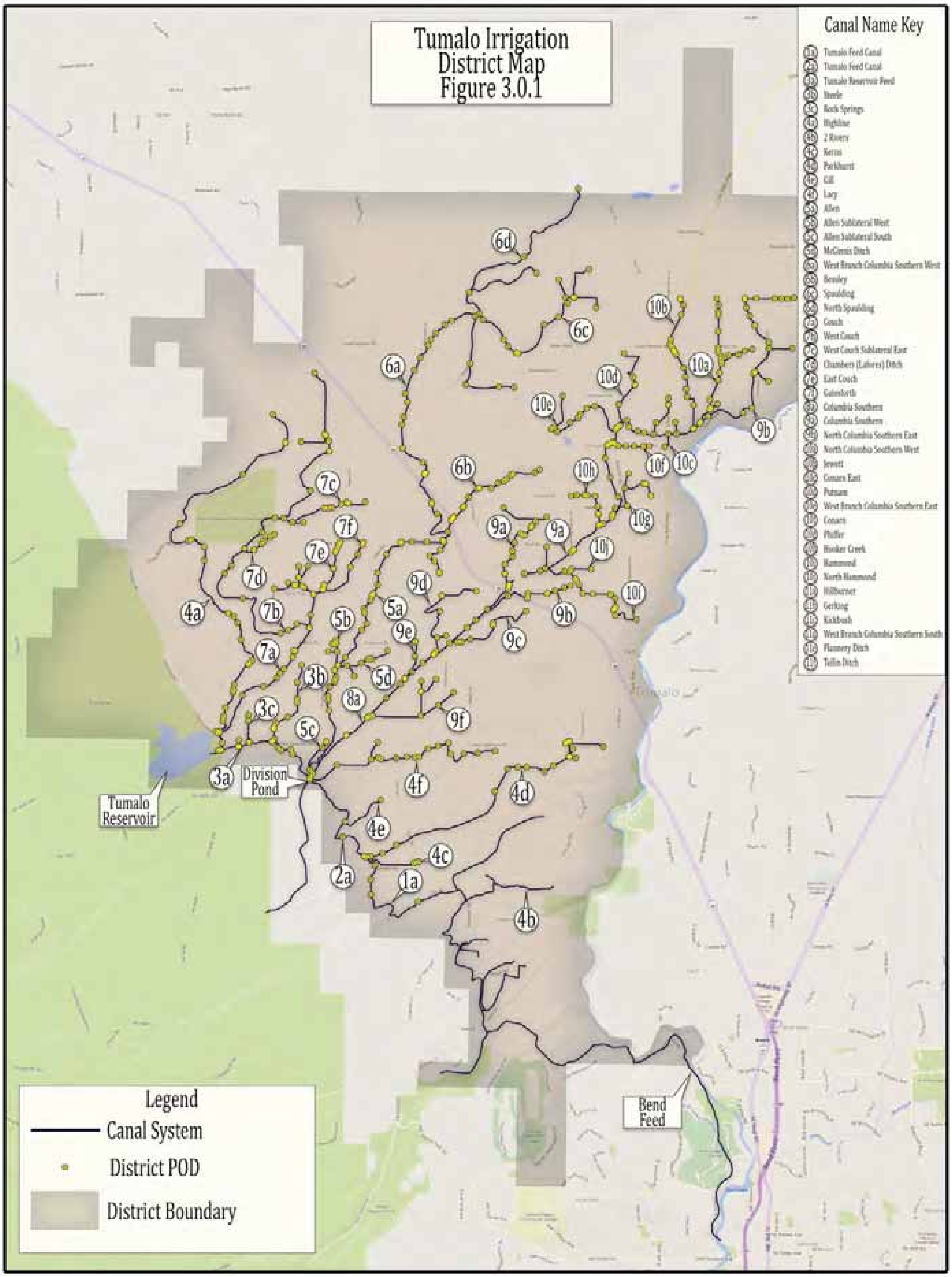
As Tumalo Creek flows are insufficient to meet the districts demands, TID also maintains supplemental storage rights in Crescent Lake (Reservoir) and conveys irrigation water through the Deschutes River to it diversion facility at Steidl Dam in Bend, Oregon. This diversion is known as the Bend Feed Canal diversion and includes powered head-gates, fish passage, and a compliant fish-screen. The Bend Feed Canal and the Tumalo Feed canal confluence approximately 4,000 LF downstream of the Tumalo Feed Canal diversion. The Tumalo Feed Canal continues approximately 7 miles to the north until it terminates in the Tumalo Reservoir. Laterals stem from the Tumalo Feed Canal, commence at the Tumalo Reservoir and spur off of the Columbia Southern Lateral, a primary lateral of the Tumalo Feed Canal.

The Bend Feed Canal is completely piped throughout its approximate 5-Mile length. The piping consists of a combination of 72-IN diameter reinforced concrete pipe that was installed in the 1970s by the United States Bureau of Reclamation and 84-IN diameter high density polyethylene (Weholite) profile wall pipe that was installed over the last 15-years. This piping program has continued within the Tumalo Feed Canal and approximately 60% of the Tumalo Feed Canal has been piped from the top toward the Tumalo Reservoir. Predominantly, Weholite pipe has been used to perform this recent piping although steel pipe was used at siphon locations, reinforced concrete dual-barrel piping was used from the intake approximately 2,967 LF downstream of the TFC intake, and a segment of Duromaxx pipe was also installed. Four total phases of the Tumalo Feed Canal piping program have been completed to date.

Below the four piped phases of the Tumalo Feed Canal, the canal continues approximately 2.5-Miles as open channel canal to a junction known as the Division. At the Division, the Columbia Southern Lateral carries water into the District in a northeasterly direction. The primary District canal continues to the Tumalo Reservoir and supplies water to the reservoir for the purpose of re-regulation and supply to the Couch Lateral. As indicated on Figure 3.01, a variety of laterals stem from the Tumalo Feed Canal, and the Columbia Southern Lateral. In total, the unpiped canals, laterals and ditches of the District total approximately 69-Miles in length.

Water diverted into the Tumalo Irrigation District falls approximately 370-FT as it travels from its diversion in Bend and Tumalo Creek to the northern limit of the District system.

Patron turnouts from the District canals and from laterals are typically gate regulated and weir measured. The District regulates flows at its primary diversion and to each system lateral and patron turnout via its ditch-rider staff.


Tumalo Irrigation
District Map
Figure 3.0.1
Canal Name Key
Tumalo Feed Canal
Tumalo Feed Canal
Tumalo Reservoir Feed
Steele
Rock Springs
Highline
2 Rivers
Kerns
Parkhurst
Gill
Lacy
Allen
Allen Sublateral West
Allen Sublateral South
McGinnis Ditch
West Branch Columbia Southern West
Bensley
Spaulding
North Spaulding
Couch
West Couch
West Couch Sublateral East
Chambers (Lafores) Ditch
East Couch
Gainsforth
Columbia Southern
Columbia Southern
North Columbia Southern East
North Columbia Southern West
Jewett
Conarn East
Putnam
West Branch Columbia Southern East
Conarn
Pfeiffer
Hooker Creek
Hammond
North Hammond
Hillburner
Gerking
Kickbush
West Branch Columbia Southern South
Flannery Ditch
Tellin Ditch
1a
2a
3a
3b
3c
4a
4b
4c
4d
4e
4f
5a
5b
5c
5d
6a
6b
6c
6d
7a
7b
7c
7d
7e
7f
8a
9a
9b
9c
9d
9e
9f
10a
10b
10c
10d
10e
10f
10g
10h
10i
10j
Division Pond
Tumalo Reservoir
Bend Feed
Legend
Canal System
District POD
District Boundary

3.1 Water Supply and Certificates

The District has numerous water rights with priority dates between 1900 and 1913. The rights were all adjudicated or certificated, at which time maximum diversion rates were also established for the irrigation season.

The primary diversion rights for the District are on Tumalo Creek, that is a tributary to the Deschutes River, with a confluence point approximately 2-miles downstream of Bend on the Deschutes River. The District also has supplemental Live flow from the Deschutes River, diversion rights on Crater Creek, Little Crater Creek, and The Three Spring Branches, which are seasonal streams and are diverted into the upper reaches of Tumalo Creek.

In addition to diversion rights, the District has storage rights on Crescent Lake, an impoundment on Crescent Creek, a tributary to the Little Deschutes River, and thence to the Deschutes River.

Under the water rights, the beneficial uses for the District are livestock, irrigation, industrial, and storage. Based upon conservation piping projects implemented over the last two decades, water right transfers have occurred that have modified the District's water rights. These are best described by CW-9 for the Bend Feed Canal Project group conservation dedicated instream and by CW-37 for the Tumalo Feed Canal Project Group currently in progress. The District's 2016 Water Management and Conservation Plan and the Oregon Water Resources Department's water right certificate look-up on-line feature may be used to access the complete suite of certificates held by the District. Water right certificate #74147 indicates the following:

"The amount of water used for irrigation, together with the amount secured under any other water right existing for the same lands, is limited to:"

CUBIC FEET PER SECOND PER ACRE AT DIVERSION

April 1- May 1	May 1- May 15	May 15- Sept 15	Sept 15- Oct 1	Oct 1- Nov 1	Total AF/Ac at Diversion
1/80	1/60	1/32.4	1/60	1/80	9.91

As indicated above, the District's water rights include a long history of certificates and updated certificate modifications as water conservation in the District has progressed. For the purposes of this SIP, the most critical elements of this certificate are the on-farm delivery component. Although the water right at peak diversion would allow 1 CFS per 32.4 Acres (13.86 GPM/Acre) this rate was originally established to allow for transmission losses in the system. This loss accounts for evapotranspiration, seepage and other losses within the large District canal conveyance systems as water is conveyed in open excavated canals that cross a variety of rocky and soil substrates. The piping evaluated to improve the open canal system in the Tumalo Irrigation District will mitigate system losses. The extent of mitigation is further discussed in the System Loss Assessment section of this SIP.

As indicated above, the peak diversion rate into the district at peak season is approximately 13.86 GPM/Acre. For the purposes of delivery to on-farm the District has historically coordinated with the Water Resources Department and resolved that approximately 1 CFS per 60 Acres (7.48 GPM/Acre) should be used by the District as peak delivery to each on-farm parcel given the level of seepage losses experienced by the District in transmission of the water after diversion. This represents an approximate 46% allowance for transmission loss. Therefore, given a fully piped system with little or no losses, the diversion flow rate may clearly be reduced significantly. It should also be noted that at the beginning and the end of the irrigation season the allowable low flow rate for diversion from the Deschutes River is 1 CFS per 80.0 Acres (or 5.61 GPM/Acre) and to each farm is 3.03 GPM/Acre (after reducing by 46%). This is important to the SIP simply to note that system improvements should include provisions to not only accommodate peak system flow rates but to accommodate lower system flow rates that can create sedimentation issues if not properly accounted for.

3.2 On-Farm Water Demand Analysis - Acreage and Duty

As indicated above, the current allowable diversion during irrigation season is 9.91 AF/Acre. The rate during peak season is 7.48 GPM/Acre after reducing the diversion rate by the historically experienced transmission losses.

For the purposes of this SIP, and based upon District input as indicated above, a target SIP design delivery flow rate to on-farm was established at 7.48 GPM/Acre. As indicated above, pipe modeling for this SIP was based upon 7.48 GPM/Acre and 5 FT/S of maximal velocity in the proposed pipelines. Pipe models were also evaluated to an extreme value of 9 GPM/Acre to insure that the system would still function properly and to insure future flexibility to the District.

3.3 System Loss Assessment

Black Rock Consulting worked with the District to coordinate a seepage loss study performed by Farmers Conservation Alliance staff under Black Rock Consulting/Kevin L. Crew, P.E and David C. Prull, P.E. direction. District operations staff met with the measurement team prior to the commencement of measurements and also assisted with turnout measurements and logistics throughout performance of the in-District program.

During the summer of 2016, the seepage Loss Assessment Program (LAP) funded by the Farmers Conservation Alliance, the Energy Trust of Oregon and supported by the Oregon State University and the Oregon Water Resources Department was implemented in 7 of the 8 Central Oregon irrigation districts to inform the Districts of current system losses and to enhance SIP development for these Districts. The program included the use of newly purchased and calibrated Flowtracker II technology, manual, office and field training, all in accordance with the United States Geological Survey and United States Bureau of Reclamation "Discharge Measurements at Gauging Stations – Chapter 8 of Book 3, Section A, Techniques and Methods 3-A8". The program was managed by Oregon Registered Professional Engineers, Kevin L. Crew, P.E. and David C. Prull, P.E.

The primary purpose of the LAP program as applied to the Districts was to perform a one-time measurement program in each District to inform the District SIPs of approximate seepage losses in elements of each system. Clearly, the measurements were performed at different times of the irrigation season within each District, therefore the percentage of peak flow varied by District as the LAP team entered, measured and exited each District. The results were used to provide a strong indication of losses. The results were compared to the maximum expected loss within the District as indicated in this SIP, below. The final loss information was used to identify losses associated by project phase or lateral depending upon each specific District SIP. It is recommended that these results be confirmed in a subsequent loss measurement program performed by the USGS and/or the Oregon Water Resources Department prior to project implementation.

For Tumalo Irrigation District, the LAP was implemented in its main Tumalo Feed Canal and throughout its canal and lateral system. Tabular results for the LAP study within TID are included in Appendix A to this SIP. A tabulated summary version of the results are provided below.

TUMALO IRRIGATION DISTRICT CONSERVATION ESTIMATE BY CANAL AND LATERAL		
CANAL/LATERAL	MEASURED (Y/N)	LOSS MEASURED (CFS)
Tumalo Feed Canal	Yes	11.2
Tumalo Res. Feed	Yes	0.2
Steele	Head	N/A
Rock Springs	Head	N/A
Highline	Yes	2.3
2 Rivers	Yes	2.6
Kerns	Yes	0.2
Parkhurst	Yes	1.6
Gill	Head	N/A
Lacy	Yes	1.1
Allen	Yes	4.3
Allen Sublateral West	Head	Incl. in Allen
Allen Sublateral South	Head	Incl. in Allen
McGinnis Ditch	Head	Incl. in Allen
West Branch Columbia So. West	Yes	2.2
Beasley	Yes	0.5
Spaulding	Yes	1.3
N. Spaulding	Yes	0.9
Couch	Yes	0.7
West Couch	Yes	2.6
West Couch Sublateral East	Head	Incl. in West Couch
Chambers (Lafores) Ditch	Yes	0.1
East Couch	Yes	0.1
Gainsforth	Head	N/A
North Columbia So. West	Yes	Incl. in Co. So. Tail
Jewett	Yes	1.2
Conarn East	Yes	Incl. in Conarn
Putnam	Yes	0.7
West Branch Columbia So. East	Yes	4.5
Conarn	Yes	0.1
Phiffer	Yes	0.1
Hooker Creek	Yes	0.4
Hammond	Yes	1.1
North Hammond	Yes	Incl. in Hammond
Hillburner	Yes	0.7
Gerking	Yes	0.6
Kickbush	Yes	0.7
West Branch Columbia So. South	Yes	1.5
Flannery Ditch	Yes	0.1
Tellin Ditch	Yes	0.6
Columbia Southern TFC to PRV	Yes	2.0
Columbia Southern PRV to Tail	Yes	3.5
North Columbia So. East	Yes	1.0
	TOTAL=	**50.4**

Total piped system conservation estimates were developed. Delivery acreages as assessed for the TID system were used to estimate the fully piped system flow rates at the peak rate (7.48 GPM/ Acre). Flow diversion data for the District were evaluated to determine the peak diverted flow rate over the last seven years of operation (approximately 177 CFS peak). This peak was compared to the peak piped flow rate to estimate potential conservation based upon a completely piped hydraulic delivery system (including all laterals and private laterals down to the individual patron turnouts). The results of these total conservation estimates is tabulated below.

TUMALO IRRIGATION DISTRICT TOTAL PIPED CONSERVATION ESTIMATE			
Diverted Acreage	Maximum Diversion 2014-2016 (CFS)	Diversion Flow Rate at 7.48 GPM/Acre (CFS)	Estimated Cons. At 7.48 GPM/Acre (CFS)
7,417	**177**	**124**	**53**

As indicated in the table above, the total loss measured in the District during the Loss Assessment Program was 50.4 CFS. This loss does not include any losses within the Tumalo Reservoir. As indicated in the Total Piped Conservation Table, above, the total conservation estimate (fully piped system) at a delivery rate of 7.48 GPM/Acre is 53 CFS (see table above). Given that the measured losses approximately match the total estimated piped system conservation estimate, and given that losses in the Tumalo Reservoir were not included in the loss assessment, we used the measured losses to approximate conservation potential within the District for the purposes of this SIP. As indicated above, these loss assessments should be verified prior to any water conservation transfer associated with piping.

Section 4

System Improvement

4.0 System Improvement Approach

This SIP was funded by the Tumalo Irrigation District in partnership with the City of Bend, Oregon to identify water conservation, hydroelectric power, and pumped power conservation possibilities for the District. Additionally, a grant through the Energy Trust of Oregon via Farmers Conservation Alliance was utilized to perform an evaluation of system seepage losses. Although significant piping has already occurred in the main delivery canals of the District, there remains a significant open canal system calling for mitigation through piping. Consistent with its Scope of Services and the subsequent goals and direction provided by the District, Black Rock Consulting performed a comprehensive hydraulic and piping evaluation of the District.

There are two primary alternatives for the mitigation of seepage losses. The first is canal lining and the second is canal piping. Within each of these alternatives there are a variety of material choices. Canal lining involves the installation of an impervious system to cover the canal bottom and banks. Materials typically employed include geomembranes, rubber liners, shotcrete or similar materials. Canal lining does not provide pressurization of the irrigation system and it also increases canal velocities, thus increasing risk to people. Black Rock Consulting has performed 50-year life-cycle evaluations of lining versus piping alternatives to the District and has not including these in this Plan. In summary, over a 50-year life cycle, it was found that canal lining may be less expensive to implement in its first installation cycle than piping, however canal lining requires significant maintenance and replacement cycles that ultimately cause it to exceed the cost of piping over time. Also, given the significant elevation differential across the District and the desire of the District to provide pressurized deliveries to its patrons and significantly reduce pumping electricity effects on the utility grid, piping was chosen as the District's preferred choice for canal water loss mitigation.

Hydraulic modeling of the Tumalo Irrigation District was performed on two separate areas of the District using two different types of software and analysis. The upper extremities of the system including the Bend Feed Canal and the Tumalo Feed Canal and associated laterals were modeled using WSPGW 2010 software. This modeling software is excellent for the purpose of modeling open channel flow hydraulics consistent with the operation of the upper limits of the TID system. The balance of the District was modeled using EPANET software for pressurized flow systems consistent with the lower extremities of the TID system downstream of the Tumalo Feed Canal Phase 4 project. Details of the software used are discussed in more detail below.

Black Rock Consulting commenced the process of hydraulic modeling for the Tumalo Irrigation District by obtaining construction drawings and past specifications for piping projects on the Bend and Tumalo Feed Canals. Pipe specifics were entered into the WSPGW 2010 software and calibrated based upon field water surface measurements provided by the District. For the lower pressurized system modeling, Black Rock Consulting receiving base EPANET files from FireWhat? in electronic form (.inp format). The files were generated by FireWhat? by including spatially (i.e. northing, easting and elevation) correct patron turnout locations including patron delivery flow rates at each turnout. Updated acreages by patron were provided by the District for this purpose. EPANET modeling is discussed further in this SIP below. From the base files, Black Rock Consulting inserted the data in WSPGW and EPANET and then began the process of including existing piped elements of the District. The District was modeled based upon the District's current system approach with intakes at the Deschutes River and Tumalo Creek. Based upon discussions and subsequent direction by the District, pressurization to optimize patron deliveries was assumed over optimizing hydroelectric power production. The District acknowledges the benefits of patron pressurization and the global reduction in patron pumping costs. Generally, as system static pressures reached 95 PSI, pressure regulating stations were incorporated to reduce downstream pressures to 35-40 PSI and then allowed to build back up again as the system hydraulic grade line dictated.

The completed EPANET model was calibrated and pipes were sized based upon selected pipe manufacturer information and a peak velocity of 5 FT/S for proposed piping at 7.48 GPM/Acre throughout the system.

For the upper system developed in the WSPG2010 gravity flow model, once the pipe network as it exists at the time of this report was calibrated, segments of the Bend Feed Canal system (i.e. 72-IN and 62-IN diameter pipe segments) were further evaluated. Details of this evaluation are provided below.

Once this process was completed, the system was evaluated for cost as further detailed below. To provide the greatest flexibility to the District for funding and project "packaging" a lateral by lateral and main canal piping breakdown was provided in the SIP.

4.1 Pipe and Valve Materials

Pipe materials selections were made by Kevin L. Crew, P.E., based upon 29 years of experience with large diameter piping systems including 20 years of experience in Central Oregon. From the hydraulic model, both static and dynamic pressures were evaluated throughout the system to select appropriate pipe material options. For pipe up to 63-inches in diameter (covering all District piping needs), high density polyethylene solid-wall pipe was selected due to its outstanding abrasion resistance, longevity, and ability to be pulled into canal curve alignments. Costs for materials were obtained from large, reputable vendors that are active in bidding to Central Oregon projects.

Valves for pressure reducing stations were technically assessed and narrowed down to plunger valves and Cla-Val valves. Both use internal energy dissipation within the valve to accomplish the needed pressure-sustaining function downstream of the valves. Cla-Val valves use a control tubing and a diaphragm/bonnet arrangement to adjust pressures within the pressure reducing apparatus. No power is necessary for the operation of a Cla-Val. For the purposes of this study, Cla-Val E-90-01 pressure reducing valves were assumed.

4.2 Hydroelectric Power Potential, Pumping Mitigation and Pressurization Approach

Based upon District direction that patron pressurization is a priority for the District as it moves forward with its system improvements, the pressure drop associated with pressure reducing stations was limited. This was because although the pressure on the upstream side of pressure reducing stations was high (i.e. 95PSI,) the downstream side was set to 35-40 PSI versus atmospheric pressure (i.e. 0 PSI). Given limited pressure differential across pressure reducing valves, the resulting hydroelectric power potential was found to be limited.

Consistent with the Scope of Services for this SIP, a reconnaissance-level power production evaluation was performed at each of the three pressure reducing station locations identified during the hydraulic modeling performed. The evaluation assumed that head loss through the power plant would be approximately 4-FT and that the total efficiency of generation (i.e. water to wire) was 80% average. Flow rates and net head at each location were extracted from EPANET hydraulic model runs. Furthermore, the average flow rate at each PRV was developed by reducing the peak flow rate by 17%. This reduction value was the calculated difference between the peak diversion rate into the District versus the average diversion rate into the District in 2015. Based upon these assumptions, the following hydroelectric power generation estimates were calculated (reconnaissance-level):

ESTIMATED HYDROELECTRIC POWER POTENTIAL - RECONNAISSANCE LEVEL					
PRV STATION	PEAK FLOW RATE AT 7.48 GPM/ACRE (CFS)	ESTIMATED AVERAGE FLOW RATE (CFS)	ESTIMATED NET HEAD (FT)	NAMEPLATE (KW)	ESTIMATED ANNUAL KWH 180 DAYS RUN TIME
Columbia Southern Hillburner	39.8	33.1	121	325	1,166,762
Columbia Southern Jewett	15.1	12.5	44	45	162,263
West Branch West	16.8	13.9	51	58	209,467
TOTAL					**1,538,492**

As indicated above, the Tumalo Irrigation District system commences with two diversion locations and conveyance pipelines that confluence in the Tumalo Feed Canal. The Tumalo Feed Canal continues to the north and has been piped through Phase IV of the system development. This upper system area operates largely under open-channel flow and low-head flow conditions. For the purposes of this SIP, it was assumed that all properties served from this portion of the system, with the exception of the 2 Rivers Lateral, were served by unpressurized water. The balance of the District's 7,012 acres currently served were evaluated for proportion of pumping mitigation and associated energy savings on a reconnaissance-level basis. The pressurization analysis was based upon the results of the EPANET model for the District at peak flow. Pressures at peak flow within laterals and main canals were compared to a higher-end pressurization goal of 60 PSI for sprinkler irrigating. Where system pressures met or exceeded this goal, a 100% "Estimation of Pumping Percentage" was applied. Where lesser pressures resulted in the model, a proportionately lower percentage was applied. Technically, this is a satisfactory approach as any pressure developed in the system can be used to offset pumping horsepower. It should be noted that with the advent of lower-head sprinklers (i.e. down to 35 PSI) that provide satisfactory results, the actual power savings by patrons within the District will likely exceed the estimate provided.

Another primary assumption was that the District is currently 100% pump and sprinkler irrigated. Based upon our discussions with the District, this assumption is likely over 96% accurate.

Total season pumping estimates were developed based upon the following assumptions:

- 3-FT of water applied to grow grass or alfalfa/season
- 70% application efficiency
- 4.28-FT required to leave the sprinkler heads/season
- 70% pumping efficiency

The overall District private pumping mitigation and associated patron kWh savings was estimated as follows:

ESTIMATED PUMPING POWER SAVINGS THROUGH PRESSURIZATION					
CANAL/LATERAL	iRRIGATED ACRES ASSOCIATED WITH SEGMENT	ESTIMATED % OF PUMPING MITIGATED	70% EFF. PUMPING PER ACRE AT 60 PSI GRASS HAY (KWH)	SAVINGS/AC (KWH)	TOTAL ESTIMATED PUMPING SAVINGS (KWH/YR)
Tumalo Feed Canal	103.9	7%	867.3	60.7	6,307
Tumalo Res. Feed	124.5	20%	867.3	173.5	21,590
Steele	103.5	30%	867.3	260.2	26,924
Rock Springs	44.4	20%	867.3	173.5	7,699
Highline	502.0	30%	867.3	260.2	130,621
2 Rivers	197.2	16%	867.3	138.8	27,365
Kerns	30.0	25%	867.3	216.8	6,505
Parkhurst	339.0	83%	867.3	719.9	244,029
Gill	0.0		867.3		
Lacy	231.8	46%	867.3	399.0	92,489
Allen	507.2	67%	867.3	581.1	294,751
Allen Sublateral West	INCL. IN ALLEN		867.3		
Allen Sublateral South	INCL. IN ALLEN		867.3		
McGinnis Ditch	INCL. IN ALLEN		867.3		
West Branch Columbia So. West	545.1	67%	867.3	581.1	316,737
Beasley	INCL. W.B.C.S.W.		867.3		
Spaulding	484.1	90%	867.3	780.6	377,880
N. Spaulding	INCL. IN SPAULDING		867.3		
Couch	803.9	55%	867.3	477.0	383,475
West Couch	INCL. IN COUCH		867.3		
West Couch Sublateral East	INCL. IN COUCH		867.3		
Chambers (Lafores) Ditch	INCL. IN COUCH		867.3		
East Couch	INCL. IN COUCH		867.3		
Gainsforth	INCL. IN COUCH		867.3		
North Columbia So. West	INCL. IN N.C.S.EAST		867.3		
Jewett	INCL. IN N.C.S.EAST		867.3		
Conarn East	INCL. IN C.S. TAIL		867.3		
Putnam	INCL. IN C.S. TAIL		867.3		
West Branch Columbia So. East	INCL. IN C.S. TAIL		867.3		
Conarn	INCL. IN C.S. TAIL		867.3		
Phiffer	INCL. IN C.S. TAIL		867.3		
Hooker Creek	INCL. IN C.S. TAIL		867.3		
Hammond	INCL. IN C.S. TAIL		867.3		
North Hammond	INCL. IN C.S. TAIL		867.3		
Hillburner	INCL. IN C.S. UPPER		867.3		
Gerking	INCL. IN C.S. UPPER		867.3		
Kickbush	INCL. IN C.S. UPPER		867.3		
West Branch Columbia So. South	INCL. IN C.S. UPPER		867.3		
Flannery Ditch	INCL. IN C.S. UPPER		867.3		
Tellin Ditch	INCL. IN C.S. UPPER		867.3		
Columbia Southern TFC to PRV	605.3	80%	867.3	693.9	420,029
Columbia Southern PRV to Tail	1484.8	87%	867.3	754.6	1,120,365
North Columbia So. East	905.5	67%	867.3	581.1	526,185
TOTAL=	**7012.0**				**4,002,951**

4.3 Elevation Data

Elevation data for use in modeling was obtained through a lidar flight performed in March of 2016 by Quantum Spatial of Corvallis, Oregon. The data was post-processed to the requirements of FCA and Black Rock Consulting. Specifications for the data collection are provided below.

Multi-Swath Pulse Density	≥ 8 pulses/m^2
Scan Angle	≤30^o (+/-15^o from Nadir)
Returns Collected Per Laser Pulse	Up to 4
Intensity Range	1-255
Swath Overlap	50% side-lap (100% overlap)
Maximum GPS Baseline	13 nautical miles

With the use of on-ground RTK and OPUS corrections, the data was provided in 1-FT contour interval format and was considered better than 1-FT accuracy vertically.

Units for the elevation information were reported and used in the following systems:

- Horizontal Projection: Oregon State Plane (ORSP) South Zone. International Feet
- Horizontal Datum: NAD83(2011) (Epoch2010.00)
- Vertical Datum: NAVD88 using Geoid12A

4.4 Future Delivery Flexibility

The District has requested system flexibility to insure that, within reason, system changes, added and subtracted irrigated acreage, effects of climate change, effects of changes in cropping patterns and similar system demands may be addressed in this SIP. It was determined, given that 7.48 GPM/Acre was the chosen peak delivery flow rate, that using 9 GPM/Acre as an upper flow limit for system flexibility purposes was appropriate. This upper flow limit was modeled to determine the associated maximal system velocities under this scenario. It was determined through modeling at 9 GPM/Acre delivered to on-farm that:

- The peak system velocity was found to be an acceptable 6.19 FT/S and generally were below 6 FT/S.
- The only system pressure issue found under a 9GPM/Acre scenario was in the Highline lateral. At turnout SH-0140 the pressure was determined to be -8.49 PSI in the model. There are two potential solutions to this situation should the District wish to run system flows at this higher rate. The first would be to use the proposed reservoir pump to supplement pressures in the Highline lateral and the second would be to upsize pipes within the Highline lateral during its design and construction.

No other issues were noted with respect to increasing system velocities to 9 GPM/Acre should the District choose to do so.

4.5 Hydraulic Modeling

WSPG 2010 -

Water Surface Pressure Gradient (WSPG) is an open-channel hydraulics modeling software that is maintained by XP and governed to a large degree by the needs of the LA County Flood Control department. It has a robust open channel hydraulics code that also covers pressurized flow, rapidly varying flow, hydraulic jumps and other hydraulic equation solutions. Details for the products may be further reviewed at:

http://xpsolutions.com/Software/XPWSPG/Free-WSPG-2010/

EPANET –

EPANET was used to model the District's proposed piped network downstream of the Tumalo Feed Canal phase 4 where total pressurization of the system will occur. EPANET is a free-ware product that is maintained by the EPA. The Natural Resources Conservation Service technical offices in Oregon use EPANET exclusively for hydraulic modeling. For these reasons, EPANET was selected as the modeling software of choice for this SIP where pressurization occurs.

EPANET modeling capabilities go beyond steady-state hydraulic modeling. The software is capable of chemical transport analysis and varying flow modeling. A description of some of its capabilities follows:

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. Sampling program design, hydraulic model calibration, chlorine residual analysis, and consumer exposure assessment are some examples. EPANET can help assess alternative management strategies for improving water quality throughout a system. These can include:

- altering source utilization within multiple source systems,
- altering pumping and tank filling/emptying schedules,
- use of satellite treatment, such as re-chlorination at storage tanks,
- targeted pipe cleaning and replacement.

Running under Windows, EPANET provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.

Hydraulic Modeling Capabilities -

Full-featured and accurate hydraulic modeling is a prerequisite for doing effective water quality modeling. EPANET contains a state-of-the-art hydraulic analysis engine that includes the following capabilities:

- places no limit on the size of the network that can be analyzed
- computes friction headloss using the Hazen-Williams, Darcy-Weisbach, or Chezy-Manning formulas
- includes minor head losses for bends, fittings, etc.
- models constant or variable speed pumps
- computes pumping energy and cost
- models various types of valves including shutoff, check, pressure regulating, and flow control valves
- allows storage tanks to have any shape (i.e., diameter can vary with height)
- considers multiple demand categories at nodes, each with its own pattern of time variation

- models pressure-dependent flow issuing from emitters (sprinkler heads)
- can base system operation on both simple tank level or timer controls and on complex rule-based controls.

Velocity Criteria –

As stated above, the maximal velocity criteria was set at 5 FT/S for on-farm deliveries at 7.48 GPM/Acre. The peak evaluated flow rate was 9 GPM/Acre for future system flexibility and was allowed to increase beyond 5 FT/S in modeling as indicated above.

Elevations –

As indicated above, elevation data was derived from a 2016 Lidar flight.

Spatially Correct Layout –

Horizontal information for the various system elements and patron turnouts was collected through a field survey performed by District staff in 2016. Turnout locations were "snapped" to the canal centerline (perpendicular to the centerline) as determined through post-processing of the Lidar data and locating canal and lateral centerlines. The "snapped" locations represented turnout node locations used during hydraulic modeling of the system and were represented in the model by Northing and Easting coordinates of the Oregon State Plane South Zone.

Pressure Reduction –

Pressure reducing stations and/or hydroelectric power plants were entered into the model as PRVs (Pressure Reducing Valves). These valves are a programmed element in EPANET. The diameter of the valve and the downstream pressure set-point are entered to establish the downstream system pressure to be held by the PRV.

Pipe Diameter Selection –

Pipe diameter selections were derived iteratively in the hydraulic model with the first iteration being a rough estimate, The second iteration utilized actual pipe diameters for high density polyethylene pipe material at the appropriate dimension ratio and pressure rating for each model "link" (pipe). Generally, the third iteration adjusted all pipes in the system to a range of 4 FT/S to 5 FT/S at the peak system flow rates based upon 7.48 GPM/ Acre.

Pipe Pressure Rating Selection –

HDPE solid-wall pipes (PE4710 resin) were sized from HDPE pipe sizing tables for the expected static pressure for each pipe segment.

The model for the Tumalo Irrigation District is included in Appendix B of this SIP.

4.6 Cost Estimating by Lateral (and Main Canal)

Pipe Estimates –

Pipe material estimates were provided by a reputable vendor that routinely supplied pipe materials to Central Oregon projects. Pipe material budgetary estimates are provided in Appendix C for reference.

PRV Station Estimates -

As indicated above, pressure reducing valves selected for use in this SIP were Cla-Val brand pilot operated, hydraulic pressure reducing valves. VAG plunger valves were also evaluated. It is recommended that pressure reducing valves be thoroughly evaluated in design and if used in hydroelectric power applications, alternative valves may also be considered. Cla-Val cost estimates were provided by GC Systems of Washington State.

Turnouts –

For the purposes of this SIP, patron turnouts were assumed to be converted to pressurized delivery systems. A standard pressurized irrigation delivery turnout was assumed to include an appropriately sized tee from the mainline or lateral, a pressure relief valve, a gear-actuated plug valve (or gate or possibly butterfly valve in smaller turnout situations), a magnetic meter, a combination air and vacuum relief valve and associated hardware and spool pipe segments. Based upon experience with similar installations at irrigation districts in Central Oregon, the cost of installation of a turnout was set at an estimated average cost of $8,000 per installation.

Construction –

Contractor procurement may come in several forms in Oregon. Design-Bid-Build is a conventional process wherein the survey and design is developed first and then a traditional competitive bid is held to obtain the lowest-cost responsive and responsible bidding contractor. In this process, typically the design engineering firm will serve as the inspection/construction management firm during the course of construction. For the purposes of this

SIP, a Construction Manager General Contractor (CMGC) model was assumed. In this contractor procurement method, design would precede obtaining the contractor, however the contractor would include construction management in its delivery of the constructed project. An estimated contractor fee structure of 12%-15% of the project value was assumed for this construction delivery method depending upon the size of the lateral or main canal project being evaluated.

Engineering, Construction Management –

Engineering and Owner's Representative/Inspection services typically range as high as 10%-18% of construction value. For the purposes of this SIP, and assuming that project phases are constructed sequentially and annually, it was assumed that total fee of 6%-15% for survey, engineering design and inspection/owner's representative services would be appropriate depending upon the scale of the particular lateral or main canal project. This was based upon the experience of Black Rock Consulting on similar projects deployed in Central Oregon.

Contingency –

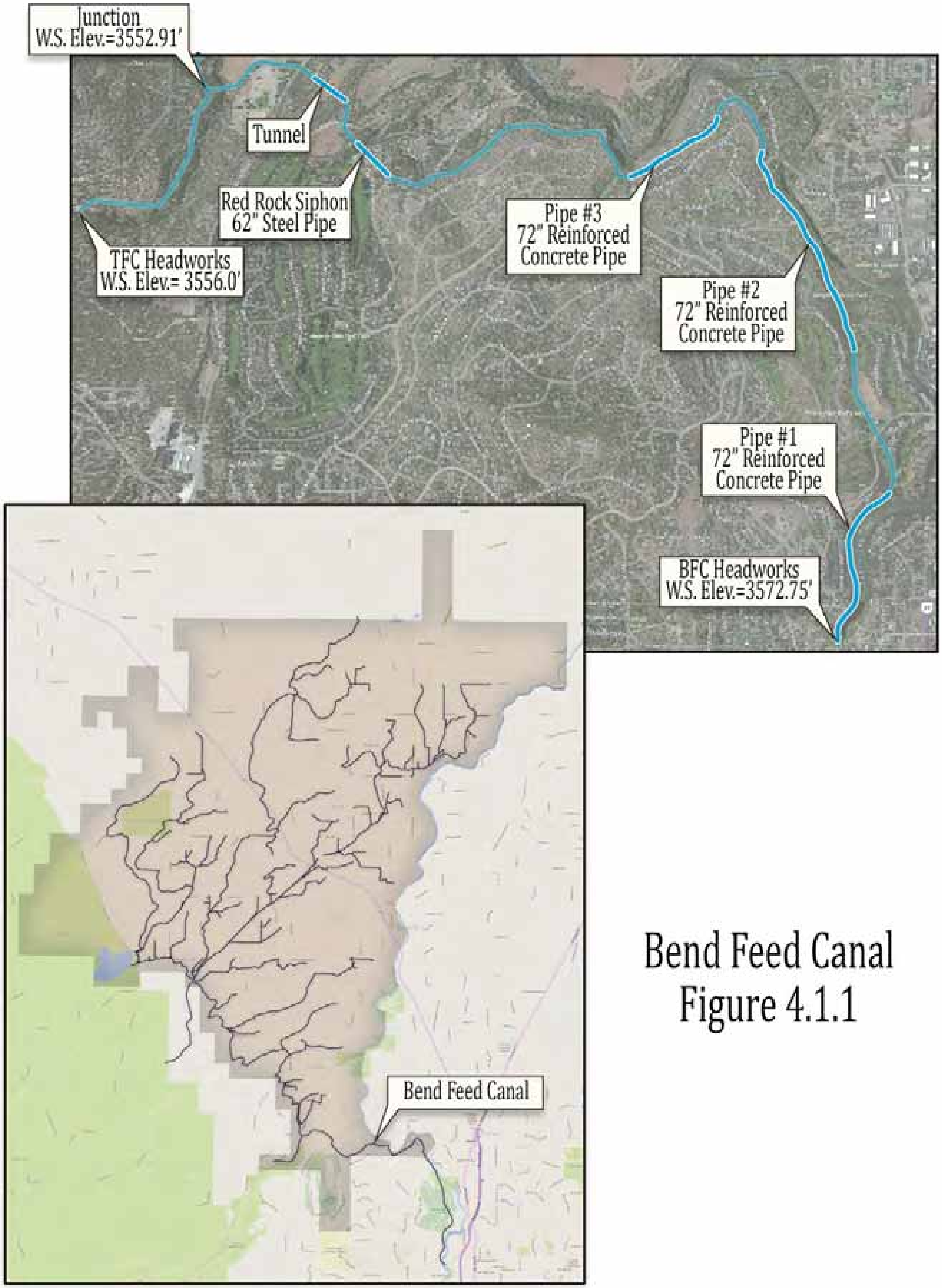
The contingency percentage was carefully considered. The Association for the Advancement of Cost Engineering (AACE) is a nationally recognized organization that has developed an accepted system of contingency ranges based upon project specificity level "Class". There are 5 project Classes starting from Class 5 with only conceptual project definition to Class 1 where a project has been completely developed and bid. This SIP was considered to fall within the Class 4 definition. The AACE Class 4 project specificity level (i.e. a project at 1%-15% definition) carries an anticipated contingency range from -15% to -30% on the low end of the range to +20% to +50% on the high end of the range. We selected a contingency value of +30% that is in the middle of the high contingency range provided by AACE. It should be noted that the phased cost estimate is based largely upon the cost of pipe materials. Budgetary pricing for steel pipe was found to be very competitive at the time of development of this SIP. For construction that is completed soon after the development of this SIP, the cost estimates should remain robust. For work lagging several years beyond the development of this SIP, the risk of cost change is greater. For this reason, it is recommended that every 2 years a cost evaluation be performed to update the phased construction cost estimates.

4.7 Bend Feed Canal Capacity Analysis

As indicated above, a specific gravity model was developed to evaluate the existing Tumalo Irrigation District conveyance system in the open-channel and low-head portion of the District's system. The model was developed in WSPG2010 software. This software, described above, is a robust software capable of modeling open channel and pressurized piping hydraulics, including modeling unsteady hydraulic conditions such as hydraulic jumps and other complex modeling scenarios. The software is also capable of modeling physical pipe transitions, differing pipe friction factors, inverted siphons, headwall and tailwalls and associated hydraulic losses and a variety of other features necessary to assess the Bend Feed Canal system.

The upper-system hydraulic model was developed based upon District drawings and information for the original construction of the Bend Feed Canal and Tumalo Feed Canal elements. Once the pipe materials, friction factors, elevations and diameters of the system were input from the original drawings, the system was calibrated based upon actual field diversion flow data and water surface profile measurements performed in the field by District staff. The hydraulic model calibration was performed successfully, emulating actual field conditions within the system to a good degree of accuracy.

Although this model was used for overall use in development of this System Improvement Plan, a more specific use of the model, as requested by the District and the City of Bend was to evaluate the hydraulic capacity of the Bend Feed Canal. As indicated above, the Bend Feed Canal is currently fully piped, but includes piped segments that restrict the capacity of the overall Bend Feed Canal delivery system. Whereas a majority of the piped Bend Feed Canal system is now comprised of lower-friction 84-IN diameter high density polyethylene "Weholite" pipe, three segments of the system are constructed of 72-IN reinforced concrete pipe, one segment is constructed of 62-IN steel pipe and one segment is a horseshoe-shaped tunnel through a hill. The WSPG2010 modeled system is indicated below and the primary elements of the Bend Feed Canal are indicated (see Figure 4.7.1 below).



Bend Feed Canal
Figure 4.1.1

Given that the District's maximal withdrawal in the last few years was 184 CFS, we capped the intake flow rate into the WSPG2010 model of the upper District at 180 CFS. Since we were trying to optimize capacity in the Bend Feed Canal, we started the base modeling case for the Bend Feed Canal (BFC) at 140 CFS and the Tumalo Feed Canal (TFC) at 40 CFS.

The base-case parameters that were critical to subsequent modeling runs with replaced pipe segments were as follows (see Figure 4.7.1 above):

- TFC Headworks Water Surface Elevation <= 3556.0 Elev.
- "Junction" or Confluence at BFC/TFC to be no Greater than Base Case Elevation of 3552.91
- Water Surface Elevation at BFC Fish Screen Channel Exit into Pipe #1 to be No Greater than Base Case Elevation of 3572.75

Pipe segments were incrementally replaced in the model. That is to say that the 72-IN Pipe #1 along the Deschutes River was replaced with 84-IN Weholite pipe in the model and then the model was run iteratively with increasing flows into the BFC and decreasing flows into the TFC (summing to 180 CFS) until one of the above parameters was exceeded. Then the model was returned to Pipe #1 being 72-IN RCP and then Pipe #2 was replaced with 84-IN HDPE and incrementally adjusted until one of the above parameters was exceeded. This process continued until all four existing pipe segments that are undersized were evaluated. The tunnel was the only segment that was not evaluated for upgrade as the physical issues and constraints of such an undertaking were considered impractical for the purposes of simply increasing system capacity. The results of the final model run for each of the pipe segment upgrades within the BFC are provided in Appendix B.

It should be noted that the base model and subsequent models and assumptions were based upon existing plan information that may not represent as-built conditions in the field. Prior to implementation of any or all of these projects, a field survey of the as-constructed conditions should be performed and associated updates to this analysis should be prepared and evaluated.

The results of this reconnaissance-level modeling analysis are tabulated below:

BFC SEGMENT REPLACEMENT AND CAPACITY GAIN EST.			
PIPE SEGMENT REPLACED WITH 84-IN WEHOLITE	LENGTH (FT)	ESTIMATED TOTAL BFC (CFS)	ESTIMATED BFC CAPACITY GAIN (CFS)
PIPE #1 72-IN RCP	3,281	149	9
PIPE #2 72-IN RCP	5,312	157	17
PIPE #3 72-IN RCP	2,051	147	7
RR SIPHON 62-IN STL	853	144	4

The associated cost for each segment upgrade was developed based upon recent construction cost information for the TFC Phase IV project. Contingency (30%), CMGC (12%), Engineering/Surveying and Construction Management (6%-8%) and pipe removal costs were added to each project estimate based upon the experience of Black Rock Consulting with similar project complexity and to try to address the broad swings in pipe material costs and construction pricing. These estimates should be revisited every 2 years and prior to construction should be updated for current estimated costs. The following estimates were developed:

Replace Bend Feed Canal Pipe #1
Tumalo Irrigation District
Reconnaissance-Level Construction Cost Estimate 10/24/16

Feature	Type	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
Remove Pipe	RCP	72	3,281	LF	$100	$328,100
PIPE	Weholite	84	3,281	LF	$720	$2,362,320
	SUBTOTAL					$2,690,420
	ENGINEERING, CM, SURVEY			8%		$215,234
	CMGC			12%		$322,850
	CONTINGENCY			30%		$968,551
	TOTAL					**$4,197,055**

Replace Bend Feed Canal Pipe #2
Tumalo Irrigation District
Reconnaissance-Level Construction Cost Estimate 10/24/16

Feature	Type	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
Remove Pipe	RCP	72	5,312	LF	$100	$531,200
PIPE	Weholite	84	5,312	LF	$720	$3,824,640
	SUBTOTAL					$4,355,840
	ENGINEERING, CM, SURVEY			6%		$261,350
	CMGC			12%		$522,701
	CONTINGENCY			30%		$1,541,967
	TOTAL					**$6,681,859**

Replace Bend Feed Canal Pipe #3
Tumalo Irrigation District
Reconnaissance-Level Construction Cost Estimate 10/24/16

Feature	Type	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
Remove Pipe	RCP	72	2,051	LF	$150	$307,650
PIPE	Weholite	84	2,051	LF	$720	$1,476,720
	SUBTOTAL					$1,784,370
	ENGINEERING, CM, SURVEY			8%		$142,750
	CMGC			12%		$214,124
	CONTINGENCY			30%		$642,373
	TOTAL					**$2,783,617**

Replace Bend Feed Canal Red Rock Siphon

Tumalo Irrigation District

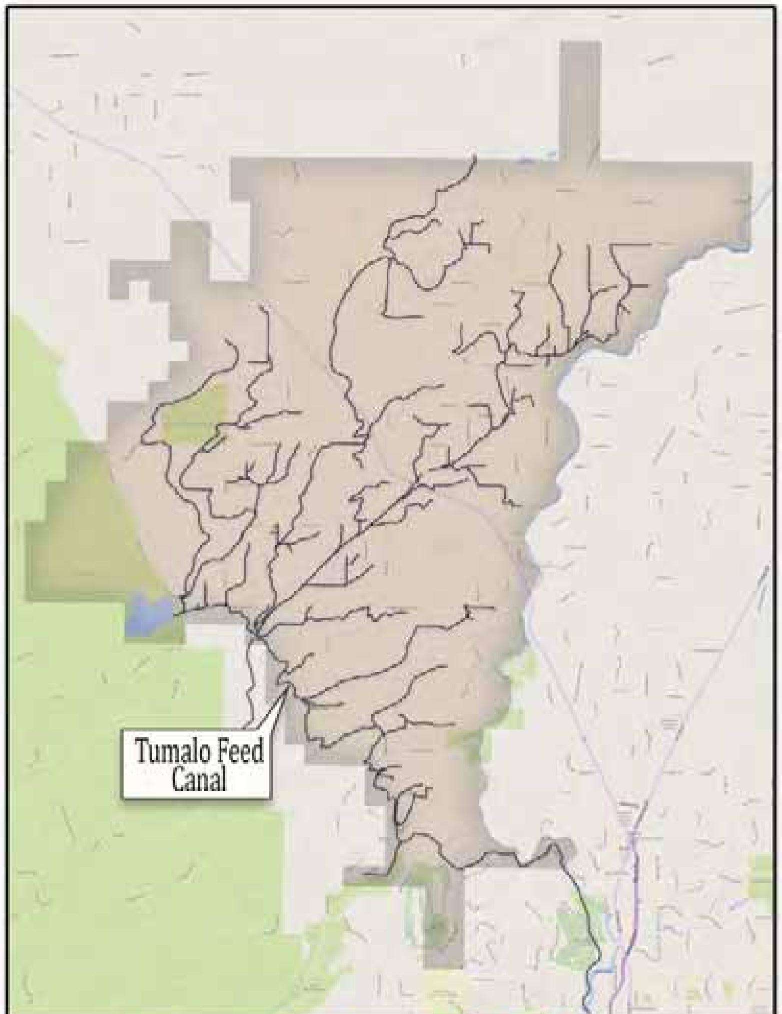
Reconnaissance-Level Construction Cost Estimate 10/24/16

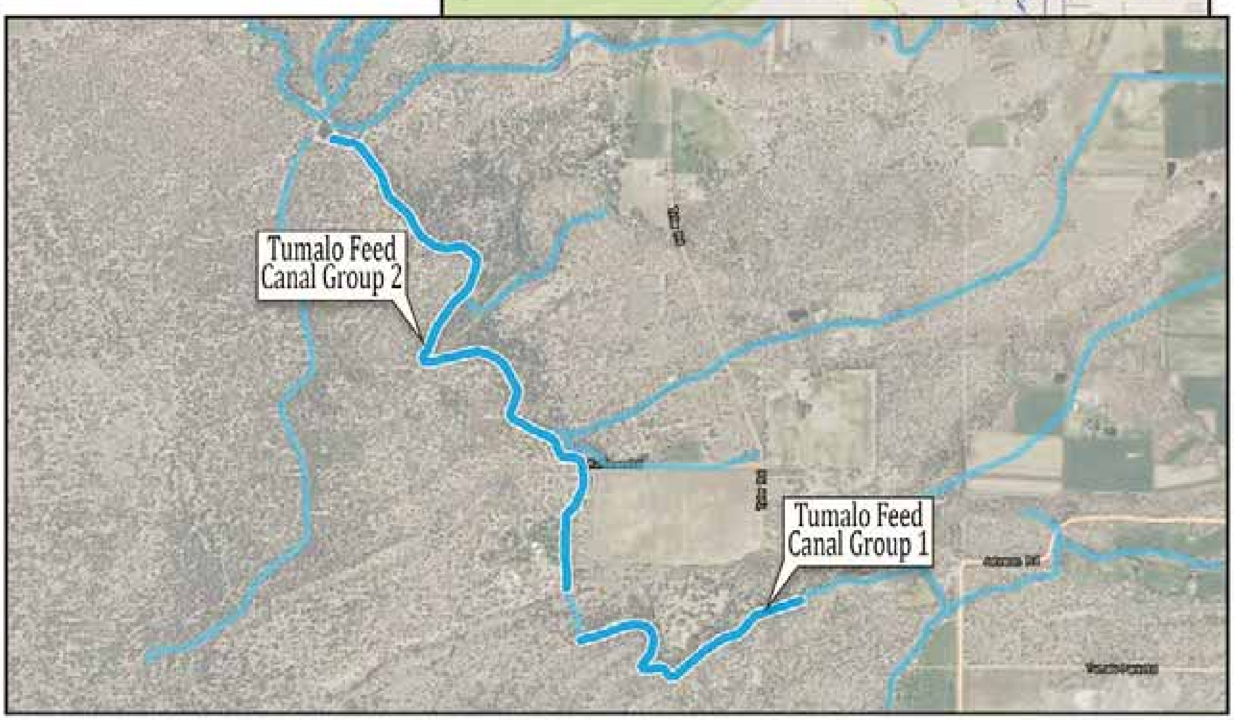
Feature	Type	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
Remove Pipe	Stl	66	853	LF	$150	$127,950
PIPE	Weholite	84	853	LF	$800	$682,400
	SUBTOTAL					$810,350
	ENGINEERING, CM, SURVEY			8%		$64,828
	CMGC			12%		$97,242
	CONTINGENCY			30%		$291,726
	TOTAL					**$1,264,146**

Section 5

Swalley Irrigation Improvements Per Lateral

Project Groups 1 & 2
Figure 5.1.1





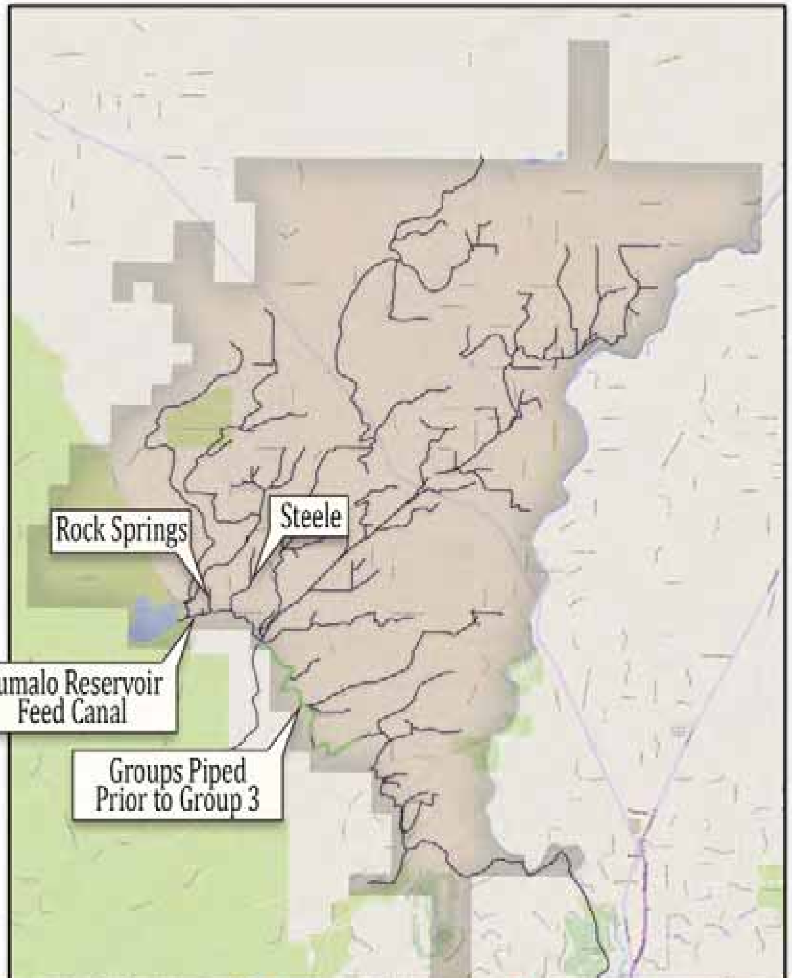
Tumalo Feed Canal Phase V						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	Weholite	84	5,500	LF	$500	$2,750,000
TURNOUT			3	EA	$8,000	$24,000
	SUBTOTAL					$2,774,000
	ENGINEERING, CM, SURVEY			6%		$166,440
	CMGC			10%		$277,400
	CONTINGENCY			8%		$257,427
	TOTAL					**$3,475,267**

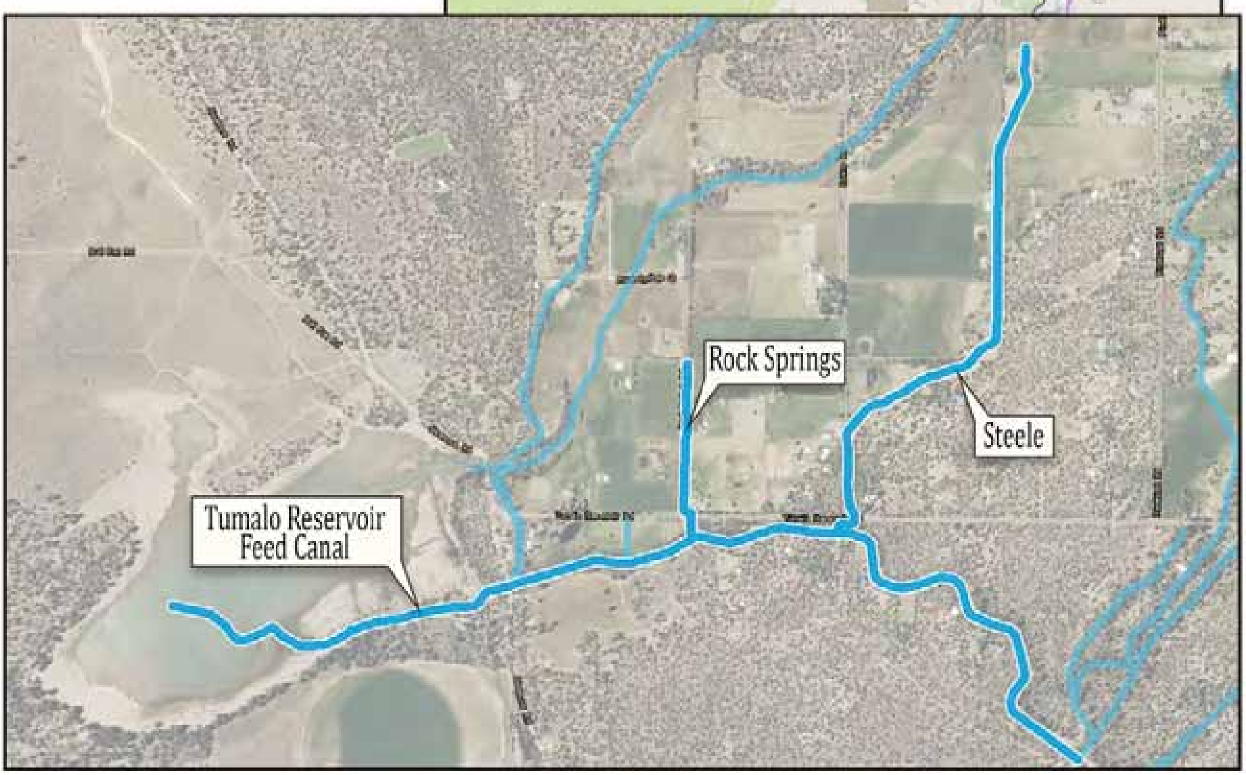
Figure 5.1.2

Tumalo Feed Canal Final Phase(s) After Phase V						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	Weholite	84	7,946	LF	$680	$5,403,148
TURNOUT			4	EA	$8,000	$32,000
	SUBTOTAL					$5,435,148
	ENGINEERING, CM, SURVEY			4%		$217,406
	CMGC			12%		$652,218
	CONTINGENCY			30%		$1,891,431
	TOTAL					**$8,196,203**

Figure 5.1.3

Project Group 3
Figure 5.2.1





Tumalo Feed Canal Reservoir Feed and Sublateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	63	718	LF	$400	$287,318
PIPE	32.5	54	4,906	LF	$240	$1,177,322
PIPE	32.5	48	177	LF	$204	$36,088
PIPE	32.5	6	4,983	LF	$7	$34,878
TURNOUT			15	EA	$8,000	$120,000
	SUBTOTAL					$1,655,606
	ENGINEERING, CM, SURVEY			10%		$165,561
	CMGC			12%		$198,673
	CONTINGENCY			30%		$605,952
	TOTAL					**$2,625,791**

Figure 5.2.2

Steele Lateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	10	281	LF	$12	$3,367
PIPE	32.5	8	2,916	LF	$8	$23,328
PIPE	32.5	6	1,813	LF	$7	$12,689
TURNOUT			11	EA	$8,000	$88,000
	SUBTOTAL					$127,384
	ENGINEERING, CM, SURVEY			15%		$19,108
	CMGC			15%		$19,108
	CONTINGENCY			30%		$49,680
	TOTAL					**$215,279**

Figure 5.2.3

Rock Springs Lateral

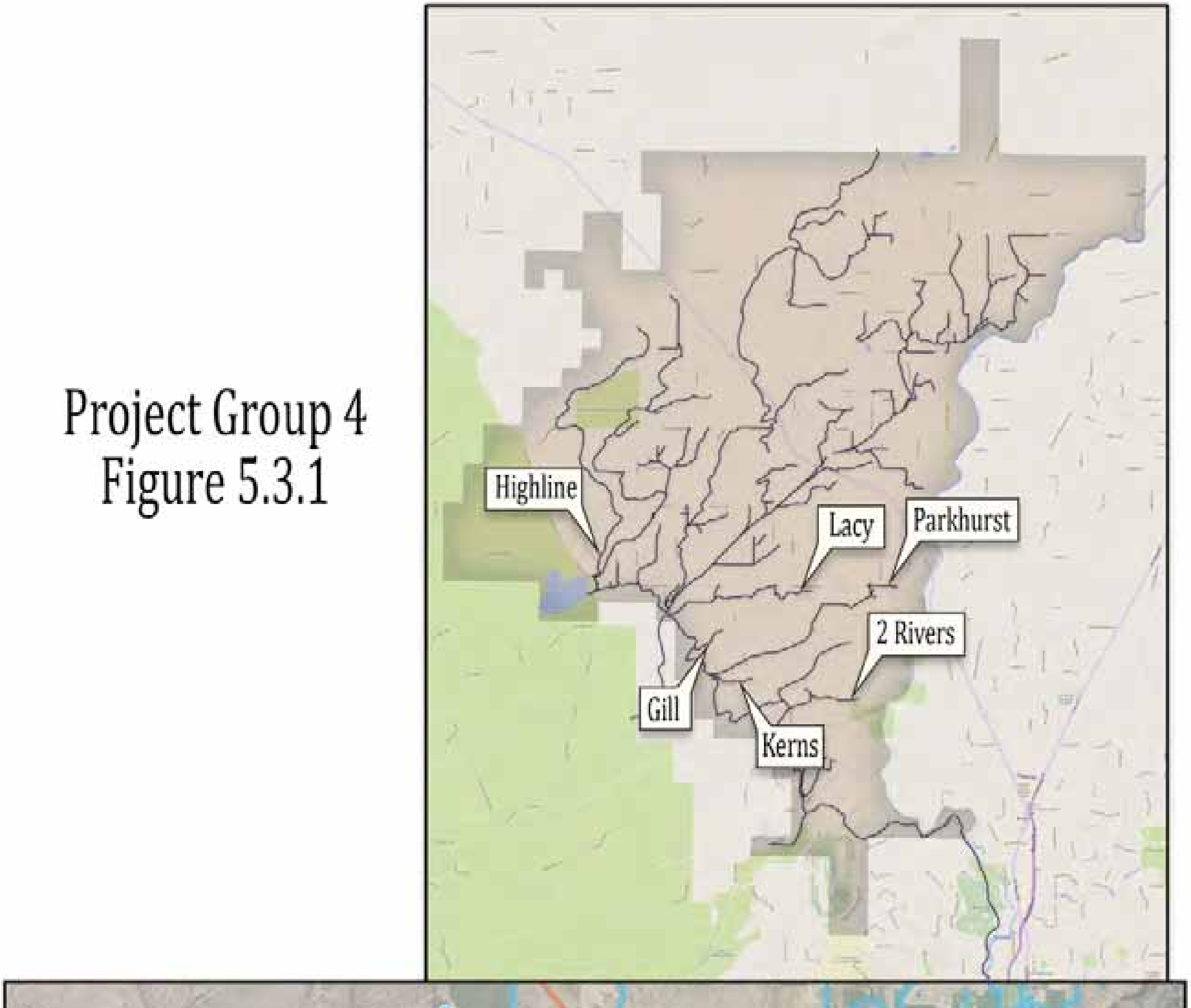
Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	6	1,516	LF	$7	$10,611
TURNOUT			4	EA	$8,000	$32,000
	SUBTOTAL					$42,611
	ENGINEERING, CM, SURVEY			15%		$6,392
	CMGC			15%		$6,392
	CONTINGENCY			30%		$16,618
	TOTAL					**$72,013**

Figure 5.2.4

Project Group 4
Figure 5.3.1



Highline Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	24	1,851	LF	$54	$99,936
PIPE	32.5	20	2,131	LF	$40	$85,233
PIPE	32.5	18	4,381	LF	$32	$140,194
PIPE	32.5	16	4,727	LF	$32	$151,268
PIPE	32.5	12	3,235	LF	$16	$51,755
PIPE	21	12	7,884	LF	$24	$189,220
PIPE	19	10	71	LF	$28	$1,995
PIPE	17	6	1,819	LF	$10	$18,193
TURNOUT			22	EA	$8,000	$176,000
	SUBTOTAL					$913,794
	ENGINEERING, CM, SURVEY			12%		$109,655
	CMGC			12%		$109,655
	CONTINGENCY			30%		$339,932
	TOTAL					**$1,473,037**

Figure 5.3.2

2 Rivers (Box S) Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	12	1,843	LF	$16	$29,488
PIPE	32.5	8	828	LF	$8	$6,624
PIPE	32.5	6	2,426	LF	$7	$16,982
TURNOUT			5	EA	$8,000	$40,000
	SUBTOTAL					$93,094
	ENGINEERING, CM, SURVEY			15%		$13,964
	CMGC			15%		$13,964
	CONTINGENCY			30%		$36,307
	TOTAL					**$157,329**

Figure 5.3.3

Kerns Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	6	2,864	LF	$7	$20,045
TURNOUT			2	EA	$8,000	$16,000
	SUBTOTAL					$36,045
	ENGINEERING, CM, SURVEY			15%		$5,407
	CMGC			15%		$5,407
	CONTINGENCY			30%		$14,058
	TOTAL					**$60,916**

Figure 5.3.4

Gill Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	6	2,635	LF	$7	$18,445
TURNOUT			1	EA	$8,000	$8,000
	SUBTOTAL					$26,445
	ENGINEERING, CM, SURVEY			15%		$3,967
	CMGC			15%		$3,967
	CONTINGENCY			30%		$10,313
	TOTAL					**$44,692**

Figure 5.3.5

Parkhurst Lateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	18	283	LF	$32	$9,043
PIPE	32.5	16	8,000	LF	$32	$255,996
PIPE	26	14	1,380	LF	$16	$22,080
PIPE	26	12	3,666	LF	$20	$73,322
PIPE	26	10	5	LF	$16	$77
PIPE	26	8	982	LF	$10	$9,820
PIPE	26	6	474	LF	$8	$3,791
PIPE	21	6	2,519	LF	$9	$22,674
TURNOUT			20	EA	$8,000	$160,000
	SUBTOTAL					$556,803
	ENGINEERING, CM, SURVEY			12%		$66,816
	CMGC			12%		$66,816
	CONTINGENCY			30%		$207,131
	TOTAL					**$897,566**

Figure 5.3.6

Lacy Lateral and Lacy SubLateral

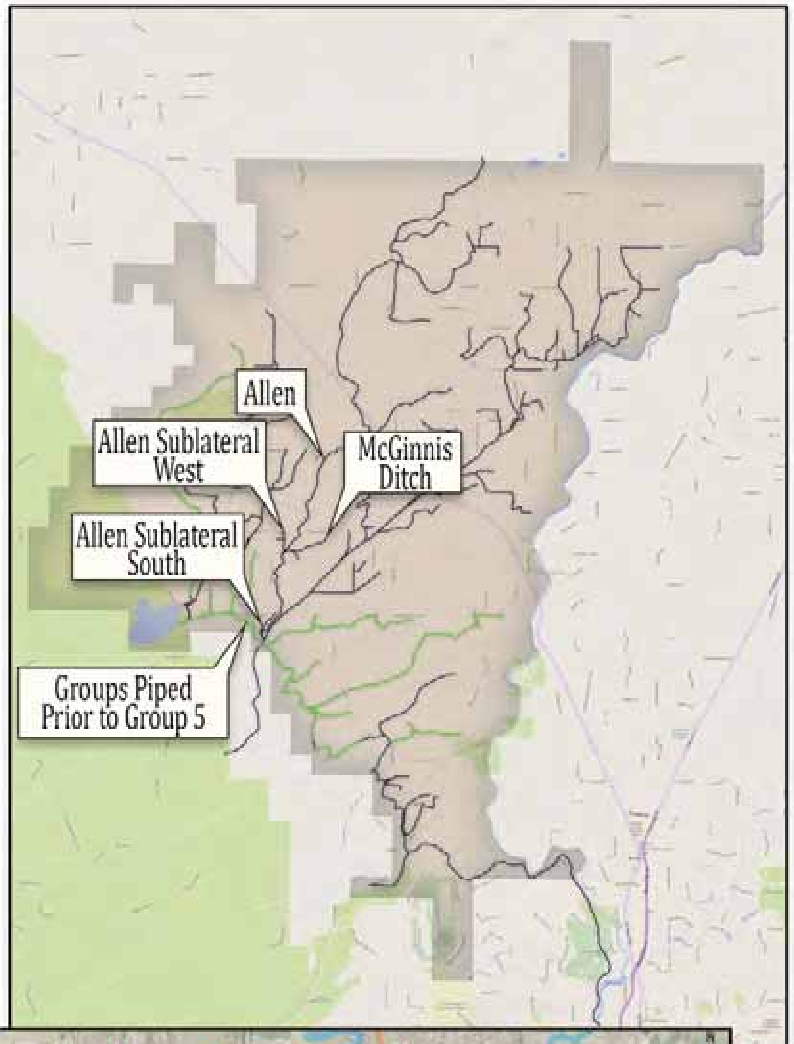
Tumalo Irrigation District

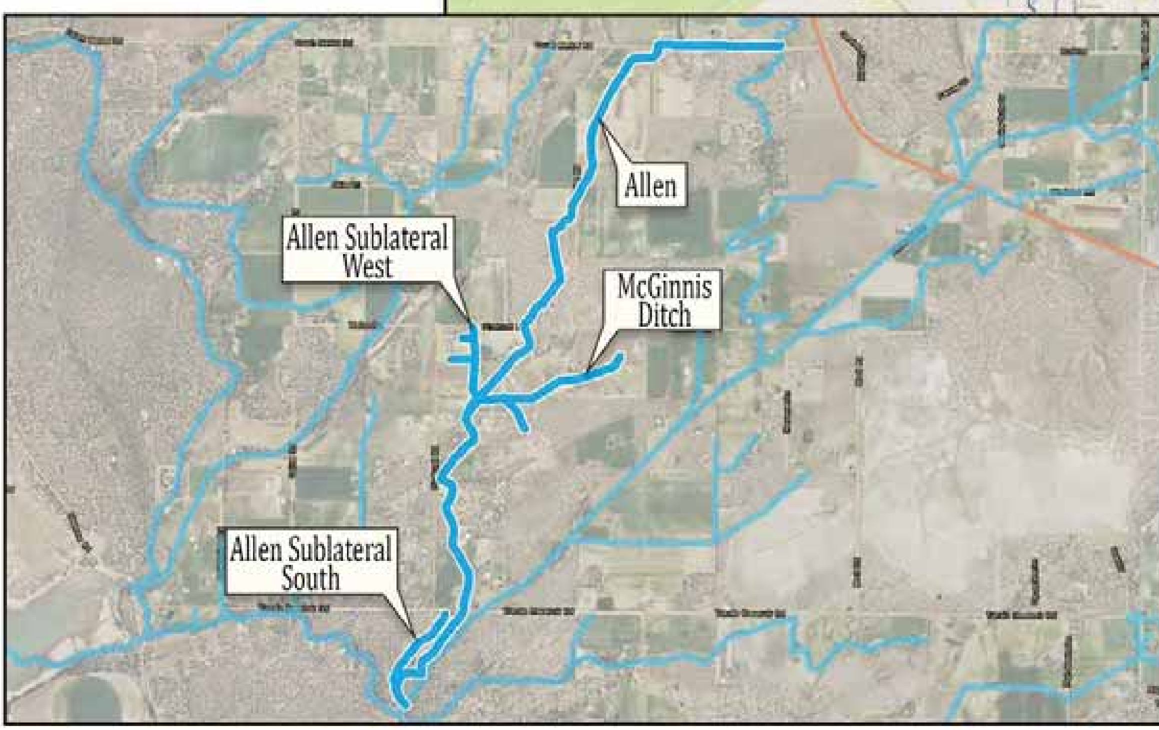
Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	12	3,809	LF	$16	$60,941
PIPE	32.5	10	1,447	LF	$12	$17,368
PIPE	32.5	8	1,327	LF	$8	$10,620
PIPE	32.5	6	5,611	LF	$7	$39,278
PIPE	26	6	952	LF	$8	$7,619
TURNOUT			16	EA	$8,000	$128,000
	SUBTOTAL					$263,825
	ENGINEERING, CM, SURVEY			15%		$39,574
	CMGC			15%		$39,574
	CONTINGENCY			30%		$102,892
	TOTAL					**$445,864**

Figure 5.3.7

Project Group 5
Figure 5.4.1





Allen Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	34	67850	LF	$110	$, 53750,
PIPE	32.5	32	57096	LF	$96	$4897191
PIPE	32.5	30	2728,	LF	$86	$1967653
PIPE	26	30	17, 43	LF	$102	$1, , 7, 84
PIPE	26	28	17, 13	LF	$90	$1547184
TURNOUT			34	EA	$87000	$2, 27000
	SUBTOTAL					$27043718
	ENGINEERING7CM7SURVEY			10%		$2047332
	CMGC			12%		$2457198
	CONTINGENCY			30%		$, 4, 7855
	TOTAL					**$3,240,703**

Figure 5.4.2

Allen Sublateral West						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	6	27040	L8	F$	F1472$,
T9 RUN9 T			4	EO	FA7000	F327000
	S9 BTNTOL					F4672$,
	EUGIUEERIUG7CM7S9 RVEY			15%		F67, 42
	CMGC			15%		F67, 42
	CNUTIUGEUCY			30%		F1A704,
	TOTAL					**$78,212**

Figure 5.4.3

Allen Sublateral South

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	6	1,899	LF	$7	$13,292
TURNOUT			3	EA	$8,000	$24,000
	SUBTOTAL					$37,292
	ENGINEERING, CM, SURVEY			15%		$5,594
	CMGC			15%		$5,594
	CONTINGENCY			30%		$14,544
	TOTAL					**$63,024**

Figure 5.4.4

McGinnis Ditch

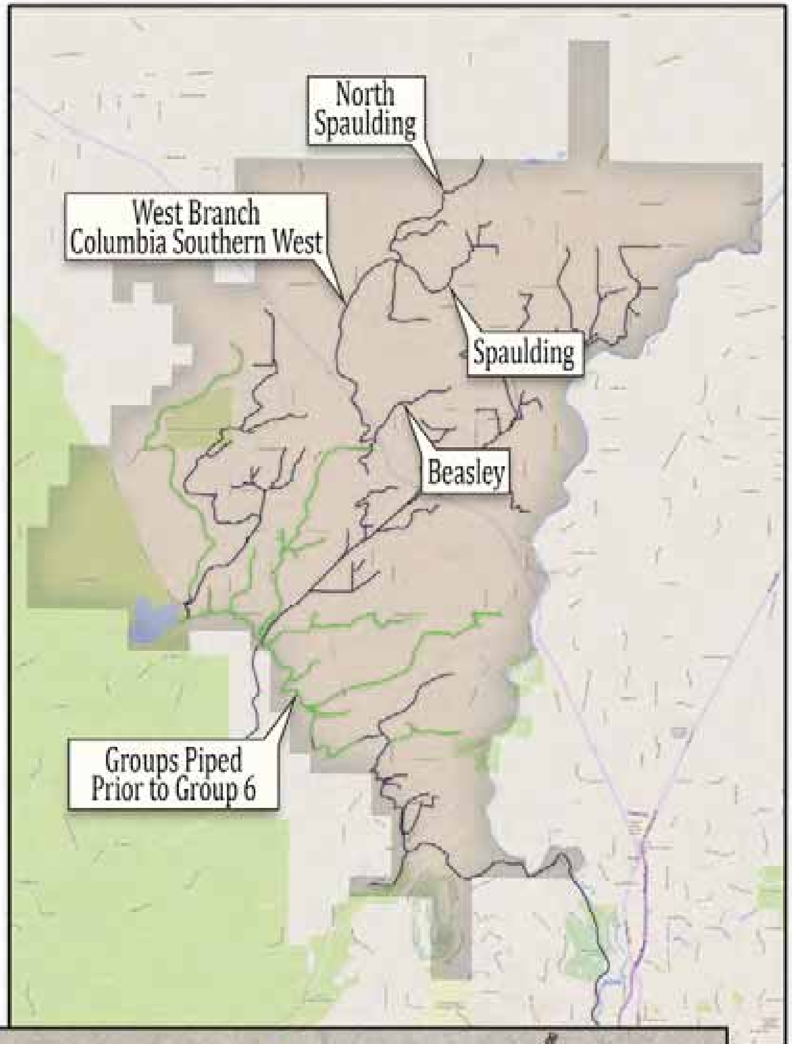
Tumalo Irrigation District

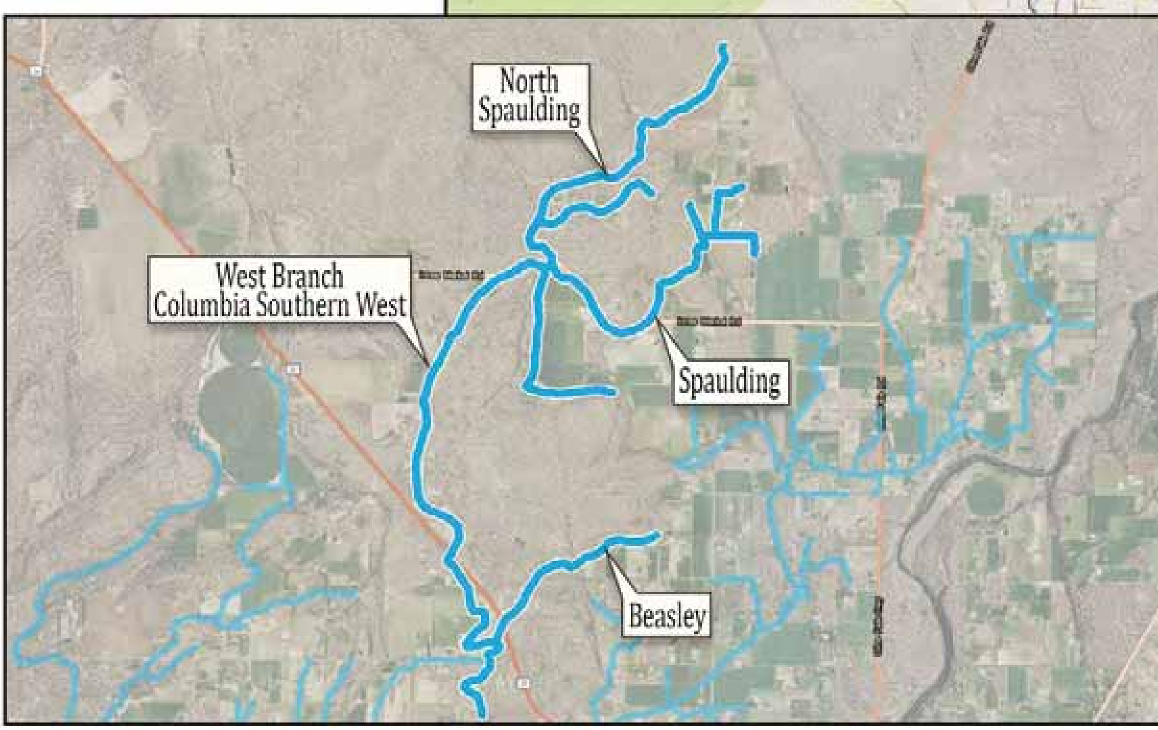
Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	6	3,891	LF	$7	$27,236
TURNOUT			5	EA	$8,000	$40,000
	SUBTOTAL					$67,236
	ENGINEERING, CM, SURVEY			15%		$10,085
	CMGC			15%		$10,085
	CONTINGENCY			30%		$26,222
	TOTAL					**$113,629**

Figure 5.4.5

Project Group 6
Figure 5.5.1





West Branch Columbia Southern West

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	27	865	LF	$84	$56,610
PIPE	32.5	26	7,703	LF	$66	$571,007
PIPE	26	24	8,555	LF	$66	$497,607
PIPE	26	10	3,703	LF	$16	$60,741
PIPE	26	7	2,632	LF	$10	$26,322
PIPE	26	6	2,421	LF	$7	$19,381
TURNOUT			31	EA	$7,000	$247,000
SUBTOTAL						$1,490,860
ENGINEERING, CM, SURVEY				10%		$149,086
CMGC				12%		$187,791
CONTINGENCY				30%		$545,617
TOTAL						**$2,364,345**

Figure 5.5.2

Beasley Lateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	7	186F0	L$	, 7	, 138521
PIPE	32.5	6	28050	L$	, 9	, 148351
PIPE	26	6	28F31	L$	, 7	, 238450
TURNOUT			20	EA	, 78000	, 1608000
SUBTOTAL						, 2118322
ENGINEERING8CM8SURVEY				15%		, 3186F7
CMGC				12%		, 25835F
CONTINGENCY				30%		, 708514
TOTAL						**$348,893**

Figure 5.5.3

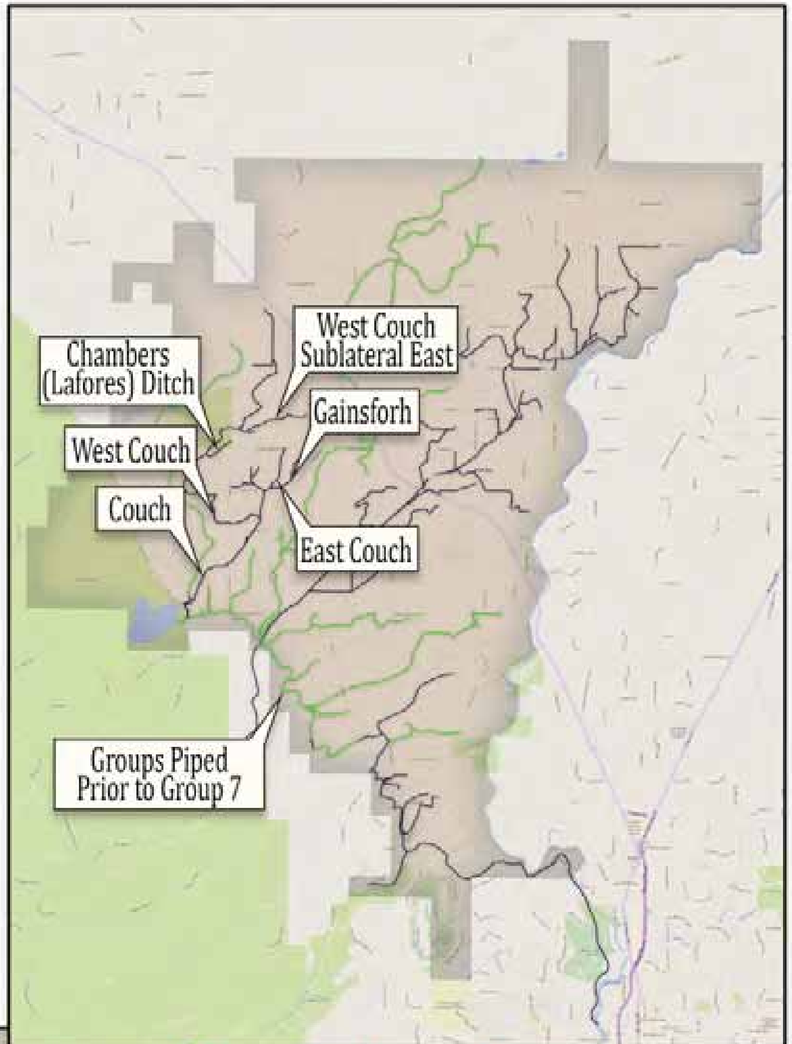
Spaulding Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	26	20	284	LF	$50	$14,203
PIPE	26	18	3,029	LF	$48	$145,371
PIPE	26	16	126	LF	$32	$4,036
PIPE	21	16	2,347	LF	$46	$107,961
PIPE	21	14	1,933	LF	$28	$54,138
PIPE	21	10	3	LF	$18	$50
PIPE	21	6	841	LF	$9	$7,571
PIPE	19	6	4,899	LF	$10	$48,992
TURNOUT			17	EA	$8,000	$136,000
	SUBTOTAL					$518,320
	ENGINEERING, CM, SURVEY			15%		$77,748
	CMGC			12%		$62,198
	CONTINGENCY			30%		$197,480
	TOTAL					**$855,747**

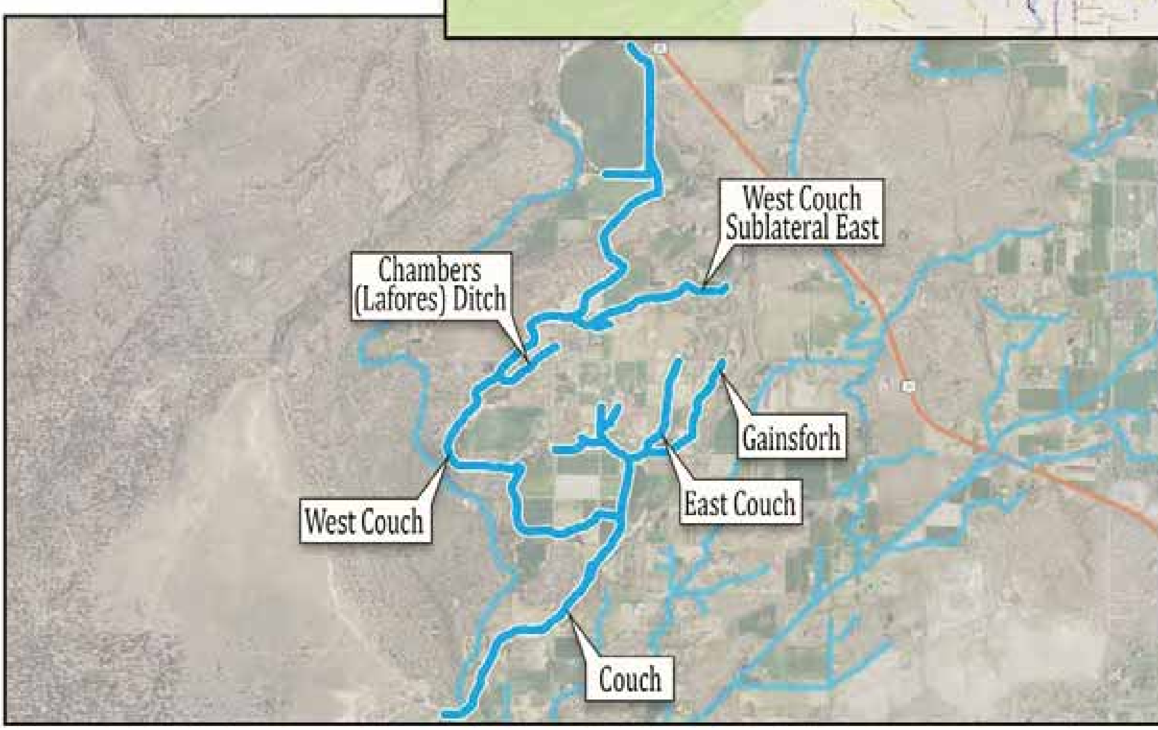
Figure 5.5.4

North Spaulding Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	6	1,617	LF	$7	$11,316
PIPE	21	6	4,446	LF	$9	$40,012
PIPE	19	6	9,376	LF	$10	$93,762
TURNOUT			4	EA	$8,000	$32,000
	SUBTOTAL					$177,090
	ENGINEERING, CM, SURVEY			15%		$26,563
	CMGC			15%		$26,563
	CONTINGENCY			30%		$69,065
	TOTAL					**$299,282**

