Five Year (2017 to 2022) Planned Deviation to the Prado Dam Water Control Plan and Sediment Management Demonstration Project

Biological Assessment

Prepared By

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Table of Contents

Section **Page**

Tables Page

Figures

Appendices

Appendix A: Revised and Supplemental Water Conservation Analysis, Prado Dam (Baker Engineering, June 2015)

Appendix B: Prado Dam Planned Deviation, Santa Ana River-Upstream Effects Due to Water Conservation (Scheevel Engineering June 2015, Upstream B)

Appendix C: Prado Dam Water Conservation, Prado Basin & Upstream SAR Morphology Trends-Elevation 498 ft. vs. 505 ft. (Scheevel Engineering, June 2015, Upstream A)

Appendix D: Prado Feasibility Study Project-Prado Water Level Analysis Sediment Transport Modeling Results (Golder, March 2015)

Appendix E: Prado Dam Planned Deviation, Santa Ana River-Downstream Effects Due to Planned Deviation (Scheevel Engineering June 2015, Downstream C)

SECTION 1 INTRODUCTION

1.1 Proposal

Based on a request from the Orange County Water District (OCWD), the U.S. Army Corps of Engineers (Corps) is proposing a Planned Deviation to the Prado Dam Water Control Plan to increase the flood season water surface elevation of the buffer pool behind Prado Dam from elevation 498 feet (ft.) to elevation 505 ft. for a period of five years, beginning with the 2017/2018 flood season. Additionally, OCWD is requesting a reduced release rate of 350 cfs on average from Prado Dam from March 1 to August 30. The purpose of the Planned Deviation is to allow for increased water conservation opportunities and to maximize groundwater recharge potential. OCWD has also requested that the Corps grant real estate rights for its implementation of a Sediment Management Demonstration Project that would dredge and dispose of up to 120,000 cubic yards of sediment from the Prado Basin. Under the Proposed Action, the Corps would grant a temporary easement to allow OCWD to construct and access road and implement storage and handling of sediment on Corps property along with consent to easement in the area of the sediment removal channel. A total of 24,500 cubic yards of sediment would be removed to offset effects of a potential increase in sediment deposition that could occur due to the Planned Deviation and from two years of previous approved temporary deviations. The remaining 100,000 cubic yards of sediment would be removed for study purposes to inform future sediment management efforts, including the Prado Basin Feasibility Study. Prior to implementation of the Sediment Management Demonstration Project, OCWD has and proposed in August of 2017, to remove up to 7,000 cubic yards of sediment from the OCWD Diversion Channel, downstream of River Road Bridge, to offset sediment deposition from the two previous temporary deviations.

OCWD would implement monitoring programs to document effects of the Planned Deviation, Sediment Management Demonstration Project and the sediment removals proposed at the OCWD Diversion Channel. These monitoring programs are intended to inform subsequent analysis related to potential effects to habitat, including but not limited to factors such as sediment transport and vegetation composition and structure.

In order to undertake the Sediment Management Project, OCWD must also obtain a Clean Water Act Section 404 permit from the Corps Regulatory Division. It is currently anticipated that the Sediment Management Demonstration Project would meet the criteria for Nationwide Permit 33. If it is later determined that an Individual Permit would be required for the Sediment Management Demonstration Project, the activities would not be undertaken prior to obtaining an Individual Section 404 Permit from the Corps and Section 401 Water Quality Certification from the Regional Water Quality Control Board.

1.2 Need and Purpose

Planned Deviation

Need: Southern California has been enduring, and continues to endure, a severe multi-year drought. OCWD relies on local and imported sources to provide water to their customers. Santa Ana River base flows have declined by nearly 50 percent over the past 10 years. This represents a significant loss of local water supply to Orange County. Storm water recharge is a vital local source of water supply to Orange County. Due to the extremely dry conditions in the Santa Ana Watershed, the Orange County Groundwater Basin has experienced overdraft increases from 179,000 acre-feet to 381,000 acre-feet in the years from June 2012 to June 2015. The Orange County Water District Groundwater Management Plan identifies a maximum accumulated overdraft target of 500,000 acre-feet. Without additional local water supplies, the Orange County Groundwater Basin would approach maximum accumulated overdraft, requiring reductions in groundwater withdrawals and an increase in imported water supplies from an already stressed import water system.

At this time there is limited availability of imported water supply to southern California. Supplies available to southern California from the State Water Project are subject to drought and environmental restrictions in the Sacramento Delta (Metropolitan Water District Urban Water Management Plan, 2016). In the short-term, Colorado River water supplies could make up a portion of the difference. However, unless the Colorado River Watershed experiences a series of above average rainfall years, this source of water supply would also be at risk. Given the limited imported water supplies from Northern California and the Colorado River, OCWD has indicated a need to use local water supplies.

Purpose: The purpose of this Planned Deviation is increase the volume of water captured behind Prado Dam during flood seasons to assist OCWD to increase their local water supplies to help reduce the overdraft and their reliance on imported water sources for a five year period through the 2021/2022 flood season.

Sediment Management Demonstration Project

Need: From 1941 to 2008 approximately 25,000 acre feet of water conservation volume has been lost below the elevation of 505 ft. due to sediment aggradation with the Prado Basin. More recently, between 1989 and 2008, sediment aggradation has resulted in the loss of 349 acres of storage area below 505 ft. This trend shows that the water conservation pool capacity has shrunk and is continuing to shrink over time due to sediment deposition.

Purpose: The proposed Sediment Management Demonstration Project would remove up to 120,000 cubic yards of sediment from the Prado Basin. A total of 24,500 cubic yards of the sediment would be removed for purposes of offsetting effects of a potential increase in sediment deposition (estimated to be up to 3,500 cubic yards per year) that could occur due to the implementation of the five year Planned Deviation request and from two years of previously approved temporary deviations. The purpose of the removal of the remaining 100,000 cubic yards of sediment and subsequent monitoring would be to collect and analyze data to help identify practical methods for the implementation of a potential long term sediment management program within Prado Basin that is being considered as part of the Prado Basin Feasibility Study.

Environmental Evaluation

The Corps is preparing an Environmental Assessment (EA) to evaluate impacts to the environment associated with the Proposed Action for the Planned Deviation and real estate approvals for the Sediment Management Demonstration Project. The Sediment Demonstration Project would also require a 404 permit from the Corps, which is anticipated to be in the form of Nationwide Permit 33 verification. This BA addresses effects of all Corps actions.

SECTION 2 PROPOSED ACTION

2.1 Request

Based on a request from the Orange County Water District (OCWD), the U.S. Army Corps of Engineers (Corps) is proposing a Planned Deviation to the Prado Dam Water Control Plan to increase the flood season water surface elevation of the buffer pool behind Prado Dam from elevation 498 feet (ft.) to elevation 505 ft. for a period of five years, beginning with the 2017/2018 flood season. Additionally, OCWD is requesting a reduced release rate of 350 cfs on average from Prado Dam from March 1 to August 30. OCWD has also requested that the Corps grant real estate rights for its implementation of a Sediment Management Demonstration Project. Under the Proposed Action, the OCWD would dredge and dispose of up to 120,000 cubic yards of sediment from the Prado Basin. Under the Proposed Action, the Corps would grant a temporary easement to allow OCWD to construct and access road and implement storage and handling of sediment on Corps property along with consent to easement in the area of the sediment removal channel. In order to undertake the Sediment Management Demonstration Project, OCWD must also obtain a Clean Water Act Section 404 permit from the Corps Regulatory Division. It is currently anticipated that the Sediment Management Demonstration Project would meet the criteria for Nationwide Permit 33. If it is later determined that an Individual Permit would be required for the Sediment Management Demonstration Project, the activities would not be undertaken prior to obtaining an Individual Section 404 Permit from the Corps and Section 401 Water Quality Certification from the Regional Water Quality Control Board.

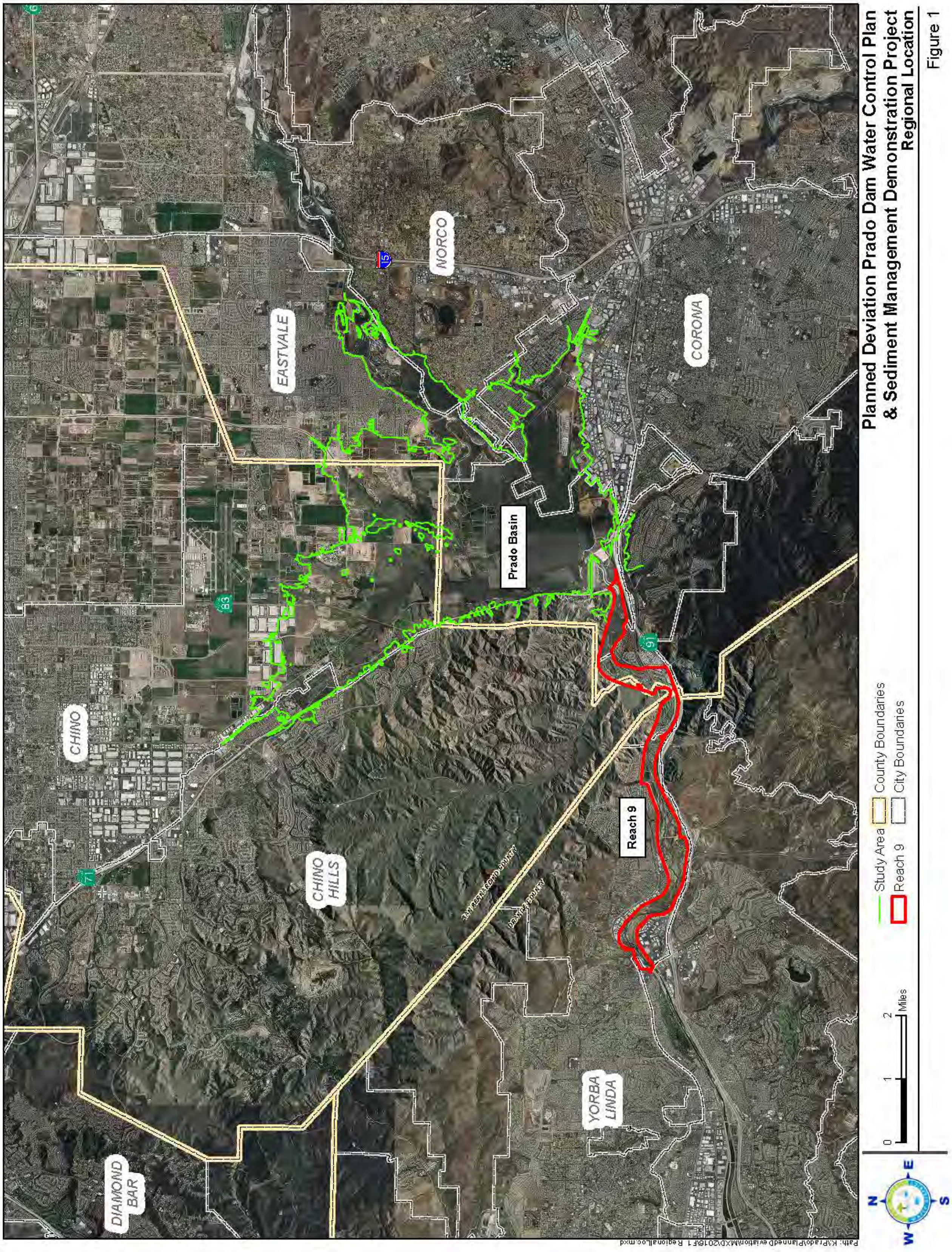
2.2 Location

As shown in Figure 1, the Planned Deviation and Sediment Management Demonstration Project (Proposed Action) would be implemented within the Prado Basin and along a segment of the Santa River situated between Prado Basin and Weir Canyon Road, referred to as Reach 9.

2.3 Background

There are four major water bodies that drain into the Prado Basin; Santa Ana River, Chino Creek, Cucamonga Creek/Mills Creek and Temescal Wash. All of these water bodies converge and are impounded behind Prado Dam in a flood control pool. The most significant structure in the Prado Basin is Prado Dam. The dam provides flood control for 2,225 square miles of the 2,650 square mile area Santa Ana River Watershed.

Prado Dam is an earth-filed dam that was constructed by the Corps in 1941. Prado Dam's primary purpose is flood control for the Santa Ana River Watershed. Prado Dam's secondary purpose is water conservation. OCWD has worked with the United States Army Corps of Engineers (Corps) for over 30 years to conserve storm water at



Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project Regional Location

Figure 1

Prado Dam. Storm water conservation occurs in a manner that does not affect the primary flood risk management purpose and operation of Prado Dam. The water conservation program at Prado Dam started at a small scale and is currently approved for temporary storm water capture up to elevation 489 ft. in the flood season and up to 505 ft. during the non-flood season. The total volume of water that can be temporarily held in the buffer pool under the current program is still a relatively small portion of the total dam storage capacity (less than 15 percent). Water temporarily captured at Prado Dam is released to the Santa Ana River and utilized at OCWD's downstream recharge facilities to replenish the Orange County Groundwater Basin. The current program is implemented in accordance with a Memorandum of Agreement (MOA) between the Corps and OCWD dated July 7, 2006. The MOA defines the roles and responsibilities of each party. Per the MOA, OCWD reimburses the Corps annually for the separable costs associated with the Corps' operation and maintenance of Prado Dam for water conservation. Additionally, the MOA requires OCWD to implement required environmental mitigation obligations related to the water conservation program.

Currently, OCWD water conservation is subject to a Biological Opinion issued by the USFWS. The USFWS issued Biological Opinion (BO) 1-6-95-F-28 on April 20, 1995 in relation to non-flood season water conservation at Prado Dam up to elevation 505 feet. The BO specifies various commitments required of OCWD, including contributing $1,000,000 to establish a fund to be used to remove Arundo donax in the Santa Ana Watershed and providing for a staff person for vireo management. The BO also specified that from March 1 to August 30 of each year, OCWD would accommodate a flow of 500 cfs or a flow that equals OCWD's maximum recharge capacity, whichever is greater, up to a pool elevation of 505 feet. The 500 cfs recharge rate in OCWD's downstream facilities applies when the Prado water surface elevation is greater than 498 ft. The BO also states that if it is in the agencies interests to reduce the outflow from Prado Dam below 500 cfs, OCWD and the USFWS must both approve the new outflow rate. In January 2017 and previous years, OCWD has requested a reduced flow rate due to clogging of OCWD's recharge facilities. Clogging occurs when fine-grained sediment conveyed with Santa Ana River water to OCWD's recharge facilities settles onto the bottom of the recharge facilities. The accumulated fine-grained sediment has a lower permeability than the native sediment in the recharge basin, and the accumulated sediment reduces the percolation or infiltration rate of the basin. In the 22 years since the BO was issued, streambed conditions in the SAR downstream of Prado Dam has changed. A decrease in sand and armoring of the channel has reduced the capacity of water to infiltrate to the aquifer. A flow of 500 cfs from Prado Dam can no longer be recharged by OCWD recharge facilities in the period from March through August. Because of the reduced ability to percolate water in the streambed, OCWD would be able to accommodate flows of no greater than 350 cfs between March 1 and August 30. In the time period of October to February, OCWD is often able to maintain an overall SAR recharge water capacity of 500 cfs. However, in March, experience has shown that clogging of the recharge facilities causes OCWD's recharge capacity to decline to 350 cfs. The 350 cfs recharge capacity is typically the limit of recharge facilities. Therefore, OCWD is requesting a reduced discharge of 350 cfs on average from March 1 to August 30 to help sustain groundwater recharge in the spring and summer months.

The regulation of Prado Dam is conducted in accordance with the 2003 Prado Dam Interim Water Control Plan (Water Control Plan). In order to temporarily deviate from the operations prescribed in an approved Water Control Plan, approval of Planned Deviation by the Corps would be necessary. A Planned Deviation must still adhere to safe regulation and operation of Prado Dam that includes structural integrity, not compromising flood risk management objections, no permanent storage of water behind the dam, and not compromising the safety of persons or property owners.

Orange County Water District Ongoing Arundo Control Program

OCWD began involvement in the Santa Ana River Watershed-wide Arundo Control Program in 1995. These mitigation activities under the Arundo Control Program have largely been accomplished in partnership with Santa Ana Watershed Association (SAWA), a non-profit corporation run by a 5-member board with one representative each from the Orange County Water District, and four Resource Conservation Districts (RCDs). Multiple partners are also involved in the efforts including the Fish and Wildlife Service (Service), California Department of Fish and Wildlife (CDFW), U.S. Army Corps of Engineers, Regional Water Quality Control Board, the counties, several cities, and many other individuals and organizations.

Approximately 5,000 acres of river bottom lands formerly infested by arundo and other weeds have been treated. The entire upper watershed of the Santa Ana River and all of the major tributaries have been cleared and are under a regime of re-treatment as needed down to the vicinity of Hamner Road and OCWD property approximately four miles upstream of Prado Dam.

In April of 2015, the Highway Fire burned about 1,000 acres of habitat in the Prado Basin including about 321 acres of arundo on OCWD property. Almost immediately after the fire the arundo began to re-sprout and invade additional acreage of the burn area. To prevent the re-sprouting of the arundo, OCWD is currently implementing a five year arundo treatment program within the 321 acre burn area on OCWD property, at a cost of $889,000.

2.4 Planned Deviation to Prado Dam Water Control Plan

In response to significant decreases in base flows of the Santa Ana River, prolonged drought condition and limited availability of imported water supplies, OCWD has requested a Planned Deviation to the current Prado Dam Water Control Plan. This deviation would allow for an increase in the elevation of the buffer pool during the flood season, (October 1st to February 28/29) from water surface elevation 498 ft. up to water surface elevation of 505 ft. Additionally, OCWD is requesting a reduced discharge rate of 350 cfs from Prado Dam from March 1 to August 30 to maximize groundwater recharge potential. In the event flood storage capacity is required March 1 to August 30, the release rates from Prado Dam would be at the sole discretion of the Corps and would be determined based on judgment informed by precipitation and inflow forecasts and real time measurements of rainfall and stream flow data.

The Planned Deviation would extend for five years beginning with the 2017/2018 flood season. During the non-flood season, the buffer pool would continue to operate at a maximum water elevation of 505 ft. The increase in the buffer pool during the flood season would provide up to approximately 10,000 acre-feet of additional temporary storm water capture capacity. Based on modeling conducted by Corps for the Prado Basin Feasibility Study, increasing the buffer pool to water elevation 505 ft. would on average result in an opportunity to conserve and recharge approximately 6,000 acre-feet of additional water per year. Implementation of the Planned Deviation would have the potential to result in higher elevation pooling and additional days of inundation in the Prado Basin. To estimate the additional days of inundation Michael Baker International Company evaluated results from an HEC-5 computer model used by the Corps in its analysis of different water conservation levels at the Prado Dam. Two inflow scenarios were developed, one for 2021 conditions and one for future 2071 conditions. For this analysis, the 2021 conditions were used. The Supplemental Water Conservation Analysis is presented in its entirety in Appendix A. The average additional days of inundation due to the proposed Planned Deviation estimated to occur in the Prado Basin by month are shown in Table 1. Areas within the Prado Basin that are bounded by the contours of 498 ft. and 505 ft. are shown in Figure 2.

Table 1 Average Days of Inundation at Prado Basin at 505 ft. During Flood Season

Time Period		days of inundation above selected pool elevations {increase from existing water conservation shown in red}										
		470'	480'	490'	494'	498'	500'	505'	510'	520'	530'	540'
Average Monthly Range	October	2 - 3	1 - 3	1 - 2	0 - 1	0	0	0	0	0	0	0
		0 - 1	0 - 1	0 - 1	0	0	0	0	0	0	0	0
	November	8 - 12	6 - 10	5 - 8	2 - 4	1	0 - 1	0	0	0	0	0
		0	0	0	0	0 - 1	0 - 1	0	0	0	0	0
	December	12 - 16	11 - 15	10 - 14	7 - 11	4 - 8	3 - 6	0 - 1	0	0	0	0
		0 - 1	0 - 1	1	2	4 - 7	3 - 6	0	0	0	0	0
	January	19 - 25	18 - 24	16 - 22	13 - 20	10 - 17	8 - 14	1 - 2	0	0	0	0
		1 - 3	2 - 4	3 - 4	4 - 6	8 - 15	7 - 13	1	0	0	0	0
	February	19 - 26	18 - 26	17 - 25	15 - 23	11 - 19	10 - 17	2	1	0	0	0
		3 - 4	4 - 5	5 - 6	6 - 8	9 - 16	9 - 16	1	0	0	0	0
	March 1-14	7 - 12	6 - 12	5 - 12	4 - 11	3 - 9	2 - 8	0 - 1	0	0	0	0
		2	2 - 3	1 - 3	1 - 5	1 - 5	1 - 5	0 - 1	0	0	0	0
	March 15-31	12 - 14	11 - 14	11 - 13	10 - 12	9 - 10	8 - 9	1	0	0	0	0
		1 - 3	1 - 3	1 - 3	2 - 4	2 - 4	2 - 3	1	0	0	0	0

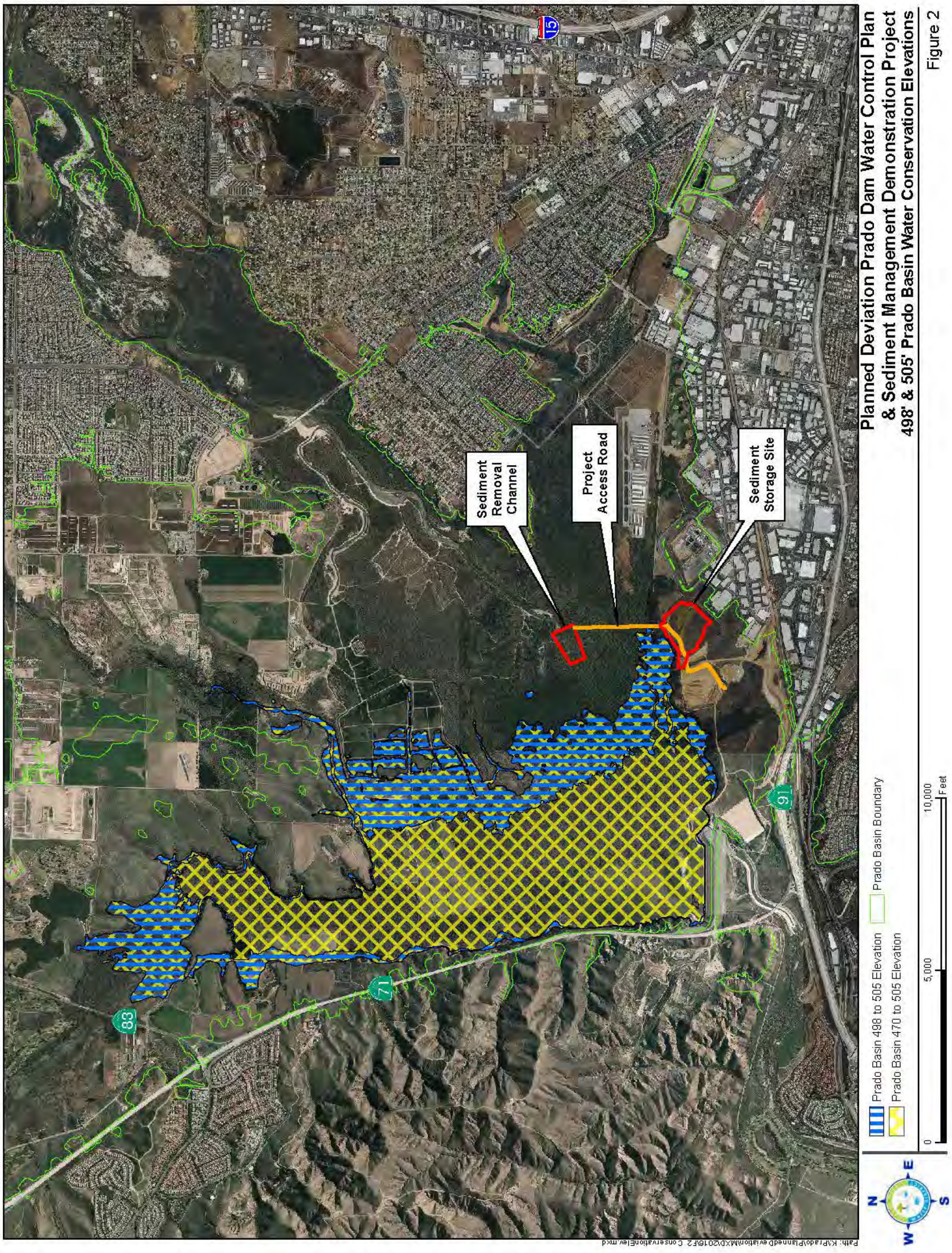
	April	13 - 21	12 - 20	11 - 19	9 - 17	7 - 13	5 - 11	0	0	0	0	0
		0 - 4	0 - 4	0 - 4	0 - 4	0 - 2	0 - 1	0	0	0	0	0
	May	5 - 13	5 - 12	4 - 11	3 - 8	3 - 6	2 - 4	0	0	0	0	0
		0 - 1	0 - 1	0 - 1	0	0	0	0	0	0	0	0
	June	1 - 3	1 - 3	1 - 3	1 - 2	1 - 2	0 - 1	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	July	0 - 1	0 - 1	0 - 1	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	August	1	1	1	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	September	1 - 2	1	1	0 - 1	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
annual average range		98 - 149	91 - 141	82 - 131	65 - 109	49 - 86	41 - 71	6 - 7	2	0	0	0
		10 - 16	11 - 18	13 - 22	17 - 29	25 - 51	22 - 45	3 - 5	0	0	0	0

Low Range Based on 350 cfs
High range Based on 500 cfs
Source: Michael Baker International Company

Based on the above data, implementation of the Planned Deviation and a reduced discharge rate of 350 cfs on average would not adversely impact flood risk management operations at Prado Dam. During the flood season from October 1 to February 28/29 the buffer pool would be maximized up to 505 ft. during flood seasons, eliminating the variation in operation for a seasonal buffer pool throughout the duration of this 5 Year Planned Deviation. In coordination with OCWD, the Corps would continue to implement controlled water releases from the buffer pool at rates consistent with the capacity of OCWD's downstream groundwater recharge facilities.

It has been estimated that an additional 3,500 cubic yards of sediment deposition occurs in the Prado Basin when buffer pools reaches 505 ft. At this time OCWD received two temporary Deviations to store water to 505 ft. during the 2015/2016 and 2016/2017 flood seasons. The water level never reached 505 ft. during the 2015/2016 flood season, but did during the 2016/2017 flood season. Nonetheless, OCWD made a commitment to remove 7,000 cubic yards of sediment to offset potential sediment deposition from the previously approved temporary deviations. Additionally, the 5 Year Planned Deviation would result in 17,500 cubic yards of sediment deposition in the Prado Basin. Therefore a total of 24,500 cubic yards of potential sediment deposition could occur in the Prado Basin from the two previously approved temporary Deviations and from the 5 Year Planned Deviation. OCWD is proposing a Sediment Management Demonstration Project that would remove up to 120,000 cubic yards of sediment from the Prado Basin.

Prior to implementation of the Sediment Management Demonstration Project, OCWD is proposing in August of 2017 to remove a total 7,000 cubic yards of sediment from the OCWD Diversion Channel at the Santa Ana River and implement a sediment collection and sediment movement monitoring program to collect data and to monitor the effects of the sediment removal. The remaining 17,500 cubic yards of sediment would be removed as part of the Sediment Management Demonstration Project along with the implementation sediment collection and sediment movement monitoring programs. The



Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project
498' & 505' Prado Basin Water Conservation Elevations

Figure 2

results of the monitoring programs would help to identify practical methods for implementing a long-term sediment management program at the Prado Basin. If the Sediment Management Project is not implemented, OCWD would remove up to 24,500 cubic yards of sediment from the Prado Wetlands Diversion Channel. The location where the sediment removal activities would occur at the OCWD Diversion Channel is shown on Figure 3.

As shown on Figure 3, the Prado Wetlands are located within the northern portion of the Prado Basin between Prado Dam and the River Road Bridge. The Prado Wetlands consist of approximately 46 individual ponds, 45 weir boxes and series of intervening dikes and maintenance roads and 1.25 miles diversion and conveyance channels that convey surface water flows through the wetland ponds. Presently, OCWD has permit approval from United States Fish and Wildlife Service (FWS-WRIV-11BO269-12FO166), U.S. Army Corps of Engineers (SPL-2012-00084-CLD), California Department Fish and Wildlife (1600-2011-0148-R6) and Regional Water Quality Control Board (30-2011-12) to conduct routine maintenance activities at the Prado Wetlands which includes up to 35,000 cubic yards of sediment allowed to be removed annually from the diversion channel at the confluence with the Santa Ana River. Prior to implementation of the Sediment Management Demonstration Project OCWD would remove 7,000 cubic yards of sediment from the diversion channel with heavy construction equipment. The sediment would be hauled to the El Sobrante Landfill for permanent disposal. The haul route would be from River Road to Main Street to SR-91 to I-15 to Temescal Canyon Road to the La Sobrante Landfill.