Figure 5.5.5

Project Group 7
Figure 5.6.1





Couch Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	26	3,814	LF	$66	$251,716
PIPE	32.5	24	5,252	LF	$54	$283,621
PIPE	32.5	6	355	LF	$7	$2,483
TURNOUT			12	EA	$8,000	$96,000
	SUBTOTAL					$633,820
	ENGINEERING, CM, SURVEY			15%		$95,073
	CMGC			15%		$95,073
	CONTINGENCY			30%		$247,190
	TOTAL					**$1,071,157**

Figure 5.6.2

West Couch Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	20	19	LF	$40	$775
PIPE	32.5	18	8,943	LF	$32	$286,162
PIPE	32.5	16	3,235	LF	$32	$103,516
PIPE	26	10	2,754	LF	$16	$44,060
PIPE	19	10	3,165	LF	$20	$63,310
PIPE	17	10	11	LF	$22	$240
PIPE	19	8	4	LF	$14	$57
PIPE	17	8	349	LF	$16	$5,577
PIPE	32.5	6	611	LF	$7	$4,278
PIPE	17	6	1,771	LF	$9	$15,939
PIPE	15.5	6	3,503	LF	$20	$70,059
TURNOUT			23	EA	$8,000	$184,000
	SUBTOTAL					$777,973
	ENGINEERING, CM, SURVEY			12%		$93,357
	CMGC			12%		$93,357
	CONTINGENCY			30%		$289,406
	TOTAL					**$1,254,093**

Figure 5.6.3

West Couch Sublateral East						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	10	2,465	LF	$12	$29,580
PIPE	32.5	8	409	LF	$8	$3,272
PIPE	26	8	890	LF	$10	$8,898
PIPE	26	6	1,104	LF	$8	$8,835
TURNOUT			10	EA	$8,000	$80,000
	SUBTOTAL					$130,584
	ENGINEERING, CM, SURVEY			15%		$19,588
	CMGC			15%		$19,588
	CONTINGENCY			30%		$50,928
	TOTAL					**$220,687**

Figure 5.6.4

Chambers (Lafores) Ditch						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	6	2,066	LF	$7	$14,462
TURNOUT			7	EA	$8,000	$56,000
	SUBTOTAL					$70,462
	ENGINEERING, CM, SURVEY			15%		$10,569
	CMGC			15%		$10,569
	CONTINGENCY			30%		$27,480
	TOTAL					**$119,081**

Figure 5.6.5

East Couch Lateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	16	1,281	LF	$32	$41,323
PIPE	32.5	14	1,706	LF	$20	$36,126
PIPE	32.5	10	580	LF	$12	$U,071
PIPE	32.5	7	1,052	LF	$7	$7,41U
PIPE	32.5	6	6,600	LF	$U	$46,18U
TNROANT			26	E9	$7,000	$207,000
	SNBTAT9L					$34U,144
	EOGIOEERIOG, CM, SNRVEY			15%		$52,0U2
	CMGC			12%		$41,65U
	CAOTIOGEOCY			30%		$132,262
	TOTAL					**$573,135**

Figure 5.6.6

Gainsforth Ditch

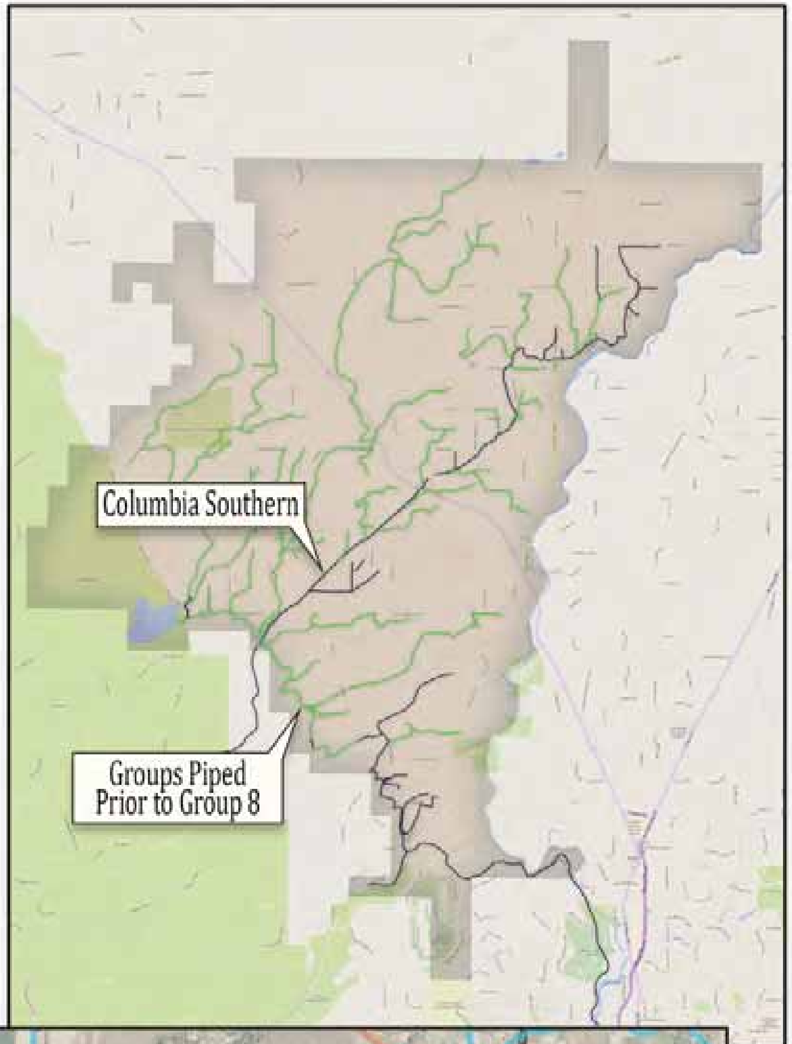
Tumalo Irrigation District

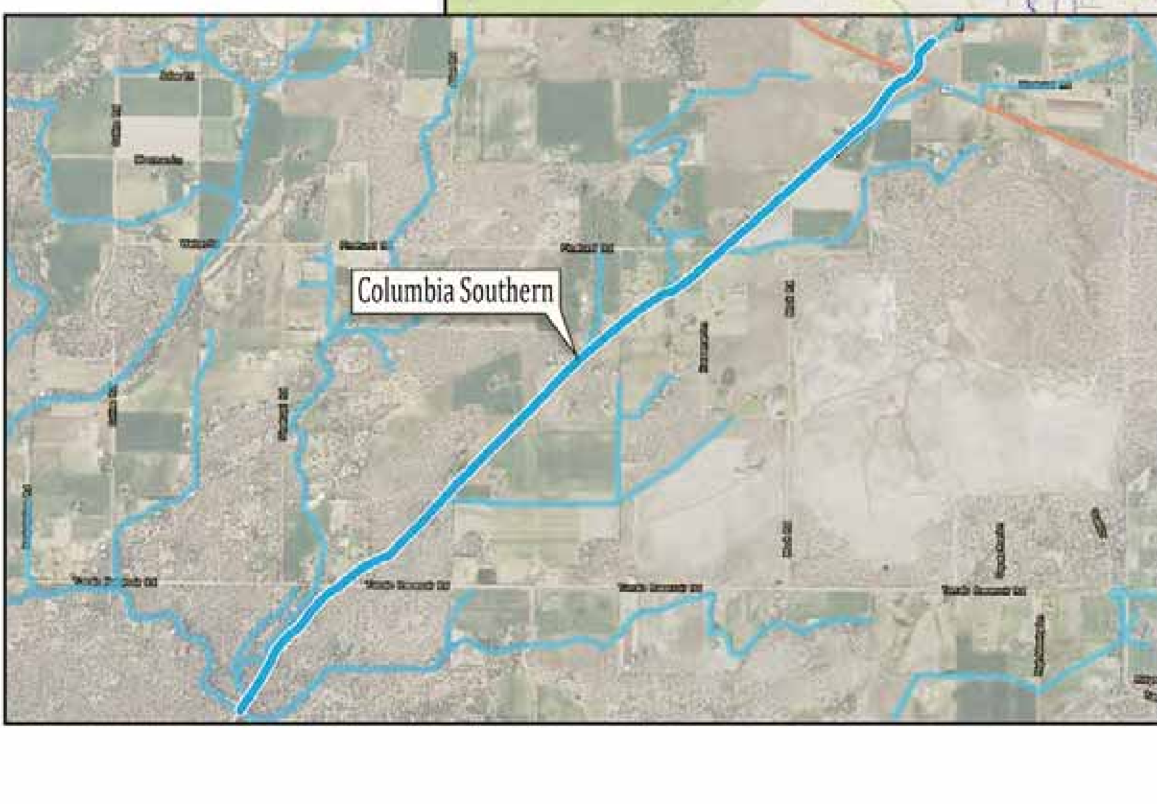
Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	6	3,891	LF	$7	$27,237
TURNOUT			4	EA	$8,000	$32,000
	SUBTOTAL					$59,237
	ENGINEERING, CM, SURVEY			15%		$8,886
	CMGC			15%		$8,886
	CONTINGENCY			30%		$23,102
	TOTAL					**$100,110**

Figure 5.6.7

Project Group 8
Figure 5.7.1

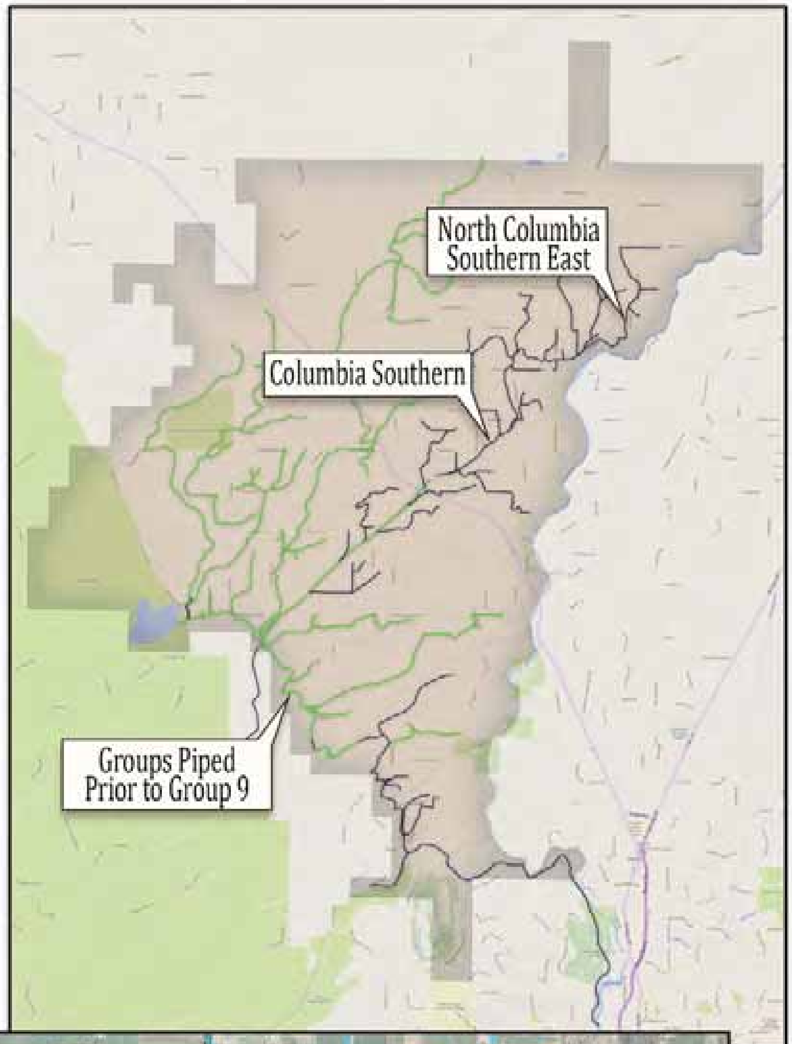


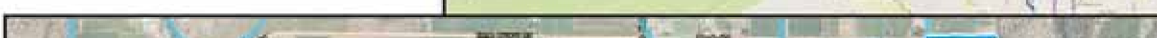


Columbia Southern Lateral TFC to Hillburner/PRV						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	63	256	LF	$400	$102,499
PIPE	32.5	48	8,426	LF	$204	$1,719,004
PIPE	26	48	6,098	LF	$250	$1,524,542
PIPE	21	48	197	LF	$300	$59,100
TURNOUT			20	EA	$8,000	$160,000
	SUBTOTAL					$3,565,144
	ENGINEERING, CM, SURVEY			6%		$213,909
	CMGC			12%		$427,817
	CONTINGENCY			30%		$1,262,061
	TOTAL					**$5,468,931**

Figure 5.7.2

Project Group 9
Figure 5.8.1





Columbia Southern Lateral Hillburner/PRV to Tail

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	42	6,099	LF	$160	$975,840
PIPE	32.5	36	5,162	LF	$120	$619,440
PIPE	26	36	943	LF	$150	$141,450
PIPE	26	32	315	LF	$116	$36,540
PIPE	26	30	941	LF	$96	$90,336
PIPE	26	28	3,729	LF	$90	$335,610
PIPE	32.5	8	331	LF	$8	$2,648
PIPE	32.5	6	1,160	LF	$7	$8,120
PIPE	26	6	3,385	LF	$8	$27,080
TURNOUT			42	EA	$8,000	$336,000
	SUBTOTAL					$2,573,064
	ENGINEERING, CM, SURVEY			8%		$205,845
	CMGC			12%		$308,768
	CONTINGENCY			30%		$926,303
	TOTAL					**$4,013,980**

Figure 5.8.2

North Columbia Southern East Lateral and Sublateral

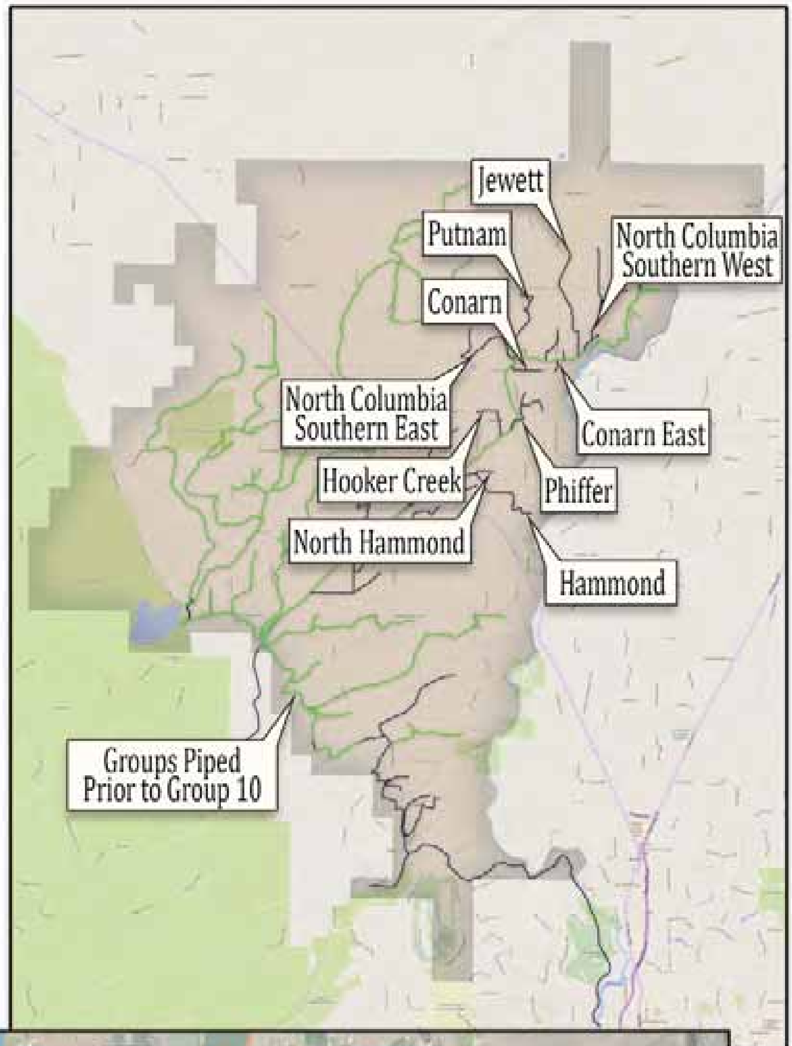
Tumalo Irrigation District

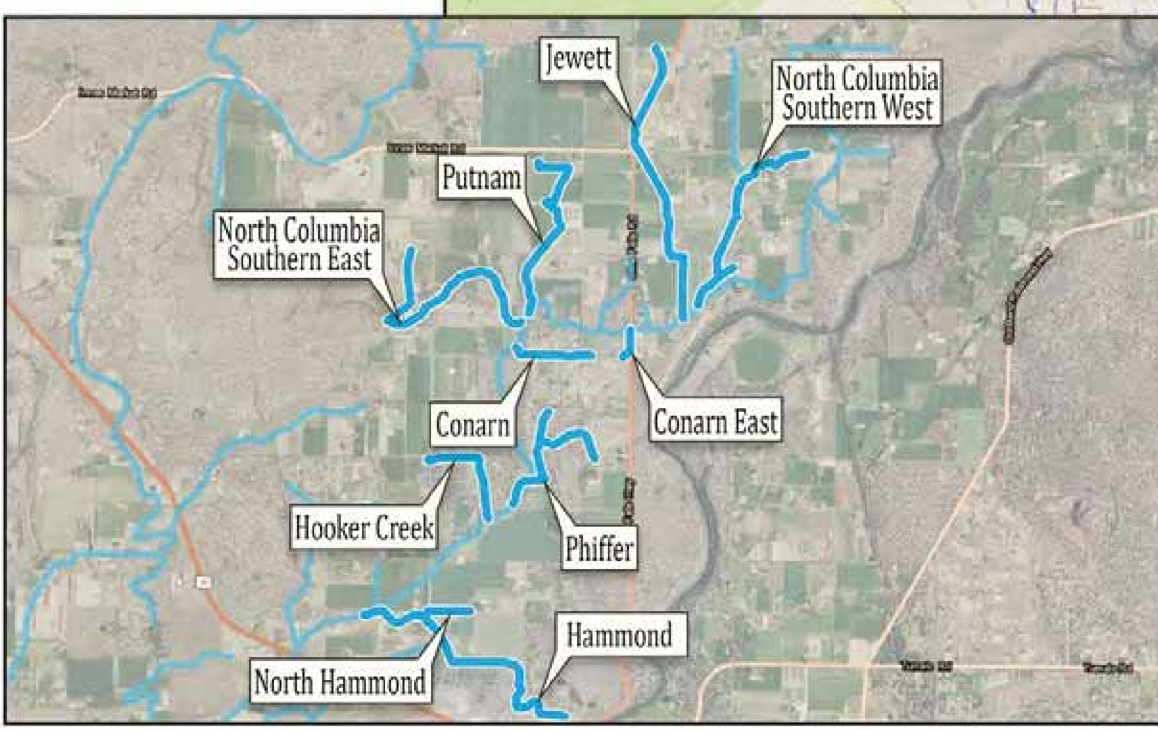
Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	24	522	LF	$54	$28,162
PIPE	32.5	14	3,407	LF	$20	$68,147
PIPE	32.5	12	3,588	LF	$16	$57,414
PIPE	32.5	6	909	LF	$7	$6,363
TURNOUT			11	EA	$8,000	$88,000
	SUBTOTAL					$248,086
	ENGINEERING, CM, SURVEY			15%		$37,213
	CMGC			15%		$37,213
	CONTINGENCY			30%		$96,753
	TOTAL					**$419,265**

Figure 5.8.3

Project Group 10
Figure 5.9.1





North Columbia Southern West Lateral and Sublateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	16	2,579	LF	$32	$82,513
PIPE	32.5	14	426	LF	$20	$8,521
PIPE	32.5	12	512	LF	$16	$8,185
PIPE	32.5	8	639	LF	$8	$5,115
PIPE	32.5	6	1,864	LF	$7	$13,049
TURNOUT			23	EA	$8,000	$184,000
	SUBTOTAL					$301,383
	ENGINEERING, CM, SURVEY			15%		$45,207
	CMGC			15%		$45,207
	CONTINGENCY			30%		$117,539
	TOTAL					**$509,337**

Figure 5.9.2

Jewett Lateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	16	2,018	LF	$32	$64,591
PIPE	32.5	14	3,056	LF	$20	$61,124
PIPE	32.5	10	2,644	LF	$12	$31,733
PIPE	26	10	59	LF	$16	$936
TURNOUT			19	EA	$8,000	$152,000
	SUBTOTAL					$310,384
	ENGINEERING, CM, SURVEY			15%		$46,558
	CMGC			15%		$46,558
	CONTINGENCY			30%		$121,050
	TOTAL					**$524,549**

Figure 5.9.3

Conarn East Tumalo Irrigation District Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	26	6	789	LF	$8	$6,315
TURNOUT			2	EA	$8,000	$16,000
	SUBTOTAL					$22,315
	ENGINEERING, CM, SURVEY			15%		$3,347
	CMGC			15%		$3,347
	CONTINGENCY			30%		$8,703
	TOTAL					**$37,713**

Figure 5.9.4

Putnam Lateral Tumalo Irrigation District Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	14	1,239	LF	$20	$24,772
PIPE	26	12	1,375	LF	$20	$27,508
PIPE	21	12	423	LF	$24	$10,156
PIPE	21	6	2,468	LF	$9	$22,214
TURNOUT			5	EA	$8,000	$40,000
	SUBTOTAL					$124,651
	ENGINEERING, CM, SURVEY			15%		$18,698
	CMGC			15%		$18,698
	CONTINGENCY			30%		$48,614
	TOTAL					**$210,660**

Figure 5.9.5

West Branch Columbia Southern East						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	26	12	2,015	LF	$20	$40,292
PIPE	26	8	444	LF	$10	$4,437
PIPE	26	6	4,103	LF	$8	$32,825
TURNOUT			9	EA	$8,000	$72,000
	SUBTOTAL					$149,554
	ENGINEERING, CM, SURVEY			15%		$22,433
	CMGC			15%		$22,433
	CONTINGENCY			30%		$58,326
	TOTAL					**$252,746**

Figure 5.9.6

Conarn Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	26	6	2,071	LF	$8	$16,567
TURNOUT			7	EA	$8,000	$56,000
	SUBTOTAL					$72,567
	ENGINEERING, CM, SURVEY			15%		$10,885
	CMGC			15%		$10,885
	CONTINGENCY			30%		$28,301
	TOTAL					**$122,638**

Figure 5.9.7

Phiffer Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	12	1,238	LF	$16	$19,801
PIPE	32.5	8	2,089	LF	$8	$16,712
PIPE	32.5	6	1,684	LF	$7	$11,791
TURNOUT			13	EA	$8,000	$104,000
	SUBTOTAL					$152,305
	ENGINEERING, CM, SURVEY			15%		$22,846
	CMGC			15%		$22,846
	CONTINGENCY			30%		$59,399
	TOTAL					**$257,395**

Figure 5.9.8

Hooker Creek Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	12	970	LF	$16	$15,528
PIPE	32.5	10	1,948	LF	$22	$42,867
TURNOUT			9	EA	$8,000	$72,000
	SUBTOTAL					$130,395
	ENGINEERING, CM, SURVEY			15%		$19,559
	CMGC			15%		$19,559
	CONTINGENCY			30%		$50,854
	TOTAL					**$220,367**

Figure 5.9.9

Hammond Lateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	14	1,473	LF	$20	$29,463
PIPE	32.5	12	284	LF	$16	$4,537
PIPE	32.5	10	1,417	LF	$12	$17,004
PIPE	32.5	8	1,499	LF	$8	$11,992
PIPE	32.5	6	344	LF	$7	$2,408
PIPE	26	6	2,515	LF	$8	$20,120
TURNOUT			18	EA	$8,000	$144,000
	SUBTOTAL					$200,061
	ENGINEERING, CM, SURVEY			15%		$30,009
	CMGC			15%		$30,009
	CONTINGENCY			30%		$78,024
	TOTAL					**$338,103**

Figure 5.9.10

North Hammond Lateral

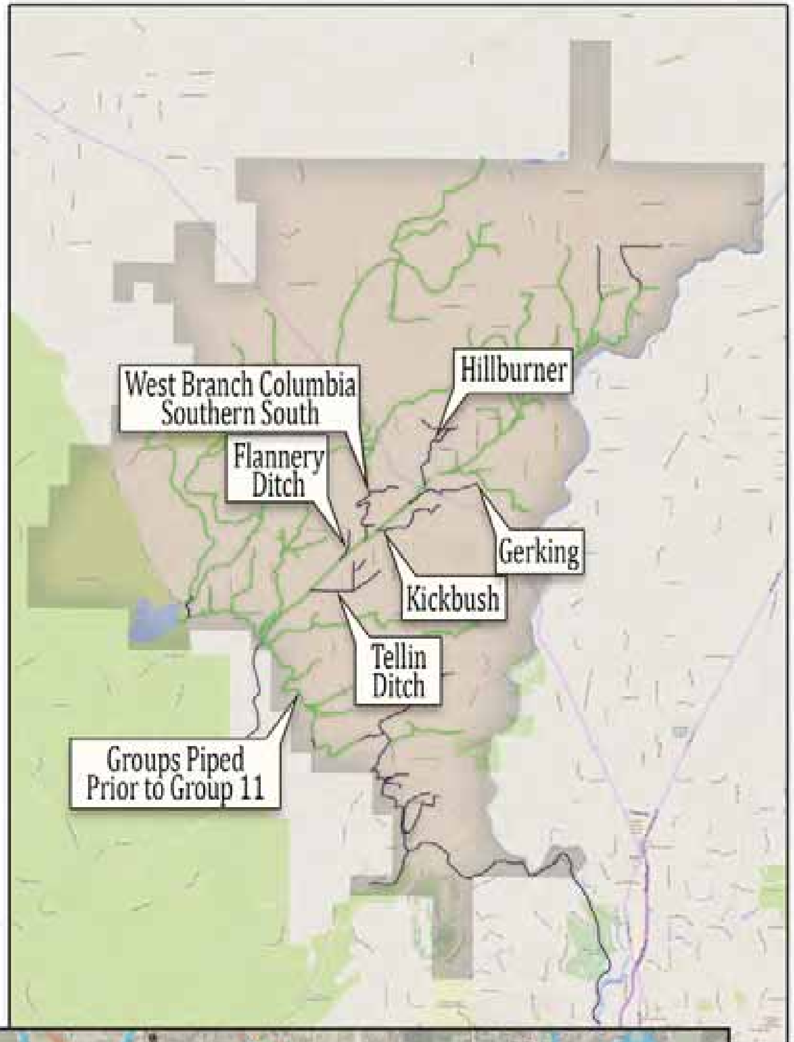
Tumalo Irrigation District

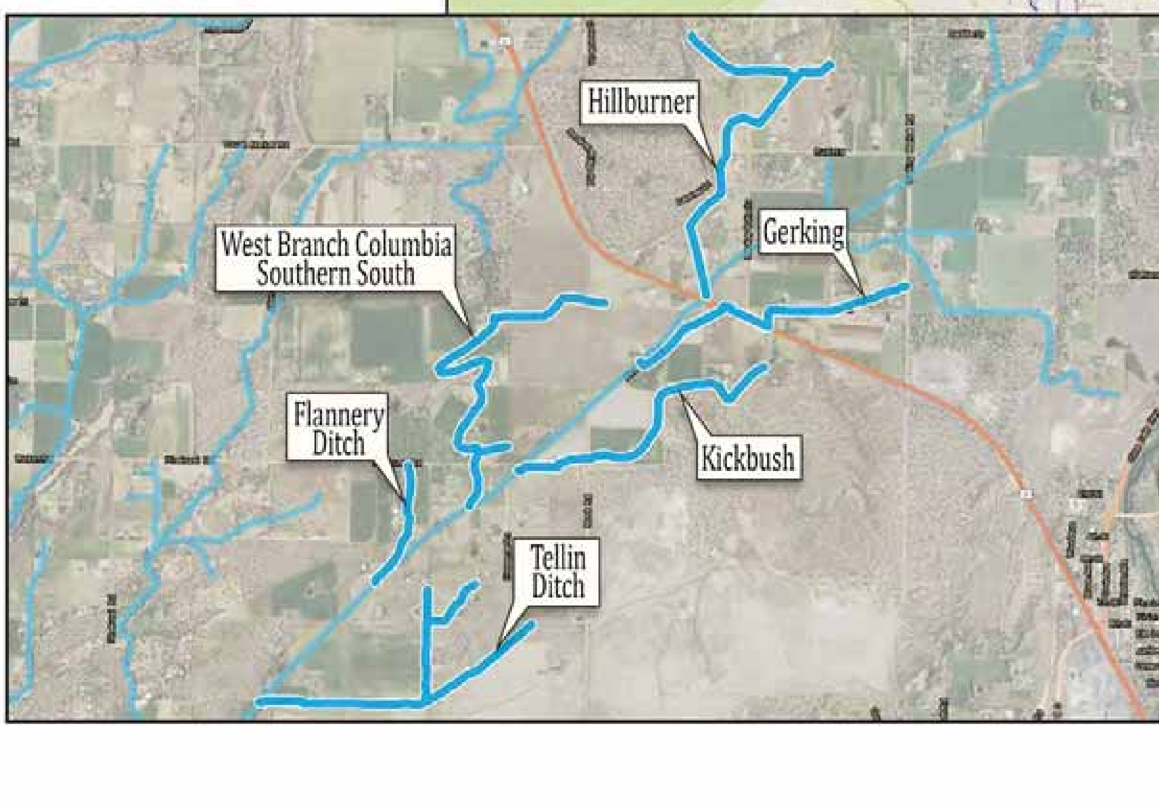
Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	32.5	8	232	LF	$8	$1,857
PIPE	32.5	6	278	LF	$7	$1,946
TURNOUT			5	EA	$8,000	$40,000
	SUBTOTAL					$43,803
	ENGINEERING, CM, SURVEY			15%		$6,571
	CMGC			15%		$6,571
	CONTINGENCY			30%		$17,083
	TOTAL					**$74,028**

Figure 5.9.11

Project Group 11
Figure 5.10.1





Hillburner Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	21	8	3,680	LF	$22	$80,968
PIPE	21	6	968	LF	$9	$8,710
PIPE	19	6	2,697	LF	$10	$26,968
TURNOUT			17	EA	$8,000	$136,000
	SUBTOTAL					$252,646
	ENGINEERING, CM, SURVEY			15%		$37,897
	CMGC			15%		$37,897
	CONTINGENCY			30%		$98,532
	TOTAL					**$426,972**

Figure 5.10.2

Gerking Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	21	6	2,629	LF	$16	$42,064
PIPE	21	8	2,626	LF	$22	$57,781
TURNOUT			11	EA	$8,000	$88,000
	SUBTOTAL					$187,845
	ENGINEERING, CM, SURVEY			15%		$28,177
	CMGC			15%		$28,177
	CONTINGENCY			30%		$73,260
	TOTAL					**$317,458**

Figure 5.10.3

Kickbush Lateral

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	26	8	1,191	LF	$10	$11,907
PIPE	26	6	4,099	LF	$8	$32,794
TURNOUT			6	EA	$8,000	$48,000
	SUBTOTAL					$92,701
	ENGINEERING, CM, SURVEY			15%		$13,905
	CMGC			15%		$13,905
	CONTINGENCY			30%		$36,153
	TOTAL					**$156,664**

Figure 5.10.4

West Branch Columbia Southern South

Tumalo Irrigation District

Reconnaissance-Level Construction Cost Estimate 10/24/2016

Feature	DR or PR	Dia. (In)	Length (ft)	Unit	$/Unit	Total Cost
PIPE	26	12	18F	L$	520	5, 3F4,
PIPE	26	10	FFF	L$	516	5123 4, 1
PIPE	26	8	43 16F	L$	510	5413 6F0
PIPE	26	6	23 4F9	L$	58	5193 8, 2
T7 RUN7 T			11	EO	583 000	5883 000
	A7 STNTOL					516B3 6F6
	EUGIUEERIUG3CM3A7 RVEY			1B%		5243 8B1
	CMGC			1B%		5243 8B1
	CNUTIUGEUCY			, 0%		5643 614
	TOTAL					**$279,993**

Figure 5.10.5

Flannery Ditch						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	6	2,178	LF	$7	$15,248
TURNOUT			4	EA	$8,000	$32,000
	SUBTOTAL					$47,248
	ENGINEERING, CM, SURVEY			15%		$7,087
	CMGC			15%		$7,087
	CONTINGENCY			30%		$18,427
	TOTAL					**$79,850**

Figure 5.10.6

Tellin Lateral						
Tumalo Irrigation District						
Reconnaissance-Level Construction Cost Estimate						10/24/2016
Feature	**DR or PR**	**Dia. (In)**	**Length (ft)**	**Unit**	**$/Unit**	**Total Cost**
PIPE	32.5	7	28720	LF	$7	$228556
PIPE	32.5	6	58152	LF	$,	$368063
T9 RUN9 T			O	EA	$78000	$, 28000
	S9 BTNTAL					$130861O
	EUGIUEERIUG8CM8S9 RVEY			15%		$108503
	CMGC			15%		$108503
	CNUTIUGEUCY			30%		$508042
	TOTAL					**$220,747**

Figure 5.10.7

APPENDIX A
TABULATED SEEPAGE LOSS DATA

TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

10/4/2016
Final

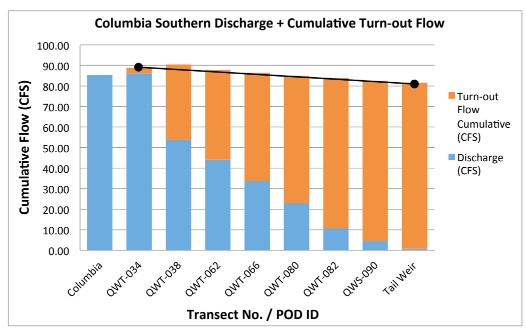
Color	Meaning
(green)	=
(yellow)	= Not Measured or Estimated
(red)	= Return Flow
(purple)	= Turn-outs to Laterals and Sub Laterals

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Columbia Southern (South + North)				
Columbia Southern Weir	**85.27**		0.00	16 ft cipolletti, 1.39 ft deep
SCS-0010		-0.07		32.9 GPM
SCS-0020		-0.03		14.96 GPM
SCS-0030		-0.32		142.12 GPM
Tellin Lateral		-2.31		QWT-028, measurement rated as "Fair"
QWT-034	**86.10**		2.73	Measurement rated as "Fair"
SCS-0080		0.00		No Water usage
SCS-0090		-0.05		22.44 GPM
SCS-0100		-0.07		29.92 GPM, Beginning of Flannery Ditch
SCS-0110		-0.02		7.48 gpm
Flannery Ditch		-0.96		QWT-036, measurement rated as "Fair"
SCS-0140		-0.03		14.96 GPM
SCS-0150		-0.08		37.4 GPM
SCS-0160		0.00		No Water usage
West Branch Lateral		-32.70		QWT-040, measurement rated as "Good"
QWT-038	**53.81**		36.64	Measurement rated as "Good"
Kickbush Lateral		-2.76		QWT-060, measurement rated as "Fair"
SCS-0210		0.00		No Water usage
SCS-0220		-0.02		7.48 GPM
North Gerking Lateral		-1.57		3 ft cipolletti, 3.5 inch depth
Hillburner Lateral		-2.50		Head of Lateral, 2.5 CFS
NCS-0001		0.00		No water usage, OFF
NCS-0010		0.00		No water usage, OFF
NCS-0011		-0.15		1 ft cipolletti, 1.5 inch depth
QWT-062	**44.08**		43.64	Measurement rated as "Good"
North Hammond Lateral		-4.11		4 ft cipolletti, 5.5 inch depth
NCS-0020		-0.46		2 ft cipolletti, 2 inch depth
NCS-0030		-0.05		21.69 GPM
NCS-0040		-0.51		1 ft cipolletti, 3 3/8 inch depth
NCS-0050		-0.11		6 inch cipolletti, 1 7/8 inch depth
NCS-0055		-0.21		6 inch cipolletti, 2 7/8 inch depth
NCS-0060		0.00		No water usage, OFF
NCS-0070		-0.03		11.97 GPM
NCS-0080		-0.55		247 GPM
NCS-0090		-0.03		14.96 GPM
Hooker Creek Lateral		-2.98		QWT-064, measurement rated as "Good"
NCS-0100		-0.02		7.48 GPM
QWT-066	**33.65**		52.70	Measurement rated as "Good"
Phiffer Lateral		-4.59		QWT-070, measurement rated as "Fair"
NCS-0110		-0.03		14.96 GPM
NCS-0111		-0.01		6 inch cipolletti, 0.25 inch depth
NCS-0120		-0.54		2 ft cipolletti, 2.25 inch depth
NCS-0130		-0.65		1 ft cipolletti, 4 inch depth
NCS-0140		0.00		No water usage, OFF
NCS-0150		0.00		No water usage, OFF
Conarn Lateral		-0.88		QWT-072, measurement rated as "Good"
Return Flow		*2.94*		From West Branch, QWT-058, rated "Poor"
NCS-0160		0.00		No water usage, OFF
Putnam Lateral		-4.40		QWT-076, measurement rated as "Good"
NCS-0170		-0.05		22.44 GPM
NCS-0180		0.00		No water usage, OFF
NCS-0190		0.00		No water usage, OFF
NCS-0200		-0.12		52.36 GPM
NCS-0210		-0.20		89.76 GPM
North Hagerty Lat		-0.77		QWT-078B, measurement rated as "Fair"
QWT-080	**22.93**		61.99	Measurement rated as "Poor"
Return Flow		*0.00*		From Conarn, QWT-074, no measure, est 0.0 CFS
NCS-0220		-0.06		26.16 GPM
NCS-0230		-0.07		29.17 GPM
NCS-0240		-0.19		83.02 GPM
NCS-0250		-0.08		37.46 GPM
NCS-0260		-0.13		59.84 GPM
Jewett Lateral		-5.90		4 ft cipolletti, 7 inch depth
NCS-0270		-0.02		7.48 GPM
NCS-0280		-0.10		44.88 GPM
Columbia Southern East		-4.66		QWT-084, rated as "Good", measured downstr
QWT-082	**10.64**		73.20	Measurement rated as "Good"
NCS-0290		-0.17		74.86 GPM
NCS-0300		-0.18		6 inch cipolletti, 2 5/8 inch depth
NCS-0310		-0.62		1 ft cipolletti, 3 7/8 inch depth
NCS-0320		-0.06		6 inch cipolletti, 1.25 inch depth
NCS-0330		-0.53		1 ft cipolletti, 3.5 inch depth
NCS-0340		0.00		No water usage, OFF

Columbia Southern (South + North)

Over-all Tumalo Irrigation District Discharge Measurements

Overall TID System Intake	=	425.13		
Overall TID System Turnout + Flow Remaining	=	-374.85		
Overall TID System Losses in the Study Reach	=	50.28	=	11.83%



Columbia Southern Intake to the Study Reach	=	86.10		
Columbia Southern Turnout + Flow Remaining	=	-80.80		
Columbia Southern Losses in the Study Reach	=	5.29	=	6.15%

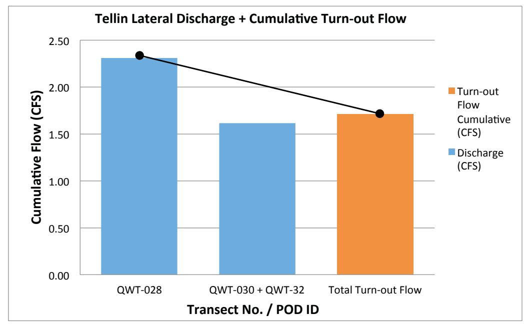
TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

10/4/2016
Final

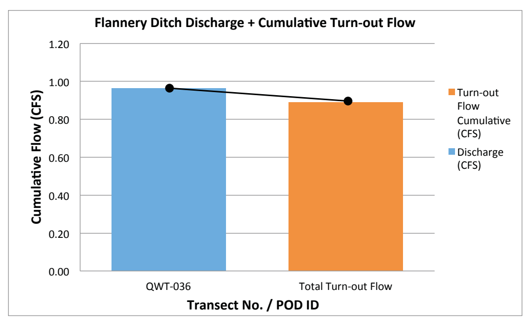
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
NCS-0350		-0.56		1 ft cipolletti, 3 5/8 inch depth
NCS-0360		-0.02		7.48 GPM
NCS-0362		-0.08		37.4 GPM
NCS-0364		-0.07		29.92 GPM
NCS-0366		-0.05		22.44 GPM
NCS-0368		0.00		No water usage, OFF
NCS-0370		-0.28		6 inch cipolletti, 3.5 inch depth
NCS-0375		-0.04		1 ft cipolletti, 0.625 inch depth
NCS-0380		0.00		No water usage, OFF
Davis Fill		-2.00		estimate at 2.00 CFS
QWS-090	**4.54**		77.86	Measurement rated as "Fair"
NCS-0400		-1.53		2 ft cipolletti, 4.5 inch depth
NCS-0410		0.00		No water usage, OFF
NCS-0420 (Linder Pipe)		-0.25		1 ft cipolletti, 2.125 inch depth
NCS-0425 (Linder Pipe)		-0.14		6 inch cipolletti, 2.25 inch depth
NCS-0430 (Linder Pipe)		-0.59		1 ft cipolletti, 3.75 inch depth
Linder Pipe		-1.32		estimate at 1.32 CFS
Return Flow		*2.35*		From C.S. East, QWT-088, rated as "Poor"
NCS-0440		-1.46		653.75 GPM
Tail Weir	**0.78**		80.80	4 ft cipolletti, 0.15 ft depth
Columbia S Flow Remaining	0.00			
Tellin Lateral				
SCS-0040		-0.27		1 ft cipolletti, 2.25 inch depth
QWT-028	**2.31**		0.00	Measurement rated as "Fair"
QWT-030 + QWT-32	**1.61**		0.00	QWT-030 rated "Good", QWT-032 est. 0.6 CFS
SCS-0050		-0.42		1 ft cipolletti, 3 inch depth
SCS-0060		-0.42		1 ft cipolletti, 3 inch depth
SCS-0065		0.00		1 ft cipolletti, headgate shut, OFF
SCS-0070		-0.75		No weir, estimate 0.75 CFS
SCS-0075		-0.12		6 inch cipolletti, flooded, estimate 2.0 inch
Total Turn-out Flow	**0.00**		1.71	
Tellin Lat Flow Remaining	0.00			
Flannery Ditch				
SCS-0110		-0.02		7.48 gpm
QWT-036	**0.96**		0.00	Measurement rated as "Fair"
SCS-0120		-0.30		2 ft cipolletti, 1.5 inch depth
SCS-0130		-0.09		6 in cipolletti, 1.625 inch depth
SCS-0131		-0.48		1 ft cipolletti, 3.25 inch depth
Total Turn-out Flow	**0.00**		0.89	
Flannery Ditch Flow Remaining	0.00			
West Branch				
SWB-0010		0.00		Pump 1.5 HP, 1.5" outlet, OFF
SWB-0020		-0.08		1 ft Cipolletti, 1 inch depth
QWT-040	**32.70**		0.08	Measurement rated as "Good"
SWB-0030		-0.23		2 ft Cipolletti, 1.25 inch depth
SWB-0035		-0.37		2 ft Cipolletti, 1.75 inch depth
SWB-0040		-0.06		2 ft Cipolletti, 0.5 inch depth
SWB-0050		-0.64		2 ft cipolletti, 2.5 inch depth
SWB-0051		-0.27		1 ft Cipolletti, 2.25 inch depth
SWB-0060				NOT APPLICABLE
SWB-0070		-0.18		No weir, estimate, 80 GPM
SWB-0080		-0.04		Pump 1 HP, 1.5" outlet estimate, 20 GPM
SWB-0090		-0.04		Pump 1 HP, 1.5" outlet estimate, 20 GPM
SWB-0100		0.00		Pump 1 HP, 1.5" outlet, OFF
Return Flow		*1.05*		QWT-026 (return flow from Allen Lateral)
QWT-042	**28.79**		0.86	Measurement rated as "Fair"
Beasley Lateral		-1.53		2 ft Cipolletti, 4.5 inch depth
QWT-044	**29.54**		2.39	Measurement rated as "Fair"

Tellin Lateral

Flannery Ditch



Tellin Lateral Intake to the Study Reach	=	2.31		
Tellin Lateral Turnout + Flow Remaining	=	-1.71		
Tellin Lateral Losses in the Study Reach	=	0.60	=	25.96%



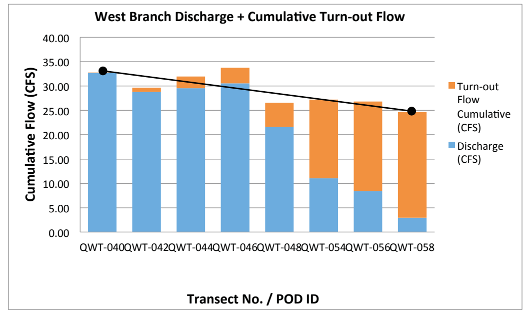
Flannery Ditch Intake to the Study Reach	=	0.96		
Flannery Ditch Turnout + Flow Remaining	=	-0.87		
Flannery Ditch Losses in the Study Reach	=	0.09	=	9.68%

TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

10/4/2016
Final

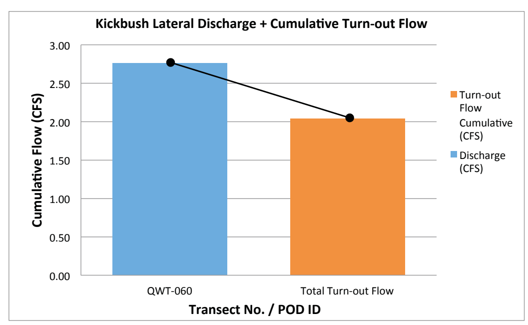
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
SWB-0110		-0.08		1 ft Cipolletti, 1 inch depth
SWB-0120		-0.28		Pump 10 HP, 3"outlet, estimate 125 GPM
SWB-0130		-0.21		No weir, estimate 95 GPM
NWB-0010		0.00		Pump 5HP 2" outlet, OFF
NWB-0020		0.00		Pump 1.5 HP, 1.5" outlet, OFF
NWB-0030		0.00		Pump 1.5 HP, 1.5" outlet, OFF
NWB-0040		-0.03		1 ft cipolletti, 0.5 inch depth
NWB-0050		-0.15		1 ft cipolletti, 1.5 inch depth
NWB-0055		-0.08		1 ft cipolletti, 1 inch depth
QWT-046	**30.53**		3.22	Measurement rated as "Fair"
NWB-0060		-0.10		6 inch cipolletti, 1.75 inch depth
NWB-0070		0.00		2 ft cipolletti, headgate closed, OFF
NWB-0071		-0.23		1 ft cipolletti, 2 inch depth
NWB-0072		-0.27		1 ft cipolletti, 2.25 inch depth
NWB-0080		0.00		1 ft cipolletti, headgate closed, OFF
NWB-0090		-0.85		1 ft Cipolletti, 4.75 Inch depth
NWB-0100		-0.01		1 ft cipolletti, 0.25 inch depth
NWB-0110		-0.15		1 ft cipolletti, 1.5 inch depth
NWB-0115		0.00		1 ft cipolletti, weir flooded, no irrig. , OFF
NWB-0120		0.00		1 ft cipolletti, headgate closed, OFF
NWB-0130		-0.11		Pump 2.5HP 2" outlet, estimate 50 GPM
QWT-048	**21.60**		4.94	Measurement rated as "Poor"
Spaulding + N. Spaulding Lat		-11.23		Head of Spalding Lats, QWT-050 and 052, est.
QWT-054	**11.04**		16.17	Measurement rated as "Good"
NWB-0140		-0.08		Pump 2HP 1.5" outlet, estimate 35 GPM
NWB-0150		-0.92		1 ft cipolletti, 5 inch depth
NWB-0160		-0.37		1 ft cipolletti, 2.75 inch depth
NWB-0165		-0.32		1 ft cipolletti, 2.5 inch depth
NWB-0170		-0.54		2 ft cipolletti, 2.25 inch depth
QWT-056	**8.41**		18.40	Measurement rated as "Good"
NWB-0180		-0.54		2 ft cipolletti, 2.25 inch depth
NWB-0190		-0.12		6 inch cipolletti, 2 inch depth
NWB-0200		-0.08		1 ft cipolletti, 1 inch depth
NWB-0210		-0.48		1 ft cipolletti, 3.25 inch depth
NWB-0220		-0.17		6 inch cipolletti, 2.5 inch depth
NWB-0230		-0.23		1 ft cipolletti, 2 inch depth
NWB-0240		-1.66		2 ft cipolletti, 4.75 inch depth
QWT-058	**2.94**		21.68	Return to Columbia Southern, measure rated "Poor"
(remaining flow returns to Columbia Southern)				
West Branch flow remaining	2.94			
Kickbush Lateral				
QWT-060	**2.76**		0.00	Measurement rated as "Fair"
SCS-0180		-0.12		6 inch cipolletti, 2 inch depth
SCS-0190				Not Applicable
SCS-0900		-1.92		3 ft cipolletti, 4 inch depth
Total Turn-out Flow	**0.00**		2.04	
Kickbush Lat Flow Remaining	0.00			
North Gerking Lateral				
North Gerking Lat Weir	**1.57**		0.00	3 ft cipolletti, 3.5 inch depth
NG-0010		-0.11		Pump 2HP 1.5 " outlet, estimate 50 GPM
NG-0020		-0.08		6 inch cipolletti, 1.5 inch depth
NG-0030		-0.08		1 ft cipolletti, 1.0 inch depth
NG-0040		-0.01		1 ft cipolletti, 0.25 inch depth
NG-0050		-0.27		1 ft cipolletti, 2.25 inch depth
NG-0060		-0.08		No weir, estimate 35 GPM
NG-0070		-0.12		6 inch cipolletti, 2 inch depth
NG-0080		-0.10		6 inch cipolletti, 1.75 inch depth

West Branch

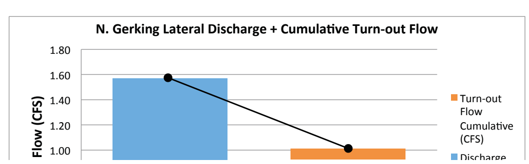


West Branch Intake to the Study Reach	=	32.70		
West Branch Turnout + Flow Remaining	=	-24.54		
West Branch Losses in the Study Reach	=	8.16	=	24.96%

Kickbush Lateral



Kickbush Lateral Intake to the Study Reach	=	2.76		
Kickbush Lateral Turnout + Flow Remaining	=	-2.04		
Kickbush Lateral Losses in the Study Reach	=	0.72	=	26.17%



TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

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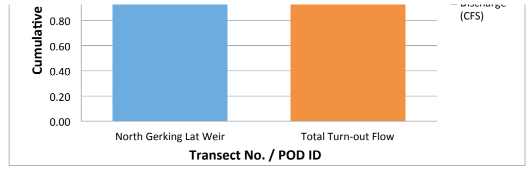
North Gerking La

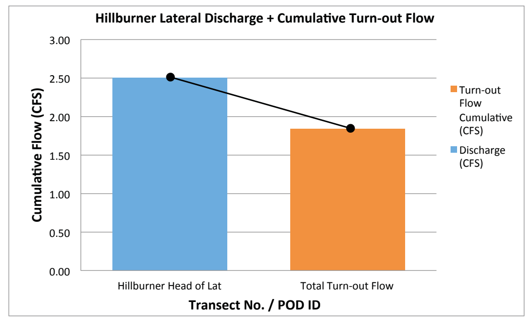
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
NG-0090		-0.08		6 inch cipolletti, 1.5 inch depth
NG-0100		-0.08		6 inch cipolletti, 1 inch depth
Total Turn-out Flow	**0.00**		1.01	
N. Gerking Flow Remaining	0.00			



N. Gerking Lateral Intake to the Study Reach = 1.57
N. Gerking Lateral Turnout + Flow Remaining = -1.01
N. Gerking Lateral Losses in the Study Reach = 0.56 = 35.67%

Hillburner Lateral

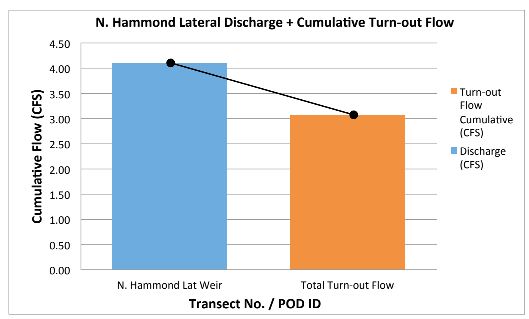
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Hillburner Lateral				
Hillburner Head of Lat	**2.50**		0.00	2.5 CFs
NHIL-0010		0.00		No water use, OFF
NHIL-0015		-0.06		6 inch cipolletti, 1.25 inch depth
NHIL-0020		-0.03		14.96 gpm
NHIL-0021		0.00		No water use, OFF
NHIL-0030		-0.01		6 inch cipolletti, 0.5 inch depth
NHIL-0035		0.00		No water use, OFF
NHIL-0040		-0.18		6 inch cipolletti, 2.625 inch depth
NHIL-0050		0.00		No water use, OFF
NHIL-0051		-0.22		6 inch cipolletti, 3.0 inch depth
NHIL-0052		0.00		No water use, OFF
NHIL-0053		-0.10		6 inch cipolletti, 1.75 inch depth
NHIL-0060		-0.21		1 foot cipolletti, 1.875 inch depth
NHIL-0061		-0.10		6 inch cipolletti, 1.75 inch depth
NHIL-0070		-0.22		10 inch rectangular, 2.25 inch depth
NHIL-0081		-0.10		5 inch rectangular, 2.125 inch depth
NHIL-0082		-0.12		6 inch rectangular, 2.125 inch depth
Tailwater		-0.49		22 inch rectangular, 2.25 inch depth
Total Turn-out Flow	**0.00**		1.84	
Hillburner Lat Flow Remaining	0.00			



Hillburner Lateral Intake to the Study Reach = 2.50
Hillburner Lateral Turnout + Flow Remaining = -1.84
Hillburner Lateral Losses in the Study Reach = 0.66 = 26.40%

North Hammond Lateral

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
North Hammond				
N. Hammond Lat Weir	**4.11**		0.00	4 ft cipolletti, 5.5 inch depth
NHAM-0010		-0.23		2 ft cipolletti, 1.25 inch depth
NHIGH-0010 (Highland Lat - Pipe)		-0.54		2 ft cipolletti, 2.25 inch depth
NHIGH-0020 (Highland Lat - Pipe)		-0.07		Paddle wheel flow meter 30 GPM
NHIGH-0030 (Highland Lat - Pipe)		-0.06		Paddle wheel flow meter 26 GPM
NHIGH-0040 (Highland Lat - Pipe)		-0.36		Paddle wheel flow meter 162 GPM
NHAM-0030		-0.08		6 inch cipolletti, 1.5 inch depth
NHAM-0040		-0.15		1 ft cipolletti, 1.5 inch depth
NHAM-0050		-0.04		6 inch cipolletti, 1 inch depth
NHAM-0060		-0.08		6 inch cipolletti, 1.5 inch depth
NHAM-0070		-0.08		6 inch cipolletti, 1.5 inch depth
NHAM-0080		-0.31		2 ft cipolletti, 1.5 inch depth
NHAM-0081		-0.19		1 ft cipolletti, 1.75 inch depth
NHAM-0061		-0.12		6 inch cipolletti, 2.0 inch depth
NHAM-0090		-0.32		1 ft cipolletti, 2.5 inch depth
NHAM-0100		-0.01		6 inch cipolletti, 0.5 inch depth
NHAM-0110		0.00		6 inch cipolletti, head gate closed, OFF
NHAM-0120		-0.10		6 inch cipolletti, 1.75 inch depth
NHAM-0130		-0.32		1 ft cipolletti, 2.5 inch depth
Total Turn-out Flow	**0.00**		3.06	
Hammond Lat Flow Remaining	0.00			

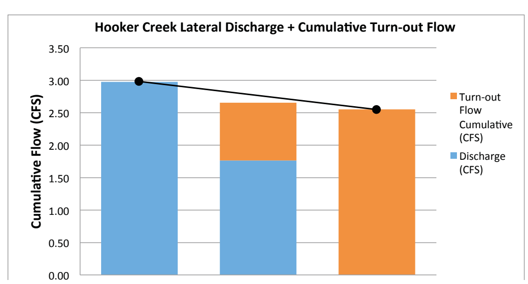


N. Hammond Lateral Intake to the Study Reach = 4.11
N. Hammond Lateral Turnout + Flow Remaining = -3.06
N. Hammond Lateral Losses in the Study Reach = 1.05 = 25.62%

Note: Highland Lateral (fully piped) pulls from the North Hammond Lateral btwn NHAM-0010 and NHAM-0030

Hooker Creek Lateral

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Hooker Creek Lateral				
QWT-064	**2.98**		0.00	Measurement rated as "Good"
NHOO-0010		-0.04		15.96 gpm
NHOO-0020		-0.02		7.48 gpm
NHOO-0030		-0.11		48.62 gpm
NHOO-0040		0.00		No water use, OFF
NHOO-0050		-0.72		1 ft cipolletti, 4.25 inch depth
NHOO-0060		0.00		No water use, OFF
NHOO-0070		0.00		No water use, OFF
NHOO-0080		0.00		No water use, OFF
QWT-068	**1.76**		0.89	Measurement rated as "Fair"
NHOO-0100		-1.66		2 ft cipolletti, 4.75 inch depth
Total Turn-out Flow	**0.00**		2.55	
Hooker Crk Lat Flow Remaining	0.00			

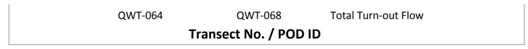


Attachment 6: System Improvement Plan

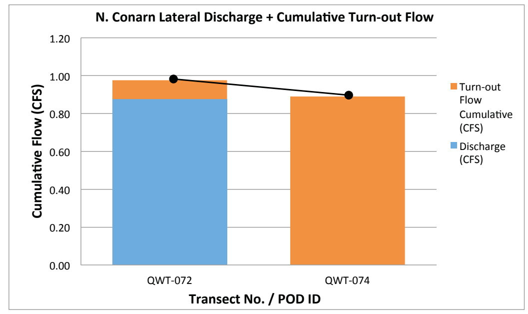
TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

10/4/2016
Final

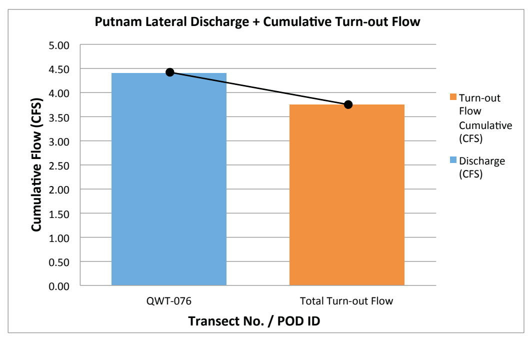
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Phiffer Lateral				
QWT-070	**4.59**			Measurement rated as "Fair"
no data				
North Conarn Lateral				
NC-0010		-0.10		No weir, estimate 45 GPM
QWT-072	**0.88**		0.10	Measurement rated as "Good"
NC-0020		-0.02		No weir, estimate 10 GPM
NC-0021		-0.08		1 ft cipolletti, 1 inch depth
NC-0030		-0.02		No weir, estimate 10 GPM
NC-0040		-0.02		No weir, estimate 10 GPM
NC-0050		-0.12		6 inch cipolletti, 2 inch depth
NC-0060		-0.15		1 ft cipolletti, 1.5 inch depth
NC-0065		-0.23		1 ft cipolletti, 2 inch depth
NC-0070		-0.03		1 ft cipolletti, 0.5 inch depth
NC-0080		-0.12		6 inch cipolletti, 2 inch depth
QWT-074	**0.00**		0.89	Return flow to C.S., no measure, too shallow /
N. Conarn Lat Flow Remaining	0.00			
Putnam Lateral				
QWT-076	**4.40**		0.00	Measurement rated as "Good"
NPUT-0030		-0.21		
NPUT-0040		-0.55		
NPUT-0050				Doesn't exist, same as turnout NPUT-0060
NPUT-0060		-2.99		
Total Turn-out Flow	**0.00**		3.75	
Putnam Lat Flow Remaining	0.00			
North Hagerty Lat				
QWT-078A	**0.81**		0.00	Measurement rated as "Fair"
QWT-078B	**0.77**		0.00	Measurement rated as "Fair"
NHAG-0010		0.00		1 ft cipolletti, headgate closed, OFF
NHAG-0020		-0.08		No weir, estimate 35 GPM
NHAG-0030		-0.46		2 ft cipolletti, 2 inch depth
Total Turn-out Flow	**0.00**		0.54	
N. Hagerty Lat Flow Remaining	0.00			



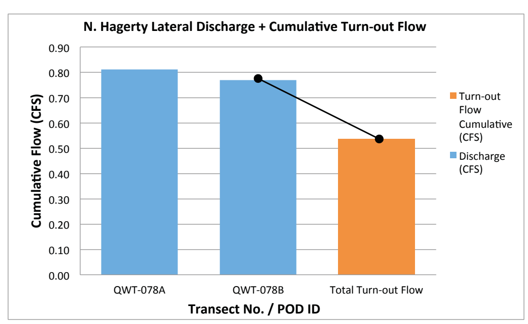
Hooker Creek Lateral Intake to the Study Reach	=	2.98		
Hooker Creek Lateral Turnout + Flow Remaining	=	-2.55		
Hooker Creek Lateral Losses in the Study Reach	=	0.43	=	14.30%



N. Conarn Lateral Intake to the Study Reach	=	0.88		
N. Conarn Lateral Turnout + Flow Remaining	=	-0.79		
N. Conarn Lateral Losses in the Study Reach	=	0.09	=	9.78%



Putnam Lateral Intake to the Study Reach	=	4.40		
Putnam Lateral Turnout + Flow Remaining	=	-3.75		
Putnam Lateral Losses in the Study Reach	=	0.65	=	14.73%



N. Hagerty Lateral Intake to the Study Reach	=	0.77		
N. Hagerty Lateral Turnout + Flow Remaining	=	-0.54		
N. Hagerty Lateral Losses in the Study Reach	=	0.23	=	30.06%

TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

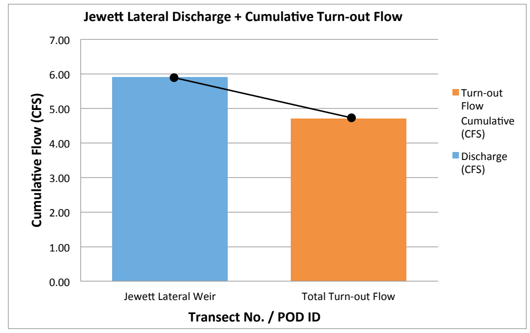
10/4/2016
Final

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Jewett Lateral				
Jewett Lateral Weir	**5.90**		0.00	4 ft cipolletti, 7.0 inch depth
NJ-0010		-0.29		130.9 gpm
NJ-0020		0.00		No water use, OFF
NJ-0030		-0.18		82.28 gpm
NJ-0040		-0.27		1 ft cipolletti, 2.25 inch depth
NJ-0050		-0.05		22.446 gpm
NJ-0060		-0.22		6 inch cipolletti, 3.0 inch depth
NJ-0061		-0.13		6 inch cipolletti, 2.125 inch depth
NJ-0070		0.00		No water use, OFF
NJ-0080		-0.48		1 ft cipolletti, 3.25 inch depth
NJ-0085		-0.56		1 ft cipolletti, 3.625 inch depth
NJ-0090		0.00		No water use, OFF
NJ-0092		0.00		No water use, OFF
NJ-0094		0.00		No water use, OFF
NJ-0100		-0.01		6 inch cipolletti, 0.25 inch depth
NJ-0110		-0.06		26.18 gpm
NJ-0120		-0.07		31.11 gpm
NJ-0130		-1.28		2 ft cipolletti, 4.0 inch depth
NJ-0140		-1.11		2 ft cipolletti, 3.625 inch depth
Total Turn-out Flow	**0.00**		4.71	
Jewett Lat Flow Remaining	0.00			
East Columbia Southern				
QWT-084	**4.66**		0.00	Measurement rated as "Good"
NSCE-0010		-0.07		29.92 gpm
NSCE-0015		0.00		No water use, OFF
NCSE-0020		0.00		No water use, OFF
QWT-086	**4.08**		0.07	Measurement rated as "Poor"
NCSE-0030		-0.13		1 ft cipolletti, 1.375 inch depth
NCSE-0040		-0.11		1 ft cipolletti, 1.25 inch depth
NCSE-0050		-0.09		6 inch cipolletti, 1.625 inch depth
NCSE-0051		-0.23		104.72 gpm
QWT-088	**3.05**		0.63	Measurement rated as "Poor"
NCSE-0060		-0.70		317.15 gpm
E. Columbia Southern Lateral Flow Remaining	2.35			Return flow to Columbia Southern
S. Tumalo Feed Canal				
QWT-006	**155.23**		0.00	Measurement rated as "Fair"
STF-0220		0.00		Pump, disconnected, OFF
STF-0230		0.00		Valve off when on site, OFF
STF-0240				
STF-0250		0.00		2 ft cipolletti, OFF
Kerns Lateral		-0.77		QWT-008C, measurement rated 'Poor'
Parkhurst Lateral		-5.51		QWT-010, measurement rated 'Good'
STF-0260		0.00		Pump, 2 HP, 1.5" outlet, OFF
QWT-014	**138.21**		6.28	Measurement rated as "Good"
STF-0270		0.00		Pump, 2 HP, 1.5" outlet, OFF
STF-0280 (Gill Lateral)		-0.85		1 ft Cipolletti, 4.75 Inches
QWT-016	**136.94**		7.13	Measurement rated as "Good"

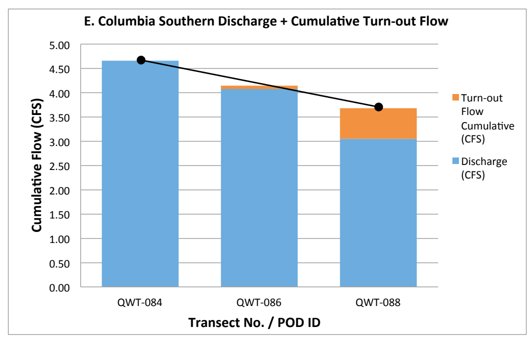
Jewett Lateral

East Columbia Southern

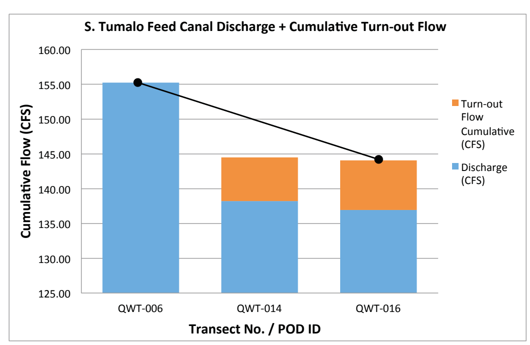
South Tumalo Feed Canal



Jewett Lateral Intake to the Study Reach = 5.90
Jewett Lateral Turnout + Flow Remaining = -4.71
Jewett Lateral Losses in the Study Reach = 1.19 = 20.17%



E. Columbia Southern Intake to the Study Reach = 4.66
E. Columbia Southern Turnout + Flow Remaining = -3.68
E. Columbia Southern Losses in the Study Reach = 0.98 = 21.02%



S. Tumalo Feed Canal Intake to the Study Reach = 155.23
S. Tumalo Feed Canal Turnout + Flow Remaining = -144.06
S. Tumalo Feed Canal Losses in the Study Reach = 11.17 = 7.19%

Attachment 6: System Improvement Plan

TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

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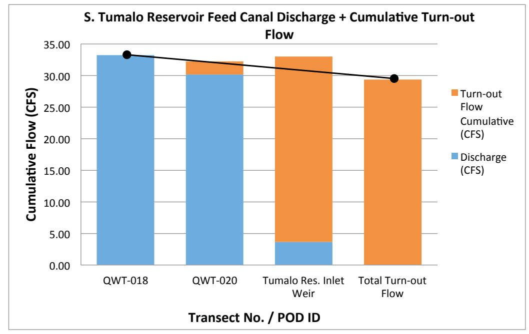
Final

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
S. Tumalo Reservoir Feed Canal				
QWT-018	**33.22**		0.00	Measurement rated as "Good"
STRF-0010		0.00		pump, 1.5 HP, 1.5" outlet, OFF
STRF-0020		0.00		pump, 1.5 HP, 1.5" outlet, OFF
STRF-0030		0.00		pump, 2.0 HP, 2.0" outlet, OFF
STRF-0040		0.00		pump, 1.5 HP, 1.5" outlet, OFF
STRF-0050		0.00		pump, 1.5 HP, 1.5" outlet, OFF
STRF-0060		0.00		pump, 3.0 HP, 2.0" outlet, OFF
Steel Lateral		-2.09		4 ft cipolletti, 3.5 inch depth
QWT-020	**30.15**		2.09	Measurement rated as "Fair"
STRF-0070		-0.15		1 ft cipolletti, 1.5 inch depth
STRF-0071		-0.29		DuBois Flow Meter, est. flow 130 gpm
STRF-0072		-0.22		DuBois Flow Meter, est. flow 100 gpm
STRF-0080		-0.65		1 ft cipolletti, 4.0 inch depth
STRF-0090		0.00		pump, OFF
STRF-0100		0.00		pump, OFF
STRF-0110		-0.06		2 ft cipolletti, 0.5 inch depth
Couch Lateral		-16.70		Seametrics flowmeter, 24" HDPE, 16.7 CFS
Highline Lateral		-9.20		Seametrics flowmeter, 24" HDPE, 9.2 CFS
Tumalo Res. Inlet Weir	**3.66**		29.36	16 ft cipolletti, 2 inch depth
Total Turn-out Flow	**0.00**		29.36	
S. Tumalo Res. Feed Canal flow remaining	3.66			

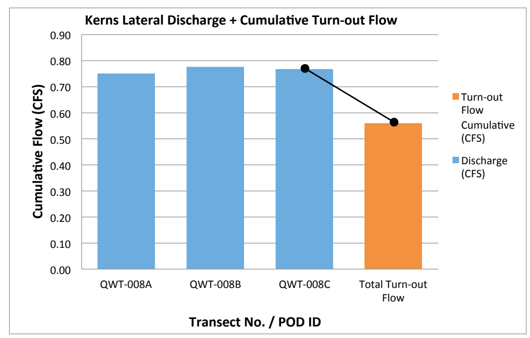
South Tumalo Reservoir Feed Canal



S. Tumalo Res. Feed Canal Intake to Study Reach	=	33.22		
S. Tumalo Res. Feed Canal Turnout + Flow Remaining	=	-33.02		
S. Tumalo Res. Feed Canal Losses in the Study Reach	=	0.20	=	0.60%

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Kerns Lateral				
QWT-008A	**0.75**		0.00	Measurement rated as "Poor"
QWT-008B	**0.78**		0.00	Measurement rated as "Poor"
QWT-008C	**0.77**		0.00	Measurement rated as "Poor"
SP-0010		-0.56		1 ft cipolletti, 3.625 inch depth
Total Turn-out Flow	**0.00**		0.56	
Kerns Lat Flow Remaining	0.00			

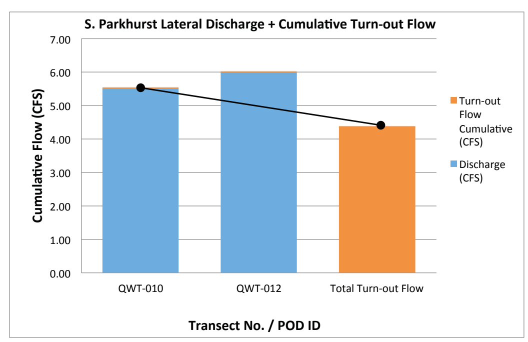
Kerns Lateral



Kerns Lateral Intake to the Study Reach	=	0.77		
Kerns Lateral Turnout + Flow Remaining	=	-0.56		
Kerns Lateral Losses in the Study Reach	=	0.21	=	27.06%

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
South Parkhurst Lateral				
SP-0020		-0.01		2 gpm
SP-0030		-0.02		6.73 gpm
QWT-010	**5.51**		0.03	Measurement rated as "Good"
QWT-012	**5.99**		0.03	Measurement rated as "Fair"
SP-0031		0.00		No water use, OFF
SP-0040		0.00		No water use, OFF
SP-0050		-0.19		2 ft cipolletti, 1.125 inch depth
SP-0051		0.00		No water use, OFF
SP-0052		0.00		No water use, OFF
SP-0060		-0.10		1 ft cipolletti, 1.125 inch depth
SP-0070		-0.55		248.33 gpm
SP-0080		-0.57		257.61 gpm
SP-0090		-0.03		14.96 gpm
SP-0100		-0.32		1 ft cipolletti, 2.5 inch depth
SP-0110		-2.59		2 ft cipolletti, 6.375 inch depth
Total Turn-out Flow	**0.00**		4.38	
Parkhurst Lat Flow Remaining	0.00			

South Parkhurst Lateral



S. Parkhurst Lateral Intake to the Study Reach	=	5.99		
S. Parkhurst Lateral Turnout + Flow Remaining	=	-4.38		
S. Parkhurst Lateral Losses in the Study Reach	=	1.61	=	26.88%

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
South Couch Lateral				
S. Couch Lat Intake Meter	**16.70**		0.00	Seametrics flowmeter, 24" HDPE, 16.7 CFS
QWT-096	**16.54**		0.00	Measurement rated as "Poor"
SC-0020		0.00		Pump OFF, not irrigating
QWT-098	**16.48**		0.00	Measurement rated as "Good"
SC-0030		-0.19		1 ft cipolletti, 1.75 inch depth
SC-0040		0.00		Headgate closed, no water use, OFF
SC-0041		-0.15		6 inch cipolletti, 2.375 inch depth

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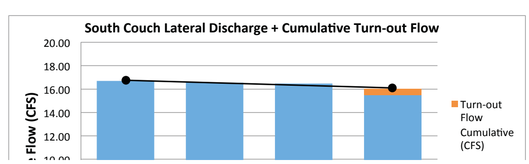
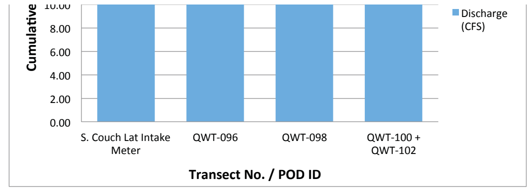


TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

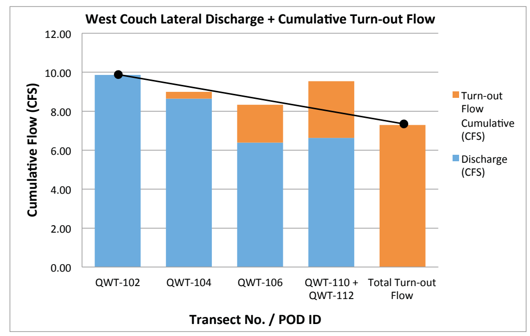
10/4/2016
Final

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
SC-0042		0.00		No water use, OFF
SC-0050		-0.12		Estimated flow at 52.36 gpm
SC-0060		-0.07		1 ft cipolletti, 0.875 inch depth
SWC-0010		0.00		Headgate closed, no water use, OFF
SWC-0011		0.00		Headgate closed, no water use, OFF
QWT-100 + QWT-102	**15.47**		0.53	Measurements rated as "Fair"
South Couch Flow Remaining	15.47			



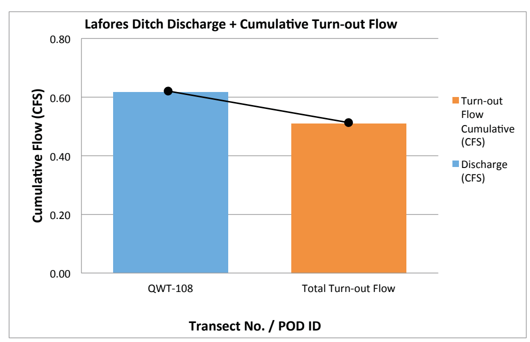
South Couch Lateral Intake to the Study Reach	=	16.70		
South Couch Lateral Turnout + Flow Remaining	=	-16.00		
South Couch Lateral Losses in the Study Reach	=	0.70	=	4.19%

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
West Couch Lateral				
SWC-0010		0.00		Headgate closed, no water use, OFF
SWC-0011		0.00		Headgate closed, no water use, OFF
QWT-102	**9.86**		0.00	Measurement rated as "Fair"
SWC-0020		-0.03		6 inch cipolletti, 0.875 inch depth
SWC-0030		-0.05		Estimated flow at 22.44 gpm
SWC-0040		-0.27		1 ft cipolletti, 2.25 inch depth
QWT-104	**8.64**		0.35	Measurement rated as "Fair"
SWC-0045		-0.03		1 ft cipolletti, 0.5 inch depth
SWC-0046		-0.51		1 ft cipolletti, 3.375 inch depth
SWC-0047		-1.05		2 ft cipolletti, 3.5 inch depth
QWT-106	**6.39**		1.94	Measurement rated as "Fair"
SWC-0049		0.00		No water use, OFF
Lafores Ditch		-0.62		QWT-108, measurement rates as "Fair"
SWC-0101		-0.08		Estimated flow at 37.4 gpm
SWC-0110		-0.27		1 ft cipolletti, 2.25 inch depth
QWT-110 + QWT-112	**6.63**		2.91	Measurements rated as "Good"
SWC-0120		0.00		No water use, OFF
SWC-0130		-0.41		2 ft cipolletti, 1.875 inch depth
SWC-0135		-0.03		1 ft cipolletti, 0.5 inch depth
SWC-0150		-0.31		Estimated flow at 137.63 gpm
SWC-0160		-0.12		6 inch cipolletti, 2.0 inch depth
SWC-0170		-0.08		1 ft cipolletti, 1.0 inch depth
SWC-0180		-0.03		Estimated flow at 14.96 gpm
SWC-0190		0.00		No water use, OFF
SWC-0200		-1.53		2 ft cipolletti, 4.5 inch depth
SWC-0210		-0.25		Estimated flow at 112.2 gpm
SWC-0220		-0.08		6 inch cipolletti, 1.5 inch depth
SWC-0230		-0.08		1 ft cipolletti, 1.0 inch depth
SWC-0240		-0.07		6 inch cipolletti, 1.375 inch depth
SWC-0250		-0.07		6 inch cipolletti, 1.375 inch depth
SWC-0260		-0.32		1 ft cipolletti, 2.5 inch depth
SWC-0270		-1.00		2 ft cipolletti, 3.375 inch depth
Total Turn-out Flow	**0.00**		7.29	
W. Couch Lat Flow Remaining	0.00			



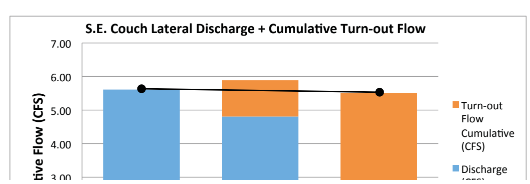
West Couch Lateral Intake to the Study Reach	=	9.86		
West Couch Lateral Turnout + Flow Remaining	=	-7.29		
West Couch Lateral Losses in the Study Reach	=	2.57	=	26.10%

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Lafores Ditch				
QWT-108	**0.62**		0.00	Measurement rated as "Fair"
SWC-0050		0.00		No water use, OFF
SWC-0060		0.00		No water use, OFF
SWC-0070		-0.23		1 ft cipolletti, 2.0 inch depth
SWC-0080		-0.15		1 ft cipolletti, 1.5 inch depth
SWC-0090		-0.01		6 inch cipolletti, 0.5 inch depth
SWC-0100		-0.12		Estimated at 52.36 gpm
Total Turn-out Flow	**0.00**		0.51	
Lafores Ditch Flow Remaining	0.00			



Lafores Ditch Intake to the Study Reach	=	0.62		
Lafores Ditch Turnout + Flow Remaining	=	-0.51		
Lafores Ditch Losses in the Study Reach	=	0.11	=	17.33%

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
Southeast Couch Lateral				
QWT-100	**5.61**			Measurement rated as "Fair"
SEC-0009		-0.54		2 ft cipolletti, flooded, est. 2.25 inch depth
SEC-0010		-0.54		2 ft cipolletti, flooded, est. 2.25 inch depth
QWT-114 + QWT-116	**4.81**		1.08	QWT-114 rated "Good", QWT-116 rated "Fair"
SEC-0011		-0.06		6 inch cipolletti, 1.25 inch depth
SEC-0020		-0.42		1 ft cipolletti, 3.0 inch depth
SEC-0030		-0.73		2 ft cipolletti, 2.75 inch depth
SEC-0040		-0.27		1 ft cipolletti, 2.25 inch depth
SEC-0050		-0.23		1 ft cipolletti, 2.0 inch depth
SEC-0051		0.00		No water use, OFF
SEC-0060		-0.25		1 ft cipolletti, 2.125 inch depth



TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

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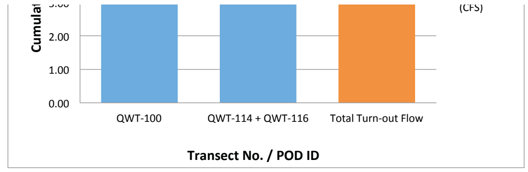
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
SEC-0070		-0.26		2 ft cipolletti, 1.375 inch depth
SEC-0080		-0.17		6 inch cipolletti, 2.5 inch depth
SEC-0090		-0.35		6 inch cipolletti, 4.0 inch depth
SEC-0100		-0.01		6 inch cipolletti, 0.25 inch depth
SEC-0110		-0.21		6 inch cipolletti, 2.875 inch depth
SEC-0115		-0.38		6 inch cipolletti, 4.5 inch depth
SEC-0120		-0.10		6 inch cipolletti, 1.75 inch depth
SEC-0130		-0.10		6 inch cipolletti, 1.75 inch depth
SEC-0140		-0.10		6 inch cipolletti, 1.75 inch depth
SEC-0150		-0.78		2 ft cipolletti, 2.875 inch depth
Total Turn-out Flow	**0.00**		5.50	
S.E. Couch Lat Flow Remaining	0.00			
Highline Lateral				
Highline Lat Intake Meter	**9.20**		0.00	Seametrics flowmeter, 24" HDPE, 9.2 CFS
SH-0010		-0.19		1 ft cipolletti, 1.75 inch depth
SH-0015		-0.12		6 inch cipolletti, 2 inch depth
SH-0020		-0.15		1 ft cipolletti, old, estimate 1.5 inch depth
SH-0030		-0.23		1 ft cipolletti, old, estimate 2 inch depth
SH-0040		-0.15		1 ft cipolletti, 1.5 inch depth
SH-0041		-0.19		1 ft cipolletti, 1.75 inch depth
SH-0050		-0.11		1 ft cipolletti, 1.25 inch depth
SH-0060		-0.19		6 inch cipolletti, 2.75 inch depth
SH-0070		-0.16		2 ft cipolletti, 1 inch depth
SH-0080		-0.27		1 ft cipolletti, 2.5 inch depth
QWT-092	**7.84**		1.76	Measurement rated as "Good"
SH-0090		-0.14		3 inch cipolletti, 3.25 inch depth
SH-0100		-0.32		1 ft cipolletti, 2.5 inch depth
SH-0110		-0.64		2 ft cipolletti, flooded, estimate 2.5 inch
SH-0111		-0.08		1 ft cipolletti, 1 inch depth
SH-0115		-0.06		6 inch cipolletti, 1.25 inch depth
SH-0120		-0.04		6 inch cipolletti, 1 inch depth
SH-0125		0.00		2 ft cipolletti, P.O.D. closed, OFF
SH-0130		0.00		Pump OFF
QWT-094	**5.53**		3.04	Measurement rated as "Good"
SH-0140		-0.10		6 inch cipolletti, 1.75 inch depth
SH-0150		-0.59		1 ft cipolletti, 3.75 inch depth
SH-0160		-0.64		2 ft cipolletti, 2.5 inch depth
SH-0170		-2.52		2 ft cipolletti, 6.25 inch depth
Total Turn-out Flow	**0.00**		6.89	
Highline Lat Flow Remaining	0.00			
South Lacy Lateral				
S. Lacy Lat Weir	**4.11**		0.00	4 ft cipolletti, 5.5 inch depth
SL-0010		-0.02		7.48 gpm
SL-0020		-1.17		2 ft cipolletti, 3.75 inch depth
SL-0030		-0.13		1 ft cipolletti, 1.375 inch depth
SL-0040		0.00		No water use, OFF
SL-0050		0.00		No water use, OFF
SL-0055		-0.32		1 ft cipolletti, 2.5 inch depth
SL-0060		-0.17		74.8 gpm
SL-0070		-0.04		18.7 gpm
SL-0080		-0.12		6 inch cipolletti, 2 inch depth
SL-0090		-0.11		1 ft cipolletti, 1.25 inch depth
SL-0100		-0.13		6 inch cipolletti, 2.125 inch depth
SL-0110		-0.28		6 inch cipolletti, 3.5 inch depth
SL-0120		-0.53		1 ft cipolletti, 3.5 inch depth
Total Turn-out Flow	**0.00**		3.02	
South Lacy Lat Flow Remaining	0.00			
Box-S Lateral (2 Rivers Lateral)				
STF-0140		0.00		2" Valve, OFF
QWT-002	**5.20**		0.00	Measurement rated as "Fair"
STF-0150		-1.25		3 ft cipolletti, 3 inch depth
STF-0161		-0.42		1 ft cipolletti, 3 inch depth
STF-0162		-0.15		1 ft cipolletti, 1.5 inch depth
QWT-004	**0.79**		1.82	Measurement rated as "Excellent"
STF-0170		-0.55		18 inch cipolletti, 2.75 inch depth
STF-0180				Not applicable
Total Turn-out Flow	**0.00**		2.37	
Box-S Lat Flow Remaining	0.24			

Southeast Couc

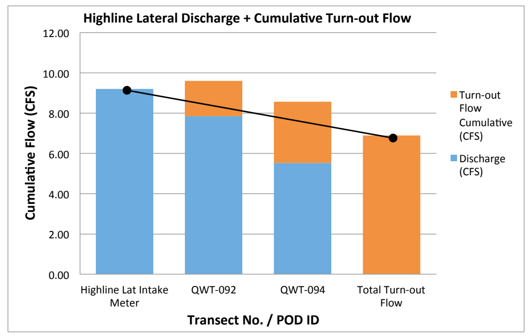
Highline Lateral

South Lacy Lateral

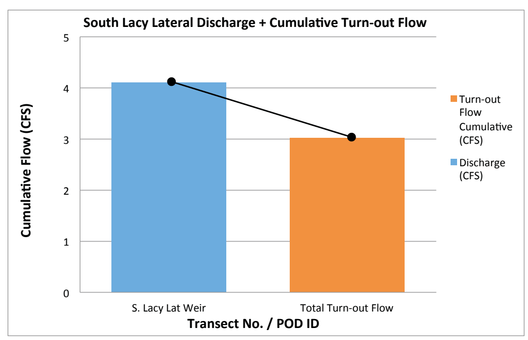
Box-S Lateral (2-Rivers Lateral)



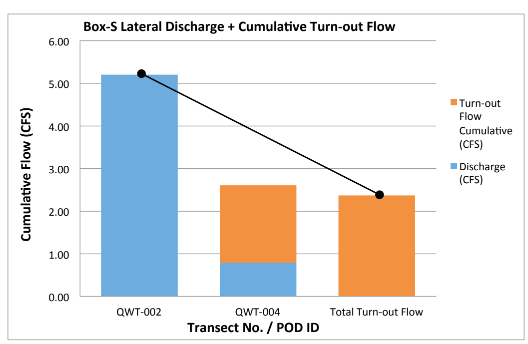
S.E. Couch Lateral Intake to the Study Reach	=	5.61		
S.E. Couch Lateral Turnout + Flow Remaining	=	-5.50		
S.E. Couch Lateral Losses in the Study Reach	=	0.11	=	1.95%



Highline Lateral Intake to the Study Reach	=	9.20		
Highline Lateral Turnout + Flow Remaining	=	-6.89		
Highline Lateral Losses in the Study Reach	=	2.31	=	25.11%



S. Lacy Lateral Intake to the Study Reach	=	4.11		
S. Lacy Lateral Turnout + Flow Remaining	=	-3.02		
S. Lacy Lateral Losses in the Study Reach	=	1.09	=	26.52%



TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

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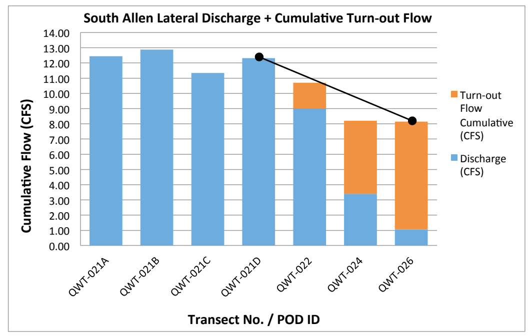
Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
(South) Allan Lateral				
QWT-021A	**12.44**		0.00	Measurement rated as "Good"
QWT-021B	**12.87**		0.00	Measurement rated as "Good"
QWT-021C	**11.34**		0.00	Measurement rated as "Good"
QWT-021D	**12.31**		0.00	Measurement rated as "Good"
SA-0025		-0.08		1 ft cipolletti, 1.0 inch depth
SA-0030		0.00		No water use, OFF
SA-0040		-0.12		6 inch cipolletti, 2.0 inch depth
SA-0050		0.00		No water use, OFF
SA-0060		-0.22		6 inch cipolletti, 3.0 inch depth
SA-0070		-0.11		6 inch cipolletti, 1.875 inch depth
SA-0080		-0.11		6 inch cipolletti, 1.875 inch depth
SA-0090		-0.07		31.56 gpm
SA-0100		-0.01		1 ft cipolletti, 0.25 inch depth
SA-0110		-0.05		6 inch cipolletti, 1.125 inch depth
SA-0111		-0.23		6 inch rectangular, 3.25 inch depth
SA-0120		-0.68		20 inch rectangular, 3.0 inch depth
QWT-022	**9.01**		1.68	Measurement rated as "Good"
SA-0130		0.00		No water use, OFF
SA-0140		-0.08		1 ft cipolletti, 1.0 inch depth
SA-0150		-0.06		6 inch cipolletti, 1.25 inch depth
SA-0160		0.00		No water use, OFF
SA-0161		-0.68		2 ft cipolletti, 2.625 inch depth
SA-0170		0.00		No water use, OFF
SA-0180		-0.13		6 inch cipolletti, 2.125 inch depth
SA-0190		-0.12		6 inch cipolletti, flooded, est. 2.0 inch depth
SA-0200		0.00		6 inch cipolletti, no flow, OFF
SA-0210		-0.03		Pump ON, estimated flow 15 gpm
SA-0220		-0.06		1 Pump ON, (2) turn-outs, est. 25 gpm
SA-0225				
SA-0230		-0.23		1 ft cipolletti, flooded, est 2.0 inch depth
SA-0240		-0.32		1 ft cipolletti, 2.5 inch depth
SA-0250		-0.54		2 ft cipolletti, 2.25 inch depth
SA-0260		-0.15		1 ft cipolletti, 1.5 inch depth
SA-0270		-0.73		2 ft cipolletti, 2.75 inch depth
QWT-024	**3.39**		4.81	Measurement rated as "Fair"
SA-0280		-0.19		1 ft cipolletti, 1.75 inch depth
SA-0290		-0.04		6 inch cipolletti, 1.0 inch depth
SA-0300		-0.22		6 inch cipolletti, 3.0 inch depth
SA-0310		-0.08		6 inch cipolletti, 1.5 inch depth
SA-0320		-0.32		1 ft cipolletti, 2.5 inch depth
SA-0330		-0.94		2 ft cipolletti, 3.25 inch depth
SA-0340		-0.46		2 ft cipolletti, 2.0 inch depth
SA-0350		-0.03		1 ft cipolletti, 0.5 inch depth
QWT-026	**1.05**		7.09	Return flow to West Branch, Measure rated "Poor"
S. Allen Lat Flow Remaining	1.05			
Little Allen Lateral				
Little Allen Lat Weir	**0.69**		0.00	1 ft cipolletti, 4.125 inch depth
SA-0010		-0.21		1 ft cipolletti, 1.875 inch depth
SA-0015		-0.06		6 inch cipolletti, 1.25 inch depth
SA-0016		-0.07		6 inch cipolletti, 1.375 inch depth
SA-0020		-0.25		1 ft cipolletti, 2.125 inch depth
Total Turn-out Flow	**0.00**		0.59	
Little Allen Flow Remaining	0.00			
Beasley Lateral				
Beasley Lat Weir	**1.80**		0.00	
NB-0005		-0.02		7.48 gpm
NB-0010		-0.02		7.48 gpm
NB-0020		-0.07		29.92 gpm
NB-0030		-0.02		7.48 gpm
NB-0040		-0.25		1 ft cipolletti, 2.125 inch depth
NB-0050		-0.13		56.1 gpm
NB-0051		0.00		No water use, OFF
NB-0060		0.00		No water use, OFF

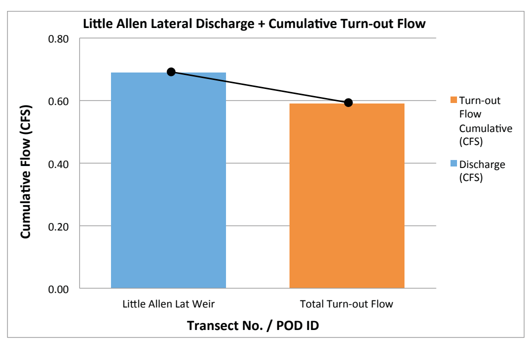
(South) Allen Lateral

Little Allen Lateral

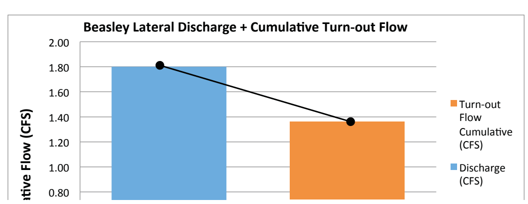
Box-S Lateral Intake to the Study Reach = 5.20
Box-S Lateral Turnout + Flow Remaining = -2.61
Box-S lateral Losses in the Study Reach = 2.59 = 49.87%



S. Allen Lateral Intake to the Study Reach = 12.31
S. Allen Lateral Turnout + Flow Remaining = -8.14
S. Allen lateral Losses in the Study Reach = 4.17 = 33.88%



Little Allen Lateral Intake to the Study Reach = 0.69
Little Allen Lateral Turnout + Flow Remaining = -0.59
Little Allen lateral Losses in the Study Reach = 0.10 = 14.49%



TUMALO IRRIGATION DISTRICT - DISCHARGE FLOW MEASUREMENTS

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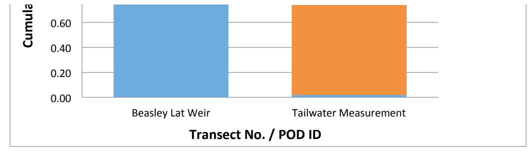
Final

Transect No. POD #ID	Discharge (CFS)	Turn-out Flow Rate (CFS)	Turn-out Flow Cumulative (CFS)	Comments
NB-0070		-0.07		6 inch cipolletti, 1.375 inch depth
NB-0080		0.00		No water use, OFF
NB-0090		0.00		No water use, OFF
NB-0100		0.00		No water use, OFF
NB-0110		-0.11		6 inch cipolletti, 1.875 inch depth
NB-0120		0.00		No water use, OFF
NB-0130		-0.23		1 ft cipolletti, 2.0 inch depth
NB-0140		-0.42		1 ft cipolletti, 5.0 inch depth
Tailwater Measurement	**0.02**		1.34	Estimated flow at 10 gpm
Beasley Lat Flow Remaining	0.00			
North Spalding Lateral (Dusty Loop Ditch)				
QWT-050	**2.45**		0.00	Measurement rated as "Fair"
NS-0010		-0.72		1 ft cipolletti, 4.5 inch depth
NS-0020		-0.83		2 ft cipolletti, 3.0 inch depth
Total Turn-out Flow	**0.00**		1.55	
N. Spaulding Lat Flow Remaining	0.00			
Spaulding Lateral				
QWT-052	**8.78**		0.00	Measurement rated as "Good"
NS-0030		0.00		No water use, OFF
NS-0040		-0.59		1 ft cipolletti, 3.75 inch depth
NS-0041		-0.68		2 ft cipolletti, 2.625 inch depth
NS-0050		-0.12		6 in cipolletti, 2.0 inch depth
NS-0055		-0.17		6 in cipolletti, 2.5 inch depth
NS-0060		-0.94		2 ft cipolletti, 3.25 inch depth
NS-0070		-0.30		2 ft cipolletti, 1.5 inch depth
NS-0080		-0.32		1 ft cipolletti, 2.5 inch depth
NS-0090		-0.42		1 ft cipolletti, 3.0 inch depth
NS-0100		-1.53		2 ft cipolletti, 4.5 inch depth
NS-0110		-2.44		2 ft cipolletti, 6.125 inch depth
Total Turn-out Flow	**0.00**		7.51	
Spaulding Lat Flow Remaining	0.00			

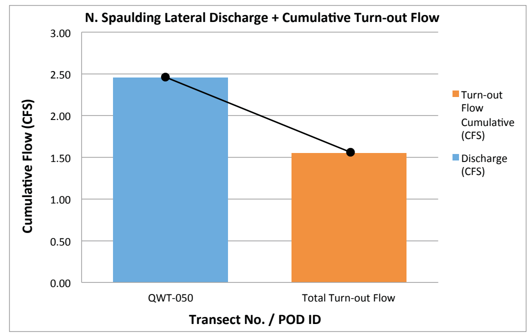
Beasley Late

North Spaulding Lateral (Dusty Loop Ditch)

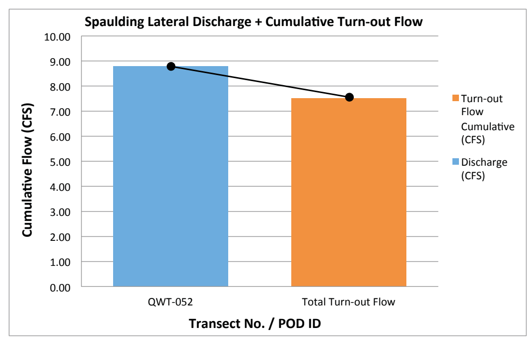
Spaulding Lateral



Beasley Lateral Intake to the Study Reach = 1.80
Beasley Lateral Turnout + Flow Remaining = -1.34
Beasley lateral Losses in the Study Reach = 0.46 = 25.56%



N. Spaulding Lateral Intake to the Study Reach = 2.45
N. Spaulding Lateral Turnout + Flow Remaining = -1.55
N. Spaulding lateral Losses in the Study Reach = 0.90 = 36.86%



Spaulding Lateral Intake to the Study Reach = 8.78
Spaulding Lateral Turnout + Flow Remaining = -7.51
Spaulding lateral Losses in the Study Reach = 1.27 = 14.46%

APPENDIX B
EPANET and WSPG2010
HYDRAULIC MODELS

[TITLE]
Farmers Conservation Alliance (FCA)
Irrigation Modernization Program (IMP)
Hydraulic Modeling
EPANET Input File
TUMALO IRRIGATION DISTRICT
Demands based on 7.48 GPM per acre
Version: August 11, 2016

[JUNCTIONS]

;ID	Elev	Demand	Pattern	
HG-10	3528.2800	0.00		;
HG-11	3524.0700	0.00		;
HG-12	3523.3100	0.00		;
HG-13	3381.5500	0.00		;
HG-14	3457.7400	0.00		;
HG-15	3445.1800	0.00		;
HG-16	3462.3100	0.00		;
HG-17	3466.6000	0.00		;
HG-18	3450.3300	0.00		;
HG-19	3384.0600	0.00		;
HG-20	3382.8000	0.00		;
HG-21	3395.8700	0.00		;
HG-22	3385.6200	0.00		;
HG-23	3367.5400	0.00		;
HG-24	3351.1000	0.00		;
HG-25	3328.1600	0.00		;
HG-26	3323.7300	0.00		;
HG-27	3285.5200	0.00		;
HG-28	3284.1200	0.00		;
HG-29	3273.4000	0.00		;
HG-30	3251.4300	0.00		;
HG-31	3250.9200	0.00		;
HG-32	3247.9000	0.00		;
HG-33	3247.4900	0.00		;
HG-34	3235.8200	0.00		;
HG-35	3233.0800	0.00		;
HG-36	3213.4500	0.00		;
HG-37	3221.2100	0.00		;
HG-38	3206.5000	0.00		;
HG-39	3046.5400	0.00		;
HG-40	3303.4700	0.00		;
HG-41	3301.0600	0.00		;
HG-42	3276.6000	0.00		;
HG-43	3249.0300	0.00		;
HG-44	3245.2800	0.00		;
HG-45	3527.5100	0.00		;
HG-46	3501.6500	0		;
HG-47	3527.3200	0.00		;
HG-48	3527.0700	0.00		;
HG-49	3499.3600	0.00		;
HG-50	3468.3600	0.00		;
HG-51	3447.9000	0.00		;
HG-52	3445.4700	0.00		;
HG-53	3431.3000	0.00		;
HG-54	3431.5900	0.00		;
HG-55	3428.9800	0.00		;
HG-56	3431.8800	0.00		;
HG-57	3432.0500	0.00		;
HG-58	3422.2500	0.00		;
HG-59	3281.3500	0.00		;
HG-60	3418.2100	0.00		;
HG-7	3530.2600	0.00		;
HG-8	3530.1400	0.00		;
HG-9	3529.2500	0.00		;
N-10	3373.8600	0.00		;
N-11	3377.2100	0.00		;
N-12	3354.7900	0.00		;
N-13	3482.2700	0.00		;
N-14	3420.3400	0.00		;
N-15	3414.5900	0.00		;
N-16	3453.7800	0.00		;
N-17	3449.5900	0.00		;
N-18	3430.2800	0.00		;

N-19	3288.4700	0.00	;
N-20	3306.1000	0.00	;
N-21	3310.7700	0.00	;
N-22	3376.3700	0.00	;
N-23	3363.3600	0.00	;
N-24	3392.3000	0.00	;
N-25	3237.0100	0.00	;
N-26	3279.4600	0.00	;
N-27	3244.5700	0.00	;
N-28	3232.7300	0.00	;
N-29	3235.7600	0.00	;
N-30	3204.9400	0.00	;
N-31	3231.9900	0.00	;
N-32	3213.7800	0.00	;
N-33	3263.8800	0.00	;
N-34	3223.6300	0.00	;
N-35	3241.6500	0.00	;
N-36	3229.7000	0.00	;
N-37	3458.3800	0.00	;
N-38	3468.1500	0.00	;
N-39	3524.6800	0.00	;
N-40	3504.6300	0.00	;
N-41	3423.8500	0.00	;
N-42	3430.8100	0.00	;
N-43	3412.9700	0.00	;
N-44	3415.8500	0.00	;
N-45	3406.8700	0.00	;
N-46	3404.7500	0.00	;
N-47	3418.6100	0.00	;
N-48	3366.2000	0.00	;
N-49	3270.1000	0.00	;
N-50	3245.1600	0.00	;
N-51	3287.8100	0.00	;
N-52	3501.5900	0.00	;
N-53	3385.8100	0.00	;
N-55	3443.5200	0.00	;
N-56	3442.7200	0.00	;
N-57	3520.7100	0.00	;
N-58	3379.9300	0.00	;
N-59	3380.1000	0.00	;
N-60	3252.9800	0.00	;
N-61	3219.9600	0.00	;
N-62	3261.7900	0.00	;
N-63	3247.6800	0.00	;
N-64	3260.8200	0.00	;
N-65	3300.7000	0.00	;
N-66	3370.7200	0.00	;
N-67	3300.9700	0.00	;
N-68	3209.2400	0.00	;
N-69	3284.7300	0.00	;
N-70	3305.8800	0.00	;
N-71	3427.9400	0.00	;
N-8	3501.8100	0.00	;
N-9	3380.7800	0.00	;
NB-0005	3372.6400	7.48	;
NB-0010	3370.7200	7.48	;
NB-0020	3371.4600	29.92	;
NB-0030	3370.7000	7.48	;
NB-0040	3370.3000	104.72	;
NB-0050	3356.7200	56.10	;
NB-0051	3353.4100	33.66	;
NB-0060	3337.4700	29.17	;
NB-0070	3337.4700	29.17	;
NB-0080	3327.8400	11.97	;
NB-0090	3326.2600	7.48	;
NB-0100	3306.5300	37.40	;
NB-0110	3303.0900	29.92	;
NB-0120	3303.4900	37.40	;
NB-0130	3298.9800	104.72	;
NB-0140	3288.3900	153.34	;
NC-0010	3273.8600	29.92	;
NC-0020	3262.5700	29.92	;
NC-0021	3259.8200	22.44	;
NC-0030	3262.0900	7.48	;

NC-0040	3259.0300	52.36	;
NC-0050	3258.4500	29.92	;
NC-0060	3258.4000	78.54	;
NC-0065	3258.7900	84.52	;
NC-0070	3256.0300	52.36	;
NC-0080	3255.8900	22.44	;
NCS-0001	3345.7700	82.28	;
NCS-0010	3346.5300	37.40	;
NCS-0011	3330.8400	100.98	;
NCS-0020	3329.8900	432.34	;
NCS-0030	3329.8800	209.44	;
NCS-0040	3320.0500	21.69	;
NCS-0050	3303.8400	91.26	;
NCS-0055	3303.0300	62.68	;
NCS-0060	3303.0300	7.48	;
NCS-0070	3303.8500	11.97	;
NCS-0080	3305.6800	247.06	;
NCS-0090	3286.0300	14.96	;
NCS-0100	3284.7700	7.48	;
NCS-0110	3276.5400	14.96	;
NCS-0111	3274.5100	37.40	;
NCS-0120	3273.7500	219.91	;
NCS-0130	3273.4000	201.96	;
NCS-0140	3273.5200	109.21	;
NCS-0150	3273.1700	67.32	;
NCS-0160	3251.2600	33.66	;
NCS-0170	3250.4100	22.44	;
NCS-0180	3250.0000	119.68	;
NCS-0190	3249.2000	29.92	;
NCS-0200	3248.8200	52.36	;
NCS-0210	3248.4700	89.76	;
NCS-0220	3246.0900	26.11	;
NCS-0230	3246.7000	29.17	;
NCS-0240	3246.5600	83.03	;
NCS-0250	3246.7000	37.40	;
NCS-0260	3246.0900	59.84	;
NCS-0270	3236.3100	7.48	;
NCS-0280	3235.9300	44.88	;
NCS-0290	3232.6200	74.80	;
NCS-0300	3232.8800	246.84	;
NCS-0310	3232.6100	64.33	;
NCS-0320	3233.5500	22.44	;
NCS-0330	3230.6900	136.14	;
NCS-0340	3226.2800	7.48	;
NCS-0350	3225.1500	194.48	;
NCS-0360	3225.5300	44.88	;
NCS-0362	3225.1100	29.92	;
NCS-0364	3224.8900	22.44	;
NCS-0366	3225.1500	50.86	;
NCS-0370	3221.3800	59.84	;
NCS-0375	3221.6400	26.93	;
NCS-0380	3221.2200	39.64	;
NCS-0400	3219.9200	323.88	;
NCS-0410	3218.2000	19.45	;
NCS-0420	3216.1700	56.10	;
NCS-0425	3216.1200	28.42	;
NCS-0430	3216.1700	249.83	;
NCS-0440	3206.5000	653.75	;
NCSE-0010	3229.4300	29.92	;
NCSE-0015	3222.3100	26.18	;
NCSE-0020	3214.8800	145.86	;
NCSE-0030	3213.0200	57.22	;
NCSE-0040	3213.3800	50.12	;
NCSE-0050	3213.0600	19.45	;
NCSE-0051	3213.2300	104.72	;
NCSE-0060	3206.5000	171.29	;
NDF-0009	3221.9300	44.88	;
NDF-0010	3221.5100	22.44	;
NDF-0011	3220.2000	52.36	;
NDF-0020	3220.2000	59.84	;
NDF-0025	3217.2700	112.20	;
NDF-0030	3206.8000	149.00	;
NDF-0040	3202.6700	105.47	;
NDF-0045	3202.3800	11.22	;

NDF-0050	3204.0600	29.92	;
NDF-0060	3201.9600	29.92	;
NDF-0070	3201.9600	149.60	;
NDF-0080	3201.9600	149.60	;
NG-0010	3358.5200	22.44	;
NG-0020	3356.2900	15.41	;
NG-0030	3355.7800	67.32	;
NG-0040	3353.8600	119.68	;
NG-0050	3337.8100	23.94	;
NG-0060	3335.3900	37.40	;
NG-0070	3330.8100	29.92	;
NG-0080	3330.8100	29.92	;
NG-0090	3329.2100	37.40	;
NG-0100	3329.3000	37.40	;
NHAG-0010	3242.2100	117.44	;
NHAG-0020	3234.9200	65.82	;
NHAG-0030	3235.9100	254.32	;
NHAM-0010	3324.4500	97.24	;
NHAM-0030	3322.8500	22.44	;
NHAM-0040	3322.6100	59.84	;
NHAM-0050	3321.7500	33.66	;
NHAM-0060	3320.9500	37.40	;
NHAM-0061	3320.9500	37.40	;
NHAM-0070	3322.1700	29.92	;
NHAM-0080	3308.1900	134.64	;
NHAM-0081	3286.0900	138.38	;
NHAM-0090	3308.0300	37.40	;
NHAM-0100	3285.8200	37.40	;
NHAM-0110	3282.3800	29.92	;
NHAM-0120	3262.1500	33.66	;
NHAM-0130	3243.5800	368.02	;
NHIGH-0010	3320.6200	410.50	;
NHIGH-0020	3304.5400	22.44	;
NHIGH-0030	3304.5400	22.44	;
NHIGH-0040	3304.5400	165.23	;
NHIGH-0050	3304.5400	89.76	;
NHIL-0010	3354.1700	18.70	;
NHIL-0015	3352.6900	22.44	;
NHIL-0020	3340.2800	22.44	;
NHIL-0021	3338.5000	14.96	;
NHIL-0030	3337.9400	14.96	;
NHIL-0035	3337.4500	18.70	;
NHIL-0040	3336.0400	47.72	;
NHIL-0050	3336.4100	20.50	;
NHIL-0051	3335.4200	65.08	;
NHIL-0052	3335.5200	14.96	;
NHIL-0053	3335.7800	22.44	;
NHIL-0060	3324.1500	22.44	;
NHIL-0061	3322.9200	32.16	;
NHIL-0070	3318.5100	259.56	;
NHIL-0081	3318.5100	59.84	;
NHIL-0082	3318.6200	18.70	;
NHOO-0010	3284.9200	14.96	;
NHOO-0020	3284.9200	7.48	;
NHOO-0030	3284.3600	48.62	;
NHOO-0040	3282.3300	67.32	;
NHOO-0050	3281.0600	181.76	;
NHOO-0060	3276.6100	7.48	;
NHOO-0070	3276.4400	14.96	;
NHOO-0080	3275.0800	29.92	;
NHOO-0100	3274.2600	887.88	;
NJ-0010	3229.8500	142.12	;
NJ-0015	3229.0900	56.10	;
NJ-0020	3228.9200	72.26	;
NJ-0030	3225.4900	82.28	;
NJ-0040	3217.3500	112.20	;
NJ-0050	3208.6000	22.44	;
NJ-0060	3209.3400	84.22	;
NJ-0061	3208.4100	68.82	;
NJ-0070	3208.4100	47.87	;
NJ-0080	3207.9900	213.18	;
NJ-0085	3207.9900	290.22	;
NJ-0090	3205.2700	29.92	;
NJ-0092	3205.2700	29.92	;

NJ-0094	3205.0900	29.92	;
NJ-0100	3190.8600	37.40	;
NJ-0110	3189.3900	26.18	;
NJ-0120	3187.6000	31.12	;
NJ-0130	3187.0900	454.04	;
NJ-0140	3187.0900	425.61	;
NLP-0010	3204.7400	32.16	;
NLP-0020	3201.9400	95.74	;
NLP-0021	3201.9000	57.97	;
NLP-0030	3194.6300	22.44	;
NLP-0040	3195.0500	29.92	;
NLP-0050	3194.3300	29.92	;
NLP-0060	3194.6300	74.80	;
NLP-0065	3194.6300	82.28	;
NLP-0070	3187.9600	74.80	;
NLP-0080	3181.8000	33.14	;
NLP-0090	3179.2700	10.70	;
NLP-0100	3177.6500	10.70	;
NLP-0110	3174.5700	37.40	;
NPHI-0010	3284.3900	7.48	;
NPHI-0015	3284.6500	7.48	;
NPHI-0020	3283.5100	7.48	;
NPHI-0030	3282.6500	710.60	;
NPHI-0040	3283.3900	149.60	;
NPHI-0050	3282.9800	25.66	;
NPHI-0060	3280.5400	112.20	;
NPHI-0070	3280.8300	37.40	;
NPHI-0075	3280.5300	22.96	;
NPHI-0080	3281.8600	301.67	;
NPHI-0100	3282.1700	172.04	;
NPHI-0110	3282.1700	124.17	;
NPUT-0030	3239.6200	82.28	;
NPUT-0040	3231.4000	247.59	;
NPUT-0050	3230.8500	130.60	;
NPUT-0060	3226.3200	1296.73	;
NS-0010	3296.8600	252.82	;
NS-0020	3235.9300	142.12	;
NS-0030	3300.1800	20.20	;
NS-0040	3298.9600	267.04	;
NS-0041	3298.1900	280.50	;
NS-0050	3291.9600	44.88	;
NS-0055	3292.5900	14.96	;
NS-0060	3289.4300	424.12	;
NS-0070	3285.2900	172.04	;
NS-0080	3284.3700	175.78	;
NS-0090	3284.2200	155.58	;
NS-0100	3280.8300	598.40	;
NS-0110	3282.4800	1072.56	;
NWB-0010	3377.3700	11.22	;
NWB-0020	3376.8300	52.36	;
NWB-0030	3376.6600	22.44	;
NWB-0040	3375.6400	73.30	;
NWB-0050	3369.7400	76.30	;
NWB-0055	3369.7700	44.88	;
NWB-0060	3337.5100	57.60	;
NWB-0070	3334.3200	480.59	;
NWB-0071	3315.1600	106.22	;
NWB-0072	3314.4700	91.26	;
NWB-0080	3302.8400	175.41	;
NWB-0081	3301.9200	0.00	;
NWB-0082	3301.9200	0.00	;
NWB-0090	3301.5900	254.32	;
NWB-0100	3300.6200	26.18	;
NWB-0110	3301.2200	149.60	;
NWB-0115	3300.6600	45.63	;
NWB-0120	3300.2900	40.39	;
NWB-0130	3300.5200	29.92	;
NWB-0140	3297.3300	37.40	;
NWB-0150	3296.8200	351.56	;
NWB-0160	3295.0200	189.99	;
NWB-0165	3294.9200	174.28	;
NWB-0170	3294.5400	396.44	;
NWB-0180	3260.2800	190.74	;
NWB-0190	3248.8500	37.40	;

NWB-0200	3260.8700	36.95	;
NWB-0210	3260.8200	134.64	;
NWB-0220	3254.2100	31.42	;
NWB-0230	3253.0900	82.28	;
NWB-0240	3252.4400	679.93	;
SA-0010	3511.3800	22.44	;
SA-0015	3510.3000	14.96	;
SA-0016	3509.7400	26.18	;
SA-0020	3509.1400	183.48	;
SA-0025	3478.9400	14.96	;
SA-0030	3478.8300	22.44	;
SA-0040	3475.1400	44.88	;
SA-0050	3473.9100	42.94	;
SA-0060	3472.6600	29.92	;
SA-0070	3470.7900	18.03	;
SA-0080	3471.5300	29.92	;
SA-0090	3468.1200	31.57	;
SA-0100	3461.7100	97.24	;
SA-0110	3447.7200	22.44	;
SA-0111	3444.0600	44.88	;
SA-0120	3441.5700	147.36	;
SA-0130	3462.5100	37.40	;
SA-0140	3462.5700	67.32	;
SA-0150	3462.6400	22.44	;
SA-0160	3449.4400	26.18	;
SA-0161	3449.2100	290.22	;
SA-0170	3459.0500	48.62	;
SA-0180	3459.0500	48.62	;
SA-0190	3436.0300	22.44	;
SA-0200	3435.7400	37.40	;
SA-0210	3430.4600	2.47	;
SA-0220	3432.6400	5.98	;
SA-0230	3429.1800	209.44	;
SA-0240	3427.6100	200.84	;
SA-0250	3427.5300	284.24	;
SA-0260	3426.8600	97.24	;
SA-0270	3421.5800	381.48	;
SA-0280	3413.2100	89.76	;
SA-0290	3413.2100	18.70	;
SA-0300	3407.3700	52.36	;
SA-0310	3406.4500	48.62	;
SA-0320	3404.0000	187.00	;
SA-0330	3403.9100	426.36	;
SA-0340	3400.0900	193.73	;
SA-0350	3393.6700	201.21	;
SC-0020	3478.0700	37.40	;
SC-0030	3467.2600	40.39	;
SC-0040	3448.4900	7.48	;
SC-0041	3468.3900	14.96	;
SC-0042	3468.7700	37.40	;
SC-0050	3455.5600	52.36	;
SC-0060	3455.5600	22.44	;
SCS-0010	3477.8300	32.91	;
SCS-0020	3483.4900	14.96	;
SCS-0030	3459.9000	142.12	;
SCS-0040	3456.5600	98.74	;
SCS-0050	3430.1900	153.34	;
SCS-0060	3429.9600	37.40	;
SCS-0065	3435.2900	74.80	;
SCS-0070	3420.0900	201.96	;
SCS-0075	3429.5600	22.44	;
SCS-0080	3436.0300	134.64	;
SCS-0090	3421.6100	22.44	;
SCS-0100	3418.4200	29.92	;
SCS-0110	3418.8500	7.48	;
SCS-0120	3413.6300	261.80	;
SCS-0130	3412.1900	20.57	;
SCS-0131	3412.0900	162.17	;
SCS-0140	3411.0600	14.96	;
SCS-0150	3403.0100	37.40	;
SCS-0160	3397.4200	65.08	;
SCS-0180	3385.3800	37.40	;
SCS-0190	3386.8500	74.80	;
SCS-0200	3384.3100	461.37	;

SCS-0210	3374.8500	7.48	;
SCS-0220	3371.1900	7.48	;
SEC-0009	3441.6000	240.86	;
SEC-0010	3432.6500	295.46	;
SEC-0011	3431.4600	92.00	;
SEC-0020	3429.0600	142.12	;
SEC-0030	3429.1100	191.49	;
SEC-0040	3430.8900	103.22	;
SEC-0050	3430.8500	104.72	;
SEC-0051	3415.6100	23.56	;
SEC-0060	3408.7200	97.24	;
SEC-0070	3405.4500	160.82	;
SEC-0080	3430.9600	82.28	;
SEC-0090	3430.5200	112.20	;
SEC-0100	3430.6100	26.18	;
SEC-0110	3413.8000	69.94	;
SEC-0115	3413.4700	89.76	;
SEC-0120	3409.6100	37.40	;
SEC-0130	3408.9700	26.18	;
SEC-0140	3408.3500	26.18	;
SEC-0150	3408.3400	201.66	;
SH-0010	3521.3800	100.98	;
SH-0015	3522.1400	44.88	;
SH-0020	3521.5200	56.10	;
SH-0030	3519.0800	37.40	;
SH-0040	3518.7300	62.83	;
SH-0041	3516.9700	82.28	;
SH-0050	3516.1900	104.72	;
SH-0060	3515.9600	37.40	;
SH-0070	3515.3500	172.04	;
SH-0080	3512.6100	138.38	;
SH-0090	3513.3000	29.92	;
SH-0100	3509.8600	149.60	;
SH-0110	3508.9300	284.24	;
SH-0111	3509.4400	41.89	;
SH-0115	3502.5600	14.96	;
SH-0120	3487.8800	14.96	;
SH-0125	3498.7500	780.16	;
SH-0130	3488.8300	54.23	;
SH-0140	3485.0	44.88	;
SH-0150	3314.6200	279.00	;
SH-0160	3299.2600	424.86	;
SH-0170	3297.7400	799.99	;
SL-0010	3510.4800	7.48	;
SL-0020	3488.8200	691.15	;
SL-0030	3480.5400	44.88	;
SL-0040	3464.5800	160.82	;
SL-0050	3449.8500	246.84	;
SL-0055	3443.2700	165.31	;
SL-0060	3440.6200	74.80	;
SL-0070	3440.1600	18.70	;
SL-0080	3440.3800	76.07	;
SL-0090	3435.5000	56.85	;
SL-0100	3427.5600	41.89	;
SL-0110	3418.3000	97.24	;
SL-0120	3402.0800	52.36	;
SP-0010	3503.1400	224.40	;
SP-0020	3520.3800	149.60	;
SP-0030	3508.5700	6.73	;
SP-0031	3419.7500	278.26	;
SP-0040	3420.2400	67.32	;
SP-0050	3404.8900	437.58	;
SP-0051	3398.3000	100.46	;
SP-0052	3392.6500	101.50	;
SP-0060	3388.0700	74.80	;
SP-0070	3381.6200	310.42	;
SP-0080	3379.6800	322.01	;
SP-0090	3378.8700	14.96	;
SP-0100	3378.4800	130.15	;
SP-0110	3378.0500	542.30	;
SS-0010	3524.9200	14.96	;
SS-0020	3512.2800	14.21	;
SS-0030	3510.2500	14.96	;
SS-0040	3510.3100	14.21	;

SS-0050	3503.0600	40.39	;
SS-0061	3499.5700	112.20	;
SS-0070	3483.4300	142.12	;
SS-0080	3490.8400	14.96	;
SS-0090	3484.2100	104.72	;
SS-0100	3472.8900	301.44	;
STF-0220	3533.1100	74.80	;
STF-0230	3532.1500	22.44	;
STF-0240	3530.5000	37.40	;
STF-0250	3530.2300	423.37	;
STF-0260	3530.5700	7.48	;
STF-0270	3530.3700	14.96	;
STF-0280	3529.3600	195.23	;
STRF-0010	3527.9300	14.21	;
STRF-0020	3527.7700	14.96	;
STRF-0030	3527.7100	14.96	;
STRF-0040	3527.6700	7.48	;
STRF-0050	3527.3200	22.44	;
STRF-0060	3527.2800	29.17	;
STRF-0070	3532.3500	44.88	;
STRF-0071	3509.2000	175.78	;
STRF-0072	3509.4000	112.20	;
STRF-0080	3527.4700	149.60	;
STRF-0090	3527.1000	44.88	;
STRF-0100	3530.5000	37.40	;
STRF-0110	3526.6200	299.20	;
SWB-0010	3397.4400	18.70	;
SWB-0020	3395.8000	52.36	;
SWB-0030	3394.4100	255.07	;
SWB-0035	3394.3100	270.03	;
SWB-0040	3392.7400	76.52	;
SWB-0050	3388.6000	443.49	;
SWB-0051	3388.8900	117.14	;
SWB-0060	3386.7000	73.30	;
SWB-0070	3386.7900	74.05	;
SWB-0080	3385.8400	7.48	;
SWB-0090	3385.3200	5.98	;
SWB-0100	3384.5300	2.99	;
SWB-0110	3380.4900	127.16	;
SWB-0120	3379.6600	77.12	;
SWB-0130	3378.4100	134.64	;
SWC-0010	3444.7500	223.80	;
SWC-0011	3445.3300	0.00	;
SWC-0020	3443.9500	37.40	;
SWC-0030	3442.9300	22.44	;
SWC-0040	3442.6200	67.32	;
SWC-0045	3437.7300	99.48	;
SWC-0046	3435.1800	172.04	;
SWC-0047	3434.7600	288.73	;
SWC-0049	3430.1800	14.96	;
SWC-0050	3426.1600	0.00	;
SWC-0060	3426.3400	14.96	;
SWC-0070	3425.4200	172.04	;
SWC-0080	3425.0100	59.84	;
SWC-0090	3424.3800	23.19	;
SWC-0100	3423.9100	52.36	;
SWC-0101	3423.9400	50.12	;
SWC-0110	3422.5100	112.20	;
SWC-0120	3421.7400	68.07	;
SWC-0130	3421.0300	153.34	;
SWC-0135	3415.4300	228.89	;
SWC-0150	3415.4000	172.04	;
SWC-0160	3414.9900	41.14	;
SWC-0170	3410.4600	20.94	;
SWC-0180	3399.9200	14.96	;
SWC-0190	3402.4200	82.28	;
SWC-0200	3399.1100	384.10	;
SWC-0210	3383.4300	56.10	;
SWC-0220	3308.7300	32.16	;
SWC-0230	3305.6600	69.56	;
SWC-0240	3305.9600	26.25	;
SWC-0250	3305.6600	26.93	;
SWC-0260	3285.7100	156.63	;
SWC-0270	3281.5800	696.01	;

2	3527.32	0		;
NG-0052	3337.81	73.3		;
3	3346.5	0		;
4	3236	0		;
5	3384.0	0		;
6	0	0		;

[RESERVOIRS]

;ID	Head	Pattern	
1	3560.0		;Begin Phase 5
TumaloRes	3500.0		;Couch Lateral

[TANKS]

;ID	Elevation	InitLevel	MinLevel	MaxLevel	Diameter	MinVol	VolCurve

[PIPES]

;ID	Node1	Node2	Length	Diameter	Roughness	MinorLoss	Status	
8	HG-37	NDF-0009	182.4808	10.05	135	0	Open	;10 DR32.5
9	NDF-0009	NDF-0010	210.1684	10.05	135	0	Open	;10 DR32.5
10	NDF-0010	NDF-0011	302.4087	10.05	135	0	Open	;10 DR32.5
11	NDF-0011	NDF-0020	0.3799	10.05	135	0	Open	;
12	NDF-0020	NDF-0025	237.3592	8.06	135	0	Open	;8 DR32.5
13	NDF-0025	NDF-0030	858.3486	8.06	135	0	Open	;8 DR32.5
14	NDF-0045	NDF-0050	335.4884	6.19	135	0	Open	;6 DR32.5
15	NDF-0030	NDF-0040	832.6558	8.06	135	0	Open	;8 DR32.5
16	NDF-0040	NDF-0045	235.0751	6.19	135	0	Open	;6 DR32.5
17	NDF-0050	NDF-0060	378.0054	6.19	135	0	Open	;6 DR32.5
19	N-61	NCS-0430	426.0271	6.19	135	0	Open	;6 DR32.5
21	NCS-0420	NCS-0425	2.4746	6.19	135	0	Open	;6 DR32.5
22	NCS-0430	NCS-0420	1.1168	6.19	135	0	Open	;6 DR32.5
23	HG-38	NLP-0010	348.9017	8.06	135	0	Open	;8 DR32.5
24	NLP-0010	NLP-0020	1209.0479	8.06	135	0	Open	;8 DR32.5
25	NLP-0020	NLP-0021	9.9403	8.06	135	0	Open	;8 DR32.5
26	NLP-0021	NLP-0030	595.3518	6.08	135	0	Open	;6 DR32.5
27	NLP-0030	NLP-0040	503.5853	6.08	135	0	Open	;6 DR26
28	NLP-0040	NLP-0050	439.9630	6.08	135	0	Open	;6 DR26
29	NLP-0050	NLP-0060	64.5706	6.08	135	0	Open	;6 DR26
30	NLP-0065	NLP-0070	622.8636	6.08	135	0	Open	;6 DR26
31	NLP-0070	NLP-0080	990.2194	6.08	135	0	Open	;6 DR26
32	NLP-0080	NLP-0090	352.1650	6.08	135	0	Open	;6 DR26
33	NLP-0090	NLP-0100	325.9986	6.08	135	0	Open	;6 DR26
34	NLP-0100	NLP-0110	345.27	6.08	135	0	Open	;6 DR26
50	STF-0240	STF-0250	826.34	84	130	0	Open	;
51	STF-0230	STF-0240	809.10	84	130	0	Open	;
52	STF-0220	STF-0230	4178.84	84	130	0	Open	;
58	HG-8	STF-0260	144.02	84	130	0	Open	;
59	STF-0260	STF-0270	1905.89	84	130	0	Open	;
60	STF-0250	HG-8	718.2958	84	130	0	Open	;
61	STF-0280	HG-9	3437.42	84	130	0	Open	;
62	STF-0270	STF-0280	1468.09	84	130	0	Open	;
63	HG-9	HG-10	150.16	84	130	0	Open	;
64	N-62	N-63	115.8527	6.08	135	0	Open	;6 DR26
65	NHAM-0061	NHAM-0060	2.8137	10.05	135	0	Open	;10 DR32.5
66	NHAM-0060	NHAM-0090	530.5562	8.06	135	0	Open	;8 DR32.5
67	HG-26	NHIGH-0010	232.1695	8.06	135	0	Open	;8 DR32.5
68	NHIGH-0010	NHIGH-0040	1035.8063	6.19	135	0	Open	;6 DR32.5
69	NHIGH-0020	NHIGH-0030	0.8966	6.19	135	0	Open	;6 DR32.5
70	NHIGH-0040	NHIGH-0050	0.3377	6.19	135	0	Open	;
71	NHIGH-0050	NHIGH-0020	0.9100	6.19	135	0	Open	;6 DR32.5
72	HG-47	STRF-0100	393.94	22.44	135	0	Open	;Exist 24DR32.5
73	STRF-0100	N-57	559.58	22.44	135	0	Open	;Exist24DR32.5
78	HG-9	SL-0010	1808.93	11.92	135	0	Open	;12 DR32.5
79	SL-0010	SL-0020	1999.87	11.92	135	0	Open	;12 DR32.5
80	SL-0020	SL-0030	431.5094	10.05	135	0	Open	;10 DR32.5
81	SL-0030	SL-0040	181.4680	10.05	135	0	Open	;10 DR32.5
82	SL-0040	SL-0050	834.3213	10.05	135	0	Open	;10 DR32.5
83	SL-0050	SL-0055	578.2832	8.06	135	0	Open	;8 DR32.5
84	SL-0055	N-55	430.1423	8.06	135	0	Open	;8 DR32.5
85	SL-0020	N-13	1032.39	6.19	135	0	Open	;6 DR32.5
86	N-56	SL-0060	659.1358	6.19	135	0	Open	;6 DR32.5
87	SL-0060	SL-0070	581.5251	6.19	135	0	Open	;6 DR32.5
88	SL-0070	SL-0080	578.9298	6.19	135	0	Open	;6 DR32.5
89	SL-0080	SL-0090	832.2861	6.19	135	0	Open	;6 DR32.5
90	SL-0090	SL-0100	1096.3154	6.19	135	0	Open	;6 DR32.5

91	SL-0100	SL-0110	830.5654	6.19	135	0	Open	;6 DR32.5
92	SL-0110	SL-0120	952.34	6.08	135	0	Open	;6 DR26
93	N-55	N-56	319.0259	8.06	135	0	Open	;8 DR32.5
94	HG-8	HG-7	282.5954	16.83	135	0	Open	;18 DR32.5
95	HG-7	SP-0020	660.8434	14.96	135	0	Open	;16 DR32.5
96	SP-0030	SP-0031	6480.00	14.7	135	0	Open	;16 DR32.5
97	SP-0020	SP-0030	857.50	14.96	135	0	Open	;16 DR32.5
98	SP-0031	SP-0040	1.53	14.7	135	0	Open	;16 DR32.5
99	SP-0040	SP-0050	1379.98	12.86	135	0	Open	;14 DR26
100	SP-0052	SP-0060	1037.39	11.71	135	0	Open	;12 DR26
101	SP-0051	SP-0052	471.29	11.71	135	0	Open	;12 DR26
102	SP-0050	SP-0051	625.48	11.71	135	0	Open	;12 DR26
103	SP-0060	N-53	571.53	11.71	135	0	Open	;12 DR26
104	SP-0080	SP-0070	4.84	9.87	135	0	Open	;10 DR26
105	SP-0100	SP-0110	72.8477	7.92	135	0	Open	;8 DR26
106	SP-0070	SP-0090	796.59	7.92	135	0	Open	;8 DR26
107	SP-0090	SP-0100	112.5914	7.92	135	0	Open	;8 DR26
108	SP-0110	N-11	86.49	6.08	135	0	Open	;6 DR26
109	N-53	SP-0080	960.41	11.71	135	0	Open	;12 DR26
110	SP-0100	N-12	2052.49	5.96	135	0	Open	;6 DR21
117	HG-7	SP-0010	2599.5358	6.19	135	0	Open	;6 DR32.5
118	SP-0010	N-8	264.07	6.19	135	0	Open	;6 DR32.5
119	HG-10	STRF-0010	1833.01	58.891	135	0	Open	;63 DR32.5
120	STRF-0110	HG-46	3016.81	44.869	135	0	Open	;48 DR32.5
121	HG-48	STRF-0080	589.03	50.477	135	0	Open	;54 DR32.5
123	STRF-0090	HG-47	937.44	50.477	135	0	Open	;54 DR32.5
124	STRF-0080	STRF-0090	43.2903	50.477	135	0	Open	;54 DR32.5
125	HG-45	STRF-0050	20.78	58.891	135	0	Open	;63 DR32.5
126	STRF-0060	HG-48	1228.87	50.477	135	0	Open	;54 DR32.5
127	STRF-0050	STRF-0060	11.54	58.891	135	0	Open	;63 DR32.5
128	STRF-0040	HG-45	504.79	58.891	135	0	Open	;63 DR32.5
129	STRF-0030	STRF-0040	263.66	58.891	135	0	Open	;63 DR32.5
130	STRF-0020	STRF-0030	530.90	58.891	135	0	Open	;63 DR32.5
131	STRF-0010	STRF-0020	279.32	58.891	135	0	Open	;63 DR32.5
132	HG-10	HG-11	256.2470	58.89	135	0	Open	;63 DR32.5
133	HG-11	SCS-0010	2777.7920	44.86	135	0	Open	;48 DR32.5
134	SCS-0010	SCS-0020	30.3205	44.86	135	0	Open	;48 DR32.5
135	SCS-0020	SCS-0030	1410.2820	44.86	135	0	Open	;48 DR32.5
136	HG-14	SCS-0080	1368.3083	44.86	135	0	Open	;48 DR32.5
137	SCS-0080	SCS-0090	1060.7423	44.86	135	0	Open	;48 DR32.5
138	SCS-0030	HG-14	148.9746	44.86	135	0	Open	;48 DR32.5
139	SCS-0150	SCS-0160	709.8389	44.86	135	0	Open	;48 DR26
140	SCS-0140	SCS-0150	761.7815	44.86	135	0	Open	;48 DR32.5
141	SCS-0090	SCS-0100	351.3643	44.86	135	0	Open	;48 DR32.5
142	HG-60	SCS-0140	510.6059	44.86	135	0	Open	;48 DR32.5
143	HG-21	HG-22	1028.0884	44.86	135	0	Open	;48 DR32.5
144	SWB-0010	HG-21	39.2758	44.86	135	0	Open	;48 DR26
145	SCS-0160	SWB-0010	5.8291	44.86	135	0	Open	;48 DR26
146	HG-22	SCS-0210	1271.7458	44.86	135	0	Open	;48 DR32.5
147	SCS-0210	SCS-0220	609.7691	44.86	135	0	Open	;48 DR32.5
148	HG-23	HG-24	1592.94	39.26	135	0	Open	;42 DR32.5
149	SCS-0220	HG-23	840.68	44.86	135	0	Open	;
151	NCS-0010	NCS-0001	21.02	39.26	135	0	Open	;42 DR32.5
152	HG-25	NCS-0050	1921.2866	39.26	135	0	Open	;42 DR32.5
153	NCS-0001	NCS-0011	1043.16	39.26	135	0	Open	;42 DR32.5
154	NCS-0011	HG-25	874.97	39.26	135	0	Open	;42 DR32.5
155	NCS-0060	NCS-0070	25.1741	39.26	135	0	Open	;42 DR32.5
156	NCS-0050	NCS-0055	202.6899	39.26	135	0	Open	;42 DR32.5
157	NCS-0055	NCS-0060	0.6678	39.26	135	0	Open	;
158	NCS-0070	NCS-0080	2.5159	39.26	135	0	Open	;42 DR32.5
159	NCS-0080	NCS-0090	1930.4971	39.26	135	0	Open	;42 DR32.5
160	HG-28	NCS-0110	1330.4114	33.65	135	0	Open	;36 DR32.5
161	HG-27	NCS-0100	215.5777	33.65	135	0	Open	;36 DR32.5
162	NCS-0090	HG-27	76.8183	39.26	135	0	Open	;42 DR32.5
163	NCS-0100	HG-28	565.4046	33.65	135	0	Open	;36 DR32.5
164	NCS-0111	NCS-0120	1079.9614	33.65	135	0	Open	;36 DR32.5
165	NCS-0110	NCS-0111	1123.0348	33.65	135	0	Open	;36 DR32.5
166	HG-29	HG-30	715.9869	33.06	135	0	Open	;36 DR26
167	NCS-0120	NCS-0130	695.5945	33.65	135	0	Open	;36 DR32.5
168	NCS-0130	NCS-0140	7.9498	33.65	135	0	Open	;36 DR32.5
169	NCS-0140	NCS-0150	143.8452	33.65	135	0	Open	;36 DR32.5
170	NCS-0150	HG-29	226.5268	33.06	135	0	Open	;36 DR26
171	HG-33	NCS-0240	457.1618	25.72	135	0	Open	;28 DR26
172	NCS-0250	NCS-0220	0.1517	25.72	135	0	Open	;

173	NCS-0230	NCS-0250	1.3959	25.72	135	0	Open	;28 DR32.5
175	NCS-0240	NCS-0230	2.1941	25.72	135	0	Open	;28 DR26
176	N-29	NCS-0270	403.7804	22.44	135	0	Open	;24 DR32.5
177	NCS-0270	HG-34	117.7352	22.44	135	0	Open	;24 DR32.5
178	HG-34	NCSE-0010	496.8328	13.09	135	0	Open	;14 DR32.5
179	NCSE-0010	NCSE-0015	2216.3925	13.09	135	0	Open	;14 DR32.5
180	NCSE-0015	NCSE-0020	694.1214	13.09	135	0	Open	;14 DR32.5
181	NCSE-0020	NCSE-0030	1888.4871	11.92	135	0	Open	;12 DR32.5
182	NCSE-0040	NCSE-0050	2.8347	11.92	135	0	Open	;12 DR32.5
183	NCSE-0050	HG-36	1.9933	11.92	135	0	Open	;12 DR32.5
184	NCSE-0030	NCSE-0040	128.1861	11.92	135	0	Open	;12 DR32.5
185	NCS-0290	HG-35	89.2493	14.96	135	0	Open	;16 DR32.5
186	HG-34	NCS-0280	3.7206	14.96	135	0	Open	;16 DR32.5
187	NCS-0280	NCS-0290	874.5250	14.96	135	0	Open	;16 DR32.5
188	HG-35	NCS-0310	419.4750	6.19	135	0	Open	;6 DR32.5
189	NCS-0310	NCS-0300	8.3674	6.19	135	0	Open	;6 DR32.5
190	HG-35	NCS-0320	466.3918	14.96	135	0	Open	;16 DR32.5
191	NCS-0360	NCS-0380	410.3685	13.09	135	0	Open	;14 DR32.5
192	NCS-0362	NCS-0360	0.5109	13.09	135	0	Open	;
193	NCS-0364	NCS-0362	1.1670	13.09	135	0	Open	;14 DR32.5
194	NCS-0320	NCS-0330	5.3957	14.96	135	0	Open	;16 DR32.5
195	NCS-0330	NCS-0340	1139.2428	14.96	135	0	Open	;16 DR32.5
196	NCS-0340	NCS-0350	4.2778	13.09	135	0	Open	;14 DR32.5
197	NCS-0350	NCS-0366	0.6834	13.09	135	0	Open	;14 DR32.5
198	NCS-0366	NCS-0364	5.1203	13.09	135	0	Open	;14 DR32.5
199	NCS-0370	NCS-0375	2.9813	13.09	135	0	Open	;14 DR32.5
200	NCS-0375	HG-37	511.5842	11.92	135	0	Open	;12 DR32.5
201	NCS-0380	NCS-0370	0.9258	13.09	135	0	Open	;14 DR32.5
202	HG-37	NCS-0400	639.3856	8.06	135	0	Open	;8 DR32.5
203	NCS-0400	NCS-0410	591.4295	6.19	135	0	Open	;6 DR32.5
204	NCS-0410	N-61	415.2421	6.19	135	0	Open	;6 DR32.5
205	HG-36	NCSE-0051	909.0522	6.19	135	0	Open	;6 DR32.5
206	HG-36	HG-38	1566.8518	11.92	135	0	Open	;12 DR32.5
207	HG-38	NCS-0440	1.3043	10.05	135	0	Open	;10 DR32.5
208	NCS-0440	NCSE-0060	1.1148	10.05	135	0	Open	;10 DR32.5
209	NCSE-0060	HG-39	2694.50	5.72	135	0	Open	;6 DR15.5
210	HG-29	NC-0010	91.4070	6.08	135	0	Open	;6 DR26
211	NC-0010	NC-0020	326.8413	6.08	135	0	Open	;6 DR26
212	NC-0020	NC-0030	396.9122	6.08	135	0	Open	;6 DR26
213	NC-0030	NC-0021	432.1828	6.08	135	0	Open	;6 DR26
214	NC-0021	NC-0040	502.2149	6.08	135	0	Open	;6 DR26
215	NC-0040	NC-0050	312.6493	6.08	135	0	Open	;6 DR26
216	NC-0050	NC-0060	4.0853	6.08	135	0	Open	;6 DR26
217	NC-0060	NC-0065	4.5992	6.08	135	0	Open	;6 DR26
219	NC-0070	NC-0080	1.8316	6.08	135	0	Open	;
220	NC-0080	HG-33	787.5870	6.08	135	0	Open	;6 DR26
221	N-63	NHAM-0130	387.0451	6.08	135	0	Open	;6 DR26
222	NHAM-0130	N-25	1427.9215	6.08	135	0	Open	;6 DR26
223	NHAM-0080	NHAM-0081	965.7424	8.06	135	0	Open	;8 DR32.5
224	NHAM-0090	NHAM-0080	2.3601	8.06	135	0	Open	;8 DR32.5
225	NHAM-0081	NHAM-0100	6.3234	6.19	135	0	Open	;6 DR32.5
226	NHAM-0100	NHAM-0110	337.4680	6.19	135	0	Open	;6 DR32.5
227	NHAM-0110	NHAM-0120	463.3806	6.08	135	0	Open	;6 DR26
228	NHAM-0120	N-62	120.4344	6.08	135	0	Open	;6 DR26
229	HG-25	NHAM-0010	1473.1664	13.09	135	0	Open	;14 DR32.5
230	NHAM-0050	NHAM-0070	499.1571	10.05	135	0	Open	;10 DR32.5
231	NHAM-0070	NHAM-0061	4.7925	10.05	135	0	Open	;10 DR32.5
232	HG-26	NHAM-0030	505.8049	10.05	135	0	Open	;10 DR32.5
233	NHAM-0010	HG-26	283.5424	11.92	135	0	Open	;
234	NHAM-0030	NHAM-0040	137.1450	10.05	135	0	Open	;10 DR32.5
235	NHAM-0040	NHAM-0050	267.1284	10.05	135	0	Open	;10 DR32.5
236	HG-23	NG-0010	1419.21	7.75	135	0	Open	;8 DR21
237	NG-0010	NG-0030	1207.2055	7.75	135	0	Open	;8 DR21
238	NG-0020	NG-0040	262.1281	5.96	135	0	Open	;6 DR21
239	NG-0030	NG-0020	12.5515	5.96	135	0	Open	;6 DR21
240	NG-0040	NG-0050	1025.5037	5.96	135	0	Open	;6 DR21
243	NG-0060	NG-0070	521.2293	5.96	135	0	Open	;6 DR21
245	NG-0070	NG-0080	0.4305	5.96	135	0	Open	;6 DR21
246	NG-0080	NG-0090	344.3780	5.96	135	0	Open	;6 DR21
247	NG-0090	NG-0100	3.2303	5.96	135	0	Open	;6 DR21
248	HG-22	SCS-0180	441.5135	7.92	135	0	Open	;8 DR26
249	SCS-0200	N-59	1691.2173	6.08	135	0	Open	;6 DR26
250	SCS-0180	SCS-0190	235.3390	7.92	135	0	Open	;8 DR26
251	SCS-0190	SCS-0200	513.8469	7.92	135	0	Open	;8 DR26

252	N-58	N-22	2275.7721	6.08	135	0	Open	;6 DR26
253	N-59	N-58	132.2213	6.08	135	0	Open	;6 DR26
254	HG-11	HG-12	262.3521	31.78	135	0	Open	;34 DR32.5
255	HG-12	SA-0010	1508.6696	6.19	135	0	Open	;6 DR32.5
256	SA-0016	SA-0020	18.8970	6.19	135	0	Open	;6 DR32.5
257	SA-0015	SA-0016	4.5600	6.19	135	0	Open	;6 DR32.5
258	SA-0010	SA-0015	366.7487	6.19	135	0	Open	;6 DR32.5
259	HG-12	SA-0025	3947.1490	31.78	135	0	Open	;34 DR32.5
260	SA-0025	SA-0030	1.6204	31.78	135	0	Open	;34 DR32.5
261	SA-0030	SA-0040	588.1286	31.78	135	0	Open	;34 DR32.5
262	SA-0040	SA-0050	261.8319	31.78	135	0	Open	;34 DR32.5
263	SA-0050	SA-0060	673.4228	31.78	135	0	Open	;34 DR32.5
264	SA-0060	SA-0070	404.7963	31.78	135	0	Open	;34 DR32.5
265	SA-0070	SA-0080	273.7843	31.78	135	0	Open	;34 DR32.5
266	SA-0080	SA-0090	418.9776	31.78	135	0	Open	;34 DR32.5
267	SA-0090	HG-17	17.9969	31.78	135	0	Open	;34 DR32.5
268	HG-17	SA-0100	758.9893	6.19	135	0	Open	;6 DR32.5
269	HG-17	SA-0130	314.3896	29.91	135	0	Open	;32 DR32.5
270	HG-16	SA-0180	567.3114	29.91	135	0	Open	;32 DR32.5
271	SA-0150	HG-16	4.3069	29.91	135	0	Open	;32 DR32.5
272	SA-0130	SA-0140	6.0333	29.91	135	0	Open	;32 DR32.5
273	SA-0140	SA-0150	3.8484	29.91	135	0	Open	;32 DR32.5
274	SA-0170	SA-0190	1910.2749	29.91	135	0	Open	;32 DR32.5
275	SA-0180	SA-0170	0.4376	29.91	135	0	Open	;
276	SA-0190	SA-0200	438.3565	29.91	135	0	Open	;32 DR32.5
277	SA-0200	SA-0220	563.7846	29.91	135	0	Open	;32 DR32.5
278	SA-0270	SA-0280	668.2782	28.04	135	0	Open	;30 DR32.5
279	SA-0210	SA-0230	643.6475	29.91	135	0	Open	;32 DR32.5
280	SA-0220	SA-0210	239.7684	29.91	135	0	Open	;32 DR32.5
281	SA-0230	SA-0240	273.1865	29.91	135	0	Open	;32 DR32.5
282	SA-0240	SA-0250	128.4893	29.91	135	0	Open	;32 DR32.5
283	SA-0250	SA-0260	1.9034	29.91	135	0	Open	;32 DR32.5
284	SA-0260	SA-0270	530.4072	28.04	135	0	Open	;30 DR32.5
285	SA-0280	SA-0290	0.2772	28.04	135	0	Open	;
286	SA-0290	SA-0300	1087.7003	28.04	135	0	Open	;30 DR32.5
287	SA-0300	SA-0310	5.5240	27.55	135	0	Open	;30 DR26
288	SA-0310	SA-0320	1059.4806	27.55	135	0	Open	;30 DR26
289	SA-0350	HG-19	900.4605	25.72	135	0	Open	;28 DR26
290	SA-0320	SA-0330	108.3230	27.55	135	0	Open	;30 DR26
291	SA-0330	SA-0340	569.6559	27.55	135	0	Open	;30 DR26
292	SA-0340	SA-0350	812.6912	25.72	135	0	Open	;28 DR26
293	SA-0100	N-37	708.3565	6.19	135	0	Open	;6 DR32.5
294	SA-0100	SA-0110	812.9337	6.19	135	0	Open	;6 DR32.5
295	SA-0110	SA-0111	413.4859	6.19	135	0	Open	;6 DR32.5
296	SA-0111	SA-0120	196.0037	6.19	135	0	Open	;6 DR32.5
297	SA-0120	N-18	1001.0769	6.19	135	0	Open	;6 DR32.5
298	HG-21	SWB-0020	187.1271	11.71	135	0	Open	;12 DR26
299	SWB-0020	SWB-0030	772.2440	9.87	135	0	Open	;10 DR26
300	SWB-0030	SWB-0035	4.7247	9.87	135	0	Open	;10 DR26
301	SWB-0035	SWB-0040	1867.3665	7.92	135	0	Open	;8 DR26
302	SWB-0040	SWB-0050	2299.6652	7.92	135	0	Open	;8 DR26
304	SWB-0050	SWB-0051	17.2746	6.08	135	0	Open	;6 DR26
305	SWB-0080	SWB-0090	470.1058	6.08	135	0	Open	;6 DR26
306	SWB-0090	SWB-0100	673.2023	6.08	135	0	Open	;6 DR26
307	SWB-0070	SWB-0080	638.5696	6.08	135	0	Open	;6 DR26
308	SWB-0100	HG-19	538.3364	6.08	135	0	Open	;6 DR26
309	SWB-0060	SWB-0070	98.9300	6.08	135	0	Open	;6 DR26
310	HG-20	SWB-0110	2444.8080	24.3	135	0	Open	;26 DR32.5
312	SWB-0110	SWB-0120	670.9120	24.3	135	0	Open	;26 DR32.5
313	SWB-0120	SWB-0130	141.3830	24.3	135	0	Open	;26 DR32.5
314	SWB-0130	NWB-0010	1788.9458	24.3	135	0	Open	;26 DR32.5
315	NWB-0030	NWB-0040	616.3340	24.3	135	0	Open	;26 DR32.5
316	NWB-0020	NWB-0030	21.1690	24.3	135	0	Open	;26 DR32.5
317	NWB-0010	NWB-0020	77.7831	24.3	135	0	Open	;26 DR32.5
318	NWB-0055	NWB-0060	1272.56	24.3	135	0	Open	;26 DR32.5
319	NWB-0040	NWB-0050	1336.9148	24.3	135	0	Open	;26 DR32.5
320	NWB-0050	NWB-0055	8.76	24.3	135	0	Open	;26 DR32.5
321	NWB-0060	NWB-0070	423.5860	24.3	135	0	Open	;26 DR32.5
322	NWB-0070	NWB-0071	854.5014	22.04	135	0	Open	;24 DR26
323	NWB-0180	NWB-0200	352.4879	6.08	135	0	Open	;6 DR26
324	NWB-0210	N-64	0.1328	6.08	135	0	Open	;
325	NWB-0200	NWB-0210	882.0785	6.08	135	0	Open	;6 DR26
326	NWB-0082	NWB-0081	0.48	22.04	135	0	Open	;24 DR26
328	NWB-0071	NWB-0072	8.38	22.04	135	0	Open	;24 DR26

329	NWB-0072	NWB-0080	490.27	22.04	135	0	Open	;24 DR26
330	NWB-0080	NWB-0082	1368.9990	22.04	135	0	Open	;24 DR26
331	NWB-0150	NWB-0160	1815.5180	7.92	135	0	Open	;8 DR26
332	NWB-0160	NWB-0170	816.6973	7.92	135	0	Open	;8 DR26
333	NWB-0170	NWB-0165	2.1812	6.08	135	0	Open	;6 DR26
335	NWB-0090	NWB-0100	842.7590	22.04	135	0	Open	;24 DR26
336	NWB-0100	NWB-0110	345.6764	22.04	135	0	Open	;24 DR26
337	NWB-0110	NWB-0115	401.2199	22.04	135	0	Open	;24 DR26
338	NWB-0115	NWB-0120	694.1916	22.04	135	0	Open	;24 DR26
339	NWB-0140	NWB-0150	1239.8137	9.87	135	0	Open	;10 DR26
340	NWB-0130	HG-40	1385.1728	22.04	135	0	Open	;24 DR26
341	NWB-0120	NWB-0130	435.8536	22.04	135	0	Open	;24 DR26
342	HG-40	NWB-0140	2562.7365	9.87	135	0	Open	;10 DR26
343	N-60	NWB-0220	265.5837	6.08	135	0	Open	;6 DR26
344	NWB-0230	NWB-0240	443.6565	7.92	135	0	Open	;8 DR26
345	NWB-0220	NWB-0230	466.3432	6.08	135	0	Open	;6 DR26
346	NWB-0240	HG-30	2014.6223	11.71	135	0	Open	;12 DR26
347	HG-31	NCS-0170	31.4644	27.55	135	0	Open	;30 DR26
348	HG-30	NCS-0160	161.5467	29.39	135	0	Open	;32 DR26
349	NCS-0190	NCS-0200	566.4044	25.72	135	0	Open	;28 DR26
350	NCS-0200	NCS-0210	372.2416	25.72	135	0	Open	;28 DR26
351	NCS-0170	NCS-0180	492.2995	27.55	135	0	Open	;30 DR26
352	NCS-0160	HG-31	153.1869	29.39	135	0	Open	;32 DR26
353	NCS-0180	NCS-0190	417.7160	27.55	135	0	Open	;30 DR26
354	NCS-0210	HG-32	548.1775	25.72	135	0	Open	;28 DR26
355	HG-32	HG-33	820.1025	25.72	135	0	Open	;28 DR26
356	N-64	N-60	487.2869	6.08	135	0	Open	;6 DR26
357	HG-41	NS-0010	1616.6038	6.19	135	0	Open	;6 DR32.5
358	NS-0010	N-35	4445.7562	5.96	135	0	Open	;6 DR21
359	NS-0010	NS-0020	3924.8878	5.89	135	0	Open	;6 DR19
360	NS-0020	N-36	5451.29	5.89	135	0	Open	;6 DR19
361	HG-40	HG-41	284.0575	18.37	135	0	Open	;20 DR26
362	NS-0040	NS-0041	435.2088	16.53	135	0	Open	;18 DR26
363	NS-0055	NS-0050	5.1213	14.70	135	0	Open	;16 DR26
364	NS-0041	NS-0055	575.4083	16.53	135	0	Open	;18 DR26
365	NS-0050	NS-0060	120.9901	14.70	135	0	Open	;16 DR26
366	NS-0060	NS-0070	2346.9878	14.38	135	0	Open	;16 DR21
367	HG-41	NS-0030	388.6135	16.53	135	0	Open	;18 DR26
368	NS-0030	NS-0040	1629.3224	16.53	135	0	Open	;18 DR26
369	NS-0090	NS-0100	1069.7463	12.59	135	0	Open	;14 DR21
370	NS-0070	NS-0080	860.0360	12.59	135	0	Open	;14 DR21
371	NS-0080	NS-0090	3.7019	12.59	135	0	Open	;14 DR21
372	NS-0100	NS-0110	2.7625	9.66	135	0	Open	;
374	NS-0100	HG-42	339.3022	5.96	135	0	Open	;6 DR21
375	HG-44	N-32	1695.0722	5.89	135	0	Open	;6 DR19
376	HG-42	HG-43	440.9773	5.96	135	0	Open	;6 DR21
377	HG-42	N-33	1033.0858	5.89	135	0	Open	;6 DR19
378	HG-43	HG-44	60.9152	5.96	135	0	Open	;6 DR21
379	HG-43	N-34	2171.0458	5.89	135	0	Open	;6 DR19
380	HG-20	NB-0005	639.6080	8.06	135	0	Open	;8 DR32.5
381	NB-0010	N-66	0.6016	8.06	135	0	Open	;8 DR32.5
382	NB-0005	NB-0010	5.1874	8.06	135	0	Open	;8 DR32.5
383	N-65	NB-0120	191.6549	6.08	135	0	Open	;6 DR26
384	NB-0120	N-67	296.7339	6.08	135	0	Open	;6 DR26
385	N-66	NB-0020	13.8171	8.06	135	0	Open	;8 DR32.5
386	NB-0030	NB-0040	80.6812	8.06	135	0	Open	;8 DR32.5
387	NB-0020	NB-0030	164.1614	8.06	135	0	Open	;8 DR32.5
388	NB-0040	NB-0050	681.9127	8.06	135	0	Open	;8 DR32.5
389	NB-0050	NB-0051	104.1164	8.06	135	0	Open	;8 DR32.5
390	NB-0051	NB-0060	555.7347	6.19	135	0	Open	;6 DR32.5
391	NB-0060	NB-0070	1.6713	6.19	135	0	Open	;6 DR32.5
392	NB-0070	NB-0080	685.9304	6.19	135	0	Open	;6 DR32.5
393	NB-0080	NB-0090	117.0358	6.19	135	0	Open	;6 DR32.5
394	NB-0090	NB-0100	689.80	6.19	135	0	Open	;6 DR32.5
395	NB-0100	NB-0110	463.90	6.08	135	0	Open	;6 DR26
396	NB-0110	N-65	336.8086	6.08	135	0	Open	;6 DR26
397	N-67	NB-0130	181.3312	6.08	135	0	Open	;6 DR26
398	NB-0130	NB-0140	1144.9116	6.08	135	0	Open	;6 DR26
399	NB-0140	N-19	315.96	6.08	135	0	Open	;6 DR26
400	HG-24	NHIL-0015	820.24	7.75	135	0	Open	;8 DR21
401	NHIL-0015	NHIL-0010	19.9787	7.75	135	0	Open	;8 DR21
402	NHIL-0010	NHIL-0020	549.8566	7.75	135	0	Open	;8 DR21
403	NHIL-0020	NHIL-0021	589.6914	7.75	135	0	Open	;8 DR21
404	NHIL-0021	NHIL-0030	310.6544	7.75	135	0	Open	;8 DR21

405	NHIL-0030	NHIL-0035	458.9542	7.75	135	0	Open	;8 DR21
406	NHIL-0082	NHIL-0081	1.6743	5.96	135	0	Open	;6 DR21
407	NHIL-0061	NHIL-0082	305.8345	5.96	135	0	Open	;6 DR21
408	NHIL-0053	NHIL-0060	527.7337	5.96	135	0	Open	;6 DR21
409	NHIL-0052	NHIL-0053	3.9086	5.96	135	0	Open	;6 DR21
410	NHIL-0051	NHIL-0052	3.0390	5.96	135	0	Open	;6 DR21
411	NHIL-0035	NHIL-0040	704.1654	7.75	135	0	Open	;8 DR21
412	NHIL-0040	NHIL-0050	220.0899	7.75	135	0	Open	;8 DR21
413	NHIL-0050	NHIL-0051	6.7170	7.75	135	0	Open	;8 DR21
414	NHIL-0060	NHIL-0061	124.0174	5.96	135	0	Open	;6 DR21
415	NHIL-0070	N-21	694.0269	5.89	135	0	Open	;6 DR19
416	NHIL-0070	N-20	2002.8125	5.89	135	0	Open	;6 DR19
417	HG-31	NPUT-0030	1238.5955	12.86	135	0	Open	;14 DR32.5
418	NPUT-0030	NPUT-0040	1339.1841	11.71	135	0	Open	;12 DR26
419	NPUT-0040	NPUT-0050	36.2376	11.71	135	0	Open	;12 DR26
420	NPUT-0050	NPUT-0060	423.1850	11.46	135	0	Open	;12 DR21
421	NPUT-0060	N-30	2468.2340	5.96	135	0	Open	;6 DR21
422	N-29	NJ-0010	1264.2141	14.96	135	0	Open	;16 DR32.5
423	NJ-0010	NJ-0015	754.2467	14.96	135	0	Open	;16 DR32.5
424	NJ-0030	NJ-0040	507.5974	13.09	135	0	Open	;14 DR32.5
425	NJ-0020	NJ-0030	690.1155	13.09	135	0	Open	;14 DR32.5
426	NJ-0015	NJ-0020	419.3351	13.09	135	0	Open	;14 DR32.5
427	N-68	NJ-0060	53.6200	13.09	135	0	Open	;14 DR32.5
428	NJ-0094	NJ-0100	1463.3307	10.05	135	0	Open	;10 DR32.5
429	NJ-0092	NJ-0090	2.7636	10.05	135	0	Open	;10 DR32.5
430	NJ-0060	NJ-0061	195.2579	13.09	135	0	Open	;14 DR32.5
431	NJ-0070	NJ-0080	207.7964	13.09	135	0	Open	;14 DR32.5
432	NJ-0090	NJ-0094	1.4374	10.05	135	0	Open	;10 DR32.5
433	NJ-0085	NJ-0092	288.6918	10.05	135	0	Open	;10 DR32.5
434	NJ-0110	NJ-0120	342.4096	9.87	135	0	Open	;10 DR32.5
435	NJ-0100	NJ-0110	545.8165	9.87	135	0	Open	;10 DR32.5
436	NJ-0120	NJ-0140	58.2215	9.87	135	0	Open	;10 DR26
437	NJ-0040	NJ-0050	819.7156	13.09	135	0	Open	;14 DR32.5
438	NJ-0050	N-68	162.4553	13.09	135	0	Open	;14 DR32.5
439	HG-28	NPHI-0010	208.3993	11.92	135	0	Open	;12 DR32.5
440	NPHI-0010	NPHI-0015	11.7299	11.92	135	0	Open	;12 DR32.5
441	NPHI-0015	NPHI-0020	332.7330	11.92	135	0	Open	;12 DR32.5
442	NPHI-0020	NPHI-0030	678.8440	11.92	135	0	Open	;12 DR32.5
443	NPHI-0040	NPHI-0050	1009.7625	8.06	135	0	Open	;8 DR32.5
444	NPHI-0050	NPHI-0060	1079.2300	8.06	135	0	Open	;8 DR32.5
445	NPHI-0075	NPHI-0080	670.5754	6.19	135	0	Open	;6 DR32.5
446	NPHI-0060	NPHI-0070	149.2133	6.19	135	0	Open	;6 DR32.5
447	NPHI-0080	N-26	19.1815	6.19	135	0	Open	;6 DR32.5
448	NPHI-0050	NPHI-0100	844.0024	6.19	135	0	Open	;6 DR32.5
449	HG-27	NHOO-0010	556.6482	11.92	135	0	Open	;12 DR32.5
450	NHOO-0030	NHOO-0040	367.3980	11.92	135	0	Open	;12 DR32.5
451	NHOO-0020	NHOO-0030	45.7882	11.92	135	0	Open	;12 DR32.5
452	NHOO-0080	NHOO-0100	351.0750	10.05	135	0	Open	;10 DR32.5
453	NHOO-0040	NHOO-0050	589.2141	10.05	135	0	Open	;10 DR32.5
454	NHOO-0050	NHOO-0060	434.2658	10.05	135	0	Open	;10 DR32.5
455	NHOO-0060	NHOO-0070	155.8358	10.05	135	0	Open	;10 DR32.5
456	NHOO-0070	NHOO-0080	418.1046	10.05	135	0	Open	;10 DR32.5
457	HG-60	SCS-0110	32.0303	6.19	135	0	Open	;6 DR32.5
458	SCS-0110	SCS-0120	1358.4512	6.19	135	0	Open	;6 DR32.5
459	SCS-0120	SCS-0130	770.6022	6.19	135	0	Open	;6 DR32.5
460	SCS-0130	SCS-0131	17.2530	6.19	135	0	Open	;6 DR32.5
461	HG-14	SCS-0040	210.9702	8.06	135	0	Open	;8 DR32.5
462	SCS-0040	HG-15	2608.5778	8.06	135	0	Open	;8 DR32.5
463	HG-15	SCS-0065	1118.2661	6.19	135	0	Open	;6 DR32.5
464	SCS-0065	SCS-0070	1068.2073	6.19	135	0	Open	;6 DR32.5
465	HG-15	SCS-0075	1288.4825	6.19	135	0	Open	;6 DR32.5
466	SCS-0075	SCS-0060	36.8957	6.19	135	0	Open	;6 DR32.5
467	SCS-0060	SCS-0050	6.6118	6.19	135	0	Open	;6 DR32.5
468	SCS-0050	N-14	525.2053	6.19	135	0	Open	;6 DR32.5
469	SCS-0050	N-15	1108.1871	6.19	135	0	Open	;6 DR32.5
470	STF-0280	N-52	2634.98	6.19	135	0	Open	;6 DR32.5
471	HG-45	SS-0010	280.61	10.05	135	0	Open	;10 DR32.5
472	SS-0010	SS-0020	536.9615	8.06	135	0	Open	;8 D32.5
473	SS-0040	SS-0050	285.2462	8.06	135	0	Open	;8 DR32.5
474	SS-0030	SS-0040	7.0459	8.06	135	0	Open	;8 DR32.5
475	SS-0020	SS-0030	77.5385	8.06	135	0	Open	;8 DR32.5
476	SS-0050	SS-0061	712.9145	8.06	135	0	Open	;8 DR32.5
477	SS-0061	SS-0080	1079.2610	8.06	135	0	Open	;8 DR32.5
478	SS-0080	SS-0090	217.0739	8.06	135	0	Open	;8 DR32.5

479	SS-0070	SS-0100	852.0470	6.19	135	0	Open	;6 DR32.5
480	SS-0090	SS-0070	3.1998	6.19	135	0	Open	;6 DR32.5
481	SS-0100	N-38	957.3967	6.19	135	0	Open	;6 DR32.5
482	HG-16	HG-18	741.4965	6.19	135	0	Open	;6 DR32.5
483	HG-18	N-16	464.9091	6.19	135	0	Open	;6 DR32.5
484	HG-18	SA-0160	400.3728	6.19	135	0	Open	;6 DR32.5
485	SA-0160	N-17	217.8573	6.19	135	0	Open	;6 DR32.5
486	SA-0160	SA-0161	215.2416	6.19	135	0	Open	;6 DR32.5
487	HG-49	SC-0020	2462.91	24.3	135	0	Open	;26 DR32.5
488	SC-0020	HG-50	1350.9683	24.30	135	0	Open	;26 DR32.5
490	SC-0040	HG-51	354.7139	6.19	135	0	Open	;6 DR32.5
491	HG-51	HG-52	1494.7876	22.44	135	0	Open	;24 DR32.5
492	HG-57	SEC-0051	2307.4747	6.19	135	0	Open	;6 DR32.5
493	SEC-0051	SEC-0060	847.0962	6.19	135	0	Open	;6 DR32.5
494	SEC-0060	SEC-0070	570.1425	6.19	135	0	Open	;6 DR32.5
495	SEC-0070	N-46	166.2420	6.19	135	0	Open	;6 DR32.5
496	HG-50	SC-0041	872.9846	22.44	135	0	Open	;24 DR32.5
497	SC-0042	SC-0030	320.0766	22.44	135	0	Open	;24 DR32.5
498	SC-0030	SC-0050	1095.2124	22.44	135	0	Open	;24 DR32.5
499	SC-0041	SC-0042	301.5168	22.44	135	0	Open	;24 DR32.5
500	SC-0060	HG-51	97.2041	22.44	135	0	Open	;24 DR32.5
501	HG-52	SWC-0011	14.8629	18.7	135	0	Open	;20 DR32.5
502	SWC-0030	SWC-0040	445.5553	16.83	135	0	Open	;18 DR32.5
503	SWC-0040	SWC-0045	3951.1038	16.83	135	0	Open	;18 DR32.5
504	SWC-0011	SWC-0010	4.5202	18.7	135	0	Open	;20 DR32.5
505	SWC-0010	SWC-0020	771.7750	16.83	135	0	Open	;18 DR32.5
506	SWC-0020	SWC-0030	594.8912	16.83	135	0	Open	;18 DR32.5
507	SWC-0045	SWC-0046	2608.2169	16.83	135	0	Open	;18 DR32.5
508	N-71	SWC-0101	1351.8029	14.96	135	0	Open	;16 DR32.5
509	SWC-0046	SWC-0047	571.0265	16.83	135	0	Open	;18 DR32.5
510	SWC-0101	SWC-0110	1413.3720	14.96	135	0	Open	;16 DR32.5
511	SWC-0110	HG-58	469.7058	14.96	135	0	Open	;16 DR32.5
512	HG-58	SWC-0120	551.5382	10.05	135	0	Open	;10 DR32.5
513	SWC-0120	SWC-0130	6.1560	10.05	135	0	Open	;10 DR32.5
514	SWC-0130	SWC-0150	1907.2674	10.05	135	0	Open	;10 DR32.5
515	SWC-0150	SWC-0135	8.2537	8.06	135	0	Open	;8 DR32.5
516	SWC-0135	SWC-0160	210.3246	8.06	135	0	Open	;8 DR 32.5
517	SWC-0160	SWC-0170	190.3921	8.06	135	0	Open	;8 DR32.5
518	SWC-0170	SWC-0180	541.3454	7.92	135	0	Open	;8 DR26
519	SWC-0180	SWC-0190	348.4476	7.92	135	0	Open	;8 DR26
520	SWC-0190	SWC-0200	132.1307	6.08	135	0	Open	;6 DR26
521	SWC-0200	N-48	972.2051	6.08	135	0	Open	;6 DR26
522	HG-58	SWC-0210	2226.1862	9.87	135	0	Open	;10 DR26
523	SWC-0210	SWC-0220	3149.7223	9.55	135	0	Open	;10 DR19
524	SWC-0220	SWC-0250	13.4025	9.55	135	0	Open	;10 DR19
525	SWC-0230	N-70	1.4760	9.55	135	0	Open	;10 DR19
526	SWC-0250	SWC-0230	0.8954	9.55	135	0	Open	;10 DR19
527	N-69	SWC-0270	348.5521	7.55	135	0	Open	;8 DR17
528	SWC-0270	HG-59	111.6952	5.8	135	0	Open	;6 DR17
529	HG-59	N-49	1659.2735	5.8	135	0	Open	;6 DR17
530	HG-59	N-50	3502.96	5.72	135	0	Open	;6 DR15.5
531	N-70	SWC-0240	4.0570	9.55	135	0	Open	;8 DR19
532	SWC-0240	SWC-0260	527.5724	9.87	135	0	Open	;10 DR26
533	SWC-0260	N-69	10.9195	9.41	135	0	Open	;10 DR17
534	HG-48	STRF-0070	20.98	6.19	135	0	Open	;6 DR32.5
535	STRF-0070	STRF-0072	1191.09	6.19	135	0	Open	;6 DR32.5
536	STRF-0072	STRF-0071	3.8088	6.19	135	0	Open	;6 DR32.5
537	STRF-0071	N-40	299.9842	6.19	135	0	Open	;6 DR32.5
538	N-57	HG-49	116.80	22.44	135	0	Open	;Exist24DR32.5
540	SH-0015	SH-0020	478.2089	18.7	135	0	Open	;20 DR32.5
541	SH-0010	SH-0015	268.6854	18.7	135	0	Open	;20 DR32.5
542	SH-0020	SH-0030	940.5170	18.7	135	0	Open	;20 DR32.5
543	SH-0030	SH-0040	174.0757	18.7	135	0	Open	;20 DR32.5
544	SH-0040	SH-0041	269.3353	18.7	135	0	Open	;20 DR32.5
545	SH-0041	SH-0050	1311.6992	16.83	135	0	Open	;18 DR32.5
546	SH-0050	SH-0060	35.8928	16.83	135	0	Open	;18 DR32.5
547	SH-0060	SH-0070	242.8307	16.83	135	0	Open	;18 DR32.5
548	SH-0070	SH-0080	1425.5281	16.83	135	0	Open	;18 DR32.5
549	SH-0080	SH-0090	958.7092	16.83	135	0	Open	;18 DR32.5
550	SH-0090	SH-0100	406.4038	16.83	135	0	Open	;18 DR32.5
551	SH-0100	SH-0110	325.4082	14.96	135	0	Open	;16 DR32.5
552	SH-0110	SH-0111	9.6083	14.96	135	0	Open	;16 DR32.5
553	SH-0111	SH-0115	3652.6316	14.96	135	0	Open	;16 DR32.5
554	SH-0115	SH-0125	739.4870	14.96	135	0	Open	;16 DR32.5