2.5 Sediment Management Demonstration Project

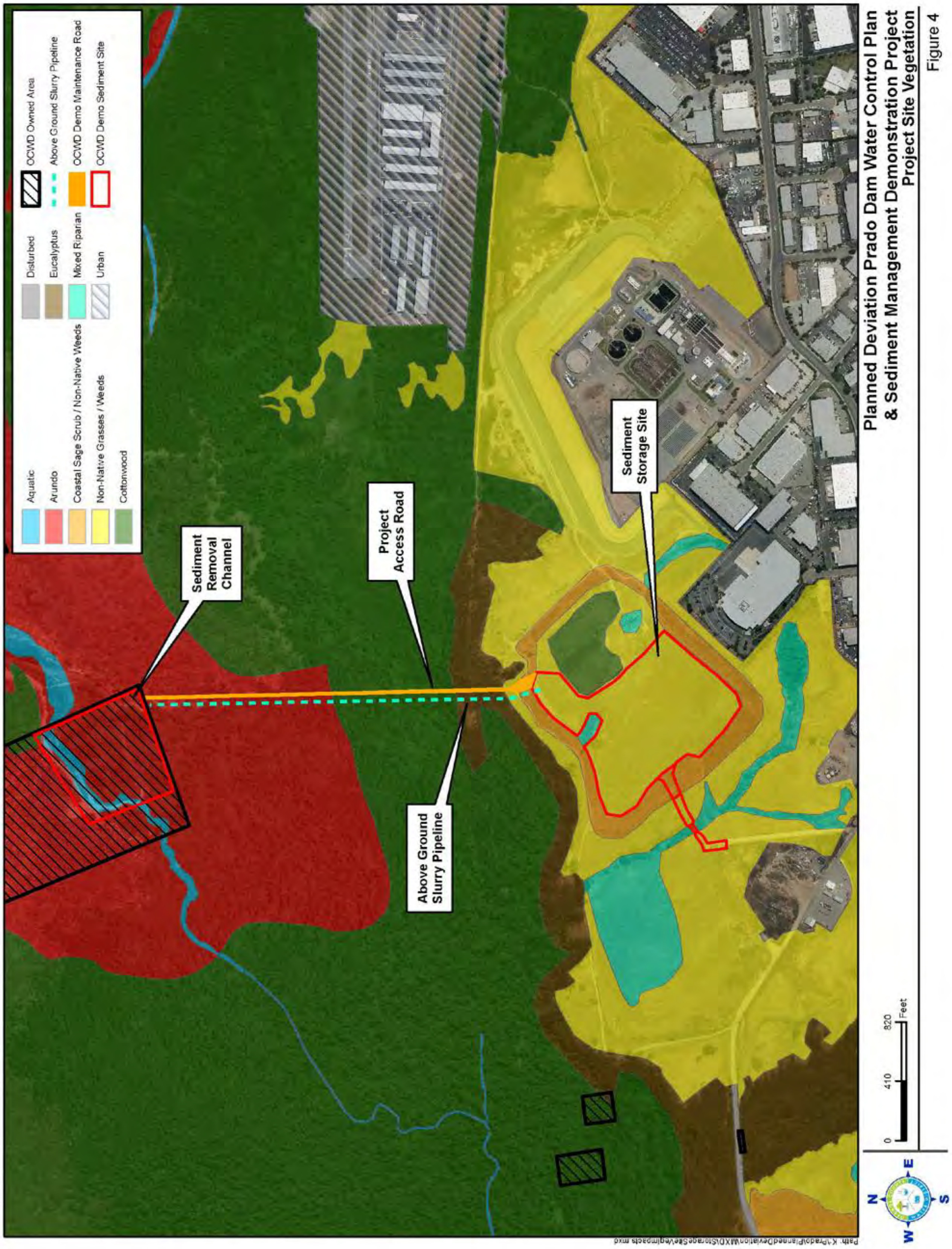
Implementation of the Sediment Management Demonstration Project would involve five primary activities; construction of a sediment removal channel, construction of a sediment storage/green waste processing area, sediment removal by dry excavation/hydraulic dredging, onsite storage/processing of the sediment material, and hauling of the removed sediment to the El Sobrante Landfill. The components of the Sediment Management Demonstration Project are shown on Figure 4 and discussed below.

Construction of Santa Ana River Sediment Removal Channel

The proposed sediment removal channel would be constructed outside of the nesting season (after August 15 and before March 1) within the wetted channel of the Santa Ana River, on the southeast portion of Prado Basin. The sediment removal channel would consist of approximately 14.3 acres and would have a maximum depth of 12 feet on property owned by the OCWD. A 30 foot wide project access road would be provided from the sediment removal channel to a sediment storage site. The project access road would be maintained during the operation of the project and during the post-operation site restoration and monitoring periods. After the monitoring program

Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project
OCWD Diversion Channel

Figure 3



Planned Deviation Prado Dam Water Control Plan
& Sediment Management Demonstration Project
Project Site Vegetation

Figure 4

period concludes, native vegetation would be re-established within the sediment removal channel and the project access road. In order to construct the sediment removal channel and project access road, all vegetation within the footprint of the sediment removal channel and project access road would be removed. The vegetation removals would occur in areas that predominately contain arundo, or other non-native vegetation, and would occur outside of the nesting season. The above-ground vegetation would be cleared, followed by removal of the vegetation root system. The removed vegetation where feasible would be processed and converted into mulch to re-surface the project access road or would be trucked offsite for disposal.

Construction of Sediment Storage Site/Green Waste Processing Site and Materials Processing

To process the green waste and to temporarily store sediment removed from the sediment removal channel, an approximately 20.55 acre sediment storage site would be prepared by clearing or mowing surface vegetation on the site outside of the nesting season, and re-contouring the area as necessary. The sediment storage site property is owned by the Corps and was the former location of a borrow site that was used during improvements to Prado Dam. At the sediment storage site the green waste would be processed and converted to mulch and sediment removed from the sediment removal channel would be temporarily stored before being hauled offsite. At the conclusion of the Sediment Management Demonstration Project the sediment storage site would be re-graded and returned to its pre-project condition and would be re-vegetated with native vegetation by combination of natural recruitment, pole cuttings and hydro-seeding with mulch, soil binders and native seed mix.

Sediment Removal Activities

A combination of dry excavation and hydraulic dredging would be used to remove sediment from the sediment removal channel. Once the vegetation is removed, heavy equipment would begin excavation of the sediment removal channel to create a pool for hydraulic dredging. Approximately 40,000 cubic yards of sediment material would be dry excavated and loaded onto off-road haul trucks or scrapers and hauled to the storage site and stockpiled.

An area approximately 200 feet in length, 200 feet in width and 12 feet in depth would be excavated in the wetted channel of the Santa Ana River. Once the pool is created, a hydraulic dredge would travel up and down the sediment removal channel by anchoring spuds into the ground. As the suction pipeline operates one of the spuds is lifted while the other remains anchored. The barge would then pivot around the anchored spud causing the barge to rotate. This process is known as walking and would be repeated along the entire sediment removal channel while drawing in slurry. As the barge walks along the sediment removal channel, a discharge pipeline trails behind the hydraulic dredger while floating on top of the water surface. The collected sediment slurry would be conveyed to the sediment storage site though a temporary 12 inch to 18 inch above ground discharge pipeline with the assistance of booster pumps. Once the sediment reaches the sediment storage site the water/sediment mixture would be separated in settling basins to remove the water. Once the water has been removed, the sediment would be stockpiled for offsite hauling. Dredging would occur over a four month period with up to approximately 20,000 cubic yards of sediment material removed each month. In the event there is not enough water for the dredge to operate, the sediment would be removed by dry excavation.

Hauling Sediment from Prado Basin

The sediment removed from the Prado Basin would be hauled offsite 17 miles to the El Sobrante Landfill. The proposed haul route would extend along an existing dirt service road to Auto Center Drive to Serfas Club to SR-91 to I-15 to Temescal Canyon Road to the El Sobrante Landfill. It is anticipated that up to a total of 10,000 truck trips would be needed to haul the sediment material to the El Sobrante Landfill. It is anticipated that 90 round trip (total 180 truck trips) would occur each day during the non-peak traffic period (9 a.m. to 3 p.m.) to haul the material to the El Sobrante Landfill. The hauling activities would be phased over a three year period.

2.6 Project Monitoring Programs

The purpose of the Sediment Management Demonstration Project is to remove sediment from the Prado Basin and to collect and analyze data and provide conclusions and recommendations to help design and implement a long-term sediment management program at Prado Basin. Similarly, the proposed Planned Deviation would also incorporate a monitoring component to assist with documenting effects of the Planned Deviation and identifying locations where habitat restoration could be warranted. A summary of the monitoring programs that would be implemented for the Planned Deviation and the Sediment Management Demonstration Project is shown in Table 2.

Table 2: Summary of Monitoring Programs

Planned Deviation	Sediment Management Demonstration Project
Habitat Monitoring Program	Sediment Data Collection Program
	Sediment Movement Monitoring Program
	Hazardous Substance/Water Quality Monitoring Program

Sediment Data Collection Program

A sediment data collection program would be implemented concurrent with the Sediment Management Demonstration Project. The sediment data collection would involve a combination of field monitoring, data collection and analysis of sediment removed from the sediment removal channel and would provide valuable information in evaluating potential future sediment management activities within the Prado Basin. An outline of the proposed sediment data collection activities is shown in Table 3.

Table 3: Outline Sediment Data Collection Program

Monitoring Task	Location	Purpose
Digital Elevation Model (DEM) from LiDAR	To be determined	Enable comparison of changes to land form, plant communities.
Hyperspectral Imagery	To be determined	Enable comparison of changes to land form, plant communities after five years.
High Resolution Aerial Imagery	To be determined	Enable comparison of changes to land form, plant communities.
Establish transects	Transects	Establishment of transects to aid in standardization of comparison with data to be collected in the future.
River Bed Gradation(Riverwalk data-use where it exists and gather data where it doesn't)	Transects	Collect river bed samples and measure gradation. Evaluate surface substrate at transects relative to sucker's and other species' requirements. Also help calibrate sediment transport model.
Water Quality (Temp, pH, turbidity, DO)	Transects	Collect river bed samples and measure gradation. Evaluate surface substrate at transects relative to sucker's and other species' requirements. Also help calibrate sediment transport model.
TSS/SSC and Particle Size Distribution	TSS/SSC and Particle Size Distribution	Measure TSS to assess the gradation of suspended solids to help calibrate sediment transport model.
Bed Load Sampling	Transects	Measure Bed Load to refine model assumptions.
Stream Flow Measurement	Transects	Measure flow rates at various locations along SAR to correlate TSS and SAR Sediment Load Rating Curve. Confirm flow measurement of existing gaging stations where applicable.
Cross-Section Surveys	Transects	Provides a higher resolution look at topography at transect lines to help calibrate sediment transport model, evaluate accuracy of DEM-topographic analysis, and evaluate how topo might affect species presence.
Sediment Transport Modeling	To be determined	Use existing model(s) to predict SAR behavior. Depending on baseline data collection results may or may not update model and run scenarios. Future motoring will be correlated back to model and used to update model if needed.

Sediment Movement Monitoring Program

A monitoring program would be implemented to evaluate changes in sediment transport that could occur from the removal of approximately 120,000 cubic yards of sediment. The monitoring program would include collecting and analyzing field data to document the baseline condition of the removal alignment and the upstream Santa Ana River (from the alignment to above River Road Bridge). A minimum of three cross section surveys would be established. Baseline riverbed material samples would also be collected and analyzed for grain size distribution. Suspended sediment samples and bed load samples in river flow would also be collected and analyzed. Stream flow measurements would be collected during two low flow events. Gradient monitoring stations would be established along the Santa Ana River to track gradient changes during and after construction. The baseline condition of River Road Bridge would also be documented.

After sediment removal is completed, field measurements, observations and analyses would be conducted to assess the effectiveness and performance of the project. Additional riverbed material samples would be collected and analyzed for grain size distribution, along with suspended sediment samples and bed load samples. At the gradient stations along the Santa Ana River, gradient changes would be measured any head cutting would be documented. Photographs would be collected to document the post-construction conditions as they change in the Santa Ana River and removal alignment. Post construction monitoring of River Road Bridge would also be completed.

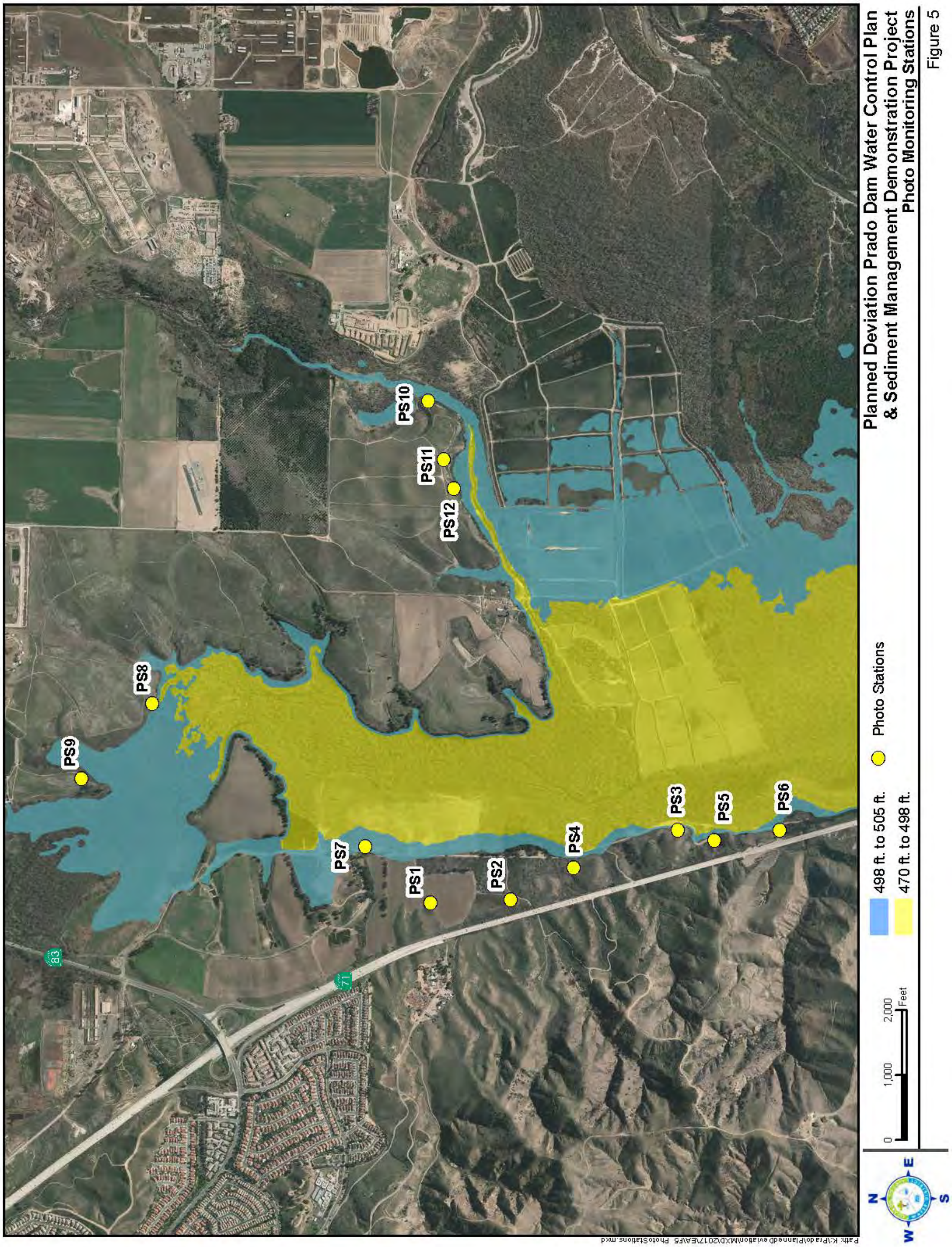
Results from the monitoring program would be utilized to develop an area-specific sediment transport model of the pre-project and post-project conditions. The model would be calibrated to data collected during the pre-construction phase and also post-construction. The results of the monitoring program and the area-specific sediment transport model would be used to provide recommendations for future sediment removal projects.

Habitat Monitoring Program

OCWD has an ongoing Habitat Monitoring Program (Effects of Reduced Outflow from Prado Dam Water Conservation) that tracks the health of habitat in the Prado Basin. As part of the Planned Deviation, the monitoring program would be expanded to monitor the health of riparian habitat between the elevations of 498 ft. and 505 ft. to help evaluate any potential effects of the Planned Deviation on habitat within the Prado Basin. A combination of visual observations, photo monitoring and Corps inundation data would be used to observe and display any habitat degradation potentially caused from increased inundation due to the Planned Deviation. The Corps data would also be utilized to attempt to segregate the effects of flood risk management from water conservation. Based on observation from OCWD’s ongoing habitat monitoring program, inundation duration of more than 10 days within a two week period could adversely affect mulefat and other understory. Whenever water levels exceed elevation 498 ft. for more than 10 days within a two week period during the flood season, OCWD would work with the Corps to calculate how long the water level would have remained above 498 ft. in the absence of water conservation operations. To the extent that habitat would have been inundated at least 10 days within a two week period due to flood control operations alone, it would be assumed that any resulting habitat degradation would not be due to water conservation. However, if the pool would have been drained below 498 ft. earlier than 10 days if not for water conservation operations, then OCWD would monitor and if necessary mitigate impacts.

Photo stations would be located in the Prado Basin based upon two criteria, elevation and habitat type. Most of the monitoring stations would be situated at elevations overlooking habitat that would be inundated due to water conservation but adjacent land would also be included in the photos. Habitat conditions would be documented photographically during wet and dry periods and compared among subsequent seasons and years. The stations would yield visual documentation of conditions over time relative to pool size as it pertains to water conservation and flood control. As shown in Figure 5, thirteen photo stations have been identified in the Prado Basin to document habitat conditions. Stakes would be planted to mark each station, and GPS readings would be taken to map and document each site. Panoramic photos would be taken while standing directly in front of the stake. Three visits to the photo stations would occur during the year. The first rounds of photos would be taken during January-February to document inundation events, if any. In addition, pending approval from the Federal Aviation Administration (FAA), photographs from a drone would be incorporated for a more penetrating, aerial view and if possible photos would be taken during all inundation events where water levels exceed elevation 498 ft. to document exactly what habitat could be completely or partially submerged at various water surface elevations. The second visit would occur in spring when temperatures have risen and the willows are coming out of dormancy and leafing out. A third visit would occur in late summer when individual plants and stands could display lasting adverse effects from the previous winter season or show signs of drought related stress**.**

Visual comparisons would be made of habitat conditions above and below elevations of prolonged inundation (one week or more) to qualitatively assess signs of reduced vigor in the habitat, stands, and of individual trees. On the ground inspections, counts, and measurements would follow to quantify observed degradation, if any. Quantitative assessments would be done in areas of observed loss of vigor and would incorporate data recorded along belt transects above and below the water conservation inundation zone to quantify differences in tree count and understory composition, particularly any mulefat loss. A transect would be flown along the 505 ft. contour or high water contour and three perpendicular transects would also be flown between elevations 505 ft. and 498 ft. to track habitat variation through time. This would be repeated twice annually during inundation and following leaf out. Dramatic changes in understory such as vegetation die back would be discussed with the Corps and USFWS and habitat would be restored, if triggers are met. The habitat would be given a minimum of 2 years to come back on its own, prior to active planting. To determine if habitat needs to be replaced, a threshold of 30% loss of cover over a two season period without any signs



Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project
Photo Monitoring Stations

Figure 5

of recovery would be the threshold to replace the vegetation. This would provide sufficient time to determine if the habitat is showing signs of recovery or degrading. In addition, appropriate in-field analysis, such as CRAM would be conducted to determine the health of the habitat, which information could be used to further track long-term changes and success of natural recovery and/or re-vegetation. In the event the monitoring program indicates that the primary constituent elements were substantially degraded, it is proposed that the degraded habitat would be replaced or restored within the same area. If it is determined that the degraded area is no longer suitable for supporting riparian habitat, then the same acreage of habitat would be planted or restored within OCWD lands in another part of Prado Basin, unless another area is approved by USFWS. OCWD would make these determinations in coordination with the Corps and USFWS. The data collected from the habitat monitoring program would be used to evaluate potential cumulative effects to habitat from the multiple year deviation. The recorded data would be provided in an annual monitoring report to the Corps and USFWS.

Water Quality Monitoring Program

OCWD would implement a water quality monitoring program to monitor the chemical analysis of sediments extracted from Prado Basin and to measure the water quality of the effluent generated from the removed sediment. Chemical analysis of the sediments in Prado Basin shows no detected organic chemicals, no pesticides, no PCBs, no PAHs, and no hydrocarbons. There were some total dissolved solids, and some inorganic nitrogen, and small quantities of metals, which appear to be within the ranges expected for background soils in California (Kearney Study, 1996). The range of background concentrations from the Kearney study and the range of concentrations detected in Prado Basin sediments are shown in Table 4.

Table 4: Chemical Results Range and Background Range

Compound	Prado Sediment Results Range (mg/kg)	Background Range (mg/kg)*
Antimony	ND - ND	0.15 - 1.95
Arsenic	1.6 - 1.8	0.6 - 11
Barium	40 - 64	133 - 1400
Beryllium	ND - ND	0.25 - 2.7
Cadmium	ND - ND	0.05 - 1.7
Chromium	9.4 - 15	23 - 1579
Cobalt	3.9 - 5.8	2.7 - 96.4
Copper	26 - 14	9.1 - 96.4
Lead	3.4 - 3.8	12.4 - 97.1
Molybdenum	ND - ND	0.1 - 9.6
Nickel	6.1 - 9.6	9 - 509
Selenium	ND - ND	0.015 - 0.43
Silver	ND - ND	0.1 - 8.3
Thallium	ND - ND	5.3 - 36.2
Vanadium	23 - 33	39 - 288
Zinc	40 - 46	88 - 236

In order to evaluate the sediment removed from the Prado Basin, the following monitoring program would be implemented: Sediment samples would be collected prior to dredging or excavation from the alignment along which the sediment removal would occur. Samples would be collected from bores that are advanced to the anticipated bottom of the dredge or as deep as feasible given access constraints. Twenty bores would be attempted. Where bores would not provide sufficient sample material, test pits would be attempted to as deep as feasible. Samples from each bore/test pit would be composited to reflect the mixed state that sediments would be in after dredging, de-silting, and stockpiling. Aliquots from the compounded bulk sediments would be analyzed for the following parameters:

- Grain size distribution.
- Metals, including boron
- Pesticides
- Ammonia-N, Nitrate-N, Nitrite-N, Total Kjeldahl N
- Higher molecular weight (diesel or jet fuel range) petroleum hydrocarbons by EPA method 8015 or an equivalent method that has few or no interferences from naturally occurring organic matter.
- Semi Volatile Organic Compounds (SVOCs)
- Poly-Chlorinated Biphenyls (PCBs) differentiated by Aroclor

The Toxicity Characteristic Leaching Procedure (TCLP) and Water Extraction Test (WET) are leachate tests specified under Title 40 CFR Part 261 and Title 22 CCR Chapter 11, Article 3, to elevate whether a material is a hazardous waste. The TCLP and WET tests would be conducted if bulk sediment concentrations exceed 20 times the TCLP regulatory values and 10 times the Soluble Threshold Limit Concentrations (STLC). If conducted, results of TCLP tests would be compared with USEPA regulatory values of 40 CFR Part 261. Results of the WET should be compared with STLCs of Title 22 CCR Chapter 11, Article 3. If no analytes exceed these criteria, the material would be suitable for upland disposal. No stockpiling of material on Corps property would occur until testing or analysis has confirmed that the material is uncontaminated.

Previous boring samples collected in the location where the sediment removal activities would occur, showed no detected organic chemicals, no pesticides, no PCBs, no PAHs, and no hydrocarbons. Therefore, it is anticipated that the sediment removed from the basin would not contain elevated contaminants or other constituents that would reduce water quality or be in conflict with the Basin Plan water quality standards. In the event elevated levels of contaminants or elevated levels of other constituents that could be in conflict with the Basin Plan are identified, the excavation activities would not proceed and a new location for the sediment removal activities would be identified and evaluated. Additionally, prior to discharging the effluent water generated from the dried out sediment into the basin reservoir, the effluent water would be analyzed for contaminants or other constituents that could be in conflict with the Basin Plan. In the event the effluent does contain contaminants or other constituents that could be in conflict with the Basin Plan, the effluent water would be placed in container and haul offsite.

2.7 Construction Phasing Plan

As shown in Table 5 the Sediment Management Demonstration Project would be implemented in six phases over a six year period.

Table 5: Construction Phasing Plan

Phase	Activity	Time frame
Phase 1	Pre-Construction Surveys-Wildlife/Habitat Monitoring, Sediment Surveys, Water Quality Data Collection	July 2018 and August 2018
Phase 2	Construction of Santa Ana River Sediment Removal Channel	September 2018
Phase 3	Construction of Sediment Storage Site and Temporary Pipeline	September 2018
Phase 4	Sediment Removal Activities	October 2018 to February 2019
Phase 5	Sediment Hauling	February 2019 to February 2022
Phase 6	Monitoring, Mitigation and Site Restoration	February 2019 to February 2024

2.8 Conservation Measures

BIO-1: All vegetation removal and sediment removal activities will be conducted outside of the migratory bird season from March 15 to September 15.

BIO-2: Once the Sediment Management Demonstration Project is completed, areas disturbed by the project will be re-established with native vegetation by a combination of natural recruitment, pole cuttings or hydro-seeding with mulch, soil binders and native seed mix.

BIO-3: OCWD would restore .48 acres of native riparian habitat along the alignment of the project access road after the project is completed and managed it for a five year period.

BIO-4: All excavation activities within the wetted channel will occur outside of the Santa Ana sucker spawning season.

BIO-5: If the habitat monitoring program indicates substantial and prolonged degradation of vegetation between 498 ft. and 505 ft., the degraded habitat would be replaced or restored within the same area. If it is determined that the degrade habitat is no longer suitable for supporting riparian habitat, then the same acreage of habitat would be restored within OCWD lands or in another part of Prado Basin or other areas approved by USFWS.

SECTION 3 ACTION AREA

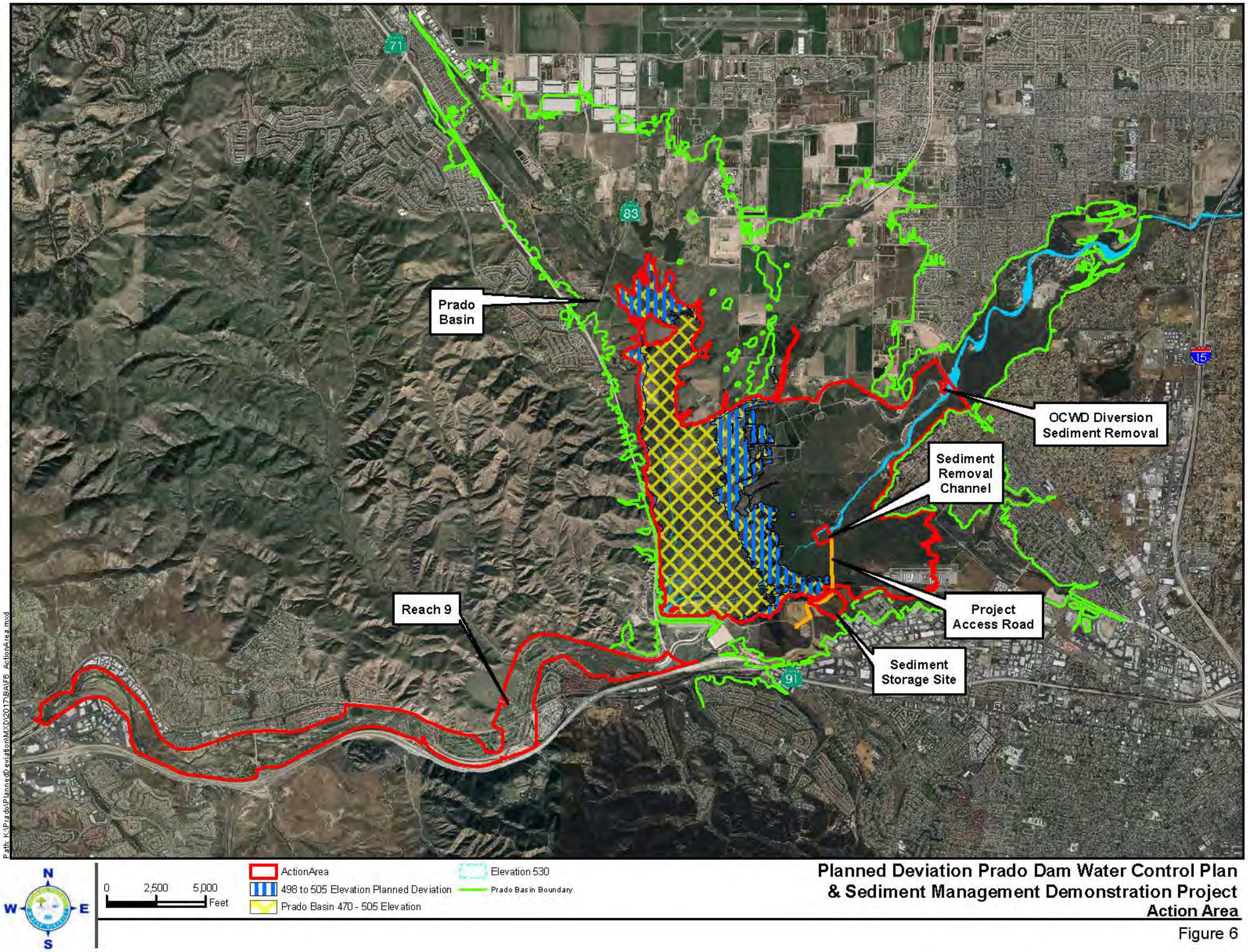
The Action Area or study area includes all areas to be directly or indirectly effected by the Planned Deviation and/or the Sediment Management Demonstration Project (Proposed Action). The area of direct effects includes the area within Prado Basin between elevation 470 ft. and elevation 505 ft., the sediment removal channel, the sediment storage site, and the project access road. The area of indirect effect includes the Santa Ana River upstream of elevation 505 ft. to the Santa Ana River/River Road Bridge crossing (elevation 530 ft.) and Reach 9 of the Santa Ana River. The Action Area is shown in Figure 6.