555	SH-0140	SH-0150	4872.65	11.46	135	0	Open	;12 DR21
556	SH-0130	SH-0140	2111.93	11.92	135	0	Open	;12 DR32.5
557	SH-0125	SH-0120	905.73	11.92	135	0	Open	;12 DR32.5
558	SH-0120	SH-0130	217.03	11.92	135	0	Open	;12 DR32.5
559	SH-0150	SH-0160	3011.53	11.46	135	0	Open	;12 DR21
560	SH-0160	SH-0170	71.2580	9.55	135	0	Open	;10 DR19
561	SH-0170	N-51	1819.2968	5.8	135	0	Open	;6 DR17
562	N-71	SWC-0049	12.6973	6.19	135	0	Open	;6 DR32.5
563	SWC-0050	SWC-0060	12.8115	6.19	135	0	Open	;6 DR32.5
564	SWC-0060	SWC-0070	509.5019	6.19	135	0	Open	;6 DR32.5
565	SWC-0049	SWC-0050	642.9002	6.19	135	0	Open	;6 DR32.5
566	SWC-0070	SWC-0080	215.1862	6.19	135	0	Open	;6 DR32.5
567	SWC-0080	SWC-0090	390.8710	6.19	135	0	Open	;6 DR32.5
568	SWC-0090	SWC-0100	282.0876	6.19	135	0	Open	;6 DR32.5
578	HG-13	N-9	323.78	6.08	135	0	Open	;6 DR26
579	HG-13	N-10	466.80	5.96	135	0	Open	;6 DR21
580	SP-0080	HG-13	63.5703	6.08	135	0	Open	;6 DR26
581	STRF-0080	N-39	358.2551	6.19	135	0	Open	;6 DR32.5
582	SWB-0035	N-24	477.4909	6.08	135	0	Open	;6 DR26
583	SWB-0050	N-23	1984.2329	6.08	135	0	Open	;6 DR26
584	HG-25	NCS-0030	327.6492	8.06	135	0	Open	;8 DR32.5
585	NCS-0020	NCS-0040	1160.3975	6.19	135	0	Open	;6 DR32.5
586	NCS-0030	NCS-0020	3.5927	8.06	135	0	Open	;8 DR32.5
587	SWC-0120	N-47	611.0769	6.19	135	0	Open	;6 DR32.5
588	HG-32	NHAG-0010	648.7727	6.08	135	0	Open	;6 DR26
589	NHAG-0010	NHAG-0020	1293.2543	6.08	135	0	Open	;6 DR26
590	NHAG-0020	NHAG-0030	14.3997	6.08	135	0	Open	;6 DR26
591	NHAG-0030	N-28	324.3538	6.08	135	0	Open	;6 DR26
592	NCS-0220	N-27	617.0245	6.08	135	0	Open	;6 DR26
593	NWB-0180	NWB-0190	207.2955	6.08	135	0	Open	;6 DR26
594	NWB-0190	N-31	1929.1842	6.08	135	0	Open	;6 DR26
595	HG-52	SEC-0009	699.5990	13.09	135	0	Open	;14 DR32.5
596	SEC-0009	HG-56	1106.7166	13.09	135	0	Open	;14 DR32.5
597	HG-56	SEC-0010	29.6262	10.05	135	0	Open	;10 DR32.5
598	SEC-0010	SEC-0011	605.5585	8.06	135	0	Open	;8 DR32.5
599	SEC-0011	HG-54	159.0241	8.06	135	0	Open	;8 DR32.5
600	HG-56	HG-57	560.4543	10.05	135	0	Open	;10 DR32.5
601	HG-57	SEC-0080	47.0882	8.06	135	0	Open	;8 DR32.5
602	SEC-0080	SEC-0100	222.7189	8.06	135	0	Open	;8 DR32.5
603	SEC-0100	SEC-0090	17.6808	8.06	135	0	Open	;8 DR32.5
604	SEC-0090	SEC-0110	1082.6156	6.19	135	0	Open	;
605	SEC-0120	SEC-0130	16.4427	6.19	135	0	Open	;6 DR32.5
606	SEC-0115	SEC-0120	890.6155	6.19	135	0	Open	;6 DR32.5
607	SEC-0110	SEC-0115	10.9444	6.19	135	0	Open	;6 DR32.5
608	SEC-0130	SEC-0140	229.9712	6.19	135	0	Open	;6 DR32.5
609	SEC-0140	SEC-0150	202.9853	6.19	135	0	Open	;6 DR32.5
610	SEC-0150	N-45	159.9660	6.19	135	0	Open	;6 DR32.5
611	HG-54	HG-53	337.3843	6.19	135	0	Open	;6 DR32.5
612	HG-54	HG-55	497.2132	6.19	135	0	Open	;6 DR32.5
613	HG-53	SEC-0040	95.1238	6.19	135	0	Open	;6 DR32.5
614	SEC-0040	N-42	361.8336	6.19	135	0	Open	;6 DR32.5
615	HG-53	SEC-0050	94.1417	6.19	135	0	Open	;6 DR32.5
616	SEC-0050	N-41	1169.7030	6.19	135	0	Open	;6 DR32.5
617	HG-55	SEC-0030	13.7122	6.19	135	0	Open	;6 DR32.5
618	SEC-0030	N-43	603.9314	6.19	135	0	Open	;6 DR32.5
619	HG-55	SEC-0020	9.4136	6.19	135	0	Open	;6 DR32.5
620	SEC-0020	N-44	823.5616	6.19	135	0	Open	;6 DR32.5
621	SCS-0100	HG-60	6.3171	44.86	135	0	Open	;48 DR32.5
622	NCS-0220	NCS-0260	0.0287	25.72	135	0	Open	;
623	SWC-0047	N-71	1291.3508	14.96	135	0	Open	;16 DR32.5
624	NPHI-0100	NPHI-0110	0.0200	6.19	135	0	Open	;
625	NJ-0140	NJ-0130	0.2978	9.87	135	0	Open	;10 DR26
626	NLP-0060	NLP-0065	0.0724	6.08	135	0	Open	;6 DR32.5
627	NHIL-0081	NHIL-0070	1.5571	5.96	135	0	Open	;6 DR21
628	NJ-0061	NJ-0070	0.0346	48.0	135	0	Open	;
629	NJ-0080	NJ-0085	0.2511	13.09	135	0	Open	;
630	NPHI-0030	NPHI-0040	5.8811	11.92	135	0	Open	;12 DR32.5
631	NPHI-0070	NPHI-0075	1.4878	6.19	135	0	Open	;6 DR32.5
632	NHOO-0010	NHOO-0020	0.6529	11.92	135	0	Open	;12 DR32.5
633	SC-0050	SC-0060	0.1472	22.44	135	0	Open	;24 DR32.5
634	NDF-0070	NDF-0080	0.0143	6.19	135	0	Open	;
635	NDF-0060	NDF-0070	0.0158	6.19	135	0	Open	;
1	STF-0220	1	638.49	84	130	0	Open	;
2	HG-47	2	26.74	50.477	135	0	Open	;54 DR32.5

3	2	STRF-0110	132.70	44.869	135	0	Open	;
4	2	SH-0010	1850.66	22.44	135	0	Open	;Existing 24 DR32.5
7	NG-0050	NG-0052	39.16	5.96	135	0	Open	;6 DR21
18	NG-0052	NG-0060	420.38	5.96	135	0	Open	;6 DR21
150	3	HG-24	197	43.15	135	0	Open	;48 DR21
6	NCS-0220	4	1000	25.72	135	0	Open	;28 DR26
20	5	HG-20	765.0	26.17	135	0	Open	;
35	NWB-0090	NWB-0081	727.16	22.04	135	0	Open	;
5	TumaloRes	6	30	12	135	0	Open	;

[PUMPS]

;ID	Node1	Node2	Parameters	
36	6	HG-49	POWER 75	;

[VALVES]

;ID	Node1	Node2	Diameter	Type	Setting	MinorLoss	
PRVHydro1	3	NCS-0010	48	PRV	30	0	;
PRVHydro2	4	N-29	48	PRV	45	0	;
PRVHydro3	HG-19	5	48	PRV	35	0	;

[TAGS]

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;ID	Multipliers		
[CURVES]			
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[RULES]			
[ENERGY]			
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Global Price	0		
Demand Charge	0		
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;Node	InitQual		
[SOURCES]			
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;Type	Pipe/Tank	Coefficient	
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Order Tank	1		
Order Wall	1		
Global Bulk	0		
Global Wall	0		
Limiting Potential	0		
Roughness Correlation	0		
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[TIMES]			
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Hydraulic Timestep	1:00		
Quality Timestep	0:05		
Pattern Timestep	1:00		
Pattern Start	0:00		
Report Timestep	1:00		
Report Start	0:00		
Start ClockTime	12 am		
Statistic	None		
[REPORT]			
Status	No		
Summary	No		
Page	0		
[OPTIONS]			
Units	GPM		
Headloss	H-W		
Specific Gravity	1		
Viscosity	1		
Trials	40		
Accuracy	0.001		
CHECKFREQ	2		

MAXCHECK	10
DAMPLIMIT	0
Unbalanced	Continue 10
Pattern	1
Demand Multiplier	1.0
Emitter Exponent	0.5
Quality	None mg/L
Diffusivity	1
Tolerance	0.01

[COORDINATES]

;Node	X-Coord	Y-Coord
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HG-11	4686117.65	900273.62
HG-12	4685967.63	900486.24
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HG-14	4689110.39	903326.84
HG-15	4691894.32	903354.63
HG-16	4687474.31	906036.33
HG-17	4687287.48	905773.56
HG-18	4687418.45	906734.45
HG-19	4693114.47	912612.10
HG-20	4693330.44	913126.50
HG-21	4692605.30	906601.32
HG-22	4693430.87	907186.89
HG-23	4695451.94	909002.67
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HG-25	4698265.88	911061.13
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HG-30	4702296.68	918592.06
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HG-32	4704326.87	918356.82
HG-33	4705101.88	918376.18
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NLP-0065	4709192.17	925614.46
NLP-0070	4709814.80	925612.67
NLP-0080	4710804.71	925612.84
NLP-0090	4711156.45	925595.50
NLP-0100	4711482.45	925596.93
NLP-0110	4711824.94	925640.62
NPHI-0010	4702156.34	914083.66
NPHI-0015	4702158.64	914095.16
NPHI-0020	4702272.80	914400.93
NPHI-0030	4702914.83	914525.38
NPHI-0040	4702918.14	914530.24
NPHI-0050	4702796.90	915469.41
NPHI-0060	4703784.87	915723.27
NPHI-0070	4703924.58	915695.93
NPHI-0075	4703925.72	915694.96
NPHI-0080	4704182.49	915081.10
NPHI-0100	4702994.83	916264.66
NPHI-0110	4702994.84	916264.67
NPUT-0030	4702459.58	919956.77
NPUT-0040	4703313.61	920980.91
NPUT-0050	4703340.84	921004.14
NPUT-0060	4703226.99	921405.31
NS-0010	4694472.32	925922.61
NS-0020	4697395.23	927829.60
NS-0030	4695229.21	924477.98
NS-0040	4696315.45	923422.16
NS-0041	4696553.54	923060.18
NS-0050	4696993.26	922702.60
NS-0055	4696989.07	922705.55
NS-0060	4697109.33	922671.48
NS-0070	4698488.61	924221.42
NS-0080	4699230.87	924623.55
NS-0090	4699234.34	924624.84
NS-0100	4699735.36	925356.51
NS-0110	4699737.57	925358.16
NWB-0010	4692097.25	916226.60
NWB-0020	4692143.63	916288.91
NWB-0030	4692153.50	916307.64
NWB-0040	4692001.30	916854.63
NWB-0050	4690931.33	917592.54
NWB-0055	4690928.78	917600.92
NWB-0060	4690872.52	918860.24
NWB-0070	4690980.72	919266.67
NWB-0071	4691178.27	920078.90
NWB-0072	4691175.89	920086.94
NWB-0080	4691060.98	920514.07
NWB-0081	4691552.30	921777.46
NWB-0082	4691552.10	921777.03
NWB-0090	4691867.06	922432.96
NWB-0100	4692286.56	923112.50
NWB-0110	4692432.20	923425.12
NWB-0115	4692676.64	923742.14
NWB-0120	4693183.31	924206.88
NWB-0130	4693551.43	924427.98
NWB-0140	4694534.10	922134.07
NWB-0150	4694288.81	921001.08
NWB-0160	4696068.75	920894.76
NWB-0165	4696878.23	920856.19
NWB-0170	4696877.57	920854.11
NWB-0180	4698850.58	918618.57

NWB-0190	4699024.30	918731.68
NWB-0200	4699175.98	918492.67
NWB-0210	4699861.99	918971.00
NWB-0220	4700418.19	919434.39
NWB-0230	4700761.50	919744.05
NWB-0240	4701187.81	919855.49
SA-0010	4686642.57	901648.83
SA-0015	4686837.70	901956.71
SA-0016	4686839.54	901960.89
SA-0020	4686847.16	901978.18
SA-0025	4687001.69	903641.64
SA-0030	4687001.30	903643.22
SA-0040	4686954.60	904170.07
SA-0050	4686955.34	904414.60
SA-0060	4687016.22	904896.74
SA-0070	4687293.07	905169.58
SA-0080	4687366.91	905386.77
SA-0090	4687277.11	905759.52
SA-0100	4687947.80	906014.29
SA-0110	4688717.11	906157.11
SA-0111	4689078.36	906341.58
SA-0120	4689272.99	906363.33
SA-0130	4687464.50	906026.09
SA-0140	4687468.67	906030.44
SA-0150	4687471.33	906033.22
SA-0160	4687383.83	907133.31
SA-0161	4687357.98	907346.88
SA-0170	4687864.19	906444.83
SA-0180	4687863.89	906444.51
SA-0190	4688749.44	907900.02
SA-0200	4689012.08	908237.58
SA-0210	4688859.15	909023.74
SA-0220	4688894.09	908788.00
SA-0230	4689211.11	909466.14
SA-0240	4689282.97	909720.36
SA-0250	4689345.90	909831.89
SA-0260	4689346.79	909833.57
SA-0270	4689588.08	910302.30
SA-0280	4689590.45	910953.90
SA-0290	4689590.56	910954.15
SA-0300	4690063.51	911927.20
SA-0310	4690066.05	911932.10
SA-0320	4690826.27	912513.52
SA-0330	4690840.25	912619.25
SA-0340	4691408.51	912613.08
SA-0350	4692219.62	912600.20
SC-0020	4682367.98	904453.18
SC-0030	4684589.37	905854.38
SC-0040	4685067.68	906439.81
SC-0041	4684213.72	905364.05
SC-0042	4684381.52	905611.95
SC-0050	4685090.26	906791.18
SC-0060	4685090.37	906791.28
SCS-0010	4687915.79	902317.52
SCS-0020	4687941.36	902333.31
SCS-0030	4689008.04	903218.66
SCS-0040	4689318.47	903349.31
SCS-0050	4691923.77	904672.48
SCS-0060	4691917.27	904671.85
SCS-0065	4692837.50	903923.89
SCS-0070	4693646.30	904618.07
SCS-0075	4691904.10	904641.08
SCS-0080	4690058.52	904308.99
SCS-0090	4690804.90	905060.80
SCS-0100	4691045.22	905316.53
SCS-0110	4691040.41	905349.41
SCS-0120	4691576.21	906492.34
SCS-0130	4691597.12	907252.21
SCS-0131	4691591.45	907268.50
SCS-0140	4691413.58	905672.36
SCS-0150	4691994.48	906162.71
SCS-0160	4692571.26	906571.91
SCS-0180	4693853.14	907242.44
SCS-0190	4694083.48	907244.05

SCS-0200	4694541.48	907393.15
SCS-0210	4694374.91	908034.46
SCS-0220	4694829.72	908440.30
SEC-0009	4686006.98	908704.60
SEC-0010	4686160.90	909814.59
SEC-0011	4685674.93	910155.38
SEC-0020	4685380.02	910687.17
SEC-0030	4685372.05	910695.57
SEC-0040	4685133.06	910272.20
SEC-0050	4685132.78	910288.31
SEC-0051	4688135.34	911258.53
SEC-0060	4688539.72	911937.34
SEC-0070	4688777.12	912422.75
SEC-0080	4686687.96	910076.12
SEC-0090	4686736.25	910307.52
SEC-0100	4686725.52	910293.79
SEC-0110	4687227.90	911170.81
SEC-0115	4687231.44	911181.16
SEC-0120	4687337.90	912050.41
SEC-0130	4687341.47	912066.45
SEC-0140	4687449.65	912268.40
SEC-0150	4687519.73	912457.71
SH-0010	4681329.51	903072.98
SH-0015	4681364.38	903324.95
SH-0020	4681464.07	903789.52
SH-0030	4681864.42	904598.15
SH-0040	4681899.91	904768.04
SH-0041	4681923.53	905035.93
SH-0050	4682672.08	906079.35
SH-0060	4682700.10	906101.76
SH-0070	4682869.83	906271.93
SH-0080	4682286.15	907375.39
SH-0090	4682112.49	908288.73
SH-0100	4681902.39	908628.64
SH-0110	4681620.20	908785.92
SH-0111	4681611.18	908789.22
SH-0115	4680321.46	911626.59
SH-0120	4679665.85	912735.31
SH-0125	4680319.73	912325.28
SH-0130	4679464.10	912655.85
SH-0140	4679033.80	913571.52
SH-0150	4682394.52	916222.02
SH-0160	4684659.05	917880.43
SH-0170	4684681.01	917945.77
SL-0010	4687411.81	900738.57
SL-0020	4689245.25	901035.88
SL-0030	4689619.48	901132.90
SL-0040	4689778.26	901045.47
SL-0050	4690583.07	901098.55
SL-0055	4691142.99	901160.19
SL-0060	4692281.84	901603.44
SL-0070	4692818.62	901754.37
SL-0080	4693370.36	901912.02
SL-0090	4693500.89	901316.13
SL-0100	4694194.07	901341.67
SL-0110	4694935.40	901379.62
SL-0120	4695864.93	901481.43
SP-0010	4691517.18	895494.13
SP-0020	4689848.41	896034.35
SP-0030	4690585.36	896453.64
SP-0031	4695836.04	899316.47
SP-0040	4695837.01	899317.66
SP-0050	4696519.14	900510.20
SP-0051	4697078.66	900613.81
SP-0052	4697548.38	900605.64
SP-0060	4698504.05	900366.77
SP-0070	4699803.51	901175.97
SP-0080	4699803.98	901171.16
SP-0090	4699625.48	901884.57
SP-0100	4699684.89	901945.74
SP-0110	4699755.90	901960.98
SS-0010	4684088.64	902125.84
SS-0020	4684040.63	902653.08
SS-0030	4684034.23	902730.27

SS-0040	4684033.58	902737.27
SS-0050	4684159.86	902974.16
SS-0061	4684779.60	903294.66
SS-0070	4685293.85	904288.28
SS-0080	4685292.15	904068.05
SS-0090	4685293.77	904285.08
SS-0100	4685303.74	905140.15
STF-0220	4691745.30	893424.25
STF-0230	4689224.95	893804.86
STF-0240	4689219.15	894610.81
STF-0250	4689443.81	895369.09
STF-0260	4688854.24	895872.11
STF-0270	4687730.21	896882.10
STF-0280	4687841.16	897707.22
STRF-0010	4685049.81	901306.63
STRF-0020	4684949.02	901563.63
STRF-0030	4684437.53	901510.73
STRF-0040	4684255.51	901665.26
STRF-0050	4683938.30	901965.69
STRF-0060	4683926.78	901965.13
STRF-0070	4682724.93	901940.64
STRF-0071	4682683.82	903091.54
STRF-0072	4682683.88	903087.73
STRF-0080	4682184.16	901711.48
STRF-0090	4682141.08	901712.96
STRF-0100	4681294.68	901911.78
STRF-0110	4681081.23	901491.74
SWB-0010	4692575.44	906575.98
SWB-0020	4692710.73	906754.72
SWB-0030	4692770.35	907492.68
SWB-0035	4692772.32	907496.97
SWB-0040	4692913.37	908886.49
SWB-0050	4693024.88	909718.29
SWB-0051	4693017.21	909733.76
SWB-0060	4692883.34	910918.43
SWB-0070	4692881.70	911016.83
SWB-0080	4692626.63	911565.23
SWB-0090	4692366.03	911869.05
SWB-0100	4692930.46	912160.23
SWB-0110	4692770.50	914101.56
SWB-0120	4692482.64	914601.22
SWB-0130	4692465.11	914741.49
SWC-0010	4685934.95	908025.36
SWC-0011	4685937.25	908021.46
SWC-0020	4685266.20	908221.28
SWC-0030	4684806.95	907884.11
SWC-0040	4684397.07	907719.04
SWC-0045	4682379.57	909581.86
SWC-0046	4681410.64	910919.15
SWC-0047	4681781.17	911341.49
SWC-0049	4682488.85	912234.74
SWC-0050	4682987.21	912169.90
SWC-0060	4682995.32	912179.81
SWC-0070	4683386.31	912488.05
SWC-0080	4683524.13	912647.25
SWC-0090	4683833.47	912883.39
SWC-0100	4684079.40	913007.56
SWC-0101	4683421.81	913122.20
SWC-0110	4684108.58	913897.47
SWC-0120	4685046.19	913654.03
SWC-0130	4685051.82	913656.53
SWC-0135	4686752.05	914403.94
SWC-0150	4686743.84	914403.06
SWC-0160	4686961.38	914399.60
SWC-0170	4687148.01	914432.47
SWC-0180	4687648.93	914622.00
SWC-0190	4687928.36	914730.36
SWC-0200	4688033.45	914655.81
SWC-0210	4686006.45	915340.37
SWC-0220	4687012.62	917428.27
SWC-0230	4687009.89	917442.31
SWC-0240	4687009.41	917447.81
SWC-0250	4687010.07	917441.43
SWC-0260	4686983.63	917974.75

SWC-0270	4686825.95	918295.04
2	4681208.64	901528.82
NG-0052	4698671.65	909848.58
3	4696608.05	910268.39
4	4706430.03	918635.62
5	4693080.05	912697.24
6	4680954.69	902523.02
1	4692349.25	893631.40
TumaloRes	4680903.69	902524.10

```
*************************************
Water Surface Profile Gradient (WSPG)
XP WSPG
Engine Version 1.3         06/09/2010
XP Software        www.xpsoftware.com
*************************************

INPUT FILE
*************************************
C:\XPS\wspg2010\Samples\TID Main Canals to Phase IV with 140 at BFC 102016 Upgrade PL1 to 84 Weholite.wsx
Computed  10/21/16  14:17:17

TITLE INFORMATION
*************************************

WARNING SUMMARY
*************************************
 WARNING 48: Manning's n for pipe flow of element JUNCTION not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link25 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link26 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link27 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link28 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link28 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link29 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link29 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link42 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link44 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link45 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link45 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link46 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link47 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link48 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link49 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link49 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link50 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Pipe2 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipe3 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipe 3B is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element RR Siph is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipeline 4 is not larger than invert elevation of the direct downstream
element.
 WARNING 48: Manning's n for pipe flow of element Tunnel not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element F4 Siph is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Link80 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Link81 is not larger than invert elevation of the direct downstream element.
 WARNING 25: Link type element Link30 has different invert elevation than its upstream node.
 WARNING 48: Manning's n for pipe flow of element Link43 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to 62 not in recommended range 0.010 - 0.015.
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 WARNING 48: Manning's n for pipe flow of element 62 to 84 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to Arch not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Arch to 84 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to 90 not in recommended range 0.010 - 0.015.
 WARNING 06: Upstream channel and downstream channel are the same for transition Link86. Use a reach instead?
 WARNING 36: D/S processing stopped in junction JUNCTION because critical momentum is greater than maximum momentum.

RESULTS
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   Main Line
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 Composite Profile:

ELEMENT    TYPE       STATION    INVERT   GROUND   W.S.      DEPTH    Q        VELOC.  VELOC. ENERGY     SUPER
CRITICAL FROUDE  SLOPE    NORMAL   CROSS
NAME                             ELEV     ELEV     ELEV                                HEAD   GRADE LN   ELEV    DEPTH
 NUMBER           DEPTH    SECTION
---------- ---------- ---------- -------- -------- --------  -------- -------- ------- ------ ---------- ------
-------- ------  -------  ------   ---------
###
"Node97"   Outlet     22000.00   3531.01  0.00     *3534.200  3.190    180.00   10.54   1.73   3535.93    0.000   3.490
  0.000   0.00000  0.000    Pipe
           "i.p."     22177.81   3532.05  0.00     *3535.236  3.190    180.00   10.54   1.73   3536.96    0.000   3.490
  1.187   0.00583  3.190    Pipe
           "i.p."     22297.00   3532.74  0.00     *3535.981  3.239    180.00   10.33   1.66   3537.64    0.000   3.490
  1.153   0.00583  3.190    Pipe
           "i.p."     22342.40   3533.01  0.00     *3536.367  3.361    180.00   9.85    1.51   3537.87    0.000   3.490
  1.074   0.00583  3.190    Pipe
"Link84"   Reach      22350.00   3533.05  0.00     *3536.539  3.489    180.00   9.39    1.37   3537.91    0.000   3.490
  1.001   0.00583  3.190    Pipe
 HYDRAULIC JUMP  at 22582.96  of length  0.09
           "i.p."     22352.63   3533.05  0.00     *3536.675  3.623    180.00   8.95    1.24   3537.92    0.000   3.490
  0.931   0.00051  7.000    Pipe
           "i.p."     22361.63   3533.06  0.00     *3536.820  3.764    180.00   8.54    1.13   3537.95    0.000   3.490
  0.866   0.00051  7.000    Pipe
           "i.p."     22378.82   3533.06  0.00     *3536.976  3.911    180.00   8.14    1.03   3538.00    0.000   3.490
  0.804   0.00051  7.000    Pipe
           "i.p."     22406.53   3533.08  0.00     *3537.146  4.067    180.00   7.76    0.94   3538.08    0.000   3.490
  0.746   0.00051  7.000    Pipe
           "i.p."     22447.87   3533.10  0.00     *3537.332  4.232    180.00   7.40    0.85   3538.18    0.000   3.490
  0.692   0.00051  7.000    Pipe
           "i.p."     22506.96   3533.13  0.00     *3537.537  4.406    180.00   7.06    0.77   3538.31    0.000   3.490
  0.640   0.00051  7.000    Pipe
           "i.p."     22582.96   3533.17  0.00     *3537.748  4.578    180.00   6.75    0.71   3538.46    0.000   3.490
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0.594	0.00051	7.000	Pipe										
	"i.p."		22582.96	3533.17	0.00	*3535.781	2.611	180.00	13.75	2.94	3538.72	0.000	3.490
1.743	0.00051	7.000	Pipe										
	"i.p."		22594.51	3533.18	0.00	*3535.724	2.548	180.00	14.21	3.14	3538.86	0.000	3.490
1.827	0.00051	7.000	Pipe										
	"i.p."		22611.11	3533.18	0.00	*3535.644	2.460	180.00	14.91	3.45	3539.10	0.000	3.490
1.955	0.00051	7.000	Pipe										
	"i.p."		22627.83	3533.19	0.00	*3535.569	2.376	180.00	15.64	3.80	3539.36	0.000	3.490
2.091	0.00051	7.000	Pipe										
	"i.p."		22644.54	3533.20	0.00	*3535.496	2.295	180.00	16.40	4.18	3539.67	0.000	3.490
2.236	0.00051	7.000	Pipe										
	"i.p."		22661.13	3533.21	0.00	*3535.426	2.217	180.00	17.20	4.59	3540.02	0.000	3.490
2.391	0.00051	7.000	Pipe										
	"i.p."		22677.51	3533.22	0.00	*3535.360	2.142	180.00	18.04	5.05	3540.41	0.000	3.490
2.556	0.00051	7.000	Pipe										
	"i.p."		22693.64	3533.23	0.00	*3535.296	2.069	180.00	18.92	5.56	3540.85	0.000	3.490
2.732	0.00051	7.000	Pipe										
	"i.p."		22709.45	3533.23	0.00	*3535.234	2.000	180.00	19.84	6.11	3541.35	0.000	3.490
2.920	0.00051	7.000	Pipe										
	"i.p."		22724.92	3533.24	0.00	*3535.175	1.933	180.00	20.81	6.73	3541.90	0.000	3.490
3.120	0.00051	7.000	Pipe										
"Link87"	Reach		22740.00	3533.25	0.00	*3535.118	1.868	180.00	21.83	7.40	3542.52	0.000	3.490
3.333	0.00051	7.000	Pipe										
"Link86"	Transition		22750.00	3538.50	0.00	*3541.989	3.489	180.00	9.39	1.37	3543.36	0.000	3.490
1.001	0.52500	0.000	Pipe										
	"i.p."		22753.90	3538.50	0.00	*3542.164	3.664	180.00	8.83	1.21	3543.37	0.000	3.490
0.911	0.00000	7.000	Pipe										
	"i.p."		22767.18	3538.50	0.00	*3542.347	3.847	180.00	8.31	1.07	3543.42	0.000	3.490
0.830	0.00000	7.000	Pipe										
	"i.p."		22792.16	3538.50	0.00	*3542.540	4.040	180.00	7.82	0.95	3543.49	0.000	3.490
0.756	0.00000	7.000	Pipe										
	"i.p."		22831.52	3538.50	0.00	*3542.742	4.242	180.00	7.38	0.85	3543.59	0.000	3.490
0.689	0.00000	7.000	Pipe										
	"i.p."		22888.36	3538.50	0.00	*3542.954	4.454	180.00	6.97	0.75	3543.71	0.000	3.490
0.627	0.00000	7.000	Pipe										
	"i.p."		22966.16	3538.50	0.00	*3543.176	4.676	180.00	6.59	0.67	3543.85	0.000	3.490
0.570	0.00000	7.000	Pipe										
	"i.p."		23068.71	3538.50	0.00	*3543.410	4.910	180.00	6.24	0.60	3544.02	0.000	3.490
0.518	0.00000	7.000	Pipe										
"Link82"	Reach		23100.00	3538.50	0.00	*3543.473	4.973	180.00	6.16	0.59	3544.06	0.000	3.490
0.506	0.00000	7.000	Pipe										
	"i.p."		23239.41	3538.50	0.00	*3543.721	5.221	180.00	5.85	0.53	3544.25	0.000	3.490
0.458	0.00000	7.000	Pipe										
	"i.p."		23412.51	3538.50	0.00	*3543.982	5.482	180.00	5.57	0.48	3544.46	0.000	3.490
0.414	0.00000	7.000	Pipe										
	"i.p."		23622.62	3538.50	0.00	*3544.256	5.756	180.00	5.32	0.44	3544.70	0.000	3.490
0.372	0.00000	7.000	Pipe										
	"i.p."		23871.79	3538.50	0.00	*3544.544	6.044	180.00	5.10	0.40	3544.95	0.000	3.490

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  0.331   0.00000  7.000    Pipe
           "i.p."     24159.48   3538.50  0.00     *3544.847  6.347    180.00   4.91    0.37   3545.22    0.000   3.490
  0.288   0.00000  7.000    Pipe
           "i.p."     24480.13   3538.50  0.00     *3545.164  6.664    180.00   4.76    0.35   3545.52    0.000   3.490
  0.236   0.00000  7.000    Pipe
"Link53"   Reach      24700.00   3538.50  0.00     *3545.379  6.879    180.00   4.70    0.34   3545.72    0.000   3.490
  0.181   0.00000  7.000    Pipe
"Link52"   Reach      24850.00   3538.50  0.00     *3545.533  7.033    180.00   4.68    0.34   3545.87    0.000   3.490
  0.000   0.00000  7.000    Pipe
"Link51"   Transition 24861.00   3538.61  0.00     *3545.815  7.205    180.00   2.50    0.10   3545.91    0.000   2.159
  0.164   0.01000  0.000    Rect.open
"Phase II" WallExt    24861.00   3538.61  0.00     *3545.815  7.205    180.00   4.83    0.36   3546.18    0.000   3.507
  0.000   0.00000  0.000    Pipe
"Link50"   Reach      24951.00   3538.61  0.00     *3545.932  7.322    180.00   4.83    0.36   3546.29    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link49"   Reach      25001.00   3532.50  0.00     *3545.998  13.498   180.00   4.83    0.36   3546.36    0.000   3.507
  0.000   -0.12220  6.890    Pipe
"Link48"   Reach      25197.00   3535.44  0.00     *3546.254  10.814   180.00   4.83    0.36   3546.62    0.000   3.507
  0.000   0.01500  2.566    Pipe
           "i.p."     25222.02   3539.40  0.00     *3546.287  6.890    180.00   4.83    0.36   3546.65    0.000   3.507
  0.032   0.15812  1.404    Pipe
           "i.p."     25225.86   3540.00  0.00     *3546.255  6.252    180.00   5.06    0.40   3546.65    0.000   3.507
  0.299   0.15812  1.404    Pipe
           "i.p."     25227.97   3540.34  0.00     *3546.218  5.881    180.00   5.31    0.44   3546.66    0.000   3.507
  0.355   0.15812  1.404    Pipe
"Link47"   Reach      25229.00   3540.50  0.00     *3546.194  5.694    180.00   5.46    0.46   3546.66    0.000   3.507
  0.383   0.15812  1.404    Pipe
           "i.p."     25427.97   3540.50  0.00     *3546.479  5.979    180.00   5.24    0.43   3546.90    0.000   3.507
  0.340   0.00000  6.890    Pipe
           "i.p."     25657.66   3540.50  0.00     *3546.778  6.278    180.00   5.05    0.40   3547.17    0.000   3.507
  0.295   0.00000  6.890    Pipe
           "i.p."     25913.17   3540.50  0.00     *3547.092  6.592    180.00   4.90    0.37   3547.46    0.000   3.507
  0.239   0.00000  6.890    Pipe
"Link46"   Reach      27095.00   3540.50  0.00     *3548.627  8.127    180.00   4.83    0.36   3548.99    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link45"   Reach      27223.00   3538.05  0.00     *3548.795  10.745   180.00   4.83    0.36   3549.16    0.000   3.507
  0.000   -0.01914  6.890    Pipe
"Link44"   Reach      27273.00   3538.05  0.00     *3548.860  10.810   180.00   4.83    0.36   3549.22    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link43"   Transition 27275.00   3538.05  0.00     *3548.980  10.930   180.00   4.07    0.26   3549.24    0.000   3.416
  0.000   0.00000  0.000    Pipe
"Link42"   Reach      27408.00   3519.50  0.00     *3549.077  29.577   180.00   4.07    0.26   3549.34    0.000   3.416
  0.000   -0.13947  7.500    Pipe
"Link41"   Reach      27508.00   3521.00  0.00     *3549.151  28.151   180.00   4.07    0.26   3549.41    0.000   3.416
  0.000   0.01500  2.395    Pipe
"Link40"   Reach      27554.00   3538.41  0.00     *3549.184  10.774   180.00   4.07    0.26   3549.44    0.000   3.416
  0.000   0.37848  1.072    Pipe
"Link39"   Reach      27606.00   3538.41  0.00     *3549.222  10.812   180.00   4.07    0.26   3549.48    0.000   3.416
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  0.000   0.00000  7.500    Pipe
"Link38"   Reach      27768.00   3540.50  0.00     *3549.341  8.841    180.00   4.07    0.26   3549.60    0.000   3.416
  0.000   0.01290  2.491    Pipe
"Link37"   Reach      30558.00   3540.50  0.00     *3551.382  10.882   180.00   4.07    0.26   3551.64    0.000   3.416
  0.000   0.00000  7.500    Pipe
"Link36"   Reach      30733.00   3543.23  0.00     *3551.510  8.280    180.00   4.07    0.26   3551.77    0.000   3.416
  0.000   0.01560  2.370    Pipe
"Link35"   Reach      32146.00   3543.23  0.00     *3552.544  9.314    180.00   4.07    0.26   3552.80    0.000   3.416
  0.000   0.00000  7.500    Pipe
"Link34"   Reach      32272.00   3543.29  0.00     *3552.636  9.346    180.00   4.07    0.26   3552.89    0.000   3.416
  0.000   0.00048  7.500    Pipe
"Link33"   Reach      32280.00   3543.29  0.00     *3552.642  9.352    180.00   4.07    0.26   3552.90    0.000   3.416
  0.000   0.00000  7.500    Pipe
"JUNCTION" Join       32280.00   3543.29  0.00     *3552.892  9.602    31.00    0.70    0.01   3552.90    0.000   1.379
  0.000   0.00000  0.000    Pipe
"Link32"   Reach      32338.00   3543.46  0.00     *3552.893  9.433    31.00    0.70    0.01   3552.90    0.000   1.379
  0.000   0.00293  1.333    Pipe
"Link31"   Reach      33308.00   3544.00  0.00     *3552.906  8.906    31.00    0.70    0.01   3552.91    0.000   1.379
  0.000   0.00056  2.015    Pipe
"Node35"   WallEnt    33308.00   3544.00  0.00     *3552.917  8.917    31.00    0.38    0.00   3552.92    0.000   0.717
  0.000   0.00000  0.000    Trapez.open
"Link30"   Transition 33321.00   3542.00  0.00     *3552.918  10.918   31.00    0.28    0.00   3552.92    0.000   0.668
  0.015   -0.15385  0.000    Rect.open
"TFC EXIT" WallExt    33321.00   3542.00  0.00     *3552.918  10.918   31.00    0.87    0.01   3552.93    0.000   1.421
  0.000   0.00000  0.000    Pipe
"Link29"   Reach      33405.00   3536.40  0.00     *3552.922  16.522   31.00    0.87    0.01   3552.93    0.000   1.421
  0.000   -0.06667  6.730    Pipe
"Link28"   Reach      33505.00   3508.00  0.00     *3552.927  44.927   31.00    0.87    0.01   3552.94    0.000   1.421
  0.000   -0.28400  6.730    Pipe
"Link27"   Reach      33625.00   3508.00  0.00     *3552.933  44.933   31.00    0.87    0.01   3552.94    0.000   1.421
  0.000   0.00000  6.730    Pipe
"Link26"   Reach      34825.00   3523.87  0.00     *3552.993  29.123   31.00    0.87    0.01   3553.00    0.000   1.421
  0.000   0.01322  1.130    Pipe
"Link25"   Reach      36288.00   3546.17  0.00     *3553.065  6.895    31.00    0.87    0.01   3553.08    0.000   1.421
  0.000   0.01524  1.091    Pipe
"TFC HDWL" WallEnt    36288.00   3546.17  0.00     *3553.082  6.912    31.00    0.45    0.00   3553.09    0.000   0.668
  0.000   0.00000  0.000    Rect.open
"Link24"   Transition 36298.00   3548.20  0.00     *3553.084  4.884    31.00    0.32    0.00   3553.09    0.000   0.421
  0.025   0.20300  0.000    Rect.open
"Link23"   Reach      36308.00   3548.20  0.00     *3553.084  4.884    31.00    0.32    0.00   3553.09    0.000   0.421
  0.025   0.00000  9.000    Rect.open
"TFC Head" Headwrk    36308.00   3548.20  0.00     *3553.084  4.884    31.00    0.32    0.00   3553.09    0.000   0.421
  0.000   0.00000  0.000    Rect.open

 *) in the W.S.ELEV column indicates flooding, it is set whenever W.S.ELEV > GROUND ELEV
    i.p. = intermediate point processing results for reaches
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   JUNCTION_Branch1
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 Composite Profile:

ELEMENT    TYPE       STATION    INVERT   GROUND   W.S.      DEPTH    Q        VELOC.  VELOC. ENERGY     SUPER
CRITICAL FROUDE  SLOPE    NORMAL   CROSS
NAME                             ELEV     ELEV     ELEV                                HEAD   GRADE LN   ELEV    DEPTH
 NUMBER           DEPTH    SECTION
---------- ---------- ---------- -------- -------- --------  -------- -------- ------- ------ ---------- ------
-------- ------  -------  ------   ---------
###
"Outlet/J" Outlet     32280.00   3543.39  0.00     *3552.767  9.377    149.00   3.37    0.18   3552.94    0.000   3.095
  0.000   0.00000  0.000    Pipe
"Link81"   Reach      32314.00   3542.50  0.00     *3552.775  10.275   149.00   3.37    0.18   3552.95    0.000   3.095
  0.000   -0.02618  7.500    Pipe
"Link80"   Reach      32339.00   3540.00  0.00     *3552.780  12.780   149.00   3.37    0.18   3552.96    0.000   3.095
  0.000   -0.10000  7.500    Pipe
"84 to 90" Transition 32343.00   3540.00  0.00     *3552.744  12.744   149.00   3.87    0.23   3552.98    0.000   3.161
  0.000   0.00000  0.000    Pipe
"F4 Siph"  Reach      32543.00   3477.00  0.00     *3552.822  75.822   149.00   3.87    0.23   3553.05    0.000   3.161
  0.000   -0.31500  7.000    Pipe
"F4 Sipho" Reach      32827.00   3540.85  0.00     *3552.932  12.082   149.00   3.87    0.23   3553.17    0.000   3.161
  0.000   0.22482  0.974    Pipe
           "i.p."     33741.82   3546.23  0.00     *3553.227  7.000    149.00   3.87    0.23   3553.46    0.000   3.161
  0.025   0.00588  2.304    Pipe
           "i.p."     33853.97   3546.89  0.00     *3553.237  6.351    149.00   4.06    0.26   3553.49    0.000   3.161
  0.238   0.00588  2.304    Pipe
           "i.p."     33916.86   3547.26  0.00     *3553.230  5.974    149.00   4.26    0.28   3553.51    0.000   3.161
  0.282   0.00588  2.304    Pipe
           "i.p."     33967.69   3547.55  0.00     *3553.218  5.664    149.00   4.47    0.31   3553.53    0.000   3.161
  0.320   0.00588  2.304    Pipe
"Pipe5"    Reach      34001.00   3547.75  0.00     *3553.206  5.456    149.00   4.63    0.33   3553.54    0.000   3.161
  0.346   0.00588  2.304    Pipe
           "i.p."     34429.28   3548.13  0.00     *3553.334  5.205    149.00   4.86    0.37   3553.70    0.000   3.161
  0.382   0.00088  3.922    Pipe
"Pipe 5"   Reach      34578.00   3548.26  0.00     *3553.381  5.121    149.00   4.94    0.38   3553.76    0.000   3.161
  0.395   0.00088  3.922    Pipe
"Arch to " Transition 34586.00   3548.26  0.00     *3553.206  4.946    149.00   6.47    0.65   3553.86    0.000   3.386
  0.451   0.00000  0.000    Pipe
           "i.p."     34715.21   3548.44  0.00     *3553.747  5.310    149.00   6.17    0.59   3554.34    0.000   3.386
  0.349   0.00137  5.600    Pipe
           "i.p."     34821.83   3548.58  0.00     *3554.183  5.600    149.00   6.05    0.57   3554.75    0.000   3.386
  0.000   0.00137  5.600    Pipe
"Tunnel"   Reach      35338.00   3549.29  0.00     *3556.368  7.078    149.00   6.05    0.57   3556.94    0.000   3.386
  0.000   0.00137  5.600    Pipe
"84 to Ar" Transition 35346.00   3549.29  0.00     *3556.780  7.490    149.00   3.87    0.23   3557.01    0.000   3.161
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  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      36266.00   3547.26  0.00     *3557.076  9.816    149.00   3.87     0.23   3557.31    0.000   3.161
  0.000   -0.00221  7.000    Pipe
"62 to 84" Transition 36274.00   3547.26  0.00     *3556.698  9.438    149.00   7.10     0.78   3557.48    0.000   3.467
  0.000   0.00000  0.000    Pipe
"RR Siph"  Reach      36419.00   3469.86  0.00     *3556.982  87.122   149.00   7.10     0.78   3557.76    0.000   3.467
  0.000   -0.53379  5.170    Pipe
"RR Sipho" Reach      36679.00   3469.86  0.00     *3557.492  87.632   149.00   7.10     0.78   3558.27    0.000   3.467
  0.000   0.00000  5.170    Pipe
"RR Sipho" Reach      37111.00   3541.50  0.00     *3558.339  16.839   149.00   7.10     0.78   3559.12    0.000   3.467
  0.000   0.16583  1.151    Pipe
"84 to 62" Transition 37119.00   3541.50  0.00     *3559.004  17.504   149.00   3.87     0.23   3559.24    0.000   3.161
  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      37519.00   3548.50  0.00     *3559.133  10.633   149.00   3.87     0.23   3559.37    0.000   3.161
  0.000   0.01750  1.741    Pipe
"Pipe3B"   Reach      41439.00   3552.30  0.00     *3560.395  8.095    149.00   3.87     0.23   3560.63    0.000   3.161
  0.000   0.00097  3.812    Pipe
"Pipe 3B"  Reach      41731.00   3549.61  0.00     *3560.489  10.879   149.00   3.87     0.23   3560.72    0.000   3.161
  0.000   -0.00921  7.000    Pipe
"Node72"   WallExt    41731.00   3549.61  0.00     *3560.489  10.879   149.00   5.27     0.43   3560.92    0.000   3.315
  0.000   0.00000  0.000    Pipe
"Pipe3"    Reach      42757.00   3524.00  0.00     *3561.759  37.759   149.00   5.27     0.43   3562.19    0.000   3.315
  0.000   -0.02496  6.000    Pipe
"Pipe 3"   Reach      43782.00   3554.14  0.00     *3563.027  8.887    149.00   5.27     0.43   3563.46    0.000   3.315
  0.000   0.02940  1.844    Pipe
"Node70"   WallEnt    43782.00   3554.14  0.00     *3563.325  9.185    149.00   3.87     0.23   3563.56    0.000   3.161
  0.000   0.00000  0.000    Pipe
"Pipe 2B"  Reach      45542.00   3555.50  0.00     *3563.892  8.392    149.00   3.87     0.23   3564.12    0.000   3.161
  0.000   0.00077  4.092    Pipe
"Node69"   WallExt    45542.00   3555.50  0.00     *3563.892  8.392    149.00   5.27     0.43   3564.32    0.000   3.315
  0.000   0.00000  0.000    Pipe
"Pipe2"    Reach      48198.00   3530.00  0.00     *3567.179  37.179   149.00   5.27     0.43   3567.61    0.000   3.315
  0.000   -0.00960  6.000    Pipe
"Pipe 2"   Reach      50854.00   3559.58  0.00     *3570.467  10.887   149.00   5.27     0.43   3570.90    0.000   3.315
  0.000   0.01114  2.386    Pipe
"Node67"   WallExt    50854.00   3559.58  0.00     *3570.467  10.887   149.00   3.87     0.23   3570.70    0.000   3.161
  0.000   0.00000  0.000    Pipe
"Pipe1B"   Reach      52654.00   3562.38  0.00     *3571.046  8.666    149.00   3.87     0.23   3571.28    0.000   3.161
  0.000   0.00156  3.312    Pipe
"Pipe 1B"  Reach      53794.00   3562.38  0.00     *3571.413  9.033    149.00   3.87     0.23   3571.65    0.000   3.161
  0.000   0.00000  7.000    Pipe
"Pipeline" Reach      57075.00   3565.16  0.00     *3572.469  7.309    149.00   3.87     0.23   3572.70    0.000   3.161
  0.000   0.00085  3.974    Pipe
"Node64"   Headwrk    57075.00   3565.16  0.00     *3572.469  7.309    149.00   2.25     0.08   3572.55    0.000   3.161
  0.000   0.00000  0.000    Trapez.open

 *) in the W.S.ELEV column indicates flooding, it is set whenever W.S.ELEV > GROUND ELEV
    i.p. = intermediate point processing results for reaches
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*************************************
Water Surface Profile Gradient (WSPG)
XP WSPG
Engine Version 1.3         06/09/2010
XP Software        www.xpsoftware.com
*************************************

INPUT FILE
*************************************
C:\XPS\wspg2010\Samples\TID Main Canals to Phase IV with 140 at BFC 102016 Upgrade PL 2 to 84 Weholite.wsx
Computed  10/21/16  14:41:22

TITLE INFORMATION
*************************************

WARNING SUMMARY
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 WARNING 48: Manning's n for pipe flow of element JUNCTION not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link25 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link26 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link27 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link28 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link28 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link29 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link29 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link42 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link44 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link45 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link45 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link46 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link47 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link48 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link49 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link49 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link50 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Pipe2 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipe3 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipe 3B is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element RR Siph is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipeline 4 is not larger than invert elevation of the direct downstream
element.
 WARNING 48: Manning's n for pipe flow of element Tunnel not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element F4 Siph is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Link80 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Link81 is not larger than invert elevation of the direct downstream element.
 WARNING 25: Link type element Link30 has different invert elevation than its upstream node.
 WARNING 48: Manning's n for pipe flow of element Link43 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to 62 not in recommended range 0.010 - 0.015.
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 WARNING 48: Manning's n for pipe flow of element 62 to 84 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to Arch not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Arch to 84 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to 90 not in recommended range 0.010 - 0.015.
 WARNING 06: Upstream channel and downstream channel are the same for transition Link86. Use a reach instead?
 WARNING 36: D/S processing stopped in junction JUNCTION because critical momentum is greater than maximum momentum.

RESULTS
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   Main Line
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 Composite Profile:

ELEMENT    TYPE       STATION    INVERT   GROUND   W.S.      DEPTH    Q        VELOC.  VELOC. ENERGY     SUPER
CRITICAL FROUDE  SLOPE    NORMAL   CROSS
NAME                             ELEV     ELEV     ELEV                                HEAD   GRADE LN   ELEV    DEPTH
 NUMBER           DEPTH    SECTION
---------- ---------- ---------- -------- -------- --------  -------- -------- ------- ------ ---------- ------
-------- ------  -------  ------   ---------
###
"Node97"   Outlet     22000.00   3531.01  0.00     *3534.200  3.190    180.00   10.54   1.73   3535.93    0.000   3.490
  0.000   0.00000  0.000    Pipe
           "i.p."     22177.81   3532.05  0.00     *3535.236  3.190    180.00   10.54   1.73   3536.96    0.000   3.490
  1.187   0.00583  3.190    Pipe
           "i.p."     22297.00   3532.74  0.00     *3535.981  3.239    180.00   10.33   1.66   3537.64    0.000   3.490
  1.153   0.00583  3.190    Pipe
           "i.p."     22342.40   3533.01  0.00     *3536.367  3.361    180.00   9.85    1.51   3537.87    0.000   3.490
  1.074   0.00583  3.190    Pipe
"Link84"   Reach      22350.00   3533.05  0.00     *3536.539  3.489    180.00   9.39    1.37   3537.91    0.000   3.490
  1.001   0.00583  3.190    Pipe
 HYDRAULIC JUMP  at 22582.96  of length  0.09
           "i.p."     22352.63   3533.05  0.00     *3536.675  3.623    180.00   8.95    1.24   3537.92    0.000   3.490
  0.931   0.00051  7.000    Pipe
           "i.p."     22361.63   3533.06  0.00     *3536.820  3.764    180.00   8.54    1.13   3537.95    0.000   3.490
  0.866   0.00051  7.000    Pipe
           "i.p."     22378.82   3533.06  0.00     *3536.976  3.911    180.00   8.14    1.03   3538.00    0.000   3.490
  0.804   0.00051  7.000    Pipe
           "i.p."     22406.53   3533.08  0.00     *3537.146  4.067    180.00   7.76    0.94   3538.08    0.000   3.490
  0.746   0.00051  7.000    Pipe
           "i.p."     22447.87   3533.10  0.00     *3537.332  4.232    180.00   7.40    0.85   3538.18    0.000   3.490
  0.692   0.00051  7.000    Pipe
           "i.p."     22506.96   3533.13  0.00     *3537.537  4.406    180.00   7.06    0.77   3538.31    0.000   3.490
  0.640   0.00051  7.000    Pipe
           "i.p."     22582.96   3533.17  0.00     *3537.748  4.578    180.00   6.75    0.71   3538.46    0.000   3.490
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  0.594   0.00051  7.000    Pipe
           "i.p."     22582.96   3533.17  0.00     *3535.781  2.611    180.00   13.75   2.94   3538.72    0.000   3.490
  1.743   0.00051  7.000    Pipe
           "i.p."     22594.51   3533.18  0.00     *3535.724  2.548    180.00   14.21   3.14   3538.86    0.000   3.490
  1.827   0.00051  7.000    Pipe
           "i.p."     22611.11   3533.18  0.00     *3535.644  2.460    180.00   14.91   3.45   3539.10    0.000   3.490
  1.955   0.00051  7.000    Pipe
           "i.p."     22627.83   3533.19  0.00     *3535.569  2.376    180.00   15.64   3.80   3539.36    0.000   3.490
  2.091   0.00051  7.000    Pipe
           "i.p."     22644.54   3533.20  0.00     *3535.496  2.295    180.00   16.40   4.18   3539.67    0.000   3.490
  2.236   0.00051  7.000    Pipe
           "i.p."     22661.13   3533.21  0.00     *3535.426  2.217    180.00   17.20   4.59   3540.02    0.000   3.490
  2.391   0.00051  7.000    Pipe
           "i.p."     22677.51   3533.22  0.00     *3535.360  2.142    180.00   18.04   5.05   3540.41    0.000   3.490
  2.556   0.00051  7.000    Pipe
           "i.p."     22693.64   3533.23  0.00     *3535.296  2.069    180.00   18.92   5.56   3540.85    0.000   3.490
  2.732   0.00051  7.000    Pipe
           "i.p."     22709.45   3533.23  0.00     *3535.234  2.000    180.00   19.84   6.11   3541.35    0.000   3.490
  2.920   0.00051  7.000    Pipe
           "i.p."     22724.92   3533.24  0.00     *3535.175  1.933    180.00   20.81   6.73   3541.90    0.000   3.490
  3.120   0.00051  7.000    Pipe
"Link87"   Reach      22740.00   3533.25  0.00     *3535.118  1.868    180.00   21.83   7.40   3542.52    0.000   3.490
  3.333   0.00051  7.000    Pipe
"Link86"   Transition 22750.00   3538.50  0.00     *3541.989  3.489    180.00   9.39    1.37   3543.36    0.000   3.490
  1.001   0.52500  0.000    Pipe
           "i.p."     22753.90   3538.50  0.00     *3542.164  3.664    180.00   8.83    1.21   3543.37    0.000   3.490
  0.911   0.00000  7.000    Pipe
           "i.p."     22767.18   3538.50  0.00     *3542.347  3.847    180.00   8.31    1.07   3543.42    0.000   3.490
  0.830   0.00000  7.000    Pipe
           "i.p."     22792.16   3538.50  0.00     *3542.540  4.040    180.00   7.82    0.95   3543.49    0.000   3.490
  0.756   0.00000  7.000    Pipe
           "i.p."     22831.52   3538.50  0.00     *3542.742  4.242    180.00   7.38    0.85   3543.59    0.000   3.490
  0.689   0.00000  7.000    Pipe
           "i.p."     22888.36   3538.50  0.00     *3542.954  4.454    180.00   6.97    0.75   3543.71    0.000   3.490
  0.627   0.00000  7.000    Pipe
           "i.p."     22966.16   3538.50  0.00     *3543.176  4.676    180.00   6.59    0.67   3543.85    0.000   3.490
  0.570   0.00000  7.000    Pipe
           "i.p."     23068.71   3538.50  0.00     *3543.410  4.910    180.00   6.24    0.60   3544.02    0.000   3.490
  0.518   0.00000  7.000    Pipe
"Link82"   Reach      23100.00   3538.50  0.00     *3543.473  4.973    180.00   6.16    0.59   3544.06    0.000   3.490
  0.506   0.00000  7.000    Pipe
           "i.p."     23239.41   3538.50  0.00     *3543.721  5.221    180.00   5.85    0.53   3544.25    0.000   3.490
  0.458   0.00000  7.000    Pipe
           "i.p."     23412.51   3538.50  0.00     *3543.982  5.482    180.00   5.57    0.48   3544.46    0.000   3.490
  0.414   0.00000  7.000    Pipe
           "i.p."     23622.62   3538.50  0.00     *3544.256  5.756    180.00   5.32    0.44   3544.70    0.000   3.490
  0.372   0.00000  7.000    Pipe
           "i.p."     23871.79   3538.50  0.00     *3544.544  6.044    180.00   5.10    0.40   3544.95    0.000   3.490
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  0.331   0.00000  7.000    Pipe
           "i.p."     24159.48   3538.50  0.00     *3544.847  6.347    180.00   4.91    0.37   3545.22    0.000   3.490
  0.288   0.00000  7.000    Pipe
           "i.p."     24480.13   3538.50  0.00     *3545.164  6.664    180.00   4.76    0.35   3545.52    0.000   3.490
  0.236   0.00000  7.000    Pipe
"Link53"   Reach      24700.00   3538.50  0.00     *3545.379  6.879    180.00   4.70    0.34   3545.72    0.000   3.490
  0.181   0.00000  7.000    Pipe
"Link52"   Reach      24850.00   3538.50  0.00     *3545.533  7.033    180.00   4.68    0.34   3545.87    0.000   3.490
  0.000   0.00000  7.000    Pipe
"Link51"   Transition 24861.00   3538.61  0.00     *3545.815  7.205    180.00   2.50    0.10   3545.91    0.000   2.159
  0.164   0.01000  0.000    Rect.open
"Phase II" WallExt    24861.00   3538.61  0.00     *3545.815  7.205    180.00   4.83    0.36   3546.18    0.000   3.507
  0.000   0.00000  0.000    Pipe
"Link50"   Reach      24951.00   3538.61  0.00     *3545.932  7.322    180.00   4.83    0.36   3546.29    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link49"   Reach      25001.00   3532.50  0.00     *3545.998  13.498   180.00   4.83    0.36   3546.36    0.000   3.507
  0.000   -0.12220  6.890    Pipe
"Link48"   Reach      25197.00   3535.44  0.00     *3546.254  10.814   180.00   4.83    0.36   3546.62    0.000   3.507
  0.000   0.01500  2.566    Pipe
           "i.p."     25222.02   3539.40  0.00     *3546.287  6.890    180.00   4.83    0.36   3546.65    0.000   3.507
  0.032   0.15812  1.404    Pipe
           "i.p."     25225.86   3540.00  0.00     *3546.255  6.252    180.00   5.06    0.40   3546.65    0.000   3.507
  0.299   0.15812  1.404    Pipe
           "i.p."     25227.97   3540.34  0.00     *3546.218  5.881    180.00   5.31    0.44   3546.66    0.000   3.507
  0.355   0.15812  1.404    Pipe
"Link47"   Reach      25229.00   3540.50  0.00     *3546.194  5.694    180.00   5.46    0.46   3546.66    0.000   3.507
  0.383   0.15812  1.404    Pipe
           "i.p."     25427.97   3540.50  0.00     *3546.479  5.979    180.00   5.24    0.43   3546.90    0.000   3.507
  0.340   0.00000  6.890    Pipe
           "i.p."     25657.66   3540.50  0.00     *3546.778  6.278    180.00   5.05    0.40   3547.17    0.000   3.507
  0.295   0.00000  6.890    Pipe
           "i.p."     25913.17   3540.50  0.00     *3547.092  6.592    180.00   4.90    0.37   3547.46    0.000   3.507
  0.239   0.00000  6.890    Pipe
"Link46"   Reach      27095.00   3540.50  0.00     *3548.627  8.127    180.00   4.83    0.36   3548.99    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link45"   Reach      27223.00   3538.05  0.00     *3548.795  10.745   180.00   4.83    0.36   3549.16    0.000   3.507
  0.000   -0.01914  6.890    Pipe
"Link44"   Reach      27273.00   3538.05  0.00     *3548.860  10.810   180.00   4.83    0.36   3549.22    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link43"   Transition 27275.00   3538.05  0.00     *3548.980  10.930   180.00   4.07    0.26   3549.24    0.000   3.416
  0.000   0.00000  0.000    Pipe
"Link42"   Reach      27408.00   3519.50  0.00     *3549.077  29.577   180.00   4.07    0.26   3549.34    0.000   3.416
  0.000   -0.13947  7.500    Pipe
"Link41"   Reach      27508.00   3521.00  0.00     *3549.151  28.151   180.00   4.07    0.26   3549.41    0.000   3.416
  0.000   0.01500  2.395    Pipe
"Link40"   Reach      27554.00   3538.41  0.00     *3549.184  10.774   180.00   4.07    0.26   3549.44    0.000   3.416
  0.000   0.37848  1.072    Pipe
"Link39"   Reach      27606.00   3538.41  0.00     *3549.222  10.812   180.00   4.07    0.26   3549.48    0.000   3.416
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  0.000   0.00000  7.500    Pipe
"Link38"   Reach      27768.00   3540.50  0.00     *3549.341  8.841    180.00   4.07    0.26   3549.60    0.000   3.416
  0.000   0.01290  2.491    Pipe
"Link37"   Reach      30558.00   3540.50  0.00     *3551.382  10.882   180.00   4.07    0.26   3551.64    0.000   3.416
  0.000   0.00000  7.500    Pipe
"Link36"   Reach      30733.00   3543.23  0.00     *3551.510  8.280    180.00   4.07    0.26   3551.77    0.000   3.416
  0.000   0.01560  2.370    Pipe
"Link35"   Reach      32146.00   3543.23  0.00     *3552.544  9.314    180.00   4.07    0.26   3552.80    0.000   3.416
  0.000   0.00000  7.500    Pipe
"Link34"   Reach      32272.00   3543.29  0.00     *3552.636  9.346    180.00   4.07    0.26   3552.89    0.000   3.416
  0.000   0.00048  7.500    Pipe
"Link33"   Reach      32280.00   3543.29  0.00     *3552.642  9.352    180.00   4.07    0.26   3552.90    0.000   3.416
  0.000   0.00000  7.500    Pipe
"JUNCTION" Join       32280.00   3543.29  0.00     *3552.872  9.582    23.00    0.52    0.00   3552.88    0.000   1.185
  0.000   0.00000  0.000    Pipe
"Link32"   Reach      32338.00   3543.46  0.00     *3552.872  9.412    23.00    0.52    0.00   3552.88    0.000   1.185
  0.000   0.00293  1.152    Pipe
"Link31"   Reach      33308.00   3544.00  0.00     *3552.879  8.879    23.00    0.52    0.00   3552.88    0.000   1.185
  0.000   0.00056  1.734    Pipe
"Node35"   WallEnt    33308.00   3544.00  0.00     *3552.885  8.885    23.00    0.28    0.00   3552.89    0.000   0.587
  0.000   0.00000  0.000    Trapez.open
"Link30"   Transition 33321.00   3542.00  0.00     *3552.886  10.886   23.00    0.21    0.00   3552.89    0.000   0.548
  0.011   -0.15385  0.000    Rect.open
"TFC EXIT" WallExt    33321.00   3542.00  0.00     *3552.886  10.886   23.00    0.65    0.01   3552.89    0.000   1.220
  0.000   0.00000  0.000    Pipe
"Link29"   Reach      33405.00   3536.40  0.00     *3552.888  16.488   23.00    0.65    0.01   3552.89    0.000   1.220
  0.000   -0.06667  6.730    Pipe
"Link28"   Reach      33505.00   3508.00  0.00     *3552.891  44.891   23.00    0.65    0.01   3552.90    0.000   1.220
  0.000   -0.28400  6.730    Pipe
"Link27"   Reach      33625.00   3508.00  0.00     *3552.894  44.894   23.00    0.65    0.01   3552.90    0.000   1.220
  0.000   0.00000  6.730    Pipe
"Link26"   Reach      34825.00   3523.87  0.00     *3552.927  29.057   23.00    0.65    0.01   3552.93    0.000   1.220
  0.000   0.01322  0.977    Pipe
"Link25"   Reach      36288.00   3546.17  0.00     *3552.967  6.797    23.00    0.65    0.01   3552.97    0.000   1.220
  0.000   0.01524  0.944    Pipe
"TFC HDWL" WallEnt    36288.00   3546.17  0.00     *3552.976  6.806    23.00    0.34    0.00   3552.98    0.000   0.548
  0.000   0.00000  0.000    Rect.open
"Link24"   Transition 36298.00   3548.20  0.00     *3552.977  4.777    23.00    0.24    0.00   3552.98    0.000   0.345
  0.019   0.20300  0.000    Rect.open
"Link23"   Reach      36308.00   3548.20  0.00     *3552.977  4.777    23.00    0.24    0.00   3552.98    0.000   0.345
  0.019   0.00000  9.000    Rect.open
"TFC Head" Headwrk    36308.00   3548.20  0.00     *3552.977  4.777    23.00    0.24    0.00   3552.98    0.000   0.345
  0.000   0.00000  0.000    Rect.open

 *) in the W.S.ELEV column indicates flooding, it is set whenever W.S.ELEV > GROUND ELEV
    i.p. = intermediate point processing results for reaches
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   JUNCTION_Branch1
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 Composite Profile:

ELEMENT    TYPE       STATION    INVERT   GROUND   W.S.      DEPTH    Q        VELOC.  VELOC. ENERGY     SUPER
CRITICAL FROUDE  SLOPE    NORMAL   CROSS
NAME                             ELEV     ELEV     ELEV                                HEAD   GRADE LN   ELEV    DEPTH
 NUMBER           DEPTH    SECTION
---------- ---------- ---------- -------- -------- --------  -------- -------- ------- ------ ---------- ------
-------- ------  -------  ------   ---------
###
"Outlet/J" Outlet     32280.00   3543.39  0.00     *3552.757  9.367    157.00   3.55    0.20   3552.95    0.000   3.181
  0.000   0.00000  0.000    Pipe
"Link81"   Reach      32314.00   3542.50  0.00     *3552.765  10.265   157.00   3.55    0.20   3552.96    0.000   3.181
  0.000   -0.02618  7.500    Pipe
"Link80"   Reach      32339.00   3540.00  0.00     *3552.771  12.771   157.00   3.55    0.20   3552.97    0.000   3.181
  0.000   -0.10000  7.500    Pipe
"84 to 90" Transition 32343.00   3540.00  0.00     *3552.731  12.731   157.00   4.08    0.26   3552.99    0.000   3.248
  0.000   0.00000  0.000    Pipe
"F4 Siph"  Reach      32543.00   3477.00  0.00     *3552.817  75.817   157.00   4.08    0.26   3553.08    0.000   3.248
  0.000   -0.31500  7.000    Pipe
"F4 Sipho" Reach      32827.00   3540.85  0.00     *3552.940  12.090   157.00   4.08    0.26   3553.20    0.000   3.248
  0.000   0.22482  0.999    Pipe
           "i.p."     33749.13   3546.27  0.00     *3553.270  7.000    157.00   4.08    0.26   3553.53    0.000   3.248
  0.027   0.00588  2.368    Pipe
           "i.p."     33861.49   3546.93  0.00     *3553.281  6.351    157.00   4.28    0.28   3553.57    0.000   3.248
  0.251   0.00588  2.368    Pipe
           "i.p."     33924.23   3547.30  0.00     *3553.273  5.974    157.00   4.49    0.31   3553.59    0.000   3.248
  0.297   0.00588  2.368    Pipe
           "i.p."     33974.82   3547.60  0.00     *3553.260  5.664    157.00   4.71    0.34   3553.60    0.000   3.248
  0.337   0.00588  2.368    Pipe
"Pipe5"    Reach      34001.00   3547.75  0.00     *3553.250  5.500    157.00   4.84    0.36   3553.61    0.000   3.248
  0.359   0.00588  2.368    Pipe
           "i.p."     34462.47   3548.16  0.00     *3553.402  5.244    157.00   5.08    0.40   3553.80    0.000   3.248
  0.396   0.00088  4.054    Pipe
"Pipe 5"   Reach      34578.00   3548.26  0.00     *3553.443  5.183    157.00   5.14    0.41   3553.85    0.000   3.248
  0.406   0.00088  4.054    Pipe
"Arch to " Transition 34586.00   3548.26  0.00     *3553.247  4.987    157.00   6.78    0.71   3553.96    0.000   3.479
  0.464   0.00000  0.000    Pipe
           "i.p."     34702.83   3548.42  0.00     *3553.795  5.375    157.00   6.46    0.65   3554.44    0.000   3.479
  0.343   0.00137  5.600    Pipe
           "i.p."     34773.42   3548.52  0.00     *3554.117  5.600    157.00   6.37    0.63   3554.75    0.000   3.479
  0.000   0.00137  5.600    Pipe
"Tunnel"   Reach      35338.00   3549.29  0.00     *3556.770  7.480    157.00   6.37    0.63   3557.40    0.000   3.479
  0.000   0.00137  5.600    Pipe
"84 to Ar" Transition 35346.00   3549.29  0.00     *3557.228  7.938    157.00   4.08    0.26   3557.49    0.000   3.248
```

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  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      36266.00   3547.26  0.00     *3557.557  10.297   157.00   4.08    0.26   3557.81    0.000   3.248
  0.000   -0.00221  7.000    Pipe
"62 to 84" Transition 36274.00   3547.26  0.00     *3557.136  9.876    157.00   7.48    0.87   3558.00    0.000   3.561
  0.000   0.00000  0.000    Pipe
"RR Siph"  Reach      36419.00   3469.86  0.00     *3557.452  87.592   157.00   7.48    0.87   3558.32    0.000   3.561
  0.000   -0.53379  5.170    Pipe
"RR Sipho" Reach      36679.00   3469.86  0.00     *3558.018  88.158   157.00   7.48    0.87   3558.89    0.000   3.561
  0.000   0.00000  5.170    Pipe
"RR Sipho" Reach      37111.00   3541.50  0.00     *3558.958  17.458   157.00   7.48    0.87   3559.83    0.000   3.561
  0.000   0.16583  1.182    Pipe
"84 to 62" Transition 37119.00   3541.50  0.00     *3559.697  18.197   157.00   4.08    0.26   3559.96    0.000   3.248
  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      37519.00   3548.50  0.00     *3559.840  11.340   157.00   4.08    0.26   3560.10    0.000   3.248
  0.000   0.01750  1.788    Pipe
"Pipe3B"   Reach      41439.00   3552.30  0.00     *3561.241  8.941    157.00   4.08    0.26   3561.50    0.000   3.248
  0.000   0.00097  3.937    Pipe
"Pipe 3B"  Reach      41731.00   3549.61  0.00     *3561.345  11.735   157.00   4.08    0.26   3561.60    0.000   3.248
  0.000   -0.00921  7.000    Pipe
"Node72"   WallExt    41731.00   3549.61  0.00     *3561.345  11.735   157.00   5.55    0.48   3561.82    0.000   3.407
  0.000   0.00000  0.000    Pipe
"Pipe3"    Reach      42757.00   3524.00  0.00     *3562.755  38.755   157.00   5.55    0.48   3563.23    0.000   3.407
  0.000   -0.02496  6.000    Pipe
"Pipe 3"   Reach      43782.00   3554.14  0.00     *3564.164  10.024   157.00   5.55    0.48   3564.64    0.000   3.407
  0.000   0.02940  1.895    Pipe
"Node70"   WallEnt    43782.00   3554.14  0.00     *3564.494  10.354   157.00   4.08    0.26   3564.75    0.000   3.248
  0.000   0.00000  0.000    Pipe
"Pipe 2B"  Reach      45542.00   3555.50  0.00     *3565.123  9.623    157.00   4.08    0.26   3565.38    0.000   3.248
  0.000   0.00077  4.234    Pipe
"Pipe2"    Reach      48198.00   3530.00  0.00     *3566.073  36.073   157.00   4.08    0.26   3566.33    0.000   3.248
  0.000   -0.00960  7.000    Pipe
"Pipe 2"   Reach      50854.00   3559.58  0.00     *3567.022  7.442    157.00   4.08    0.26   3567.28    0.000   3.248
  0.000   0.01114  2.006    Pipe
           "i.p."     51222.69   3560.15  0.00     *3567.153  7.000    157.00   4.08    0.26   3567.41    0.000   3.248
  0.027   0.00156  3.414    Pipe
           "i.p."     51732.69   3560.95  0.00     *3567.298  6.351    157.00   4.28    0.28   3567.58    0.000   3.248
  0.251   0.00156  3.414    Pipe
           "i.p."     52015.57   3561.39  0.00     *3567.361  5.974    157.00   4.49    0.31   3567.67    0.000   3.248
  0.297   0.00156  3.414    Pipe
           "i.p."     52247.55   3561.75  0.00     *3567.411  5.664    157.00   4.71    0.34   3567.76    0.000   3.248
  0.337   0.00156  3.414    Pipe
           "i.p."     52450.79   3562.06  0.00     *3567.455  5.391    157.00   4.94    0.38   3567.83    0.000   3.248
  0.374   0.00156  3.414    Pipe
           "i.p."     52634.59   3562.35  0.00     *3567.496  5.146    157.00   5.18    0.42   3567.91    0.000   3.248
  0.412   0.00156  3.414    Pipe
"Pipe1B"   Reach      52654.00   3562.38  0.00     *3567.500  5.120    157.00   5.20    0.42   3567.92    0.000   3.248
  0.416   0.00156  3.414    Pipe
           "i.p."     53154.00   3562.38  0.00     *3567.756  5.376    157.00   4.95    0.38   3568.14    0.000   3.248
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  0.377   0.00000  7.000    Pipe
           "i.p."     53758.51   3562.38  0.00     *3568.025  5.645    157.00   4.72    0.35   3568.37    0.000   3.248
  0.339   0.00000  7.000    Pipe
"Pipe 1B"  Reach      53794.00   3562.38  0.00     *3568.040  5.660    157.00   4.71    0.34   3568.38    0.000   3.248
  0.337   0.00000  7.000    Pipe
"Node65"   WallExt    53794.00   3562.38  0.00     *3568.040  5.660    157.00   5.68    0.50   3568.54    0.000   3.407
  0.000   0.00000  0.000    Pipe
           "i.p."     54568.77   3563.04  0.00     *3569.036  6.000    157.00   5.55    0.48   3569.52    0.000   3.407
  0.000   0.00085  6.000    Pipe
"Pipeline" Reach      57075.00   3565.16  0.00     *3572.481  7.321    157.00   5.55    0.48   3572.96    0.000   3.407
  0.000   0.00085  6.000    Pipe
"Node64"   Headwrk    57075.00   3565.16  0.00     *3572.481  7.321    157.00   2.36    0.09   3572.57    0.000   3.407
  0.000   0.00000  0.000    Trapez.open

 *) in the W.S.ELEV column indicates flooding, it is set whenever W.S.ELEV > GROUND ELEV
    i.p. = intermediate point processing results for reaches
```

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*************************************
Water Surface Profile Gradient (WSPG)
XP WSPG
Engine Version 1.3         06/09/2010
XP Software       www.xpsoftware.com
*************************************

INPUT FILE
*************************************
C:\XPS\wspg2010\Samples\TID Main Canals to Phase IV with 140 at BFC 102016 Upgrade PL 3 to 84 Weholite.wsx
Computed  10/21/16  14:48:30

TITLE INFORMATION
*************************************

WARNING SUMMARY
*************************************
 WARNING 48: Manning's n for pipe flow of element JUNCTION not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link25 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link26 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link27 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link28 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link28 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link29 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link29 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link42 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link44 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link45 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link45 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link46 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link47 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link48 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link49 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link49 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link50 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Pipe2 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipe3 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipe 3B is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element RR Siph is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipeline 4 is not larger than invert elevation of the direct downstream
element.
 WARNING 48: Manning's n for pipe flow of element Tunnel not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element F4 Siph is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Link80 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Link81 is not larger than invert elevation of the direct downstream element.
 WARNING 25: Link type element Link30 has different invert elevation than its upstream node.
 WARNING 48: Manning's n for pipe flow of element Link43 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to 62 not in recommended range 0.010 - 0.015.
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 WARNING 48: Manning's n for pipe flow of element 62 to 84 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to Arch not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Arch to 84 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to 90 not in recommended range 0.010 - 0.015.
 WARNING 06: Upstream channel and downstream channel are the same for transition Link86. Use a reach instead?
 WARNING 36: D/S processing stopped in junction JUNCTION because critical momentum is greater than maximum momentum.

RESULTS
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   Main Line
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 Composite Profile:

ELEMENT    TYPE       STATION    INVERT   GROUND   W.S.      DEPTH    Q        VELOC.  VELOC. ENERGY     SUPER
CRITICAL FROUDE  SLOPE    NORMAL   CROSS
NAME                             ELEV     ELEV     ELEV                                HEAD   GRADE LN   ELEV    DEPTH
 NUMBER           DEPTH    SECTION
---------- ---------- ---------- -------- -------- --------  -------- -------- ------- ------ ---------- ------
-------- ------  -------  ------   ---------
###
"Node97"   Outlet     22000.00   3531.01  0.00     *3534.200  3.190    180.00   10.54   1.73   3535.93    0.000   3.490
  0.000   0.00000  0.000    Pipe
           "i.p."     22177.81   3532.05  0.00     *3535.236  3.190    180.00   10.54   1.73   3536.96    0.000   3.490
  1.187   0.00583  3.190    Pipe
           "i.p."     22297.00   3532.74  0.00     *3535.981  3.239    180.00   10.33   1.66   3537.64    0.000   3.490
  1.153   0.00583  3.190    Pipe
           "i.p."     22342.40   3533.01  0.00     *3536.367  3.361    180.00   9.85    1.51   3537.87    0.000   3.490
  1.074   0.00583  3.190    Pipe
"Link84"   Reach      22350.00   3533.05  0.00     *3536.539  3.489    180.00   9.39    1.37   3537.91    0.000   3.490
  1.001   0.00583  3.190    Pipe
 HYDRAULIC JUMP  at 22582.96  of length  0.09
           "i.p."     22352.63   3533.05  0.00     *3536.675  3.623    180.00   8.95    1.24   3537.92    0.000   3.490
  0.931   0.00051  7.000    Pipe
           "i.p."     22361.63   3533.06  0.00     *3536.820  3.764    180.00   8.54    1.13   3537.95    0.000   3.490
  0.866   0.00051  7.000    Pipe
           "i.p."     22378.82   3533.06  0.00     *3536.976  3.911    180.00   8.14    1.03   3538.00    0.000   3.490
  0.804   0.00051  7.000    Pipe
           "i.p."     22406.53   3533.08  0.00     *3537.146  4.067    180.00   7.76    0.94   3538.08    0.000   3.490
  0.746   0.00051  7.000    Pipe
           "i.p."     22447.87   3533.10  0.00     *3537.332  4.232    180.00   7.40    0.85   3538.18    0.000   3.490
  0.692   0.00051  7.000    Pipe
           "i.p."     22506.96   3533.13  0.00     *3537.537  4.406    180.00   7.06    0.77   3538.31    0.000   3.490
  0.640   0.00051  7.000    Pipe
           "i.p."     22582.96   3533.17  0.00     *3537.748  4.578    180.00   6.75    0.71   3538.46    0.000   3.490
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  0.594   0.00051  7.000    Pipe
           "i.p."      22582.96   3533.17  0.00      *3535.781  2.611    180.00   13.75    2.94    3538.72     0.000    3.490
  1.743   0.00051  7.000    Pipe
           "i.p."      22594.51   3533.18  0.00      *3535.724  2.548    180.00   14.21    3.14    3538.86     0.000    3.490
  1.827   0.00051  7.000    Pipe
           "i.p."      22611.11   3533.18  0.00      *3535.644  2.460    180.00   14.91    3.45    3539.10     0.000    3.490
  1.955   0.00051  7.000    Pipe
           "i.p."      22627.83   3533.19  0.00      *3535.569  2.376    180.00   15.64    3.80    3539.36     0.000    3.490
  2.091   0.00051  7.000    Pipe
           "i.p."      22644.54   3533.20  0.00      *3535.496  2.295    180.00   16.40    4.18    3539.67     0.000    3.490
  2.236   0.00051  7.000    Pipe
           "i.p."      22661.13   3533.21  0.00      *3535.426  2.217    180.00   17.20    4.59    3540.02     0.000    3.490
  2.391   0.00051  7.000    Pipe
           "i.p."      22677.51   3533.22  0.00      *3535.360  2.142    180.00   18.04    5.05    3540.41     0.000    3.490
  2.556   0.00051  7.000    Pipe
           "i.p."      22693.64   3533.23  0.00      *3535.296  2.069    180.00   18.92    5.56    3540.85     0.000    3.490
  2.732   0.00051  7.000    Pipe
           "i.p."      22709.45   3533.23  0.00      *3535.234  2.000    180.00   19.84    6.11    3541.35     0.000    3.490
  2.920   0.00051  7.000    Pipe
           "i.p."      22724.92   3533.24  0.00      *3535.175  1.933    180.00   20.81    6.73    3541.90     0.000    3.490
  3.120   0.00051  7.000    Pipe
"Link87"   Reach       22740.00   3533.25  0.00      *3535.118  1.868    180.00   21.83    7.40    3542.52     0.000    3.490
  3.333   0.00051  7.000    Pipe
"Link86"   Transition 22750.00   3538.50  0.00      *3541.989  3.489    180.00   9.39     1.37    3543.36     0.000    3.490
  1.001   0.52500  0.000    Pipe
           "i.p."      22753.90   3538.50  0.00      *3542.164  3.664    180.00   8.83     1.21    3543.37     0.000    3.490
  0.911   0.00000  7.000    Pipe
           "i.p."      22767.18   3538.50  0.00      *3542.347  3.847    180.00   8.31     1.07    3543.42     0.000    3.490
  0.830   0.00000  7.000    Pipe
           "i.p."      22792.16   3538.50  0.00      *3542.540  4.040    180.00   7.82     0.95    3543.49     0.000    3.490
  0.756   0.00000  7.000    Pipe
           "i.p."      22831.52   3538.50  0.00      *3542.742  4.242    180.00   7.38     0.85    3543.59     0.000    3.490
  0.689   0.00000  7.000    Pipe
           "i.p."      22888.36   3538.50  0.00      *3542.954  4.454    180.00   6.97     0.75    3543.71     0.000    3.490
  0.627   0.00000  7.000    Pipe
           "i.p."      22966.16   3538.50  0.00      *3543.176  4.676    180.00   6.59     0.67    3543.85     0.000    3.490
  0.570   0.00000  7.000    Pipe
           "i.p."      23068.71   3538.50  0.00      *3543.410  4.910    180.00   6.24     0.60    3544.02     0.000    3.490
  0.518   0.00000  7.000    Pipe
"Link82"   Reach       23100.00   3538.50  0.00      *3543.473  4.973    180.00   6.16     0.59    3544.06     0.000    3.490
  0.506   0.00000  7.000    Pipe
           "i.p."      23239.41   3538.50  0.00      *3543.721  5.221    180.00   5.85     0.53    3544.25     0.000    3.490
  0.458   0.00000  7.000    Pipe
           "i.p."      23412.51   3538.50  0.00      *3543.982  5.482    180.00   5.57     0.48    3544.46     0.000    3.490
  0.414   0.00000  7.000    Pipe
           "i.p."      23622.62   3538.50  0.00      *3544.256  5.756    180.00   5.32     0.44    3544.70     0.000    3.490
  0.372   0.00000  7.000    Pipe
           "i.p."      23871.79   3538.50  0.00      *3544.544  6.044    180.00   5.10     0.40    3544.95     0.000    3.490
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  0.331   0.00000  7.000    Pipe
           "i.p."     24159.48   3538.50  0.00     *3544.847  6.347     180.00   4.91     0.37   3545.22     0.000    3.490
  0.288   0.00000  7.000    Pipe
           "i.p."     24480.13   3538.50  0.00     *3545.164  6.664     180.00   4.76     0.35   3545.52     0.000    3.490
  0.236   0.00000  7.000    Pipe
"Link53"   Reach      24700.00   3538.50  0.00     *3545.379  6.879     180.00   4.70     0.34   3545.72     0.000    3.490
  0.181   0.00000  7.000    Pipe
"Link52"   Reach      24850.00   3538.50  0.00     *3545.533  7.033     180.00   4.68     0.34   3545.87     0.000    3.490
  0.000   0.00000  7.000    Pipe
"Link51"   Transition 24861.00   3538.61  0.00     *3545.815  7.205     180.00   2.50     0.10   3545.91     0.000    2.159
  0.164   0.01000  0.000    Rect.open
"Phase II" WallExt    24861.00   3538.61  0.00     *3545.815  7.205     180.00   4.83     0.36   3546.18     0.000    3.507
  0.000   0.00000  0.000    Pipe
"Link50"   Reach      24951.00   3538.61  0.00     *3545.932  7.322     180.00   4.83     0.36   3546.29     0.000    3.507
  0.000   0.00000  6.890    Pipe
"Link49"   Reach      25001.00   3532.50  0.00     *3545.998  13.498    180.00   4.83     0.36   3546.36     0.000    3.507
  0.000   -0.12220  6.890    Pipe
"Link48"   Reach      25197.00   3535.44  0.00     *3546.254  10.814    180.00   4.83     0.36   3546.62     0.000    3.507
  0.000   0.01500  2.566    Pipe
           "i.p."     25222.02   3539.40  0.00     *3546.287  6.890     180.00   4.83     0.36   3546.65     0.000    3.507
  0.032   0.15812  1.404    Pipe
           "i.p."     25225.86   3540.00  0.00     *3546.255  6.252     180.00   5.06     0.40   3546.65     0.000    3.507
  0.299   0.15812  1.404    Pipe
           "i.p."     25227.97   3540.34  0.00     *3546.218  5.881     180.00   5.31     0.44   3546.66     0.000    3.507
  0.355   0.15812  1.404    Pipe
"Link47"   Reach      25229.00   3540.50  0.00     *3546.194  5.694     180.00   5.46     0.46   3546.66     0.000    3.507
  0.383   0.15812  1.404    Pipe
           "i.p."     25427.97   3540.50  0.00     *3546.479  5.979     180.00   5.24     0.43   3546.90     0.000    3.507
  0.340   0.00000  6.890    Pipe
           "i.p."     25657.66   3540.50  0.00     *3546.778  6.278     180.00   5.05     0.40   3547.17     0.000    3.507
  0.295   0.00000  6.890    Pipe
           "i.p."     25913.17   3540.50  0.00     *3547.092  6.592     180.00   4.90     0.37   3547.46     0.000    3.507
  0.239   0.00000  6.890    Pipe
"Link46"   Reach      27095.00   3540.50  0.00     *3548.627  8.127     180.00   4.83     0.36   3548.99     0.000    3.507
  0.000   0.00000  6.890    Pipe
"Link45"   Reach      27223.00   3538.05  0.00     *3548.795  10.745    180.00   4.83     0.36   3549.16     0.000    3.507
  0.000   -0.01914  6.890    Pipe
"Link44"   Reach      27273.00   3538.05  0.00     *3548.860  10.810    180.00   4.83     0.36   3549.22     0.000    3.507
  0.000   0.00000  6.890    Pipe
"Link43"   Transition 27275.00   3538.05  0.00     *3548.980  10.930    180.00   4.07     0.26   3549.24     0.000    3.416
  0.000   0.00000  0.000    Pipe
"Link42"   Reach      27408.00   3519.50  0.00     *3549.077  29.577    180.00   4.07     0.26   3549.34     0.000    3.416
  0.000   -0.13947  7.500    Pipe
"Link41"   Reach      27508.00   3521.00  0.00     *3549.151  28.151    180.00   4.07     0.26   3549.41     0.000    3.416
  0.000   0.01500  2.395    Pipe
"Link40"   Reach      27554.00   3538.41  0.00     *3549.184  10.774    180.00   4.07     0.26   3549.44     0.000    3.416
  0.000   0.37848  1.072    Pipe
"Link39"   Reach      27606.00   3538.41  0.00     *3549.222  10.812    180.00   4.07     0.26   3549.48     0.000    3.416
```

```
  0.000   0.00000  7.500    Pipe
"Link38"   Reach      27768.00   3540.50  0.00     *3549.341  8.841    180.00   4.07    0.26   3549.60    0.000   3.416
  0.000   0.01290  2.491    Pipe
"Link37"   Reach      30558.00   3540.50  0.00     *3551.382  10.882   180.00   4.07    0.26   3551.64    0.000   3.416
  0.000   0.00000  7.500    Pipe
"Link36"   Reach      30733.00   3543.23  0.00     *3551.510  8.280    180.00   4.07    0.26   3551.77    0.000   3.416
  0.000   0.01560  2.370    Pipe
"Link35"   Reach      32146.00   3543.23  0.00     *3552.544  9.314    180.00   4.07    0.26   3552.80    0.000   3.416
  0.000   0.00000  7.500    Pipe
"Link34"   Reach      32272.00   3543.29  0.00     *3552.636  9.346    180.00   4.07    0.26   3552.89    0.000   3.416
  0.000   0.00048  7.500    Pipe
"Link33"   Reach      32280.00   3543.29  0.00     *3552.642  9.352    180.00   4.07    0.26   3552.90    0.000   3.416
  0.000   0.00000  7.500    Pipe
"JUNCTION" Join       32280.00   3543.29  0.00     *3552.897  9.607    33.00    0.75    0.01   3552.91    0.000   1.424
  0.000   0.00000  0.000    Pipe
"Link32"   Reach      32338.00   3543.46  0.00     *3552.898  9.438    33.00    0.75    0.01   3552.91    0.000   1.424
  0.000   0.00293  1.374    Pipe
"Link31"   Reach      33308.00   3544.00  0.00     *3552.913  8.913    33.00    0.75    0.01   3552.92    0.000   1.424
  0.000   0.00056  2.080    Pipe
"Node35"   WallEnt    33308.00   3544.00  0.00     *3552.925  8.925    33.00    0.41    0.00   3552.93    0.000   0.747
  0.000   0.00000  0.000    Trapez.open
"Link30"   Transition 33321.00   3542.00  0.00     *3552.927  10.927   33.00    0.30    0.00   3552.93    0.000   0.697
  0.016   -0.15385  0.000    Rect.open
"TFC EXIT" WallExt    33321.00   3542.00  0.00     *3552.927  10.927   33.00    0.93    0.01   3552.94    0.000   1.467
  0.000   0.00000  0.000    Pipe
"Link29"   Reach      33405.00   3536.40  0.00     *3552.931  16.531   33.00    0.93    0.01   3552.94    0.000   1.467
  0.000   -0.06667  6.730    Pipe
"Link28"   Reach      33505.00   3508.00  0.00     *3552.937  44.937   33.00    0.93    0.01   3552.95    0.000   1.467
  0.000   -0.28400  6.730    Pipe
"Link27"   Reach      33625.00   3508.00  0.00     *3552.944  44.944   33.00    0.93    0.01   3552.96    0.000   1.467
  0.000   0.00000  6.730    Pipe
"Link26"   Reach      34825.00   3523.87  0.00     *3553.011  29.141   33.00    0.93    0.01   3553.02    0.000   1.467
  0.000   0.01322  1.165    Pipe
"Link25"   Reach      36288.00   3546.17  0.00     *3553.094  6.924    33.00    0.93    0.01   3553.11    0.000   1.467
  0.000   0.01524  1.125    Pipe
"TFC HDWL" WallEnt    36288.00   3546.17  0.00     *3553.113  6.943    33.00    0.48    0.00   3553.12    0.000   0.697
  0.000   0.00000  0.000    Rect.open
"Link24"   Transition 36298.00   3548.20  0.00     *3553.115  4.915    33.00    0.34    0.00   3553.12    0.000   0.439
  0.027   0.20300  0.000    Rect.open
"Link23"   Reach      36308.00   3548.20  0.00     *3553.116  4.916    33.00    0.34    0.00   3553.12    0.000   0.439
  0.027   0.00000  9.000    Rect.open
"TFC Head" Headwrk    36308.00   3548.20  0.00     *3553.116  4.916    33.00    0.34    0.00   3553.12    0.000   0.439
  0.000   0.00000  0.000    Rect.open
```

*) in the W.S.ELEV column indicates flooding, it is set whenever W.S.ELEV > GROUND ELEV
i.p. = intermediate point processing results for reaches

```
==============================================================
   JUNCTION_Branch1
==============================================================

 Composite Profile:

ELEMENT    TYPE       STATION    INVERT   GROUND   W.S.      DEPTH    Q        VELOC.  VELOC. ENERGY     SUPER
CRITICAL FROUDE  SLOPE    NORMAL   CROSS
NAME                             ELEV     ELEV     ELEV                               HEAD   GRADE LN   ELEV    DEPTH
 NUMBER           DEPTH    SECTION
---------- ---------- ---------- -------- -------- --------  -------- -------- ------- ------ ---------- ------
-------- ------  -------  ------   ---------
###
"Outlet/J" Outlet     32280.00   3543.39  0.00     *3552.769  9.379    147.00   3.33    0.17   3552.94    0.000   3.073
  0.000   0.00000  0.000    Pipe
"Link81"   Reach      32314.00   3542.50  0.00     *3552.777  10.277   147.00   3.33    0.17   3552.95    0.000   3.073
  0.000   -0.02618  7.500    Pipe
"Link80"   Reach      32339.00   3540.00  0.00     *3552.782  12.782   147.00   3.33    0.17   3552.95    0.000   3.073
  0.000   -0.10000  7.500    Pipe
"84 to 90" Transition 32343.00   3540.00  0.00     *3552.747  12.747   147.00   3.82    0.23   3552.97    0.000   3.138
  0.000   0.00000  0.000    Pipe
"F4 Siph"  Reach      32543.00   3477.00  0.00     *3552.822  75.822   147.00   3.82    0.23   3553.05    0.000   3.138
  0.000   -0.31500  7.000    Pipe
"F4 Sipho" Reach      32827.00   3540.85  0.00     *3552.930  12.080   147.00   3.82    0.23   3553.16    0.000   3.138
  0.000   0.22482  0.968    Pipe
           "i.p."     33740.03   3546.22  0.00     *3553.216  7.000    147.00   3.82    0.23   3553.44    0.000   3.138
  0.025   0.00588  2.288    Pipe
           "i.p."     33852.13   3546.88  0.00     *3553.226  6.351    147.00   4.01    0.25   3553.48    0.000   3.138
  0.235   0.00588  2.288    Pipe
           "i.p."     33915.05   3547.24  0.00     *3553.219  5.974    147.00   4.20    0.27   3553.49    0.000   3.138
  0.279   0.00588  2.288    Pipe
           "i.p."     33965.94   3547.54  0.00     *3553.207  5.664    147.00   4.41    0.30   3553.51    0.000   3.138
  0.315   0.00588  2.288    Pipe
"Pipe5"    Reach      34001.00   3547.75  0.00     *3553.196  5.446    147.00   4.58    0.33   3553.52    0.000   3.138
  0.343   0.00588  2.288    Pipe
           "i.p."     34421.83   3548.12  0.00     *3553.317  5.195    147.00   4.80    0.36   3553.68    0.000   3.138
  0.378   0.00088  3.889    Pipe
"Pipe 5"   Reach      34578.00   3548.26  0.00     *3553.366  5.106    147.00   4.89    0.37   3553.74    0.000   3.138
  0.392   0.00088  3.889    Pipe
"Arch to " Transition 34586.00   3548.26  0.00     *3553.196  4.936    147.00   6.40    0.64   3553.83    0.000   3.362
  0.447   0.00000  0.000    Pipe
           "i.p."     34719.06   3548.44  0.00     *3553.737  5.295    147.00   6.10    0.58   3554.31    0.000   3.362
  0.349   0.00137  5.600    Pipe
           "i.p."     34836.23   3548.60  0.00     *3554.203  5.600    147.00   5.97    0.55   3554.76    0.000   3.362
  0.000   0.00137  5.600    Pipe
"Tunnel"   Reach      35338.00   3549.29  0.00     *3556.270  6.980    147.00   5.97    0.55   3556.82    0.000   3.362
  0.000   0.00137  5.600    Pipe
"84 to Ar" Transition 35346.00   3549.29  0.00     *3556.671  7.381    147.00   3.82    0.23   3556.90    0.000   3.138
```

```
  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      36266.00   3547.26  0.00     *3556.960  9.700     147.00   3.82    0.23   3557.19    0.000   3.138
  0.000   -0.00221  7.000    Pipe
"62 to 84" Transition 36274.00   3547.26  0.00     *3556.591  9.331     147.00   7.00    0.76   3557.35    0.000   3.443
  0.000   0.00000  0.000    Pipe
"RR Siph"  Reach      36419.00   3469.86  0.00     *3556.868  87.008    147.00   7.00    0.76   3557.63    0.000   3.443
  0.000   -0.53379  5.170    Pipe
"RR Sipho" Reach      36679.00   3469.86  0.00     *3557.364  87.504    147.00   7.00    0.76   3558.13    0.000   3.443
  0.000   0.00000  5.170    Pipe
"RR Sipho" Reach      37111.00   3541.50  0.00     *3558.188  16.688    147.00   7.00    0.76   3558.95    0.000   3.443
  0.000   0.16583  1.143    Pipe
"84 to 62" Transition 37119.00   3541.50  0.00     *3558.836  17.336    147.00   3.82    0.23   3559.06    0.000   3.138
  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      37519.00   3548.50  0.00     *3558.961  10.461    147.00   3.82    0.23   3559.19    0.000   3.138
  0.000   0.01750  1.729    Pipe
"Pipe3B"   Reach      41439.00   3552.30  0.00     *3560.189  7.889     147.00   3.82    0.23   3560.42    0.000   3.138
  0.000   0.00097  3.780    Pipe
"Pipe 3B"  Reach      41731.00   3549.61  0.00     *3560.281  10.671    147.00   3.82    0.23   3560.51    0.000   3.138
  0.000   -0.00921  7.000    Pipe
"Pipe3"    Reach      42757.00   3524.00  0.00     *3560.602  36.602    147.00   3.82    0.23   3560.83    0.000   3.138
  0.000   -0.02496  7.000    Pipe
           "i.p."     43774.56   3553.92  0.00     *3560.921  7.000     147.00   3.82    0.23   3561.15    0.000   3.138
  0.025   0.02940  1.519    Pipe
"Pipe 3"   Reach      43782.00   3554.14  0.00     *3560.919  6.779     147.00   3.86    0.23   3561.15    0.000   3.138
  0.172   0.02940  1.519    Pipe
           "i.p."     44763.73   3554.90  0.00     *3561.167  6.268     147.00   4.04    0.25   3561.42    0.000   3.138
  0.245   0.00077  4.057    Pipe
           "i.p."     45452.95   3555.43  0.00     *3561.340  5.909     147.00   4.24    0.28   3561.62    0.000   3.138
  0.286   0.00077  4.057    Pipe
"Pipe 2B"  Reach      45542.00   3555.50  0.00     *3561.363  5.863     147.00   4.27    0.28   3561.65    0.000   3.138
  0.292   0.00077  4.057    Pipe
"Node69"   WallExt    45542.00   3555.50  0.00     *3561.363  5.863     147.00   5.23    0.42   3561.79    0.000   3.292
  0.000   0.00000  0.000    Pipe
"Pipe2"    Reach      48198.00   3530.00  0.00     *3564.567  34.567    147.00   5.20    0.42   3564.99    0.000   3.292
  0.000   -0.00960  6.000    Pipe
"Pipe 2"   Reach      50854.00   3559.58  0.00     *3567.766  8.186     147.00   5.20    0.42   3568.19    0.000   3.292
  0.000   0.01114  2.368    Pipe
"Node67"   WallExt    50854.00   3559.58  0.00     *3567.766  8.186     147.00   3.82    0.23   3567.99    0.000   3.138
  0.000   0.00000  0.000    Pipe
           "i.p."     51808.76   3561.07  0.00     *3568.065  7.000     147.00   3.82    0.23   3568.29    0.000   3.138
  0.025   0.00156  3.287    Pipe
           "i.p."     52304.61   3561.84  0.00     *3568.188  6.351     147.00   4.01    0.25   3568.44    0.000   3.138
  0.235   0.00156  3.287    Pipe
           "i.p."     52581.37   3562.27  0.00     *3568.241  5.974     147.00   4.20    0.27   3568.52    0.000   3.138
  0.279   0.00156  3.287    Pipe
"Pipe1B"   Reach      52654.00   3562.38  0.00     *3568.255  5.875     147.00   4.26    0.28   3568.54    0.000   3.138
  0.290   0.00156  3.287    Pipe
           "i.p."     53587.38   3562.38  0.00     *3568.549  6.169     147.00   4.09    0.26   3568.81    0.000   3.138
```

```
  0.256   0.00000  7.000    Pipe
"Pipe 1B"  Reach      53794.00   3562.38  0.00     *3568.610  6.230    147.00   4.06    0.26   3568.87    0.000   3.138
  0.249   0.00000  7.000    Pipe
"Node65"   WallExt    53794.00   3562.38  0.00     *3568.610  6.230    147.00   5.20    0.42   3569.03    0.000   3.292
  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      57075.00   3565.16  0.00     *3572.563  7.403    147.00   5.20    0.42   3572.98    0.000   3.292
  0.000   0.00085  6.000    Pipe
"Node64"   Headwrk    57075.00   3565.16  0.00     *3572.563  7.403    147.00   2.19    0.07   3572.64    0.000   3.292
  0.000   0.00000  0.000    Trapez.open

 *) in the W.S.ELEV column indicates flooding, it is set whenever W.S.ELEV > GROUND ELEV
    i.p. = intermediate point processing results for reaches
```

```
*************************************
Water Surface Profile Gradient (WSPG)
XP WSPG
Engine Version 1.3         06/09/2010
XP Software        www.xpsoftware.com
*************************************

INPUT FILE
*************************************
C:\XPS\wspg2010\Samples\TID Main Canals to Phase IV with 140 at BFC 102016 Upgrade RR Siphon to 84 Weholite.wsx
Computed  10/21/16  15:07:07

TITLE INFORMATION
*************************************

WARNING SUMMARY
*************************************
 WARNING 48: Manning's n for pipe flow of element JUNCTION not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link25 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link26 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link27 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link28 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link28 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link29 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link29 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link42 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link44 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link45 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link45 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link46 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link47 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link48 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Link49 is not larger than invert elevation of the direct downstream element.
 WARNING 48: Manning's n for pipe flow of element Link49 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Link50 not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element Pipe2 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipe3 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipe 3B is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element RR Siph is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Pipeline 4 is not larger than invert elevation of the direct downstream
element.
 WARNING 48: Manning's n for pipe flow of element Tunnel not in recommended range 0.010 - 0.015.
 WARNING 15: Invert elevation of element F4 Siph is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Link80 is not larger than invert elevation of the direct downstream element.
 WARNING 15: Invert elevation of element Link81 is not larger than invert elevation of the direct downstream element.
 WARNING 25: Link type element Link30 has different invert elevation than its upstream node.
 WARNING 48: Manning's n for pipe flow of element Link43 not in recommended range 0.010 - 0.015.
 WARNING 06: Upstream channel and downstream channel are the same for transition 84 to 62. Use a reach instead?
```

```
 WARNING 48: Manning's n for pipe flow of element 84 to 62 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to Arch not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element Arch to 84 not in recommended range 0.010 - 0.015.
 WARNING 48: Manning's n for pipe flow of element 84 to 90 not in recommended range 0.010 - 0.015.
 WARNING 06: Upstream channel and downstream channel are the same for transition Link86. Use a reach instead?
 WARNING 36: D/S processing stopped in junction JUNCTION because critical momentum is greater than maximum momentum.

RESULTS
*************************************


==============================================================
   Main Line
==============================================================

 Composite Profile:

ELEMENT    TYPE       STATION    INVERT   GROUND   W.S.      DEPTH    Q        VELOC.  VELOC. ENERGY     SUPER
CRITICAL FROUDE  SLOPE    NORMAL   CROSS
NAME                             ELEV     ELEV     ELEV                                 HEAD   GRADE LN   ELEV    DEPTH
 NUMBER           DEPTH    SECTION
---------- ---------- ---------- -------- -------- --------  -------- -------- ------- ------ ---------- ------
-------- ------  -------  ------   ---------
###
"Node97"   Outlet     22000.00   3531.01  0.00     *3534.200  3.190    180.00   10.54   1.73   3535.93    0.000   3.490
  0.000   0.00000  0.000    Pipe
           "i.p."     22177.81   3532.05  0.00     *3535.236  3.190    180.00   10.54   1.73   3536.96    0.000   3.490
  1.187   0.00583  3.190    Pipe
           "i.p."     22297.00   3532.74  0.00     *3535.981  3.239    180.00   10.33   1.66   3537.64    0.000   3.490
  1.153   0.00583  3.190    Pipe
           "i.p."     22342.40   3533.01  0.00     *3536.367  3.361    180.00   9.85    1.51   3537.87    0.000   3.490
  1.074   0.00583  3.190    Pipe
"Link84"   Reach      22350.00   3533.05  0.00     *3536.539  3.489    180.00   9.39    1.37   3537.91    0.000   3.490
  1.001   0.00583  3.190    Pipe
 HYDRAULIC JUMP  at 22582.96  of length  0.09
           "i.p."     22352.63   3533.05  0.00     *3536.675  3.623    180.00   8.95    1.24   3537.92    0.000   3.490
  0.931   0.00051  7.000    Pipe
           "i.p."     22361.63   3533.06  0.00     *3536.820  3.764    180.00   8.54    1.13   3537.95    0.000   3.490
  0.866   0.00051  7.000    Pipe
           "i.p."     22378.82   3533.06  0.00     *3536.976  3.911    180.00   8.14    1.03   3538.00    0.000   3.490
  0.804   0.00051  7.000    Pipe
           "i.p."     22406.53   3533.08  0.00     *3537.146  4.067    180.00   7.76    0.94   3538.08    0.000   3.490
  0.746   0.00051  7.000    Pipe
           "i.p."     22447.87   3533.10  0.00     *3537.332  4.232    180.00   7.40    0.85   3538.18    0.000   3.490
  0.692   0.00051  7.000    Pipe
           "i.p."     22506.96   3533.13  0.00     *3537.537  4.406    180.00   7.06    0.77   3538.31    0.000   3.490
  0.640   0.00051  7.000    Pipe
           "i.p."     22582.96   3533.17  0.00     *3537.748  4.578    180.00   6.75    0.71   3538.46    0.000   3.490
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  0.594   0.00051  7.000    Pipe
           "i.p."     22582.96   3533.17  0.00      *3535.781  2.611    180.00   13.75   2.94   3538.72    0.000   3.490
  1.743   0.00051  7.000    Pipe
           "i.p."     22594.51   3533.18  0.00      *3535.724  2.548    180.00   14.21   3.14   3538.86    0.000   3.490
  1.827   0.00051  7.000    Pipe
           "i.p."     22611.11   3533.18  0.00      *3535.644  2.460    180.00   14.91   3.45   3539.10    0.000   3.490
  1.955   0.00051  7.000    Pipe
           "i.p."     22627.83   3533.19  0.00      *3535.569  2.376    180.00   15.64   3.80   3539.36    0.000   3.490
  2.091   0.00051  7.000    Pipe
           "i.p."     22644.54   3533.20  0.00      *3535.496  2.295    180.00   16.40   4.18   3539.67    0.000   3.490
  2.236   0.00051  7.000    Pipe
           "i.p."     22661.13   3533.21  0.00      *3535.426  2.217    180.00   17.20   4.59   3540.02    0.000   3.490
  2.391   0.00051  7.000    Pipe
           "i.p."     22677.51   3533.22  0.00      *3535.360  2.142    180.00   18.04   5.05   3540.41    0.000   3.490
  2.556   0.00051  7.000    Pipe
           "i.p."     22693.64   3533.23  0.00      *3535.296  2.069    180.00   18.92   5.56   3540.85    0.000   3.490
  2.732   0.00051  7.000    Pipe
           "i.p."     22709.45   3533.23  0.00      *3535.234  2.000    180.00   19.84   6.11   3541.35    0.000   3.490
  2.920   0.00051  7.000    Pipe
           "i.p."     22724.92   3533.24  0.00      *3535.175  1.933    180.00   20.81   6.73   3541.90    0.000   3.490
  3.120   0.00051  7.000    Pipe
"Link87"   Reach      22740.00   3533.25  0.00      *3535.118  1.868    180.00   21.83   7.40   3542.52    0.000   3.490
  3.333   0.00051  7.000    Pipe
"Link86"   Transition 22750.00   3538.50  0.00      *3541.989  3.489    180.00   9.39    1.37   3543.36    0.000   3.490
  1.001   0.52500  0.000    Pipe
           "i.p."     22753.90   3538.50  0.00      *3542.164  3.664    180.00   8.83    1.21   3543.37    0.000   3.490
  0.911   0.00000  7.000    Pipe
           "i.p."     22767.18   3538.50  0.00      *3542.347  3.847    180.00   8.31    1.07   3543.42    0.000   3.490
  0.830   0.00000  7.000    Pipe
           "i.p."     22792.16   3538.50  0.00      *3542.540  4.040    180.00   7.82    0.95   3543.49    0.000   3.490
  0.756   0.00000  7.000    Pipe
           "i.p."     22831.52   3538.50  0.00      *3542.742  4.242    180.00   7.38    0.85   3543.59    0.000   3.490
  0.689   0.00000  7.000    Pipe
           "i.p."     22888.36   3538.50  0.00      *3542.954  4.454    180.00   6.97    0.75   3543.71    0.000   3.490
  0.627   0.00000  7.000    Pipe
           "i.p."     22966.16   3538.50  0.00      *3543.176  4.676    180.00   6.59    0.67   3543.85    0.000   3.490
  0.570   0.00000  7.000    Pipe
           "i.p."     23068.71   3538.50  0.00      *3543.410  4.910    180.00   6.24    0.60   3544.02    0.000   3.490
  0.518   0.00000  7.000    Pipe
"Link82"   Reach      23100.00   3538.50  0.00      *3543.473  4.973    180.00   6.16    0.59   3544.06    0.000   3.490
  0.506   0.00000  7.000    Pipe
           "i.p."     23239.41   3538.50  0.00      *3543.721  5.221    180.00   5.85    0.53   3544.25    0.000   3.490
  0.458   0.00000  7.000    Pipe
           "i.p."     23412.51   3538.50  0.00      *3543.982  5.482    180.00   5.57    0.48   3544.46    0.000   3.490
  0.414   0.00000  7.000    Pipe
           "i.p."     23622.62   3538.50  0.00      *3544.256  5.756    180.00   5.32    0.44   3544.70    0.000   3.490
  0.372   0.00000  7.000    Pipe
           "i.p."     23871.79   3538.50  0.00      *3544.544  6.044    180.00   5.10    0.40   3544.95    0.000   3.490
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  0.331   0.00000  7.000    Pipe
           "i.p."     24159.48   3538.50  0.00     *3544.847  6.347    180.00   4.91    0.37   3545.22    0.000   3.490
  0.288   0.00000  7.000    Pipe
           "i.p."     24480.13   3538.50  0.00     *3545.164  6.664    180.00   4.76    0.35   3545.52    0.000   3.490
  0.236   0.00000  7.000    Pipe
"Link53"   Reach      24700.00   3538.50  0.00     *3545.379  6.879    180.00   4.70    0.34   3545.72    0.000   3.490
  0.181   0.00000  7.000    Pipe
"Link52"   Reach      24850.00   3538.50  0.00     *3545.533  7.033    180.00   4.68    0.34   3545.87    0.000   3.490
  0.000   0.00000  7.000    Pipe
"Link51"   Transition 24861.00   3538.61  0.00     *3545.815  7.205    180.00   2.50    0.10   3545.91    0.000   2.159
  0.164   0.01000  0.000    Rect.open
"Phase II" WallExt    24861.00   3538.61  0.00     *3545.815  7.205    180.00   4.83    0.36   3546.18    0.000   3.507
  0.000   0.00000  0.000    Pipe
"Link50"   Reach      24951.00   3538.61  0.00     *3545.932  7.322    180.00   4.83    0.36   3546.29    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link49"   Reach      25001.00   3532.50  0.00     *3545.998  13.498   180.00   4.83    0.36   3546.36    0.000   3.507
  0.000   -0.12220  6.890    Pipe
"Link48"   Reach      25197.00   3535.44  0.00     *3546.254  10.814   180.00   4.83    0.36   3546.62    0.000   3.507
  0.000   0.01500  2.566    Pipe
           "i.p."     25222.02   3539.40  0.00     *3546.287  6.890    180.00   4.83    0.36   3546.65    0.000   3.507
  0.032   0.15812  1.404    Pipe
           "i.p."     25225.86   3540.00  0.00     *3546.255  6.252    180.00   5.06    0.40   3546.65    0.000   3.507
  0.299   0.15812  1.404    Pipe
           "i.p."     25227.97   3540.34  0.00     *3546.218  5.881    180.00   5.31    0.44   3546.66    0.000   3.507
  0.355   0.15812  1.404    Pipe
"Link47"   Reach      25229.00   3540.50  0.00     *3546.194  5.694    180.00   5.46    0.46   3546.66    0.000   3.507
  0.383   0.15812  1.404    Pipe
           "i.p."     25427.97   3540.50  0.00     *3546.479  5.979    180.00   5.24    0.43   3546.90    0.000   3.507
  0.340   0.00000  6.890    Pipe
           "i.p."     25657.66   3540.50  0.00     *3546.778  6.278    180.00   5.05    0.40   3547.17    0.000   3.507
  0.295   0.00000  6.890    Pipe
           "i.p."     25913.17   3540.50  0.00     *3547.092  6.592    180.00   4.90    0.37   3547.46    0.000   3.507
  0.239   0.00000  6.890    Pipe
"Link46"   Reach      27095.00   3540.50  0.00     *3548.627  8.127    180.00   4.83    0.36   3548.99    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link45"   Reach      27223.00   3538.05  0.00     *3548.795  10.745   180.00   4.83    0.36   3549.16    0.000   3.507
  0.000   -0.01914  6.890    Pipe
"Link44"   Reach      27273.00   3538.05  0.00     *3548.860  10.810   180.00   4.83    0.36   3549.22    0.000   3.507
  0.000   0.00000  6.890    Pipe
"Link43"   Transition 27275.00   3538.05  0.00     *3548.980  10.930   180.00   4.07    0.26   3549.24    0.000   3.416
  0.000   0.00000  0.000    Pipe
"Link42"   Reach      27408.00   3519.50  0.00     *3549.077  29.577   180.00   4.07    0.26   3549.34    0.000   3.416
  0.000   -0.13947  7.500    Pipe
"Link41"   Reach      27508.00   3521.00  0.00     *3549.151  28.151   180.00   4.07    0.26   3549.41    0.000   3.416
  0.000   0.01500  2.395    Pipe
"Link40"   Reach      27554.00   3538.41  0.00     *3549.184  10.774   180.00   4.07    0.26   3549.44    0.000   3.416
  0.000   0.37848  1.072    Pipe
"Link39"   Reach      27606.00   3538.41  0.00     *3549.222  10.812   180.00   4.07    0.26   3549.48    0.000   3.416
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  0.000   0.00000  7.500    Pipe
"Link38"   Reach      27768.00   3540.50  0.00     *3549.341  8.841    180.00   4.07    0.26   3549.60    0.000   3.416
  0.000   0.01290  2.491    Pipe
"Link37"   Reach      30558.00   3540.50  0.00     *3551.382  10.882   180.00   4.07    0.26   3551.64    0.000   3.416
  0.000   0.00000  7.500    Pipe
"Link36"   Reach      30733.00   3543.23  0.00     *3551.510  8.280    180.00   4.07    0.26   3551.77    0.000   3.416
  0.000   0.01560  2.370    Pipe
"Link35"   Reach      32146.00   3543.23  0.00     *3552.544  9.314    180.00   4.07    0.26   3552.80    0.000   3.416
  0.000   0.00000  7.500    Pipe
"Link34"   Reach      32272.00   3543.29  0.00     *3552.636  9.346    180.00   4.07    0.26   3552.89    0.000   3.416
  0.000   0.00048  7.500    Pipe
"Link33"   Reach      32280.00   3543.29  0.00     *3552.642  9.352    180.00   4.07    0.26   3552.90    0.000   3.416
  0.000   0.00000  7.500    Pipe
"JUNCTION" Join       32280.00   3543.29  0.00     *3552.903  9.613    36.00    0.81    0.01   3552.91    0.000   1.488
  0.000   0.00000  0.000    Pipe
"Link32"   Reach      32338.00   3543.46  0.00     *3552.904  9.444    36.00    0.81    0.01   3552.91    0.000   1.488
  0.000   0.00293  1.434    Pipe
"Link31"   Reach      33308.00   3544.00  0.00     *3552.923  8.923    36.00    0.81    0.01   3552.93    0.000   1.488
  0.000   0.00056  2.175    Pipe
"Node35"   WallEnt    33308.00   3544.00  0.00     *3552.937  8.937    36.00    0.44    0.00   3552.94    0.000   0.792
  0.000   0.00000  0.000    Trapez.open
"Link30"   Transition 33321.00   3542.00  0.00     *3552.938  10.938   36.00    0.33    0.00   3552.94    0.000   0.738
  0.018   -0.15385  0.000    Rect.open
"TFC EXIT" WallExt    33321.00   3542.00  0.00     *3552.938  10.938   36.00    1.01    0.02   3552.95    0.000   1.534
  0.000   0.00000  0.000    Pipe
"Link29"   Reach      33405.00   3536.40  0.00     *3552.944  16.544   36.00    1.01    0.02   3552.96    0.000   1.534
  0.000   -0.06667  6.730    Pipe
"Link28"   Reach      33505.00   3508.00  0.00     *3552.951  44.951   36.00    1.01    0.02   3552.97    0.000   1.534
  0.000   -0.28400  6.730    Pipe
"Link27"   Reach      33625.00   3508.00  0.00     *3552.959  44.959   36.00    1.01    0.02   3552.97    0.000   1.534
  0.000   0.00000  6.730    Pipe
"Link26"   Reach      34825.00   3523.87  0.00     *3553.039  29.169   36.00    1.01    0.02   3553.05    0.000   1.534
  0.000   0.01322  1.215    Pipe
"Link25"   Reach      36288.00   3546.17  0.00     *3553.137  6.967    36.00    1.01    0.02   3553.15    0.000   1.534
  0.000   0.01524  1.174    Pipe
"TFC HDWL" WallEnt    36288.00   3546.17  0.00     *3553.161  6.991    36.00    0.51    0.00   3553.16    0.000   0.738
  0.000   0.00000  0.000    Rect.open
"Link24"   Transition 36298.00   3548.20  0.00     *3553.163  4.963    36.00    0.36    0.00   3553.16    0.000   0.465
  0.029   0.20300  0.000    Rect.open
"Link23"   Reach      36308.00   3548.20  0.00     *3553.163  4.963    36.00    0.36    0.00   3553.16    0.000   0.465
  0.029   0.00000  9.000    Rect.open
"TFC Head" Headwrk    36308.00   3548.20  0.00     *3553.163  4.963    36.00    0.36    0.00   3553.16    0.000   0.465
  0.000   0.00000  0.000    Rect.open

 *) in the W.S.ELEV column indicates flooding, it is set whenever W.S.ELEV > GROUND ELEV
    i.p. = intermediate point processing results for reaches
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   JUNCTION_Branch1
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 Composite Profile:

ELEMENT    TYPE       STATION    INVERT   GROUND   W.S.      DEPTH    Q        VELOC.  VELOC. ENERGY     SUPER
CRITICAL FROUDE  SLOPE    NORMAL   CROSS
NAME                             ELEV     ELEV     ELEV                                HEAD   GRADE LN   ELEV    DEPTH
 NUMBER           DEPTH    SECTION
---------- ---------- ---------- -------- -------- --------  -------- -------- ------- ------ ---------- ------
-------- ------  -------  ------   ---------
###
"Outlet/J" Outlet     32280.00   3543.39  0.00     *3552.773  9.383    144.00   3.26    0.16   3552.94    0.000   3.040
  0.000   0.00000  0.000    Pipe
"Link81"   Reach      32314.00   3542.50  0.00     *3552.780  10.280   144.00   3.26    0.16   3552.94    0.000   3.040
  0.000   -0.02618  7.500    Pipe
"Link80"   Reach      32339.00   3540.00  0.00     *3552.785  12.785   144.00   3.26    0.16   3552.95    0.000   3.040
  0.000   -0.10000  7.500    Pipe
"84 to 90" Transition 32343.00   3540.00  0.00     *3552.751  12.751   144.00   3.74    0.22   3552.97    0.000   3.105
  0.000   0.00000  0.000    Pipe
"F4 Siph"  Reach      32543.00   3477.00  0.00     *3552.824  75.824   144.00   3.74    0.22   3553.04    0.000   3.105
  0.000   -0.31500  7.000    Pipe
"F4 Sipho" Reach      32827.00   3540.85  0.00     *3552.927  12.077   144.00   3.74    0.22   3553.14    0.000   3.105
  0.000   0.22482  0.958    Pipe
           "i.p."     33737.38   3546.20  0.00     *3553.201  7.000    144.00   3.74    0.22   3553.42    0.000   3.105
  0.024   0.00588  2.263    Pipe
           "i.p."     33849.40   3546.86  0.00     *3553.210  6.351    144.00   3.92    0.24   3553.45    0.000   3.105
  0.230   0.00588  2.263    Pipe
           "i.p."     33912.38   3547.23  0.00     *3553.204  5.974    144.00   4.12    0.26   3553.47    0.000   3.105
  0.273   0.00588  2.263    Pipe
           "i.p."     33963.35   3547.53  0.00     *3553.192  5.664    144.00   4.32    0.29   3553.48    0.000   3.105
  0.309   0.00588  2.263    Pipe
"Pipe5"    Reach      34001.00   3547.75  0.00     *3553.180  5.430    144.00   4.50    0.31   3553.49    0.000   3.105
  0.338   0.00588  2.263    Pipe
           "i.p."     34411.19   3548.11  0.00     *3553.294  5.181    144.00   4.71    0.35   3553.64    0.000   3.105
  0.373   0.00088  3.840    Pipe
"Pipe 5"   Reach      34578.00   3548.26  0.00     *3553.343  5.083    144.00   4.81    0.36   3553.70    0.000   3.105
  0.387   0.00088  3.840    Pipe
"Arch to " Transition 34586.00   3548.26  0.00     *3553.181  4.921    144.00   6.28    0.61   3553.79    0.000   3.326
  0.442   0.00000  0.000    Pipe
           "i.p."     34725.61   3548.45  0.00     *3553.724  5.273    144.00   5.99    0.56   3554.28    0.000   3.326
  0.349   0.00137  5.600    Pipe
           "i.p."     34859.79   3548.64  0.00     *3554.235  5.600    144.00   5.85    0.53   3554.77    0.000   3.326
  0.000   0.00137  5.600    Pipe
"Tunnel"   Reach      35338.00   3549.29  0.00     *3556.126  6.836    144.00   5.85    0.53   3556.66    0.000   3.326
  0.000   0.00137  5.600    Pipe
"84 to Ar" Transition 35346.00   3549.29  0.00     *3556.511  7.221    144.00   3.74    0.22   3556.73    0.000   3.105
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  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      36266.00   3547.26  0.00     *3556.787  9.527    144.00   3.74    0.22   3557.00    0.000   3.105
  0.000   -0.00221  7.000    Pipe
"62 to 84" Reach      36274.00   3547.26  0.00     *3556.790  9.530    144.00   3.74    0.22   3557.01    0.000   3.105
  0.000   0.00000  7.000    Pipe
"RR Siph"  Reach      36419.00   3469.86  0.00     *3556.833  86.973   144.00   3.74    0.22   3557.05    0.000   3.105
  0.000   -0.53379  7.000    Pipe
"RR Sipho" Reach      36679.00   3469.86  0.00     *3556.911  87.051   144.00   3.74    0.22   3557.13    0.000   3.105
  0.000   0.00000  7.000    Pipe
"RR Sipho" Reach      37111.00   3541.50  0.00     *3557.041  15.541   144.00   3.74    0.22   3557.26    0.000   3.105
  0.000   0.16583  0.985    Pipe
"84 to 62" Transition 37119.00   3541.50  0.00     *3557.060  15.560   144.00   3.74    0.22   3557.28    0.000   3.105
  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      37519.00   3548.50  0.00     *3557.180  8.680    144.00   3.74    0.22   3557.40    0.000   3.105
  0.000   0.01750  1.712    Pipe
           "i.p."     40031.92   3550.94  0.00     *3557.936  7.000    144.00   3.74    0.22   3558.15    0.000   3.105
  0.024   0.00097  3.733    Pipe
           "i.p."     40943.03   3551.82  0.00     *3558.171  6.351    144.00   3.92    0.24   3558.41    0.000   3.105
  0.230   0.00097  3.733    Pipe
"Pipe3B"   Reach      41439.00   3552.30  0.00     *3558.282  5.982    144.00   4.11    0.26   3558.54    0.000   3.105
  0.272   0.00097  3.733    Pipe
           "i.p."     41468.48   3552.03  0.00     *3558.310  6.281    144.00   3.96    0.24   3558.55    0.000   3.105
  0.238   -0.00921  7.000    Pipe
           "i.p."     41500.03   3551.74  0.00     *3558.333  6.595    144.00   3.83    0.23   3558.56    0.000   3.105
  0.199   -0.00921  7.000    Pipe
           "i.p."     41533.79   3551.43  0.00     *3558.352  6.925    144.00   3.75    0.22   3558.57    0.000   3.105
  0.128   -0.00921  7.000    Pipe
"Pipe 3B"  Reach      41731.00   3549.61  0.00     *3558.412  8.802    144.00   3.74    0.22   3558.63    0.000   3.105
  0.000   -0.00921  7.000    Pipe
"Node72"   WallExt    41731.00   3549.61  0.00     *3558.412  8.802    144.00   5.09    0.40   3558.81    0.000   3.257
  0.000   0.00000  0.000    Pipe
"Pipe3"    Reach      42757.00   3524.00  0.00     *3559.598  35.598   144.00   5.09    0.40   3560.00    0.000   3.257
  0.000   -0.02496  6.000    Pipe
"Pipe 3"   Reach      43782.00   3554.14  0.00     *3560.783  6.643    144.00   5.09    0.40   3561.19    0.000   3.257
  0.000   0.02940  1.812    Pipe
"Node70"   WallEnt    43782.00   3554.14  0.00     *3561.061  6.921    144.00   3.75    0.22   3561.28    0.000   3.105
  0.000   0.00000  0.000    Pipe
           "i.p."     44907.14   3555.01  0.00     *3561.342  6.333    144.00   3.93    0.24   3561.58    0.000   3.105
  0.232   0.00077  4.004    Pipe
"Pipe 2B"  Reach      45542.00   3555.50  0.00     *3561.494  5.994    144.00   4.10    0.26   3561.76    0.000   3.105
  0.271   0.00077  4.004    Pipe
"Node69"   WallExt    45542.00   3555.50  0.00     *3561.494  5.994    144.00   5.09    0.40   3561.90    0.000   3.257
  0.000   0.00000  0.000    Pipe
"Pipe2"    Reach      48198.00   3530.00  0.00     *3564.564  34.564   144.00   5.09    0.40   3564.97    0.000   3.257
  0.000   -0.00960  6.000    Pipe
"Pipe 2"   Reach      50854.00   3559.58  0.00     *3567.635  8.055    144.00   5.09    0.40   3568.04    0.000   3.257
  0.000   0.01114  2.342    Pipe
"Node67"   WallExt    50854.00   3559.58  0.00     *3567.634  8.054    144.00   3.74    0.22   3567.85    0.000   3.105
```

```
  0.000   0.00000  0.000    Pipe
           "i.p."     51694.26   3560.89  0.00     *3567.887  7.000    144.00   3.74    0.22   3568.10    0.000   3.105
  0.024   0.00156  3.248    Pipe
           "i.p."     52186.23   3561.65  0.00     *3568.004  6.351    144.00   3.92    0.24   3568.24    0.000   3.105
  0.230   0.00156  3.248    Pipe
           "i.p."     52461.30   3562.08  0.00     *3568.055  5.974    144.00   4.12    0.26   3568.32    0.000   3.105
  0.273   0.00156  3.248    Pipe
"Pipe1B"   Reach      52654.00   3562.38  0.00     *3568.089  5.709    144.00   4.28    0.29   3568.37    0.000   3.105
  0.304   0.00156  3.248    Pipe
           "i.p."     53551.79   3562.38  0.00     *3568.374  5.994    144.00   4.10    0.26   3568.64    0.000   3.105
  0.271   0.00000  7.000    Pipe
"Pipe 1B"  Reach      53794.00   3562.38  0.00     *3568.447  6.067    144.00   4.06    0.26   3568.70    0.000   3.105
  0.262   0.00000  7.000    Pipe
"Node65"   WallExt    53794.00   3562.38  0.00     *3568.447  6.067    144.00   5.09    0.40   3568.85    0.000   3.257
  0.000   0.00000  0.000    Pipe
"Pipeline" Reach      57075.00   3565.16  0.00     *3572.240  7.080    144.00   5.09    0.40   3572.64    0.000   3.257
  0.000   0.00085  6.000    Pipe
"Node64"   Headwrk    57075.00   3565.16  0.00     *3572.240  7.080    144.00   2.24    0.08   3572.32    0.000   3.257
  0.000   0.00000  0.000    Trapez.open

 *) in the W.S.ELEV column indicates flooding, it is set whenever W.S.ELEV > GROUND ELEV
    i.p. = intermediate point processing results for reaches
```

APPENDIX C
PIPE BUDGET ESTIMATES FROM VENDORS

From: **Theetge, Mark A** <Mark.Theetge@hdsupply.com>
Date: Thu, Sep 15, 2016 at 8:55 AM
Subject: RE: Swalley Pipe Lengths
To: Kevin Crew <blackrockci@gmail.com>

Great to hear! I have attached basic pricing that I may end up refining for my own interest and share that later. The cost that I have used is based on actual footage which could include partial loads. The freight cost I have included is for the furthest distance which would be Kingman AZ. I have also included cost for a tech and equipment to weld the material. I used current project pricing levels and a conservative mark up about 12%. All of this could change with the market so for basic estimation only!!

If it was my district I might want to include cost for fusion equipment purchase in the cost of the project. For material 24" and down or possibly 18" and down based on the cooperation of other districts. Given Marc has a 36" machine and since there is not a whole lot of larger pipe it would make sense to rent possibly. Just a thought?

Thanks,

Mark A. Theetge

Fusible Plastics Specialist

HD Supply WaterWorks

M 503 341 3614

F 855 222-0361

	Proposed DR32.5		Proposed DR26		Proposed DR21	
54in	0.00		0.00		0.00	
48in	2,094.13	$105.50	0.00		0.00	
42in	4,559.92	$81.92	0.00		0.00	
36in	6,708.70	$62.89	0.00		0.00	
34in	1,932.25	$54.73	0.00		0.00	
32in	830.58	$4,703	0.00		0.00	
30in	2,558.88	$42.15	0.00		0.00	
28in	3,085.71	$37.05	1,664.91	$44.98	0.00	
26in	0.00	$0.00	2,745.63	$39.95	0.00	
24in	5,727.49	$26.86	2,533.51	$32.98	0.00	
22in	0.00	$0.00	0.00		0.00	
20in	6,350.76	$19.45	1,282.68	$24.15	0.00	
18in	5,644.83	$15.41	347.84	$23.97	319.85	$28.14
16in	2,295.26	$15.27	1,926.59	$15.61	3,038.68	$22.13
14in	9,163.29	$9.48	1,119.91	$12.78	1,565.95	$13.77
12in	8,351.11	$7.81	4,588.71	$9.56	2,437.56	$11.35
10in	9,020.98	$5.82	2,197.32	$7.23	2,380.32	$8.75
8in	13,531.69	$3.93	4,736.81	$4.68	525.96	$10.16

Irrigation District Water Efficiency Cost Analysis and Prioritization

DWA Final Report

August 2006

David Newton, P.E.[1]

Mathias Perle[1]

The authors wish to thank the Bureau of Reclamation for sponsoring this report as part of the Deschutes Water Alliance Water 2025 Grant (see www.deschutesriver.org/Water_summit for more information).

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Deschutes Water Alliance
Irrigation District Water Efficiency Cost Analysis and Prioritization– May 2006

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FOREWORD

BACKGROUND

The upper Deschutes Basin comprises about 4,500 square miles of watershed between the highland areas to the east, south and west, and Lake Billy Chinook to the north. The Central Oregon area, located within the upper basin, is experiencing rapid growth and changes in both lifestyle and land uses. Along with these changes, long-recognized water resources issues have become more important and a number of others have developed.

More effective use of water resources to broaden the benefits of water use in connection with irrigation, stream flow restoration, protection of scenic waterway flows and water quality improvements has long been an important resource management issue in the upper basin. Other developing issues include need for safe, reliable water supply for future basin needs, urbanization of irrigated lands and impacts on agriculture, and needs to protect flows for fishery, recreation and other in-stream uses.

The significance of basin water issues has increased considerably over the last few years. The rapid growth and subsequent water needs that the region is experiencing presents an opportunity to study these issues in more detail given changing values and availability of funding. Consequently, water usage and availability are now a major topic in discussions among basin water suppliers and planners. Due to increased dialogue and awareness relative to water issues, regional urban water suppliers, irrigation districts and other private, government and individual water users now recognize their interdependency in the use, management and protection of Deschutes Basin water resources. This recognition and related dialogue enjoined the major water suppliers in a common vision that commits energy and resources in a collaborative effort to respond to basin water issues.

Water supply, water quality, flow depletion and irrigation district urbanization issues in the upper Deschutes Basin establish the framework for need for the Deschutes Water Alliance. Mutually beneficial opportunities exist for municipalities and flow restoration interests to obtain needed water supply and for irrigation districts to resolve urbanization and conservation issues. Some of the key management considerations involved with these opportunities:

- Full appropriation of surface waters
- Declaration of groundwater restrictions and related mitigation requirements
- Dependency of municipal water providers on groundwater for future needs
- Diversion of substantial river flows by irrigation districts
- 303(d) listings for water quality parameters and need for TMDLs throughout the Deschutes and Crooked Subbasins.
- Protection of scenic waterway flows in the lower reaches of the Deschutes and Crooked Rivers

- Potential Endangered Species Act issues
- Re-Introduction of anadramous fish species in the Deschutes and Crooked Rivers
- Rapid growth, urbanization and land-use change in the basin

Organization

The Deschutes Water Alliance (DWA) was formed by four major basin partners to develop and implement integrated water resources management programs in the upper Deschutes Basin. The partners include**:**

- Deschutes Basin Board of Control (DBBC): represents seven irrigation districts in the basin including Bureau of Reclamation's Deschutes Project North Unit Irrigation District and Ochoco Projects formed under ORS 190.125.
- Central Oregon Cities' Organization (COCO): which is comprised of cities in the basin and affiliated drinking water districts and private companies providing potable water supply.
- Deschutes River Conservancy (DRC):
- Confederated Tribes of Warm Springs (CTWS)

Goals and objectives

The DWA is investing in managing the water resources of the Deschutes Basin in a unified way to provide:

- Reliable and safe water supply for the region's future municipal and agriculture needs and sustained economic viability considering growth, urbanization and related effects on water resources;
- Financial stability for the Basin's irrigation districts and their patrons;
- Protection of the fishery, wildlife, existing water rights, recreational and aesthetic values of the Deschutes River along with stream flow and water quality improvements;
- Focus on maintaining the resource and land base in the Basin, consistent with acknowledged comprehensive land use plans; and
- An institutional framework that supports the orderly development of local water markets to protect participants and create an "even playing field" for water transactions.

These considerations are key elements to be incorporated into development of the integrated water resources management and restoration program.

Approach

Mutually beneficial opportunities exist to boost water supply for agriculture, municipal needs and stream flow for fish, wildlife and water quality improvements. Mutually beneficial opportunities also exist through integrated planning for irrigation districts to resolve urbanization issues. In order to develop a framework and program to achieve these objectives, the DWA is implementing five planning studies under a Water 2025 Program grant to generate facts and background information necessary for program formulation. The planning study results will be synthesized into a Water Supply, Demand and Water Reallocation document with project scenarios, five-year implementation bench marks and 20-year timeframe. The five planning studies are as follows:

- Irrigation District Water Conservation Cost Analysis and Prioritization-an evaluation and prioritization of opportunities to save water through piping and lining of canals, laterals and ditches, as well as through on-farm conservation technologies.
- Growth, Urbanization and Land Use Change: Impacts on Agriculture and Irrigation Districts in Central Oregon. (Title in Water 2025 Grant was *Impacts of Urbanization on Irrigable Lands*) -an inventory of amounts, patterns and rates of district water rights becoming surplus due to urbanization or other changes in land use patterns in Central Oregon and corresponding impact on district assessments.
- Reservoir Management (Title in Water 2025 Grant was *Reservoir Optimization Study and Water Quality*)- prepare rapid assessment of potential gains from optimization of existing reservoirs and their potential impact on improving flow and quality, and prepare terms of reference for more formal and rigorous assessment.
- Future Groundwater Demand in the Deschutes Basin (Title in Water 2025 Grant was *Municipal Water Demand*)-assessment of the water supply needs, quantity and timeline of the Basin's regional urban suppliers.
- In-stream Flow in the Deschutes Basin: Monitoring, Status and Restoration Needs (Title in Water 2025 Grant was *Measurement, Monitoring and Evaluations* Systems)- In-stream Flow Needs for Fish, Wildlife and recreation along with Measurement, Monitoring and Evaluation Systems-assessment of the suitability and completeness of existing flow measurement sites and existing Water Quality and Monitoring Plan for the Upper Deschutes Basin and prepare funding and implementation action plan.

EXECUTIVE SUMMARY

Background

There has been a push in recent years to reduce conveyance losses and broaden the benefits of water use by utilizing water more effectively in connection with irrigation, stream flow restoration, protection of scenic waterway flows and water quality improvements. This concern for making more effective use of existing water resources is linked to a number of factors. These include fully appropriated surface water rights, annual shortages of water within irrigation districts including Bureau of Reclamation (Reclamation) projects and irrigation water storage and diversion that significantly decrease flows in the Upper/Middle Reaches of the Deschutes River and its tributaries subsequently contributing to habitat loss and water quality degradation.

Water quality and re-introduction of anadromous fish species are increasing the need for proactive management of basin water resources to account for these issues and to improve supply for basin water users in ways that reduce competition and conflict. Other developing concerns include the need for safe, reliable water supply for future basin needs, urbanization of irrigated lands and impacts on agriculture.

Previous studies have been conducted by Reclamation beginning in the 1960's to conserve water for improving supply reliability to irrigators and to increase river flows for habitat and water quality purposes; however, projects have never been implemented due to funding constraints. The most recent Reclamation 1997 report *"Upper Deschutes River Basin Water Conservation Study, Special Report, Crook, Deschutes, and Jefferson Counties, Oregon"*, published in April 1997 specifically appraised how improved water use efficiency could improve irrigation water supply reliability and increase winter and summer flows in the Upper Deschutes River. Irrigation District locations in the basin are shown in Figure 1.

Purpose

This study was prepared by the DWA to demonstrate the feasibility of efficiency projects throughout the basin. This report summarizes completed efficiency projects throughout the basin along with their associated water savings and costs. Sets of potential criteria were developed to help determine how best to prioritize proposed future efficiency projects within the basin. The proposed criteria are:

- Total volume of saved water available for in-stream flow augmentation and water availability for use by agricultural interests;
- Restrictions on use of saved water that would delay availability of saved water for other uses.
- Urbanization impacts on district operations and increased O&M efficiency;
- Energy conservation and hydropower opportunities.

Proposed efficiency projects are presented for the eight irrigation districts in the basin based on these above criteria. Potential efficiency projects were chosen within each district based on underlying geology and seepage loss potential, benefits related to urbanization pressures, implementation costs, potential tax credits linked to hydroelectric facilities and potential power generation and associated revenue.

A brief overview of potential water savings from on-farm conservation practices is also presented along with common on-farm conservation methods and associated water savings. More analysis should be conducted to accurately determine costs and associated water savings of on-farm conservation measures within individual districts.

Findings

Completed Efficiency Projects

A number of irrigation district efficiency improvements have been completed since the 1997 Reclamation report. These improvements through reducing seepage losses in conveyance systems and improving on-farm efficiency have reduced water losses by 45,360 acre-feet on an annual basis in the Upper Deschutes Basin. These results can be seen in Table ES-1 below. Locations of proposed projects are shown in Figures ES-1 through ES-3.

Table ES-1 Completed Efficiency Projects

Irrigation District	Reach / Canal / Lateral	Length of Project (miles)	Total Water Savings per season (ac-ft)	Total Water Savings per season (cfs)	Total Cost of Project ($)	Cost of Project per acre-foot of water saved ($)
Central Oregon	H14-1 lateral piping	1.3	180.2	0.43	$168,000	$932
	Alfalfa H & J lateral[1]	1.86	1,103	3.10	$50,877	$46
North Unit	Main Canal lining	11.8	23,000	64.40	$7,405,172	$322
	NUID 51-4 lateral piping	4.75	300	1.40	$89,217	$297
Swalley	Deschutes Lateral	1.43	627	1.51	$229,019	$365
	Kotzman Lateral	2.2	1864	4.48	$227,902	$122
Three Sisters	Fryrear & Cloverdale laterals	6.3	2,578	7.20	$432,307	$168
	Vermilyea, Schaad, B-Ditch, Z-Ditch, Vetterlein laterals piping	7.2	990	2.80	$?	$?
	Brown[2], Bartlemay[2], laterals	1.52	900	2.52	$?	$?
	Thompson[2][1]	Not applicable	714	2.00	$?	$?
Tumalo	Bend Feed Canal piping[3]	5.0	13,103	36.70	$6,400,000	$488
TOTALS		**43.36**	**45,360**	**126.53**	**$15,002,494**	

[1]Water savings represent waters transferred in-stream. Total water saved from project is higher.
[2]Savings from both canal removal and/or piping/lining and on-farm efficiency projects.
[3]Savings represent water used for in-stream flow augmentation and improving irrigation supply reliability.

These waters were then used for multiple beneficial uses including augmentation of irrigation supply and in-stream flows. Districts implemented additional efficiency projects. Water savings, however, for these additional projects were not quantified. These projects were constructed to alleviate the pressures of urbanization on districts by diminishing safety concerns and operations and maintenance costs associated with laterals in urban areas.

Proposed Efficiency Projects

Data was gathered from all eight irrigation districts, the 1997 Reclamation study and consulting firms within the basin to select project locations with higher potential for efficiency, cost and time effective conservation, and market benefits. Where multiple projects existed within districts, they were ranked in ascending order of cost per acre-foot of water conserved. Total water saving and cost from all proposed district piping and lining efficiency projects are included in Table ES-2 below. Locations of proposed projects are shown in Figures ES-1 through ES-3.

Table ES-2 Summary of Proposed Efficiency Projects

Project	Location	Length (Miles)	Length (Feet)	SAVED WATER (per irrigation season)			COST	
				Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)	Total Saved Water Cost 2006	Cost per AF Saved (average)
AID (P)	Laterals	3.03	16,000	2,250	6.30	3.28	ND	ND
COID (P) (1)	Central Oregon Main	6.35	33,528	15,052	42.16	14.29	$21,020,000	$1,396
	Pilot Butte Main(5)	5.80	30,624	20,458	57.30	17.12	$16,366,400	$800
	Central Oregon Laterals	10.36	54,699	3,700	10.36	5.98	$4,217,610	$1,140
	Pilot Butte Laterals	16.08	84,902	6,770	18.96	15.69	$3,510,276	$518
LPID (P)	Main Canals & Laterals	14.41	76,085	2,947	8.27	7.38	$4,800,000	$1,629
NUID (L) (2)(3)	Main(5)	18.70	98,736	14,395	40.39	71.56	$15,291,002	$1,062
	58-9 Lateral	7.48	39,515	2,678	7.50	4.60	$2,946,240	$1,100
OID	Prineville Diversion Canal	1.25	6,600	ND	ND	0.39	ND	ND
SID (P)(4)	Main Canal(5)	5.10	26,928	9,663	23.20	19.24	$4,628,639	$479
	Laterals	15.92	84,073	9,500	22.81	22.81	$3,631,613	$382
TSID (P)	McKenzie/Black Butte Canal	10.70	56,520	3,035	8.50	6.83	$5,440,800	$1,793
	Main Canal	3.70	19,536	2,678	7.50	2.07	ND	ND
TID (P)(4)	Main	6.00	31,680	7,141	20.00	7.22	$14,000,000	$1,961
Sub-Total		**124.89**	**659,426**	**100,268**	**273.26**	**198.46**	**$95,852,580**	**$1,115**
On-Farm Efficiency Projects	All Districts(6)			10,000	28.10	46.23	$4,956,910	$496
Totals for all potential projects		**124.88**	**655,129**	**110,268**	**301.36**	**244.69**	**$100,809,490**	**$1,022**

ND: No Data Available

(1) Construction and piping cost include a 10% contingency

(2) Lining project conserved water assumes an average loss of 1100 AF/mile and a 70% efficiency.

(3) Construction and lining cost include a 30% contingency. Construction and lining cost includes shotcrete sides from mile 7.4 to 12.3.

(4) Construction and Piping cost include surveying, engineering.

(5) Total saved water costs reflect savings from hydropower production.

(6) Water savings cost based on $/ac-ft saved water for same projects in Reclamation 1997 report.

It is estimated that 110,268 acre-feet could be saved on an annual basis if all efficiency projects listed in Table ES-2 were implemented. This saved water could then be used for agricultural and in-stream flow purposes without increasing consumptive use in the upper Deschutes Basin and would be available to both Reclamation and non-Reclamation projects. Distribution of saved water to users with short supply, including Reclamation projects (NUID), could be facilitated through a water bank. Analysis shows that these proposed projects are cost effective considering previous Reclamation evaluations (1997), completed projects, water savings and costs. Costs associated with implementing the efficiency projects listed in Table ES-2 are approximately $100,809,490. The average cost of saved water per acre foot is about $1,022. Net costs of saved water could actually be lower after accounting for energy benefits related to hydro power. Costs associated with certain efficiency projects in the Three Sisters Irrigation District and Arnold Irrigation District are currently being assessed and are therefore not reflected in the above total cost. The cost for proposed individual lateral and main piping projects ranged from $97 to $1,961 per acre-foot of conserved water. Costs per acre-foot of conserved water in Table ES-2 represent averages across all proposed projects within each district.

Certain districts through further feasibility studies have been able to reduce piping project costs by incorporating hydroelectric facilities in suitable reaches. Water conveyance efficiency projects cover a wide range of benefits including:

- Piping reduces liability exposure from safety hazards inherent in open canals in urbanizing areas;
- Piping/lining provides water for in-stream flow and other district water needs;
- Piping can eliminate conflict between urban/suburban landowners;
- Piping will substantially reduce or eliminate operations and maintenance requirements;
- Piping can provide gravity pressure with energy conservation benefits;
- Piping improves reliability of water delivery and improves control of water delivery to more closely match demand fluctuations, which reduces need for additional transport flows;
- Piping provides the opportunity to develop small hydropower facilities for revenue opportunities;
- Piping is a logical and practical solution for water conservation, improved delivery efficiency, energy conservation, reduced operations and maintenance and reduced safety concerns in urbanizing areas.

1.

Additional benefits involve reduction of annual operations and maintenance costs associated with canals and laterals, reduction in safety hazards associated with open canal systems in developing areas, and decreased power costs to irrigators associated with piped pressurized water systems.

On-Farm Efficiency

Since the 1997 report, irrigation districts in cooperation with consultants, Soil and Water Conservation Districts (SWCD) and the National Resources Conservation Service (NRCS) have compiled and implemented water conservation plans furthering the goal of improving and identifying on-farm efficiency opportunities. Analysis of on-farm conservation opportunities based on the 1997 Reclamation study show that an additional 112,410 to 146,698 ac-ft of water could be saved if on-farm efficiency were improved to 70-80% across all districts. It is unlikely, however, that on-farm efficiency improvements could be implemented district wide within the next 20 years. Given implementation feasibility, it has been estimated that approximately 10,000 ac-ft could be saved within the next 20 years by on-farm conservation at a cost of approximately $496 per acre-foot of water saved.

Issues

Further study should be conducted in order to identify efficiency projects on a district by district basis. By utilizing measuring and monitoring systems combined with seepage analysis, efficiency projects providing the greatest potential for saved water can be identified. This analysis combined with studies of implementation costs, surrounding land use pressures and use of saved water limitation will help further prioritize potential projects in the basin. Currently, this level of detailed analysis has been carried out for only a number of irrigation districts in the Deschutes Basin. These studies carried out for all districts will further help prioritize efficiency project implementation.

Additional issues to be addressed are listed below:

- Further evaluate project selection criteria developed in this report to ensure that all basin needs and concerns are addressed. Solidifying these criteria by all interested parties will promote project selection and implementation scheduling.
- Further determine and assess restraints that exist on the use of saved water for multiple purposes so that projects selected have the greatest potential for satisfying water supply needs of the upper basin.
- Piping and lining of canals and laterals reduces seepage, which contributes to aquifer recharge in the central area of the upper basin. The estimated annual water savings from piping and lining projects is approximately 3% of total average annual recharge. Nonetheless, considerations of potential impacts of piping and lining related to aquifer recharge are warranted.
- Reduced water demand brought about by conveyance efficiency projects should be integrated with reservoir management to help allocate saved water to in-stream flows during winter in the upper Deschutes River and during summer in the middle Deschutes River.
- Further evaluate the non-water savings benefit potential of these projects so as to provide additional financing sources.

Figure ES-1 Completed and Proposed Efficiency Projects (COID, NUID, LPID)

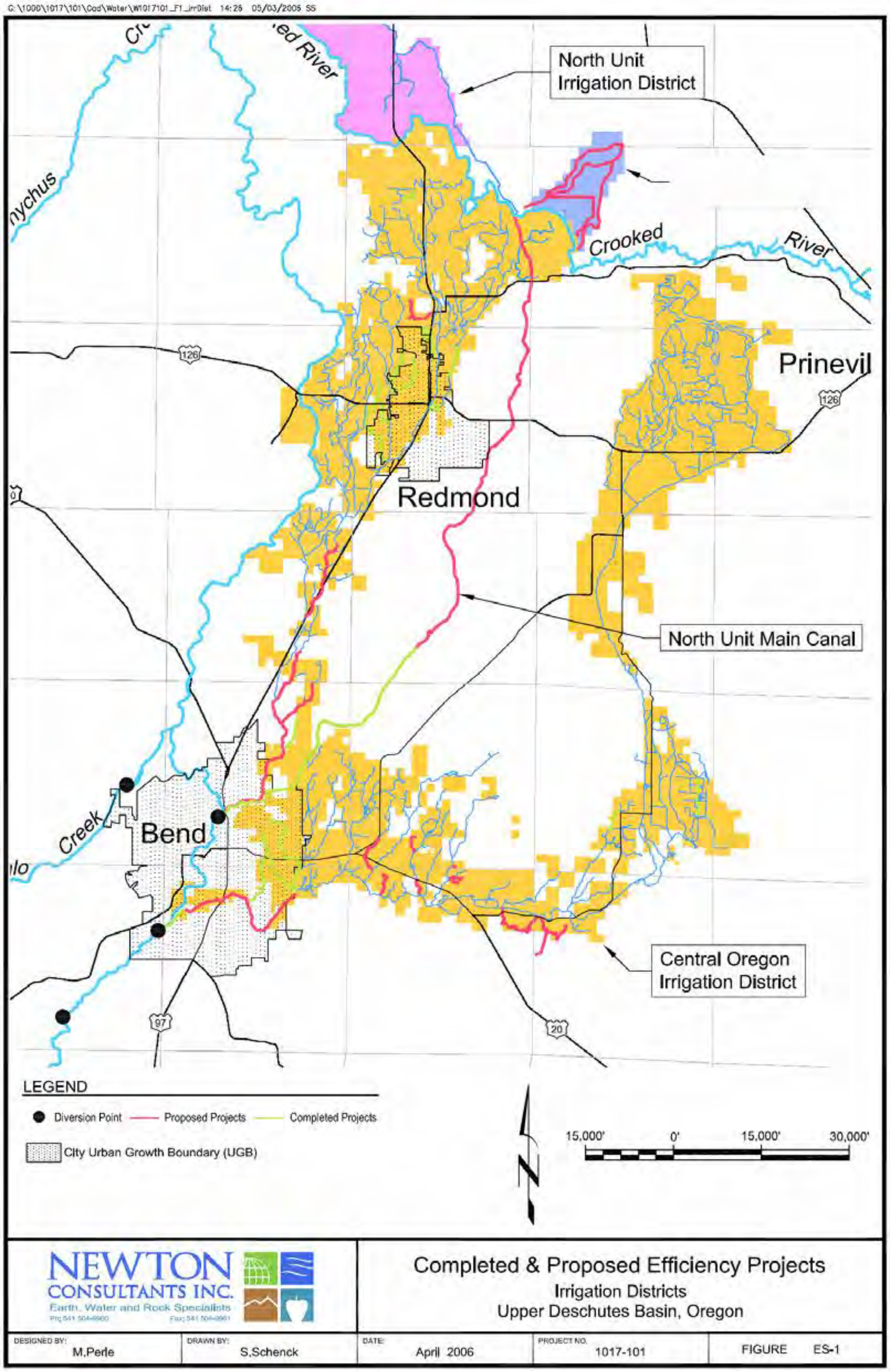


Figure ES-2 Completed and Proposed Efficiency Projects (NUID, OID)

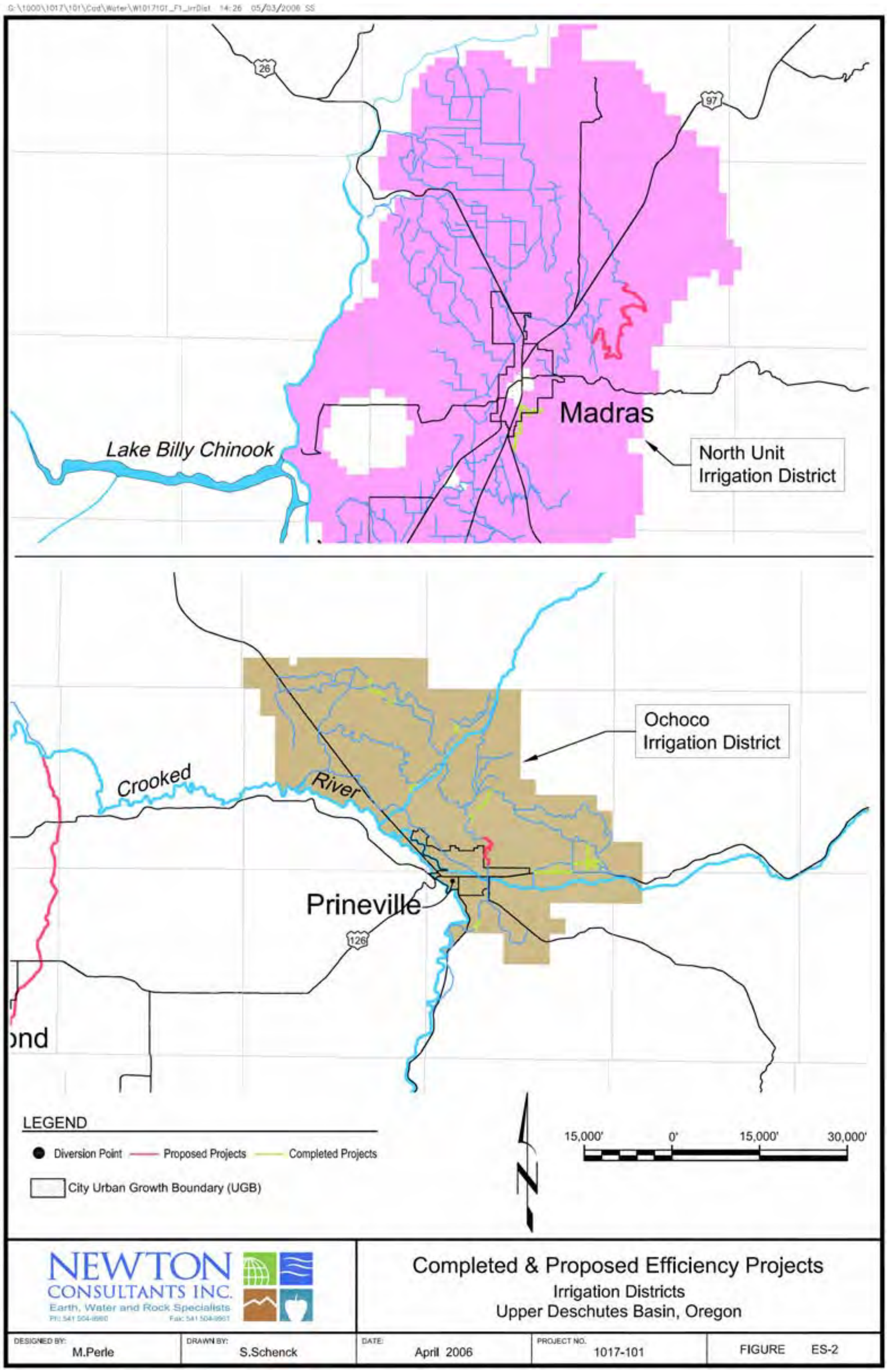
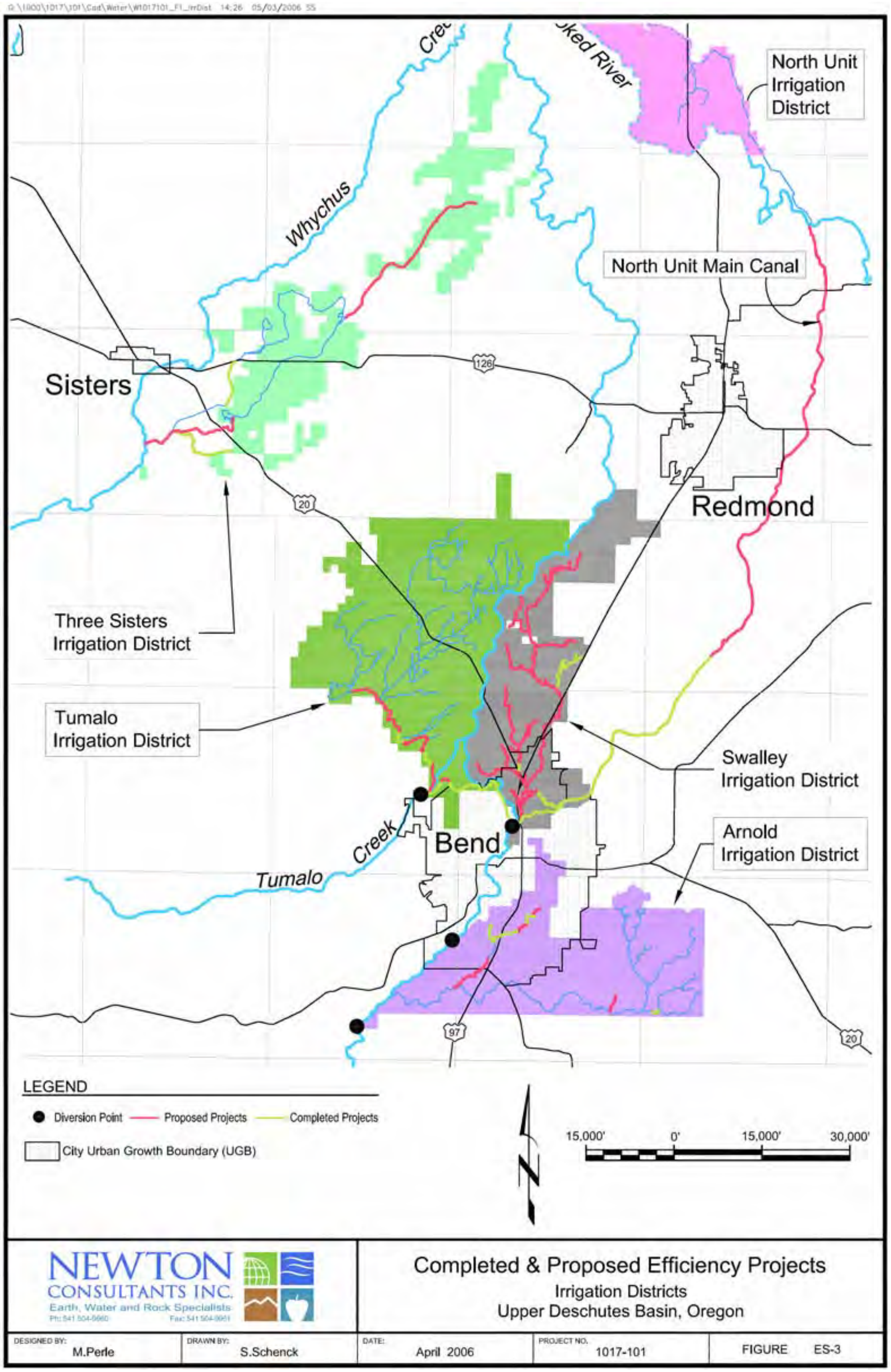


Figure ES-3 Completed and Proposed Efficiency Projects (SID, AID, TID, TSID)



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Tables

DEFINITIONS

Saved Water: Efficiency improvements including piping/lining of canals and improved on-farm efficiency reduce seepage losses that would recharge groundwater. The total amount of water available from these efficiency improvements is considered saved water.

Conserved water: Amount of saved water that is made available for transfer. Conserved water transfers allow for a portion of the conserved water to either be used on additional lands, apply the water to new uses, or dedicate the water to in-stream use. The percentage of saved water that may be applied to new uses or lands depends on the amount of state or federal funding contributed to the conservation project. The State of Oregon defines Conserved Water as: “that amount of water that results from conservation measures, measured as the difference between the smaller of the amount stated on the water right or the maximum amount of water that can be diverted using the existing facilities and the amount of water needed after implementation of conservation measures to meet the beneficial use under the water right certificate. (ORS 537.455 & ORS 537.460)

Seepage Loss: Refers to waters infiltrating into the ground through the walls of open irrigation distribution systems. In the Deschutes Basin, this water “lost” to the ground becomes in large part recharge to basin groundwater. This distribution system “seepage loss” therefore moves through the Deschutes subbasin as groundwater and eventually into the Lower Deschutes River. Piping and lining by reducing “seepage loss” does not generate new water but redistributes how the water flows through surface/groundwater system.

Acre-foot: The amount of water required to cover one acre to a depth of one foot. An acre-foot equals 326,851 gallons, or 43,560 cubic feet.

CFS: The rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and equivalent to 7.48 gallons per second or 448.8 gallons per minute.

1 PURPOSE

This paper presents the results of Irrigation District cost analysis and prioritization evaluation for efficiency improvements in irrigation districts located in the upper Deschutes Basin, Oregon. The evaluation is focused on opportunities for efficiency improvements in water conveyance facilities and in on-farm irrigation practice.

Improvement of water use efficiency is an important element of water resources planning and management activities in the upper basin for responding to changing basin needs. Opportunities for improving efficiency were evaluated and prioritized according to costs and potential for broadening the benefits of water use in the upper basin under existing water rights. The intent of this paper is to identify specific projects and their priorities for implementation under an integrated water resources management and restoration program implemented by the Deschutes Water Alliance. The intent is also to describe the amount of water that can be made available through efficiency improvements that can be used to broaden water use benefits in the upper basin under existing water rights. A fundamental objective is to help meet water supply needs with existing water rights, while maintaining consumptive use increases at limited levels. Finally, the intent of this paper is to also provide a basis for planning and implementing other projects in conjunction with efficiency improvements. A companion Reservoir Optimization Study paper addresses how efficiency improvements and reduced water demand described in this paper combined with optimizing reservoir management can help provide for future basin water needs.

2 PREVIOUS STUDIES

Improved effectiveness of water use for a broader range of benefits has long been considered for the upper basin. Previous investigations and reports reflect management objectives with the intent and prior commitment of upper basin stakeholders to develop solutions for water supply issues.

The Bureau of Reclamation (BOR) prepared a report in 1961 on unassigned space in Prineville Reservoir. This report indicated that much more dry land was available that could be irrigated with available water supply. The Oregon State Water Resources Board evaluated the entire Deschutes Basin and concluded that water shortages on irrigated land could be reduced significantly by sealing reservoirs and lining canals and ditches. Sealing would reduce seepage losses, providing more water for beneficial uses.

The BOR initiated plans in 1963 for studying final disposition of unassigned water in Prineville Reservoir. The scope of the BOR study was modified to account for a flume crossing pumping plant planned by the North Unit Irrigation District (NUID) and public demand for fish and wildlife enhancement, recreation, water quality and domestic, municipal and industrial water. The study was then directed to development and use of water supplies for existing and potential needs in the Central Deschutes area.

Field studies for the 1963 study were essentially complete for a “plan of development”; however, dramatic increases in project costs and increases in federal discount rate made the plan economically infeasible. On this basis, the purpose of the study was changed to develop a "framework plan" with recommendations for detailed studies of project components that appeared economically justifiable at that time.

The "framework plan" was presented in the 1972 BOR investigation *"Special Report on Potentials for Expansion and Improvement of Water Supplies, Deschutes Project, Central Division, Oregon"*. The framework plan is based on the utilization of water from: 1) unassigned space in Prineville Reservoir, 2) new storage in the Deschutes and Crooked Rivers and 3) an extensive canal lining-water savings program. Components of the framework plan were intended to meet portions of the intermediate and long-range multipurpose water resource needs of the Central Deschutes area. These fundamental components provided for the following:

- Reservoir recreation development;
- Storage releases to sustain flows for enhancing stream fishery resources and recreation opportunities, and to improve stream quality and esthetic values;
- Provision of water supply for irrigation of about 178,000 acres, of which about 53,000 acres were dry at the time; and
- Provisions for municipal, industrial and domestic water supplies to meet the growing needs of the area.

The unassigned space in Prineville Reservoir remains at 82,500 acre-feet. Although the framework plan assigned the unassigned space in the Prineville Reservoir to various uses, this was never implemented. The framework plan assigned 73,400 acre-feet to reservoir fishery and recreation enhancement. The plan assigned 6,500 acre-feet to municipal, industrial and domestic water supplies for the City of Prineville and around Prineville Reservoir, and assigned 2,600 acre-feet for irrigation of about 300 acres of new land in the Jap Creek area downstream from Prineville.

Four new storage reservoirs were proposed in the framework plan: Monner, Big Marsh, Big Prairie and Beaver Creek. The total storage capacity of these four reservoirs was estimated at 393,000 acre-feet.

The BOR conducted investigations of various liner alternatives in the early to middle 1990's as part of a follow-up study of conservation opportunities in the upper Deschutes Basin. The report *"Upper Deschutes River Basin Water Conservation Study, Special Report, Crook, Deschutes, and Jefferson Counties, Oregon"*, published in April 1997 by the BOR is the culmination of this study and presents a wide range of potential conservation projects intended for the following purposes:

- Improve the reliability of irrigation supplies; and
- Improve the availability of water for other uses, including in-stream flows, through increased water use efficiency in the upper Deschutes River basin.

Specific emphasis of the study was on increasing winter flows in the Deschutes River downstream from Wickiup Dam and increasing summer flows in the River downstream from the North Dam in Bend. The BOR recognized that improvement of flows in these two reaches would enhance fish and wildlife resources, recreation and water quality.

Although the study presents many potential conservation projects in the various irrigation districts, it also stipulates that districts must develop a systematic plan for implementing conservation projects. Water resources issues in the upper basin resulted in more district focus on conservation planning to find proactive ways for responding to these issues. Conservation planning efforts by many districts in recent years provide a basis for implementing conservation projects in a systematic manner.

The State of Oregon has declared a policy in statute, ORS 537.460(2), that conservation and efficient utilization of water benefits all water users, provides water to satisfy current and future needs through reduction of consumptive waste, improves water quality by reducing contaminated return flow, prevents erosion and allows increased in-stream flow by aggressively promoting conservation, encouraging the highest and best use of water by allowing the sale or lease of the right to the use of conserved water; and encourage local cooperation and coordination in development of conservation projects to provided incentives for increased efficiency and to improve stream flows.

All of the upper basin districts have prepared conservation plans, which identify specific projects, potential reductions in seepage loss and costs based on more detailed consideration of district operations. In conjunction with these plans, many districts also implemented flow measurement programs to obtain more accurate seepage loss information and to better define conservation opportunities.

The USGS 2001 report "*Groundwater Hydrology of the Upper Deschutes Basin, Oregon*" determined seepage losses by major canal service areas in evaluating the groundwater hydrology of the basin. The findings are summarized in Table 1. The summary also includes the estimated seepage losses per acre of irrigated area to help indicate locations of higher seepage losses. This ratio is based on irrigated area of only high and medium water-use crops and does not include area of low water-use crops. .

Table 1. USGS 2001 Canal Losses

Canal	Total Irrigated Area	High & Medium Water use Irrigated Area (ac)	Losses (ac-ft)	Losses / ac (ac-ft / ac)
Arnold	4,385	2,310	16,170	7.00
Central Oregon	44,800	37,300	142,050	3.81
North Unit	58,925	45,000	99,520	2.21
Lone Pine	2,369	2,390	4,920	2.06
Ochoco	20,145	16,600	21,680	1.31
Three Sisters	7,570	5,450	13,210	2.42
Tumalo	8,195	4,890	23,770	4.86
Swalley	4,540	2,450	27,500	11.22
Totals	150,929	116,390	348,820	

Table 1 indicates that districts with highest seepage losses, in descending order are Swalley, Arnold, Central Oregon (Pilot Butte and Central Oregon Canals) and Tumalo. The least amount of seepage loss is in the Ochoco Irrigation District.

3 COMPLETED PROJECTS

Irrigation districts have completed many conservation projects since 1997 to improve conveyance efficiency and provide water for irrigation and stream flow augmentation. Completed project locations are shown in Figures 2, 3, 4. As can be seen on the maps, certain canals and laterals were piped within Bend, Redmond and Madras Urban Growth Boundaries to remedy urbanization pressures near open canals and facilitate transportation infrastructure near and over open canals. These piping projects were implemented in conjunction with developers and in many instances no water savings data is available, as seepage loss measurements were not made before and after project implementation. Examples of piping projects with known water savings and costs are described below and summarized in Table 2. The completed projects in the basin have saved an estimated 45,360 acre-feet or 126.53 cfs on an annual basis. These saved waters were used to both augment in-stream flows and improve irrigation supply reliability. The total cost of the projects for which water savings data is available is approximately $15 million.

Table 2. Completed Lining and Piping Projects and Water Savings

Irrigation District	Reach / Canal / Lateral	Length of Project (miles)	Total Water Saving per season (ac-ft)	Total Water Savings per season (cfs)	Total Cost of Project ($)	Cost of Project per acre-foot of water saved ($)
Central Oregon	H14-1 lateral piping	1.3	180.2	0.43	$168,000	$932
	Alfalfa H & J lateral(1)	1.86	1,103	3.10	$50,877	$46
North Unit	Main Canal lining	11.8	23,000	64.40	$7,405,172	$322
	NUID 51-4 lateral piping	4.75	300	1.40	$89,217	$297
Swalley	Deschutes Lateral	1.43	627	1.51	$229,019	$365
	Kotzman Lateral	2.2	1864	4.48	$227,902	$122
Three Sisters	Fryrear & Cloverdale laterals	6.3	2,578	7.20	$432,307	$168
	Vermilyea, Schaad, B-Ditch, Z-Ditch, Vetterlein laterals piping	7.2	990	2.80	$?	$?
	Brown(2), Bartlemay(2), laterals	1.52	900	2.52	$?	$?
	Thompson(2)(1)	Not applicable	714	2.00	$?	$?
Tumalo	Bend Feed Canal piping(3)	5.0	13,103	36.70	$6,400,000	$488
TOTALS		**43.36**	**45,360**	**126.53**	**$15,002,494**	

(1) Water savings represent waters transferred in-stream. Total water saved from project is higher.
(2) Savings from both canal removal and/or piping/lining and on-farm efficiency projects.
(3) Savings represent water used for in-stream flow augmentation and improving irrigation supply reliability.

3.1 Central Oregon Irrigation District

The Central Oregon Irrigation District has piped about 1.3 miles of its Pilot Butte H14-1 lateral in Redmond and is currently applying for transfer of portions of the conserved waters for in-stream use. The District has also piped about 1.86 miles of its laterals in Alfalfa. Parts of the project costs were covered by the DRC and approximately 1,103 acre-feet per year or 3.09 cfs of reduced seepage losses were transferred to in-stream flow in exchange for funding from the Bonneville Power Administration Transaction Program facilitated by the National Fish & Wildlife Foundation. Locations of completed projects are shown in Figure 2.

3.2 North Unit Irrigation District

The North Unit Irrigation District has completed a number of lining and piping projects from 1997 to 1998. The first project lined the first 6.9 miles of the main canal in 1997-1998. The lining was constructed of roller compacted concrete placed on the bottom of the canal and shotcrete on the sides of the canal. The last 4.9 miles of the project were lined on the bottom only and leakage still occurs through the canal side walls. Seepage losses in the project reach were reduced by approximately 23,000 acre-feet per year or 64.4 cfs over a 180-day irrigation season. The total cost of the project was $7.4 million or $322 / acre-foot of water saved. Funding for the project relied upon the sale of bonds by the North Unit Irrigation District. The second project involved piping 4.75 miles of its NUID 51-4 lateral canal in 1998. This project reduced seepage losses in the project reach by about 300 acre-feet per year or 1.39 cfs at a total cost of $89,217. This equates to a cost per acre-foot of water conserved of $297. Locations of completed projects are shown in Figure 2 and 3.

3.3 Swalley Irrigation District

The Swalley Irrigation District (SID) has piped approximately 3.6 miles of its canal and laterals with another 1.4 miles of canal being piped in 2006. Seepage losses were reduced by 2,491 ac-ft or 5.98 cfs on an annual basis by completed projects within the district. Completion of the Kotzman Lateral piping project in late 2006 will save an additional 1,864 ac-ft or 4.4 cfs annually. Additional piping will complete the Kotzman Lateral in late 2006.

The total costs of the Deschutes and Kotzman Lateral piping projects was $229,019 and $227,902 or $365 and $122 per ac-ft of water conserved respectively. Joint funding agreements involved financial support from Swalley Irrigation District and The Deschutes River Conservancy. Locations of completed projects are shown in Figure 4.

3.4 Three Sisters Irrigation District

The Three Sisters Irrigation District (TSID) is very active in conveyance efficiency improvements. With funding from the DRC, the District has already piped about 6.3 miles of its Cloverdale and Fryrear laterals. The total costs of these projects were $432,307 or $168 per acre-foot of water saved. Additional piping projects include sections of the Vermilyea, Schaad, B-Ditch, Z-Ditch and Vetterlein Ditches. Projects on the Brown, Bartlemay and Thompson Laterals involved combinations of piping, on-farm efficiency projects involving pond lining and conversion from flood to sprinkler irrigation and eliminating different sections of canal.

These projects have improved water use efficiency allowing more reliable water supply to water users and augmentation of stream flows in Whychus Creek. Reducing seepage losses and increasing on-farm efficiency in the TSID has allowed approximately 5,182 acre-feet per year, or an average of 14.5 cfs to be saved on annual basis. This saved water has been used to provide reliable irrigation supply to irrigators and to improve in-stream flows. As a result of these projects, year round flow has been restored to Whychus Creek where it had traditionally been dewatered during the irrigation season. Locations of completed projects are shown in Figure 4.

3.5 Tumalo Irrigation District

The Tumalo Irrigation District has piped about 5 miles of its Bend Feed Canal. The 108-inch diameter High Density Polyethelene Pipe (HDPE) reduced seepage allowing more reliable water supply to users and augmentation of stream flows in Tumalo Creek. This piping project has made approximately 13,103 acre-feet or 36.7 cfs of water per irrigation season available for multiple uses including improved irrigation supply reliability and in-stream flow augmentation.

Over half of these waters or 7,719 acre feet (21.6 cfs) have been protected for in-stream flow augmentation. Saved water ranging from 1.7 to 7.8 cfs (1,642 ac-ft or 4.6 cfs average) is conserved for in-stream flow augmentation in Tumalo Creek between April and October. Up to 6,077 acre-feet per year or 17.02 cfs (5.82 cfs with senior water right and 11.2 cfs with junior water right) is conserved for in-stream flow augmentation in Tumalo Creek. The balance of the saved waters are used by the irrigation district to improve irrigation supply reliability.

The total costs of these projects were \$6.4 million or \$488 per acre-foot of water saved. Joint funding agreements involved financial support from Tumalo Irrigation District, The Deschutes River Conservancy, the BOR and the Oregon Watershed Enhancement Board (OWEB). Locations of completed projects are shown in Figure 4.

4 CONSIDERATIONS IN SELECTING EFFICIENCY IMPROVEMENT OPPORTUNITIES FOR ANALYSIS

4.1 Objective

The principal objective of evaluating opportunities to improve conveyance efficiency in district canal systems is to identify projects with greater overall benefit potential. There are numerous opportunities for efficiency improvements; however, when the number of initial projects that can be implemented is limited, focus is on those with more beneficial results. Sets of potential criteria were developed to help determine how best to prioritize efficiency projects.

The evaluation focus was developed in two stages. The first stage included general consideration of all districts, and selection of districts based primarily on seepage loss potential. In the second stage, additional criteria were applied, narrowing the focus to a smaller number of districts for efficiency improvement evaluations. These criteria include:

1) Benefit potential from efficiency improvements,
2) Federal and other constraints, and
3) Urbanization impacts on districts.

4.2 Benefit Potential from Efficiency Improvements

4.2.1 Agriculture

Agriculture is an important component of the Central Oregon history, culture and economy. Improved water conveyance efficiency through reduced seepage losses and through on-farm irrigation improvements will provide more water for agricultural needs. Water supply for agricultural purposes has been supplied since the early 1900's by eight irrigation districts for irrigation of approximately 164,000 acres of land. Water for irrigation is diverted from the Deschutes River and its tributaries including the Crooked River, Whychus Creek and Tumalo Creek.

Water for most of the irrigated land is diverted from the Deschutes River at Bend. The Bend diversions supply water to the Arnold (AID), Central Oregon (COID), Swalley (SID), Lone Pine (LPID), North Unit (NUID) and Tumalo Irrigation Districts (TID). These diversions include both natural stream flows and flows released from storage reservoirs. The diversions reduce the combined natural and storage release flows in the Deschutes River at Bend by about 95 percent. The Three Sisters Irrigation District near Sisters depends on Whychus Creek for water and the Ochoco Irrigation District in the Prineville area depends on Ochoco Creek and the Crooked River for water.

Water is distributed to irrigated areas by a network of canals, laterals and ditches, most of which are unlined. The total combined length of canals and laterals is about 720 miles. Many of the facilities are constructed in permeable volcanic lava flows and sedimentary materials. Seepage losses range from about 30 to 50 percent of the total diversions. In other words, 1.4 to 2.0 gallons of water must be diverted from a stream to provide 1 gallon of water to a farm for irrigation use, on an overall average basis for all districts. Total annual seepage losses were estimated at 350,170 acre-feet (USGS, 2001) for the 1994 irrigation season (May-September). This volume of loss over a 180-day season corresponds to an average seepage flow rate of around 983 cubic feet per second (cfs). This magnitude of loss is 45 percent of total diversions into canals in the upper basin and is quite high relative to losses generally tolerated in unlined water distribution systems.