The upstream extent of the Action Area within Prado Basin was determined to be the Santa Ana River/River Road Bridge crossing. This location was selected because it fully encompasses the extent of the expected area of influence of the proposed Five Year Planned Deviation. This upstream boundary is also located immediately upstream of the OCWD wetlands diversion which provides the last opportunity to divert flow, and sediment, from the Santa Ana River before it flows into the main basin area. The current modeling and analysis includes the operation of the diversion and would be a practical location for monitoring efforts that would be associated with the Proposed Action.

The downstream extent of the Action Area below Prado Dam was determined to be the portion of the Santa Ana River known as Reach 9. The channel invert at the downstream end of Reach 9 is controlled by a drop structure near the Santa Ana River/Weir Canyon Road crossing. Additionally, the Santa Ana River below Weir Canyon is controlled by improved side slopes and the regular placement of drop structures and channel invert stabilizers. No direct affects (channel incision or bank erosion) are expected to occur from the Proposed Action in Reach 9. This location was selected because it does provide a barrier which controls these affects should they unexpectedly occur. This site also provides a practical location for the downstream limit relevant to the modeling and monitoring efforts associated with the Proposed Action.

Prado Basin

Prado Basin is located within the Santa Ana River Watershed. There are four major tributaries that drain into the Prado Basin; Santa Ana River, Chino Creek, Cucamonga Creek (which flows into Mill Creek) and Temescal Wash. All of these water bodies converge behind Prado Dam. The biological setting in the Prado Basin is significantly influenced by the presence of Prado Dam. As a result of a combination of high groundwater, storm flow accumulation held in the reservoir, ongoing sewage treatment plant effluent and irrigation runoff, perennial flows occur throughout much of the Prado Basin. During the winter months the river maintains flow throughout Prado Basin. In the summer months the surface flow is substantially reduced, but is typically still present. Prado Basin consists of a wide mixture of biological resources and habitats, including;



Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project

Action Area

Figure 6

cottonwood/willow riparian forest, riparian scrub, herbaceous riparian, freshwater ponds, freshwater marsh, and riverine. Riparian forest is the most dominant wetland habitat in the Prado Basin. The dominant plant species within the riparian forest are black willow, (*Salix goodingii*), arroyo willow (*Salix lasiolepis*), Freemont cottonwood, (*Populus fremontii*) eucalyptus, sycamore (*Platanus recemosa)*, and mulefat (*Baccharis salicifolia*).

The riparian habitat within Prado Basin is a dynamic community that is dependent upon periodic flooding. Winter flows create areas of scour and sedimentation that cycle the community back to earlier successional stages. Periodic floods of large magnitude and migration of the river channel lay down fresh alluvial deposits where seeds can germinate and plant roots can take hold. The basin contains an expansive riparian forest. At lower elevations in the basin, the riparian forest coverage is nearly complete with an over story of trees reaching as high as 50 feet and an understory of both native vegetation and non-native vegetation. At the higher elevations in the basin the forest is patchier and the understory consists of more non-native vegetation.

The riparian forest in the Prado Basin contains an abundance and diversity of bird species. Neotropical migrants depend on deciduous trees and shrubs for foraging during migration. The mature trees provide numerous cavities for cavity dependent wildlife and the taller trees are used by nesting raptors. The emergent vegetation at the water’s edge provides escape cover, shade and a source of food for fish. The basin supports a wide variety of mammal, amphibian and reptile species, several of which are biologically significant. Additionally, Prado Basin functions as a wildlife movement corridor between core habitats in the Chino Hills, the Santa Ana Mountains and Prado Basin and the undeveloped Santa Ana River Floodplain.

Santa Ana River Prado Dam to River Road

The segment of the Santa Ana River (SAR) extending from the River Road Bridge/Santa Ana River crossing downstream into Prado Basin can be divided into two sub-segments. The upper segment, extending from River Road Bridge downstream to the south and west is approximately 10,000 feet, and is typically a well-defined channel composed of primarily sand channel slopes and a sand river bed. The river bed gradation ranges from very fine sand to coarse sand with occasional, brief and intermittent gravel deposits. This segment of the Santa Ana River receives high amounts of sediment deposition and can often move laterally during large flow events. The slope of the river in this location typically ranges from 0.003 to 0.0001, depending on sedimentation and river flow conditions.

The segment of the Santa Ana River extending from 10,000 feet below River Road Bridge, south and west 7,000 feet to Prado Dam is indiscernible as a single river channel and can be defined as a series of braided streams meandering towards the Prado Dam outlet works. The braided stream beds and stream bank gradations are composed of a higher silt and clay content than what is present in the upper segment. The slope of the braided streams in this location of the basin can vary dramatically depending on their location in the basin and annual sedimentation deposition, but typically range from 0.01 to 0.0001.

Santa Ana River Reach 9

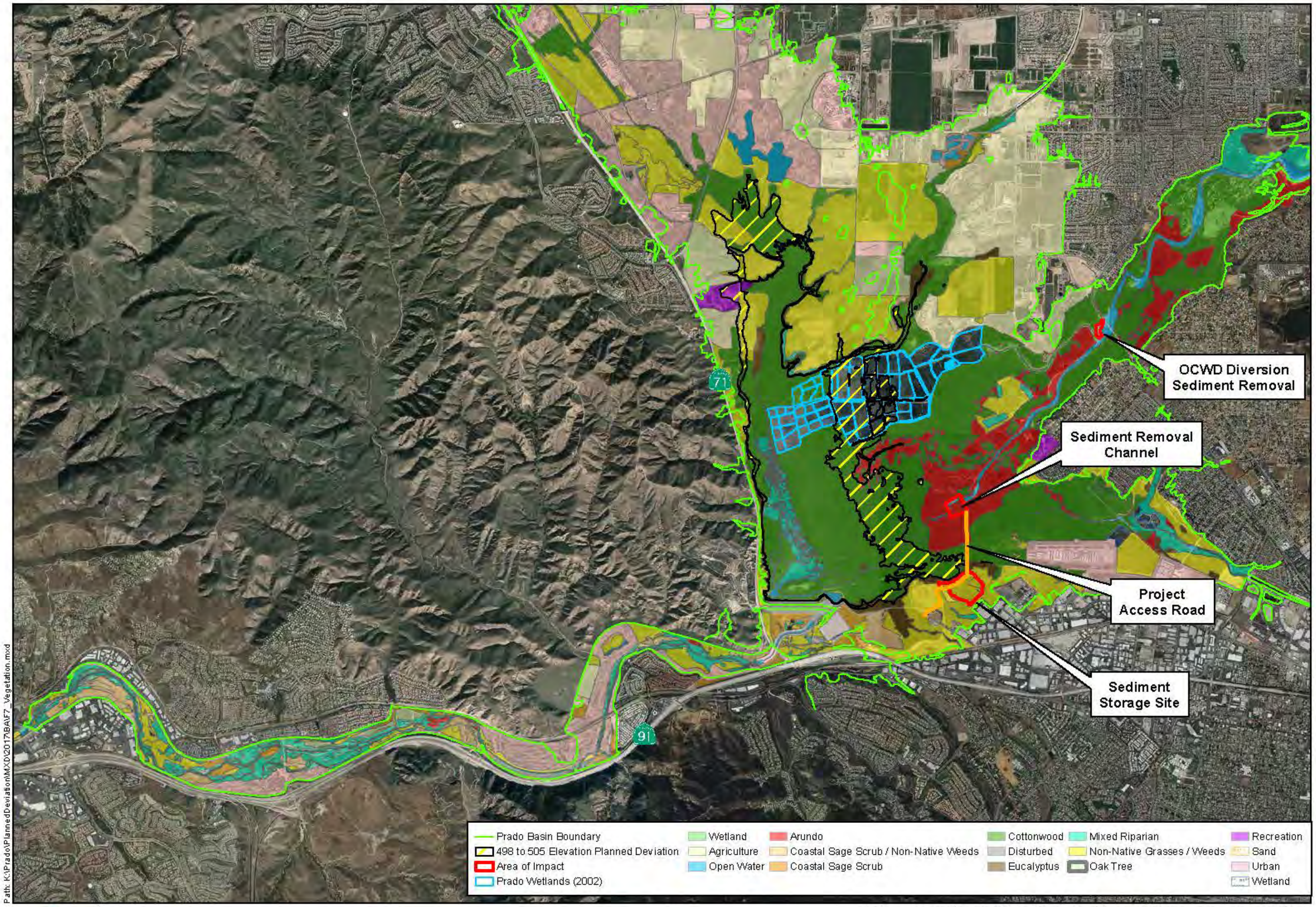
The stretch of the Santa Ana River occurring downstream of Prado Dam to Weir Canyon Road, referred to as Reach 9, runs through Santa Ana Canyon and has several distinctive characteristics. At the Prado Dam outlet structure to the Green River Golf Course the river has a relatively flat slope. Within this reach, the river flow is perennial and the floodplain is covered with riparian vegetation. The banks are moderately incised with vegetated islands that dot the main channel. Near the Green River Golf Course the slope increases and the river becomes more incised. Between the Green River Golf Course and Imperial Highway the flood plain becomes much more expansive with several flow splits forming natural islands. Riparian vegetation is mostly concentrated near the river bank. Except for a drop structure located downstream of Weir Canyon, this reach does not contain any other water control structures.

The bed material in Reach 9 is much coarser than the sandy bed material of the river above Prado Dam. Reach 9 bed material generally consists of gravels and cobbles compared to the predominantly sand substrate characteristic of the river upstream of Prado Dam. The dominant bed form in this reach is pool-riffle, where high gradient high velocity riffles flow into low gradient low velocity pools. Additionally, there are several stretches where the river has a plane bed, where the gradient and velocity are approximately constant and the river bottom material is dominated by gravel and cobble.

The Corps is currently implementing major improvements and associated mitigation for the Santa Ana River Mainstem Project, which includes improvements within Prado Basin and along the Santa Ana River downstream to the Pacific Ocean. Also included in Reach 9 is the Corps Santa Ana Sucker Perennial Stream Restoration Project.

Vegetation Communities

The vegetation communities within the Prado Basin portion of the Action Area are shown in Figure 7. A statistical summary of vegetation communities in the Prado Basin between elevations 470 ft. to 498 ft., 498 ft. to 505 ft. and 505 ft. to 530 ft. is shown in Table 6. As shown in Table 6, the majority of the vegetation in the basin between these elevations is cottonwood/willow habitat. Most of the habitat is mature, contains high biological values to support wildlife and is known to be occupied by special status bird species such as the Least Bell’s Vireo and Southwestern Willow Flycatcher.



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Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project
Vegetation Communities

Figure 7

Table 6: Prado Basin Vegetation Communities

Vegetation Community	Acres Between 470 ft. and Elevation 498 ft.	Acres Between 498 ft. and 505 ft.	Acres Between 505 ft. and 530 ft. (River Road Bridge)
Cottonwood/Willow	852.50	425.59	1,112.63
Mixed Riparian	98.80	.17	17.35
Coastal Sage Scrub	0.0	0.0	0.07
Coastal Sage Scrub/No-Native Weeds	0.0	0.0	9.20
Open Water	34.27	.59	109.74
Non-Native Weeds/Grasses	50.47	59.58	460.07
Arundo	0.0	8.75	362.58
Disturbed	0.75	1.5	6.64
Eucalyptus	23.63	17.93	83.35
Constructed Wetlands	91.82	154.95	211.38
Agriculture	0.0	0.0	58.18
Recreation	4.03	11.72	12.09
Urban	0.0	0.0	189.52
Total	1,156.27	680.78	2,632.8
Source: Orange County Water District and United States Army Corps of Engineers, 2016			

The vegetation communities within the Reach 9 portion of the Action Area are shown in Figure 7. A statistical summary of vegetation communities along Reach 9 of the Santa Ana River is shown in Table 7. As shown in Table 7, the Reach 9 study area contains a mix of urban land uses and vegetation communities. The higher biological valued vegetation communities are located on riparian sites that are interspersed along the wetted channel of the river. These areas are known to be occupied by special status bird species such as the Least Bell's Vireo. The upland terrace above the river contains coastal sage habitat and provides suitable habitat for the Coastal California Gnatcatcher.

Table 7: Santa Ana River Reach 9 Vegetation Communities (Acres)

Vegetation Community	Acres
Mixed Riparian	321.69
Open Water	54.82
Coastal Sage Scrub	77.21
Non-Native Weeds/Grasses	172.94
Mix Coastal Sage Scrub/Non-Native Weeds	105.56
Arundo	11.35
Eucalyptus	1.16
Agriculture	41.18
Oak	.54
Urban	436.52
Wetlands	2.71
Total	1225.68
Source: Orange County Water District and Untied States Army Corps Engineers	

The vegetation communities within the footprint of the sediment removal channel, sediment storage site and project access road is shown in Figure 7. A statistical summary of vegetation communities at the sediment removal channel, sediment storage site and project access road is shown in Table 8. As shown in Table 8, a substantial amount of the vegetation communities at the sediment removal channel site and the sediment storage site are arundo and non-native weeds and grasses. The higher quality cottonwood/willow habitat is located along the alignment of the project access road. The sediment storage site contains a scattering of mixed riparian and a mix of coastal sage/non-native weeds. The vegetation is dominated with non-native weeds and does not provide suitable habitat to support special status species such as the Least Bell's Vireo or the Coastal California Gnatcatcher.

Table 8: Sediment Management Project

Vegetation Community	Sediment Removal Channel (Acres)	Sediment Storage Site (Acres)	Access Road (Acres)
Cottonwood/Willow	0.0	0.0	0.48
Open Water	1.29	0.0	0.0
Mixed Native/Non-Native Riparian	0.0	.03	0.0
Mix Coastal Sage/Non-Native Weeds	0.0	.36	.20
Arundo	13.05	0.0	0.73
Non-Native Grasses/Weeds	0.0	20.21	0.12
Eucalyptus	0.0	0.0	0.19
Total	14.34	20.55	1.72
Source: Orange County Water District and Untied States Army Corps Engineers			

SECTION 4 SPECIAL STATUS SPECIES/CRITICAL HABITAT

4.1 Federal Listed Special Status Plants

To determine the potential for Federal Listed special status plant species to occur within the Action Area, a review of the U.S. Department of Interior Information Planning and Conservation System Database and the California Department of Fish and Wildlife California Natural Diversity Data Base was conducted. A listing of Federal Listed special status plant species that have potential to occur within the Action Area is shown in Table 9. The determination on the potential for the species to occur within the Action Area was based on the criteria shown below. Based on existing habitat conditions there are no Federal Listed special status plant species that have a moderate or high potential to occur within the Action Area.

Present: The species is commonly observed or observed within the Action Area within the last year.

High: The Action Area supports suitable habitat and the species has been observed within last 2 years.

Moderate: The Action Area supports suitable habitat and the species has not been observed within last 2 years.

Low: The Action Area lacks suitable habitat for the species.

Table 9: List of Federal Special Status Plant Species

	Federal	State	CNPS	General Habitat Requirement	Action Area Habitat Suitability	Potential Occurrence in Action Area
Plants						
Slender Horned Spineflower (*Dodecahema leptoceras)*	E	E	1B.2	Sandy places Coastal Sage Scrub, Chaparral, cismontane woodlands, stream banks and washes. Flowering period April to June.	The Action Area does not support adequate amount of suitable habitat to support the species.	Low
Santa Ana River Woollystar *(Eriastrum densifolium ssp. Sanctorum)*	E	E	1B.1	Sandy gravelly Soils on River Floodplain. Flowering period May to September.	The Action Area does not support adequate amount suitable habitat to support the species.	Low

Legend **Federal** E- Endangered T-Threatened SSC- Special Species of Concern C-Candidate for Listing NL-Not Listed **State Listing (California Endangered Species Act, CDFG** FP-Fully Protected E-Endangered T-Threatened S-Sensitive SSC-Special Species of Concern WL-Watch List NL-Not Listed	**California Native Plant Society CNPS** 1A-Plants presumed extinct in California 1B- Plants rare, threatened, or endangered in California and elsewhere 2-Plants rare, threatened, or endangered in California but more common elsewhere 3-Plants about which we need more review 4-Plants of limited distribution **CNPS Threat Rank** .1 Seriously Endangered .2 Fairly Endangered .3 Not Very Endangered	

4.2 Federal Listed Special Status Wildlife Species

To determine the potential for Federal Listed special status wildlife species to occur within the Action Area a review of the U.S. Department of Interior Information Planning and Conservation System Database and the California Department of Fish and Wildlife California Natural Diversity Data Base was conducted. A listing of Federal Listed special status wildlife species with the potential to occur within the Action Area is shown in Table 10. The determination on the potential for the species to occur within the Action Area was based on the following criteria.

Present:	The species is commonly observed or observed within the Action Area within the last year.
High:	The Action Area supports suitable habitat and the species has been observed within last 2 years.
Moderate:	The Action Area supports suitable habitat and the species has not been observed within last 2 years.
Low:	The Action Area lacks suitable habitat for the species

Table 10: List of Federal Special Status Wildlife Species

	Federal	**State**	**General Habitat Requirement**	**Action Area Habitat Suitability**	**Potential Occurrence in Action Area**
Birds					
Least Bell's vireo *(Vireo bellii pusillus)*	E	E	Summer resident of southern California in low riparian habitats in vicinity of water or dry river bottoms, nests placed along margins of bushes or on twigs landing on pathways, usually willow, mesquite or mulefat.	The Action Area supports suitable habitat and species is annually reported in the Prado Basin.	Present

Western yellow billed cuckoo (*Coccyzus americanus occidentalis)*	C	E	Riparian Woodlands with thick stands of Cottonwoods and Willows	Species typically require a minimum of 25 acres of area and forage predominantly in cottonwood tree stands. Within the last 15 years 2 sightings have been reported in the Prado Basin, 1 in 2000 and 1 in 2011.	Low
Southwestern willow flycatcher (*Empidonax traillii extimus)*	E	E	Breeds in willow riparian forest and shrub ands	The Action Area supports suitable habitat. Species has intermittently been reported in the Prado Basin, most recently in 2015.	Present
Coastal California gnatcatcher (*Polioptila californica californica*)	T	SSC	Obligate, permanent resident of coast sage scrub below 2,500 feet in southern California. Inhabits low coastal sage scrub in arid washes, on mesas, and slopes.	The Action Area supports suitable habitat and the species is present. The species has been documented on terraces in Reach 9 that are higher in elevation than would be expected to be affected by the Proposed Action.	Present
Aquatics					
Santa Ana sucker (*Catostomus santaanae*)	T	SSC	Cool, clear streams, rivers, rocky bottom in riparian woodlands	The Prado Basin Action Area does not contain adequate amounts of suitable habitat. The Reach 9 Action Area contains marginally suitable habitat.	Low
E- Endangered T-Threatened SSC- Special Species of Concern C-Candidate for Listing **California Endangered Species Act/California Department Fish Game** E-Endangered FP-Fully Protected S-Sensitive SSC-Special Species of Concern T-Threatened WL-Watch List					

Federal Listed Special Status Species Habitat Affinities and Critical Habitat

Least Bell's Vireo (vireo)

Status

The vireo was listed as a Federal Endangered Species in 1986.

Species Description

The vireo is a small migratory songbird that historically was common in lowland riparian habitat, ranging from coastal southern California through Sacramento and San Joaquin Valleys with scattered populations in Coast Ranges of the Sierra Nevada, Mojave Desert and Death Valley. Presently, the species only occurs in riparian woodlands in southern California. Until about 1986 when only 300 pairs were documented throughout the U. S. range. The enactment of protective measures and subsequent management led to steadily increasing vireo numbers and, by 2005, there were nearly 3000 territorial male vireos (USFWS 2006).

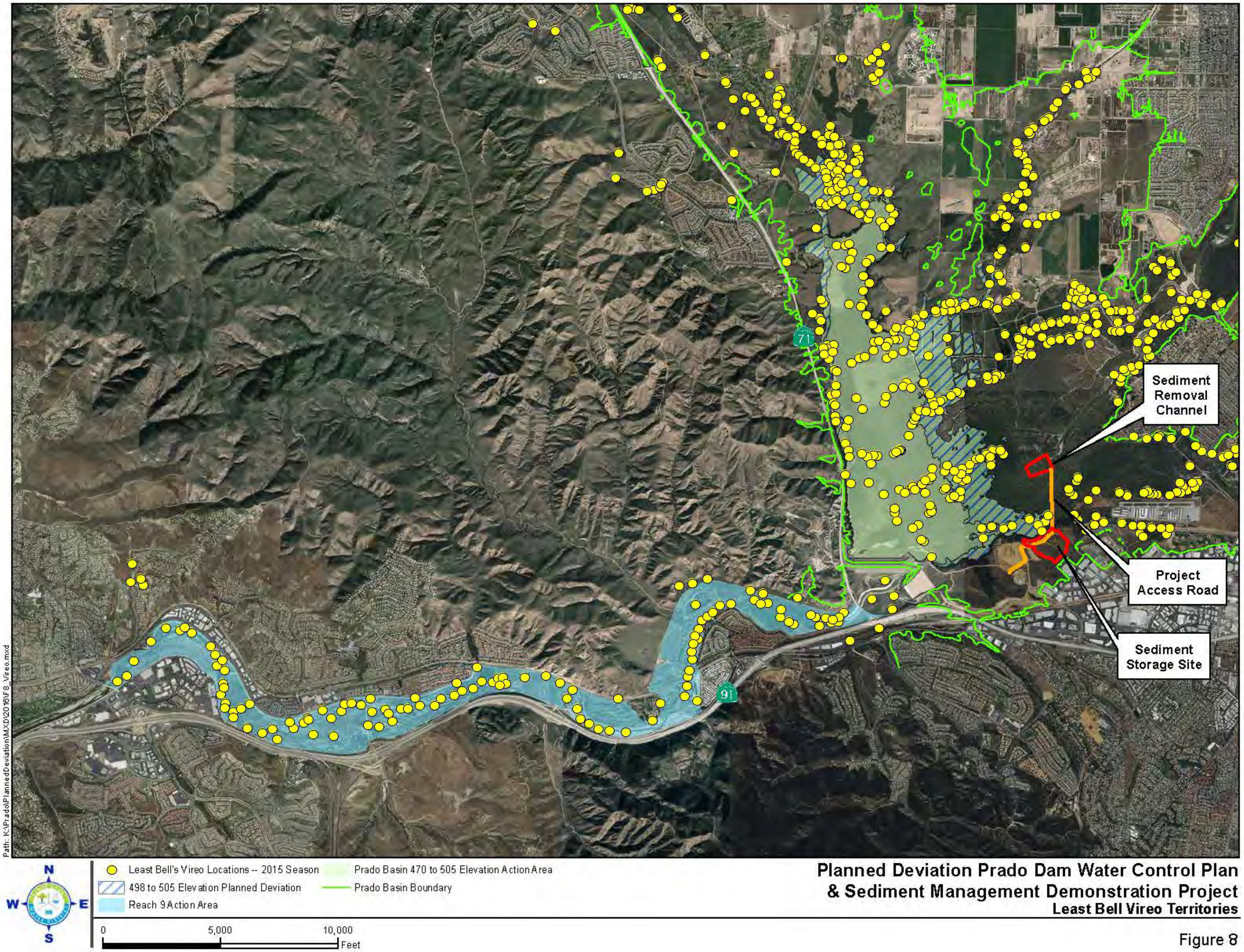
Action Area Occurrence: As shown on Figure 8, surveys conducted in the last year have identified numerous vireos territories within the Prado Basin and along the Santa Ana River Reach 9.

Critical Habitat

As shown in Figure 9, the Action Area includes lands that are designated critical habitat for the vireo. The primary constituent elements for the vireo include riparian woodland vegetation that generally contains both canopy and shrub layers, and includes some associated upland habitats. Vireos typically occupy low riparian growth either in the vicinity of water or in dry parts or river bottoms. The center of activity is within a few feet of the ground, in the fairly open twigs canopied above by the foliage of willows and cottonwoods. Most typical plants frequented are willows, mulefat, and wild blackberry. As shown in Table 11 there is approximately 3,349.36 acres of critical habitat for the vireo within the Action Area.

Table 11: Action Area Critical Habitat

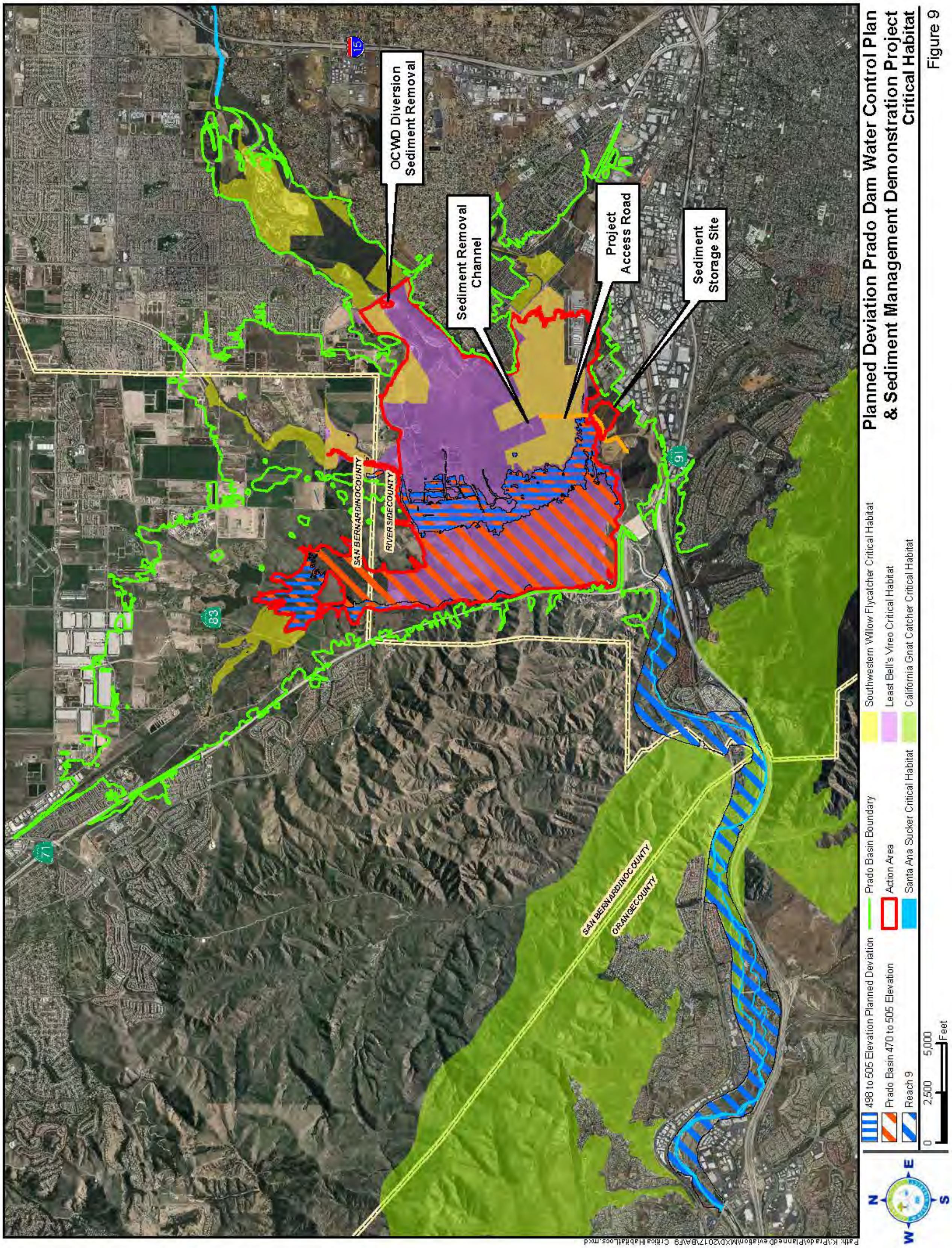
Critical Habitat	Acres 470 ft.to 498 ft.	Acres 498 ft. to 505 ft.	Acres 505 ft.to 530 ft. (River Road Bridge)	Acres Reach 9	Total
Least bell's vireo	961.71	507.54	1880.11	0.0	3,349.36
Southwestern willow flycatcher	0.0	0.77	1492.52	0.0	1,443.29
*Western yellow billed cuckoo	0.0	0.0	0.0	0.0	0.0
Coastal California gnatcatcher	0.0	0.0	0.0	313.21	313.21
Santa Ana sucker	0.0	0.0	0.0	1225.68	1225.68



Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project

Least Bell Vireo Territories

Figure 8



Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project Critical Habitat

Figure 9

Status

The flycatcher was listed as a Federal Endangered Species in 1995

Species Description

The flycatcher is a small, insect-eating generalist, neo-tropical migrant bird. It grows to about 15 centimeters in length. It eats a wide range of invertebrate prey including flying and ground and vegetation dwelling insect species of terrestrial and aquatic origins. The flycatcher spends the winter in locations such as southern Mexico, Central America and South America. Flycatchers are often present and singing in territories around mid-May. They have been documented in southern California in April in exceptional circumstances (USFWS 2001).