To demonstrate the magnitude of overall seepage losses in the basin, we can note that the seepage losses for the Tumalo canal over an irrigation season for example are nearly the same as the estimated total amount of ground water that was consumed (not returned to the hydrologic system) by public supply and irrigation uses in the upper basin during the middle 1990's (USGS, 2001). Another example shows that the Central Oregon Canal losses are nearly the same as the estimated total amount of ground water pumped from the regional aquifer system for public supply and irrigation uses for the same time period, based on 50 percent consumptive use.

Agriculture is the main use of water in the Upper Deschutes Basin. During years of normal or above normal runoff, sufficient water is available for most irrigation needs. Issues arise, however, in years when runoff is below normal. In these instances, some irrigation districts do not receive sufficient water to meet all crop demands. Table 2 indicates that reducing seepage losses in water conveyance systems could generate substantial quantities of water for shoring up supply for agricultural uses. Additional benefits of reducing seepage losses specifically linked to canal piping include added advantages in power savings related to pressurized water and potential for power production. Pressurized water in pipes can significantly reduce or eliminate the power needed to operate sprinkler irrigation pumps. The potential for power production that that arises with piping canals can help defray the costs of construction and make the projects more feasible from an economic standpoint.

Additional water can be generated by improving efficiency of water use during irrigation. These "on-farm" opportunities basically include switching from flood irrigation to pressurized sprinkler systems, upgrading nozzles in sprinklers and application of weather-control systems to better match water demand with crop need. The USGS (2001) estimated on-farm losses at 166,560 acre-feet over a total irrigated area (high and medium water-use crops only) of 117,930 acres. On-farm losses based on these numbers are about 1.41 acre-feet per acre. On-farm losses are lowest in the North Unit Irrigation District (94 percent mean irrigation efficiency) and highest in the Central Oregon Irrigation District (43 percent mean irrigation efficiency). Although significant quantities of water can be conserved by on-farm improvements, reduction of seepage losses in conveyance systems will generate the largest volume of water for expanding benefits of water use to agriculture and other basin needs.

4.2.2 Stream Flow

The flow regime of the Upper Deschutes River has been altered from historic natural conditions as a result of construction and operation of reservoirs and irrigation diversions in the upper basin. In the river reach above Bend, summer flows exceed historic natural flows to provide water for irrigation diversions at Bend. Heavy summer flows in this reach carry irrigation water released from the storage reservoirs in the extreme upper end of the basin. Up to 95 percent of Deschutes River flows (natural plus storage releases) are diverted into irrigation district canals at the North Dam in Bend. The irrigation diversions reduce flows in the Middle Deschutes River below Bend to well below historic natural flows. During winter, flows in the Upper Deschutes above Bend are well below natural Historic flows due to reservoir filling.

Similar alterations to natural historic flows occur in tributaries of the Deschutes River such as the Crooked River and Tumalo Creek. Even in creeks without storage reservoirs like Whychus creek, irrigation diversions during the summer irrigation season alter the historic natural flow conditions.

The wide fluctuation of flows and timing of releases in different reaches of the Deschutes and its tributaries are detrimental to aquatic and riparian habitat. In-stream flow rights for fish and wildlife are junior in priority to irrigation district rights in most reaches of the river. The health of aquatic and riparian habitat in stressed reaches of the Deschutes River could be significantly improved through more effective use of water. More efficient water use will increase the amount of water available under existing appropriations that can be reallocated for flow restoration along with other uses including irrigation for agriculture as discussed above.

Improved conveyance efficiency in canals and laterals by piping and lining will generate significant quantities of water that can be used for flow restoration. Reductions in seepage losses also make water available in storage that can be used for a variety of purposes. Reservoir management scenarios can be developed for restoring winter flows in the upper Deschutes River, when flows are now diminished to fill the reservoirs. Scenarios can also be developed to restore summer flows in the middle Deschutes River, when flows are now depleted by irrigation diversions at Bend. More details on in-stream flows and reservoir management can be found in the DWA companion papers "*In-stream Flow in the Deschutes Basin: Monitoring, Status and Restoration Needs*" and "*Reservoir Management*".

4.2.3 Urbanization

Growth in the upper basin is rapidly converting land use inside city Urban Growth Boundaries (UGB's) from agricultural uses to urban uses. The land use conversions often bring municipal water supply for the new urban land uses, eliminating the need for irrigation district water. Urbanization also brings residential subdivisions, commercial and industrial developments to near proximity of irrigation canals and laterals, often making district operations and maintenance of the facilities more difficult and expensive.

Although piping of canals and laterals in these situations can generate substantial quantities of water for a variety of needs, piping also eliminates public safety hazards and greatly reduces operations and maintenance costs while improving water conveyance efficiency and generating pressurized irrigation water for outlying irrigators. Piping can also provide revenue for additional district projects and efficiency upgrades through power generation related to hydroelectric facilities. These hydroelectric facilities where feasible with piping projects can be cost effective given their potential eligibility for Business Energy Tax Credits (BETC). The corresponding revenue contribution from renewable power generation can help support district sustainability and could offset assessment changes related to urbanization impacts.

4.3 Federal & Other Constraints on Reallocated Water

Water rights held by the irrigation districts are subject to restrictions on where irrigation water is diverted, the quantity of use, location of use and purpose of use. Flexibility in these restrictions exists to some degree, depending on whether the district status (federal or non federal) or if they are subject to federal contracts.

Private districts can change the place and type of water use with transfers according to rules for this purpose (OAR 690.380). Districts formed as federal projects, or districts with federal contracts are restricted in flexibility to change the place and type of water use.

Selection of districts for potential efficiency improvement projects includes consideration of restrictions that could limit the range of benefits resulting from the projects, or that could increase the transaction requirements for achieving the benefits.

4.3.1 Federal Constraint

The North Unit Irrigation District (NUID) was constructed by the BOR as part of the BOR's Deschutes Project. The authorized use of water is for irrigation. Use of project canals to move water for other purposes than those laid out in federal permits requires special permits and/or legislation. For example, if water made available from reduced seepage is to be conveyed from a private district through NUID canals for boosting irrigation supply, federal authorization is required under the Warren Act. Use of conserved water generated by NUID efficiency improvements for other purposes is also subject to federal authorization; however, restrictions on use of conserved water are less onerous, evidenced by water leases currently in place between NUID and the DRC on a year-to-year basis. These temporary leases do not alter the water rights of individual users.

The Ochoco Irrigation District (OID) is under contract with the BOR for repairs to the Ochoco Dam. Contract provisions restrict use of District water to irrigation. Presently, use of water for in-stream purposes is prohibited under the contracts. Flexibility in use of water for in-stream purposes is under investigation.

The allocation of conserved water program was developed as an incentive to conserve water (OAR 690.018). Under the program, a water user can conserve water through efficiency improvements and use part of the conserved water for other uses under the user's existing water rights. A condition of the additional water use is that at least 25 percent of the conserved water is dedicated to public use (transferred in-stream). If public or other funds are used to implement the conservation project, the amount of conserved water dedicated to in-stream use is proportional to the funding amount provided by the public, or other sources.

The net amount of conserved water available for use by the water user is subject to factors other than proportionate amounts of outside funding. Water right transfers are required in accordance with OAR 690.380 to change the place and type of use for conserved water. Approval of transfers and the net amount allowed for other uses under the transfer are subject to potential for injury to other water rights. Injury potential is determined by the Oregon Water Resources Department (OWRD) in the transfer review process. Based on injury potential, a transfer application can be denied, or the net amount of water for other uses can be reduced to protect other water rights.

Transfer of conserved water resulting from efficiency improvements is also subject to consideration of district water rights and flows historically conveyed by the canal or lateral subject to the improvements. The issue in this situation is the amount of credit for conserved water considering whether the canal carried its full water right allotment, or some lesser historic flow. In one case, the amount of credit could be calculated as the difference between the maximum water right flow and the flow after conservation. In another case, the amount of credit could be calculated as the difference between historic canal flows and conservation, possibly a lesser amount than for the first case. Finally, credit could be calculated as the difference between flow that the district is "ready, willing and able" to deliver and conservation.

The above constraints apply to efficiency improvement projects, where use of conserved water is intended for in-stream and irrigation uses. Injury constraints also apply to use of conserved water from canal efficiency improvements for mitigation in connection with new ground water permits required under OAR 690.505. In this case, piping of canals and laterals reduces seepage losses. Water from reduced seepage can then be transferred to in-stream use, increasing stream flow. For mitigation, the concept is that increased stream flow in an amount equal to consumed water under a new ground water permit would offset impacts of the ground water appropriation on stream flow. However, the issue relative to mitigation is that piping reduces aquifer recharge by the canal leakage and the effect of a new consumptive use (ground water pumping) is a net deficit in ground water discharge to stream flow. This deficit theoretically reduces stream flow, resulting in injury to senior water rights (in-stream flows, lower Deschutes River, etc.).

Based on the above considerations, water generated from efficiency improvements to canals and laterals could be used primarily for agriculture and in-stream purposes. Water for mitigation purposes must be obtained from other sources based on present conditions.

4.4 Urbanization Impacts on Districts

Consideration of urbanization impact potential is warranted in selecting opportunities to improve water use efficiency with an extended range of benefits for the capital investment. In many instances, costs to pipe canals are less expensive than engineering, building and maintaining the water/sewer systems, bridges and infrastructure that must go over or under irrigation canals when development occurs. In addition to reducing public safety hazards, piping canals reduces risks of water contamination in urban environments. Canals in Central Oregon are designated by the Army Corps of Engineers (ACOE) as Waterways of the United States. Under this designation, these canals would be subject to provisions of the Clean Water Act (CWA) and any accidental or incidental discharge of pollutants from storm water runoffs from parking lots, streets, bridges or other improvements would be subject to potential National Pollutant Discharge Elimination System (NPDES) permit requirements. As discussed earlier, piping of canals and laterals also greatly reduces operations and maintenance costs, and conflicts between districts and owners of urban real estate located near the facilities. The impacts of urbanization on district operations is discussed further in the companion DWA paper entitled "*Growth, Urbanization and Land Use Change: Impacts on Agriculture and Irrigation Districts in Central Oregon*".

5 OVERVIEW OF DISTRICT CONDITIONS

An overview of all irrigation districts indicates that seepage loss potential is very high in some and very low in others. Further evaluation indicates seepage potential can be correlated with geologic conditions in the district areas. Therefore, consideration of geology and seepage potential reveals opportunities to increase the benefits of efficiency projects.

The criteria discussed above were applied to the eight irrigation districts in an attempt to determine where to focus more detailed evaluation of potential efficiency improvement projects.

5.1 Geologic Influence

District records and Table 1 suggest that relatively high seepage loss in canals and laterals occurs generally in the Bend area. The Arnold, Central Oregon, Tumalo and Swalley Irrigation District main canals and laterals were constructed in permeable lava terrain with many uplifted pressure ridges of broken lava. A northwest-trending band of faults of the Sisters Fault Zone also passes through the Bend area, crossing locations of canals and laterals utilized by the above districts. Faulting and related shearing and crushing of rock, also contributes to increased permeability and higher seepage losses through the lavas in this area. Geology and fault zones are shown in Figure 5. Generally, seepage losses decrease, although they remain high, in the northward direction from Bend. Decreasing losses appear to reflect geologic influences.

District records also indicate that seepage losses in and around urbanization areas near Bend are higher than in similar geology outside urbanization areas. This can be linked to the impact of blasting that occurs in developing areas. Blasting is a common method used in Central Oregon to provide graded building sites for homes and infrastructure in the basalt rock geology. Blasting has the effect of increasing infiltration by “loosening” surrounding rock and potentially increasing basalt fracture size or fracture connectivity.

5.2 Arnold Irrigation District (AID)

District records suggest that relatively high seepage loss in AID canals and laterals occurs generally in the Bend area. The AID main canal foundation materials are mainly comprised of basalt covered over by basalt alluvium and colluvium and volcanic ash. The canal also crosses at least seven northwest-trending normal faults of the Sisters Fault Zone. District records indicate zones of high seepage loss in areas that coincide with openwork basalt vent rocks adjacent to prominent fault zones (Figure 5). Other potential areas of high seepage losses can be expected where the unlined canal traverses the broken basalt associated with faults. The Arnold Irrigation District provides water to 550 acres of irrigated land now inside the Bend UGB and 49 acres inside the Bend URA. This represents approximately 15% of the 4,384 irrigated acres in the District. Location of AID canals within Bend UGB are shown in Figure 4.

5.3 Central Oregon Irrigation District (COID)

COID records also indicate areas of very high seepage loss in the Bend area. At several locations in the first 10 miles of the Pilot Butte canal, short dike sections constructed of Volcanic Ash are used to cross collapse depressions in the basalt. These dike sections likely are highly permeable. COID records also document severe canal losses 12 miles north of Bend in areas where the pilot butte canal traverses unconsolidated to lightly cemented pumice.

District records also indicate that much of the seepage in the main Central Oregon canal occurs in the southern section of the canal, south and east of Bend up to approximately canal mile 27.5. This is corroborated by geologic observations whereby the foundation materials north of canal mile 27.5 contain local sections of highly fractured basalt and more uniform foundation conditions with more fine sediments are more conspicuous south of canal mile 27.5 (BOR 1991).

The Central Oregon Irrigation District provides irrigation water to 738 acres of irrigated land now inside the Bend UGB. The District also supplies water to 533 acres inside the present Urban Reserve Area (URA) of Bend. Location of COID canals within Bend UGB are shown in Figure 2. The District also delivers water to irrigators inside the Redmond UGB and URA. Irrigated acreage inside Redmond UGB and URA is 1,517 and 2,595 acres, respectively. Location of COID canals within Redmond UGB are shown in Figure 2. Therefore, a total of 5,383 acres of COID irrigated land lies within the present UGB and URA boundaries of Bend and Redmond. This represents approximately 13% of the irrigated acres in the District.

5.4 Lone Pine Irrigation District (LPID)

The LPID is a small irrigation district serving seventeen water users on 2369 acres in Lone Pine near Terrebonne, Oregon. District water is diverted out of the Deschutes River near Bend, travels through COID's Pilot Butte Canal, is diverted at the Lone Pine weir and travels across the Crooked River in a flume to Lone Pine Valley. The network of unlined canals are constructed in alluvium and glacial outwash made up of sands and gravels. District records and past studies indicate that seepage losses are high in these canals and represent up to 32% of total water diverted at the Lone Pine weir. The LPID currently does not provide water to irrigated lands with any city UGB's or URA's.

5.5 North Unit Irrigation District (NUID)

The NUID main canal conveys water about 65 miles from the river diversion at Bend to irrigated areas near the Warm Springs Reservation and Gateway area north of Madras. The first approximate 12 miles of the NUID main canal passes through fractured permeable lava terrain. This section of the canal was recently lined, reducing seepage losses by more than 60 cfs, or 23,000 acre-feet per year. Analysis of the next 12 miles to the Crooked River indicates that canal lining could eliminate about 37 cfs in seepage losses, or about 13,000 acre-feet. Irrigation district records suggest that over half of the leakage from the NUID main canal occurs between Bend and the Crooked River crossing. The North Unit Irrigation District provides water to 536 acres of irrigated land now inside the Madras UGB (Figure 3). This represents approximately 1% of the irrigated acres by NUID.

5.6 Ochoco Irrigation District (OID)

The Ochoco Irrigation District (OID) in the Prineville area is located primarily in sedimentary deposits developed in lake beds, stream beds, river terraces and slope wash areas. The source of the sediments is primarily the Ochoco Mountains, consisting of relatively old, weathered volcanic rocks with a significant silt and clay content. Permeability of these materials is generally less than the broken lava terrain in the Bend area, resulting in reduced levels of seepage. Although canal and lateral piping or lining can reduce seepage losses in the OID, the overall magnitude of potential seepage reductions is significantly less than in the Arnold, Central Oregon and Swalley Districts. These conditions are reflected in Table 1.

The Ochoco Irrigation District serves about 1,571 acres inside the present Prineville UGB (Figure 3). This represents approximately 8% of the 20,150 irrigated acres in the District. The District is presently developing a management plan for responding to changing operational needs and urbanization pressures.

5.7 Swalley Irrigation District (SID)

Discussion with the Swalley Irrigation District reveals areas of very high seepage loss in the Bend area, extending to approximately Deschutes Junction, about 6 miles north of Bend. Given canal foundation geology, potentially high water losses are to be expected in the Swalley main canal where the canal crosses fault scarps in the basalt. High losses can also be expected where the canal crosses collapse-depression terrain and skirts frontal areas of pressure ridges with uplifted and broken basalt flows.

The Swalley Irrigation District provides water to approximately 343 acres of irrigated land now inside the Bend UGB. The District also supplies water to 559 acres inside the present Bend

URA. Location of SID canals within Bend UGB are shown in Figure 4. This acreage is approximately 20 percent of the 4,587 acres served by the District. Urbanization of these lands will put about 7.2 miles of main canal and laterals in areas of high-density land use and related infrastructure.

5.8 Three Sisters Irrigation District (TSID)

The Three Sisters Irrigation District (TSID) east and northeast of Sisters is located primarily in an area of sedimentary deposits formed by stream and glacial activity. Certain canal and lateral reaches pass through broken and permeable lavas as well. The sedimentary deposits are generally less weathered and more permeable than sediments in the OID area, resulting in relatively high seepage losses in local areas. The TSID has completed several canal and lateral piping projects to reduce seepage losses. The TSID is also outside the Sisters UGB (Figure 4) and is not subject to urbanization issues faced by the COID, OID, AID, NUID and SID.

5.9 Tumalo Irrigation District (TID)

Tumalo Irrigation District canals and laterals traverse areas of broken, permeable lava. Review of geologic maps indicates at least three faults cross the area of district canals. Leakage potential was considered moderate for the District by the BOR in development of the 1991 geologic report. Table 1 above reflects a potential mid-range level of seepage potential at 4.86 acre-feet per acre of irrigated area, recognizing that this value is based on acreage of high to medium water use only. The Bend Feed Canal has been piped and funding is being requested for piping the approximate five-mile reach of the Tumalo Feed Canal.

The Tumalo Irrigation District provides water to approximately 2 acres of irrigated land now inside the Bend UGB. Location of TID canals within Bend UGB are shown in Figure 4. The District also supplies water to 131 acres inside the present Bend URA. This acreage is less than 2 percent of the 8,109 total acres served by the District.

6 METHODS FOR EFFICIENCY IMPROVEMENTS

6.1 Liners

Lining canals is intended to reduce seepage by sealing the bottom and sides of canal channels with liners. Reduction of seepage in canals can provide water to improve reliability and amount of supply for agriculture. It can also reduce diversions and make more water available to the middle reach of the Deschutes River as part of a multi-benefit water management program. In addition to water conservation, canal lining reduces maintenance requirements relative to aquatic vegetation control on canal banks (where they are lined) and will also bring some related water quality benefit. Drawbacks include the necessity for continued maintenance to account for weathering and cracking of canal materials over time. Also safety hazards of open canals remain with lined delivery systems, and in fact, may be increased. These increased safety concerns are linked to increased water velocities due to reduced friction losses and increased difficulty in climbing out of canals related to smooth sloping sidewalls.

Traditional canal-lining materials typically include compacted earth, reinforced or un-reinforced concrete and buried geomembranes. For many jobs, these materials are not always viable in the Upper Deschutes Basin because they are either: not locally available, too expensive or require extensive over-excavation and easy access for heavy equipment. The issues of access and over excavation become important drawbacks when considering lining of canals in urban environments.

The Bureau of Reclamation conducted multiple studies "*Canal-Lining Demonstration Project*" between 1992 and 2000 whereby a variety of lining materials were tested on 18 sections of canals in the Upper Deschutes Basin. The study looked at less expensive alternative canal lining materials that were easier to construct with limited access and were more compatible with severe rocky sub-grades such as the fractured volcanic rock commonly found in central Oregon. These alternative options included: fluid-applied membrane, concrete alone, exposed geomembrane and geomembrane with concrete covers.

Of these four options, the concrete with geomembrane underliner provides the best long-term performance. The effectiveness at seepage reduction is approximately 95% while long term durability ranges from 40 to 60 years. The concrete protects the geomembrane from mechanical damage due to weathering, animal traffic, construction equipment and vandalism while the geomembrane provides the water barrier. Irrigation district personnel are familiar with concrete and can easily perform the required maintenance (BOR 1999). Operations and maintenance costs can however be high with open canal using concrete given the frost-heave situation that occurs annually in the Central Oregon climate. District records and experience however indicate durability of 20 years at a maximum for these lining options in Central Oregon with 15 years being the average.

Lining of canals does not address a key component in urban and agricultural areas. Urbanization brings a substantial list of issues to bordering canals, including trespass and safety. Lining of canals does not address water quality problems that may occur in urbanized and agricultural areas due to close proximity of roadways and bridges along with runoff from agricultural lands. In urban areas this infrastructure presents potential contamination sources in the form of runoff from parking lots, streets and bridges.

6.2 Pipe

Piping of canals shifts water conveyance to buried pipelines, eliminating open canals and related operations and maintenance issues in urbanizing areas. Use of pipe materials such as High Density Poly-Ethylene (HDPE) has the advantage of reducing seepage losses to nearly zero. By reducing seepage losses, piping of canals also can provide additional water for agriculture and stream flow restoration. In addition, the near elimination of seepage losses associated with the increased efficiency by which water is conveyed helps secure irrigation district function and viability by ensuring water deliveries to irrigators furthest from the point of water diversion.

Piping of canals has the added advantage of providing pressurized water created by gravity. This can either eliminate the need for pumps or significantly reduce power demand and related costs associated with sprinkler systems. Canal piping can also offer the opportunity for low-head hydropower generation in canals with sufficient head drops. The power produced from these plants can help offset the cost of piping construction as well as irrigation operating costs.

HDPE pipe also offers many savings both in water and in cost. Joints between sections of pipe are heat fused and are as strong as the pipe itself. These types of joints reduce maintenance costs and eliminate potential leak points that might occur every 10-20 feet PVC and Ductile Iron bell and spigot connections. Due to the lower density of HDPE compared to steel or PVC it is much easier to handle and install. This translates to cost savings in the construction process. HDPE pipe can also withstand impacts better than other pipe materials, especially in cold weather installations when other pipes are more prone to cracks and breaks. Since it is flexible, it is well suited for dynamic soils including areas prone to earthquake. Finally, the polyethylene pipe industry conservatively estimates a service life for HDPE pipe to be 50-100 years. This nearly doubles the maximum expected life of 40-60 years for concrete canal lining.

Some of the disadvantages of canal piping include reduced artificial groundwater recharge, loss of aesthetics associated with open canals or laterals, loss of habitat provided by open canals, laterals & ditches and potential reduction in spring discharge to the Deschutes River and its tributaries.

7 PROPOSED PROJECT ANALYSIS

7.1 Conveyance Efficiency

Although urbanization is occurring on significant land areas within the Districts, large areas of irrigated agricultural land outside urban areas rely on the Districts for water. The diversions for COID, SID and NUID main canals supply water by gravity flow and will remain at their existing locations in urban areas for this reason. The Deschutes River enters a deepening canyon at Bend and diversions farther north of the City require pumping for water delivery. Relocating diversions farther south outside City limits are not practical due to extensive construction of new canals to maintain supply to the existing lateral network. Therefore, main canals and laterals remain key water distribution components for water delivery through urban areas to outlying irrigation areas.

Laterals require the largest commitment of operations and maintenance budgets, particularly in urbanizing areas and are therefore the primary focus of efficiency projects. Ditches are relatively minor components of the distribution. Ditches in urbanizing areas are most often abandoned and investments in efficiency projects bring short-term results.

The focus on conveyance efficiency opportunities in this analysis is on irrigation districts in the upper Deschutes Basin. Although conveyance efficiency is important among all water providers and users, the districts provide opportunities to conserve relatively large quantities of water for significant up-front benefits for the basin. Seepage from unlined canals comprises a large amount of water and opportunities to conserve this water for other uses are controlled by basin geology, institutional barriers to use of conserved water and costs related to construction of efficiency projects. Accordingly, conveyance efficiency opportunities in some districts are much greater than others and warrant priority in project implementation.

Conveyance efficiency opportunities were evaluated in the main canals and the laterals. Main canals are the primary distribution facilities, carrying water from the stream diversion point to the outlying reaches of the district. Laterals are smaller than the main canals and distribute water away from the main canals, into the interior of irrigated areas. Much work has been done in all districts to better manage water use and distribution efficiency since the Reclamation 1997 study. Projects identified in the tables below have been identified by each district as providing the most benefits in terms of either water savings, reduction in operating costs or response to urbanization pressures. Further study is needed across all districts to further identify and evaluate efficiency opportunities.

7.1.1 Arnold Irrigation District

The AID is comprised of approximately 40 miles of laterals and main canal with a maximum flow capacity of 125 cfs. Cross-sectional dimensions of the main canal are generally14 feet wide by 2.5 feet deep. Laterals are from 4 to 8 feet wide by 2.0 to 2.5 feet deep (BOR 1997).

Priority for evaluating conveyance efficiency opportunities was given to laterals inside or near urbanizing areas based on the operations and maintenance and seepage loss numbers from district records. Laterals within the UGB's and URA's of Bend are shown on Figure 4. Proposed projects are summarized in Table 3 and their locations are shown on Figure 4.

Table 3. AID Summary of Potential Projects

				SAVED WATER (per irrigation season = 180 days)				COST	
Location	Length (Miles)	Length (Feet)	In UGB	Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)	Pipe Diameter (Inches)	Total Saved Water Cost 2006	Cost per AF Saved (average)
North Lateral	2.65	14,000	PART	2,100	5.88	2.95	ND	ND	ND
Estes Lateral	0.38	2,000	NO	150	0.42	0.33	ND	ND	ND
Totals for all Projects	**3.03**	**16,000**		**2,250**	**6.30**	**3.28**			

Source of saved water data: District Records
ND = No Data Available

Piping of the proposed projects could if implemented save approximately 2,250 ac-ft or 6.3 cfs on an annual basis that could be used to guarantee supplies to irrigators or used to improve in-stream flows in the Deschutes River. Further analysis should be performed to refine seepage losses and determine construction and piping costs for the proposed projects.

7.1.2 Central Oregon Irrigation District

The COID is comprised of approximately 206 miles of laterals and main canal. The two main canals in the COID are the Central Oregon and the Pilot Butte Main Canals. Cross-section dimensions of the Central Oregon Main Canal are generally 24 to 30 feet wide and 4.0 to 4.5 feet deep. The Pilot Butte cross-section is about 15 to 35 feet wide and 3.5 to 4.0 feet deep (BOR 1997). The range of flow capacity for laterals in the COID is approximately 2 to 38 cfs. Lateral cross-sections range from 2 to 15 feet wide by 0.5 to 4 feet deep (BOR 1997). These laterals vary in length from 2 to 6 miles.

Urbanizing areas include lands within the Urban Growth Boundary (UGB) and the Urban Reserve Areas (URA). Laterals within the UGB's and URA's of Bend and Redmond are shown on Figure 2. Proposed projects are summarized in Table 4 and their locations are shown on Figure 2.

Table 4. COID Proposed Efficiency Projects

Location	Length (Miles)	Length (Feet)	In UGB	SAVED WATER (per irrigation season = 180 days)			Pipe Diameter (Inches)	COST				
				Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)		Total Saved Water Cost 2006(1)	Cost per AF Saved (average)	Annual O & M Cost ($)(2)	Cost per AF Saved (annualized)(3)	BOR 1997 Estimates Cost per AF Saved (Annualized) L=Lined P=Piped
PB Lateral F-2	4.58	24,182	YES	1,874	5.25	7.51	21	$846,384	$452	$35,306	$43	$41 (L)
PB Lateral A-12	3.50	18,480	NO	1,821	5.10	2.49	24	$850,080	$467	$26,981	$45	$93 (P)
CO D Lateral D-12-1	0.30	1,592	NO	143	0.40	0.18	10	$74,333	$519	$2,324	$50	$71 (P)
PB Lateral A-16	3.50	18,480	NO	2,433	6.81	2.49	30	$1,328,158	$546	$26,981	$53	$93 (P)
CO D-1 Lateral D-1-5	0.32	1,667	NO	95	0.27	0.18	10	$54,010	$570	$2,434	$54	$71 (P)
CO D Lateral D-12	0.40	2,133	NO	192	0.54	0.23	16	$130,364	$679	$3,114	$66	$71 (P)
PB Lateral A-10	4.50	23,760	PART	643	1.80	3.20	15	$485,654	$755	$34,690	$70	$93 (P)
CO D-1 Lateral D-1-4-3	0.08	425	NO	24	0.07	0.05	10	$18,586	$770	$621	$74	$71 (P)
CO D-1 Lateral D-1-4-0	0.31	1,660	NO	94	0.26	0.18	12	$74,734	$793	$2,424	$77	$71 (P)
Pilot Butte Main(4)	5.80	30,624	PART	20,458	57.30	17.12	108	$16,366,400	$800	$0	$80	$51 (L)
CO Lateral F-2	4.58	24,189	NO	1,538	4.31	2.48	21	$1,642,438	$1,068	$35,316	$104	$42 (L)
CO C-3 Lateral	0.80	4,235	NO	306	0.86	0.50	20	$333,198	$1,088	$6,183	$107	$42 (L)
CO C Lateral C-1	2.82	14,898	NO	956	2.68	1.75	24	$1,282,083	$1,340	$21,751	$132	$42 (L)
Central Oregon Main	6.35	33,528	PART	15,052	42.16	14.29	108	$21,020,000	$1,396	$0	$140	$65 (L)
CO D Lateral	0.74	3,900	NO	351	0.98	0.43	30	$607,866	$1,732	$5,694	$171	$71 (P)
Totals for all Projects	**38.59**	**203,753**		**45,981**	**128.79**	**53.08**		**$45,114,286**		**$203,818**		

Source of saved water data: District Records

(1) Based on $1.46 / linear foot of lateral

(2) Construction and piping cost include a 10% contingency

(3) Based on subtracting O & M Costs from total project cost and a 20 year life expectancy at a 7.75% interest rate.

(4) Total saved water costs reflect savings from hydropower production.

Annual seepage losses listed in the table represent adjusted 5-year averages for laterals in the Pilot Butte and Central Oregon Canal based on district records. COID personnel measured these losses over the course of the irrigation season (180 days). Seepage losses in both the Central Oregon Canal and the Pilot Butte Canal were measured by flume tests conducted by David Evans and Associates (DEA) and district personnel.

Based on district records piping of the proposed projects could if implemented save approximately 45,981 ac-ft or 128.79 cfs on an annual basis that could be used to guarantee supplies to irrigators or used to improve in-stream flows in the Deschutes River. For the two COID main canals alone, seepage losses range from approximately 15,000 to 20,000 acre-feet annually.

Total costs of piping took into account varying pipe diameters for specific reaches and construction costs. Pipe costs reflect current post-hurricane Katrina prices. The hurricane damaged petroleum and pipe manufacturing facilities, reducing production capability, which in turn resulted in dramatic price increases up to 200 percent. .

Construction costs were estimated by COID personnel based on their prior experience with piping projects and included installation, engineering, surveying, deliveries, fittings and contingency. The total cost of piping laterals ranged from $450 to $1,732 per acre-foot of water conserved. Costs of piping the main canals were $800 to $1,396 per acre-foot of water conserved for Pilot Butte and Central Oregon Canals respectively. The costs of piping the Pilot Butte canal are significantly reduced when hydropower production revenue is factored in.

The total cost of the project listed in Table 4 was $45,114,286. The annual cost of Operations and Maintenance (O&M) can essentially be eliminated by piping canals, and thus can be subtracted from the total construction costs. This would lower the total cost of the projects to $44,910,468.

7.1.3 Lone Pine Irrigation District

The LPID is comprised of approximately 13.6 miles of laterals and main canal. The canals in the LPID have flow capacities ranging from 5 cfs to 45 cfs (DRC 2005). Cross-section dimensions of the Canals are generally 2.0 ft to 12 ft wide and 1.5 ft to 2.5 ft deep (BOR 1997). Proposed projects are summarized in Table 5 and their locations are shown on Figure 2.

Table 5. LPID Proposed Efficiency Projects

Location	Length (Miles)	Length (Feet)	In UGB	SAVED WATER (per irrigation season = 180 days)			Pipe Diameter (Inches)	COST			
				Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)		Total Saved Water Cost 2006(2)	Cost per AF Saved (average)	Cost per AF Saved (annualized)(1)	BOR 1997 Estimates Cost per AF Saved (Annualized) L=Lined P=Piped
Main Canal	0.81	4,259	NO	119	0.33	1.65	48	$4,800,000	$1,629	$248	$18 (L)
Pump Ditch	3.41	18,022	NO	396	1.11	1.36	12 to 24				$61 (L)
Middle Ditch	6.37	33,651	NO	683	1.91	3.37	12 to 36				$23 (L)
Lower Ditch	3.00	15,856	NO	740	2.07	1.00	12 to 24				$55 (L)
Tail Water Loss Reduction				1,009	2.83						
Totals for all Projects	**13.60**	**71,788**		**2,947**	**8.25**	**7.38**		**$4,800,000**			

Source saved water data: District Records

(1)Based on a 20 year life expectancy at a 7.75% interest rate.

(2)Cost for entire project implementation.

Seepage losses and opportunities for efficiency improvements were evaluated in the 2005 study entitled "*Water Monitoring & Conservation Opportunities in Crook County Improvement District #1*" written by the Deschutes River Conservancy. Study findings found that approximately 1,938 acre-feet or 5.43 cfs could be saved on an annual basis if efficiency improvements were implemented throughout the district. Preliminary engineering studies showed an approximate cost for these projects of $4,800,000 or $2,477 per acre of conserved water. Further analysis should be performed to refine construction and piping costs for the proposed projects.

7.1.4 North Unit Irrigation District

The NUID is comprised of approximately 149 miles of laterals and main canal with a maximum flow capacity of 1,000 cfs. The main canal has cross-sectional dimensions of 14 ft to 40 ft wide and 5ft to 8ft feet deep (BOR 1997). Conveyance efficiency opportunities were evaluated in district main canals and laterals. The main canal has a flow capacity of approximately 535 cfs based on average annual flow records for the period 1983 to 1987.

District records indicate that approximately 2,678 acre-feet or 7.5 cfs could be saved on an annual basis if the lateral 58-9 were piped. Costs to implement this piping project were estimated by district personnel at approximately $2,946,240 or $1,100 per acre of conserved water. Additional benefits of this project would involve lowered power costs for pumping due to pressurized water and lowered Operations and Maintenance costs.

A study conducted by HDR Engineering (HDR) evaluated feasibility of extending the main canal lining from the prior lining project to the Crooked River. The main canal invert and side slopes are lined from mile 0.5 to mile 7.4 and only the invert from mile 7.4 to 12.3. The canal is unlined from mile 12.3 to mile 26.1 except for a 0.3 mile section between mile 10.19 and mile 10.49 (invert and side slope).

The study considered various lining materials, benefit/cost analysis and potential for conserved water. Results are shown in Table 6. To line the remaining section of main canal, lining of the side slopes would have to occur from mile 7.4 to 12.3. Both the invert and the side slopes would need to be lined from mile 12.3 to 26.1. Proposed projects are summarized in Table 6 and their locations are shown on Figures 2 and 3.

Table 6. NUID Proposed Efficiency Projects

Location	Length (Miles)	Length (Feet)	In UGB	SAVED WATER (per irrigation season = 180 days)			Pipe Diameter (Inches)	COST			
				Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)		Total Saved Water Cost 2006	Cost per AF Saved (average)	Cost per AF Saved (annualized)(2)	BOR 1997 Estimates Cost per AF Saved (Annualized) L=Lined P=Piped
Main(1)(3)	18.70	98,736	NO	14,395	40.32	71.56	N/A	$15,291,002	$1,062	$106	$86 (L)
Lateral 58-9	7.48	39,515	NO	2,678	7.50	4.60	10 to 27	$2,946,240	$1,100	$110	$126 (P)
Totals for all Projects	**26.18**	**138,251**		**17,073**	**47.82**	**76.16**		**$18,237,242**			

Source saved water data: District Records

(1)Lining project conserved water assumes an average loss of 1030 AF/mile and a 70% efficiency.

(2) Based a 20 year life expectancy at a 7.75% interest rate.
(3) Total saved water costs reflect savings from reduced power savings from the Crooked River..

Loss estimates for these remaining 18.7 miles were made by HDR and are based on limited measurements made during the initial phases of canal lining in the first 12.3 miles. Based on an average annual discharge of 212,000 acre-feet before lining, seepage losses in the remaining unlined sections were approximated at an average of 1,030 acre-feet per mile. This translates to an annual seepage loss of 19,300 acre-feet. Estimating that concrete liners are 70% efficient over time at reducing seepage losses, this would translate to a net amount of 13,510 acre-feet of conserved water annually. This volume corresponds approximately to 37.84 cfs.

Further study should be performed however to accurately determine current water losses and potential water savings that lining could offer. The above numbers are based on 1 year of data completed after the last phase of canal lining was completed.

Costs to line the remaining 18.7 miles were analyzed and are also shown in Table 1. Four different scenarios were evaluated and roller compacted concrete with shotcrete side slopes was determined to be the most cost-effective method of lining. Overall costs of lining took into account mobilization, surveying, construction and a 30% contingency. The cost of lining the main canal was $15,291,002. This cost for lining the main canal reflects savings from reduced pumping costs associated with pumping out of the Crooked River. The total cost of all NUID projects would be $18,237,242.

7.1.5 Ochoco Irrigation District

The OID is comprised of approximately 71.4 miles of laterals and main canal. The main canal in the OID is generally 9 ft to 11 ft wide and 2 ft deep. Lateral cross-sections range from 4 ft to 8 ft wide by 2 ft deep (BOR 1997).

Although seepage losses are lower given canal and lateral Geology in the OID compared to other districts in the upper Deschutes Basin, the district serves about 1,571 acres inside the present Prineville UGB (Figure 3). To address the growing population and account for urbanization pressures on canal and lateral networks within the district, the OID is also studying opportunities for efficiency improvements. Proposed projects are summarized in Table 7 and locations are shown on Figure 3.

Table 7. OID Proposed Efficiency Projects

Location	Length (Miles)	Length (Feet)	In UGB	SAVED WATER (per irrigation season = 180 days)			Pipe Diameter (Inches)	COST	
				Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)		Total Saved Water Cost 2006	Cost per AF Saved (average)
Prineville Diversion Canal	1.25	6,600	YES	ND	ND	0.39	ND	ND	ND
Totals savings for all Projects	**1.25**	**6,600**				**0.39**			

ND: No Data Available

The proposed 6,600 feet of piping would reduce the annual O&M costs in addition to limiting the safety concerns associated with the open canal reach through a populated urban area. Further analysis should be performed to determine seepage losses and determine construction and piping costs for the proposed project.

7.1.6 Swalley Irrigation District

The main canal in the SID has a flow capacity of approximately 110 cubic feet per second (cfs). Cross-sectional dimensions of the Swalley Main Canal are generally 15 feet wide and 2 feet deep. There are 11 laterals in the SID with maximum flow capacities ranging from 1.4 to 17.8 cfs. Lateral cross-sections range from 3 to 5 feet wide by 1 to 2 feet deep and vary in length from 0.5 to 4 miles. Conveyance efficiency opportunities were evaluated in the main canals and the laterals. Urbanizing areas include lands within the Urban Growth Boundary (UGB) and the Urban Reserve Areas (URA). Laterals within the UGB's and URA's of Bend are shown on Figure 4.

Table 8 shows a list of laterals originating from Swalley main canal. Annual seepage losses listed in Table 8 for laterals represents values calculated in the BOR 1997 report based on a 210 day irrigation season. Seepage rates for laterals were estimated given foundation geology and data collected in ponding tests. Seepage losses shown in Table 8 for the laterals represent losses ranging from 200 to 2,190 ac-feet per 210-day irrigation season.

Table 8. SID Proposed Efficiency Projects

Location	Length (Miles)	Length (Feet)	In UGB	SAVED WATER (per irrigation season = 210 days)			Pipe Diameter (Inches)	COST				
				Total AF/Irrigation Season (210 days)	Total CFS	Total CFS (BOR 1997 Estimates)		Total Saved Water Cost 2006(1)	Cost per AF Saved (average)	Annual O & M Cost ($)(2)	Cost per AF Saved (annualized)(2)	BOR 1997 Estimates Cost per AF Saved (Annualized) L=Lined P=Piped
NC-1 Lateral	0.61	3,203	YES	800	1.92	1.92	8 to 6	$77,874	$97	$4,260	$10	$17 (L)
Rogers Sub Lateral	0.42	2,239	NO	450	1.08	1.08	10 to 8	$67,100	$149	$2,978	$15	$24 (L)
Kotzman Lateral	2.21	11,658	YES	1,580	3.79	3.79	12	$435,803	$276	$15,505	$28	$17 (L)
Riley Sub Lateral	1.27	6,731	NO	710	1.70	1.70	12 to 10	$242,852	$342	$8,952	$34	$24 (L)
Butte Lateral	1.03	5,459	NO	480	1.15	1.15	10.00	$166,143	$346	$7,260	$35	$24 (L)
Frakes Lateral	1.34	7,080	NO	550	1.32	1.32	10.00	$222,799	$405	$9,416	$40	$28 (L)
Mickelson Lateral	0.41	2,164	NO	200	0.48	0.48	8.00	$84,650	$423	$2,878	$42	$25 (L)
Deschutes Lateral	1.43	7,560	NO	530	1.27	1.27	10.00	$239,919	$453	$10,055	$45	$24 (L)
Rogers Lateral	3.95	20,830	PART	2,190	5.26	5.26	18 to 10	$1,026,175	$469	$27,704	$47	$18 (P)
Main(4)(5)	5.10	26,928	PART	9,663	23.20	19.24	up to 63	$4,628,639	$479	$35,814	$48	$17 (L)
Riley Lateral	1.34	7,066	PART	1,150	2.76	2.76	24 to 10	$580,608	$505	$9,398	$50	$24 (L)
Elder Lateral	1.91	10,083	NO	860	2.06	2.06	18.00	$487,690	$567	$13,410	$57	$24 (L)
Totals for all Projects	**21.02**	**111,001**		**19,163**	**46.01**	**42.05**		**$8,260,252**		**$147,631**		

Source saved water data: BOR 1997 Report except for Main Canal: District Records

(1) Based on $1.33 / linear foot of lateral

(2) Construction and Piping cost include surveying, engineering

(3) Based on subtracting O & M Costs from total project cost and a 20 year life expectancy at a 7.75% interest rate.

(4) Seepage losses for the main canal were measured in flumes on four occassions by DEA during Summer 2005 with 20-25% uncertainty. Measured flows and losses were:

Date	Flow	Loss
06/15/05	83.91 cfs	23.55 cfs
07/14/05	98.73 cfs	27.1 cfs
07/20/05	113.88 cfs	27.46 cfs
09/27/05	64.1 cfs	14.67 cfs

(5) Total saved water costs reflect savings from hydropower production.

Seasonal seepage losses for the Swalley Main Canal were estimated by a series of flume measurements during Summer 2005 by David Evans & Associates (DEA) in coordination with SID. The area measured for the Swalley Main Canal took into account the first approximate 5.1 miles of canal from the diversion at North Dam in Bend northward. Seepage losses shown in Table 10 for the Swalley Main Canal represents the average amount of water that could be conserved over a 210 day irrigation season given a measurement uncertainty of 25%. Actual seepage losses and potential for water use efficiency could range from 17 to 29 cfs. Seepage rates measured by DEA for the Seepage losses for the Swalley Main Canal over the first 5.1 miles were 9,663 ac-ft or 23.20 cfs over a 210 irrigation season.

Costs to convert these open unlined canals to pipe were analyzed and are also shown in Table 8. Overall costs of piping took into account varying pipe diameters for specific reaches and installation construction costs. Pipe costs reflected current post-hurricane Katrina prices. Construction costs were estimated by SID personnel and included installation, engineering, surveying, deliveries, fittings and contingency. The cost of piping lateral canals were $97 to $567 per acre-foot of water conserved. The cost of piping the main canal was $497 per acre-foot of water conserved. This cost for the main canal piping reflects savings from hydropower production that would help offset construction costs.

The total cost of the projects listed in Table 8 was $8,260,252. The annual cost of Operations and Maintenance (O&M) can essentially be eliminated by piping canals, and thus can be subtracted from the total construction costs. This would lower the total cost of the projects to $8,112,621.

7.1.7 Three Sisters Irrigation District

The TSID is comprised of approximately 60.4 miles of laterals and main canal. The main canal in the TSID is generally 12 ft to 14 ft wide and 2 ft deep. Lateral cross-sections range from 2 ft to 10 ft wide by 2 ft deep (BOR 1997).

The TSID has implemented a number of efficiency projects and is continuing in its efforts to improve the efficiency of its irrigation network. Proposed projects are summarized in Table 9 and their locations are shown on Figure 4.

Table 9. TSID Proposed Efficiency Projects

Location	Length (Miles)	Length (Feet)	In UGB	SAVED WATER (per irrigation season = 180 days) Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)	Pipe Diameter (Inches)	COST Total Saved Water Cost 2006	Cost per AF Saved (average)
McKenzie/Black Butte Canal	10.70	56,520	NO	3,035	8.50	6.83	ND	$5,440,800	$1,793
Main Canal	3.70	19,536	NO	2,678	7.50	2.07	ND	ND	ND
Totals for all Projects	**10.70**	**56,520**		**3,035**	**8.50**	**6.83**			

Source saved water data: District Records
ND: No Data Available

Piping of the proposed projects could if implemented save approximately 3,035 ac-ft or 8.5 cfs on an annual basis that could be used to guarantee supplies to irrigators or used to improve in-stream flows in Whychus Creek. The hydroelectric facility included in the main canal project could also lower project implementation costs by potentially benefiting from BETC tax credits and hydropower revenue. The corresponding revenue contribution from renewable power generation could also help support district sustainability in the future. Cost of the McKenzie/Black Butte efficiency project are estimated at $5,440,800 or $1,793 per acre-foot of water conserved. Further analysis should be performed to determine construction and piping costs for the main canal piping and hydroelectric project.

7.1.8 Tumalo Irrigation District

The TID is comprised of approximately 59.3 miles of laterals and main canal. The main canals in the TID are generally 10 ft to 16 ft wide and 2 ft to 2.5 ft deep. Lateral cross-sections range from 2 ft to 6 ft wide by 1 ft to 2 ft deep (BOR 1997).

Conveyance efficiency opportunities were evaluated in the Tumalo Feed canal of the district that conveys water from Tumalo creek north and west to outlying reaches of the district. A study conducted by David Evans & Associates (DEA) looked at the feasibility of piping remaining sections of the Tumalo Feed canal in terms of costs and potential water savings. Results are shown in Table 2. Location of canals and laterals can be found in Figure 4.

Table 10. TID Proposed Efficiency Projects

Location	Length (Miles)	Length (Feet)	In UGB	SAVED WATER (per irrigation season = 180 days) Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)	Pipe Diameter (Inches)	COST Total Saved Water Cost 2006(1)	Cost per AF Saved (average)	Cost per AF Saved (annualized)(2)	BOR 1997 Estimates Cost per AF Saved (Annualized) L=Lined P=Piped
Main	6.00	31,680	?	7,141	20.00	7.22	84	$14,000,000	$1,961	$196	$56 (L)
Totals for all Projects	**6.00**	**31,680**		**7,141**	**20.00**	**7.22**		**$14,000,000**			

Source saved water data: District Records
(1) Construction and piping cost include a 10% contingency
(2) Based on a 20 year life expectancy at a 7.75% interest rate.

The total length of canal considered for piping with HDPE pipe was 6.0 miles. DEA estimated that piping these sections could conserve 7,141 acre-feet per year or 20 cfs based on a 180 day irrigation season. Costs to pipe these 6.0 miles of the Tumalo Feed Canal were estimated at $14,000,000. These costs include materials, surveying, engineering and installation. This translates to a cost of $1,961 per acre-foot of water conserved.

7.2 On-Farm Efficiency

7.2.1 Potential Water Savings & Limitations

The 1997 BOR report *"Upper Deschutes River Basin Water Conservation Study, Special Report, Crook, Deschutes, and Jefferson Counties, Oregon"* analyzed the on-farm efficiency of eight irrigation districts mentioned in this report. On-farm efficiency was calculated by dividing crop water use by reported farm deliveries and multiplying by 100. The results from this analysis are shown in Table 11.

Table 11. On-Farm Efficiency Summary (1997 BOR)

Irrigation Districts	Irrigation System Diversions (ac-ft)	Reported Farm Deliveries (ac-ft)	Annual On-Farm Losses (ac-ft)	Crop Water Use (ac-ft)	Efficiency (%)	Potential water saved with 70% efficiency (ac-ft)	Potential water saved with 80% efficiency (ac-ft)
Arnold	38,400	17,400	8,420	8,980	51.6	4,571	6,175
Central Oregon	351,510	241,000	137,550	103,450	42.9	93,214	111,688
Lone Pine	14,560	5,200	580	4,620	88.8	NA	NA
North Unit	221,770	127,290	7,890	119,400	93.8	NA	NA
Ochoco	75,560	60,440	20,490	39,950	66.1	3,369	10,503
Three Sisters	26,420	23,000	8,700	14,300	62.2	2,571	5,125
Swalley	42,410	18,350	8,990	9,360	51.0	4,979	6,650
Tumalo	67,000	26,520	10,550	15,970	60.2	3,706	6,558
TOTALS	**837,630**	**519,200**	**203,170**			**112,410**	**146,698**

Since the 1997 report, irrigation districts in cooperation with consultants, Soil and Water Conservation Districts (SWCD) and the National Resources Conservation Service (NRCS) have compiled and implemented water conservation plans furthering the goal of improving and identifying on-farm efficiency opportunities. Taking the 1997 BOR data shown above in Table 11, it can be shown for example that an additional 112,410 to 146,698 ac-ft annually could be saved if irrigation districts increased their on-farm efficiency to 70-80%.

It is unlikely, however, that on-farm efficiency improvements could be implemented district wide within the next 20 years. Given implementation feasibility, it has been estimated that approximately 10,000 ac-ft could be saved within the next 20 years by on-farm conservation at a cost of approximately $496 per acre-foot of water saved (Table 13).

The following are estimates for various opportunities for improvements, and reduction in water use:

- Sprinkler system improvements: 5 %
- Surface (flood) system improvements: 10 – 20%
- Piping open earth ditches (seepage loss) 30 – 45%
- Irrigation scheduling 5%
- Convert surface to sprinkler irrigation systems: 30 – 35%

It must be recognized that it takes specialized experience to provide adequate technical assistance to landowners to improve or convert to alternative on-farm irrigation methods and systems. Some of these issues could be addressed by the following:

- Provide experienced on-farm technical assistance to irrigators, possibly through a DWA funded OSU irrigation engineering/technician (or team). This would reduce possible friction with many other local agencies and groups. Current technology is readily available through OSU, NRCS and SWCDs. Cost estimate would be approximately $150,000 to $200,000 per year.
- Provide cost sharing funding (i.e. materials) for on-farm installations of water efficiency practices. Cost share estimate would be approximately $1,500,000 per year.

Within the Upper Deschutes Basin, many miles of on-farm delivery and distribution system pipelines, sprinkler irrigation systems, gated pipe facilities, tail water collection and pump back facilities, have been installed with technical assistance from local Soil & Water Conservation Districts (SWCD), Natural Resources & Conservation Service (NRCS) and irrigation equipment supply dealers. Financial cost sharing from the NRCS and the American Society of Civil Engineers (ASCE) has been provided on many installations over the years.

7.2.2 On-Farm Efficiency Methods

On-farm improvements may include: delivery & distribution facilities, improvements to existing sprinkler and surface irrigation systems, conversion from surface (flood) to sprinkler irrigation systems, reducing seepage in small ponds by lining, improving irrigation system operations and water management (i.e. irrigation scheduling) and providing adequate maintenance to sprinkler system hardware and pumps. Potential irrigation efficiencies using these different methods can be found in Table 12.

Table 12. Potential Irrigation Efficiency (Ultimate, Design, Seasonal & Typical)

Irrigation Method	Irrigation System	Ultimate 1/ Potential Efficiency	Irrigation System Design Efficiency	Overall 2/ Seasonal Irrigation Efficiency	Typical 3/ Irrigation Efficiency
Surface	Borders				
	Level or Basin	90	50-80	50-90	80
	Graded	80	50-60	45-60	60
	Furrow				
	Graded	75	50-60	50-60	60
	Corrugation	75	50-60	50-60	50
	Flood – controlled	60	40-50	30-50	40
	Flood – semi controlled	50	30-40	25-40	35
Sprinkler	Periodic move				
	Side-roll Wheel line	70	65-70	60-65	65
	Hand Move	70	65-70	50-65	65
	Solid Set	75	65-75	50-65	65
	Big guns	60	60	50-60	60
	Continuous Move				
	Big guns	60	60	50-60	60
	Center Pivot	85	85	75-85	80
Micro	Continuous Tape	90	85-90	80-85	85
	Point Source Emitters	90	85-90	80-85	85
	Mini Spray	85	85	80-85	85

7.2.3 Sprinkler Irrigation System Improvements:

On-farm water efficiency can be achieved by implementing the following measures on sprinkler irrigation systems:

- Provide uniform and adequate sized nozzles that meet local crop evapotranspiration (ET), soil characteristics and system return capacity (i.e. considering head spacing, nozzle size, nozzle discharge pressure, discharge flow, etc).
- Replace worn nozzles that discharge greater than design flows.
- Use appropriate operating design pressure at the sprinkler head. Check with pressure gauge (with pitot tube attachment).
- Replace non-functioning sprinkler heads and gaskets.
- Use “off-sets” on lateral returns to improve application uniformity.
- Use flow control nozzles on fields with elevation differences greater then 20-40 ft.
- Use pressure control valves in the delivery lines to maintain adequate operation pressures.
- Adjust operation or set times to operate pumps and apply water to match soil type, depth and crop growth conditions. Using simple irrigation scheduling techniques (i.e. soil moisture checking, BOR’s “Agrimet” Bend or Powell Butte Station, etc.).

- Repair leaks in flex hose, valve gaskets, pipe gaskets, etc.
- Measure delivery flows.
- Provide a pump audit/evaluation to potentially improve pump operation.
- Maintain trash screens to prevent plugging of pump and sprinkler head nozzles.

7.2.4 Surface (flood) Irrigation Systems

On-farm water efficiency can be achieved by implementing the following measures on surface irrigation systems:

- Use tail water collection systems and pump-back systems to reuse runoff from flood irrigation. A summary of cumulative overall efficiency with reuse of runoff can be found in Table 6.
- Install lengths-of-run and use appropriate in-flow at head of field, for graded borders, furrows and corrugations, that is based on soil intake and water holding characteristics, field slope, and crop growth. Runoff from the lower end of the field must occur to obtain optimum irrigation application efficiency throughout the field length (i.e. 30 – 35%).
- Convert from open head ditch operations to gated pipe in order to optimize & control flow at the head of field, and decrease seepage losses in head ditch.

7.2.5 Delivery Systems

On-farm water efficiency can be achieved by implementing the following measures on Delivery systems:

- Pipe open earth delivery and distribution facilities that have high seepage losses.
- Line existing ponds and pump sumps that have high seepage losses.
- Convert open earth pump sumps to “concrete boxes”.

7.2.6 Conversion of Flood Systems to Sprinkler Systems

On-farm water efficiency can be achieved by converting from flood irrigation systems to sprinkler irrigation systems. Sprinkler irrigation systems make more efficient use of irrigation water by reducing surface runoff due to over irrigating lands. Although a pumping cost can occur if delivered water is not pressurized, labor for sprinkler irrigation may actually be less. Surface (flooding) irrigation requires knowledgeable physical labor rather frequently. It may not, however, be currently provided as often as is necessary to prevent excessive runoff and deep percolation. Sprinkler irrigation, which includes periodic move wheel line and hand line systems, typically requires moving fixtures twice per day. Center pivot systems require very little day-to-day labor.

8 SUMMARY OF FINDINGS

This paper presents the results of a cost analysis and prioritization evaluation for efficiency improvements in irrigation districts located in the upper Deschutes Basin, Oregon. Evaluation focus looked at opportunities for efficiency improvements in water conveyance facilities and in on-farm irrigation practices.

Opportunities for improving efficiency were evaluated and prioritized according to costs and potential for broadening the benefits of water use in the upper basin under existing water rights. Specific projects were identified given a set of criteria that included total amount of water that could be made available through efficiency improvements, restraints and limitations on water made available by efficiency improvements and impact of urbanization on district conveyance facilities.

Suitable project locations were divided into two categories; main canal projects and lateral canal projects. These projects are listed in Table 3 through Table 10 and were ranked by district in ascending order according to total cost of installation per acre-feet of conserved water. A summary of potential water savings that could be achieved from proposed efficiency projects throughout Upper Deschutes Basin Irrigation Districts is summarized in Table 13.

Table 13. Summary of Potential Water Savings From All Districts

				SAVED WATER (per irrigation season)			COST	
Project (P) Piping (L) Lining	Location	Length (Miles)	Length (Feet)	Total AF/Irrigation Season (180 days)	Total CFS	Total CFS (BOR 1997 Estimates)	Total Saved Water Cost 2006	Cost per AF Saved (average)
AID (P)	Laterals	3.03	16,000	2,250	6.30	3.28	ND	ND
COID (P) [1]	Central Oregon Main	6.35	33,528	15,052	42.16	14.29	$21,020,000	$1,396
	Pilot Butte Main[5]	5.80	30,624	20,458	57.30	17.12	$16,366,400	$800
	Central Oregon Laterals	10.36	54,699	3,700	10.36	5.98	$4,217,610	$1,140
	Pilot Butte Laterals	16.08	84,902	6,770	18.96	15.69	$3,510,276	$518
LPID (P)	Main Canals & Laterals	14.41	76,085	2,947	8.27	7.38	$4,800,000	$1,629
NUID (L) [2][3]	Main[5]	18.70	98,736	14,395	40.39	71.56	$15,291,002	$1,062
	58-9 Lateral	7.48	39,515	2,678	7.50	4.60	$2,946,240	$1,100
OID	Prineville Diversion Canal	1.25	6,600	ND	ND	0.39	ND	ND
SID (P)[4]	Main Canal[5]	5.10	26,928	9,663	23.20	19.24	$4,628,639	$479
	Laterals	15.92	84,073	9,500	22.81	22.81	$3,631,613	$382
TSID (P)	McKenzie/Black Butte Canal	10.70	56,520	3,035	8.50	6.83	$5,440,800	$1,793
	Main Canal	3.70	19,536	2,678	7.50	2.07	ND	ND
TID (P)[4]	Main	6.00	31,680	7,141	20.00	7.22	$14,000,000	$1,961
Sub-Total		**124.89**	**659,426**	**100,268**	**273.26**	**198.46**	**$95,852,580**	**$1,115**
On-Farm Efficiency Projects	All Districts[6]			10,000	28.10	46.23	$4,956,910	$496
Totals for all potential projects		**124.88**	**655,129**	**110,268**	**301.36**	**244.69**	**$100,809,490**	**$1,022**

ND: No Data Available

(1) Construction and piping cost include a 10% contingency

(2) Lining project conserved water assumes an average loss of 1030 AF/mile and a 70% efficiency.

(3) Construction and lining cost include a 30% contingency. Construction and lining cost includes shotcrete sides from mile 7.4 to 12.3.
(4) Construction and Piping cost include surveying, engineering.

These projects represent a small fraction of total potential efficiency projects that exist throughout the basin irrigation districts. Certain irrigation districts have further studied the potential for piping projects by conducting engineering and construction cost analysis in addition to studying the potential for installing hydroelectric facilities. Costs of piping projects that include hydroelectric facilities could be significantly lowered given the Oregon BETC benefits and hydropower revenue. The pressurized water in piped canals could generate power revenue and reduce power cost to irrigators by eliminating or reducing the need for pumps. Piping projects would also eliminate O&M costs associated with open un-lined canals and laterals. These reduced O&M costs would lower the cost of the initial project construction and would also be eliminated in future years effectively lowering annual operating costs.

Table 13 indicates that implementing all efficiency projects could potentially reduce seepage losses by 100,268 ac-ft or 273.26 cfs on an annual basis. Costs of these projects would be approximately $95,852,580, however, costs for certain projects listed in Table 13 were not available.

Analysis of on-farm conservation opportunities showed that an additional 112,410 to 146,698 ac-ft of water could be saved if on-farm efficiency were improved to 70-80% across all districts. It is unlikely, however, that on-farm efficiency improvements could be implemented district wide within the next 20 years. Given implementation feasibility, it has been estimated that approximately 10,000 ac-ft could be saved within the next 20 years by on-farm conservation at a cost of approximately $496 per acre-foot of water saved (Table 13).

If both proposed piping/lining projects and on-farm conservation measures were implemented throughout the basin, approximately 110,268 acre-feet or 301.36 cfs of water could be made available on an annual basis to broaden the benefits of water use in the upper basin under existing water rights. The total cost of this saved water would be approximately $100,809,490.

The effective reductions in demand brought about by efficiency projects could then help implement alternative reservoir management schemes. Combining these two management practices could significantly improve ecosystem functions by increasing both the volume and timing of in-stream flows. A companion DWA paper "*Reservoir Management*" addresses how efficiency improvements and reduced water demand described in this paper combined with optimizing reservoir management can help provide for future basin water needs.

Further considerations and study must be made before implementing these projects. Prioritization criteria for how these projects are selected should be further evaluated to ensure that all basin needs and concerns are addressed. Some of these considerations are listed below:

- The North Unit main canal lining project has the potential for reducing seepage losses by 37.84 CFS on annual basis. These seepage losses as mentioned above are estimated and are based on very limited measurements. In addition, reallocation of water obtained by efficiency improvements requires special federal legislations approving other than irrigation use on a federal project.

- Prioritization criteria in selecting project implementation scheduling should further be solidified.

- In order to compare and prioritize projects between districts, true construction and piping costs must be determined. While uniform piping costs in terms of cost per linear foot of pipe can be determined, construction costs for each district may vary according to district capabilities or options to subcontract project construction.

- Further analysis must be conducted with the districts to determine where piping and lining in specific lateral and main reaches would be most effective in terms of reducing seepage losses.

- Potential opportunities for offsetting construction costs should be further evaluated. These opportunities can include reduced operations and maintenance costs, power production, tax credits and cost sharing with land owners and developers in urban areas.

- Piping laterals before mains can reduce costs of piping main canals in the future by reducing pipe sizes needed to pipe main canals.

- Further analysis must be conducted to refine the feasibility and potential water savings that could be made available by implementing on-farm conservation measures.

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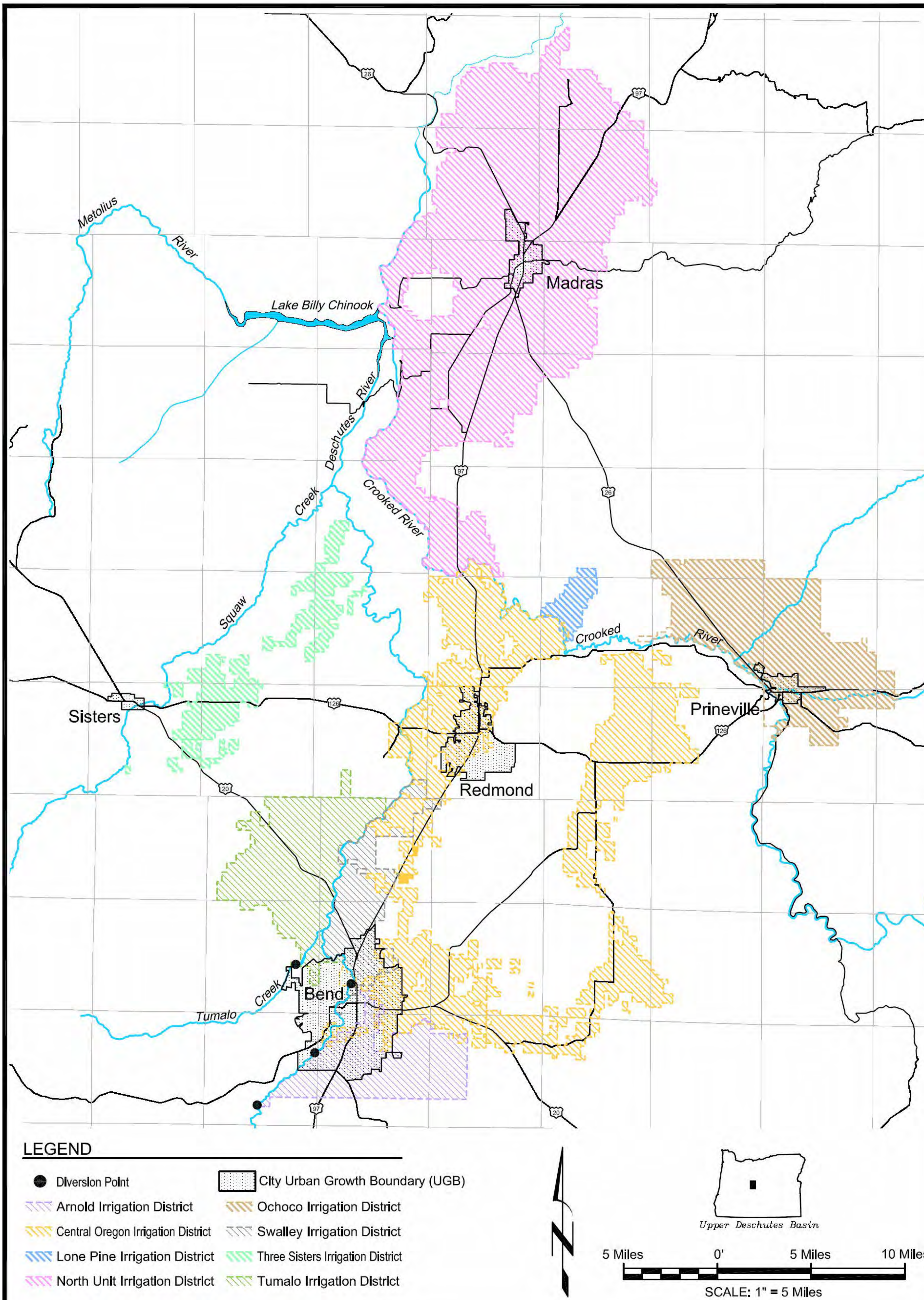

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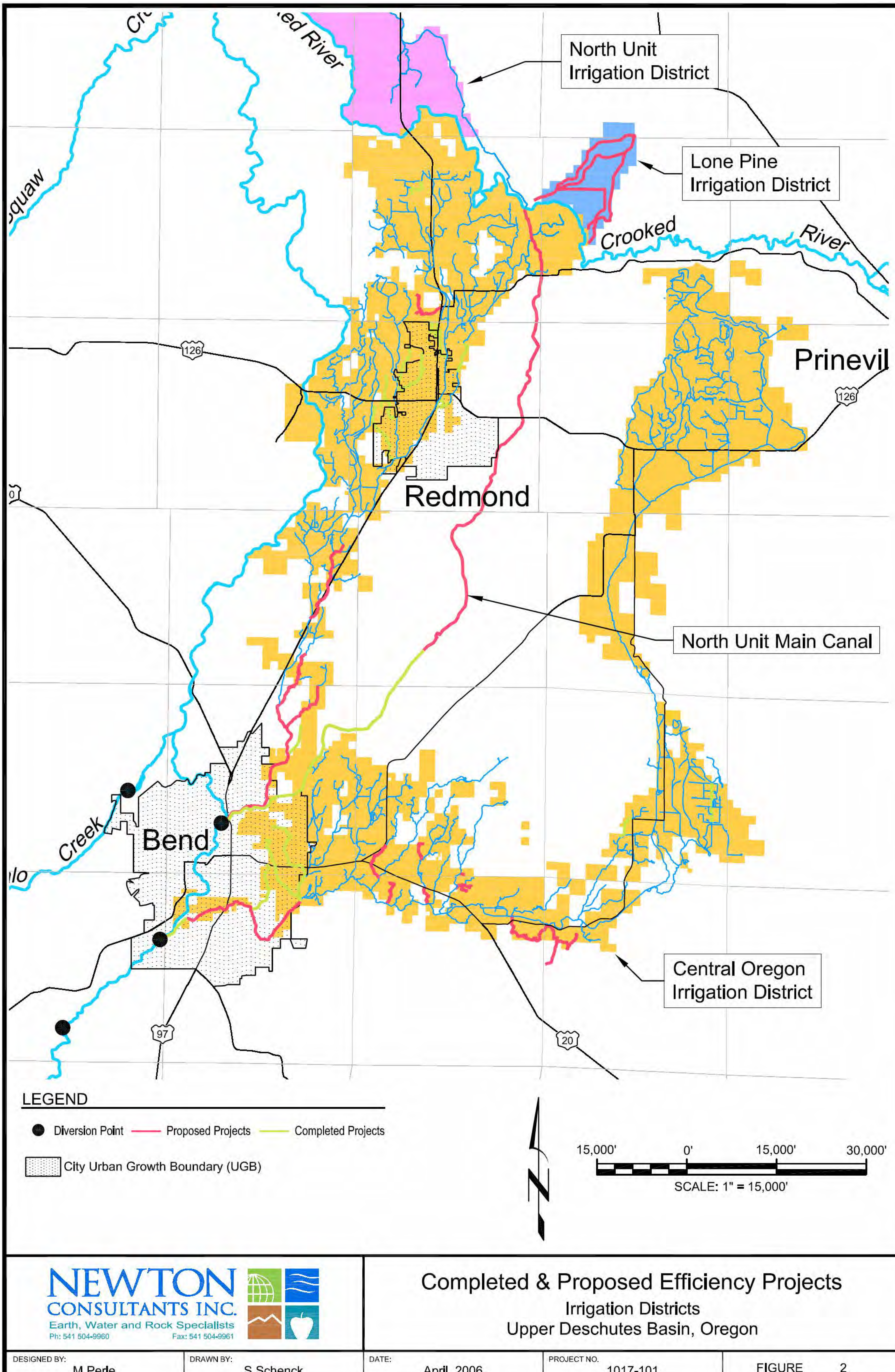
Master Index Sheet
Irrigation Districts
Upper Deschutes Basin, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO.	FIGURE
M.Perle	S.Schenck	April 2006	1017-101	1


North Unit
Irrigation District
Lone Pine
Irrigation District
Crooked River
Prinevil
126
Redmond
North Unit Main Canal
Bend
Creek
Central Oregon
Irrigation District
97
20
LEGEND
Diversion Point
Proposed Projects
Completed Projects
City Urban Growth Boundary (UGB)
15,000'
0'
15,000'
30,000'
SCALE: 1" = 15,000'
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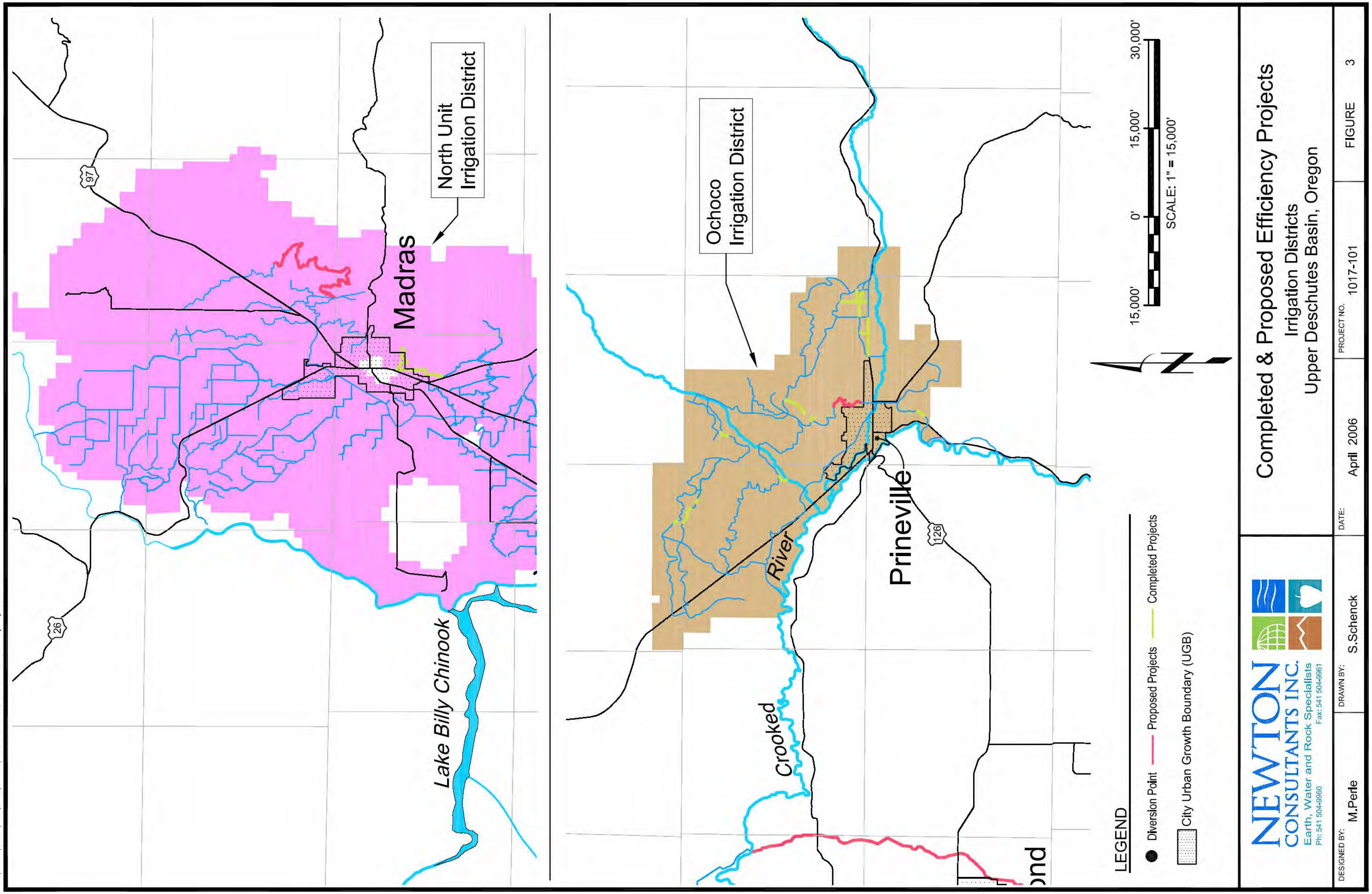
Completed & Proposed Efficiency Projects
Irrigation Districts
Upper Deschutes Basin, Oregon
DESIGNED BY: M.Perle
DRAWN BY: S.Schenck
DATE: April 2006
PROJECT NO. 1017-101
FIGURE 2


North Unit Irrigation District
Madras
97
26
Lake Billy Chinook
Ochoco Irrigation District
Prineville
126
Crooked River
ond
15,000'
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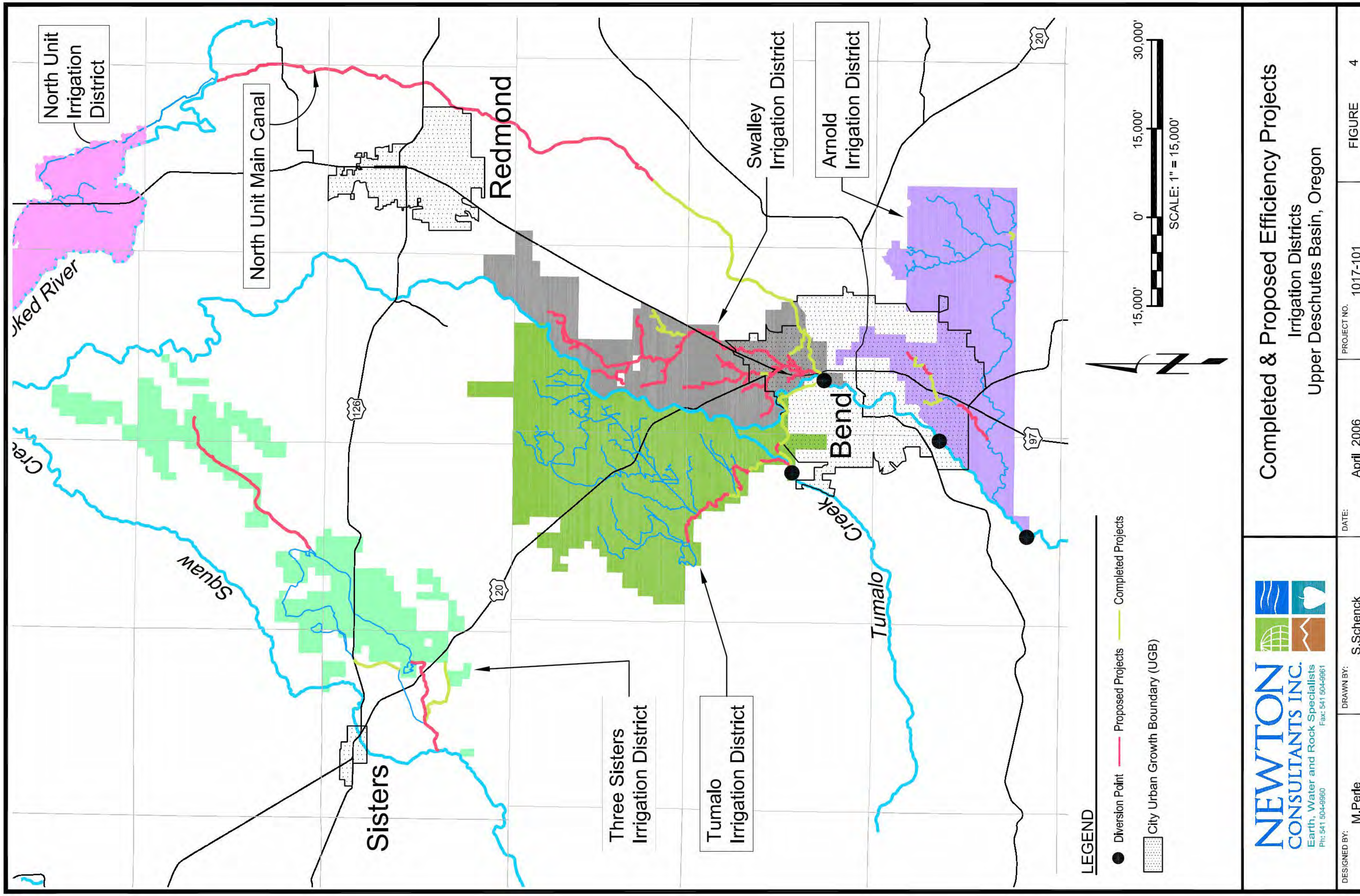
15,000'
30,000'
SCALE: 1" = 15,000'
LEGEND
Diversion Point
Proposed Projects
Completed Projects
City Urban Growth Boundary (UGB)
Completed & Proposed Efficiency Projects
Irrigation Districts
Upper Deschutes Basin, Oregon
NEWTON CONSULTANTS INC.
Earth, Water and Rock Specialists
Ph: 541 504-9960
Fax: 541 504-9961
DESIGNED BY:
M.Perle
DRAWN BY:
S.Schenck
DATE:
April 2006
PROJECT NO.
1017-101
FIGURE
3


North Unit Irrigation District
North Unit Main Canal
Redmond
Swalley Irrigation District
Arnold Irrigation District
Bend
Sisters
Three Sisters Irrigation District
Tumalo Irrigation District
Tumalo Creek
Squaw Creek
Crooked River
126
20
97
LEGEND
Diversion Point
Proposed Projects
Completed Projects
City Urban Growth Boundary (UGB)
15,000'
0'
15,000'
30,000'
SCALE: 1" = 15,000'
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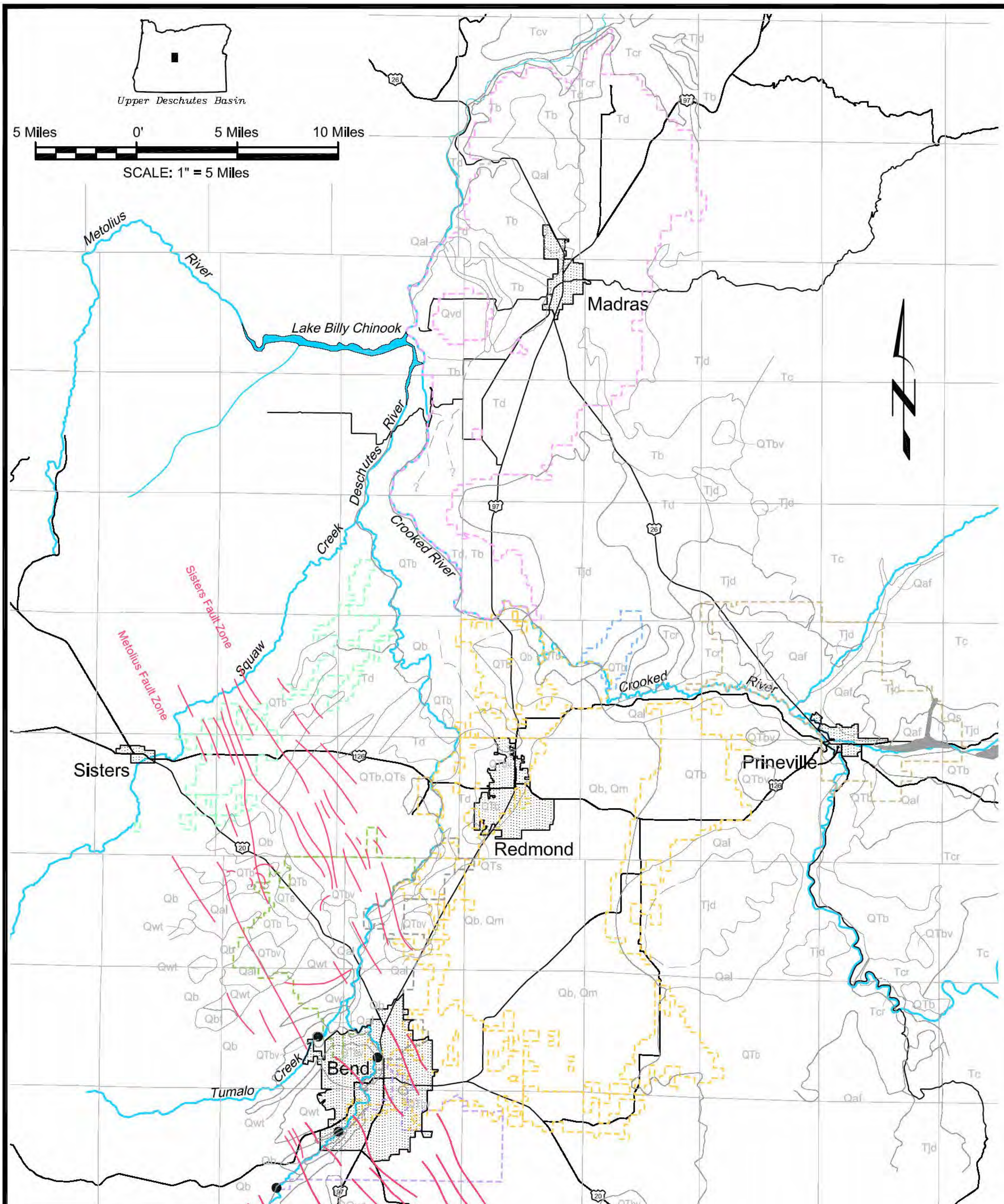
DATE: April 2006
PROJECT NO. 1017-101
FIGURE 4



LEGEND

- Diversion Point
- City Urban Growth Boundary (UGB)
- Arnold Irrigation District
- Ochoco Irrigation District
- Central Oregon Irrigation District
- Swalley Irrigation District
- Lone Pine Irrigation District
- Three Sisters Irrigation District
- North Unit Irrigation District
- Tumalo Irrigation District

GEOLOGIC LEGEND

*Tb, Qb, QTb: Basalt, gray, vesicular to dense, olivine basalt & basaltic - andesite flows that soucred from vents in the Newberry volcanic complex.

*Tc: Clarno Formation, Late Eocene to early Oligocene, Coarse volcanic breccia and tuffoceous sedimentary rocks.

*Tcr: Columbia River Basalt, Miocene basalt flows and associated rocks of the Columbia River basalt Group. Does not crop out in the foundations of the project canals.

*Td: Deschutes Formation, Upper Miocene to Lower Pliocene tuff, tuff breccia, basalt flows and welded ash flows, lapilli, ash deposits, volcaniclastic sediments, and flood and debris.

*Tjd: John Day Formation, Late Oligocene to early Miocene, bedded tuff, lapilli tuff & tuffaceous sedimentary rocks & rhyolite & docite flows & domes.

*Qaf: fan alluvium and colluvium, consists of angular to subrounded sand, gravel and cobbles in a matrix of silt and minor clay.

*Qal: undifferentiated alluvium and colluvium, consists of the alluvium and colluvium described within this legend.

*Qm: volcanic ash, consists of tan to light yellow, unconsolidated silt and sand sized particles of police and fine gravel size volcanic rock formations.

*Qs: unconsolidated to semiconsolidated lacustrine clay, silt, sand, and gravel; in places includes mudflow and fluvial deposits and discontinuous layers of peat.

*Qtbv: basalt vents, domes, cones and other constructional features made up of basalt flows and pyroclastic deposits.

*Qwt: ash flow deposits, partly welded to welded ash flow tuffs exposed on the flanks of the cascade range primarily west & northwest of Bend.

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Earth, Water and Rock Specialists
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Central Oregon Geology
Irrigation Districts
Upper Deschutes Basin, Oregon

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO.	FIGURE
M.Perle	S.Schenck	April 2006	1017-101	5

Upper Deschutes Watershed Council

Technical Report

Middle Deschutes River Instream Flow Restoration and Temperature Responses 2001-2013

Prepared by

Lauren Mork

Upper Deschutes Watershed Council

www.upperdeschuteswatershedcouncil.org

Prepared for

Deschutes River Conservancy

www.deschutesriver.org

June 11, 2014

Attachment 8: Upper Deschutes Watershed Council Instream Flow Restoration and Temperature Responses Technical Report

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Executive Summary

Since 1996, the Deschutes River Conservancy (DRC) has engaged in efforts to restore summer stream flow in the Middle Deschutes River and lower Tumalo Creek through a variety of techniques, including conservation, leasing, and acquisition. The DRC has identified stream flow restoration in the Middle Deschutes and Tumalo Creek as a priority because very low summer flows consistently result in summer water temperatures that exceed the Oregon Department of Environmental Quality (ODEQ) standard established to protect salmon and trout rearing and migration.

To evaluate the effectiveness of stream flow restoration efforts in reducing temperature in the Middle Deschutes, the DRC, its funders, and other partners have been interested in tracking 1) whether cumulative stream flow restoration actions have reduced water temperatures in downstream reaches of the river, 2) whether reductions in temperature, if observed, can be attributed to stream flow restoration projects, and 3) how stream flow restoration in the Middle Deschutes and in Tumalo Creek may differentially affect stream temperature. Since 2008 the DRC has partnered with the Upper Deschutes Watershed Council (UDWC) to conduct temperature monitoring to investigate potential temperature changes associated with stream flow restoration projects. This ongoing monitoring effort incorporates data collected from 2001 to 2013 to address the following key questions:

1) Temperature status: What was the status of Middle Deschutes River water temperature relative to the State of Oregon 18°C (64°F) standard as of 2013?

   July temperatures downstream of Bend exceeded the 18°C state standard set to protect salmon and trout rearing and migration at all four monitoring locations downstream of North Canal Dam, confirming the temperature impaired status of the middle Deschutes River under Clean Water Act Section 303(d). Temperatures at the most impaired site, Lower Bridge Road, exceeded 18°C for 102 days between May 6 and September 16, and were above the 24°C lethal threshold for ten days. Temperatures exceeded 18°C along 31 miles of the Middle Deschutes River, between North Canal Dam and Lower Bridge Road, for 29 days in 2013. These data represent some of the most extreme temperatures, and worst flow conditions, observed since 2007. Although stream flow restoration has resulted in far better flow conditions in the Deschutes than occurred previously, 2013 flows were rarely higher than the instream water rights protected through stream flow restoration, and were the lowest recorded since 2007, with the smallest proportion of cooler Tumalo Creek flow.

2) Restoration effectiveness: Have cumulative increases in stream flow resulted in reduced water temperatures at key locations along the Middle Deschutes?

   Comparison of flows protected to flows observed and regression of the mean 7DMAX temperatures for all associated observed flows provide support for increased stream flow secured through stream flow restoration reducing temperatures in the Middle Deschutes. July median flows in the Deschutes closely track median protected flows; July median protected

flows in Tumalo Creek have been inconsistently met, but observed July median flows rarely fall below levels observed during early years of restoration efforts. Temperatures describe an inverse relationship, decreasing from highest at the lowest flows to lowest at the highest flows. Comparison of mean temperatures at three different sites at the lowest and highest flows recorded from 2001 to 2013 show that increased July flows produced substantially lower temperatures. Together, these data provide support for higher protected flows guaranteeing higher baseflows and lower stream temperature.

3) Target stream flow: What flow scenarios for the Deschutes River and Tumalo Creek will achieve the 18°C temperature standard between North Canal Dam and Lower Bridge Road?

   We used temperature estimates calculated from regression of temperature-flow data in a mass balance equation to develop flow scenarios for the Deschutes River and Tumalo Creek that would achieve the 18°C state standard temperature in the Deschutes below the confluence with Tumalo Creek. Mass balance equation results suggest 24 cfs are required from Tumalo Creek to achieve 18°C in the Deschutes immediately downstream of the confluence with Tumalo Creek at the Deschutes River flow target of 250 cfs. Increasing Tumalo flow by only 13 cfs, to 37 cfs, results in a temperature reduction equivalent to increasing Deschutes River flows by 90 cfs, achieving 18°C at a Deschutes flow of 160 cfs. It is worth noting that this Tumalo Creek flow is only five cfs above the 32 cfs state water right. Especially in light of the current status of protected flows, 124 cfs in the Deschutes and 20 cfs in Tumalo, these results suggest that achieving the desired reductions in stream temperature in the Middle Deschutes may be accelerated by strategically prioritizing Tumalo Creek water transactions; preferentially increasing flows in Tumalo Creek over restoring stream flow in the Deschutes may achieve greater temperature benefits at an equivalent cost.

Temperatures thus remain elevated in the middle Deschutes River, exceeding the state standard and likely compromising rearing and migration habitat for resident native trout. Temperatures showed substantial improvement with higher combined flows from the Deschutes and from Tumalo Creek in July 2011 and 2012, but 2013 flows that barely met the instream water rights protected through stream flow restoration resulted in the worst temperature conditions observed since 2007. The 2013 status of flow and corresponding temperature in the Middle Deschutes emphasizes the critical importance of stream flow restoration in maintaining elevated baseflows. Mass balance results suggest strategically increasing flows in Tumalo Creek will maximize temperature reductions in the Deschutes downstream of the confluence. Particularly at the low flow currently protected in Tumalo Creek, increasing flows in the Deschutes is also expected to achieve some temperature benefit.

Increasing stream flow to approach the state water right and instream flow targets in the Deschutes River and in Tumalo Creek will confer habitat benefits beyond improving temperature conditions, by increasing stream width and depth and thereby habitat availability and diversity. Whereas temperature requirements for native trout are well-documented and encoded in state water quality standards, specific requirements for habitat functions of the hydrograph in the Middle Deschutes have not been well described. Data on fish response to increased flows and use of habitat including cold-water refuges, to be collected by ODFW through 2016, will greatly improve our knowledge of how stream flow affects habitat quality and contribute to the ability of restoration partners to refine stream flow targets accordingly to maximize ecological benefits. Restoration approaches that prioritize increasing Tumalo Creek flows to achieve temperature reductions should take into account potential strategic long-term trade-offs of deferring greater gains in stream flow volume, and corresponding habitat benefits, in favor of achieving lower temperatures at lower flows.

Acknowledgments

Deschutes River Conservancy provided funding in support of research and analyses that form the basis for this report. Water quality monitoring conducted by Upper Deschutes Watershed Council is funded in large part by the Oregon Watershed Enhancement Board and the Oregon Department of Environmental Quality (ODEQ) 319 Grant Program; their generous support has been instrumental in the data collection and analysis informing this report. Monitoring by the City of Bend, ODEQ, Oregon State University (OSU), Oregon Water Resources Department (OWRD), and DRC has contributed invaluable data to this long-term effort. Many thanks to members of the Water Quality Committee and contributing partners who provided expertise, insight, and time in support of the development of the UDWC Regional Water Quality Monitoring Program from which the data and analyses included here emerged. Special thanks to Lesley Jones, who spearheaded and grew the UDWC Regional Water Quality Monitoring Program to produce rigorous statistical analyses of the effects of stream flow restoration on temperature, and to Mike Cole of Cole Ecological Inc., who provided excellent insight into and thoughtful review of the analyses presented.

Abbreviations

Organizations

DRC	Deschutes River Conservancy
UDWC	Upper Deschutes Watershed Council
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OWRD	Oregon Water Resources Department

Terminology

°C	Degree Celsius
°F	Degree Fahrenheit
7DMAX	Seven Day Moving Average Maximum
df	Degrees of freedom
CI	Confidence interval
cfs	Cubic feet per second
Ln	Natural logarithm
QA/QC	Quality assurance / quality control
QD	Average daily flow
S	Standard distance from regression line

1 Introduction

The Middle Deschutes River Watershed is located in the Deschutes Basin, Oregon, and is bordered by the Metolius River, Whychus Creek, Tumalo Creek, and Upper Deschutes River watersheds (Figure 1). The Middle Deschutes River is listed as a temperature impaired waterway under Clean Water Act Section 303(d) for not meeting State of Oregon water temperature standards for salmon and trout rearing and migration.

Since 1996, the Deschutes River Conservancy (DRC) has engaged in efforts to restore summer stream flow in the Middle Deschutes River and lower Tumalo Creek. Through a variety of techniques, including conservation, leasing, and acquisition, the DRC has successfully protected approximately 124 cubic feet per second (cfs) of stream flow instream in the Middle Deschutes River and more than 17 cfs in Tumalo Creek. Bolstered by higher base flows resulting from stream flow restoration, July median average daily stream flow entering the Deschutes River from Tumalo Creek has increased from 5 cfs in 2001 to 12 cfs in 2013, and July median average daily flow in the Deschutes River at North Canal Dam has increased from 48 cfs in 2001 to 129 cfs in 2013. Combined, stream flow restoration efforts at each of these locations have contributed to an increase in middle Deschutes River July median average daily flows that in 2013 amounted to 90 cfs, from 53 cfs in 2001 to 143 cfs in 2013. Because flows downstream of North Canal Dam have historically resulted in temperatures that exceed the Oregon Department of Environmental Quality standard of 18°C/64°F established to protect salmon and trout rearing and migration, and because downstream temperatures are driven by stream flow and temperature in these two reaches, DRC has prioritized stream flow restoration in these reaches. DRC stream flow restoration efforts aim to meet the State of Oregon instream flow targets of 250 cfs in the Middle Deschutes from North Canal Dam (RM 165) to Round Butte Reservoir (RM 119), and 32 cfs in Tumalo Creek from the South Fork of Tumalo Creek to the mouth, in order to, among other objectives, improve water temperature to support sustainable anadromous and resident fish populations.

Prior analyses of water temperature in the Middle Deschutes and Tumalo Creek (UDWC, 2013) have suggested that the relative contribution of flows from the two waterways substantially influences the effects of increased flow on temperature downstream of the confluence. Middle Deschutes water flowing over North Canal Dam is consistently at or above 18°C in July (UDWC, 2006) (ODEQ, 2004) (UDWC, unpublished data). Tumalo Creek, approximately five miles downstream of the dam, is the only tributary and source of additional flow between North Canal Dam and Lower Bridge Road, approximately 31 miles downstream, where temperatures are historically highest and conditions worst for fish. Increasing the total volume of flow between North Canal Dam and Lower Bridge Road is anticipated to lower the rate of warming in this reach, making some contribution to reducing temperatures downstream. However, because increasing flows that are already at or around 18°C at North Canal Dam will not create an active cooling effect, restoration that increases flows at North Canal Dam is likely to be minimally effective in achieving the necessary temperature reductions to result in that same 18°C temperature 31 miles downstream. While the temperature of flows entering the Deschutes from Tumalo Creek varies with volume, Tumalo Creek flows are typically substantially cooler than flows in the Deschutes above the confluence (UDWC, 2006). Increasing flows in Tumalo Creek may therefore represent an opportunity to achieve the greatest cooling effect in the Middle Deschutes between Tumalo Creek and Lower Bridge Road by contributing a greater volume of colder water at the confluence, both reducing warming and actively cooling Deschutes River flows.

The DRC has partnered with the Upper Deschutes Watershed Council (UDWC) since 2008 to monitor water temperature in the Middle Deschutes River and quantify temperature changes associated with stream flow restoration projects. Although model results and substantial empirical evidence indicate that reductions in summer stream flow lead to increased water temperatures in central Oregon (ODEQ, 2004) (ODEQ, 2007) (UDWC, 2003) (UDWC, 2006), the DRC and restoration partners are interested in evaluating how increasing flows in the Middle Deschutes River and Tumalo Creek through stream flow restoration transactions affects water temperatures in downstream reaches. We evaluated available Deschutes River and Tumalo Creek temperature and flow data from 2001 through 2013 to address the following questions: 1) What was the status of Middle Deschutes River water temperatures relative to the State of Oregon 18°C/64°F standard as of 2013; 2) Have cumulative increases in stream flow resulted in reduced water temperatures at key locations along the Middle Deschutes; and 3) What flow scenarios for the Deschutes River and Tumalo Creek will achieve the 18°C temperature standard in the Deschutes River immediately below the confluence with Tumalo Creek? We present 2013 temperature results and discuss implications for stream flow restoration.

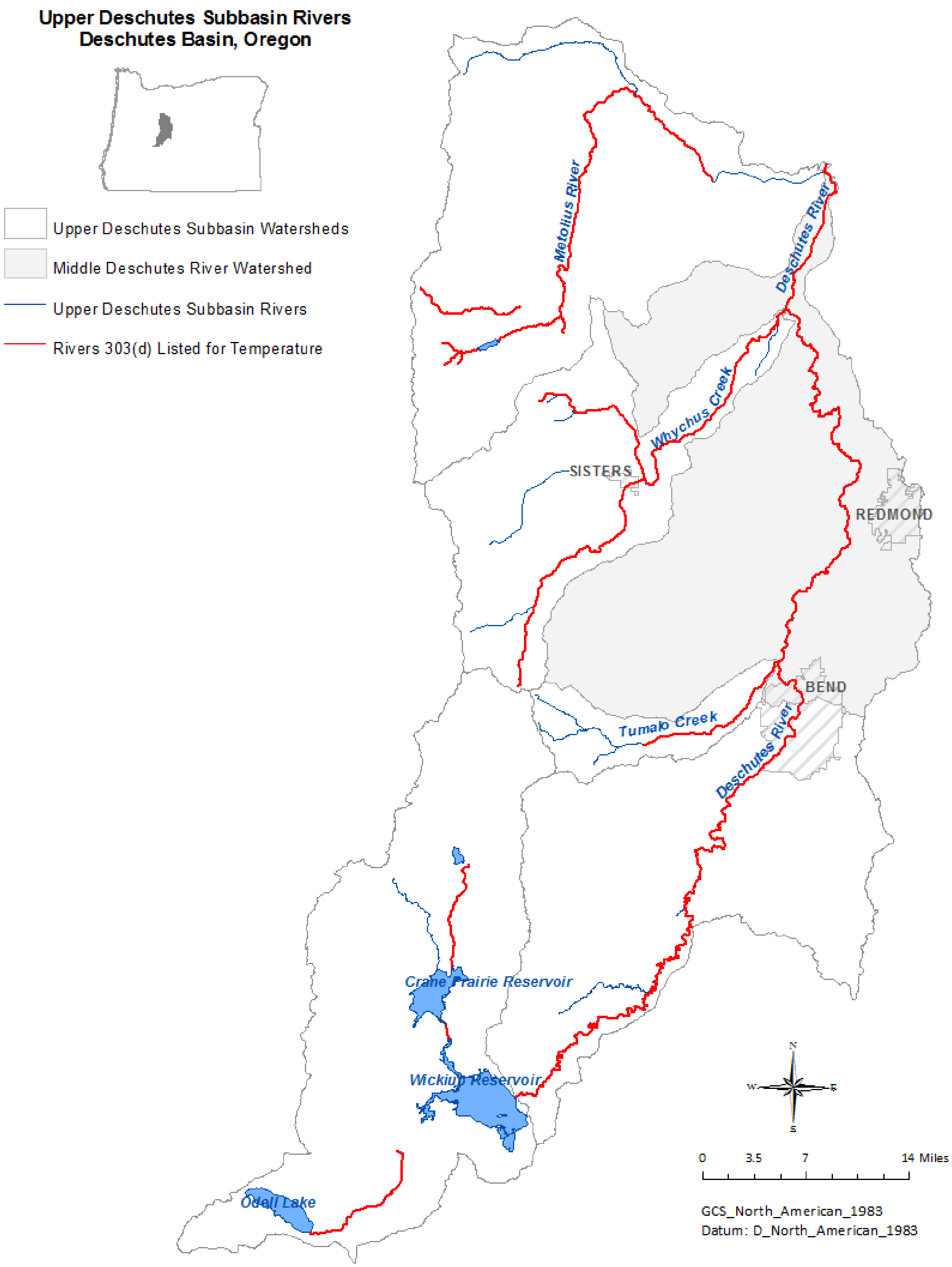


Figure 1. The Upper Deschutes Subbasin and Middle Deschutes River Watershed.
Extensive reaches of most Upper Deschutes Subbasin rivers are 303(d) listed as exceeding state temperature standards for salmon and trout rearing and migration (ODEQ 2010).

2 Methods

2.1 Data Collection

2.1.1 Water Temperature

UDWC collected and compiled continuous water temperature data for 2001-2013 from six water temperature monitoring stations on the Deschutes River and one monitoring station on Tumalo Creek (Table 1; Figure 2). Data for Tumalo Creek since 2009 were obtained from the City of Bend. Data is not available for all years due to equipment failure or no monitoring (Table 2). All temperature data used in analyses were collected by ODEQ, the City of Bend, and UDWC. UDWC operates per the *Water Quality Monitoring Program Standard Operating Procedures* (UDWC, 2008) under a State of Oregon approved Quality Assurance Project Plan (UDWC, 2008).

2.1.2 Average Daily Flow

UDWC obtained average daily stream flow (QD) data for the Deschutes River and Tumalo Creek from the Oregon Water Resources Department (OWRD, 2014) (Table 1; Figure 2). In the absence of an active gage station on the Deschutes River downstream of Tumalo Creek, stream flows recorded at OWRD gage #14070500, Deschutes River below Bend, and at OWRD gage #14073520, Tumalo Irrigation District Feed Canal, are combined to approximate the stream flow below the confluence of the Deschutes River and Tumalo Creek. All Deschutes River flow data through September 2012 and Tumalo Creek flow data through September 2008 and from October 2009 through September 2011 are considered published; Deschutes flow data from October 1, 2012 to the present, and Tumalo flow data from October 2008 through September 2009 and from October 2011 to the present are considered provisional and subject to change.

2.1.3 Median Protected Flow

We obtained July median daily instream water rights data for the Deschutes River and for Tumalo Creek from Deschutes River Conservancy. Reductions in July median daily instream water rights between years reflect water leases in previous years which were not renewed in subsequent years. We refer to July median daily instream water rights as median protected flow to differentiate from the state instream water right. July median daily instream water right data are available from 2001-2013.

Table 1. Middle Deschutes River Flow Gages and Temperature Monitoring Stations

Station ID	Waterway	Description	Latitude	Longitude	Elev. (ft)
OWRD gage #14073520	Tumalo Creek	d/s of Tumalo Feed Canal	44.08944	-121.36667	3550
OWRD gage #14070500	Deschutes River	d/s of North Canal Dam, Bend	44.08280	-121.30690	3495
DR 217.25	Deschutes River	Pringle Falls	43.74075	-121.60672	4250
DR 181.50	Deschutes River	Benham Falls	43.93080	-121.41107	4140
DR 164.75	Deschutes River	u/s of Riverhouse Hotel	44.07733	-121.30592	3540
DR 160.25	Deschutes River	u/s of Tumalo Creek	44.11501	-121.33904	3240
DR 160.00	Deschutes River	d/s of Tumalo Creek	44.11767	-121.33326	3210
DR 133.50	Deschutes River	Lower Bridge	44.35970	-121.29378	2520
TC 000.25	Tumalo Creek	u/s of Tumalo Creek mouth	44.11567	-121.34031	3250

Table 2. Summary of Available July Temperature Data

Station ID	Waterway	Description	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
DR 217.25	Deschutes River	Pringle Falls		X	X	X	X	X	X	-	X	X	X	X	X
DR 181.50	Deschutes River	Benham Falls			X		X	X	X	X	X	X	X	X	X
DR 164.75	Deschutes River	u/s Riverhouse Hotel				X	X		-	X	X	X	X	X	X
DR 160.25	Deschutes River	u/s Tumalo Creek		X	X	X	X		-	X	X	X	X	X	X
DR 160.00	Deschutes River	d/s Tumalo Boulder Field					X	X	X	X	X	X	X	X	-
DR 133.50	Deschutes River	Lower Bridge	X	X		X	X	X	X	X	-	-	-	X	X
TC 000.25	Tumalo Creek	u/s of Tumalo Creek mouth				X	X	-	X		X	X	X	X	X
X	Data available for analysis														
-	Limited data available for analyses														

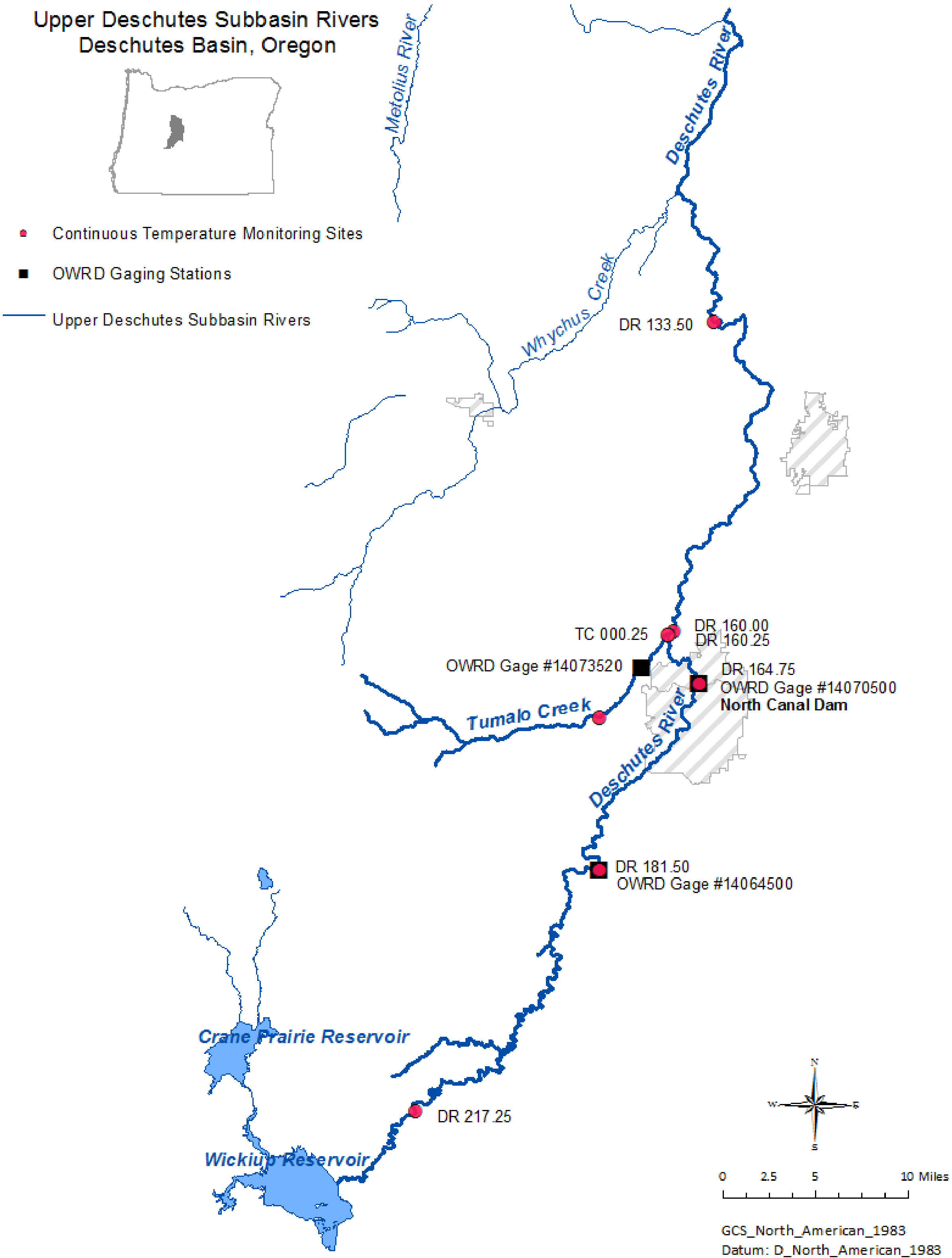


Figure 2. UDWC continuous temperature monitoring sites and OWRD stream flow gages on the Middle and Upper Deschutes.

2.2 Data Analysis

2.2.1 Temperature Status

We used the Oregon Department of Environmental Quality (ODEQ) Hydrostat Simple spreadsheet (ODEQ, 2010) to calculate the seven day moving average maximum (7DMAX) temperature, the same statistic used by the State of Oregon to evaluate stream temperatures. The current State of Oregon water temperature standard for salmon and trout rearing and migration identifies a 7DMAX threshold of 18°C/64°F (OAR 340-041-0028) (ODEQ, 2012). We evaluated July 7DMAX temperatures from 2001-2013 in relation to the state standard of 18°C to describe changes in temperature in the Middle Deschutes since 2001 and to assess progress toward the 18°C state standard for salmonid rearing and migration. We evaluated July temperature data from DR 160.00, downstream of the confluence of the Deschutes and Tumalo Creek, in relation to the July median average daily flow in the Deschutes below North Canal Dam, Tumalo Creek below the Tumalo Feed Canal, and the July median of combined flows from these two sources. To illustrate temperature status at Lower Bridge Road (DR 133.50) we present data for August in addition to July because more data are available for August for the years of interest and because the range of stream temperatures in July and August differ substantially. Both July and August data represent summer conditions characterized by high temperatures and low flows.

2.2.2 Restoration Effectiveness and Target Stream flow

We compared July median daily protected flow to July median average daily flow to evaluate the relationship between observed and protected stream flow. We used regressions of temperature and stream flow data to 1) evaluate the effectiveness of increasing flows through stream flow restoration in reducing stream temperature, and 2) to develop flow scenarios for the Deschutes River and Tumalo Creek that would achieve the 18°C state standard temperature in the Deschutes below the confluence with Tumalo Creek. To quantify reductions in temperature with increasing flows and to estimate corresponding temperature and flow values we used temperature data from the Deschutes River above Tumalo Creek (DR 160.25) and corresponding flow data from OWRD gage #14070500, Deschutes River Below Bend, and temperature data from the mouth of Tumalo Creek (TC 000.25) with flow data from OWRD gage #14073520, Tumalo Creek Below Tumalo Feed Canal. The two sites are short distances downstream of major sites of stream flow restoration on each waterway and are anticipated to demonstrate reductions in temperature resulting from increased flows; due to their respective locations immediately upstream of the confluence they also most accurately represent the temperature-flow relationships that directly affect stream temperature downstream of the confluence. Because no tributaries or known springs enter the Deschutes between Tumalo Creek and Lower Bridge Road, the relative flow contributions of the Deschutes and Tumalo Creek at the two upstream sites directly influence stream temperature 26.5 miles downstream at Lower Bridge Road (DR 133.50), where temperature conditions are historically the worst on the Middle Deschutes. We used temperature data from Lower Bridge Road, DR 133.50, with the combined average daily flow values from the two OWRD gages to show the longitudinal temperature effects of increasing flows 26.5 miles upstream at the confluence of the Deschutes River and Tumalo Creek.

We restricted data included in the analysis to one month of the year to reduce the effect of inter-annual seasonal variation in the analysis (Helsel & Hirsch, 1991) and selected July as the historically hottest month for water temperatures in the Deschutes River and therefore the month during which stream temperature requires the greatest mitigation and when increased stream flow will most improve stream conditions (UDWC, 2003) (UDWC, 2006). We used the seven day moving average maximum temperature (7DMAX), the statistic used by DEQ to determine the status of a waterway in relation to the state water quality standard. For DR 160.25 upstream of Tumalo Creek, we analyzed July 7DMAX temperature and average daily flow data from 2002-2013, with the exception of 2006 for which temperature data were unavailable; for TC 000.25 at the mouth of Tumalo Creek we analyzed July temperature and flow data for 2004-2013 with the exception of 2008, for which temperature data were also not available. For DR 133.50 at Lower Bridge Road, we analyzed July temperature and flow data for 2001-2002 and 2005-2011. Temperature data were not available for this site for 2003 and 2004, and limited data were available for 2009, 2010 and 2011.

To evaluate the relationship between stream flow and temperature and to estimate temperatures at corresponding flows we performed a regression of temperature and flow data. The resulting equations accurately represent the relationship between flow and temperature, and can be used to calculate temperature values for the specified locations, within the evaluated time period, and within the range of flows observed. We paired 7DMAX temperature records with the natural log of the corresponding average daily flow (LnQD) for each July day included in the analysis, then ranked flow values and assigned all July temperature records to their corresponding flow value. The seven day moving average maximum temperature for a given day is the average of the maximum temperature for that day, the three days prior, and the three days following; we paired the 7DMAX for a given day with the flow for the same day to best match the 7DMAX temperature to flow conditions on both the first and seventh days represented by the 7DMAX temperature. Although this approach does not reflect the flow corresponding to maximum daily temperatures on the fifth, sixth, or seventh days included in the 7DMAX, the flow corresponding to the 7DMAX for the same date is related to the flow three days before and three days after. On this premise we selected the flow for the same date as the 7DMAX to represent flow conditions corresponding to that temperature statistic.

For our 2012 analysis we had plotted flow versus temperature and fitted the linear and polynomial regression trendlines for six permutations of the data to evaluate which approach best represented the observed temperature and flow data and would result in estimated temperatures that would as closely as possible approximate those we might anticipate occurring (UDWC 2013). We plotted the following permutations of temperature data: 1) all temperature-flow pairs; 2) all temperature-flow pairs excluding flows for which there were fewer than two temperature records; 3) all temperature-flow pairs excluding flows for which there were fewer than five temperature records; 4) all mean temperature-flow pairs representing the average of all temperatures observed at a given flow for all flows for which there was at least one temperature record; 5) mean temperature-flow pairs excluding flows for which there were fewer than two temperature records; and 6) mean temperature-flow pairs excluding flows for which there were fewer than five temperature records. We evaluated the resulting regression trendlines visually, and evaluated regression equations for a given regression model quantitatively by comparing adjusted R^2 values. The R^2 value represents the proportion of the variation in mean 7DMAX temperatures that is explained by stream flow (Ln QD). As the fit of the regression to the data improves, the R^2 value increases toward a maximum 100%.

We used the regression of all mean temperature-flow pairs, selected on the basis of adjusted R^2 values as the most representative of conditions observed and accordingly as the most useful for describing temperatures observed at a given flow and predicting the temperature anticipated to occur at a given flow (UDWC 2013). Because including temperature-flow pairs for which only one temperature record existed in regression of DR 133.50 temperature and flow data resulted in a standard error value >1, we performed the regression for this site including only temperature-flow pairs for which at least two temperature records were available.

For the resulting datasets we used an ANOVA in R open source statistical software to determine the highest polynomial term that statistically improved the model on the basis of the R^2 value associated with each model. For DR 160.25 data, the quadratic model was statistically better than the linear model, but the cubic model was not better than the quadratic model. For Tumalo data, the quadratic, cubic, and quartic models were each statistically better than the lower-order model. For DR 133.50 data, the quadratic model was no better than the linear model.

Using the resulting regression equation for DR 160.25 and for TC 000.25, we calculated the estimated temperature and 95% confidence interval for all flows within the observed range (Appendix A). We calculated the 95% confidence interval (CI) as:

$$Y \pm Y^{(Z_{1-\alpha/2}\, S(x)\, /\, \sqrt{N})}$$

$$\text{where } Z_{1-\alpha/2} = Z_{1-0.05/2} = Z_{0.475} = 1.9 \text{ (NIST 2011)}$$

To calculate Deschutes River temperatures downstream of the confluence with Tumalo Creek under a variety of flow scenarios we used the temperatures and given flows from the Deschutes River (DR 160.25) and Tumalo Creek (TC 000.25) temperature-flow regression equations in a mass balance equation. We used the following mass balance equation solved for T_{D2}:

$$(Q_T * T_T) + (Q_D * T_D) = (Q_T + Q_D) * (T_{D2})$$

$$((Q_T * T_T) + (Q_D * T_D)) / (Q_T + Q_D) = (T_{D2})$$

Where:

Q = average daily flow
T = 7DMAX temperature
$_T$ = Tumulo Creek (TC 000.25)
$_D$ = Deschutes River (DR 160.25)
$_{D2}$ = Deschutes River (DR 160.00)

We calculated temperatures for all Tumalo flows between 10 and 100 cfs at Deschutes River flows of 160, 180, 200, 220, and 250. Ten cfs approximates the median flow currently protected instream in Tumalo Creek during July; 100 cfs exceeds average natural July flows and is well above the ODFW instream water right of 32 cfs. 160 cfs is the median flow protected instream in the Deschutes River during July; 250 is the instream water right and DRC stream flow restoration target.

We compared temperatures calculated from temperature-flow regressions and from the mass balance equation to Heat Source model scenarios for the same locations on the Deschutes River and Tumalo Creek (ODEQ, 2007). Heat Source results report the peak seven day average daily maximum temperature; we compared mass balance equation results to the mean seven day average daily maximum temperature, calculated from Heat Source temperature data. Heat Source temperature data for the Deschutes and for Tumalo Creek included daily maximum temperatures from July 19 to August 7, 2001.

3 Results

3.1 Temperature Status

Seven-day moving average maximum (7DMAX) temperatures exceeded the 18˚C state standard for steelhead and salmon rearing and migration at four monitoring locations in 2012 by up to 6.3°C (Figure 3), supporting the existing State of Oregon Section 303(d) listing of the middle Deschutes River for temperature impairment. Temperatures upstream of Bend and all major irrigation diversions, at DR 217.25 and DR 181.50, remained below 18°C during July, the month during which the hottest water temperatures have historically been recorded. Temperatures at these sites have exceeded 18°C in some years (2002, 2004, 2005, 2009) but typically remain below 18°C. Temperatures at all four monitoring sites downstream of North Canal Dam and below major irrigation diversions exceeded the state standard in 2013 and in every other year for which data are available for analysis.

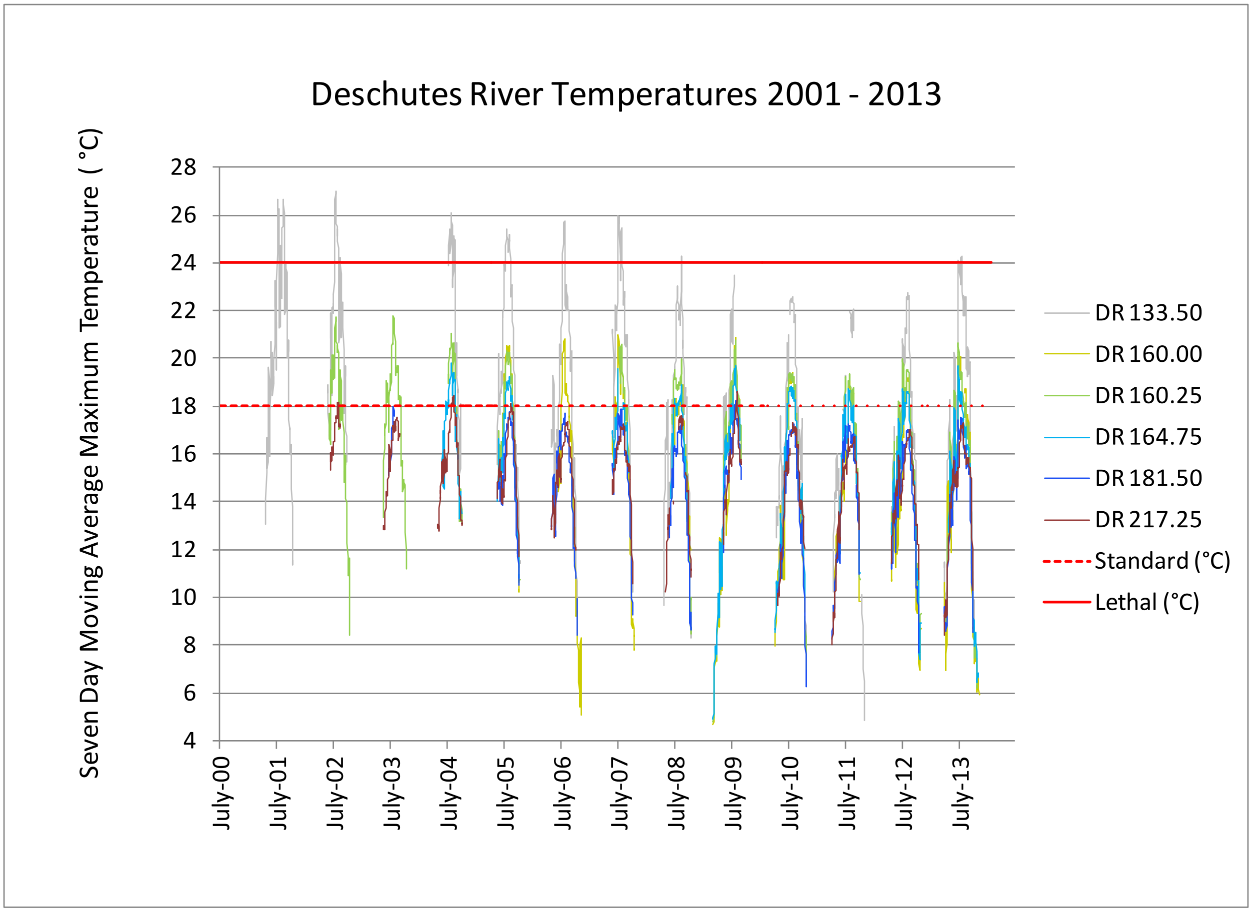


Figure 3. Deschutes River Temperatures 2001-2013
Temperatures regularly exceeded the State of Oregon temperature standard (dashed red line) at four monitoring locations along the Deschutes River from DR 133.50 to DR 164.75 between 2001 and 2013 and exceeded the temperature standard in two additional upstream locations, DR 181.50 and DR 217.25 in some years. Temperatures at DR 133.50 exceeded the lethal limit (dashed black line) for ten days in 2013.

Temperatures at DR 160.00, downstream of the confluence with Tumalo Creek, exceeded 18°C for 29 days in 2013, from June 29 to July 21 and August 15 to 20, at flows of 128-293 cfs (116-220 cfs from the Deschutes and 11-73 cfs from Tumalo Creek) (Figure 4). Data are missing for the 24 days between July 21 and August 15; during these dates temperatures exceeded 18°C at DR 160.25, upstream of the confluence with Tumalo Creek, for 17 of the 24 days; although Tumalo Creek flows sometimes cool the Deschutes, temperatures at the downstream site (DR 160.00) were higher than at DR 160.25 for two weeks prior to, and over a month subsequent to, the interim for which data were missing, suggesting that temperatures at DR 160.00, downstream of Tumalo Creek, likely also exceeded 18°C for at least the additional 17 days observed at DR 160.25, if not the entire 24 days, for a total of 46 to 53 days. Temperatures above 18°C for more than 29 days at DR 160.00 would represent an increase over 2011 and 2012.

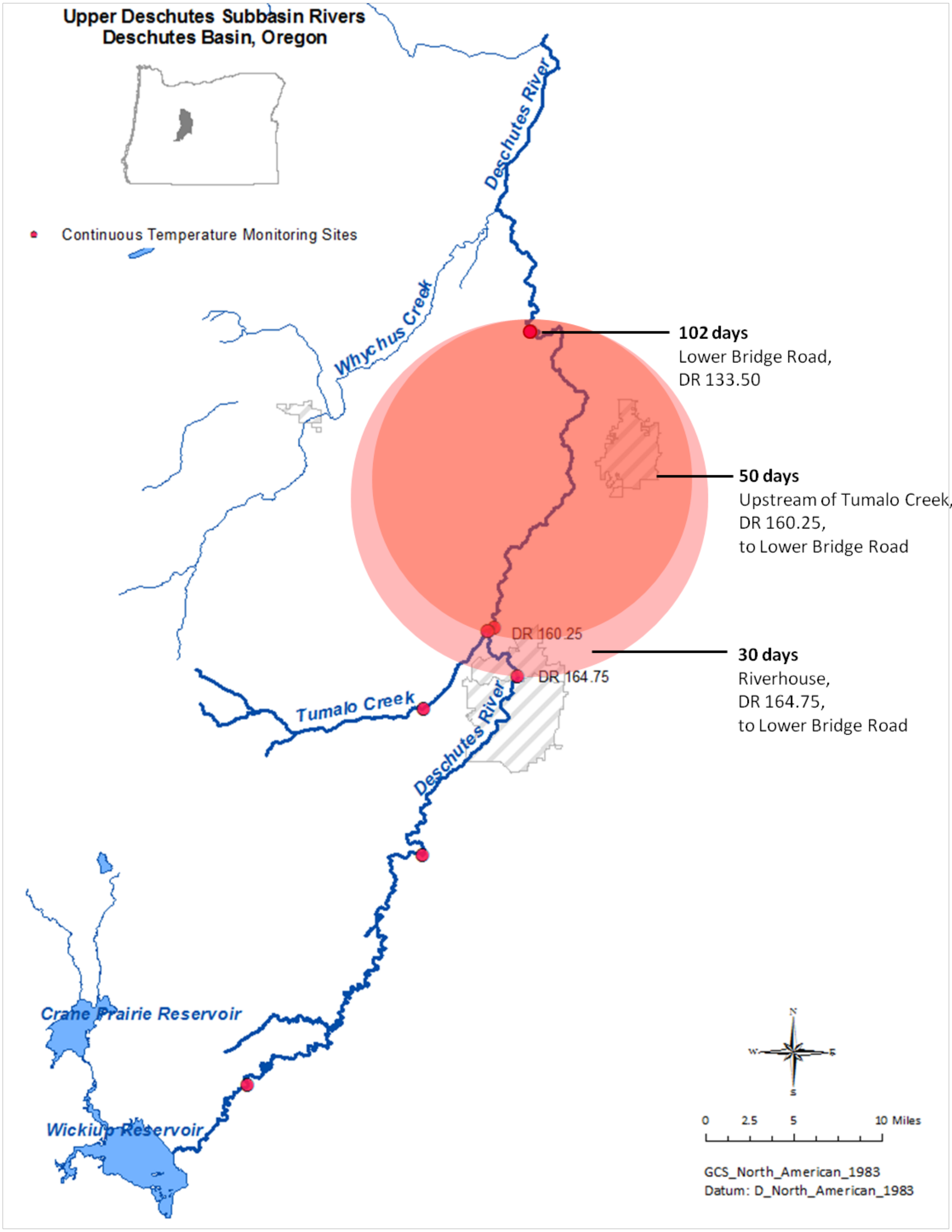
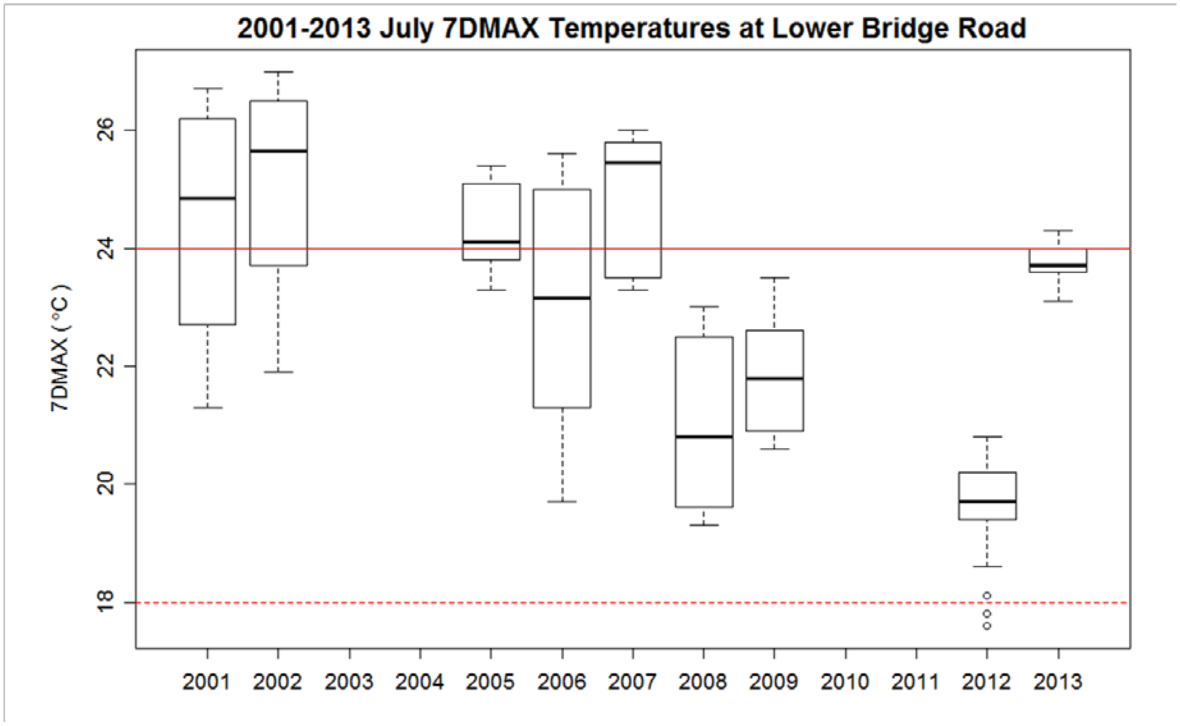


Figure 4. 2013 Middle Deschutes stream temperatures > 18°C. 7DMAX temperatures exceeded 18°C from 30 days at DR 164.75 below North Canal Dam to 102 days at Lower Bridge Road, approximately 31 miles downstream.

Despite substantial reductions in temperature observed since 2001, mean 7DMAX temperatures at Lower Bridge Road (DR 133.50) remained well above the 18°C standard in 2013 (Figure 5), exceeding this criterion for 102 days between May 6 and September 16 at flows between 122 and 364 cfs (108-353 cfs from the Deschutes and 8.4-126 cfs in Tumalo Creek). Temperatures at Lower Bridge Road were above the 24°C lethal threshold for fish for ten days, at total flows of 128-171 cfs.

a



b

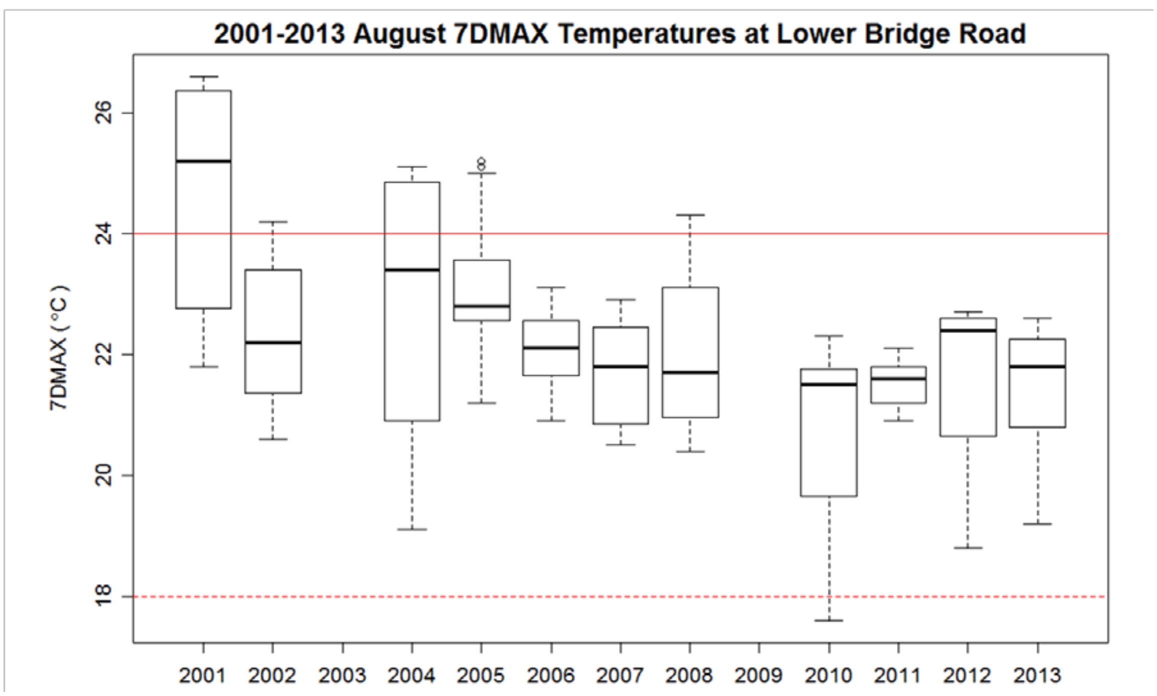
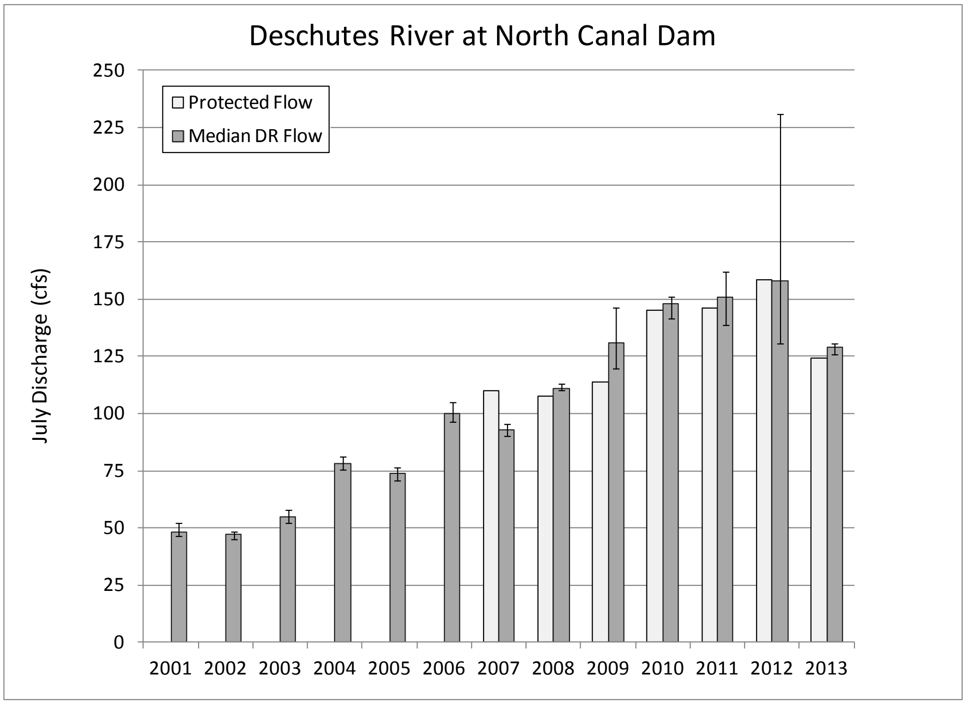


Figure 5. 2001-2013 July and August 7DMAX Temperatures at Lower Bridge Road
A) July 1-22 and b) August 6-28 mean 7DMAX temperatures at Lower Bridge Rd (DR 133.50), the most impaired site for which temperature data are available, chart a declining trend since 2001. Data for this location is missing for July 2003, 2004, 2010 and 2011 and for August 2003 and 2009. Despite reductions of approximately 3°C between 2001 and 2013, temperatures at Lower Bridge Road remain well above the 18°C standard (dashed red line) throughout July and August. July temperatures exceeded the lethal limit (solid red line) in 2013.

3.2 Stream flow Restoration Effectiveness

July median flow tracks July median protected flow, and mean temperatures chart a declining trend from the lowest to highest flows for which temperature data are available, substantiating the role of increasing stream flow through stream flow restoration in reducing temperatures in the Middle Deschutes River and in Tumalo Creek. Streamflow restoration efforts in the Middle Deschutes began in 2001; data documenting flows protected instream for the Middle Deschutes and Tumalo Creek are available from 2007 to 2013. Although stream flow restoration data (flows protected instream) are not available from 2001-2006, July median flow in the Deschutes at North Canal Dam increased steadily over this interval, from 48 to 100 cfs. From 2007 to 2013, flows protected in the Deschutes at the same location increased from 110 to 124 cfs while flows protected in Tumalo Creek increased from 17 to 20.1 cfs. Increases in median protected flow from 2007 to 2013 correspond to increased July flows in both waterways (Figure 6). July median flows in the Deschutes closely track median protected flows; July median protected flows in Tumalo Creek have been inconsistently met, but observed July median flows rarely fall below levels observed during early years of restoration efforts.

Regressions of mean July 7DMAX temperatures and corresponding flow values from 2001-2013 at two Deschutes River and one Tumalo Creek site show temperatures decreasing as flows increase (Figure 7). The regression for each site represents a range of flows for each year that reflect increased July flows resulting in part from stream flow restoration. Annual flow ranges for which temperature data are available and which are included in regressions increased from 41-51 cfs in 2002 to 100-327 cfs in 2011 in the Deschutes at North Canal Dam, from 3.3-37 cfs in 2004 to 11-177 cfs in 2008 in Tumalo Creek, and from 46.4-62 cfs in 2002 to 134-447 cfs in 2011 downstream of the confluence. At DR 160.25, where increased flows reduce warming rather than actively cooling stream temperature and the distance over which to reduce warming is relatively short (<5 mi), modest reductions in temperature were observed at increasing flows. A flow rate of 41 (3.7 LnQD) from the Deschutes River at North Canal Dam resulted in a 7DMAX temperature of 19.2°C at DR 160.25, approximately five miles downstream; flows between 290 and 313 cfs resulted in a mean temperature only 1°C lower, of 18.2°C. In Tumalo Creek, a smaller-volume system which flows directly from its headwaters with no impoundment or associated warming, proportionally greater increases in colder stream flow have a greater effect on temperature: 3.5 cfs (1.3 LnQD) resulted in a mean temperature of 21.2°C, with flows between 145 and 156 cfs (5 LnQD) resulting in a mean temperature of 11.7°C, a temperature reduction of almost 10°C. At Lower Bridge Road (DR 133.50), combined Deschutes River and Tumalo Creek flows between 47 and 52 cfs (3.9 LnQD) resulted in a mean temperature of 24.9°C; the highest flows for which temperature data are available, 355-362 cfs (5.9 LnQD) resulted in a mean temperature 5.3°C lower at 19.6°C.



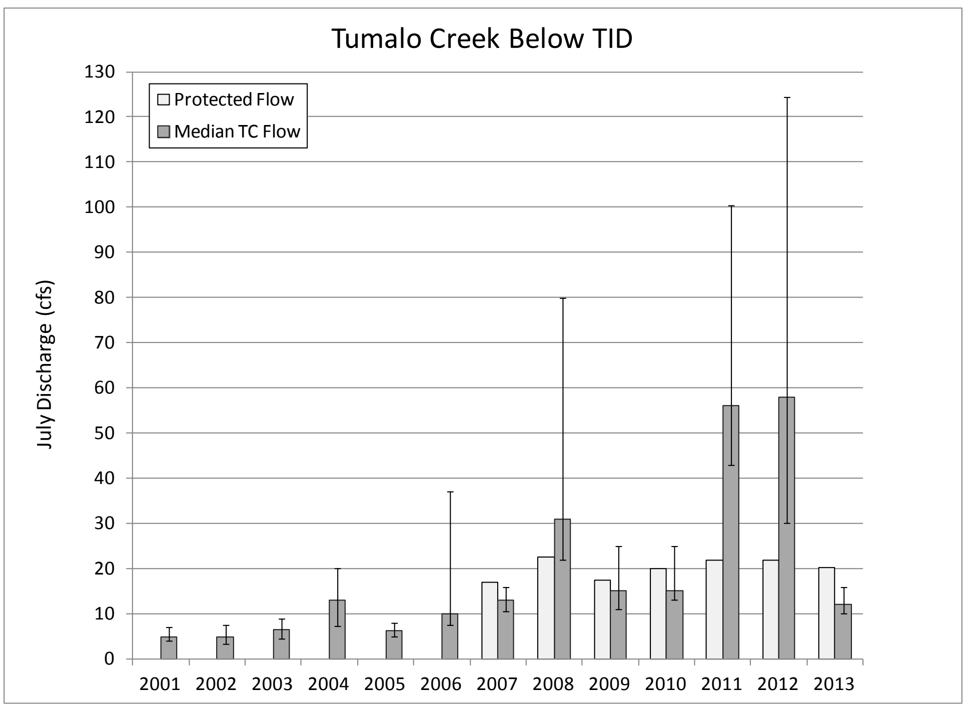
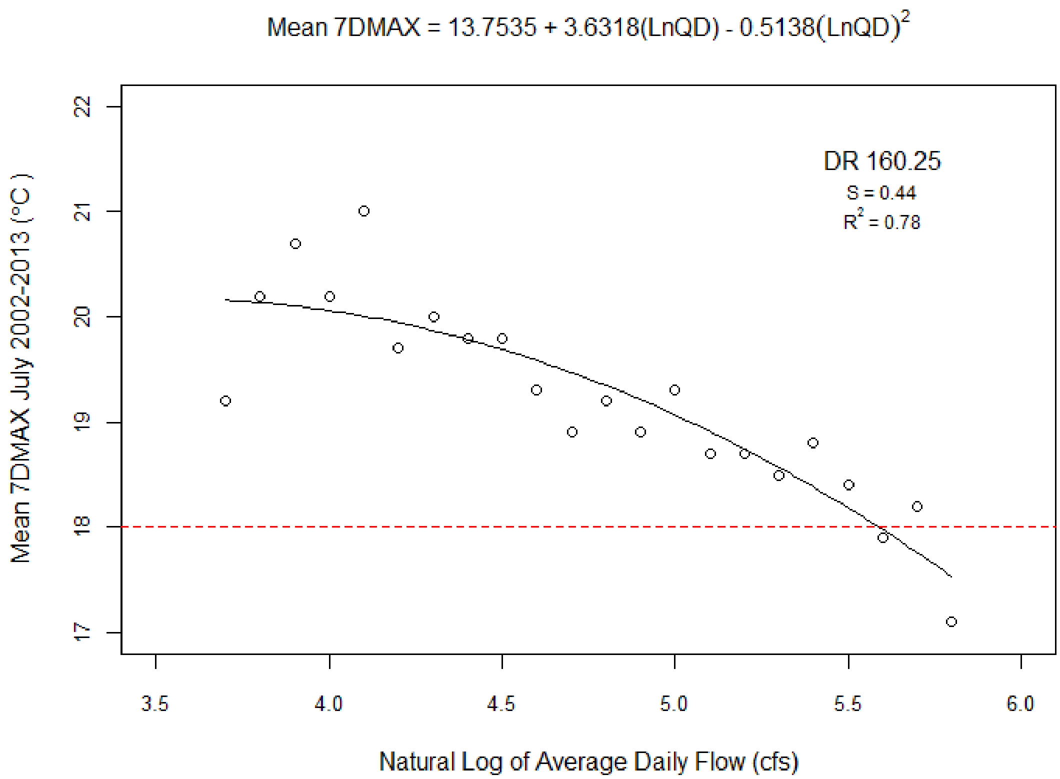
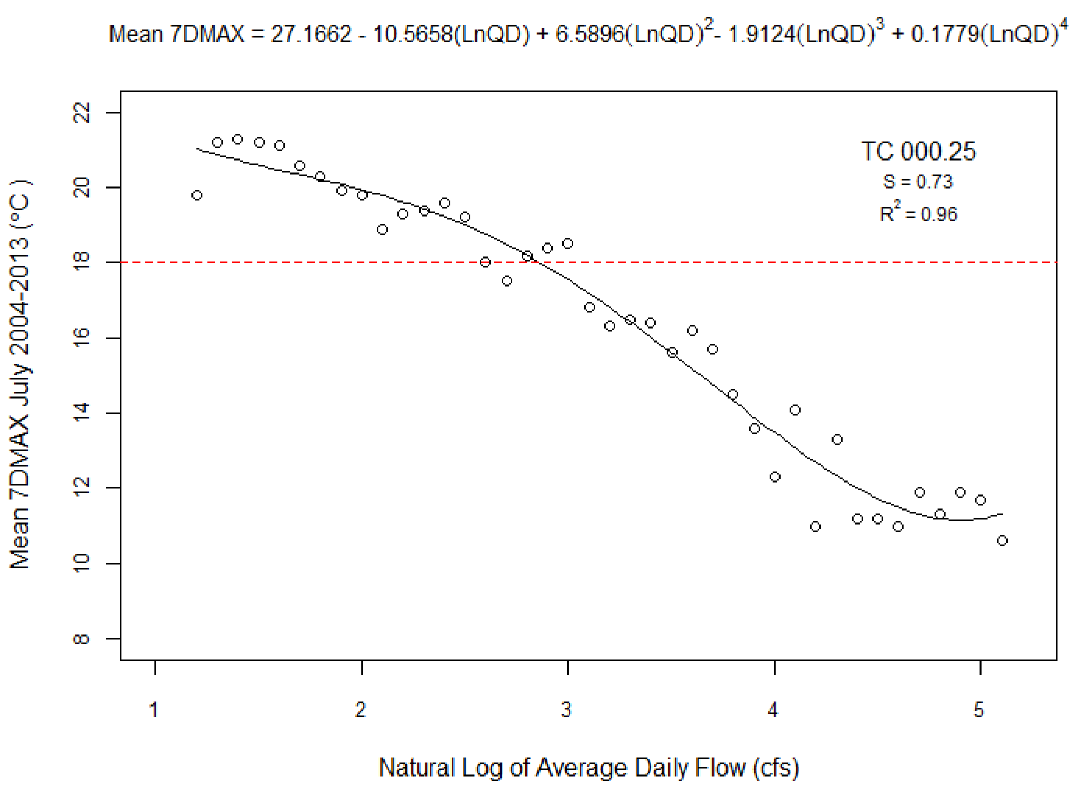


Figure 6. Deschutes River and Tumalo Creek Protected Flow and July Median Flow, 2001-2013.
July median flows steadily increased from 2001 to 2012, corresponding to increases in flow protected instream. 2013 marked a drop in July median flow from 2012 levels. Data for flows protected instream are not available prior to 2007.

a


Mean 7DMAX = 13.7535 + 3.6318(LnQD) - 0.5138(LnQD)^2
DR 160.25
S = 0.44
R^2 = 0.78
Mean 7DMAX July 2002-2013 (°C)
Natural Log of Average Daily Flow (cfs)
17
18
19
20
21
22
3.5
4.0
4.5
5.0
5.5
6.0

b


Mean 7DMAX = 27.1662 - 10.5658(LnQD) + 6.5896(LnQD)^2- 1.9124(LnQD)^3 + 0.1779(LnQD)^4
TC 000.25
S = 0.73
R^2 = 0.96
Mean 7DMAX July 2004-2013 (°C)
Natural Log of Average Daily Flow (cfs)
8
10
12
14
16
18
20
22
1
2
3
4
5

c

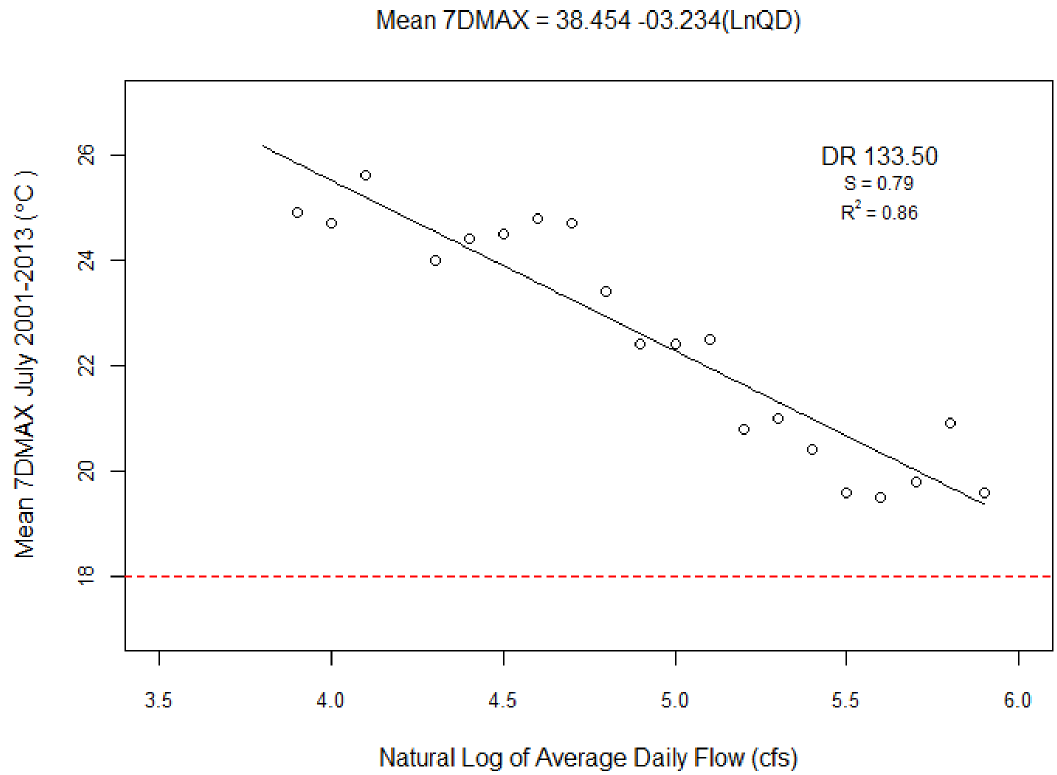


Figure 7. Temperature-Flow Regression Models

Regression models fitted to temperature-flow data demonstrate reduced temperatures at higher flows and describe the relationship between temperature and flow observed a) during July 2002-2013 at DR 160.25, the Deschutes River upstream of the confluence with Tumalo Creek, b) during July 2004-2013 at TC 000.25, Tumalo Creek upstream of the mouth, and c) during July 2001-2013 at DR 133.50, the Deschutes River at Lower Bridge Road.

3.3 Target Stream flow

Regression equations for trendlines fitted to July temperature and stream flow data from the middle Deschutes River upstream of the confluence with Tumalo Creek (DR 160.25) and from Tumalo Creek at the mouth (TC 000.25) describe the relationship between flow levels and the average 7DMAX temperature observed at each level (Figure 7). Temperature records were available from DR 160.25 for Deschutes River flows between 41 and 327cfs (3.7-5.8 LnQD), and from TC 000.25 for Tumalo Creek flows between 3.3 and 158 cfs (1.2-5.1 LnQD). A quadratic regression trendline and equation provided the best fit to DR 160.25 temperature and flow data; a quartic (4th order polynomial) regression trendline and equation best described TC 000.25 data. We used the resulting equations to calculate temperatures for Deschutes flows between 43 and 250 cfs, and for Tumalo flows between three and 158 cfs (Appendix A).

Temperature estimates calculated for five Deschutes River flow scenarios illustrated dramatic gains in temperature reductions in the Deschutes River below the confluence with Tumalo Creek (DR 160.00) as flows in Tumalo increased (Appendix B). At 250 cfs in the Deschutes below North Canal Dam, the ODFW instream water right for the Deschutes below Bend, 24 cfs from Tumalo Creek resulted in 18°C at DR

160.00. At 160 cfs in the Deschutes below North Canal Dam, the flow currently protected instream, 18°C was estimated to occur at DR 160.00 when Tumalo flows were 42 cfs; an 18 cfs difference in Tumalo flow achieved the same temperature outcome, meeting the 18°C standard, as did a 90 cfs difference in Deschutes flow from North Canal Dam. The Tumalo Creek ODFW instream water right of 32 cfs resulted in an estimated 18°C at Deschutes River flows between 220 and 250 cfs.

Estimated temperature gains were magnified as Tumalo flows increased to approximately 78 cfs. Tumalo flows of 46 cfs at Deschutes River flows of 250 cfs resulted in 17.5°C at DR 160.00; the same temperature was achieved at 160 cfs of Deschutes flow by adding nine cfs in Tumalo Creek, at a Tumalo flow of 55 cfs. Above 78 cfs in Tumalo, increases in Deschutes flows resulted in equivalent or increased temperatures, such that increasing flows in the Deschutes required commensurate increases in Tumalo flows. For example, at 81 cfs in Tumalo, Deschutes flows of 160 cfs resulted in an estimated temperature of 16.5°C; to obtain the same temperature at 250 cfs in the Deschutes required 86 cfs in Tumalo.

Heat Source model estimates are available for instream water right (ODFW) flows for the Deschutes and for Tumalo Creek. The Heat Source average seven day average daily maximum (7DADM) temperature estimate for Deschutes flows of 250 cfs at the Tumalo instream water right of 32 cfs at approximately DR 160.00 is 17.0°C, almost a full degree lower than the mass balance temperature estimate of 17.9°C for the same flow at the same site. Similarly, the Heat Source average 7DADM for the Deschutes at 250 cfs at approximately DR 160.25, above the confluence with Tumalo, was 17.2°C, a full degree lower than the 18.1°C calculated from the regression equation. The Heat Source estimate for Tumalo Creek flows of 32 cfs at approximately TC 000.25 was 15.7°C, identical to the temperature calculated from the regression equation for that flow and site.

4 Discussion

4.1 Temperature Status

Temperatures exceeded the state temperature standard of 18°C at four monitoring locations between DR 164.75 and DR 133.50 in 2013, confirming the temperature impaired status of the middle Deschutes River under Clean Water Act Section 303(d). Temperatures at the most impaired site, Lower Bridge Road, exceeded 18°C for 102 days between May 6 and September 16, and were above the 24°C lethal threshold for ten days. Temperatures exceeded the 18°C standard for 30 days at all four Deschutes River monitoring sites downstream of North Canal Dam; although we only have data for four sites along the approximately 31 miles between Lower Bridge Road and North Canal Dam, we can infer that temperatures along the entire 31 mile reach were above 18°C throughout those 30 days. This includes the only site where there is potential for cooling below North Canal Dam, at DR 160.00, below the confluence with Tumalo Creek. These data represent some of the most extreme temperatures, and worst flow conditions, observed since 2007. Although stream flow restoration has resulted in far better flow conditions in the Deschutes than occurred previously, 2013 Deschutes flows at North Canal Dam were barely higher than the instream water rights protected through stream flow restoration and flows in Tumalo Creek never met the instream water right in 2013. Flows recorded in 2013 were the lowest recorded since 2007, with the smallest proportion of cooler Tumalo Creek flow (data not shown).

4.2 Restoration Effectiveness

Regression of mean 7DMAX temperatures for all associated observed flows provides empirical evidence for increased stream flow secured through stream flow restoration reducing temperatures in the Middle Deschutes. In years for which data are available documenting flows protected instream, July median flows correspond to protected flows, particularly in the Deschutes. Temperatures describe an inverse relationship, decreasing from highest at the lowest flows to lowest at the highest flows. Comparison of flow protected instream and July median flow suggests that flows protected instream have resulted in higher July median and minimum flows. Comparison of mean temperatures at three different sites at the lowest and highest flows recorded from 2001 to 2013 show that increased July flows produced substantially lower temperatures. Together, these data provide support for higher protected flows guaranteeing higher baseflows and lower stream temperature.

4.3 Target Stream flow

Mass balance equation results suggest that the Deschutes River flow target of 250 cfs will achieve the 18°C standard immediately downstream of the confluence with Tumalo Creek at 26 cfs in Tumalo Creek. Alternatively, the Tumalo Creek flow target of 32 cfs will achieve the 18°C standard in the Deschutes downstream of the confluence at Deschutes River flows of 220 cfs. At the currently protected Deschutes flow of 160 cfs, 38 cfs will be required in Tumalo Creek to meet the 18°C state standard.

Temperature estimates indicate that as flows in Tumalo Creek increase, temperature benefits of additional flow in the Deschutes diminish and ultimately are lost altogether, such that increasing flows in the Deschutes requires commensurate increases in Tumalo flows to achieve the same temperature benefits obtained at lower Deschutes and Tumalo Creek flows. The 13 cfs increase between 24 and 37 cfs in Tumalo Creek results in temperature gains equivalent to increasing Deschutes flows by 90 cfs, from 160 cfs to 250 cfs, to produce a 7DMAX temperature of 18°C below the confluence of the Deschutes and Tumalo. At lower Tumalo Creek flows, increases in Deschutes flows result in comparatively greater temperature reductions. Temperature reductions associated with increasing Deschutes flows are greatly diminished once Tumalo flows increase above 50 cfs; above approximately 60 cfs in Tumalo, temperatures *increase* with increases in Deschutes flows. Especially in light of the current status of protected flows, 124 cfs in the Deschutes and 20.1 cfs in Tumalo, these results suggest that achieving the desired reductions in stream temperature in the Middle Deschutes may be accelerated by strategically prioritizing Tumalo Creek water transactions; preferentially increasing flows in Tumalo Creek over restoring stream flow in the Deschutes may achieve greater temperature benefits at an equivalent cost.

Mass balance results for Tumalo Creek and Deschutes River flows immediately below the confluence of Tumalo Creek and the Deschutes suggest that even by maximizing Tumalo flows and increasing Deschutes flows to 250 cfs, temperatures at DR 160.00 will still be high enough to necessitate a low rate of temperature change between DR 160.00 and DR 133.50 to obtain 18°C at Lower Bridge (DR 133.50). While direct comparison is difficult because of how river miles/kilometers are measured in the two analyses, the Heat Source model for the Deschutes suggests that at instream water right (ODFW) flows for both the Deschutes and for Tumalo, temperatures in the Deschutes exceed 18°C in reaches totaling approximately 9 miles between the confluence with Tumalo Creek and the confluence with Whychus Creek at RM 123 (Watershed Sciences 2008). Although higher flows will have some effect in reducing the rate of warming, mass balance equation and Heat Source model results suggest that current instream water right flows for the Middle Deschutes and for Tumalo may be insufficient to meet the state temperature standard in some reaches of the Middle Deschutes between Tumalo Creek and Whychus Creek.

Whether or not it is possible to meet the state temperature standard along every mile of the Middle Deschutes between North Canal Dam and Lower Bridge Road, increases in flow that approach the instream water right and DRC flow targets in both the Deschutes and in Tumalo Creek may nonetheless confer substantial ecological benefits. Although elevated stream temperature is an important consequence of modified flows in the Deschutes and in Tumalo Creek, altered flows affect other stream functions and habitat parameters, notably stream width and depth which contribute to habitat availability and diversity. And, while temperature requirements for salmon and trout are well-documented and encoded in state water quality standards, specific requirements for the habitat functions of the hydrograph in the Middle Deschutes are less well understood. Data on fish response to increased flows and use of habitat including cold-water refugia, to be collected by ODFW in the Middle Deschutes and in Tumalo Creek through 2016, will contribute to the ability of restoration partners to discern how flow and temperature affect habitat availability and use, and refine stream flow targets accordingly to maximize ecological benefits. Restoration approaches that prioritize increasing Tumalo Creek flows to achieve temperature reductions should take into account potential long-term trade-offs of deferring greater gains in stream flow volume, and corresponding habitat benefits, in favor of achieving lower temperatures at lower flows.

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APPENDIX A Estimated temperatures at given flows calculated from regression equations

Deschutes River upstream of Tumalo Creek (DR 160.25)

Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)
41	20.2	1.7	**94**	19.6	1.7	**147**	19.1	1.7	**200**	18.6	1.7
42	20.2	1.7	**95**	19.6	1.7	**148**	19.1	1.7	**201**	18.6	1.7
43	20.1	1.7	**96**	19.6	1.7	**149**	19.1	1.7	**202**	18.6	1.7
44	20.1	1.7	**97**	19.6	1.7	**150**	19.1	1.7	**203**	18.5	1.7
45	20.1	1.7	**98**	19.6	1.7	**151**	19.0	1.7	**204**	18.5	1.7
46	20.1	1.7	**99**	19.6	1.7	**152**	19.0	1.7	**205**	18.5	1.7
47	20.1	1.7	**100**	19.6	1.7	**153**	19.0	1.7	**206**	18.5	1.7
48	20.1	1.7	**101**	19.6	1.7	**154**	19.0	1.7	**207**	18.5	1.7
49	20.1	1.7	**102**	19.6	1.7	**155**	19.0	1.7	**208**	18.5	1.7
50	20.1	1.7	**103**	19.5	1.7	**156**	19.0	1.7	**209**	18.5	1.7
51	20.1	1.7	**104**	19.5	1.7	**157**	19.0	1.7	**210**	18.5	1.7
52	20.1	1.7	**105**	19.5	1.7	**158**	19.0	1.7	**211**	18.5	1.7
53	20.1	1.7	**106**	19.5	1.7	**159**	19.0	1.7	**212**	18.5	1.7
54	20.1	1.7	**107**	19.5	1.7	**160**	19.0	1.7	**213**	18.5	1.7
55	20.1	1.7	**108**	19.5	1.7	**161**	18.9	1.7	**214**	18.4	1.7
56	20.0	1.7	**109**	19.5	1.7	**162**	18.9	1.7	**215**	18.4	1.7
57	20.0	1.7	**110**	19.5	1.7	**163**	18.9	1.7	**216**	18.4	1.7
58	20.0	1.7	**111**	19.5	1.7	**164**	18.9	1.7	**217**	18.4	1.7
59	20.0	1.7	**112**	19.5	1.7	**165**	18.9	1.7	**218**	18.4	1.7
60	20.0	1.7	**113**	19.4	1.7	**166**	18.9	1.7	**219**	18.4	1.7
61	20.0	1.7	**114**	19.4	1.7	**167**	18.9	1.7	**220**	18.4	1.7
62	20.0	1.7	**115**	19.4	1.7	**168**	18.9	1.7	**221**	18.4	1.7
63	20.0	1.7	**116**	19.4	1.7	**169**	18.9	1.7	**222**	18.4	1.7
64	20.0	1.7	**117**	19.4	1.7	**170**	18.9	1.7	**223**	18.4	1.7
65	20.0	1.7	**118**	19.4	1.7	**171**	18.8	1.7	**224**	18.4	1.7
66	20.0	1.7	**119**	19.4	1.7	**172**	18.8	1.7	**225**	18.4	1.7
67	19.9	1.7	**120**	19.4	1.7	**173**	18.8	1.7	**226**	18.3	1.7
68	19.9	1.7	**121**	19.4	1.7	**174**	18.8	1.7	**227**	18.3	1.7
69	19.9	1.7	**122**	19.3	1.7	**175**	18.8	1.7	**228**	18.3	1.7
70	19.9	1.7	**123**	19.3	1.7	**176**	18.8	1.7	**229**	18.3	1.7
71	19.9	1.7	**124**	19.3	1.7	**177**	18.8	1.7	**230**	18.3	1.7
72	19.9	1.7	**125**	19.3	1.7	**178**	18.8	1.7	**231**	18.3	1.7
73	19.9	1.7	**126**	19.3	1.7	**179**	18.8	1.7	**232**	18.3	1.7
74	19.9	1.7	**127**	19.3	1.7	**180**	18.8	1.7	**233**	18.3	1.7
75	19.9	1.7	**128**	19.3	1.7	**181**	18.7	1.7	**234**	18.3	1.7
76	19.8	1.7	**129**	19.3	1.7	**182**	18.7	1.7	**235**	18.3	1.7
77	19.8	1.7	**130**	19.3	1.7	**183**	18.7	1.7	**236**	18.3	1.7
78	19.8	1.7	**131**	19.2	1.7	**184**	18.7	1.7	**237**	18.2	1.7
79	19.8	1.7	**132**	19.2	1.7	**185**	18.7	1.7	**238**	18.2	1.7
80	19.8	1.7	**133**	19.2	1.7	**186**	18.7	1.7	**239**	18.2	1.7
81	19.8	1.7	**134**	19.2	1.7	**187**	18.7	1.7	**240**	18.2	1.7
82	19.8	1.7	**135**	19.2	1.7	**188**	18.7	1.7	**241**	18.2	1.7
83	19.8	1.7	**136**	19.2	1.7	**189**	18.7	1.7	**242**	18.2	1.7
84	19.8	1.7	**137**	19.2	1.7	**190**	18.7	1.7	**243**	18.2	1.7
85	19.7	1.7	**138**	19.2	1.7	**191**	18.7	1.7	**244**	18.2	1.7
86	19.7	1.7	**139**	19.2	1.7	**192**	18.6	1.7	**245**	18.2	1.7
87	19.7	1.7	**140**	19.2	1.7	**193**	18.6	1.7	**246**	18.2	1.7
88	19.7	1.7	**141**	19.1	1.7	**194**	18.6	1.7	**247**	18.2	1.7
89	19.7	1.7	**142**	19.1	1.7	**195**	18.6	1.7	**248**	18.2	1.7
90	19.7	1.7	**143**	19.1	1.7	**196**	18.6	1.7	**249**	18.2	1.7
91	19.7	1.7	**144**	19.1	1.7	**197**	18.6	1.7	**250**	18.1	1.7
92	19.7	1.7	**145**	19.1	1.7	**198**	18.6	1.7			
93	19.7	1.7	**146**	19.1	1.7	**199**	18.6	1.7			

Tumalo Creek upstream of the mouth (TC 000.25)

Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)
3	21.2	2.0	56	13.4	1.8	109	11.3	1.7			
4	20.7	2.0	57	13.3	1.8	110	11.3	1.7			
5	20.5	2.0	58	13.2	1.8	111	11.3	1.7			
6	20.2	2.0	59	13.2	1.8	112	11.3	1.7			
7	20.0	2.0	60	13.1	1.8	113	11.3	1.7			
8	19.8	2.0	61	13.0	1.8	114	11.3	1.7			
9	19.6	2.0	62	13.0	1.8	115	11.2	1.7			
10	19.4	2.0	63	12.9	1.8	116	11.2	1.7			
11	19.2	2.0	64	12.8	1.8	117	11.2	1.7			
12	19.0	1.9	65	12.8	1.8	118	11.2	1.7			
13	18.8	1.9	66	12.7	1.8	119	11.2	1.7			
14	18.7	1.9	67	12.7	1.8	120	11.2	1.7			
15	18.5	1.9	68	12.6	1.8	121	11.2	1.7			
16	18.3	1.9	69	12.6	1.8	122	11.2	1.7			
17	18.1	1.9	70	12.5	1.8	123	11.2	1.7			
18	17.9	1.9	71	12.5	1.8	124	11.2	1.7			
19	17.7	1.9	72	12.4	1.8	125	11.2	1.7			
20	17.6	1.9	73	12.4	1.8	126	11.2	1.7			
21	17.4	1.9	74	12.3	1.8	127	11.2	1.7			
22	17.2	1.9	75	12.3	1.8	128	11.2	1.7			
23	17.1	1.9	76	12.2	1.8	129	11.2	1.7			
24	16.9	1.9	77	12.2	1.8	130	11.2	1.7			
25	16.7	1.9	78	12.1	1.8	131	11.2	1.7			
26	16.6	1.9	79	12.1	1.8	132	11.1	1.7			
27	16.4	1.9	80	12.1	1.8	133	11.1	1.7			
28	16.3	1.9	81	12.0	1.8	134	11.1	1.7			
29	16.2	1.9	82	12.0	1.8	135	11.1	1.7			
30	16.0	1.9	83	11.9	1.8	136	11.1	1.7			
31	15.9	1.9	84	11.9	1.8	137	11.1	1.7			
32	15.7	1.9	85	11.9	1.8	138	11.1	1.7			
33	15.6	1.9	86	11.8	1.7	139	11.2	1.7			
34	15.5	1.9	87	11.8	1.7	140	11.2	1.7			
35	15.4	1.9	88	11.8	1.7	141	11.2	1.7			
36	15.2	1.9	89	11.8	1.7	142	11.2	1.7			
37	15.1	1.8	90	11.7	1.7	143	11.2	1.7			
38	15.0	1.8	91	11.7	1.7	144	11.2	1.7			
39	14.9	1.8	92	11.7	1.7	145	11.2	1.7			
40	14.8	1.8	93	11.6	1.7	146	11.2	1.7			
41	14.7	1.8	94	11.6	1.7	147	11.2	1.7			
42	14.6	1.8	95	11.6	1.7	148	11.2	1.7			
43	14.5	1.8	96	11.6	1.7	149	11.2	1.7			
44	14.4	1.8	97	11.5	1.7	150	11.2	1.7			
45	14.3	1.8	98	11.5	1.7	151	11.2	1.7			
46	14.2	1.8	99	11.5	1.7	152	11.2	1.7			
47	14.1	1.8	100	11.5	1.7	153	11.2	1.7			
48	14.0	1.8	101	11.5	1.7	154	11.2	1.7			
49	13.9	1.8	102	11.4	1.7	155	11.2	1.7			
50	13.8	1.8	103	11.4	1.7	156	11.2	1.7			
51	13.8	1.8	104	11.4	1.7	157	11.2	1.7			
52	13.7	1.8	105	11.4	1.7	158	11.3	1.7			
53	13.6	1.8	106	11.4	1.7						
54	13.5	1.8	107	11.3	1.7						
55	13.4	1.8	108	11.3	1.7						

APPENDIX B Estimated temperatures at five Deschutes River flow scenarios

	Estimated temperature at TC+DR flow							Estimated temperature at TC+DR flow					
TC 000.25	DR QD (cfs)						TC 000.25	DR QD (cfs)					
Flow (cfs)	140	160	180	200	220	250	Flow (cfs)	140	160	180	200	220	250
10	19.2	19.0	18.8	18.6	18.4	18.2	56	17.5	17.5	17.5	17.4	17.4	17.3
11	19.2	19.0	18.8	18.6	18.4	18.2	57	17.5	17.5	17.4	17.4	17.3	17.2
12	19.1	19.0	18.8	18.6	18.4	18.2	58	17.4	17.4	17.4	17.4	17.3	17.2
13	19.1	18.9	18.8	18.6	18.4	18.2	59	17.4	17.4	17.4	17.3	17.3	17.2
14	19.1	18.9	18.8	18.6	18.4	18.2	60	17.3	17.4	17.3	17.3	17.3	17.2
15	19.1	18.9	18.7	18.6	18.4	18.2	61	17.3	17.3	17.3	17.3	17.2	17.1
16	19.1	18.9	18.7	18.6	18.4	18.2	62	17.3	17.3	17.3	17.2	17.2	17.1
17	19.0	18.9	18.7	18.5	18.4	18.1	63	17.2	17.2	17.2	17.2	17.2	17.1
18	19.0	18.8	18.7	18.5	18.4	18.1	64	17.2	17.2	17.2	17.2	17.1	17.1
19	19.0	18.8	18.7	18.5	18.3	18.1	65	17.1	17.2	17.2	17.2	17.1	17.0
20	19.0	18.8	18.6	18.5	18.3	18.1	66	17.1	17.1	17.1	17.1	17.1	17.0
21	18.9	18.8	18.6	18.5	18.3	18.1	67	17.1	17.1	17.1	17.1	17.1	17.0
22	18.9	18.7	18.6	18.4	18.3	18.1	68	17.0	17.1	17.1	17.1	17.0	17.0
23	18.9	18.7	18.6	18.4	18.3	18.1	69	17.0	17.0	17.0	17.0	17.0	16.9
24	18.8	18.7	18.5	18.4	18.2	18.0	70	16.9	17.0	17.0	17.0	17.0	16.9
25	18.8	18.7	18.5	18.4	18.2	18.0	71	16.9	17.0	17.0	17.0	16.9	16.9
26	18.8	18.6	18.5	18.3	18.2	18.0	72	16.9	16.9	16.9	16.9	16.9	16.9
27	18.7	18.6	18.5	18.3	18.2	18.0	73	16.8	16.9	16.9	16.9	16.9	16.8
28	18.7	18.6	18.4	18.3	18.2	18.0	74	16.8	16.9	16.9	16.9	16.9	16.8
29	18.6	18.5	18.4	18.3	18.1	17.9	75	16.8	16.8	16.8	16.9	16.8	16.8
30	18.6	18.5	18.4	18.2	18.1	17.9	76	16.7	16.8	16.8	16.8	16.8	16.8
31	18.6	18.5	18.3	18.2	18.1	17.9	77	16.7	16.8	16.8	16.8	16.8	16.7
32	18.5	18.4	18.3	18.2	18.1	17.9	78	16.6	16.7	16.8	16.8	16.8	16.7
33	18.5	18.4	18.3	18.2	18.0	17.8	79	16.6	16.7	16.7	16.7	16.7	16.7
34	18.4	18.3	18.2	18.1	18.0	17.8	80	16.6	16.7	16.7	16.7	16.7	16.7
35	18.4	18.3	18.2	18.1	18.0	17.8	81	16.5	16.6	16.7	16.7	16.7	16.6
36	18.4	18.3	18.2	18.1	18.0	17.8	82	16.5	16.6	16.6	16.7	16.7	16.6
37	18.3	18.2	18.1	18.0	17.9	17.8	83	16.5	16.6	16.6	16.6	16.6	16.6
38	18.3	18.2	18.1	18.0	17.9	17.7	84	16.4	16.5	16.6	16.6	16.6	16.6
39	18.2	18.2	18.1	18.0	17.9	17.7	85	16.4	16.5	16.6	16.6	16.6	16.6
40	18.2	18.1	18.0	17.9	17.8	17.7	86	16.4	16.5	16.5	16.5	16.6	16.5
41	18.1	18.1	18.0	17.9	17.8	17.7	87	16.3	16.4	16.5	16.5	16.5	16.5
42	18.1	18.0	18.0	17.9	17.8	17.6	88	16.3	16.4	16.5	16.5	16.5	16.5
43	18.1	18.0	17.9	17.8	17.8	17.6	89	16.3	16.4	16.4	16.5	16.5	16.5
44	18.0	18.0	17.9	17.8	17.7	17.6	90	16.2	16.3	16.4	16.4	16.5	16.4
45	18.0	17.9	17.9	17.8	17.7	17.6	91	16.2	16.3	16.4	16.4	16.4	16.4
46	17.9	17.9	17.8	17.8	17.7	17.5	92	16.2	16.3	16.4	16.4	16.4	16.4
47	17.9	17.9	17.8	17.7	17.6	17.5	93	16.2	16.3	16.3	16.4	16.4	16.4
48	17.8	17.8	17.8	17.7	17.6	17.5	94	16.1	16.2	16.3	16.3	16.4	16.4
49	17.8	17.8	17.7	17.7	17.6	17.5	95	16.1	16.2	16.3	16.3	16.3	16.3
50	17.8	17.7	17.7	17.6	17.6	17.4	96	16.1	16.2	16.3	16.3	16.3	16.3
51	17.7	17.7	17.7	17.6	17.5	17.4	97	16.0	16.2	16.2	16.3	16.3	16.3
52	17.7	17.7	17.6	17.6	17.5	17.4	98	16.0	16.1	16.2	16.3	16.3	16.3
53	17.6	17.6	17.6	17.5	17.5	17.3	99	16.0	16.1	16.2	16.2	16.3	16.3
54	17.6	17.6	17.5	17.5	17.4	17.3	100	16.0	16.1	16.2	16.2	16.2	16.2
55	17.5	17.5	17.5	17.5	17.4	17.3							

2012 Middle Deschutes Fisheries Monitoring Report

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Deschutes River, below Odin Falls. Photo: Ryan Carrasco

Abstract. ODFW sampled the middle Deschutes River during the fall of 2012 to establish a baseline of fish abundances and to identify factors limiting trout production. Although preliminary, we discovered that redband trout (*Oncorhynchus mykiss gairdneri*) numbers and size class presence increases with proximity to cold water sources on the Deschutes River. The result of occupancy models suggests that temperature and flow influence detection; however, an increased sample size is necessary for conclusive results.