Action Area Occurrence: As shown on Figure 10, the flycatcher has periodically been observed within the Prado Basin. The most recent observation was reported in 2015 near OCWD Prado Wetlands Diversion Channel.

Critical Habitat

As shown in Figure 9, the Action Area includes lands that are designated critical habitat for the flycatcher. The primary constituent elements for the flycatcher are thickets of riparian shrubs and small trees with adjacent surface water such as willows, cottonwoods, mulefat, and other wetland plants. The surface water must be available from May to September during breeding season. As shown in Table 11, there are approximately 1,493 acres of critical habitat for the flycatcher within the Action Area.

Western Yellow-Billed Cuckoo (cuckoo)

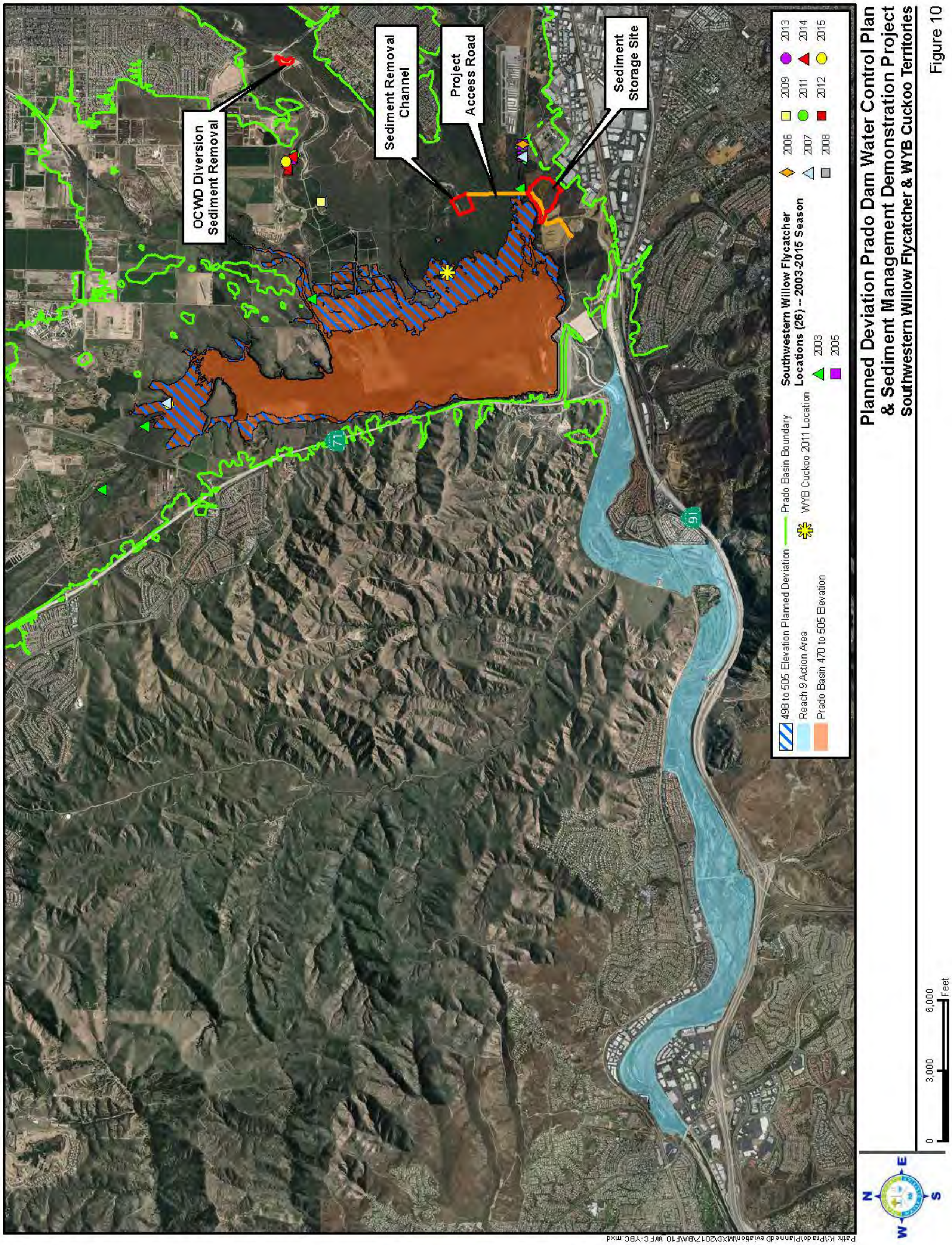
Status

The cuckoo is a Federal Candidate Proposed Threatened Species.

Species Description

The cuckoo was once widespread and common throughout lowland California. Because of habitat loss their population numbers have declined significantly. Presently, the species is considered uncommon to rare. The cuckoo is typically found in understory foliage adjacent to slow moving watercourses, backwaters or seeps. Each pair of cuckoos requires a minimum 25 acres in which to forage predominantly in Freemont Cottonwood stands. Nesting requires an area of dense understory near water or at least with adequate humidity. Typically their nests are in willows, small cottonwoods or mesquite trees with well protected overhead.

Action Area Occurrence: As shown in Figure 10, the most recent sighting of the cuckoo was in 2011. Prior to 2011, the last reported sighting in the Prado Basin was in 2000.



Planned Deviation Prado Dam Water Control Plan & Sediment Management Demonstration Project
Southwestern Willow Flycatcher & WYB Cuckoo Territories

Figure 10

Critical Habitat

Critical habitat for the western yellow-billed cuckoo was proposed in 2014. Presently, the current ruling is being revised by USFWS. The final ruling is expected sometime in 2017. Based on the ruling it appears portions of the critical habitat are proposed within the Action Area.

Coastal California Gnatcatcher (gnatcatcher)

Status

The gnatcatcher was listed as Federally Endangered in 1993.

Species Description

The gnatcatcher is primarily restricted to coastal sage scrub habitats of coastal southern California and northern Baja California. The species sometimes occurs in other types of habitats adjacent to coastal sage scrub, including grasslands, chaparral, and riparian habitat. Although breeding territories have been reported in non-sage scrub habitats, these habitats are most commonly used for foraging or dispersal in the non-breeding season (Atwood, 1980; Campbell et al., 1998; Rotenberry and Scott, 1998). In California, the gnatcatcher species is a year-round resident of scrub dominated plant communities from southern Ventura County southward through Los Angeles, Orange, San Bernardino, Riverside, and San Diego counties (Atwood, 1980).

Action Area Occurrence: Gnatcatchers were documented to have successfully nested in Reach 9 on a terrace in the floodplain extending north toward the Santa Ana River adjacent to the Coal Canyon Wildlife Corridor. They have also been documented near SARI Line construction within the immediate vicinity of Reach 9 Phase 2B and are documented in the CNDDB across the SAR from Phase 5A, and south of SR-91 in Gypsum Canyon and Weir Canyon (CDFW 2014a). Presence of the gnatcatcher has also been detected at Coal Canyon. According to Chino Hills State Park, gnatcatchers have also been detected on the north side of SR-91 near the east end of the Reach 9, Phase 5B temporary construction easement.

Critical Habitat

As shown in Figure 9, critical habitat for the gnatcatcher is designated on the terraces along Reach 9 of the Santa Ana River. Critical habitat for the coastal California gnatcatcher includes approximately 197,303 acres in San Diego, Riverside, San Bernardino, Los Angeles, and Ventura Counties. Gnatcatcher critical habitat occurs in the Reach 9 portion of the Action Area only. Its main purpose is to provide connectivity and genetic interchange between populations of the species in the Santa Ana Mountains and Chino/Puente Hills (USFWS 2010). As shown in Table 11, Reach 9 contains approximately 313 acres of critical habitat.

Santa Ana Sucker (sucker)

Status

The sucker was listed a Federal Threatened Species in 2000.

Species Description

The sucker is a short-lived member of the Catostomidae family of suckers that historically is endemic to the Los Angeles River, San Gabriel River and the Santa Ana River. Currently, the sucker is restricted to three noncontiguous populations occurring in the lower Big Tujunga Creek, the East and North Forks of the San Gabriel River and the lower and middle Santa Ana River. The sucker prefers cool and clear streams with rocky substrate with riffles and pools. The riffles and pools provide refuge from high velocity flows, provide sites for spawning and provide attachment sites for benthic invertebrates and plants for suckers to feed on. Spawning takes place in March to early June, peaking in May through early June. Sucker populations in the Santa Ana River have declined significantly in recent year. The decline in population is attributed to diminished habitat conditions and predation from exotic fish introduced into the river.

Action Area Occurrence: Between 2008 and 2013 surveys for suckers were conducted along the Santa Ana River both downstream and upstream of the Prado Dam. During this period twenty suckers were reported in 2008 at the Prado Outlet/Inlet Channel and one sucker was reported near the Green River Golf Course.

Critical Habitat

The critical habitat for the sucker extends along the Santa Ana River from above the Seven Oaks Dam in the San Bernardino Mountains to Hamner Avenue bridge crossing over the Santa Ana River and downstream from Prado Dam to Imperial Highway in Orange County. As shown on Figure 9, within the Action Area, the Reach 9 segment of the Santa Ana River downstream of Prado Dam is designated critical habitat area for the sucker. The primary constituent elements that have been recognized as essential critical habitat for the Santa Ana sucker include; a functioning hydrological system that experiences peaks and ebbs in the water column reflecting seasonal variation in precipitation throughout the year; a mosaic of loose sand, gravel, cobble and boulder substrates in a series of riffles, runs, pools and shallow sandy margins, water depths greater than 1.2 inches, non-turbid water or only seasonally turbid water, water temperatures less than 86 degree and stream habitat that includes algae, aquatic emergent vegetation, macro invertebrates and riparian vegetation. As shown in Table 11 there are approximately 1,225 acres of critical habitat along Reach 9.

SECTION 5 EFFECTS OF ACTION

5.1 Planned Deviation

5.1.1 Direct Effects to Federal Listed Species from Inundation

Least Bell's Vireo (vireo)

As the Planned Deviation would be limited to the non-nesting season, the implementation of the Planned Deviation would not result in the inundation of active or occupied nests. Over the last 17 years water elevations at the conservation buffer pool have gotten between 498 ft. and 505 ft. only four times. In the event of a wet year when the water is stored between 498 ft. and 505 ft. the Action Area would likely already be inundated before the nesting season begins, with or without the proposed Planned Deviation. Therefore, if nests that have been used in previous years are inundated during the timeframe of this deviation, the cause would most likely be attributed to flood control rather than water conservation actions. But whatever the cause, the potential exists that the pooled water could overlap into the beginning of nesting season and could inundate previous years nesting territories, which could discourage or prevent vireos from nesting in those same areas. Previous surveys conducted in the Prado Basin during wet years where a buffer pool was present, have shown no significant reduction in the overall number of vireo territories reported. As shown in Table 13, in 2004, 2005 and 2010 when the pooled water extended into the nesting season, there was not a substantial reduction numbers of vireo territories reported in the Prado Basin. In fact during years 2004, 2005 and 2010 the amount of vireo territories reported were the three highest reporting years since 2000. These results indicate that the presence of the buffer pool did not deter vireos from nesting within in the Prado Basin.

Table 12: Vireo Territories Reported Between 2000 and 2015

Year	*00*	*01*	*02*	*03*	*04**	*05**	*06*	*07*	*08*	*09*	*10**	*11*	*12*	*13*	*14*	*15*
Vireos Reported	*357*	*444*	*429*	*447*	*590*	*600*	*423*	*420*	*463*	*538*	*569*	*517*	*451*	*561*	*520*	*532*

*Years When Buffer Pool Overlapped Into Nesting Season. Source: Santa Ana Watershed Association 2014.

The data in Table 12 suggests that the presence of a buffer pool did not deter vireos from nesting within the Prado Basin, which indicates they were nesting in higher elevations above the inundation level. The elevation distribution of vireo territories with the Prado Basin from 2001 to 2015 is shown in Table 13. The table shows that an overwhelming majority of vireo territories occurred above 505 ft. Additionally, Table 13 shows that when the buffer pool was present the vireos tended to re-distribute to higher elevations. In 2004 when the buffer pool was up to 494 ft. for most of March, there was increase in the amount of vireos reported between 498 ft. and 505 ft. compared to preceding years when the buffer was not present. In 2005 when the buffer pool was 505 ft. for some of March and most of April there was an increase in the amount of vireos reported above 505 ft. In March of 2010 when the buffer pool was as high 498 ft. there was increase in the vireos reported between 498 ft. and 505 ft. and above 505 ft. These results indicate that when a buffer pool was present it did not discourage vireos from nesting within the Prado Basin, but did cause them to re-distribute to higher elevations.

Based on historical rainfall records, it is highly unlikely that the pooled water would persist into nesting season on an annual basis. However, the potential for the pooled water to overlap into the nesting season and cause vireos to redistribute into higher elevation could adversely affect the species. Because the re-distribution of vireos to higher elevations would not cause a significant reduction in the overall numbers of territories occurring in the Prado Basin, the adverse effect would be temporary and not substantial.

Table 13: Elevation Distribution of Least Bell's Vireo in Prado Basin

Year	490-494	494-498	498-505	Above 505
2001	5.85%	9.37%	17.80%	63.70
2002	9.61%	12.81%	16.70%	54.92%
2003	2.74%	7.48%	20.45%	65.59%
2004(1)	6.75%	1.24%	24.87%	63.41%
2005*(2)	4.22%	7.38%	14.76%	70.47%
2006	1.32%	6.08%	16.67%	74.60%
2007	3.23%	7.44%	14.64%	72.21%
2008	3.54%	5.53%	18.14%	67.92
2009	4.38%	9.14%	17.33%	65.52
2010*(3)	4.01%	8.01%	18.21%	67.21%
2011	2.20%	6.59%	19.16%	68.86%
2012	4.44%	7.71%	23.13%	61.92%
2013	4.91%	9.83%	21.55%	59.98%
2014	5.38%	8.96%	19.92%	58.57%

(1) Buffer pool 9 days at 498 ft. in March and at 494 ft. for most of March
(2) Buffer Pool 498 ft. from most of March, 505 ft. for most of April, and 505 ft. for half of month of July.
(3) Buffer Pool at 494 ft. for March and most of April and at 498 ft. for one half of March
Source: SAWA 2015

Southwestern willow flycatcher (flycatcher)

The species has not been reported in the Prado Basin during the winter flood season, during the time when the Proposed Action would occur. Therefore, the Planned Deviation would not be expected to have any direct effects to the species.

As shown in Figure 10, a total of 26 flycatchers have been reported in the Prado Basin between 2003 and 2015. All of the reported sightings have been reported above elevation 505 ft. Given the few numbers of flycatchers that have occurred in the Prado Basin and that those that have been reported have occurred above the 505 ft. elevation, there would be very low potential that implementation of the Planned Deviation would not have any effects to flycatchers from potential temporary alteration of nesting habitat.

Western yellow-billed cuckoo (cuckoo)

The cuckoo is a migratory bird species that is rarely reported in the Prado Basin. The most recent sighting was in 2011. As shown in Figure 10, the most recent sighting of the cuckoo was in 2011. Prior to 2011 the most recent reporting was in 2000. Both of these birds were thought to be transient individuals and not an annual resident within the basin. Based on the rarity of the species occurring along with the historic infrequency of water being stored between elevation 498 ft. and elevation 505 ft., implementation of the Planned Deviation would not affect the cuckoo or its nesting patterns.

Coastal California gnatcatcher (gnatcatcher)

The gnatcatcher occurs in higher upland areas that contain coast sage habitat. The species would not be affected by any pooled water, additional days of inundation or release rates from Prado Dam associated with the Planned Deviation.

Santa Ana sucker (sucker)

Since 2008 no suckers have been reported in the Prado Basin and only a few individuals have been reported in the Santa Ana River Reach 9 area. The fish spawns from late March to early July, peaking in late May and June. The Planned Deviation would not be expected to directly affect spawning since it would be completed well before spawning season begins. Given the lack of presence of this species within the Action Area in recent history along with the marginal habitat conditions and high populations of exotic predatory fish, the potential for populations of suckers to occur in the Action Area would be low. In the unlikely event individual suckers find their way into the Action Area, or get washed downstream into Reach 9, neither the increased pooling, additional days of inundation, the target release rates or increased sedimentation (see Sections 5.1.4) would affect them.

5.1.2 Effects to Critical Habitat from Increased Pooling

Least Bell's Vireo Critical Habitat

The Planned Deviation would allow water to be stored up to 505 ft. during the flood season, which means there could be higher elevation pooling and additional days of inundation in the Prado Basin over the current condition. As shown in Table 14, between 470 ft. and 505 ft. there are approximately 1,469 acres of vireo critical habitat within the Prado Basin, of which 1,384 acres are cottonwood/willow primary constituent habitat elements. Presently, the vireo critical habitat areas between elevation 470 ft. and elevation 505 ft. are inundated during the non-flood season as part of the existing water conservation activities at Prado Dam, and have the potential to be inundated year-round for flood control operations. Therefore, the implementation of the Planned Deviation would not increase the amount of critical habitat lands that could be potentially inundated.

Table 14: Vegetation Communities within Vireo and Flycatcher Critical Habitat 470 ft. to 505 ft. (acres)

Vegetation Community	Vireo Critical Habitat	Flycatcher Critical Habitat
Open Water	25.71	0
Primary Constituent Habitat Elements	1,384.1	.77
Other Vegetation Communities	59.3	0
Total	1,469.1	.77

The growing season within Prado Basin for the most part begins in March and extends through the summer. Presently, water can be stored up to 505 ft. during the non-flood season, which overlaps into the growing season. The data in Table 15 identifies the existing average days of inundation at various elevations in the Prado Basin during the growing season and the number of additional days of inundation that would occur from the implementation of the Planned Deviation. As shown in Table 15, implementation of the Planned Deviation would not substantially increase the average number of days that the habitat is currently inundated during the growing season.

Table 15: Days of Inundation Occurring During Growing Season

Elevation	470	480	490	494	498	500	505	510	520	530	540
Existing Average Annual Days of Inundation During Growing Season	40 to 67	37 to 64	34 to 61	27 to 51	23 to 40	17 to 33	1 to 2	0	0	0	0
Additional Average Days of Inundation During Growing Season With Water Conservation Measure	3 to 10	3 to 11	2 to 11	3 to 13	3 to 11	3 to 9	1	0	0	0	0
Low Range Based on 500 cfs Release rate High Range Based on 350 cfs Release rate Source: Supplemental Water Conservation Analysis, Michael Baker International Company, 2015											

The most common primary constituent elements of critical habitat for the vireo within the Prado Basin are mulefat and black willow. Mulefat is a perennial evergreen that would not defoliate unless under stress. Willow species are known to have high inundation tolerances and black willows are known to have especially high inundation tolerances when they are in a period of dormancy, which correlates with winter or the flood season. As part of the OCWD's ongoing Habitat Restoration Monitoring Program conducted at Prado Basin, habitat conditions are documented photographically during unusually wet periods to help evaluate the effects that extended periods of inundation has on the health of habitat in the basin. During the months of December and January of the

2010/2011 flood season the water surface elevation in the Prado Basin ranged 497 ft. to a high of 529 ft. During the month of March of 2011, the water surface elevation ranged from 494 ft. to 498 ft. and was at 498 ft. for most of April 2011. The habitat conditions at these elevations were photographed at Monitoring Stations 8 and 10 in 2011, 2012, 2013 and 2014 and are shown in Figure 11 and Figure 12. As shown in Figures 11 and 12, in 2011 the habitat was completely submerged and by early 2012 the habitat began to recover from the inundation and became healthier each subsequent year. The monitoring of the habitat shows that periodic inundation did result in permanent damage to the habitat.

Another measurement to determine the health and biological values of habitat areas would be wildlife usage. Within the last 17 years, the two wettest back to back years was in 2004 and 2005. As shown in Table 13, in 2004 and 2005 after back to back wet years, there was a decrease in vireo territories reported below 498 ft. and an increase in nesting territories at the higher elevations. The reduced wildlife usage below 498 ft. suggests that the habitat in that area experienced reduced biological values, most likely from the wetted conditions occurring in the Prado Basin after back to back wet years. However, in subsequent years during drier periods a steady increase in the amount of vireo territories was reported at lower elevations in the Prado Basin. These increases in wildlife usage at the lower elevations suggest that the biological values of the habitat recovered with the dryer conditions. These reporting levels indicate that the increased pooling and additional days of inundation occurring during the flood season did not result in long term damage to the habitat where it was no longer considered suitable habitat for wildlife usage.

The potential for increased pooling and additional days of inundation to occur within critical habitat areas would be a temporary effect. Because previous surveys have shown no long term damage to habitat or substantial reductions in wildlife usage of the habitat occurred when the buffer pool has extended into the growing season, the increased pooling and additional days of inundation may affect, but would not adversely affect critical habitat. To ensure that the Planned Deviation would not substantially degrade the value of primary constituent elements within critical habitat areas, OCWD would continue to monitor the health of the riparian habitat between 498 ft. and 505 ft. before and after inundation occurs. In the event the monitoring program indicates that the primary constituent elements are substantially degraded, it is proposed that the degraded habitat would be replaced or restored within the same area. If it is determined that the degraded area is no longer suitable for supporting riparian habitat, then the same acreage of habitat would be planted or restored within OCWD lands in another part of Prado Basin, unless another area is approved by USFWS. With the implementation of the Habitat Monitoring Program and Conservation Measure BIO-5 there would be no potential loss of critical habitat, and no long-term or permanent degradation.

Monitoring Station 8 2011 Habitat Conditions 498 ft to 505 ft Elevation

Monitoring Station 8 2012 Habitat Conditions 498 ft to 505 ft Elevation

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Prado Basin Feasibility Report
Monitoring Station 8 Habitat Conditions

Figure 11-1

Monitoring Station 10 2011 Habitat Conditions 505 ft Elevation

Monitoring Station 10 2012 Habitat Conditions 505 ft Elevation

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Prado Basin Feasibility Report
Monitoring Station 10 Habitat Conditions

Figure 12-1

Monitoring Station 8 2013 Habitat Conditions 498 ft to 505 ft Elevation

Monitoring Station 8 2014 Habitat Conditions 498 ft to 505 ft Elevation

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Prado Basin Feasibility Report
Monitoring Station 8 Habitat Conditions

Figure 11-2

Monitoring Station 10 2011 Habitat Conditions 505 ft Elevation

Monitoring Station 10 2012 Habitat Conditions 505 ft Elevation

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Prado Basin Feasibility Report
Monitoring Station 10 Habitat Conditions

Figure 12-1

Monitoring Station 10 2013 Habitat Conditions 505 ft Elevation

Monitoring Station 10 2014 Habitat Conditions 505 ft Elevation

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Prado Basin Feasibility Report
Monitoring Station 10 Habitat Conditions

Figure 12-2

Southwestern Willow Flycatcher Critical Habitat

There is a total 1,493 acres of area in the Prado Basin that are designated critical habitat for the flycatcher. As shown in Table 11, there are approximately .77 acres of flycatcher critical habitat between 498 ft. and 505 ft. of which all is considered primary constituent elements for the flycatcher. The amount of flycatcher critical habitat between elevation 498 ft. and elevation 505 ft. is minimal compared to the overall amount of flycatcher critical habitat within the Prado Basin. Presently, the flycatcher critical habitat in areas between elevation 498 ft. and 505 ft. elevation is subject to inundation year-round as necessary for flood control operations, and during the non-flood season as part of the existing water conservation activities at Prado Dam. Due to the intermittent occurrence of the flycatcher, it is difficult to evaluate flycatcher usage during periods when the critical habitat would be inundated. Because the primary constituent elements that manifest themselves in flycatcher critical habitat and vireo critical habitat are similar, it would be reasonable that vireo usage is a good indicator to determine the heath of flycatcher critical habitat after periods of inundation. The vireo wildlife usage reporting levels within similar primary constituent elements indicates that the increased pooling and additional days of inundation occurring during the flood season did not result in long term damage to the habitat. Because previous surveys in similar primary constituent elements have shown no long term reductions in wildlife usage of the habitat when the buffer pool has overlapped into the growing season, it is reasonable to assume that the potential effects to critical habitat associated with additional days of inundation due to the Planned Deviation would not be adverse. No long-term or permanent degradation of critical habitat would occur. Due to the limited number of flycatcher in the basin, the species would not be affected by temporary changes in habitat within the buffer pool area.

To ensure that the Planned Deviation would not substantially degrade the value of primary constituent elements within critical habitat areas, OCWD would continue to monitor the health of the riparian habitat between elevation 498 ft. and elevation 505 ft. before and after inundation occurs. In the event the monitoring program indicates that the primary constituent elements were substantially degraded, it is proposed that the degraded habitat would be replaced or restored within the same area. If it is determined that the degraded area is no longer suitable for supporting riparian habitat, then the same acreage of habitat would be planted or restored within OCWD lands in another part of Prado Basin, or other areas approved by USFWS.

Western Yellow-Billed Cuckoo Critical Habitat

Critical habitat for the Western yellow-billed cuckoo was proposed in 2014. Presently, the current ruling is being revised by USFWS. The final ruling is expected sometime in 2017. Because the habitat composition of the critical habitat for the cuckoo would be similar to the critical habitat for the vireo and flycatcher, potential effects from pooling would not be adverse. No long-term or permanent degradation of critical habitat would occur. Due to the limited number of cuckoo in the Basin, the species would not be affected by temporary changes in habitat within the buffer pool area.

Coastal California Gnatcatcher Critical Habitat

The gnatcatcher critical habitat occurs on the terraces along Reach 9. The increased pooling within the Prado Basin would have no effect on critical habitat for the gnatcatcher along Reach 9.

Santa Ana Sucker Critical Habitat

There is no sucker critical habitat within the Prado Basin. The increased pooling within the Prado Basin would have no effect on sucker critical habitat.

5.1.3 Effects to Critical Habitat from Sedimentation

Least Bell's Vireo Critical Habitat, Southwestern Willow Flycatcher Critical Habitat

The following analysis is based on information contained in Appendix B: Prado Dam Planned Deviation, Santa Ana River Upstream Effects Due to Water Conservation, prepared by Scheevel Engineering in June of 2015. To quantify the additional sediment deposition that could potentially occur in the Prado Basin from the Planned Deviation, and the resulting effects to critical habitat, the following facts or assumptions were considered.

- Under existing conditions, there is approximately 0.5 to 0.7 ft. of sediment deposition annually along the Santa Ana River in the Prado Basin from approximately 2,000 feet upstream of Prado Dam to 15,000 feet upstream of the dam. (Note: This is an average roughly based on calculating changes in topographic data over several decades. In dry years, very little deposition would occur, whereas rare large storm events or very wet seasons may bring a large influx of sediment.)
- Currently, nearly all of the sediment that enters into the Prado Basin deposits and settles in the Prado Basin regardless of water conservation water surface elevations.
- The additional 10,500 acre feet of water in the Prado Basin will be held for a duration that allows silt and clay particles to settle out of the water column.
- Assumed that the TSS of the Prado storm water inflow is 2,000 mg/L. Historical data shows average Prado inflow storm water TSS to range between 500 to 2,000 mg/L.
- Assume that the silt and clay portion of the TSS is 20%.
- The silt and clay will deposit across a 1,890 acre area below 505 ft.

On average it is expected that the Prado Basin water surface elevation would reach or exceed, 505 ft. one time per year. An additional volume of 10,500 acre feet of water could be impounded by the Planned Deviation. Taking into the account the above assumptions it was calculated that, on average an additional 3,500 cubic yards of silt and clay sediments could deposit in Prado Basin each year due to the Planned Deviation. The estimated annual increase of 3,500 cubic yards resulting from the Planned Deviation represents a 0.3 percent increase in the annual sedimentation volume. Once into the Prado Basin, the silt and clay sediments would disperse over large areas due to their ability to stay suspended more easily than sand, gravel and cobbles. The approximate surface area of the Prado Basin below the 505 ft. contour is 1,890 acres. Due to turbulence in the Prado Basin created by wind action and tributary inflow it is anticipated that suspended clay and silt sediments would distribute evenly over the 1,890 acre pool area below 505 ft. If the silt and clay was distributed evenly across the 1,890 acres, there would be an average of 0.001 ft. per year of sediment deposition. The 0.001 ft. per year additional silt and clay sedimentation from the Planned Deviation would be considered negligible compared to existing baseline sedimentation rate between 0.5 and 0.7 feet occurring per year. The additional 0.001 of sediment would not reduce biological values of vireo or flycatcher critical habitat where the habitat would no longer be suitable for nesting. Therefore, no effects to critical habitat would occur. To ensure that the Planned Deviation would not substantially degrade the value of primary constituent elements within vireo and flycatcher critical habitat areas, OCWD would continue to monitor the health of the riparian habitat between 498 ft. and 505 ft. before and after inundation occurs. In the event the monitoring program indicates that the primary constituent elements were substantially degraded, it is proposed that the degraded habitat would be replaced or restored within the same area. If it is determined that the degraded area is no longer suitable for supporting riparian habitat, then the same acreage of habitat would be planted or restored within OCWD lands in another part of Prado Basin, or other areas approved by USFWS.

Western Yellow-Billed Cuckoo Critical Habitat

Critical habitat for the Western yellow-billed cuckoo was proposed in 2014. Presently, the current ruling is being revised by USFWS. The final ruling is expected sometime in 2017. Because the habitat composition of the critical habitat for the cuckoo is similar to the critical habitat for the vireo and flycatcher, no effect to critical habitat would occur.

Coastal California Gnatcatcher Critical Habitat

The gnatcatcher critical habitat occurs on the terraces along Reach 9. The potential increased sedimentation occurring within the Prado Basin would have no effect on critical habitat for the gnatcatcher along Reach 9.

Santa Ana Sucker Critical Habitat

There are no lands within the Prado Basin that are designated critical habitat for the sucker. Presently, critical habitat lands are designated along the Santa Ana River upstream of the Prado Basin starting at the Hammer Avenue Bridge crossing and downstream from Prado Dam to Imperial Highway.

5.1.4 Effects to Santa Ana Sucker Critical Habitat Upstream Prado Basin

The following analysis is based on a report that evaluates Prado Basin and Upstream Santa Ana River morphology trends between 498 ft. and 505 ft. The report is presented in Appendix C. The analysis evaluates potential effects to existing riparian and native fish habitats along the Santa Ana River between Prado Dam and the Hamner Avenue crossing associated with the implementation of the Planned Deviation. A combination of historical topographic surveys, aerial imagery, recent sediment transport models, and historical data was used to estimate long-term changes to river morphology and habitats along the Santa Ana River and in the Prado Basin between Prado Dam and the Santa Ana River/Hamner Avenue crossing.

Presently, the substrate of the Santa Ana River between Prado Dam and the Hamner Avenue crossing consists of a large percentage of sand with some clays and silts. Historical imagery from 1929 through 1967 shows that the reach of the Santa Ana River between Prado Dam and the Hamner Avenue crossing was largely composed of a large percentage of sand. To this date, this condition has not changed.

The present day substrate conditions along the Santa Ana River between Prado Dam and the Hamner Avenue crossing are primarily influenced by inflows into Prado Basin, sediment transport interruption, and the presence and proliferation non-native vegetation and non-native aquatic species.

On average it is expected that the Prado Basin water surface elevation would reach or exceed, 505 ft. one time per year. An additional volume of up to 10,500 acre feet of water could be impounded under the Planned Deviation. An additional 3,500 cubic yards of silt and clay sediments could deposit annually in Prado Basin from the Planned Deviation. The annual average volume of all sediment types deposited in the Prado Basin is 1,200,000 cubic yards. The estimated increase of 3,500 cubic yards resulting from the Planned Deviation represents a 0.3 percent increase in the annual sedimentation volume.

The potential effect to habitat along the Santa Ana River from the sedimentation would be limited to a 4,000 foot long stretch of the river below elevation 505 ft. There is not any critical habitat for the sucker along this reach of the Santa Ana River. Therefore, the potential increase in sedimentation would have no effect on sucker habitat upstream of Prado Basin. There is currently no defined river channel or native fish habitat in this stretch of the river within the Prado Basin. This river area consists primarily of sandy bottom braided streams with adjacent and over-hanging riparian habitat. The primary grain size of the additional clays and silts would be fine grained which would disperse over large areas, causing no measurable increase to back water or marsh habitat along the Santa Ana River. The additional silt and clay sedimentation caused from the Planned Deviation would not have an adverse effect on the habitat of the river. There would also be approximately 14,000 cubic yards of sand transported into Prado Basin as suspended sediment with each 10,500 acre feet of water. The estimated 14,000 cubic yards of sand would be a small fraction of the total sediment transported into the Prado Basin, as there would be a high volume of sediment transported into the Prado Basin as bed load. A fundamental assumption would be that all suspended sand and sand transported into the Prado Basin as bed load would be heavy enough to be deposited in the Prado Basin regardless of water conservation operations. Once bed load sediments enter into a relatively tranquil body of water the bed load material tends to deposit quickly and relatively close to the high energy stream system which delivered it. Prado Basin surveys between 1988 and 2008 show that the greatest deposition in the Prado Basin occurs along the segment of the Santa Ana River between 505 ft. and 524 ft. To off-set the sediment deposition from the Planned Deviation and the two previously approved temporary Deviations OCWD would remove 24,500 cubic yards of sediment.

Analysis of Potential Effects to River Gradient

The potential upstream effects to the Santa Ana River gradient due to increases in water surface elevation were evaluated in a one-dimensional sediment transport analysis conducted by Golder Associates, Inc. The Technical Report is presented in entirety in Appendix D.

The sediment transport model extended from the Riverside/San Bernardino County line, downstream, to the discernible end of the Santa Ana River in the Prado Basin. Two scenarios were modeled to compare the effects of increasing the flood season water surface elevation from 498 ft. to 505 ft., an increase of seven feet. The two scenarios are the current operating condition of maintaining the buffer pool at 498 ft. during the flood season and 505 ft. during the non-flood season and under the Planned Deviation of maintaining the buffer pool at 505 ft. year round.

The results of the sediment transport model for the existing condition (flood season water surface elevation of 498.0 ft.) indicated that there would be a general trend of aggradation from above the I-15 Freeway crossing, extending downstream into Prado Basin. Aggregation over a 10 year time period would be expected to range from 1 foot to 9 feet in depth. Based on the model results, the river bed around River Road Bridge would be expected to experience the most aggradation which would be consistent with what has been observed historically.

The model for the increased water surface elevation scenario (flood season water surface elevation of 505. ft.) exhibits nearly identical aggradation trends as the existing condition model. The only expected difference in the sediment deposition trends between the two scenarios would be a slight increase in deposition within Prado Basin between the 498 ft. and 505 ft. elevation contours. Based on historical topographic surveys there is approximately 1,000 to 2,000 linear feet of area between the 498 ft. and 505 ft. contours. If the flood season water surface elevation is increased to elevation 505 ft., then transient periods of increased aggradation could occur between elevation 498 ft. and 505 ft., as high flow events coincide with periods of increased water surface elevation. During periods where high flow events coincide with relatively low water surface elevation, the aggradation trends would tend to revert back to historically observed conditions. A portion of the sediment deposited between elevations 498 ft. and 505 ft. would be transported below elevation 498 ft. when high flow events coincide with relatively low water surface elevation. It is important to note that once the water conservation pool is filled to the maximum water surface elevation it is then drained as quickly as possible to create storage volume for subsequent storms. This mode of operation reduces the frequency of occurrence when the maximum water conservation water surface elevation coincides with high flow events.

The sediment transport model results also show that there would be no appreciable change to the river bed gradation due to the increased water surface elevation. The general trend for both scenarios is that there would be deposition of primarily fine to medium sand from above the I-15 Freeway crossing, extending downstream into Prado Basin. The overall quantity of sediment and sediment particle size distribution entering Prado Basin would be the same for both water surface elevation scenarios. The alteration to the Santa Ana River morphology caused by the proposed flood season increase to the water surface would likely be limited to the spatial distribution sediments between elevations 498 ft. and 505 ft. and would have no effect on the gradient of the river upstream of 505 ft., and no effect to Santa Ana Sucker critical habitat upstream of Prado Basin.

5.1.5 Effects to Santa Ana Sucker Critical Habitat Downstream of Prado Basin

The following analysis is based on information provided in Prado Dam Planned Deviation, Santa Ana River-Downstream effects Due to Planned Deviation prepared by Scheevel Engineering, June of 2015. The report is presented in Appendix E.

Critical habitat area for the sucker extends along Reach 9 of the Santa Ana River from Prado Dam to Imperial Highway. At the Prado Dam outlet structure to the Green River Golf Course the river has a relatively flat slope. Within this reach the river flow is perennial and the floodplain is covered with riparian vegetation. The banks are moderately incised with vegetated islands that dot the main channel. Near the Green River Golf Course the slope increases and the river becomes more incised. The Corps Santa Ana Sucker Perennial Stream Restoration Project is located in this reach.

Between the Green River Golf Course and Imperial Highway the flood plain becomes much more expansive with several flow splits forming natural islands. Riparian vegetation is mostly concentrated near the river bank. The bed material along Reach 9 is much coarser consisting of gravels and cobbles compared to the sandy bed material of the river above Prado Dam. The dominant bed form in this reach is pool-riffle, where high gradient high velocity riffles flow into low gradient low velocity pools. Additionally, there are several stretches where the river has a plane bed, where the gradient and velocity are approximately constant and the river bottom material is dominated by gravel and cobble. This reach contains primary constituent elements that define critical habitat for suckers.

The implementation of the Planned Deviation could increase pooling within the Prado Dam during the flood season. Flood risk management operations would dictate the release rate from the Prado Dam. In general, the Corps uses forecast models and storm water runoff models to predict the Prado Basin inflow and resultant water surface elevation of a given storm/storm system, then the Corps adjusts the release rate to achieve certain water surface elevation before, during and after a given storm event (Scheevel, 2016, Appendix E).

Once the Prado Basin water surface elevations are within the buffer pool elevations, the release rates are typically reduced to help facilitate groundwater recharge operations downstream. The exception to this mode of operations is, when a significant storm event is forecasted and there is still water in the buffer pool, then the Corps would release water at higher rates to evacuate the buffer pool to create storage volume for forecasted inflows. In general, the Corps uses forecast models and storm water runoff models to predict the Prado Basin inflow and resultant water surface elevation of a given storm/storm system, then the Corps adjusts the release rate to achieve certain water surface elevation before, during and after a given storm event.

The need to rapidly evacuate the buffer pool occurs when there is a forecasted storm event of substantial intensity that has the potential to exceed flood risk management operational water surface elevations. In some previous planning and feasibility studies the allotted time to drain the buffer pool was 24 hours. This time allotment was partially based on forecast model capabilities at the time the water control manual was written. Storm system forecasting has improved substantially with the development of advance weather forecast modeling, and has allowed the Corps to have enough advance notification to adequately drain the buffer pool at relatively non-damaging release rates of 2,500 cfs to 5,000 cfs.

The duration required to drain the buffer pool is based on the beginning storage volume, Prado Basin inflow and Prado Basin outflow. Each storm event is different, but in general the Prado Basin inflow after the storm systems has passed (and after the peak of the inflow hydrograph occurs) tends to reach 200 to 400 cfs within 1 to 3 days and then continues to decline over time until the next storm event occurs. In order to calculate the average time to evacuate the buffer pool an inflow of 300 cfs has been used as the Prado Basin inflow rate. Two Basin outflow release rates have been analyzed to provide a range of buffer pool evacuation durations; a minimum 2,500 cfs and a probable maximum 5,000 cfs. The probable maximum rate of 5,000 cfs was identified because that is the maximum release rate typically targeted when downstream construction activity is occurring, which would be occurring during the duration of the Planned Deviation. The two release rates scenarios are shown in Table 16 and Table 17. The two buffer pool evacuation models assume that a second significant storm occurs immediately after an initial storm that fills the buffer pool volume, in reality this is a rare occurrence. It is important to note that a fundamental water conservation operational objective is to drain the water conservation pool as quickly as possible in order to make storage volume available for subsequent storm flows. This objective reduces the recurrence interval of instances when the full buffer pool volume must be evacuated due to a subsequent storm event. Both tables show that pool could be drained at reduced release rates in a few days and the additional water that could be stored under the Planned Deviation would not require significantly higher water release rates to adequately drain the pool in advance of pending storm events.

Table 16: Buffer Pool Evacuation Durations at 2,500 cfs Outflow

	Annual Sedimentation Rate Between Elev. 490.0 to 505.0	Available Water Storage Volume Between Elev. 490.0 to 505.0	Basin Inflow	Basin Outflow	Days to Drain Water Conservation Volume From Elev. 505.0 to 490.0
Year	**(aft/yr.)**	**(aft)**	**(cfs)**	**(cfs)**	**(days)**
1988	200	21,066	300	2,500	4.8
2008	200	17,326	300	2,500	4.0
2015	200	15,926	300	2,500	3.7
2020	200	14,926	300	2,500	3.4
2025	200	13,926	300	2,500	3.2
2030	200	12,926	300	2,500	3.0
2035	200	11,926	300	2,500	2.7
2040	200	10,926	300	2,500	2.5
2045	200	9,926	300	2,500	2.3
2050	200	8,926	300	2,500	2.0
2055	200	7,926	300	2,500	1.8
2060	200	6,926	300	2,500	1.6
2065	200	5,926	300	2,500	1.4
2070	200	4,926	300	2,500	1.1
2075	200	3,926	300	2,500	0.9
2080	200	2,926	300	2,500	0.7

Source Scheevel, 2016, Downstream C.

Table 17: Buffer Pool Evacuation Durations at 5,000 cfs Outflow

	Annual Sedimentation Rate Between Elev. 490.0 to 505.0	Available Water Storage Volume Between Elev. 490.0 to 505.0	Basin Inflow	Basin Outflow	Days to Drain Water Conservation Volume From Elev. 505.0 to 490.0
Year	**(aft/yr.)**	**(aft)**	**(cfs)**	**(cfs)**	**(days)**
1988	200	21,066	300	5,000	2.3
2008	200	17,326	300	5,000	1.9
2015	200	15,926	300	5,000	1.7
2020	200	14,926	300	5,000	1.6
2025	200	13,926	300	5,000	1.5
2030	200	12,926	300	5,000	1.4
2035	200	11,926	300	5,000	1.3
2040	200	10,926	300	5,000	1.2
2045	200	9,926	300	5,000	1.1
2050	200	8,926	300	5,000	1.0
2055	200	7,926	300	5,000	0.9
2060	200	6,926	300	5,000	0.7
2065	200	5,926	300	5,000	0.6
2070	200	4,926	300	5,000	0.5
2075	200	3,926	300	5,000	0.4
2080	200	2,926	300	5,000	0.3
Source: Scheevel, 2016, Downstream C.					

Downstream erosion effects along the lower Santa Ana River have been analyzed and modeled multiple times for various studies and projects. This analysis utilizes past efforts to estimate the effects that the water release rates from the Planned Deviation could have on the Santa Ana Sucker habitat along the lower Santa Ana River (Scheevel, 2016, Appendix E). Two independent studies have been identified that evaluated how flow velocities can create erosion of coarse sediments (gravel and cobbles), and potential damage to fish habitat along the Santa Ana River Reach 9 between Prado Dam and Weir Canyon.

In a 2001 Biological Opinion (FWS-SB-909.6) prepared for the Prado Mainstem and Santa Ana River Reach 9 Project, it was noted that the Corps determined through fixed bed modeling that flow velocities greater than 6 feet per second (ft./sec) along Reach 9 could have a damaging effect on riparian and fish habitat. Furthermore it was determined that flow releases from Prado Dam of 5,000 cfs or less were generally not capable of creating velocities greater than 6 ft./sec in Reach 9 (USFWS BO 2001).

In 2014 OCWD employed Golder Associates to perform a sediment transport model of the lower Santa Ana River in conjunction with the Prado Basin Sediment Management Demonstration Project. The Reach 9 portion of the analysis revealed that flow velocities greater than 4 ft. /sec could cause gravel to mobilize and flows greater than 10 ft. /sec may cause cobbles to mobilize (Scheevel, 2016, Appendix E).

Given the above analysis it has been assumed that any flow velocities greater than 5 ft. /sec could cause erosion and habitat damage through Reach 9. A HEC-RAS hydraulic model was developed to determine the worst case scenarios for a Prado Dam release rate of 2,500 cfs and 5,000 cfs for the Planned Deviation. The average velocity in Reach 9 at a flow rate of 2,500 cfs would be 3.7 ft. /sec and the average velocity in Reach 9 at a flow rate of 5,000 cfs would be 4.2 ft. /sec. At 5,000 cfs existing sands and silt would mobilize and would be conveyed to downstream reaches of the river and existing rocks and gravel would redeposit within the Santa Ana Canyon (Scheevel, 2016, Appendix E). Given the current coarse gradation of the Reach 9 riverbed, the recent Reach 9 improvements, the recurrence interval of rapid buffer pool evacuation events, and the anticipated current and future release rates and durations required to evacuate the buffer pool elevation, no substantial changes to Santa Ana sucker critical habitat primary constituent elements are expected to occur from the Planned Deviation. Additionally, the Corps Santa Ana Sucker Perennial Stream has been designed to withstand flows up to 6,000 cfs. Therefore, Santa Ana sucker perennial stream habitat would not be expected to sustain damage in the event of a release rate of 5,000 cfs occurs. Water conservation activities would not result in increased sediment deposition above the 505 ft. elevation, no increased deposition would occur in designated critical habitat upstream of Prado Basin, and no increased erosion would occur in designated critical habitat downstream of Prado Basin. Therefore, no effects to sucker critical habitat would occur as a result of the Planned Deviation.

5.2 Sediment Removal Demonstration Project

5.2.1 Effects to Federal Listed Species

Least Bell's vireo (vireo) and Southwestern willow flycatcher (Flycatcher), Western yellow-billed cuckoo (Cuckoo)

Construction of Sediment Management Channel and Access Road

The vireo, flycatcher and cuckoo all occur in riparian habitats along watercourses where dense growth of willow trees, cottonwood trees, mulefat and other dense riparian plants are present. The Action Area contains suitable habitat for all three species. A total of 120,000 cubic yards of sediment would be removed from the sediment removal channel by a combination of dry excavation and dredging activities. The construction of the sediment removal channel and access road would require the removal of all vegetation within these areas and these areas would be kept clear of vegetation for the duration of the demonstration project. All of the vegetation removal activities would occur outside of the nesting season, as required by Conservation Measure BIO-1. Therefore, the Sediment Removal Demonstration Project may affect, but not likely to adversely affects to nesting vireos, flycatchers and cuckoos.

The construction of the sediment removal channel would temporarily remove 13.05 acres of arundo. The construction of the project access road would remove .48 acres of cottonwood/willow, .73 acres of arundo, .12 acres of non-native weeds, .20 acres mix coastal sage/non-native weeds, and .19 acres of eucalyptus. The construction of the sediment storage site .03 acres of mixed native/non-native riparian vegetation, .36 acres of mix coastal sage/non-native weeds and 20.16 acres of non-native weeds and grasses. The cottonwood/willow vegetation would be suitable nesting riparian habitat for the vireo, flycatcher and cuckoo. The removal of the riparian habitat would be a temporary effect. The amount of riparian habitat that would be temporarily removed would be minimal compared to the overall amount of suitable riparian nesting habitat that currently exists within the Prado Basin, and therefore any effects to these species related to habitat removal would not be adverse. The temporary effects to .48 acres of cottonwood/willow vegetation has been pre-mitigated by OCWD's ongoing arundo removal program, which begun in the summer of 2015. A .48 acre site adjacent to the east side of the project access road that previously consisted of arundo was restored with native habitat. Additionally, after the conclusion of the Sediment Management Demonstration Project native riparian vegetation would be established within the sediment removal channel and project access road by the OCWD and the OCWD would manage the area for a period of five years to ensure that non-native vegetation does not re-establish. As a result there would be no net temporary loss of nesting habitat. Implementation of Conservation Measures BIO-2 and BIO-3 would fully compensate for the temporary loss of riparian habitat within the Action Area.

Construction of Sediment Storage Site

To create suitable conditions for processing and storing the sediment, the sediment storage site would be graded and re-contoured. The site consists of non-native weeds and does not contain suitable habitat for the vireo, flycatcher or cuckoo. Therefore, no direct effects would occur. Additionally, the construction activities would occur outside of the nesting season. Therefore, no indirect construction noise effects would occur to nesting birds that might be present in the nearby area.

Sediment Removal Activities

After all of the vegetation is removed, the sediment would be removed from the sediment area by a combination of dry excavation and from heavy construction equipment and from a floating dredge. The sediment removal activities would occur outside nesting season. Therefore, no indirect construction noise effects to nesting vireos, flycatchers and cuckoos would occur.

Coastal California Gnatcatcher (gnatcatcher)

The sediment removal activities would not occur on lands that contain suitable nesting habitat for gnatcatchers. Therefore no direct impacts or indirect construction noise effects to gnatcatchers would occur.

Santa Ana Sucker (sucker)

The sediment removal activities would occur within the wetted channel of the Santa Ana River. Based on the lack of occurrence of suckers in the Prado Basin, poor habitat conditions within and upstream of Prado Basin and high populations of exotic predatory fish, the potential for populations of suckers to occur at the sediment removal channel would be very low. In the event isolated suckers wash or swim into the sediment removal channel it would be likely they would swim away from where the sediment removal activities would be occurring. The potential that individual isolated suckers could inadvertently find their way into the sediment removal channel, where turbidity levels would be higher and less suitable for the sucker would be considered a temporary effect. However, because of the high likelihood that the suckers would swim away from the sediment removal activities, the temporary effect would not be adverse. To prevent even the slightest chance of affecting spawning fish, Conservation BIO-4 would be implemented, which requires sediment removal activities to be conducted outside of the spawning season. With the implementation of Conservation Measure BIO-4, direct effects to spawning fish would be avoided. Sediment removal activities may affect, but are not likely to adversely affect Santa Ana sucker.

5.2.2 Effects to Critical Habitat

Least Bell's Vireo Critical Habitat, Southwestern Willow Flycatcher Critical Habitat

The construction of the sediment removal channel would directly impact 13.05 acres of arundo that are on lands designated critical habitat for the vireo and .88 acres of arundo on lands designated as critical habitat for the flycatcher. Once the sediment removal activities are completed the sediment removal channel would be established with native riparian vegetation. Therefore, there would not be any permanent loss of critical habitat for the vireo or flycatcher associated with construction and the sediment removal channel.

A total of .48 acres of cottonwood/willow vegetation within vireo and flycatcher critical habitat would be temporarily removed for construction of the proposed access road between the sediment removal channel and the sediment storage site. These effects would be temporary because native vegetation would be re-established within the roadway alignment after the demonstration project has been completed. The temporary effects to.48 acres of critical habitat has been pre-mitigated by OCWD's ongoing arundo removal program. A .48 acre site adjacent to the east side of the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acre of native riparian habitat along the alignment of the project access road after the project is completed. As a result there would be no net loss of nesting habitat and no adverse effect. With the implementation of Conservation Measures BIO-2 to BIO-3 there would be no permanent or temporary loss or modification of vireo or flycatcher critical habitat from sediment removal activities.

Western Yellow-Billed Cuckoo Critical Habitat

Critical habitat for the Western yellow-billed cuckoo was proposed in 2014. Presently, the current ruling is being revised by USFWS. The final ruling is expected sometime in 2017. Because the habitat composition of the critical habitat for the cuckoo would be similar to the critical habitat for the vireo and flycatcher, the potential temporary effects from implementation of the Sediment Removal Demonstration Project would be similar and would not be adverse.

Coastal California Gnatcatcher Critical Habitat

The sediment removal activities would not occur on lands designated critical habitat for the gnatcatcher. Therefore, no effect to critical habitat for the gnatcatcher would occur.

Santa Ana Sucker Critical Habitat

There are no lands that are designated critical habitat for the sucker at the sediment removal channel, sediment storage site or along the project access road. Therefore, the implementation of the sediment removal activities would not result in direct or indirect effects to critical habitat for the sucker.

The sediment removal activities would occur within or directly adjacent to the active flow area of the Santa Ana River. After the sediment removal occurs, it is anticipated that the active flow area of the river would pass through the removal area and that a head cut would form. The term “head cut” represents a relatively sharp vertical face or scarp in the channel that moves upstream, translating the local incision depth as it moves. Head cuts typically occur in fine-grained cohesive clay and silt material. The common terminology for a similar morphologic feature in a channel comprised of coarse-grained non-cohesive materials, such as sand or gravel, are a “knick point.” A knick point has a milder inclination or slope compared to a “head cut. It is anticipated that channel incision and/or the propagation of a “head cut” upstream would help to increase the river gradient in this area and encourage fine too medium grained sediment (clay, silt and sand) to migrate into the area for future removal, while uncovering existing upstream deposits of gravel and cobbles where they exist, which could make portions of the streambed of the dredging limits somewhat more suitable for sucker occupation. These effects, however, are not expected to extend into designated critical habitat upstream of Hamner Road. A monitoring program would be implemented as part of the Sediment Management Demonstration Project to assess the degree of head cut formation, change in slope of the river bed, and other changes that could occur in sediment transport dynamics within the vicinity of the sediment removal area, downstream, and also upstream. The downstream and upstream areas of monitoring would extend as far as needed until there is no discernible change from the background or pre-existing condition.

5.3 Cumulative Effects

A cumulative impact is an “impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions (40 CFR 1508.7). Cumulative impacts can result from individually minor, but collectively significant, actions taking place over time (CFR 1508.7).

This section evaluates the potential for cumulative effects should the Planned Deviation occur in conjunction with (around the same time fame) with the Sediment Management Demonstration Project as well as with other ongoing or planned flood control operations, construction and habitat restoration activities that are reasonably expected to occur within the Action Area.

Past Actions

Since 1941 when Prado Dam was constructed there has been a number of improvements and surface water operational changes that have affected the amount of water stored behind the dam and the amount of improvements and operation changes to the water surface elevations. These changes have been analyzed in numerous environmental documents and biological opinions. Potential impacts to federally listed species and designated critical habitat from previous improvements and operational changes have been consulted on and have been adequately mitigated through the implementation of habitat restoration activities and wildlife management programs. These previous habitat restoration efforts and wildlife management activities have resulted in substantial increases in Least Bell’s Vireo populations in the Prado Basin, and general improvement of riparian habitat in and around the basin.

Present Actions

Prado Dam operations currently allow for the buffer pool to be held up to 505 ft. elevation during the non-flood season, and at 498 ft. during the flood season pursuant to a 2006 memorandum of Agreement with Orange County Water District. Prado Dam is operated for flood risk management with a secondary benefit of water conservation. There are multiple ongoing efforts in the Prado Basin and along Reach 9 of the Santa Ana River focused on flood risk management, habitat restoration and water conservation activities. These include several embankment improvements as well as ongoing arundo removal activities to enhance existing habitat within the Prado Basin and Reach 9. Additionally, the Orange County Water District is conducting ongoing maintenance activities within the Santa Ana River to maximize ground water recharge and is constructing new groundwater recharge in facilities in Orange County to help capture additional storm water.

Future Actions

Operations at Prado Dam could change in the foreseeable future. An update to the Prado Dam Water Control manual is planned once the Prado Dam spillway is raised to include the potential for increasing the basin perimeter to 566 ft. and to allow releases up to 30,000 cfs if needed. There is also an ecosystem restoration and water conservation feasibility study being prepared that is analyzing a range of activities including sediment management, habitat restoration and water conservation activities at Prado Dam. As a result of this study, future operational changes at Prado Dam could occur. Potential impacts from these future activities would be analyzed and consulted and where needed mitigation would be provided to minimize potential adverse impacts to special status species and sensitive habitat communities.

5.3.1 Cumulative Effects Vireo, Flycatcher, Cuckoo

The Planned Deviation in conjunction with existing flood management and water conservation activities at Prado Basin could cause increased pooling and additional days of inundation over the current condition. Late flood season inundation that persists into the nesting season could prevent vireos, flycatchers and cuckoos from nesting in lower locations in the Prado Basin, causing a greater percentage than usual to nest above 505 ft. If there are back-to-back wet years, this could occur for multiple nesting seasons. Surveys conducted in the Prado Basin have shown that during back–to-back wet years there was not a substantial reduction of vireos reported and that a large number of vireos redistributed and nested at locations higher than 505 ft. The surveys have shown that the effect of vireos of having to redistribute to higher locations did not result in any cumulative adverse effects or substantially reduced populations within the Prado Basin. In addition, surveys conducted during a nesting season that followed multiple wet years have not shown degraded habitat or reduced wildlife usage. The surveys also show as drier conditions occur the habitat recovers and wildlife usage increases in those areas that were previously inundated, indicating that adverse effects are temporary.

An additional 3,500 cubic yards of silt and clay sediments could be deposited annually in Prado Basin from the Planned Deviation. The estimated increase of 3,500 cubic yards resulting from the Planned Deviation would represent a 0.3 percent increase in the annual sedimentation volume. The approximate surface area of the Prado Basin below 505 ft. elevation contour is 1,890 acres. If the silt and clay would be distributed evenly across the 1,890 acres, there would be an average of 0.001 ft. per year of sediment deposition. The additional silt and clay sedimentation from the Planned Deviation would have no effect on the habitat. However, over time the depth of the sedimentation could cumulatively increase, potentially degrading habitat. With equivalent amounts of sediment removed by OCWD there would be no net cumulative increase in sediment deposition in the Prado Basin and no adverse cumulative effects in regards to the potential loss of nesting habitat.

Planned Deviation effects to habitat would not be worsened or magnified by the concurrent implementation of the sediment removal activities, ongoing flood control or existing water conservation activities. None of these activities are substantially reducing the amount of available nesting habitat above 505 ft. that vireo and other riparian obligate species could inhabit during periods of inundation, and any habitat effects from other projects would be or have been fully mitigated.

The Sediment Removal Demonstration Project would occur outside of the nesting season. No direct effects or indirect construction noise effects would occur to nesting vireos, flycatchers or cuckoos within the Action Area. The implementation of the Sediment Removal Demonstration Project would result in the temporary removal of .48 acres of suitable nesting habitat. The small amount of nesting habitat that would be temporary affected would be restored after sediment removal would be completed, and temporal losses would have already been fully compensated.