Introduction

The Deschutes River, a tributary of the Columbia River, historically was recognized for its extremely stable interannual flows. The river is fed by cold springs and groundwater originating from snowmelt and rainfall percolating into the porous volcanic geology of the Cascades (Jacobson and Jacobs 2010). The springs supplemented flows in the Deschutes River, which ranged from 1250 cubic feet per second (cfs) in August to 1310 cfs in December (Oregon Water Resources Department, 2003). These conditions were optimal for multiple native salmonid species. However, growing human populations resulted in increased extraction of river water for agricultural operations, municipal and industrial use. Logging practices altered the river morphology and flows were steadily diverted by a growing irrigation infrastructure. By 1960, four major diversions and two large reservoirs were in operation, to manipulate flows and facilitate irrigation needs. This disrupted the stable nature of Deschutes River flows downstream of Wickiup Dam, including the middle Deschutes River located between Bend (RM 166) and Lake Billy Chinook (RM 120) (Figure 1).

The largest impoundments on the upper Deschutes River are Wickiup Reservoir (RM 226.5) and Crane Prairie Reservoir (RM 238). Water is stored and released from these water bodies to inflate flows on the upper Deschutes River during irrigation season. Irrigation season typically runs from April 15th, through October 15th and managed flows are diverted at a series of dams near the city of Bend. Arnold Irrigation Dam (RM 174.5) is the first diversion dam encountered below Wickiup Reservoir, followed by Central Oregon Irrigation Dam (RM 171.0), Bend Feed Canal (RM 165.8), and finally North Canal Dam (RM 164.8). These four diversions can divert up to 2000 cfs from the Deschutes River. In 2012, flows directly below the North Canal Dam ranged from 73.5 to 369 cfs during the irrigation season and between 414-1439 cfs in non-irrigation seasons (BOR).

Tumalo Creek is a tributary to the Deschutes River, which contributes cool water to the mainstem just downstream of the North Unit Canal Dam RM 160.2 (**Error! Reference source not found.**). According to Water Resources Department (2003), the historic natural average annual flows for Tumalo Creek during a 30 year period was 90 cfs. Unfortunately, Tumalo Creek is also subject to flow manipulation with an irrigation diversion at RM 2 (**Error! Reference source not found.**). The Tumalo Irrigation District Dam can divert up to 70 cfs from Tumalo Creek and until recently the lower two miles were frequently dry during peak diversion months. Currently 11 cfs is protected instream below the diversion (Bureau of Reclamation).

Water management has a negative effect on various fish habitat parameters and their corresponding fish assemblages (Shea and Peterson 2007). Irrigation infrastructure reduces habitat connectivity and flow management affects temperature and reduces access to spawning and rearing habitat (Pringle, 2000; Freeman, 2001). The native fish assemblage of the middle Deschutes River and Tumalo Creek historically included bull trout (*Salvelinus confluentus*), redband trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), chinook salmon (*Oncorhnynchus tshawytscha*) and summer steelhead (*Oncorhnynchus mykiss*). Distributions of chinook salmon and steelhead ended at the natural barrier of Big Falls (RM 132) (Nehlsen 1995, Fies et al. 1996). Fish assemblages of the middle Deschutes River are now comprised of redband trout, mountain whitefish, brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*). Brown trout and brook trout were introduced into the Deschutes watershed by state and federal agencies in the early 1900's. Biologists believe flow management and irrigation infrastructure have affected species assemblages (Fies et al. 1996). Low flows during the summer months in the middle Deschutes River results in increased water temperatures. The Upper Deschutes Watershed Council has documented 20.5^{o}C temperatures in this reach in 2012. The Deschutes River is on the Oregon Department of Environmental Quality 303d list for water quality impairment due to excessive temperature. Negative impacts of high temperature on salmonid growth and survival are well documented (Recsetar et al. 2012).

As a result of concern for low flows and exacerbated temperatures on fish populations, aquatic resources and recreational angling, several central Oregon non-profit groups, including the Deschutes River Conservancy and Upper Deschutes Watershed Council (UDWC), began working collaboratively with the irrigation districts and Oregon Water Resources Department to engage in water conservation projects during the past 15 years. This has resulted in flows in the middle Deschutes River incrementally increasing from a summer time low of ~ 30 cfs to an average of 138 cfs in 2012. Conservation project supporters and sponsors would benefit from fisheries monitoring information indicating whether populations are responding favorably to the increase in flow. The UDWC was awarded grant funds from the Oregon Watershed Enhancement Board to fund Oregon Department of Fish and Wildlife staff to conduct a multi-year fish monitoring effort to characterize the fish assemblage in the middle Deschutes River and document changes over time.

Documentation of flow management and its corresponding effects on fish assemblages in the middle Deschutes River subbasin have been difficult to demonstrate. Rough terrain, limited access, and low capture rates limit accuracy and precision of standard population estimates. A methodology that assumes low capture rates, provides unbiased estimates of fish distribution, and calculates the effect of various habitat parameters is ideal. Our goal is to determine which habitat factors were determining the presence of fish species at different life history phases in the middle Deschutes River and its tributaries. Our objectives were to:

- Develop a sampling methodology that effectively and efficiently measures baseline fish assemblages in the Deschutes River and Tumalo Creek.
- Measure flow, temperature, and habitat conditions within the study area.
- Describe the effect of flow, temperature, and habitat conditions on middle Deschutes River and Tumalo Creek fish assemblages.
- Adapt the study protocol to facilitate future monitoring at a reduced level to document changes in response to further conservation efforts.

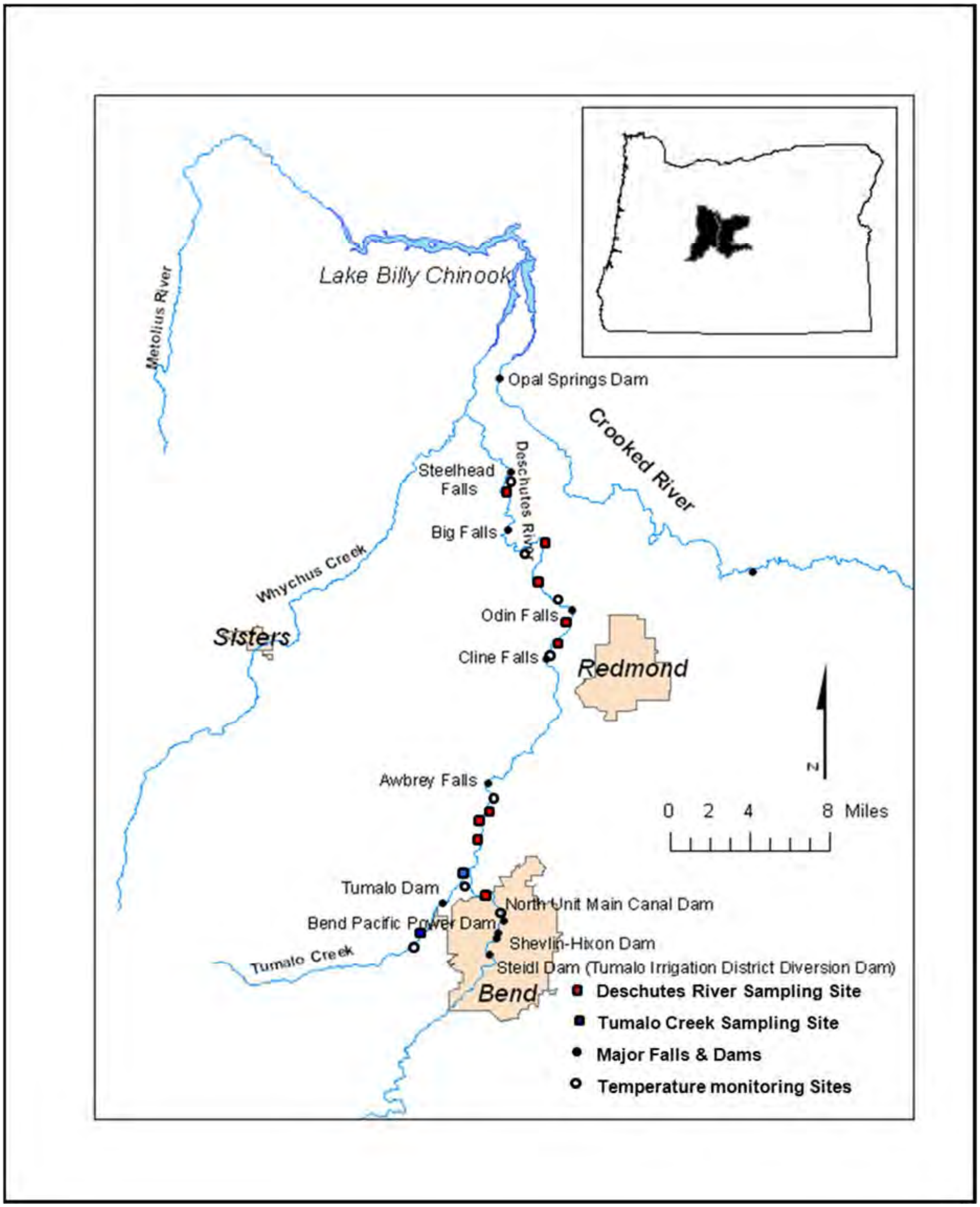

Figure 1 Map of the middle Deschutes River from Bend to Lake Billy Chinook. Red squares represent electrofishing sites on the middle Deschutes River. Blue squares represent sampling sites (electrofishing and snorkeling) in Tumalo Creek. Solid black circles represent major falls and dams. Black circles show temperature logger locations.

Methods

Site Description

The middle Deschutes River runs from the North Canal Dam in Bend to Lake Billy Chinook (**Error! Reference source not found.**). This section of river can be generalized by steep canyons and occasional reaches sweeping open to form narrow valleys. The mean gradient from North Canal Dam to Foley Waters is 6.4% and mean width is 17.4 meters. Habitat is comprised of 35.7% riffles, 27.6% scour pools, 22.3 % glides, 6.7% rapids, and 1.7% cascades, and 1 % backwater pools (Loerts & Lorz 1994).

The 2012 sampling season was abbreviated between September 5th and October 28th, which limited the number of sampling sites. The rugged topography surrounding the middle Deschutes River and private property also limited access to sampling sites. Once access sites were identified, we used discontinuous sample selection in ArcGIS to select 9 sampling sites on the middle Deschutes River and two sites on Tumalo Creek (**Error! Reference source not found.**) (Peterson et al. 2006). All sites were 200 meters (m) in length and GPS coordinates at the upper and lower terminus of each site were recorded to ensure consistency between sampling events; an additional 600 m was added to the Foley Waters site as part of population estimate study. Two seasons were defined, irrigation season and non-irrigation season when in-river flows increased. Each site was monitored three times per season. In order to achieve the maximum amount of sampling in 2012, multiple pass removal on Tumalo Creek and the mark recapture study at the North Canal Dam was postponed.

Our study sites were located from Sawyer Park, downstream of the North Canal Dam to Foley Waters. Sawyer Park is the first site downstream of the North Canal Dam (RM 164) and is comprised of shallow riffles and pools. There are three sites below the city of Tumalo (RM 156.2, 155.5, & 155) that range from shallow riffles to deep pools. The Cline Falls sites (RM 144 & 142) and Odin Falls sites (RM 138 & 137) consist of short rapids followed by glides. Our final site is located at Foley Waters (RM 129), where large spring complexes provide a stable temperature regime year round, and is comprised of shallow riffles and pools.

There are two monitoring sites located on Tumalo Creek. The first site (RM 6) flows through a broad valley near Fremont Park and is comprised of riffles and pool complexes. Site 2 is located 100 meters upstream of the confluence with the Deschutes River, but below the Tumalo Irrigation Diversion. This section is narrow and flows rapidly through a steep confined canyon, and terminates into the Deschutes River.

Flow and Temperature Monitoring

Instantaneous flow readings were recorded before the first sampling site daily from the U.S. Bureau of Reclamation Hydromet system. The middle Deschutes River stream gauge is located below the North Canal Dam in Bend (DEBO RM 164.25) and records flows on 15 minute intervals. Tumalo Creek Flows were recorded directly below the Tumalo Feed Canal (TUMO RM 2.05).

Eight temperature loggers were deployed as part of the middle Deschutes monitoring project. Loggers were placed at six sites on the Deschutes River and two sites on Tumalo Creek. Vemco Minilog II-T temperature loggers were used to be consistent with partners and the Oregon Department of Environmental Quality (UDWC 2008). We calibrated all temperature loggers by placing them in two separate baths, the first at 8.1 °C and the second at 23.0 °C for ten minutes each (UDWC 2008). A National Institute of Standards and Technology (NIST) certified thermometer was used to manually recorded temperature every minute. (ODEQ calibrated NIST #52096 Inspected 4.12.12 Expires 4.12.13). Data from each logger was then downloaded and readings were compared to the manual recording from the NIST certified thermometer. Loggers within a difference 0.5°C from the NIST received an A and loggers within 1.0°C received a B. All eight temperature loggers received either an A or a B, none exceeded a difference greater than 0.6°C. ODFW temperature loggers were set to record temperature every hour and were placed in the Deschutes River on September 24th, 2012 (RM 129.0, 139.0, 144.5, 155.0 & 165.9) and on September 25th (RM 141). Temperature loggers with the same settings were placed in Tumalo Creek on October 10th (RM 0 & 6.0). Each logger was secured to the bank with a cable extending 8-12 feet into the water. Loggers were audited every other month and data offloaded onto a Vemco field reader. At the time of audit, the NIST was used to take a manual temperature, recording river temperature to compare with the logger for accuracy. All offloaded data was entered into a database along with the NIST thermometer reading.

We used data from three UDWC Vemco temperature loggers located downstream of Tumalo Creek (RM 160), upstream of Tumalo Creek (RM 160.25) and at the Riverhouse (RM 164.75) located downstream from the North Canal Dam. UDWC temperature loggers recorded temperatures in 2012 from April 23rd to November 7th.

Sampling

A fourteen foot cataraft equipped with a Smith-Root 2.5 GPP electrofishing unit and 32” array droppers was used to collect fish on the middle Deschutes River. All sampling was conducted with one rower and two netters at the bow of the raft. To reduce the likelihood of incomplete detections, we sampled two longitudinal transects in each reach during irrigation season to ensure full coverage of the river channel (Jacobsen and Jacobs 2010). It was not possible to sample multiple transects at all sites during non-irrigation season due to high flows impeding upstream travel; mean flows were 138 cfs during irrigation season and 615 cfs after irrigation season. The electrofishing unit was set for high-range direct current (DC) with a pulse rate of 120 pulses per second and power ranged from 40-80 percent. All sites were shocked for an average of 187 seconds/transect during irrigation season and 143 seconds/transect after irrigation season. All fish captured were held in a live well until electrofishing was completed. Fish were identified to species, enumerated, measured to the nearest millimeter (total length), weighed to the nearest gram when ≥150mm in length, and then released at end of site. Fish that measured less than 150mm were not weighed due to the inaccuracy of our scales. All data was entered into a Microsoft Access database form on a Trimble Yuma.

We sampled an additional 600 m at the 200 m monitoring site at Foley Waters as part of a population estimate study. All sampling methods were consistent with the nine upstream middle Deschutes River sites; however, mark and recapture methods were also implemented within the 800 m section. Three longitudinal transects were sampled for three consecutive days from September 26th-28th, 2012. Two to three in-stream netters captured fish in front of the raft in addition to the on-boat netters. On September 26, all captured trout were given a lower caudal punch (with exception of fish <150mm) and on September 27th, all unmarked trout were given an upper caudal punch. During the final sampling, fish captured were identified by the type of caudal punch or as unmarked. Fish captured in the 200 meter section were compared to the eight upstream sites and were included in the 800-m population estimate.

Each site on Tumalo Creek was snorkeled once and electrofished with a backpack electrofisher twice between October 10th and October 15th. Snorkelers were trained in fish identification and underwater fish length estimation using various length decoys that ranged from 100mm-300mm (Peterson, 2002). Time restrictions and dangerous conditions due to high flows prevented us from sampling after October 15th.

Data Analysis

We calculated mean length, weight, relative weight, and absolute length frequency for all fish species by site and for all sites combined. The natural discontinuities in the length frequency histograms for all sites combined were used to assign size classes to each species (Isely, 2007). Length, weight, and relative weight were compared among sampling locations and three size classes assigned to each species (RB & BR; juvenile 60-120, intermediate 121-220, 221-500 reproductive) using two-way analysis of variance. Sampling location variables include river mile, flow variation, and distance to coldwater refuge.

Occupancy modeling was used to determine the effects of flow and temperature on fish distributions in the middle Deschutes River. We queried capture histories (presence/absence) of redband trout, brown trout, and their size classes for each site. We assumed study sites were closed to emigration and immigration during a season; detections were independent; and there was no unexplained heterogeneity in occupancy or detectability. Models related detection estimates to characteristics of the surveys and sites.

We used customized single season, single species models created in Presence and used two sampling covariates. We hypothesized that flow and temperature would have an influence on detection; therefore sampling covariates were instantaneous flow (cfs) and temperature (°C). Detection was modeled as a function of either flow, temperature (temp), or both temperature and flow. We did not model for occupancy probability because a site covariate was necessary and we had no covariates. (Mackenzie, Personal Communication 2013) Models were ranked according to Akaike's Information Criterion (AIC) (USGS, 2005). AIC weight, ΔAIC, and AIC determined the rank of the models. The model with the highest AIC weight and lowest AIC value ranked as the most parsimonious model. The difference between the best fitting model and the selected models AIC value is ΔAIC; models for which the ΔAIC value was within 2.0 units of the best fitting model should not be disregarded when deciphering inferences or parameter estimates (Mackenzie et al. 2006). Covariate data was standardized for the purposes of occupancy modeling.

We used the Schnabel formula for the mark-recapture population estimation at Foley Waters (Kohler and Hubert 1999). Non-game species were not included in this population estimate. The Schnabel estimation formula is:

$$\widehat{N} = \frac{\sum_{t=1}^{n} C_t M_t}{\sum_{t=1}^{n} R_t}$$

Where C refers to number of captures, M is the number marked, N refers to the estimate and R refers to captures without marks. Subscript *t* refers to the individual sample period and *n* is the number of periods.

Middle Deschutes & Tumalo Creek Results

Flow and Temperature

Flows in the middle Deschutes River were recorded from the Bureau of Reclamation (BOR) (DEBO); 2012 flows ranged from 73.49 cfs to 1439 cfs (Figure 2). Tumalo Creek flows were also recorded from a BOR stream gauge located downstream of Tumalo Irrigation District Canal (TUMO); flows ranged from 13.23 cfs to 313.14 cfs (

Figure 3). Temperature loggers began recording data on September 25, 2012 between Pioneer Park and Foley Waters. September 25, 2012 most closely represented a summer-like temperature regime and December 31, 2012 represented a winter temperature regime during this time-period. Maximum temperatures ranged from 13.15 ºC to 15.77 ºC on September 25, and between 0.6 ºC and 1.09 ºC on December 31, 2012 between Sawyer Park and Foley Waters (Figure 4). The overall maximum temperature measured in the middle Deschutes River was 20.48 °C (July 12, 2012) and the overall minimum was -0.04 °C (December 31, 2012). Maximum and minimum temperatures on Tumalo Creek at RM 1 were 12.4 ºC and -0.03 °C between October 10th and December 31 2012 (Figure 5). Maximum and minimum temperatures on Tumalo Creek RM 6 were 9.18 ºC and -0.01 ºC.

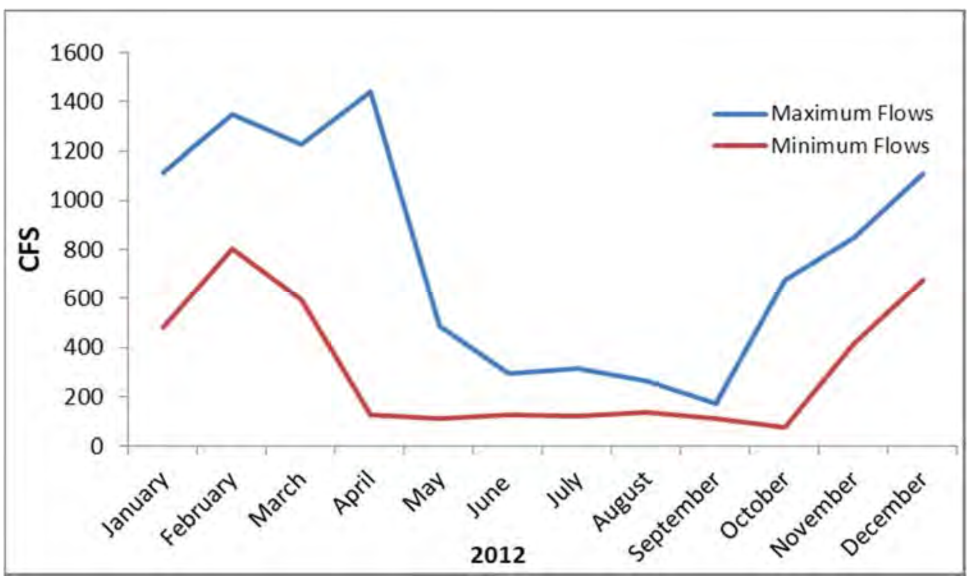

Figure 2 Middle Deschutes River monthly maximum and minimum flows as recorded by BOR for 2012. Stream gauge located at RM 164.25, below North Canal Dam.

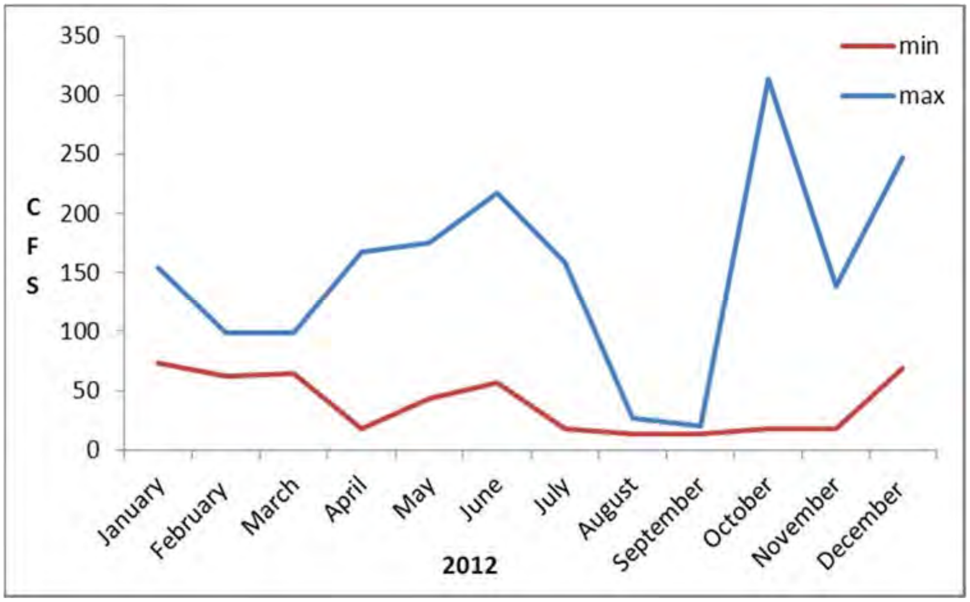

Figure 3 Tumalo Creek minimum and maximum monthly flows as recorded by the stream gauge located below Tumalo Irrigation District Canal. Data was missing before January 18th, 2012.
*This graph does not include water diverted from TIDC.

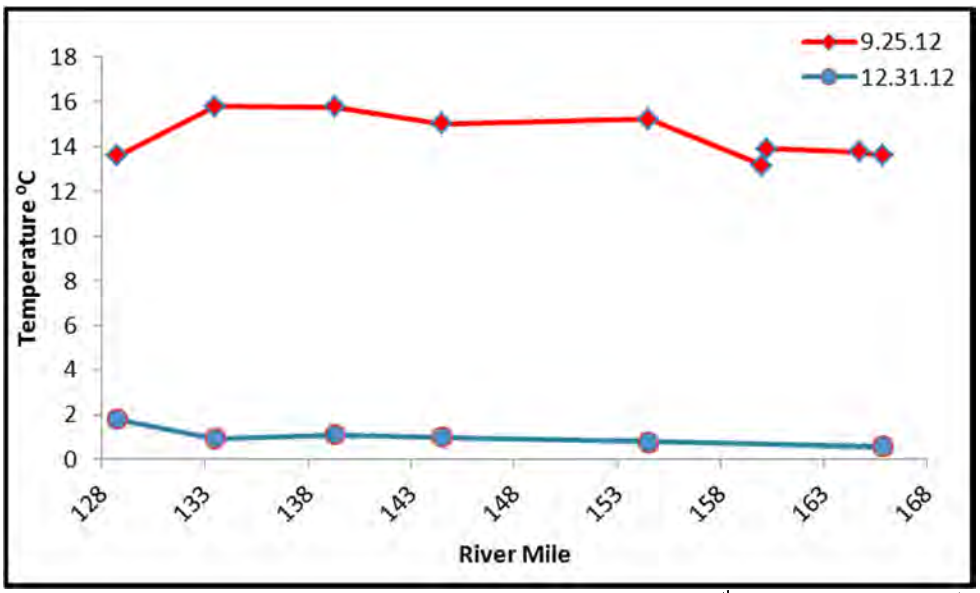

Figure 4 Maximum temperatures recorded on September 25th and December 31st, 2012. Recorded at temperatures loggers distributed throughout the middle Deschutes River by UDWC (3 loggers) and ODFW (6 loggers). Logger data for December 31st, 2012 does not include UDWC data.
*ODFW temperature loggers were not deployed until September 25th, 2012.

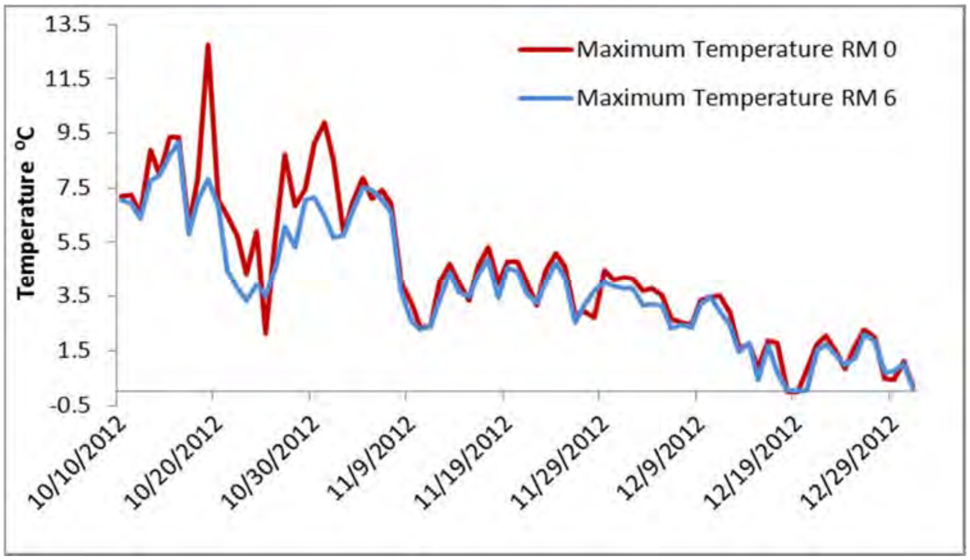

Figure 5 Temperature recorded from Tumalo Creek by ODFW temperature loggers from October 10th, 2012 to December 31st, 2012. Tumalo 1 logger is located at RM 0 (10m upstream from confluence) and Tumalo 2 logger is located at RM 6.

Fish sampling

In the middle Deschutes River we sampled nine sites three times between August 5th, 2012 and October 12th, 2012 and three times between October 15th, 2012 and October 28th, 2012. We captured mountain whitefish, kokanee, redband trout, brown bullhead (*Ameiurus nebulosus*), mottled sculpin (*Cottus bairdii*), brown trout, longnose dace (*Rhinichthys cataractae*), brook trout, tui chub (*Gila bicolor*) and three-spined stickleback (*Gasterosteus aculeatus aculeatus*). Mountain whitefish, brown trout, and redband trout were the dominant species encountered (Figure 6). The mean length and weight of mountain whitefish was 236 mm (SE ± 11.67), brown trout was 237 mm (SE ± 17.7), and redband trout was 189 mm (SE ± 15.3) (Figures 8,9,10). The mean length of redband trout was lowest at Odin Falls 2 and highest at Foley Waters. The mean length of brown trout was lowest at the site below Tumalo Creek and highest at Sawyer Park then Cline Falls 1 and Foley Waters. Mountain whitefish captured at Foley Waters were significantly longer than whitefish captured in all other sites ($P < 0.05$). The mean relative weight of whitefish captured at Foley Waters was also significantly greater than the relative weight of whitefish in all other sites ($P < 0.05$). The sample sizes of redband trout and brown trout were inadequate for statistical comparisons of means among sites.

We sampled two sites three times from October 10th -12th, 2012 on Tumalo Creek. We snorkeled on October 10th, and electrofished on October 11th and October 12th; fish sampled during electrofishing were measured and weighed. Redband trout, brown trout, and brook trout were the only species encountered in Tumalo Creek; redband were the dominant species and brown trout were only captured at the lower site (Figure 7). The mean length of redband trout was 118 mm (SE ± 4.32), brown trout was 104 mm (SE ± 8.27) and brook trout was 123 mm (SE ± 7.42). The mean relative weight of redband was 96.39 grams (SE ± 5.00), brown trout was 86.91 g (SE ± 1.70), and brook trout ranged from 82.14 to 86.84 g (n = 3). Sample sizes of fishes in Tumalo Creek were inadequate for statistical comparisons.

The length frequency of redband was normally distributed (Figure 12). The natural length frequency discontinuities of redband were at 120 mm and 220 mm; the associated size classes were between 60-120 mm (juvenile), 121-220 mm (immature), and 221+ mm (mature) (Figure 12). The brown trout length frequency was also normally distributed (Figure 13). The natural length frequency discontinuities of brown trout were at 150 mm and 270 mm; the associated size classes were between 80-150 mm (juvenile), 151-270 mm (immature), and 270+ (mature) (Figure 13).

All size classes of redband were present at higher frequencies directly downstream of or in cold water inputs; 51% of redband were caught at the site closest to Tumalo Creek and in Foley Waters (Figure 14). The highest frequencies of brown trout were at Foley Waters (Figure 15) and the highest frequencies of juvenile brown trout were located at the first site below Tumalo Creek (Figure 16). Overall frequencies of redband and brown trout among sites had an inverse relationship (Figure 15).

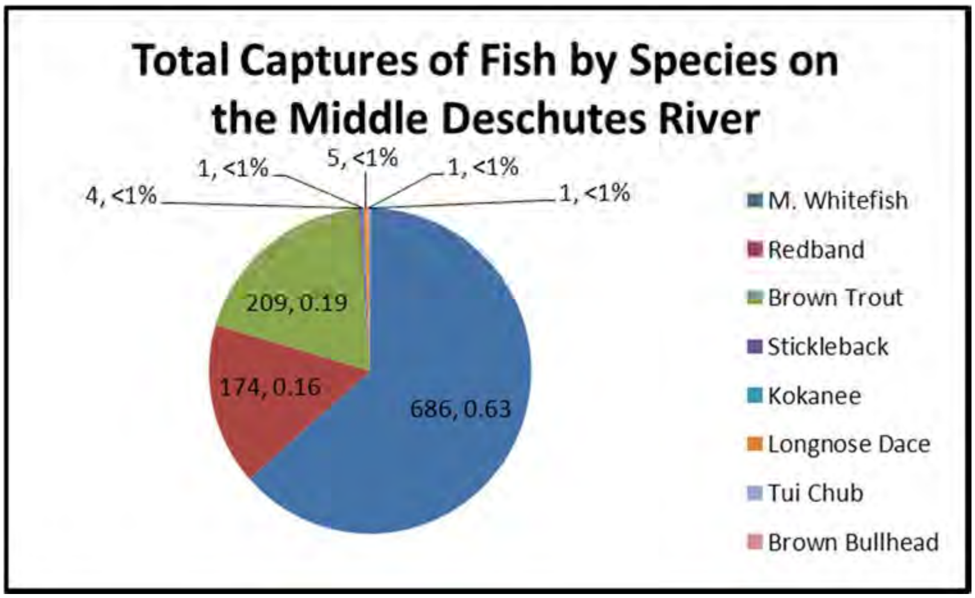

Figure 6 Total captures of fish by species on the middle Deschutes River. Species quantity and percentage is represented.

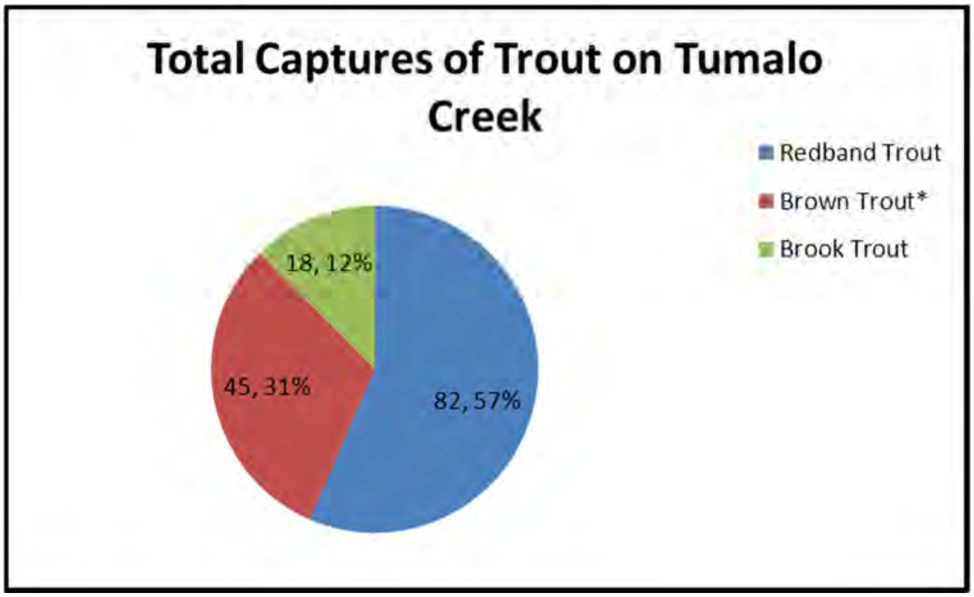

Figure 7 Total captures by species on two sites on Tumalo Creek in 2012.
*Brown trout were not captured at upper site near Fremont Meadows. Species quantity and percentage is represented.

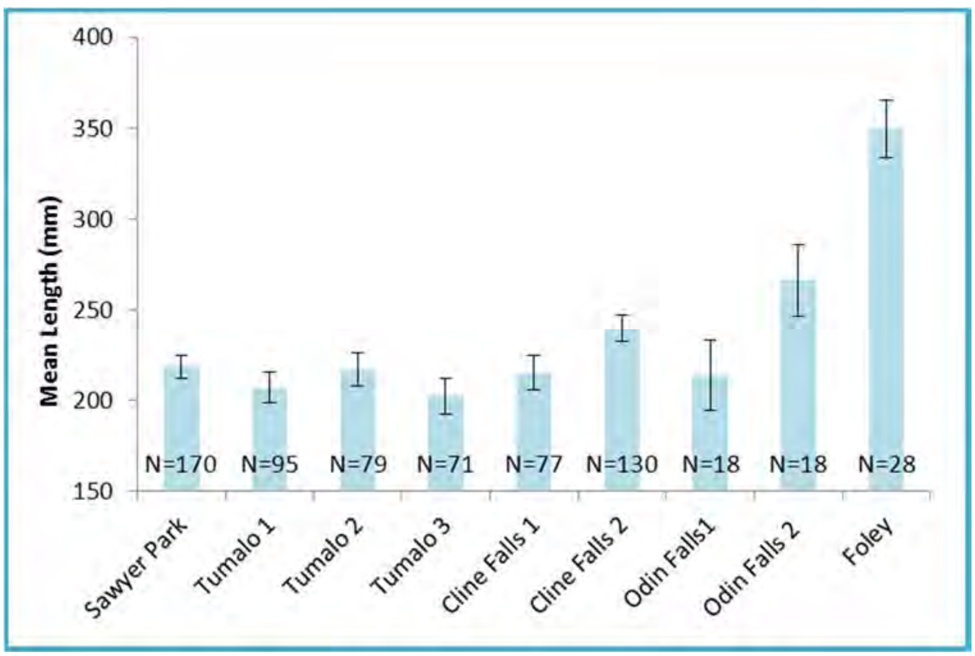

Figure 8 Mean length (mm) and standard error for mountain whitefish captured on the middle Deschutes River.

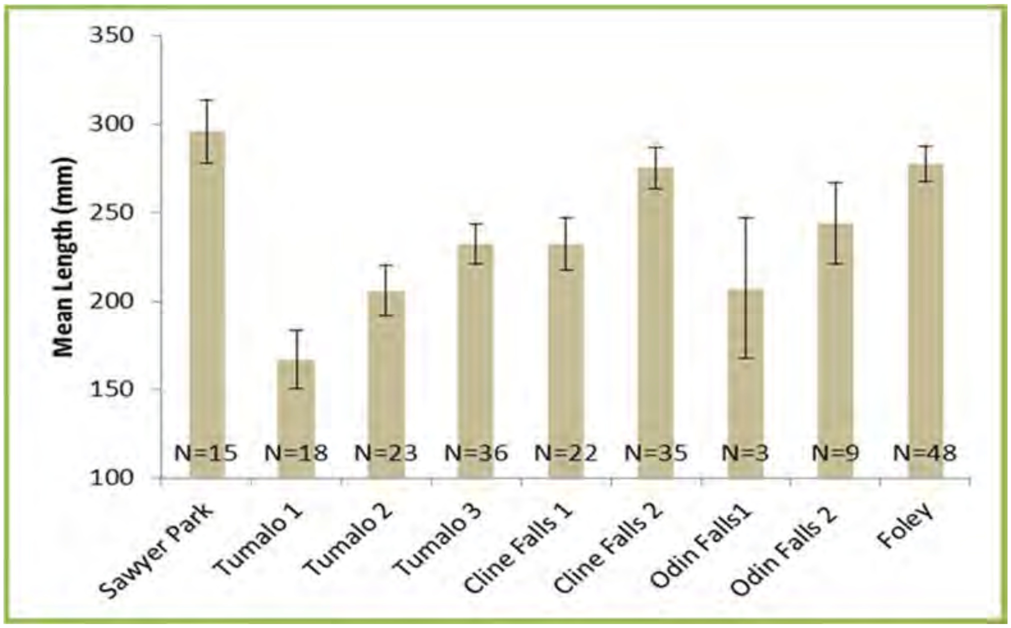

Figure 9 Brown trout mean length in millimeters with standard errors bars that were captured on the middle Deschutes River.

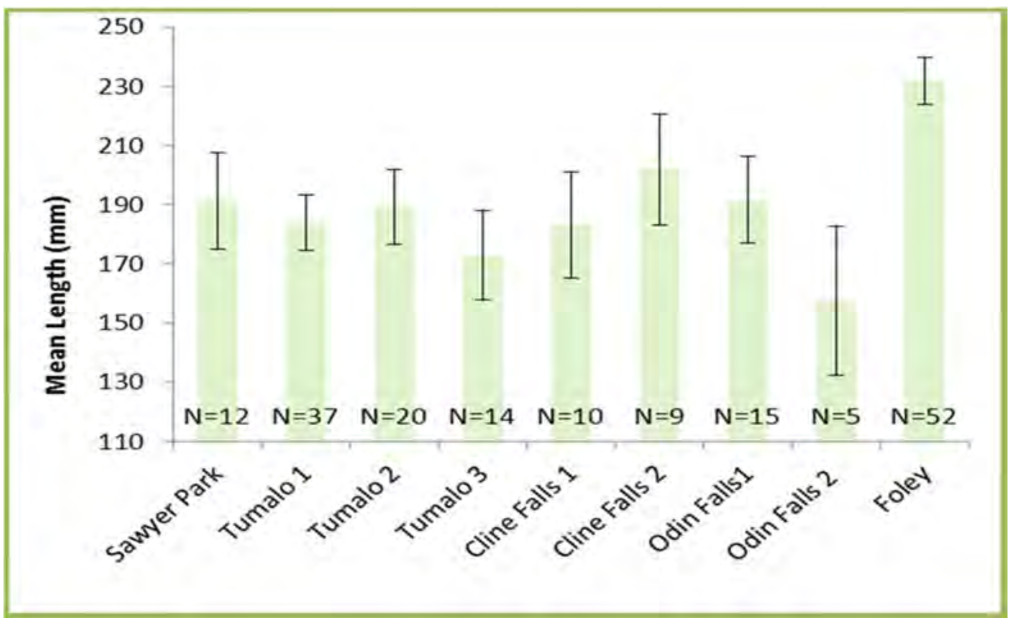

Figure 10 Redband trout mean length in millimeters with standard errors bars that were captured on the middle Deschutes River.

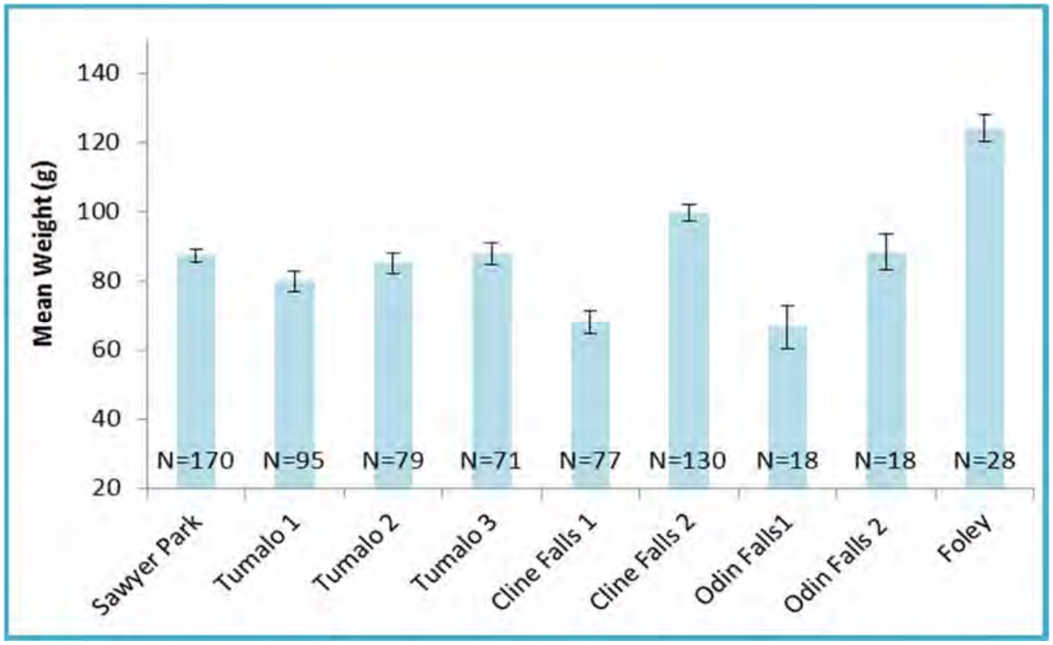

Figure 11 Mean relative weights of mountain whitefish captured in the middle Deschutes, errors bars represent standard error.

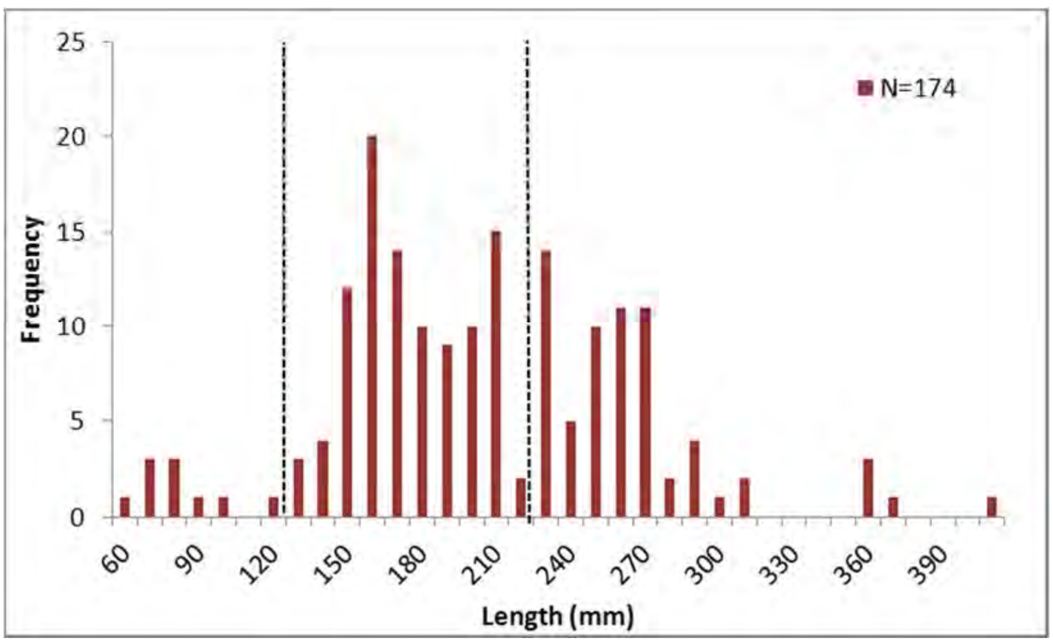

Figure 12 Length frequency distributions of redband trout captured on the middle Deschutes River. Dotted lines represent natural discontinuities in size class distributions. 30% of all redband were captured at Foley Waters.

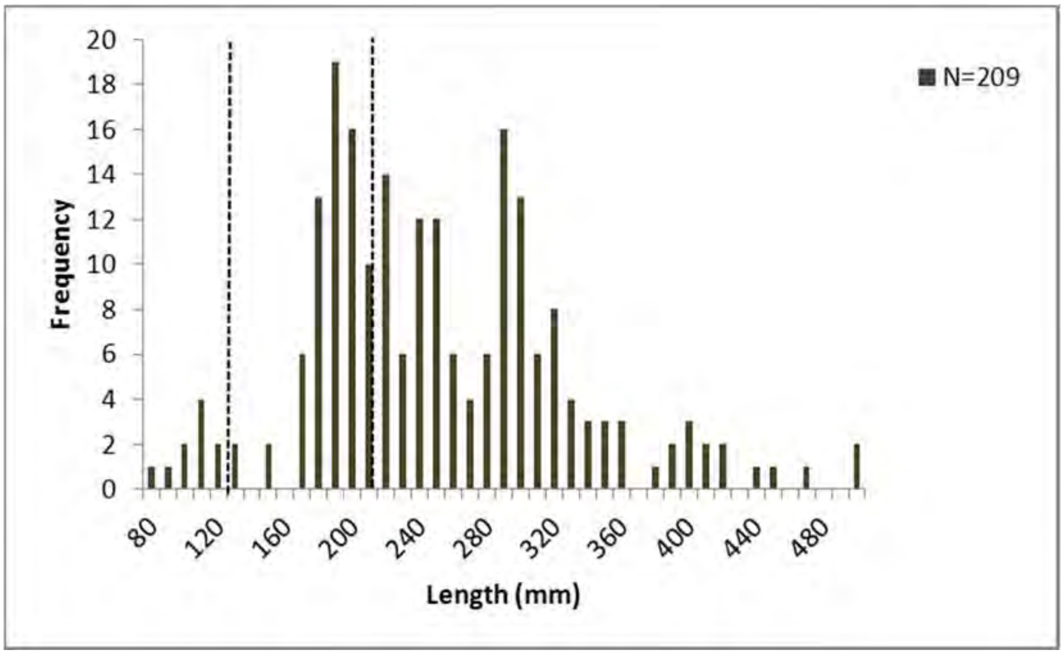

Figure 13 Length frequency distributions of brown trout captured on the middle Deschutes River. 23% of all brown trout were captured at Foley Waters.

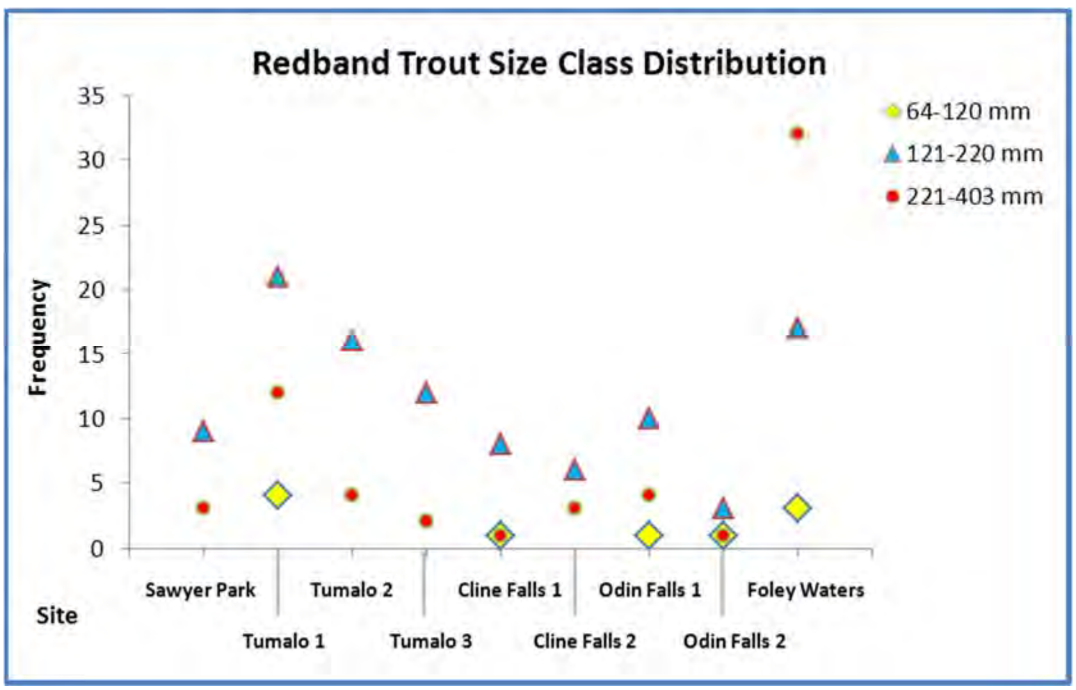

Figure 14 Middle Deschutes River size class distribution according to site, from Sawyer Park downstream to Foley Waters. Size classes are grouped from 64-120mm, 121-220mm and 221-403mm.

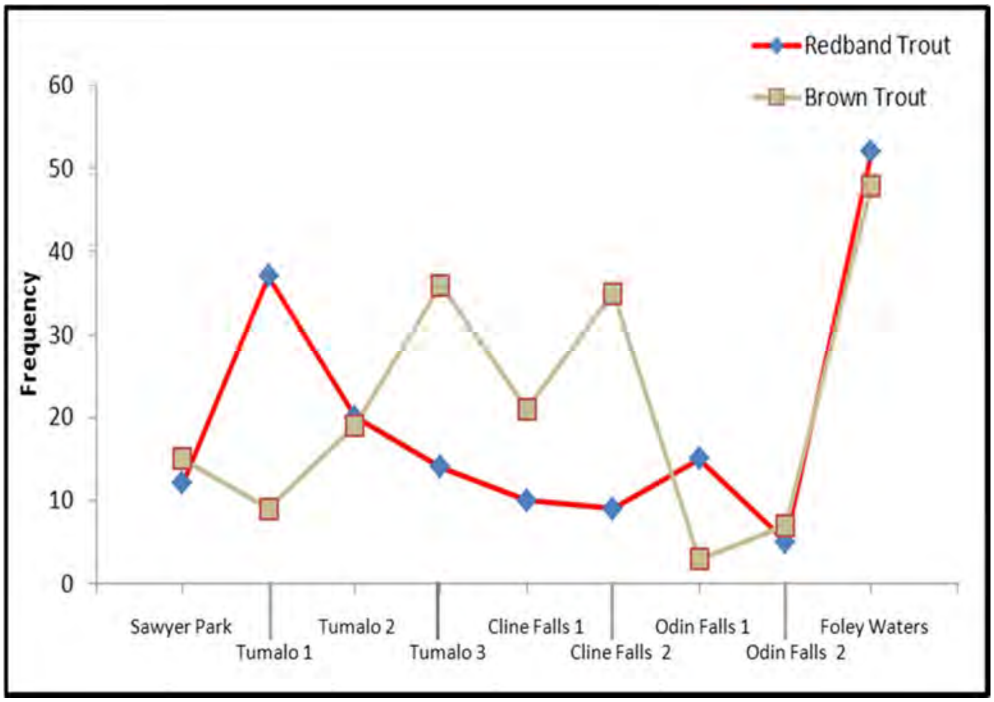

Figure 15 Distribution of brown trout and redband trout at sites sampled in the middle Deschutes River. Includes all size classes.

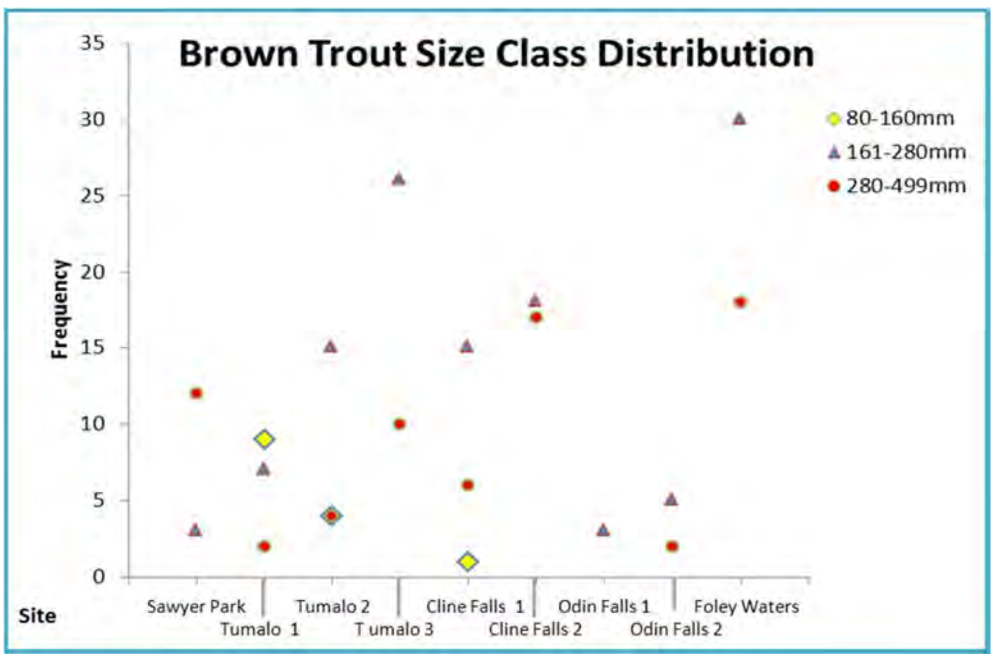

Figure 16 Distribution of brown trout size classes sampled in the middle Deschutes River. Size classes were grouped from 80-160mm, 161-280mm, and 280-499mm.

Population modeling

Four models were run in Presence to estimate occupancy probabilities of the redband trout total population, juvenile redband trout, mature redband trout, and the total population of brown trout. Each model was run with three arrangements of sampling covariates to estimate detection probabilities; temperature, flow (cfs), and temperature and flow. The occupancy parameter was held constant because no covariates remained constant throughout all sites during each sampling season.

Flow was the most likely sampling covariate affecting the presence of the redband trout total population, juvenile redband trout population, and the brown trout total population; temperature was the sampling covariate most likely to affect the presence of mature redband trout (Table 1A). The second most likely sampling covariate affecting the presence of the redband trout total population, juvenile redband, and mature redband was a combination of temperature and flow (Table 1A). The second most likely sampling covariate affecting the presence of the brown trout total population was temperature (Table 1). However, it is important to note that the four models have a high standard error (SE ± 0.75-1.00).

Table 1. Results for all Presence models run for the middle Deschutes River.
Column A indicates all four models run, with three variations of detection as a function of flow, temperature (temp), and temperature and flow. The occupancy parameter remained constant for all models. AIC, ΔAIC and AIC weights are all listed in column A for each of the models. Column B shows the results of occupancy estimates and standard errors and the corresponding covariate that was in the best selected model, which was flow, with the exception of the +250mm redband trout model.

Column A

Presence Model Results for Redband Trout

Model	AIC	ΔAIC	AIC Weight
Flow	52.64	0	0.5685
Temp, Flow	53.75	1.11	0.3263
Temp	56.06	3.42	0.1028

Presence Model Results for Brown Trout

Model	AIC	ΔAIC	AIC Weight
Flow	64.03	0.42	0.287
Temp	64.34	0.73	0.2458
Temp, Flow	65.89	2.28	0.1132

Presence Model Results for ≥250mm Redband Trout

Model	AIC	ΔAIC	AIC Weight
Temp	61.96	0	0.6039
Temp, Flow	63.3	1.34	0.309
Flow	65.9	3.94	0.0842

Presence Model Results for Juvenile Redband Trout

Model	AIC	ΔAIC	AIC Weight
Flow	34.72	0	0.5229
Temp, Flow	35.52	0.8	0.3505
Temp	37.83	3.11	0.1104

Column B

Redband Trout	**Estimate**	**Std.Error**
Occupancy	100%	100%
Flow	-2.263844	0.781645

Brown Trout	**Estimate**	**Std.Error**
Occupancy	100%	100%
Flow	-0.415265	0.336354

≥250mm Redband Trout	**Estimate**	**Std.Error**
Occupancy	88%	73%
Temp	1.480697	0.498389

Juvenile Redband Trout	**Estimate**	**Std.Error**
Occupancy	100%	100%
Flow	-2.960738	2.706747

Foley Waters Mark/Recapture Results

Fish captured at Foley Waters included mountain whitefish, redband trout, longnose dace and brown trout. Using the Schnabel equation, the redband trout population was estimated to be 645 fish/800 m with a 95% confidence interval ranging from 250 to 1776 (figure 8). The brown trout population was estimated to be 854 fish/800 m with a 95% confidence interval ranging from 476 to 1531.

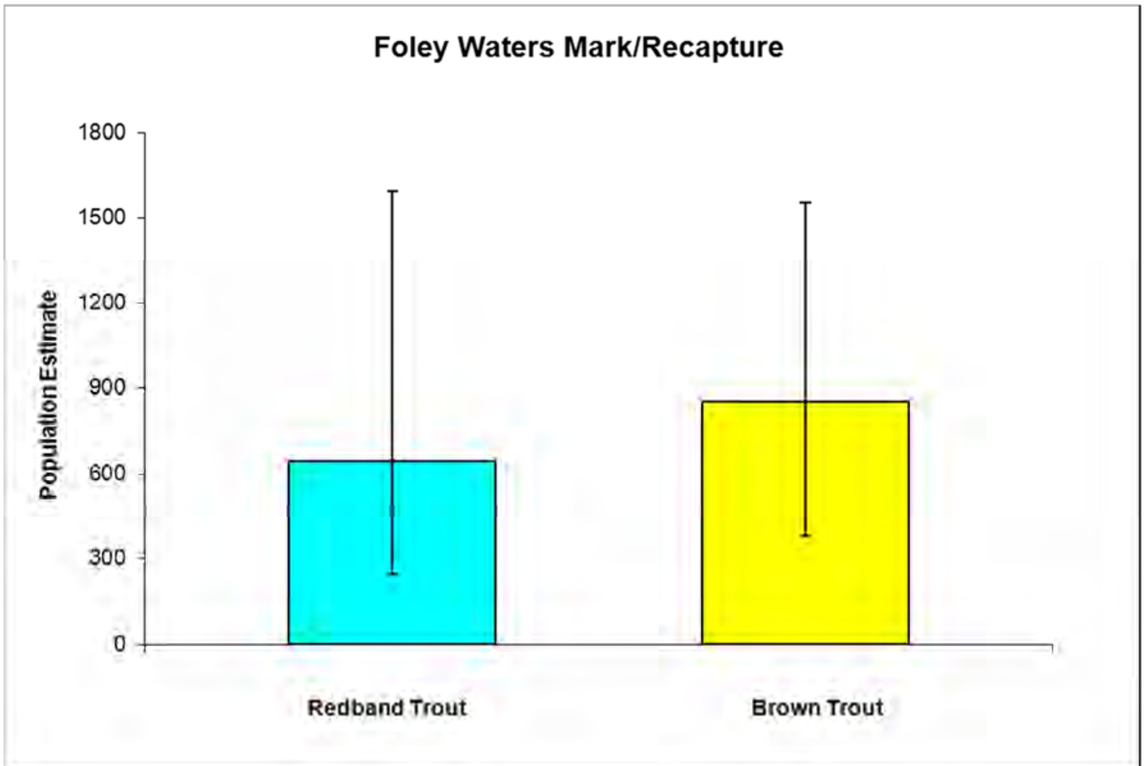

Figure 15 Foley Waters Schnabel population estimates for 800 meters for redband and brown trout with error bars representing 95% confidence intervals.

Discussion

In the middle Deschutes, the Oregon Water Resources Department estimates natural annual flows averaged 1350 cfs with an approximate annual variation of 60 cfs. In 2012, the annual average flow for the middle Deschutes was 756 cfs and it varied by 1366 cfs. In Tumalo Creek natural late summer flows averaged 65 cfs; however, late summer flows reached a minimum of 13 cfs in 2012 (OWRD 2003). Variations in flow limit habitat availability and can potentially conflict with fish spawning. Freeman et al. (2001) demonstrated that young of the year were affected significantly by alterations in flows and fish directly benefit from stable flows by an increase in reproduction. Our models supported this finding, suggesting flows affect presence of juvenile redband trout and redband trout and brown trout of all size classes combined. However, the altered flow regimes in Tumalo Creek and the Deschutes are likely to benefit brown trout and harm native redband. Native redband trout typically spawn between December and May in the Deschutes watershed and their fry emerge from the gravel between May and late July, which corresponds with the period of low flows and high temperatures. Non-native brown trout typically spawn between October and December and their fry emerge from the gravel before flows decline. Redband spawning redds are potentially subjected to dewatering while brown trout fry are allowed to emerge. Additionally, brown trout young of the year gain a size advantage over redband trout young of the year by emerging from the gravel months earlier. Both variables could result in a greater frequency of brown trout over redband trout. In Tumalo Creek, brown trout were not detected in the site unaffected by irrigation withdrawals and they were present in high numbers in the Tumalo Creek reach affected by irrigation withdrawals. Results in the middle Deschutes were not as conclusive due to low sample sizes; however, inverse distributions of redband and brown trout by sampling site suggest that the two species are affected by habitat conditions differently.

Due to time of deployment of temperature loggers, we were unable to demonstrate maximum and minimum temperatures for one year throughout our sampling sites. However, we recorded temperatures with a hand held thermometer on each sampling occasion. Our model suggests that temperature affects adult redband presence more than flow. Our distribution data also suggests fish concentrate near areas of cold-water inputs and average fish lengths and average relative weights are greater in these areas. Another point of interest was juvenile brown trout were only found in the three sites directly below Tumalo Creek and their frequency decreased with distance from Tumalo Creek. There are several explanations for this that are related to either structural habitat in the sites or a temperature effect caused by Tumalo Creek. It is important to collect more information to explain this phenomenon.

Unfortunately, our sample sizes were too small to say that flows and temperature affect fish presence, distribution, or growth with statistical certainty. Our small sample size resulted in a standard error of 100% in our occupancy model and we were unable to make other important statistical comparisons. In 2013, we will adjust the 2012 sampling protocol to increase statistical power and strengthen the models. Increasing the number of sampling sites will reduce standard error within our occupancy model and precision and accuracy will increase as annual data is added. We will shift from multiple longitudinal electrofishing transects to single longitudinal transects and will sample 30 randomly selected sites as opposed to 10. The sampling season will also be shifted from September and October to August and November to allow fish to respond to seasonal fluctuations of flow and temperature. We will also implant radio transmitters in redband trout to track movements of fish between irrigation seasons, which we suspect will support the assertions of the occupancy models. Although our data is limited it suggests that flow management and temperature affect fish presence and growth in the middle Deschutes River; it is essential to collect additional years of data to confirm this hypothesis.

Acknowledgements

ODFW would like to thank the following organizations and people for their assistance with the aforementioned project. OWEB for administering funds and UDWC for securing the funds, Matt Collver and Kristin Harris for their hard work on the project, Pacific Power for allowing us access to Cline Falls, Bruce Lilleston for access to the Odin Falls site, Lauren Mork & Mike Logan from the Upper Deschutes Watershed Council for their technical assistance and loaning of equipment, Tim Porter of ODFW for editing. And lastly, Dr. James Peterson of USGS & Mike Adams of the Forest Service for their expertise with Occupancy Modeling.

Glossary

Akaike Information Criterion (AIC): is a measure of goodness of fit of a statistical model.

Detectability: the probability of detecting a species during a single survey visit, given it is present at the site.

Discontinuous Sampling Frame: is a type of random sampling used to locate sites in an area that has constraints that prevent access to a entire stream or basin. ie. road access, land ownership, or safety concerns that may limit access.

Heterogeneity: synonymous with variation. Used here to refer to unexplained variation in parameters.

Logit function: an equation that converts a sigmoid relationship (logistic) between two factors to a linear relationship. The logit function involving detectability may be: $logit(p)=ln(p/(1-p))=y$.

Maximum likelihood estimate: method of estimating the parameters of a statistical model.

Occupancy: the proportion of sites, patches or habitat occupied by a species

Parameters: quantities to be estimated, such as occupancy or detectability, under an assumed model structure.

Sampling Covariate (survey specific): a unit that can be measured and have a direct influence over detection and varies between sampling events.

Site Covariate: a unit that can be measured and varies between sites, but must remain constant for entire season.

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CITY OF BEND

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Mr. Ken Reick, Manager
Tumalo Irrigation District
64697 Cook Avenue
Bend, Oregon 97701

October 14, 2015

SUBJECT: Letter of Support, Tumalo Irrigation District Tumalo Feed Canal Project

Dear Mr. Reick:

It is the understanding of the City of Bend that the Tumalo Irrigation District has secured funding and is planning to complete Phase IV of their Tumalo Feed Canal piping project this winter of 2015/2016. We also understand TID is seeking an additional $250,000 funding from OWEB now to increase the conserved water amount to 1.2 cfs in Tumalo Creek and 333 acre feet of water in Crescent Creek. We believe this additional request of funds is very cost effective and timely with equipment and contractors already being mobilized for the original grants. After completion of all future phases, approximately six miles of open irrigation canal in the Tumalo Feed Canal will be piped and the entire Tumalo Feed Canal will conserve an estimated 20 cfs (6,664 acre-feet) of flow annually by eliminating seepage and evaporation losses.

This conserved water is making great strides toward the flow restoration goal for Tumalo Creek. In turn, this water will increase low summer flows in the last 3 mile reach of Tumalo Creek and add cold water to a temperature limited Lower Tumalo, as well as contribute cold water to the Middle Deschutes River below Bend, and will help achieve lowering temperatures in both stream segments and will eventually result in delisting of this section of Tumalo Creek from EPA's 303(d) list of impaired streams in Oregon.
As you know, the City and the Tumalo Irrigation District have been long time stewardship partners on Tumalo Creek requiring continuing cooperation to facilitate the proration of the various water rights held by both entities. We understand the proposed District project to enhance the Tumalo Creek watershed and associated fishery as well as the upstream benefits in

Crescent Creek. Such contributions to the Tumalo Creek and Upper Deschutes related watersheds are held in high regard by the City of Bend and is very important to its citizens and those in the region and state.

The City shares the District's desire to upgrade its systems and is in the process of completing upgrades to its surface water delivery system as well and appreciates the support of the District in the City's endeavors on this same watershed.
On February 20, 2013, the City passed Resolution 2900, and within Section 8 of that Resolution, formed the Tumalo Creek Restoration Subgroup – along with Tumalo Irrigation District. This work group has established a goal of eventually meeting instream flow targets and water quality goals in both Tumalo Creek and the Middle and Upper Deschutes along with the long term water supply needs of both entities. The City of Bend continues to support the Tumalo Irrigation District's Tumalo Feed Canal piping and related water conservation projects designed to provide conserved water in-stream and to update the District's irrigation water delivery system.

Furthermore the City commits to its ongoing partnership with the District in supporting the project to potential funding entities locally, and at the State and Federal levels when practical to do so.

Should you have any questions on this letter of support, please call.

Sincerely,

Eric King,
City Manager, City of Bend

UPPER DESCHUTES
WATERSHED COUNCIL

October 14, 2015

Ken Rieck
Tumalo Irrigation District
64697 Cook Avenue
Bend, OR 97703

Re: Support for TID's Tumalo Feed Canal Piping Project

Dear Ken:

I am writing to express my support for TID's continued efforts to pipe the Tumalo Creek Feed Canal to reduce ditch losses and permanently transfer conserved water instream for the benefit of Tumalo Creek and the Deschutes River.

Tumalo Creek is the primary source of cold, clean water for the 30-mile reach of the Deschutes River downstream of Bend. Summer water temperatures in lower Tumalo Creek and the Deschutes River frequently exceed state standards for native fish when streamflows drop during the irrigation season and the water warms rapidly under the hot summer sun. Streamflow restoration in Tumalo Creek has long been a priority for local conservation organizations and I am pleased to support TID's continued efforts to pipe its canals and return saved water to Tumalo Creek using Oregon's Conserved Water Program.

I am eager to see this project completed and I am pleased to offer my support.

Sincerely,

Ryan Houston
Executive Director
Upper Deschutes Watershed Council

PO BOX 1812 BEND, OR 97709 | 700 NW HILL ST. BEND, OR 97701 www.restorethedeschutes.org

Mr. Ken Reick, Manager
Tumalo Irrigation District
64697 Cook Avenue
Bend, Oregon 97701

710 NW WALL STREET
PO BOX 431
BEND, OR 97701
[541] 388-5505 TEL
[541] 385-6676 FAX
BENDOREGON.GOV

Date: January 20, 2015

SUBJECT: LETTER OF SUPPORT, TUMALO IRRIGATION DISTRICT TUMALO FEED CANAL PROJECT

Dear Mr. Reick:

It is the understanding of the City of Bend that the Tumalo Irrigation District is planning to complete Phase IV of the Tumalo Feed Canal piping project and is seeking funding through the Reclamation Water Smart Program. Phase IV of the Tumalo Feed Canal Piping Project is expected to complete approximately 14% of the remaining project. After completion of all phases, approximately six miles of open irrigation canal in the Tumalo Feed Canal will be piped and the entire Tumalo Feed Canal will conserve an estimated 20 cfs (6,664 acre-feet) of flow annually by eliminating seepage and evaporation losses.

This conserved water is making great strides toward the flow restoration goal for Tumalo Creek. In turn, this water will increase low summer flows in the last 3 mile reach of Tumalo Creek and add cold water to a temperature limited Lower Tumalo, as well as contributing cold water to the Middle Deschutes River below Bend, and will help achieve lowering temperatures in both stream segments and will eventually result in delisting of this section of Tumalo Creek from EPA's 303(d) list of impaired streams in Oregon.

As you know, the City and the Tumalo Irrigation District have been long-time stewardship partners on Tumalo Creek, requiring continuing cooperation to facilitate the pro-ration of the various water rights held by both entities. We understand the proposed District project to enhance the Tumalo Creek watershed and associated fishery. Such contributions to the Tumalo Creek watershed are held in high regard by the City of Bend and are very important to its citizens and those in the region and state.

The City shares the District's desire to upgrade its systems and is in the process of upgrading its surface water delivery system as well and appreciates the support of the District in the City's endeavors on this same watershed.

On February 20, 2013, the City passed Resolution 2900, and within Section 8 of that resolution, formed the Tumalo Creek Restoration Subgroup – along with Tumalo Irrigation District. This work group has established a goal of eventually meeting instream flow targets set by the State, as well as meeting water quality goals in both Tumalo Creek and the Middle Deschutes along with the long- term water supply needs of both entities. The City of Bend continues to support the Tumalo Irrigation District's Tumalo Feed Canal piping and related water conservation projects designed to provide conserved water in-stream and to update the District's irrigation water delivery system.

Furthermore, the City commits to its on-going partnership with the District in supporting the project to potential funding entities locally, and at the State and Federal levels when practical to do so.

Should you have any questions on this letter of support, please call.

Sincerely,

Eric King,
City Manager, City of Bend

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Bend Field Office
63095 Deschutes Market Road
Bend, Oregon 97701
(541) 383-7146 FAX: (541) 383-7638

File Name: Tumalo Feed canal.doc
TAILS: 01EOFW00-2015-CPA-0003

January 21, 2015

Kenneth Rieck, District Manager
Tumalo Irrigation District
64697 Cook Avenue
Bend, Oregon 97701

Dear Mr. Rieck:

The U.S. Fish and Wildlife Service (Service) Bend Field Office is writing to you in support of the Tumalo Feed Canal Piping Project Phase IV. The Service supports this project because it will provide multiple benefits including conservation and permanent protection of 1.24 cfs in Tumalo Creek and provide enhanced ability to increase flows from storage in Crescent Lake into Crescent Creek which can benefit the Oregon spotted frog, a federally listed Threatened species under the Endangered Species Act.

Upon completion of all phases of the Tumalo Feed Canal Project six miles of open irrigation canal will be piped. Piping the entire Tumalo Feed Canal will conserve an estimated 20 cfs (6,664 acre-feet) of flow by eliminating seepage and evaporation. Completion of all phases of the project will increase dry-season flows in Tumalo Creek from 5.8 cfs to 17.6 cfs, could increase the Upper Deschutes River flows by 8.2 cfs upstream of the confluence of Tumalo Creek, and increase flows in the Deschutes River downstream of Tumalo Creek by 20 cfs. It is our understanding that the state of Oregon would receive the water rights to the conserved water associated with public funding which would be applied to permanent in-stream use. For the reasons stated above the Service supports the Tumalo Feed Canal Piping Project Phase IV and other associated actions to improve instream flows and habitat in Tumalo Creek, Crescent Creek, and the Deschutes River.

We appreciate your efforts to conserve water and to provide instream benefits to fish and wildlife in these rivers. If you have any questions or I can be of any assistance please contact me at 541 312-6423.

Sincerely,

Nancy Gilbert

Nancy Gilbert
Bend Field Supervisor

DESCHUTES RIVER
CONSERVANCY

January 19, 2015

Kenneth Rieck
Tumalo Irrigation District
64697 Cook Ave
Bend, OR 97701

The Deschutes River Conservancy strongly supports Tumalo Irrigation District's Tumalo Feed Canal Phase IV water conservation project. The mission of the Deschutes River Conservancy is to restore stream flow and improve water quality in the Deschutes River and its tributaries. Restoring flows in Tumalo Creek is one of the DRC's top priorities, particularly as recent analyses indicate that restoring flows in Tumalo Creek not only benefits Tumalo Creek, but is the key to reducing temperatures in the Middle Deschutes and provides key redband trout refugia in summer months in the Middle Deschutes. This project also provides needed benefit in Crescent Creek, a stronghold for the Oregon spotted frog, recently listed as threatened under the Endangered Species Act.

The DRC is currently partnering with the district on a longer-term strategy to pipe all district canals, which will meet instream water rights in Tumalo Creek, provide significant benefit in the Middle Deschutes River, and improve habitat for spotted frog. The DRC is committed to partnering with Tumalo Irrigation District to implement this long-term strategy in a cost-effective way that benefits the rivers as well as the district. The proposed project is a critical piece to keep this effort moving and to keep collaborative energy moving forward.

The Deschutes River Conservancy and Tumalo Irrigation District have partnered on prior conservation projects that have permanently restored stream flow in Tumalo Creek, Crescent Creek, and the Deschutes River. To date, the district has protected over 12 cfs of senior water rights in Tumalo Creek on an annual basis through water conservation and leasing projects.

In addition to these individual projects, Tumalo Irrigation District has joined other water users in a basin-wide water management planning effort through the Deschutes Basin Study. This effort will, when completed provide the information necessary to forge a basin-wide long-term management agreement that improves instream, agricultural, and municipal water supplies in the Deschutes Basin. Piping the Tumalo Feed Canal is a key piece of this larger planning effort, and will be integrated into the optimization of adaptation and mitigation strategies being analyzed in the Deschutes Basin. Restoring Tumalo Creek is a basin-wide priority.

Sincerely,

Kate Fitzpatrick
Program Director

From: Trout Unlimited
50 SW Bond St. Suite 4
Bend, OR, 97702

February 2, 2014

To: Elmer McDaniels, Manager
Tumalo Irrigation district
64679 Cook Avenue
Bend, OR, 97701

Dear Mr. McDaniels:

The Deschutes Chapter of Trout Unlimited enthusiastically supports Tumalo Irrigation District (TID)'s phase IV canal piping project. TID is to be commended for it previous conservation projects, which have contributed significantly to restoration of instream flows in Tumalo Creek. The direct value of phase IV piping is described in their application, but the value is greater than the direct results. It is a necessary step towards later phase projects, which when completed will contribute 17.6 cfs of flows during the dry season to the lower reach of Tumalo Creek. Completion of the TID piping projects will also enable other water management strategies that will move Tumalo Creek close to its instream water right of 32 cfs during the low flow warm water late summer season. This instream transfer of water rights has already been approved by Oregon Water Resources Department (order CW-37), and the Oregon Department of Fish and Wildlife (ODFW) has supported its value for the recovering fishery of Tumalo Creek. Also, recent studies by ODFW have further established the value of Tumalo's cold water for the sensitive species of native Redband Trout in the Middle Deschutes River. Finally it is of note that these waters are also 303d listed by Oregon DEQ for excessive high temperatures. Recent studies by the Upper Deschutes Watershed Council have highlighted the critical role the cold water of Tumalo Creek will play in correcting this water quality deficiency. Phase IV is a critical step needed for both fisheries and water quality in both Tumalo Creek and the Middle Deschutes River.

Trout Unlimited's mission is to restore, connect, protect and sustain cold water fisheries. It has over 140,000 members nationally and the Deschutes Chapter has approximately 600 members. On behalf of our Chapter and TU, we are excited to support this project.

Sincerely,

M Tripp

Michael Tripp
Conservation Chair
Deschutes Chapter of Trout Unlimited

November 3, 2010

Mr. Elmer G. McDaniels, Manager
Tumalo Irrigation District
64697 Cook Avenue
Bend, Oregon 97701

SUBJECT: LETTER OF SUPPORT, TUMALO IRRIGATION DISTRICT TUMALO FEED CANAL PROJECT

Dear Mr. McDaniels:

710 NW WALL STREET
PO BOX 431
BEND, OR 97701
[541] 388-5505 TEL
[541] 385-6676 FAX
WWW.CI.BEND.OR.US

It is the understanding of the City of Bend that the Tumalo Irrigation District is in the process of implementing its Tumalo Feed Canal piping project that involves the piping of about 5 miles of canal from the District's Tumalo Creek diversion to its re-regulating reservoir. If publicly funded, the project will result in 11.8 CFS of water conservation that will be left in Tumalo Creek. This conserved water, in addition to the 5.8 CFS already committed by the District based upon its Bend Feed Canal piping project is making great strides toward the flow restoration goal for Tumalo Creek.

As you know, the City and the Tumalo Irrigation District have been long time stewardship partners on Tumalo Creek requiring continuing cooperation to facilitate the proration of the various water rights held by both entities. We understand the proposed District project to enhance the Tumalo Creek watershed and associated fishery. Such contributions to the Tumalo Creek watershed are held in high regard by the City of Bend.

The City shares the District's desire to upgrade its systems and is in the process of upgrading its surface water delivery system as well and appreciates the support of the District in the City's endeavors on this same watershed.

The City of Bend is in support of the Tumalo Irrigation District's Tumalo Feed Canal piping and water conservation project designed to provide conserved water in-stream and to update the District's irrigation water delivery system. Furthermore the City commits to its partnership with the District in supporting the project to potential funding entities locally, and at the State and Federal levels when practical to do so.

Should you have any questions on this letter of support, please call.

Sincerely,

Eric King
City Manager

Oregon
Theodore R. Kulongoski, Governor

Department of Fish and Wildlife
High Desert Region
61374 Parrell Road
Bend, OR 97702
(541) 388-6363
FAX (541) 388-6281

RECEIVED
JAN 1 8 2010
By

January 15, 2010

Elmer McDaniels
Tumalo Irrigation District
64697 Cook Ave
Bend, Oregon 97701

Dear Mr. McDaniels:

The Oregon Department of Fish and Wildlife (ODFW) is writing in support of Tumalo Irrigation District's (TID) proposed piping project and instream transfer of the reduced seepage loss. The resulting instream water allocations will provide critical base habitat for native redband trout, bull trout, mountain whitefish, reintroduced anadromous Mid Columbia steelhead and other aquatic resources in the receiving streams. Both bull trout and Mid Columbia steelhead are federally listed as threatened species.

The proposed project will result in piping of approximately 6 miles of open canal with 100 percent of the reduced seepage loss allocated to the State of Oregon (State) as an instream water right. The completed piping project will result in an additional 20 cfs of conserved water protected instream. Of the 20 cfs, 11.8 will be protected from the Tumalo Feed Canal diversion located on Tumalo Creek downstream to Lake Billy Chinook. The primary purpose of the instream water rights are to provide for the conservation, maintenance, and enhancement of aquatic resources, fish life, and fish habitat.

The proposed transfer will compliment an earlier instream transfer of 5.8 cfs from a similar project and make significant contribution toward addressing instream flows necessary for spawning, rearing, and migration for fish populations in Tumalo Creek and the Deschutes River downstream. There have been extensive restoration efforts undertaken in Tumalo Creek including instream channel and habitat enhancements, instream flow supplementation, and most recently diversion screening and fish passage facilities at the Tumalo Feed Canal. The combination of these activities will reconnect fish populations and provide access to high quality spawning areas that have been inaccessible to redband populations in the Deschutes River for nearly 80 years. Additionally, temperature analysis by David Evans and Associates predicts this transfer will result in a net temperature reduction of approximately 1° Fahrenheit in the Deschutes River near its confluence with Tumalo Creek. It is anticipated that the temperature drop will be carried through the reach to below Lower Bridge and help reduce temperatures that have been documented to reach approximately 80° Fahrenheit.

The contribution to reduced temperatures in the Deschutes River between Big Falls and Lake Billy Chinook will provide benefits to migrating Chinook salmon, summer steelhead, and bull trout. The positive water quantity and quality benefits resulting from the increased contribution of 11.8 cfs of cold water from Tumalo Creek will be somewhat tempered by the recharge of groundwater via springs into the Deschutes River downstream of Big Falls. However, as groundwater extraction continues to increase in response to growth and development in central Oregon, it is anticipated the groundwater recharge will diminish. This will render the input of cold water from Tumalo Creek of increasing importance to the successful reintroduction of anadromous fish above the Pelton-Round Butte hydroelectric project. This project will compliment the extensive efforts by multiple partners and stakeholders devoted to restoring the historic assemblage of fish species in the Deschutes River.

ODFW appreciates the Tumalo Irrigation District's contribution and commitment to addressing multiple resource needs for all users through continued conservation and enhancement efforts.

Sincerely,

Scott Hodgson

Oregon Dept. of Fish and Wildlife

Oregon
Theodore R. Kulongoski, Governor

Water Resources Department
North Mall Office Building
725 Summer Street NE, Suite A
Salem, OR 97301-1271
503-986-0900
FAX 503-986-0904

April 26, 2005

Elmer McDaniels
Tumalo Irrigation District
64697 Cook Avenue
Bend, Oregon 97701

Dear Elmer:

As you know the Water Resources Department has long supported the Tumalo Feed Canal Project, and that support continues. Tumalo Irrigation District has been a leader in water conservation, as guidanced by your selection to receive the 2002 Oregon Water Resource Commission's Water Conservation and Restoration award, and the 2003 Governor's Oregon Plan Certificate of Appreciation.

The Tumalo Feed Canal Project will continue this tradition of excellence in water resource management. The piping of the canal will eliminate seepage loss and provide for a more reliable delivery of water to TID patrons. The project also has the potential to significantly improve streamflows in Tumalo Creek and the middle Deschutes River. We look forward to receiving your application for allocation and use of conserved water.

If you have any questions, or if the Department can be of further assistance, please contact Kyle Gorman, SC Region Manager, at 541-388-6669.

Sincerely,

Phil Ward
Director

Kyle Gorman

Oregon

Theodore R. Kulongoski, Governor

Water Resources Department
North Mall Office Building
725 Summer Street NE, Suite A
Salem, OR 97301-1271
503-986-0900
FAX 503-986-0904

May 7, 2004

Elmer McDaniels
Tumalo Irrigation District
64697 Cook Avenue
Bend, OR 97701

Dear Mr. McDaniels:

The Water Resources Department strongly supports Tumalo Irrigation District's water conservation activities. In 2002, the Oregon Water Resources Commission awarded you and the District our Water Conservation and Restoration award. And, in 2003, I presented you with the Governor's 2003 Oregon Plan Certificate of Appreciation for the District's work on the Bend Feed Canal project. That project, which is schedule to be completed this year, will improve District operations and is expected to restore up to 5.8 cfs in the Deschutes River, as well as securing a guaranteed flow in Tumalo Creek, a spawning stream of critical importance to the Deschutes River.

The Department enthusiastically supports your continued efforts to improve District operations while at the same time restoring streamflows in Tumalo Creek and the Deschutes River. The piping of the Tumalo Feed Canal will eliminate seepage loss and provide for a more reliable delivery of water to your patrons; it also has the potential of significantly improving streamflows in Tumalo Creek and the middle Deschutes River. We look forward to receiving your application for allocation and use of conserved water.

If you have any questions, or if the Department can be of further assistance, please feel free to contact Kyle Gorman, Region Manager, at 541-388-6669. Thank you for your continued leadership in Oregon's water conservation activities.

Sincerely,

Paul R Cleary

Paul R. Cleary
Director

THEODORE R. KULONGOSKI
GOVERNOR

February 26, 2004

RECEIVED
MAR 03 2004
By

Elmer McDaniels
Tumalo Irrigation District
64697 Cook Ave
Bend OR 97701

Dear Mr. McDaniels:

I am well aware of the good works Tumalo Irrigation District has done over the past several years, which include the piping of the Bend Feed Canal, the elimination of the Columbia Southern Canal Diversion and replacement of several flumes. I am pleased that Tumalo Irrigation District is continuing its water conservation efforts in seeking to pipe the Tumalo Feed Canal. The water saved and placed in Tumalo Creek, and subsequently the Deschutes River will have a great impact on Central Oregon fisheries.

Tumalo Irrigation District is and has been a leader in water conservation as can be seen in your selection to receive the 2003 Commissioner's Water Conservation Award from the Bureau of Reclamation. The new piping project will increase the efficiency of Tumalo Irrigation District's water distribution facilities by eliminating seepage loss. The District's work in achieving a more reliable water delivery for its patrons as well as enhancing stream flows is commendable and an example for other irrigation districts to follow.

Once again, Tumalo Irrigation District has provided a "win-win" solution on a complex issue and attempts to meet the needs of the diverse interests in the water resource of Central Oregon. I commend Tumalo Irrigation District on its dedication to this endeavor and strongly recommend the project.

Sincerely,

THEODORE R. KULONGOSKI
Governor

TRK:dv:tmt

c: Mike Dugan, District Attorney
Deschutes County