The sediment removal activities at the OCWD Diversion Channel and at the Sediment Management Project Demonstration Site would occur outside of the nesting season. No direct effects or indirect construction noise effects would occur to nesting vireos, flycatchers or cuckoos within the study area.

Implementation of the sediment removal activities at the OCWD Diversion Channel would not result in the temporary or permanent loss of nesting habitat. Therefore no cumulative impacts would occur in regards to the loss of nesting habitat.

Implementation of the Sediment Removal Project would result in the temporary removal of .48 acres of suitable nesting habitat. The .48 acres of nesting habitat has been pre-mitigated by OCWD’s ongoing arundo removal program. A .48 acre site adjacent to the east side of the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acre of native riparian habitat along the alignment of the project access road. As a result there would be no cumulative loss of nesting habitat.

5.3.2 Cumulative Impacts to Vireo, Flycatcher, Cuckoo Critical Habitat

Implementation of the Planned Deviation would not result in the permanent loss of critical habitat for the vireo, flycatcher or cuckoo. To ensure that the Planned Deviation would not substantially degrade the value of primary constituent elements within critical habitat areas, OCWD would continue to monitor the health of the riparian habitat between elevation 498 ft. and elevation 505 ft. before and after inundation occurs. In the event the monitoring program indicates that the primary constituent elements was substantially degraded, it is proposed that the degraded habitat would be replaced or restored within the same area. If it is determined that the degraded habitat is no longer suitable for supporting riparian habitat, then the same acreage of habitat would be planted or restored within OCWD lands or in another part of Prado Basin, or other areas approved by USFWS. With the implementation of the monitoring program there would be no potential loss of critical habitat. However, because the temporary effects could adversely affect vireo from nesting in critical habitat, the increased pooling may have an adverse effect on the species. Because there would be no loss of critical habitat, the effect would not be substantial.

Implementation of the Sediment Management Demonstration Project would temporarily remove .48 acres of vireo, flycatcher and proposed cuckoo critical habitat. The .48 acres of critical habitat has been pre-mitigated by OCWD's ongoing arundo removal program. A .48 acre site adjacent to the east side of the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acre of native riparian habitat along the alignment of the project access road after the project is completed. This acreage would be replaced within the study area, ensuring there would be no net loss of critical habitat. Therefore, the sediment removal activities would not incrementally contribute to cumulative effects that would result in the loss of critical habitat for the vireo, flycatcher or cuckoo. The scale, duration and intensity of effects from either or both actions, and the success of proposed mitigation, would not change regardless of whether or not the planned deviation and sediment removal activities occurred concurrently and in conjunction with other reasonably foreseeable actions. No significant cumulative effects are anticipated.

5.3.3 Cumulative Effects to Gnatcatcher

The gnatcatcher occurs in higher upland areas that contain coastal sage scrub habitat. The study area where the Planned Deviation and Sediment Management Project would be implemented all lack suitable habitat. The species would not be affected by the Planned Deviation or by the Sediment Management Demonstration Project. Therefore, implementation the Planned Deviation and Sediment Demonstration Project would not contribute to cumulative effects to the species.

5.3.4 Cumulative Effect Gnatcatcher Critical Habitat

The Planned Deviation and Sediment Management Project Demonstration Site would not occur on lands that are designated critical habitat for the gnatcatcher. No effects to critical habitat would occur.

5.3.5 Cumulative Effects to Santa Ana Sucker

The potential for populations of suckers to occur in the Action Area for the Planned Deviation would be very low. In the unlikely event isolated individual suckers occur, the suckers would not be affected by the increased pooling, additional days of inundation, increased silt or target release rates to recover flood storage capacity. Therefore, the implementation of the Planned Deviation would not result in cumulative adverse effects to the sucker.

The potential for populations of suckers to occur at the Sediment Management Project Demonstration Project Site would be very low. In the event individual isolated suckers find their way into the sediment removal channel, it is assumed that the suckers would swim away from the sediment removal activities to avoid areas of higher suspended sediment. Implementation of the Sediment Management Demonstration Project concurrently with Planned Deviation or other reasonably foreseeable actions would not result in adverse cumulative effects to the sucker.

5.3.6 Cumulative Impacts to Santa Ana Sucker Critical Habitat

Although, the study area contains marginal primary constituent elements for the sucker (presence of water with some overhanging vegetation but with unsuitable substrate) the potential for populations of suckers to occur within the Action Area would be very low.

The Planned Deviation in conjunction with existing flood management and water conservation activities at Prado Basin could result in additional silt and clay sediment depositing in the Prado Basin each year. The sediment from the Planned Deviation would deposit below the 505 ft. contour where no sucker critical habitat exists. Therefore, the occurrence of multiple wet years would not cumulatively affect sucker critical habitat in the Prado Basin. Critical habitat for the sucker is located upstream of the Hamner Avenue crossing. Sediment transport modeling reveals that no additional upstream deposition, reduction in slope or bed material alteration would occur from the Planned Deviation under a single year or multiple year scenarios. The anticipated release rates would not cause any substantial change to sucker critical habitat or result in any effects to the Corps sucker perennial stream mitigation site or other mitigation/restoration projects along Reach 9.

Critical habitat for the sucker is located upstream of the Hamner Avenue crossing and downstream of Prado Dam along Reach 9 of the Santa Ana River. The sediment removal activities at the Sediment Management Project Demonstration Site would not occur on lands that are designated critical habitat for the sucker. Therefore, implementation of the Sediment Management Demonstration Project would not contribute to adverse cumulative impacts to sucker critical habitat.

SECTION 6 CONCLUSIONS AND RECOMMENDATIONS

Based on a request from the Orange County Water District (OCWD), the U.S. Army Corps of Engineers (Corps) is proposing a Planned Deviation to the Prado Dam Water Control Plan to increase the flood season water surface elevation of the buffer pool behind Prado Dam from elevation 498 feet (ft.) to elevation 505 ft. for a period of five years, beginning with the 2017/2018 flood season. Additionally, OCWD is requesting a reduced release rate of 350 cfs on average from Prado Dam from March 1 to August 30. OCWD has also requested that the Corps grant real estate rights for its implementation of a Sediment Management Project. Under the Proposed Action, the OCWD would dredge and dispose of up to 120,000 cubic yards of sediment from the Prado Basin. Under the Proposed Action, the Corps would grant a temporary easement to allow OCWD to construct and access road and implement storage and handling of sediment on Corps property along with consent to easement in the area of the sediment removal channel. In order to undertake the Sediment Management Demonstration Project, OCWD must also obtain a Clean Water Act Section 404 permit from the Corps Regulatory Division. It is currently anticipated that the Sediment Management Demonstration Project would meet the criteria for Nationwide Permit 33. If it is later determined that an Individual Permit would be required for the Sediment Management Demonstration Project, the activities would not be undertaken prior to obtaining an Individual Section 404 Permit from the Corps and Section 401 Water Quality Certification from the Regional Water Quality Control Board.

This section identifies potential effects to Federally Listed Endangered Species, Threatened Species and critical habitat from the Planned Deviation and Sediment Management Demonstration Project and provides a recommendation on the determination on the level of potential effects. A summary of the issues of concern and recommended effects determination is provided in Table 18.

Special Status Species

Vireo

The Least Bell’s Vireo is present within the Action Area. Implementation of the Planned Deviation would not result in direct effects to the vireo. There is the potential that increased pooling from the Planned Deviation could extend into the beginning of the nesting season. When this has happened in the past in the Prado Basin, vireos territories that had historically occurred within the inundation zone redistributed to alternative nesting territories at higher elevations in the basin. Even though the redistribution of the vireos would not be expected to reduce populations of vireos nesting within the Prado Basin, the redistribution of the vireo territories would be considered a temporary adverse effect. This effect would be monitored and, if necessary, habitat impacts would be mitigated. The Corps has determined that the Planned Deviation may adversely affect the vireo, although the effect would not be substantial.

The proposed sediment removal activities would occur outside of nesting season. Therefore, no adverse direct effects or adverse indirect noise effects to vireos would occur. There would be a .48 acre temporary loss of nesting habitat associated with construction of the project access road. The temporary impacts to .48 acres of habitat have been pre-mitigated by OCWD's ongoing arundo removal program, which begun in the summer of 2015. A .48 acre area near the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acre of native habitat along the project access road after the project is completed. There would be no net loss of habitat. The Corps has determined that the Sediment Management Demonstration Project may affect, but not likely to adversely affect the vireo.

Flycatcher

The flycatcher has intermittently occurred in small numbers at the Prado Basin. The implementation of the Planned Deviation would not result in direct effects to the flycatcher. There is the potential that increased pooling could extend into the beginning of nesting season, however, because of the intermittent low population numbers and the propensity of flycatchers to occur above 505 ft., no adverse effects would be expected. The Corps has determined that the Planned Deviation would not affect the flycatcher.

The proposed sediment removal activities would occur outside of nesting season. Therefore, no adverse direct effects or adverse indirection noise effects to flycatchers would occur. There would be a temporary loss of nesting habitat associated with construction of the project access road. The temporary impacts to .48 acres of habitat have been pre-mitigated by OCWD's ongoing arundo removal program, which begun in the summer of 2015. A .48 acre near the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acre of native habitat along the project access road after the project is completed. There would be no net loss of habitat. The Corps has determined that the Sediment Management Demonstration Project may affect, but not likely to adversely affect the flycatcher.

Cuckoo

Within the last 15 years two Western yellow billed cuckoos have been reported within the Prado Basin. Because of the lack of frequency and transitory nature of the Western yellow billed cuckoos that have reported in the Prado Basin, the species is not considered a regular resident and the potential for the species to occur within the Action

Area would be very low. Therefore, the Corps has determined that the proposed Planned Deviation would not affect this species.

There would be a temporary loss of nesting habitat associated with construction of the project access road. The temporary impacts to .48 acres of habitat have been pre-mitigated by OCWD's ongoing arundo removal program, which begun in the summer of 2015. A .48 acre near the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acre of native habitat along the project access road after the project is completed. There would be no net loss of habitat. The Corps has determined that the Sediment Management Demonstration Project may affect, but not likely to adversely affect the cuckoo.

Gnatcatcher

The gnatcatcher occurs in higher upland areas that contain coastal sage habitat. The species would not be affected by increased pooled water and additional days of inundation from the Planned Deviation. Additionally, there is not any suitable habitat at OCWD Diversion Channel or at the Sediment Management Project Demonstration Site where sediment removal activities would occur. Therefore, the Corps has determined that the proposed Planned Deviation and Sediment Management Demonstration Project would not affect this species.

Sucker

The Action Area lacks suitable primary constituent habitat elements to support populations of sucker. Additionally, the Action Area contains high populations of exotic aquatic life that are predatory to the sucker, which would further reduce the potential for suckers to occur. Since 2009, only 3 suckers have been reported within the Action Area. Based on the lack of suitable habitat and high population of exotic aquatic life, the potential for populations of suckers to occur within the Action Area would be very low. In the event individual isolated sucker finds their way into the Action Area, neither the increased pooling, additional days of inundation, target release rates or increased sedimentation from the Planned Deviation would affect them. The Corps has determined that the Planned Deviation would not affect the sucker.

Dredging activities for the Sediment Management Demonstration Project would occur within the wetted channel of the Santa Ana River. There would be very low potential for suckers to occur where the sediment removal activities would be conducted. In the event individual isolated suckers find their way into the sediment removal channel, it is assumed the suckers would swim away from the sediment removal activities due to elevated levels of suspended sediment and other factors. However, even though it is very unlikely for suckers to occur, there is a potential that an undetermined number of suckers could swim into the sediment removal channel when sediment removal activities are occurring. The Corps has determined that the Sediment Management Demonstration Project may affect, but not likely to adversely affect the sucker.

Critical Habitat

Least Bell's Vireo Critical Habitat

There are approximately 507 acres of vireo critical habitat between elevations 498 ft. and 505 ft. These elevations in the Prado Basin are currently prone to inundation during the non-flood season as part of the existing water conservation activities at Prado Dam, and year-round as part of existing flood control operations. Therefore, the implementation of the Planned Deviation would not increase the amount of critical habitat lands that could be potentially inundated. Wildlife surveys conducted in the Prado Basin after back-to-back wet years have not shown significant long term reductions in wildlife usage of existing critical habitat that would affect vireo population dynamics. The Corps has determined that the Planned Deviation may affect but not likely to adversely affect critical habitat for the vireo.

Implementation of the Sediment Management Demonstration Project would not result in the permanent loss of critical habitat. Construction of the project access road would temporary remove .48 acres of riparian located within critical habitat areas. The temporary impacts to.48 acres of habitat have been pre-mitigated by OCWD's ongoing arundo removal program, which begun in the summer of 2015. A .48 acre area near the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acres of habitat along the alignment of the project access road after the project is completed. There would be no net loss of habitat. The Corps has determined that the Sediment Management Demonstration Project may affect, but not likely to adversely affect critical habitat for the vireo.

Southwester Willow Flycatcher Critical Habitat

There are approximately .77 acres of flycatcher critical habitat between elevations 470 ft. and 505 ft. These elevations in the Prado Basin are currently prone to inundation during the non-flood season as part of the existing water conservation activities at Prado Dam and year-round as part of existing flood control operations. Therefore, the implementation of the Planned Deviation would not increase the amount of critical habitat lands that could be potentially inundated. Wildlife surveys conducted in the Prado Basin after back-to-back wet years have not shown significant long term reductions in wildlife usage of existing critical habitat that would affect flycatcher population dynamics. The Corps has determined that the Planned Deviation may affect but not likely to adversely affect critical habitat for the flycatcher.

Implementation of the Sediment Removal Demonstration Project would result in the temporary loss .48 acres of critical habitat. The temporary impact to 48 acres of habitat has been pre-mitigated by OCWD's ongoing arundo removal program, which begun in the summer of 2015. A .48 acre area near the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acres of habitat along the alignment of the project access road after the project is completed. There would be no net loss of habitat. The Corps has determined that the Sediment Management Demonstration Project may affect but not likely to adversely affect critical habitat for the flycatcher.

Western Yellow Billed Cuckoo

The critical habitat designation for the Yellow Billed Cuckoo is expected to occur sometime in 2017. Based on the proposed ruling it appears portions of the critical habitat are proposed within the Action Area. Similar to critical habitat for the vireo, the critical habitat elevations for the cuckoo are currently prone to inundation during the non-flood season as part of the existing water conservation activities at Prado Dam and year-round as part of existing flood control operations. Therefore, the implementation of the Planned Deviation would not increase the amount of critical habitat lands that could be potentially inundated. Wildlife surveys conducted in the Prado Basin after back-to-back wet years have not shown significant long term reductions in wildlife usage of existing critical habitat that would affect flycatcher population dynamics. The Corps has determined that the Planned Deviation may affect but not likely to adversely affect critical habitat for the cuckoo.

Implementation of the Sediment Removal Demonstration Project would result in the temporary loss .48 acres of critical habitat. The temporary impact to 48 acres of habitat has been pre-mitigated by OCWD's ongoing arundo removal program, which begun in the summer of 2015. A .48 acre area near the project access road that previously consisted of arundo was restored with native habitat. Additionally, OCWD would restore .48 acres of habitat along the alignment of the project access road after the project is completed. There would be no net loss of habitat. The Corps has determined that the Sediment Management Demonstration Project may affect but not likely to adversely affect critical habitat for the cuckoo.

Gnatcatcher Critical Habitat

There is no lands designated critical habitat for the gnatcatcher where the Planned Deviation and Sediment Management Demonstration Project would be implemented. The Corps has determined that the Planned Deviation and Sediment Management Demonstration Project would not affect critical habitat for the gnatcatcher.

Santa Ana Sucker Critical Habitat

The Prado Basin is not within the limits of designated critical habitat for the Santa Ana sucker. Santa Ana sucker critical habitat lands are designated along the Santa Ana

River upstream and downstream of the Prado Basin. Sediment transport modeling conducted upstream and downstream of Prado Basin have shown that no substantial changes would occur to existing sucker habitat conditions from the Planned Deviation. The Corps has determined that the Planned Deviation would not affect critical habitat for the sucker.

The Prado Basin is not within the limits of designated critical habitat for the Santa Ana sucker. The Sediment Management Demonstration Project would not be implemented within critical habitat for the sucker. The Corps has determined that the Sediment Management Demonstration Project would not affect critical habitat for the sucker.

Table 18: Summary of Potential Effects

ISSUE OF CONCERN	***SPECIES***	***EFFECTS DETERMINATION***	***BASIS***
1. Planned Deviation:			
1a. Inundation of occupied nests or spawning grounds	Vireo	No Effect	Planned deviation is limited to the non-nesting season.
	Flycatcher	No Effect	Planned deviation is limited to the non-nesting season.
	Cuckoo	No Effect	Planned deviation is limited to the non-nesting season.
	Gnatcatcher	No Effect	Planned deviation is limited to the non-nesting season.
	Sucker	No Effect	Planned deviation would occur outside of the spawning season, and no suitable spawning habitat occurs between 498' and 505'.
1b. Increased days of inundation during the nesting/spawning season resulting in re-distribution of individuals or territories	Vireo	Likely to Adversely Affect Species (temporary, not substantial)	Prolonged inundation that would extend into the nesting season rarely occurs. When this has occurred in the past, overall vireo populations were stable or increased, despite the presence of a buffer pool. Also, most territories occur above 505'.
	Flycatcher	No Effect	Few occurrences in Prado Basin, all recent sightings have been above 505'. Prolonged inundation that

			would extend into the nesting season rarely occurs.
	Cuckoo	No Effect	Species rarely present; nesting not documented in recent years. Prolonged inundation that would extend into the nesting season rarely occurs.
	Gnatcatcher	No Effect	No or limited suitable nesting habitat occurs below 505'. Prolonged inundation that would extend into the nesting season rarely occurs.
	Sucker	No Effect	No suitable spawning habitat occurs between 498' and 505'. Presence of additional water within buffer pool zone would not improve or worsen conditions for species.
1c. Effects to critical habitat from increased pooling	Vireo	May Affect, Not likely to Adversely Effect	Monitoring of vegetation changes and replanting or restoration of affected areas will ensure that the Planned Deviation would not degrade the value of primary constituent elements within critical habitat areas located in the Prado Basin. Critical habitat in Reach 9 would not be affected as water conservation would not trigger large, erosive discharges.
	Flycatcher	May Affect, Not likely to Adversely Effect	Monitoring of vegetation changes and replanting or restoration of affected areas will ensure that the Planned Deviation would not degrade the value of primary constituent elements within critical habitat areas. Due to the limited number of flycatcher in the Basin, the species would not be affected by temporary

			changes in habitat within the buffer pool area.
	Cuckoo	May Affect, Not likely to Adversely Effect	Monitoring of vegetation changes and replanting or restoration of affected areas will ensure that the Planned Deviation would not degrade the value of primary constituent elements within critical habitat areas. Due to the limited number of cuckoo in the Basin, the species would not be affected by temporary changes in habitat within the buffer pool area.
	Gnatcatcher	No Effect to Critical Habitat	No critical habitat occurs within Prado Basin. Critical habitat in Reach 9 would not be affected as the Planned Deviation would not trigger large, erosive discharges.
	Sucker	No Effect to Critical Habitat	No critical habitat occurs within Prado Basin. Potential effects from sedimentation discussed below.
1d. Effects to critical habitat from increased sedimentation due to water conservation.	Vireo	No Effect to Critical Habitat	Minor amount of increased sedimentation in basin (estimated 3,500 cubic yards/year, spread over basin at a depth of 0.001 ft. /year) would not substantially reduce biological values of critical habitat. Nevertheless, OCWD has agreed to remove 120,000 cy from the basin which would exceed the amount of increased sedimentation associated with the Planned Deviation. In addition, monitoring of vegetation changes and replanting or restoration of affected areas will ensure that the Planned Deviation would not degrade

			the value of primary constituent elements within critical habitat areas.
	Flycatcher	No Effect to Critical Habitat	Same as above.
	Cuckoo	No Effect to Critical Habitat	Same as above.
	Gnatcatcher	No Effect to Critical Habitat	Minor amount of increased sedimentation in basin would have no effect on critical habitat for gnatcatcher in Reach 9.
	Sucker - Upstream	No Effect to Critical Habitat	Modeling demonstrates that no effect would occur to the gradient of the river upstream of 505', and therefore no effect would occur to Santa Ana sucker critical habitat upstream of Prado Basin. Nevertheless, OCWD has agreed to remove 20,000 cy of sediment from the basin which would exceed the amount of increased sedimentation associated with the Planned Deviation.
	Sucker - Downstream (Reach 9)	No Effect to Critical Habitat	No critical habitat occurs within Prado Basin. Critical habitat in Reach 9 would not be affected as the Planned Deviation would not trigger large, erosive discharges
1e: Affects to species from sediment removal at OCWD Diversion Channel (Evaluated in USFWS Biological Opinion FWS-WRIV-11B0269-12F0166)	Vireo	No Effect	Sediment removal would occur outside of the nesting season.
1d: Affects to critical habitat from sediment removal at OCWD Diversion Channel (Evaluated in USFWS Biological Opinion FWS-WRIV-11B0269-12F0166)	Vireo	No Effect	No critical habitat occurs where sediment removal would occur.

2. Sediment Removal Demonstration Project			
2a. Effects to species and critical habitat from construction of sediment removal channel and access road.	Vireo	Species My Affect, Not Likely to Adversely Affect Critical Habitat May Affect, Not Likely to Adversely Affect	Species Activity would occur outside of the nesting season. Critical Habitat Temporary removal of 0.48 acres of native riparian habitat. Impacts to habitat have been pre-mitigated by OCWD (restoration of a 0.48 acre arundo infested parcel near the action area has been completed), and temporarily affected areas will be re-planted after the demonstration project is complete. Vegetation and sediment removal will occur outside of the nesting season.
	Flycatcher	Species My Affect, Not Likely to Adversely Affect Critical Habitat May Affect, Not Likely to Adversely Affect	Species Flycatchers are known not to occur in the immediate project area. Activity would occur outside of the nesting season. Critical Habitat Impacts to habitat have been pre-mitigated as discussed above; temporarily affected areas will be revegetated;
	Cuckoo	Species My Affect, Not Likely to Adversely Affect Critical Habitat May Affect, Not Likely to Adversely Affect	Species Cuckoos are not known to occur in the immediate project area. Activity would occur outside of the nesting season. Critical Habitat Impacts to habitat have been

			pre-mitigated as discussed above; temporarily affected areas will be revegetated; and
	Gnatcatcher	<u>Species</u> No Affect <u>Critical Habitat</u> No Effect to Critical Habitat	<u>Species</u> Gnatcatchers are not known to occur in the immediate project area. Activity would occur outside of the nesting season. <u>Critical Habitat</u> Suitable habitat for gnatcatcher will not be affected.
	Sucker	<u>Species</u> May Affect, Not Likely to Adversely Affect <u>Critical Habitat</u> No Effect to Critical Habitat	<u>Species</u> Sediment removal activities would occur outside of the spawning season, and suitable spawning habitat is not present within the work area limits. It is expected that adult fish would be able to avoid the work area and therefore avoid entrainment. However, the potential that individual isolated suckers could find their way into the sediment removal channel where turbidity levels would be higher and less suitable for sucker would be considered a temporary affect. <u>Critical Habitat</u> Suitable habitat for sucker will not be affected.
2b. species and critical habitat from construction of sediment storage site		No Effects to any listed species or critical habitat.	
3. Cumulative effects			
		No additional	

		cumulative effects would occur from implementation of both the Planned Deviation and the Sediment Removal Demonstration Project.	

SECTION 7 LITERATURE CITED

California Department Fish and Game, 2015 California Natural Diversity Database.

California Native Plant Society, 2012. Electronic Inventory of Rare and Endangered Vascular Plants of California.

HDR, 2013 Orange County Water District Prado Basin Sediment Management Demonstration Project Engineering Analysis.

Metropolitan Water District Urban Water Management Plan, 2016

Moyle, P.B., 2002. Inland Fishes of California, University of California Press, Berkeley.

Orange County Water District, 2014. Draft Environmental Impact Report Prado Basin Sediment Management Demonstration Project.

Santa Ana Watershed Association, 2014. Least Bell's Vireo Survey.

Swift, C.C., 2001. The Santa Ana sucker is the Santa Ana River: distribution, relative abundance, spawning areas, and the impact of exotic predators.

Thompson, A.R., J.N. Baskin, C.C Swift, T.R. Haglund, and R.J. Nagel. 2010. Influence of habitat dynamics on the distribution and abundance of the federally threatened Santa Ana Sucker, *Catostomus santaanae,* in the Santa Ana River.

United States Army Corps of Engineers, 2005, Prado Basin Water Conservation Feasibility Study.

United States Army Corps of Engineers, 2009 Santa Ana River Interceptor Line Protection/Relocation EIS/EIR

United States Department of Agriculture, 2007. Soil Series

United States Department of Interior, 2015, Information Planning and Conservation Data Base

United States Fish and Wildlife Service, 1994, Designation of Critical Habitat for the Least Bell's Vireo, Final Rule.

United States Fish and Wildlife Service, 2004, Endangered and Threatened Wildlife and Plants, Proposed Rule to Designate Critical Habitat for the Santa Ana Sucker.

United States Fish and Wildlife Service, 2010, Initiation of 5-year Reviews of 34 Species in California and Nevada, and Availability of 96 Completed 5-Year Reviews in California and Nevada.

United States Fish and Wildlife Service Revised Critical Habitat for the Santa Ana Sucker, Final Rule.

United States Fish and Wildlife Service, 2012, Biological Opinion FWS-WRIV-11B0269-12F0166, Formal Section 7 Consultation Proposed Reconstruction and Long-Term Operations of the Prado Constructed Wetlands, Riverside County, California

United States Fish and Wildlife Service, Designation of Critical Habitat for Southwestern Willow Flycatcher.

United States Geologic Survey 7.5 Quadrangle Maps, 1981. Black Star Canyon, Corona North, Corona South, Prado Dam, Riverside West,

Western Riverside County Multiple Species Habitat Conservation Plan, Riverside County, 2007

Michael Baker
INTERNATIONAL

TECHNICAL MEMORANDUM

To: Greg Woodside, Orange County Water District **JN** 131276

From: Howard Barndt

Date: June 26, 2015

Subject: Revised and Supplemental Water Conservation Analyses: Prado Dam

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Reference: USACE, 2014, *Santa Ana River/Orange County Prado Basin Ecosystem Restoration Feasibility Study: Water Conservation and Sediment Transport Analysis Report*, Hydraulics Section, Hydrology and Hydraulics Branch, Los Angeles District, U.S. Army Corps of Engineers (USACE), May.

RBF Consulting, a Michael Baker International Company (RBF Baker) was asked by the Orange County Water District (OCWD) to evaluate potential modifications to the HEC-5 computer model used by the USACE Los Angeles District in its analysis of different water conservation levels at Prado Dam. In addition, OCWD had a supplemental model run conducted for an alternative related to submitting a temporary deviation from the approved Water Control Plan for Prado Dam.

By way of background, the HEC-5 model uses estimated inflows to the Prado Basin for a 39-year period. The estimated inflows were generated by a calibrated Waste-Load Allocation Model (WLAM) of the Santa Ana River watershed that was developed by Wildermuth Environmental, Inc. (WEI) and used by the Santa Ana Watershed Authority (SAWPA), the Chino Basin Watermaster and others for various purposes. Two inflow scenarios were developed for the USACE, one for 2021 conditions and one for future 2071 conditions. For this supplemental analysis, the 2021 conditions were used. To develop this condition, WEI used historical rainfall for the period 1949-1988, but recent land use conditions and estimated discharges from Publicly Owned Treatment Works (POTWs) to the Santa Ana River were used.

The following activities were done in this analysis:

1. Revise the baseline HEC-5 model, which represents Alternative 2 (flood season buffer pool to water surface elevation 498.0 feet; non-flood season buffer pool to water surface elevation 505.0 feet) and Present Conditions based on year 2021 (ALT2_P2021_R350; USACE, 2014), to transition from a reservoir target level of 498.0 feet up to 505.0 feet over the first 10 days of March (March 1st through March 10th), and from 505.0 feet down to 498.0 feet over the first 10 days of September (September 1st through September 10th). This was necessary because the existing HEC-5 model transitions from 498 ft to 505 ft over the entire month of March.
2. Develop an additional HEC-5 model scenario, Alternative 4A (flood season buffer pool to water surface elevation 503.9 feet; non-flood season buffer pool to water surface elevation 505.0 feet) for Present Conditions based on year 2021 (ALT4A_P2021_R350), by modifying the revised version of ALT2_P2021_R350 (Action Item 1 above) to accommodate this change in operations.

This was done in analyzing the impacts associated with requesting a temporary deviation from the approved Water Control Plan.

3. Reanalyze/analyze the statistics for Alternatives 2, 4, and 4A using the Microsoft Excel files, which were previously developed and used by the USACE (2014) to determine frequency-based days of inundation above selected pool elevations from the relevant HEC-5 model time-series reservoir elevation outputs; round reservoir elevation values to the nearest 0.5 feet prior to translating frequency-elevation pairs to frequency-days-of-inundation pairs; and determine the frequency-based impacts for ALT4_P2021_R350 and ALT4A_P2021_R350 relative to ALT2_P2021_R350 (baseline).
4. Compute the average monthly and average annual days of inundation above selected pool elevations for ALT2_P2021_R350, ALT4_P2021_R350, and ALT4A_P2021_R350, directly from the relevant HEC-5 model time-series reservoir elevation outputs; round elevation values to the nearest 0.5 feet prior to conducting this analysis; and determine the average-based (monthly and annual) impacts for ALT4_P2021_R350 and ALT4A_P2021_R350 relative to ALT2_P2021_R350 (baseline).

General assumptions and methodology

All three alternatives were evaluated for water years 1950 through 1988 (39-year span) and have a diversion rate of 350 cubic-feet-per-second (cfs).

Frequency-based days of inundation (duration) were estimated for selected pool elevations. Frequency-duration pairs were computed using the following process:

- HEC-5 computed reservoir elevations (elevations) were sorted from highest to lowest for each water year
- 20 duration-elevation pairs were sampled from each water year ranging from one to 360 days of inundation
- The sampled duration-elevation pairs were transposed and the elevations were ranked from highest to lowest for each duration followed by the assignment of an exceedance value based on the Chegodayev plotting position formula (note: given that there are only 39 years of data, the lowest exceedance value attained is 0.018, which corresponds to a 56-year event)
- Curve-fitting was applied to known frequency-elevation pairs for the purpose of extrapolating to the 100-year event for each sampled duration; due to the “magnitude” of the extrapolation (from a 56- to 100-year event), the extension of the fitted curves produced results that have a high degree of uncertainty and were not always consistent with the expected trend of decreasing pool elevations, which generally decrease with increasing duration; to limit the ambiguity of this process, the same curve type was applied to each duration and for each alternative; where an extrapolated elevation for a given duration was not physically possible, interpolation was used; while applying consistent curve fitting across all durations for all alternatives does not reduce the amount of uncertainty linked to the results of an alternative by itself, it does lend more meaning to the comparative results between two alternatives

- Days of inundation were determined for selected frequency-elevation pairs by interpolating between the known pool elevations associated with frequency-duration pairs

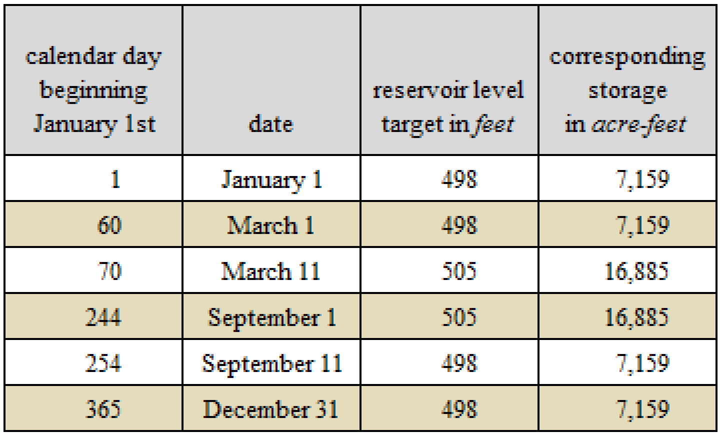
Note that the approach described above applies to the days of inundation for floods occurring at a frequency of 2, 5, 10, 25, 50, 56 and 100 years. The average annual days of inundation is calculated from daily data from the 39 year period of record (see Bullet 4 in previous section).

Detailed Revisions Applied to the ALT2_P2021_R350 HEC-5 model [Activity 1]

The HEC-5 model previously developed for ALT2_P2021_R350 (USACE, 2014) transitions the flood season buffer pool to the non-flood season buffer pool of 498.0 feet to 505.0 feet over the entire month of March, and from 505.0 feet down to 498.0 feet over the entire month of September. This model was revised to transition the change in the buffer pools from 498.0 feet up to 505.0 feet over a period of 10 days from March 1st through March 10th and transition the change in buffer pools from 505.0 feet down to 498.0 feet over a period of 10 days from September 1st through September 10th.

Buffer pool elevation targets were previously defined at the beginning of each month. To accommodate the 10-day transition periods, the "*CS* record" was implemented to define non-uniform time periods for buffer pool target assignments. The HEC-5 *CS* and *RL* record data sequence required to accommodate the 10-day transitions in March and September are presented in Table 1.

Table 1. HEC-5 *CS* and *RL* record data sequence for 10-day transitions in March and September



calendar day beginning January 1st	date	reservoir level target in *feet*	corresponding storage in *acre-feet*
1	January 1	498	7,159
60	March 1	498	7,159
70	March 11	505	16,885
244	September 1	505	16,885
254	September 11	498	7,159
365	December 31	498	7,159

The third *RL* record in sequence as defined in the HEC-5 model previously developed for ALT2_P2021_R350 (USACE, 2014) was revised to include the sequence of storage values listed in the table. The fourth *RL* record in sequence was removed (no longer needed). A *CS* record was added below "*ID PRADO*" with the calendar-day sequence listed in Table 1 (column 1).

ALT4_P2021_R350 HEC-5 model

No significant changes were applied to the HEC-5 model previously developed for ALT4_P2021_R350 (USACE, 2014). This alternative assumes a year-round maximum buffer pool water surface elevation of 505.0 feet.

Details of ALT4A_P2021_R350 HEC-5 model development [Activity 2]

This alternative represents operations, which targets a maximum flood season buffer pool of water surface elevation of 503.9 feet, transitioning from 503.9 feet to 505.0 feet from March 1st through March 10th, and then transitioning from 505.0 feet down to 503.9 feet from September 1st through September 10th. September is generally designated as the month used for maintenance activities. The HEC-5 model for this additional alternative was developed from the revised ALT2_P2021_R350 HEC-5 model (Action Item 1) by incorporating the following changes:

1. The storage capacity assignments on the *RL* records corresponding to a buffer pool elevation of 498.0 feet (7,159 acre-feet) were changed to the storage capacity corresponding to a buffer pool elevation of 503.9 feet (15,035 acre-feet).
2. A buffer pool elevation of 503.9 feet was added to the reservoir elevation rating table (*RE* records). The rating tables for storage (*RS* records) and surface area (*RA* records) were updated to include values corresponding to the added buffer pool elevation. The discharge rating table was revised to extend the long-term spreading rate of 350 cfs to occur up to and including water surface elevation 503.9 feet and begin the flood control discharge rate of 5,000 cfs at water surface elevation 504.0 feet. The HEC-5 model developed for ALT4A_P2021_R350 will interpolate between discharge rates 350 cfs and 5,000 cfs for water surface elevations between 503.9 feet and 504.0 feet.

HEC-5 model output processing and analysis (Activities 3 and 4)

The performance of each alternative by water year as derived from the corresponding HEC-5 model results is presented in Table 2 (ALT2_P2021_R350), Table 3 (ALT4_P2021_R350), and Table 4 (ALT4A_P2021_R350). The HEC-5 model time-series reservoir elevation output for ALT2_P2021_R350 (revised; Action Item 1), ALT4_P2021_R350 (USACE, 2014), and ALT4A_P2021_R350 (developed; Action Item 2) were processed and analyzed to determine days of inundation above selected pool elevations as shown in Table 5 (ALT2_P2021_R350), Table 6 (ALT4_P2021_R350), and Table 7 (ALT4A_P2021_R350). Average monthly, average annual, and frequency-based days of inundation above selected pool elevations were computed for each alternative scenario (ALT2_P2021_R350, ALT4_P2021_R350, and ALT4A_P2021_R350) as well as the impacts posed by ALT4_P2021_R350 and ALT4A_P2021_R350 relative to the performance of ALT2_P2021_R350 (baseline).

Water Conservation Yield

The yield obtained by water conservation activities is water eventually captured and recharged by OCWD it is spreading facilities. Water that is not captured is lost to the ocean. Tables 2, 3 and 4 summarize the operations of Prado Dam for each year of the simulation period (Max water surface elevation, maximum release rate, and inflow to Prado reservoir), local inflows to the Santa Ana River below Prado Dam, the total water spread by OCWD, and water lost to the ocean. Based on these tables, the benefits of each alternative in additional water spread and reduced water lost to the ocean area are as follows.

Benefit of Alternative 4

Alternative	Average Annual Water Spread (af)	Average Annual Water Lost (af)
Alt 2	151,000	73,200
Alt 4	157,000	67,200
Benefit	**6,000**	**(6,000)**

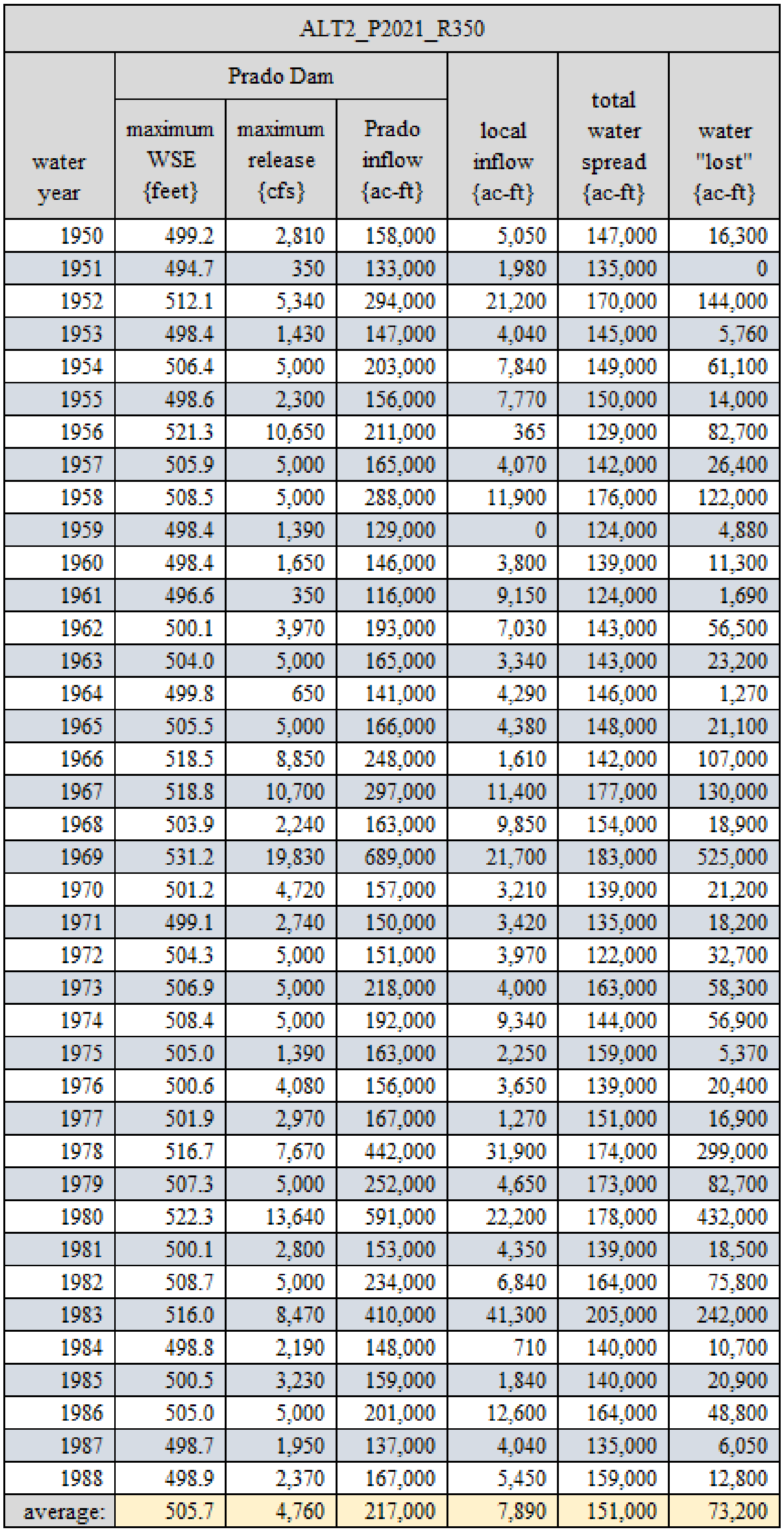
Benefit of Alternative 4A

Alternative	Average Annual Water Spread (af)	Average Annual Water Lost (af)
Alt 2	151,000	73,200
Alt 4A	156,000	68,000
Benefit	**5,000**	**(5,200)**

As summarized in the tables above, the yield of Alternative 4 is 6,000 acre-feet per year of additional water spread, which comes from reduced outflows to the ocean. Alterative 4A yields 5,000 acre-feet per year of additional water spread

Please feel free to contact me at 949-855-3668 or hbarndt@mbakerintl.com if you have any questions.

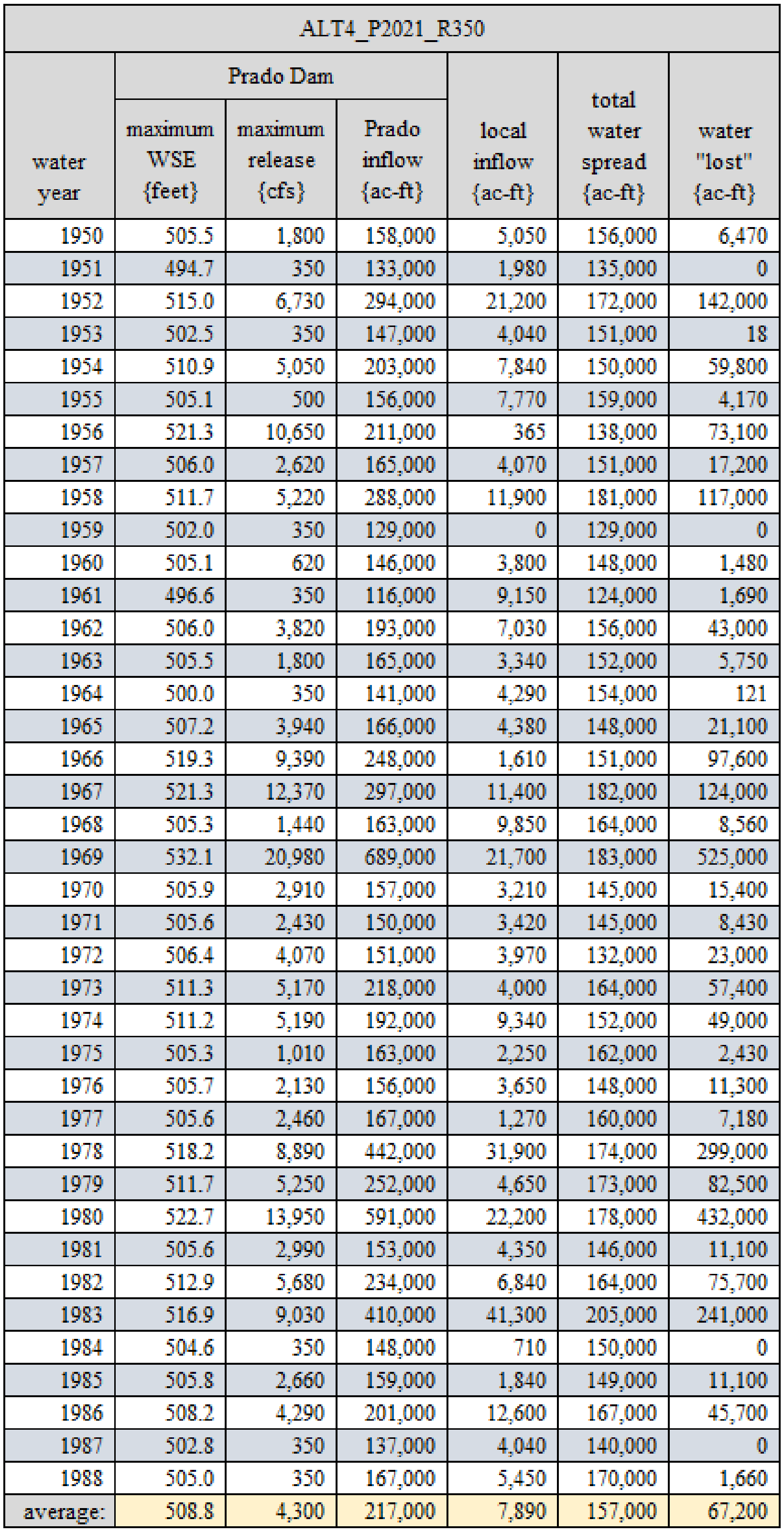
Table 2. Annual performance – Alternative 2, Present Conditions, and 350-cfs diversion rate



ALT2_P2021_R350

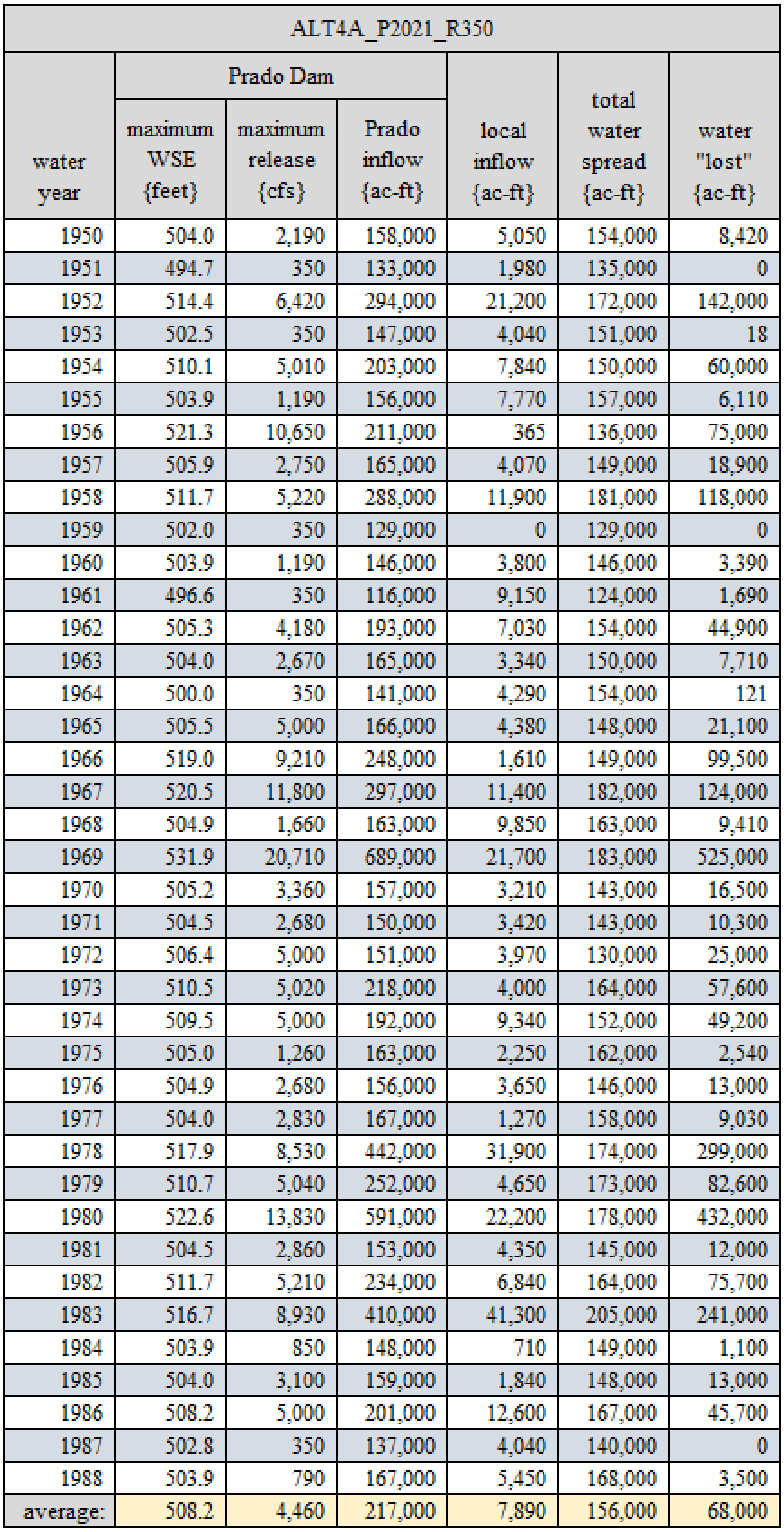
water year	Prado Dam maximum WSE {feet}	Prado Dam maximum release {cfs}	Prado Dam Prado inflow {ac-ft}	local inflow {ac-ft}	total water spread {ac-ft}	water "lost" {ac-ft}
1950	499.2	2,810	158,000	5,050	147,000	16,300
1951	494.7	350	133,000	1,980	135,000	0
1952	512.1	5,340	294,000	21,200	170,000	144,000
1953	498.4	1,430	147,000	4,040	145,000	5,760
1954	506.4	5,000	203,000	7,840	149,000	61,100
1955	498.6	2,300	156,000	7,770	150,000	14,000
1956	521.3	10,650	211,000	365	129,000	82,700
1957	505.9	5,000	165,000	4,070	142,000	26,400
1958	508.5	5,000	288,000	11,900	176,000	122,000
1959	498.4	1,390	129,000	0	124,000	4,880
1960	498.4	1,650	146,000	3,800	139,000	11,300
1961	496.6	350	116,000	9,150	124,000	1,690
1962	500.1	3,970	193,000	7,030	143,000	56,500
1963	504.0	5,000	165,000	3,340	143,000	23,200
1964	499.8	650	141,000	4,290	146,000	1,270
1965	505.5	5,000	166,000	4,380	148,000	21,100
1966	518.5	8,850	248,000	1,610	142,000	107,000
1967	518.8	10,700	297,000	11,400	177,000	130,000
1968	503.9	2,240	163,000	9,850	154,000	18,900
1969	531.2	19,830	689,000	21,700	183,000	525,000
1970	501.2	4,720	157,000	3,210	139,000	21,200
1971	499.1	2,740	150,000	3,420	135,000	18,200
1972	504.3	5,000	151,000	3,970	122,000	32,700
1973	506.9	5,000	218,000	4,000	163,000	58,300
1974	508.4	5,000	192,000	9,340	144,000	56,900
1975	505.0	1,390	163,000	2,250	159,000	5,370
1976	500.6	4,080	156,000	3,650	139,000	20,400
1977	501.9	2,970	167,000	1,270	151,000	16,900
1978	516.7	7,670	442,000	31,900	174,000	299,000
1979	507.3	5,000	252,000	4,650	173,000	82,700
1980	522.3	13,640	591,000	22,200	178,000	432,000
1981	500.1	2,800	153,000	4,350	139,000	18,500
1982	508.7	5,000	234,000	6,840	164,000	75,800
1983	516.0	8,470	410,000	41,300	205,000	242,000
1984	498.8	2,190	148,000	710	140,000	10,700
1985	500.5	3,230	159,000	1,840	140,000	20,900
1986	505.0	5,000	201,000	12,600	164,000	48,800
1987	498.7	1,950	137,000	4,040	135,000	6,050
1988	498.9	2,370	167,000	5,450	159,000	12,800
average:	505.7	4,760	217,000	7,890	151,000	73,200

Table 3. Annual performance – Alternative 4, Present Conditions, and 350-cfs diversion rate



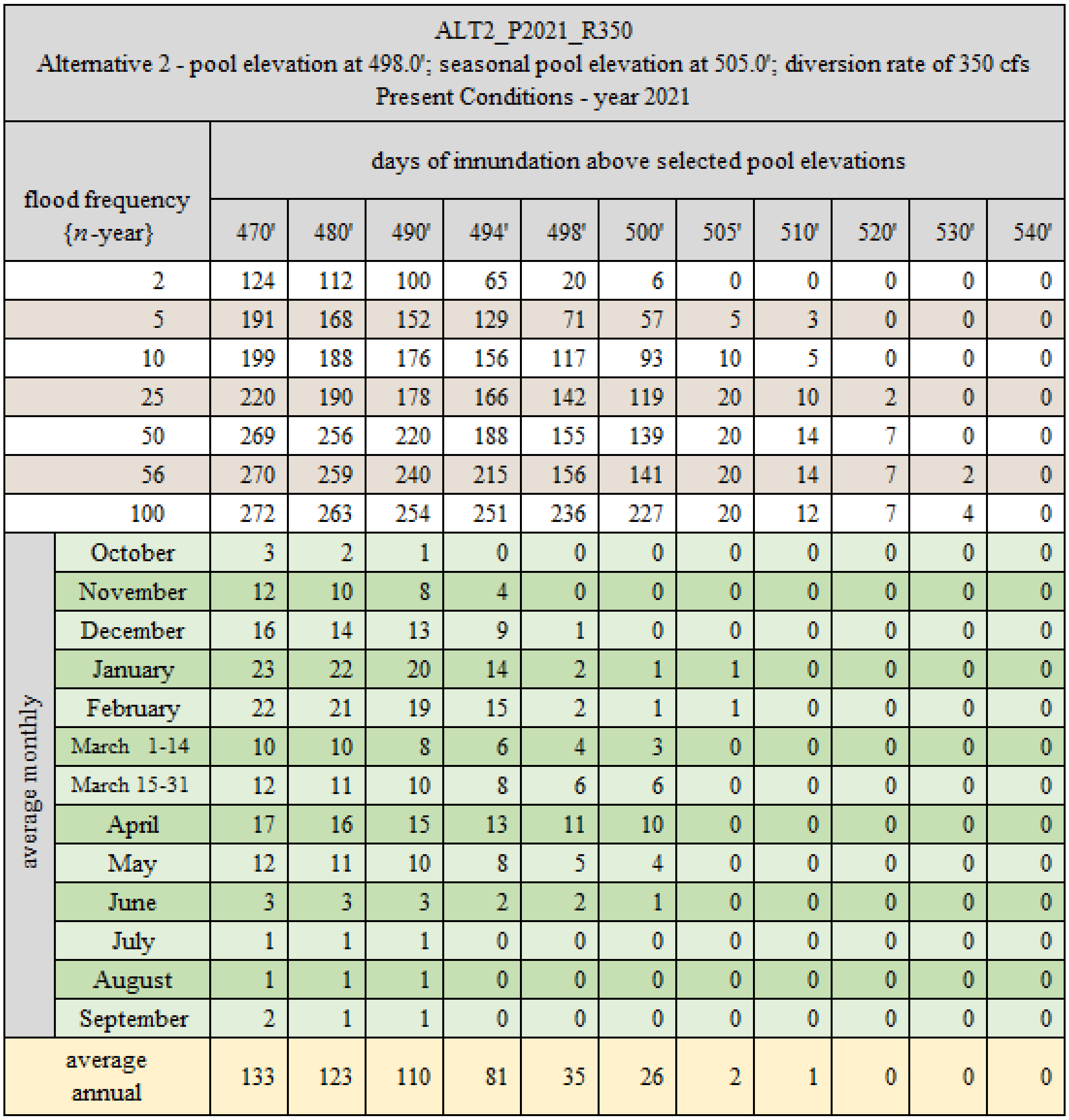
ALT4_P2021_R350						
	Prado Dam					
water year	maximum WSE {feet}	maximum release {cfs}	Prado inflow {ac-ft}	local inflow {ac-ft}	total water spread {ac-ft}	water "lost" {ac-ft}
1950	505.5	1,800	158,000	5,050	156,000	6,470
1951	494.7	350	133,000	1,980	135,000	0
1952	515.0	6,730	294,000	21,200	172,000	142,000
1953	502.5	350	147,000	4,040	151,000	18
1954	510.9	5,050	203,000	7,840	150,000	59,800
1955	505.1	500	156,000	7,770	159,000	4,170
1956	521.3	10,650	211,000	365	138,000	73,100
1957	506.0	2,620	165,000	4,070	151,000	17,200
1958	511.7	5,220	288,000	11,900	181,000	117,000
1959	502.0	350	129,000	0	129,000	0
1960	505.1	620	146,000	3,800	148,000	1,480
1961	496.6	350	116,000	9,150	124,000	1,690
1962	506.0	3,820	193,000	7,030	156,000	43,000
1963	505.5	1,800	165,000	3,340	152,000	5,750
1964	500.0	350	141,000	4,290	154,000	121
1965	507.2	3,940	166,000	4,380	148,000	21,100
1966	519.3	9,390	248,000	1,610	151,000	97,600
1967	521.3	12,370	297,000	11,400	182,000	124,000
1968	505.3	1,440	163,000	9,850	164,000	8,560
1969	532.1	20,980	689,000	21,700	183,000	525,000
1970	505.9	2,910	157,000	3,210	145,000	15,400
1971	505.6	2,430	150,000	3,420	145,000	8,430
1972	506.4	4,070	151,000	3,970	132,000	23,000
1973	511.3	5,170	218,000	4,000	164,000	57,400
1974	511.2	5,190	192,000	9,340	152,000	49,000
1975	505.3	1,010	163,000	2,250	162,000	2,430
1976	505.7	2,130	156,000	3,650	148,000	11,300
1977	505.6	2,460	167,000	1,270	160,000	7,180
1978	518.2	8,890	442,000	31,900	174,000	299,000
1979	511.7	5,250	252,000	4,650	173,000	82,500
1980	522.7	13,950	591,000	22,200	178,000	432,000
1981	505.6	2,990	153,000	4,350	146,000	11,100
1982	512.9	5,680	234,000	6,840	164,000	75,700
1983	516.9	9,030	410,000	41,300	205,000	241,000
1984	504.6	350	148,000	710	150,000	0
1985	505.8	2,660	159,000	1,840	149,000	11,100
1986	508.2	4,290	201,000	12,600	167,000	45,700
1987	502.8	350	137,000	4,040	140,000	0
1988	505.0	350	167,000	5,450	170,000	1,660
average:	508.8	4,300	217,000	7,890	157,000	67,200

Table 4. Annual performance – Alternative 4A, Present Conditions, 350-cfs diversion rate



ALT4A_P2021_R350						
	Prado Dam					
water year	maximum WSE {feet}	maximum release {cfs}	Prado inflow {ac-ft}	local inflow {ac-ft}	total water spread {ac-ft}	water "lost" {ac-ft}
1950	504.0	2,190	158,000	5,050	154,000	8,420
1951	494.7	350	133,000	1,980	135,000	0
1952	514.4	6,420	294,000	21,200	172,000	142,000
1953	502.5	350	147,000	4,040	151,000	18
1954	510.1	5,010	203,000	7,840	150,000	60,000
1955	503.9	1,190	156,000	7,770	157,000	6,110
1956	521.3	10,650	211,000	365	136,000	75,000
1957	505.9	2,750	165,000	4,070	149,000	18,900
1958	511.7	5,220	288,000	11,900	181,000	118,000
1959	502.0	350	129,000	0	129,000	0
1960	503.9	1,190	146,000	3,800	146,000	3,390
1961	496.6	350	116,000	9,150	124,000	1,690
1962	505.3	4,180	193,000	7,030	154,000	44,900
1963	504.0	2,670	165,000	3,340	150,000	7,710
1964	500.0	350	141,000	4,290	154,000	121
1965	505.5	5,000	166,000	4,380	148,000	21,100
1966	519.0	9,210	248,000	1,610	149,000	99,500
1967	520.5	11,800	297,000	11,400	182,000	124,000
1968	504.9	1,660	163,000	9,850	163,000	9,410
1969	531.9	20,710	689,000	21,700	183,000	525,000
1970	505.2	3,360	157,000	3,210	143,000	16,500
1971	504.5	2,680	150,000	3,420	143,000	10,300
1972	506.4	5,000	151,000	3,970	130,000	25,000
1973	510.5	5,020	218,000	4,000	164,000	57,600
1974	509.5	5,000	192,000	9,340	152,000	49,200
1975	505.0	1,260	163,000	2,250	162,000	2,540
1976	504.9	2,680	156,000	3,650	146,000	13,000
1977	504.0	2,830	167,000	1,270	158,000	9,030
1978	517.9	8,530	442,000	31,900	174,000	299,000
1979	510.7	5,040	252,000	4,650	173,000	82,600
1980	522.6	13,830	591,000	22,200	178,000	432,000
1981	504.5	2,860	153,000	4,350	145,000	12,000
1982	511.7	5,210	234,000	6,840	164,000	75,700
1983	516.7	8,930	410,000	41,300	205,000	241,000
1984	503.9	850	148,000	710	149,000	1,100
1985	504.0	3,100	159,000	1,840	148,000	13,000
1986	508.2	5,000	201,000	12,600	167,000	45,700
1987	502.8	350	137,000	4,040	140,000	0
1988	503.9	790	167,000	5,450	168,000	3,500
average:	508.2	4,460	217,000	7,890	156,000	68,000

Table 5. Days of inundation – Alternative 2, Present Conditions, 350-cfs diversion rate



ALT2_P2021_R350
Alternative 2 - pool elevation at 498.0'; seasonal pool elevation at 505.0'; diversion rate of 350 cfs
Present Conditions - year 2021

flood frequency {*n*-year}		days of inundation above selected pool elevations										
		470'	480'	490'	494'	498'	500'	505'	510'	520'	530'	540'
2		124	112	100	65	20	6	0	0	0	0	0
5		191	168	152	129	71	57	5	3	0	0	0
10		199	188	176	156	117	93	10	5	0	0	0
25		220	190	178	166	142	119	20	10	2	0	0
50		269	256	220	188	155	139	20	14	7	0	0
56		270	259	240	215	156	141	20	14	7	2	0
100		272	263	254	251	236	227	20	12	7	4	0
average monthly	October	3	2	1	0	0	0	0	0	0	0	0
	November	12	10	8	4	0	0	0	0	0	0	0
	December	16	14	13	9	1	0	0	0	0	0	0
	January	23	22	20	14	2	1	1	0	0	0	0
	February	22	21	19	15	2	1	1	0	0	0	0
	March 1-14	10	10	8	6	4	3	0	0	0	0	0
	March 15-31	12	11	10	8	6	6	0	0	0	0	0
	April	17	16	15	13	11	10	0	0	0	0	0
	May	12	11	10	8	5	4	0	0	0	0	0
	June	3	3	3	2	2	1	0	0	0	0	0
	July	1	1	1	0	0	0	0	0	0	0	0
	August	1	1	1	0	0	0	0	0	0	0	0
	September	2	1	1	0	0	0	0	0	0	0	0
average annual		133	123	110	81	35	26	2	1	0	0	0

Table 6. Days of inundation – Alternative 4, Present Conditions, 350-cfs diversion rate

ALT4_P2021_R350 Alternative 4 - pool elevation at 505.0 feet year-round; diversion rate of 350 cfs Present Conditions - year 2021												
flood frequency {*n*-year}		days of inundation above selected pool elevations {increase from ALT2_P2021_R350 in red}										
		470'	480'	490'	494'	498'	500'	505'	510'	520'	530'	540'
2		148	137	126	110	85	65	5	0	0	0	0
		24	25	26	45	65	59	5	0	0	0	0
5		196	183	163	151	128	110	20	3	0	0	0
		5	15	12	23	57	53	15	1	0	0	0
10		215	192	178	168	155	146	30	6	1	0	0
		16	5	2	12	38	54	20	1	1	0	0
25		233	212	195	184	171	157	50	12	3	0	0
		13	22	17	18	30	38	30	2	1	0	0
50		270	260	247	223	206	195	50	16	7	2	0
		1	3	27	35	51	56	30	2	1	2	0
56		271	261	252	238	214	203	50	16	8	3	0
		1	2	12	23	58	62	30	2	1	1	0
100		272	265	257	254	251	250	50	17	9	5	0
		1	2	3	4	15	23	30	5	1	1	0
average monthly	October	3	3	2	1	0	0	0	0	0	0	0
		1	1	1	0	0	0	0	0	0	0	0
	November	12	10	8	4	1	1	0	0	0	0	0
		0	0	0	0	1	1	0	0	0	0	0
	December	16	15	14	11	8	6	1	0	0	0	0
		0	0	1	2	7	6	0	0	0	0	0
	January	25	24	22	20	17	14	2	0	0	0	0
		1	2	3	6	14	13	1	0	0	0	0
	February	26	26	25	23	19	17	2	1	0	0	0
		4	5	6	8	16	16	1	0	0	0	0
	March 1-14	12	12	12	11	9	8	1	0	0	0	0
		2	3	3	5	5	5	1	0	0	0	0
	March 15-31	14	14	13	12	10	9	1	0	0	0	0
		3	3	3	4	4	3	1	0	0	0	0
	April	21	20	19	17	13	11	0	0	0	0	0
		4	4	4	4	2	1	0	0	0	0	0
	May	13	12	11	8	6	4	0	0	0	0	0
		1	1	1	0	0	0	0	0	0	0	
	June	3	3	3	2	2	1	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	July	1	1	1	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	August	1	1	1	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	September	2	1	1	1	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
average annual		149	141	131	110	86	71	7	2	0	0	0
		16	18	22	29	51	45	5	0	0	0	0

Table 7. Days of inundation – Alternative 4A, Present Conditions, 350-cfs diversion rate

ALT4A_P2021_R350
Alternative 4A - pool elevation at 503.9'; seasonal pool elevation at 505.0'; diversion rate of 350 cfs
Present Conditions - year 2021

flood frequency {*n*-year}		days of inundation above selected pool elevations {increase from ALT2_P2021_R350 in red}										
		470'	480'	490'	494'	498'	500'	505'	510'	520'	530'	540'
2		147	135	119	102	78	60	0	0	0	0	0
		23	23	19	37	58	54	0	0	0	0	0
5		196	182	161	147	121	104	10	3	0	0	0
		196	181	158	141	106	91	9	3	0	0	0
10		215	192	178	168	155	146	10	6	0	0	0
		16	5	2	12	38	53	0	1	0	0	0
25		233	212	194	182	167	156	20	12	2	0	0
		13	209	191	178	161	151	19	12	2	0	0
50		270	260	247	223	203	185	30	15	7	2	0
		1	3	27	35	48	46	10	2	1	2	0
56		271	261	252	238	211	194	30	15	8	2	0
		1	2	12	23	54	53	10	1	0	1	0
100		272	265	257	254	251	250	30	16	8	4	0
		1	2	3	4	15	23	10	5	1	1	0
average monthly	October	3	3	2	1	0	0	0	0	0	0	0
		1	1	1	0	0	0	0	0	0	0	0
	November	12	10	8	4	1	1	0	0	0	0	0
		0	0	0	0	1	1	0	0	0	0	0
	December	16	15	14	11	8	6	0	0	0	0	0
		0	0	1	2	7	6	0	0	0	0	0
	January	25	24	22	20	16	13	1	0	0	0	0
		1	2	3	6	14	12	0	0	0	0	0
	February	26	25	25	22	17	15	1	1	0	0	0
		4	5	6	8	15	14	0	0	0	0	0
	March 1-14	12	12	11	10	8	7	0	0	0	0	0
		2	2	3	4	4	4	0	0	0	0	0
	March 15-31	14	13	13	11	9	8	0	0	0	0	0
		2	3	3	3	3	2	0	0	0	0	0
	April	20	19	18	16	12	11	0	0	0	0	0
		3	3	3	3	1	1	0	0	0	0	0
	May	12	12	11	8	5	4	0	0	0	0	0
		1	1	1	0	0	0	0	0	0	0	0
	June	3	3	3	2	2	1	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	July	1	1	1	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	August	1	1	1	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
	September	2	1	1	1	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0
average annual		147	139	129	106	81	66	3	1	0	0	0
		14	16	19	26	46	40	1	0	0	0	0

June 11, 2015

Orange County Water District
Attn: Mr. Greg Woodside, P.G., C.HG
Executive Director of Planning and Natural Resources
18700 Ward Street
Fountain Valley, CA 92708

Subject: Prado Dam Planned Deviation
Santa Ana River - Upstream Effects Due to Water Conservation (Final)

Mr. Woodside:

This technical memo provides an assessment of how increasing the allowable water surface elevation (WSE) during the flood season (October through February) from 498.0 ft National Geodetic Vertical Datum of 1929 (NGVD29) to 505.0 ft NGVD29 may affect sediment deposition and habitat types in Prado Basin and along the Santa Ana River (SAR). The following analysis will focus on an area along the SAR from Prado Dam (Dam) and the Prado Flood Control Basin (Basin) extending upstream between River Road Bridge and the Hamner Avenue/SAR crossing, referred to as the "Dam to Hamner Reach" for the purposes of this report. This information may be used to estimate the effect on sediment deposition and on various habitat types along the SAR should the allowable water conservation WSE be increased during the flood season. Historical topographic surveys, aerial imagery, recent sediment transport models, historical data, and reports have been used to estimate how additional water conservation may contribute to any long-term changes in river morphology along the SAR immediately upstream of the Dam.

Background

The primary purpose of the Dam is to provide flood risk management benefits. A secondary beneficial use of the Dam and Basin is water conservation. Water conservation benefits provided by the Dam are possible by using the Dam structure and Basin area to capture, and hold, storm flows. The captured water is released at rates conducive to downstream groundwater recharge operations. The water conservation volume afforded by the Dam is controlled by the allowable WSE during the flood season and non-flood season (March through September). Currently, the maximum water conservation elevation is 498.0 ft NGVD29 during the flood season and 505.0 ft NGVD29 during the non-flood season.

In an effort to improve water conservation in the region, an increase to the water conservation WSE in the Basin during the flood season is being evaluated. The proposed change would increase the flood season water conservation WSE from 498.0 ft NGVD29 to 505.0 ft NGVD29. It is important to note that flood risk management operations take precedence over any water conservation objectives afforded by the Dam. An elevation of 490.0 ft NGVD29 is typically the minimum flood season WSE that is held during the early stages of a storm event. This WSE is referred to as the “Debris Pool”. The Debris Pool is necessary to help limit the amount of floating debris that enters the Dam outlet gates, which in turn helps ensure the gates can function properly during a storm event.

Once the Basin has been drained after the last storm event of the season the WSE is typically very near the streambed elevation at the Dam, or elevation 470.0 to 474.0 ft NGVD29, with the Dam outflow equal to the Basin inflow. The range of flow rates where inflow is equal to outflow are considered to be the “base flow” condition, with flows ranging between 50 cubic feet per second (CFS) to 200 cfs.

History of Prado Dam and Water Conservation

To better understand the potential future effects of increased water conservation at Prado a thorough understanding of past decisions and operations is relevant. As previously stated, the primary purpose of the Dam is flood risk management with a secondary beneficial use of water conservation. Water conservation was established as a design consideration in the mid 1930’s as the Flood Control Act of 1936 was approved. Below is a timeline (Table 1) of events that are relevant to Prado Dam, water conservation at Prado Dam and significant storm events that have affected the Dam to Hamner Reach of the SAR. A number of the events in the following timeline will be referenced later in this report.

Table 1: Prado Dam Timeline

Timeline (Year)	Events
1936	Prado Dam Authorized by Flood Control Act of 1936: Elevation 507.5 was set as the safe water conservation elevation.
1937	
1938	Flood of 1938: Flow approx. 100,000 cfs through Santa Ana Canyon
1939	
1940	
1941	Prado Dam Completed: 6 gated outlets and 2 ungated outlets.
1942	
1943	
1944	
1945	
1946	First ungated outlet was gated for water conservation purposes with new water conservation elevation set at elevation 514.0 before the remaining gates would be opened for flood control releases.
1947	
1948	
1949	
1950	
1951	
1952	
1953	
1954	
1955	
1956	
1957	
1958	
1959	
1960	
1961	
1962	
1963	
1964	Santa Ana River Mainstem Project was initiated
1965	
1966	
1967	
1968	
1969	USACE revised the design flood criteria for Prado Dam: Debris pool Elevation set at 490, 1969 Flood revealed downstream channel deficiencies, 2nd ungated outlet was gated, Water con elevation was reduced to elevation 490.0, efforts made to limit release flows to 5,000 cfs
1970	
1971	
1972	
1973	
1974	
1975	USACE completed survey for the Santa Ana River Mainstem Project
1976	
1977	
1978	USACE submitted the survey for the Santa Ana River Mainstem Project to Congress
1979	
1980	USACE completed the Phase I Mainstem General Design Memorandum
1981	
1982	
1983	
1984	
1985	
1986	Santa Ana River Mainstem Project construction was authorized
1987	
1988	
1989	Santa Ana River Mainstem Project construction started
1990	USACE reduced targeted maximum release rates to 2,500 cfs, Water conservation elevation set to 494.0 feet during "favorable hydrological and reservoir conditions". Above 494 releases are determined by runoff and weather forecasts.
1991	USACE and OCWD start to formalize water conservation Memorandums of Agreement (MOA)
1992	
1993	MOA Signed: Flood season (elevation 494) and non-flood season (elevation 505) with release rate conditions.
1994	
1995	
1996	USACE prepared a Water Conservation Reconnaissance Report recommending feasibility study to increase water conservation.
1997	
1998	
1999	
2000	
2001	
2002	
2003	
2004	
2005	2005 Storm delivered flood flows, debris and sediment that turned the SAR in the Basin into OCWD Wetlands. Feasibility Study recommended flood season water conservation elevation be increased to 498.0 feet and keep non-flood season elevation at 505.0 feet.
2006	
2007	
2008	
2009	
2010	2010 Storm delivered flood flows, debris and sediment that turned the SAR into OCWD wetlands. Flow > 38,000 cfs, and 50+ acres of debris.
2011	
2012	Prado Basin Feasibility Study Started: Focus on ecosystem restoration, increased water con to 505 year-round and sediment management.
2013	
2014	
2015	

Nearly all of the sediment that enters the Basin will be deposited in the Basin regardless of water conservation WSEs. The sediment removal efficiency of the Basin has been estimated to be greater than 95% (Warrick and Rubin 2007, Brownlie and Taylor 1981).

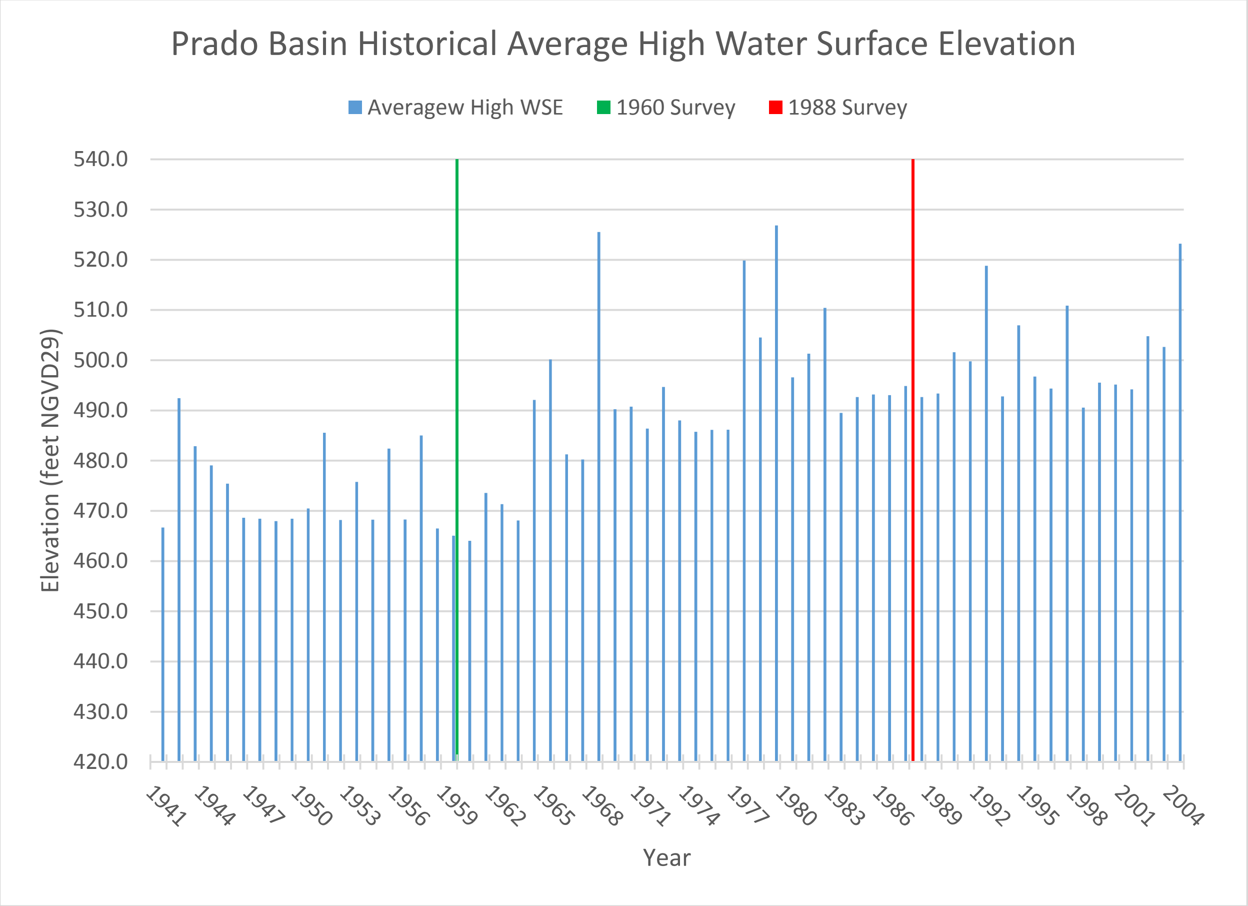
One of the variables that affects the sediment deposition along the upstream SAR within the first 13,000 feet (2.5 miles) of the Dam is the WSE during significant storm events. High flow events transport the majority of the sediment into the Basin. In 2007 the USGS reported that it was estimated that over 90% of fine grain (silt and clay) sediment is transported in less than 1% (4 days or less) of each year in southern California coastal watersheds, including the SAR watershed (USGS 2007 Report). High WSE's in the Basin coincide with the most significant storm events in any given year. A well-documented storm event in January of 2005 highlights this phenomena. The January 2005 storm resulted in seepage through a portion of Prado Dam under construction and also resulted in large debris flows and sediment deposition in the SAR adjacent to the OCWD wetlands. A section of the SAR 75 feet wide by 4,080 feet long was plugged with Arundo up to 20 feet deep (OCWD Report to Board of Directors in 2006). This event caused massive sediment deposition in the SAR, and the SAR turned and flowed into the OCWD wetlands. The WSE prior to the storm event was approximately 497 ft NGVD29 (Figure 1).

Figure 1: January 2005 Prado Data

Source: U.S. Army Corps of Engineers; Design, Construction and Seepage at Prado Dam Presentation, 2005; USACE.

An analysis was performed to compare the trends in the annual average high WSE in the Basin from 1941 to 2005. The 5 days (corresponding with the 1% highest inflow events) with the highest WSE of each year were averaged for that year to determine long term WSE trends (Figure 2). When comparing this data to the timeline in Table 1 the most significant change occurs in 1969. This year coincides with the gating of the last uncontrolled Dam outlet and the start of operations of the Debris Pool at elevation 490 ft NGVD29. An additional factor that has contributed to an increase in the Basin WSE was the historical increase in peak flows due to the addition of impervious surfaces resulting from urbanization in the upper watershed.

Figure 2: Prado Basin Historical High WSE



Data Source: U.S. Army Corps of Engineers; Online Resource Link No Longer Active, Daily Values for WY 1941-1990, 2005; USACE.

Upper Watershed Considerations

A wide variety of variables affect the habitat types along the Dam to Hamner Reach of the SAR. It is important to note that changes in the upper SAR watershed affect how the habitat types in the Dam to Hamner Reach will change over time. Below is a listing and brief discussion of several variables that have affected, and will continue to affect, the habitat changes in the Dam to Hamner Reach of the SAR. These conditions have not been fully evaluated in this report but are listed here to help provide a comprehensive view of variables affecting habitat alterations.

1) Prado Inflow – Prado Dam is situated below 2,255 square miles of the SAR watershed. The construction of upstream dams, debris basins, flood control basins and groundwater recharge facilities attenuate, flows in the Dam to Hamner Reach of the SAR (1967 USACE Sediment Report).
    a. Seven Oaks Dam – Controls flow from 177 square miles
    b. San Antonio Reservoir – Controls flow from 27 square miles
    c. Big Bear Lake – Controls flow from 38 square miles
    d. Lake Elsinore – Controls flow from 792 square miles
    e. Small Basins (<u>estimated</u>) – Controls flow from an estimated approximately 500 square miles (235 square miles in 1967).
    f. Prado Dam – Controls unregulated flow from approximately 721 square miles.

   A recent study performed by Wildermuth Environmental, Inc predicts that future storm flows into the Basin will increase slightly (by as much as 7,969 af/year) due to future land development in the upper watershed, but that total future inflow to the Basin will be reduced by as much 19% (41,356 af/year) due to recycled water re-use (Wildermuth Environmental 2013). The reduction in total inflow will reduce the SAR's ability to transport sediment into the Dam to Hamner Reach.

2) Sediment Transport Interruption – The development of upstream dams, debris basins, flood control basins and groundwater recharge facilities (as described above) remove nearly 100% of all very coarse riverbed material (gravel and cobbles). Depending upon the upstream channel and basin configurations a portion of the sands, silts and clays may make it into the Dam to Hamner Reach. The impervious ground surface area in the unregulated 721 square mile Prado Basin catchment area, as well as the rip-rap and concrete lined flood control channels and river side slopes, eliminate sources of gravel and cobble which would otherwise be available for transport into the Dam to Hamner Reach of the SAR. The reduction of available gravel and cobble for transport downstream will continue to shift the gradation of the riverbed towards predominately sand in the Dam to Hamner Reach of the SAR.

   Over time as the unregulated areas and existing river bed/bank sands are transported downstream and depleted, there may be a trend reversal, and the Dam to Hamner Reach may start to coarsen. To-date, no detailed analysis has been performed in an attempt to quantify this, but basic sediment transport principles tell us that as the incoming sand, silt and clay sediment load decreases the riverbed will begin to coarsen. Due to the uncertainty of this potential future condition, and the likely lengthy time period it would take for this condition to develop, it should not be relied upon as a means to mitigate current sediment transport issues in the upper watershed. Additional analysis would be required to fully address this issue.

3) Non-Native Aquatic and Vegetation Species – The introduction and spread of non-native species in the upper watershed results in altered habitat types in those areas as well as in the Dam to Hamner Reach.
    a. Non-Native Vegetation – The growth of non-native vegetation in the riverbed and along the river banks has the ability to restrict the transport of all sediment types into, and through, the Dam to Hamner Reach. High flows which are capable of removing some of the vegetation create large debris flows that can create jams at various locations along the SAR, thereby forcing excessive deposition of sand, silt and clay in the riverbed and surrounding flood plains. Debris jams and excessive sediment deposition in Prado Basin have destroyed the OCWD wetlands in the recent past. Debris jams were also partially the cause of excessive sediment deposition upstream of the previous River Road Bridge.
    b. Non-Native Aquatic Species – As the upstream SAR slope flattens, peak flows decrease and sand, silt and clay become the dominate riverbed material, backwater and marsh habitats can expand. Areas of standing pools of water within backwatered floodplains along the Dam to Hamner Reach will expand under the current sediment transport and hydrological conditions. This habitat type encourages non-native predatory fish to flourish and negatively impact native fish populations.

Sediment Transport

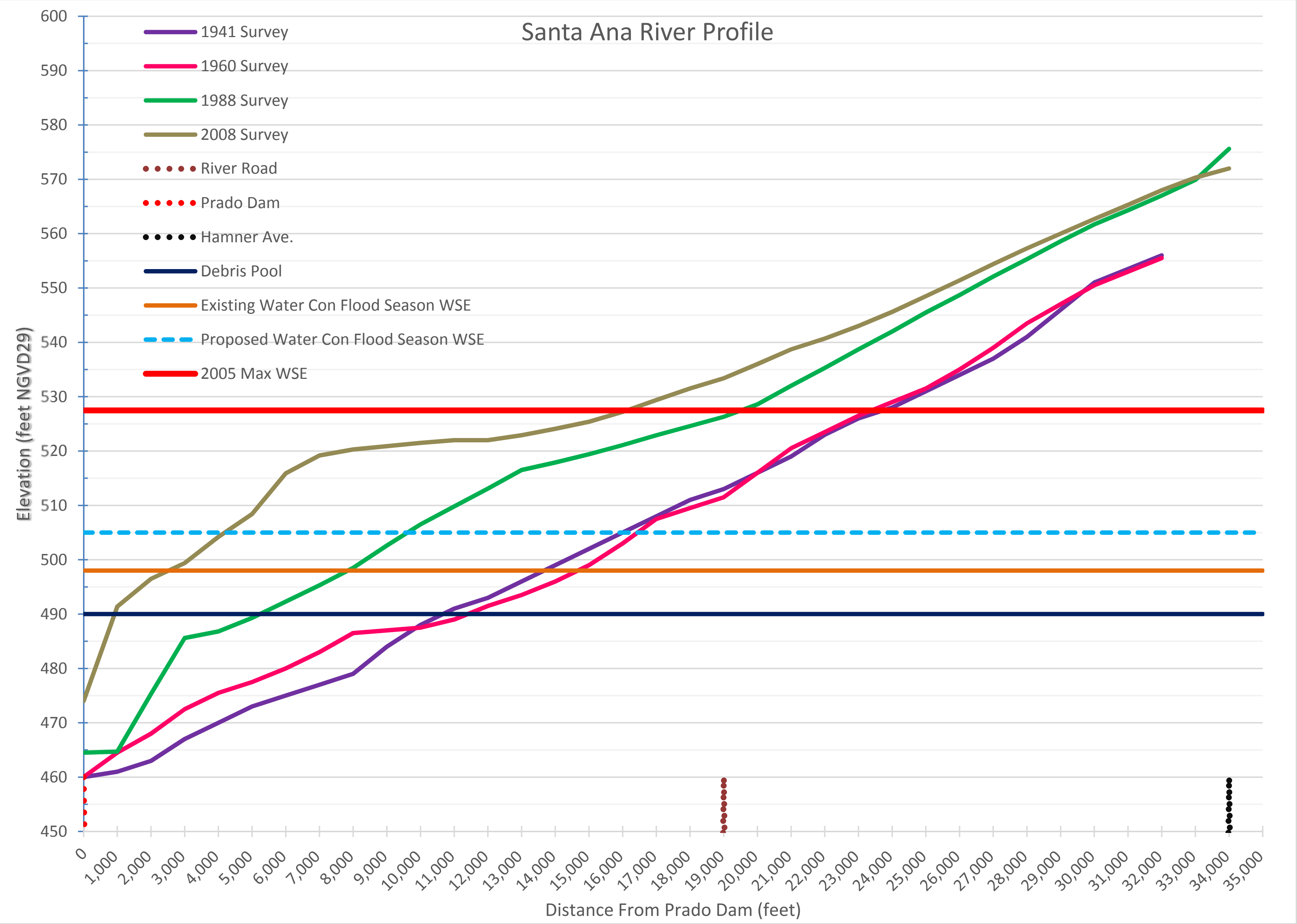
The primary downstream boundary condition that controls sediment transport in the Dam to Hamner Reach of the SAR is the WSE in the Basin during storm events. The current slope in the Dam to Hamner Reach of the SAR is primarily controlled by the Debris Pool elevation (elevation 490 ft NGVD29), and the WSE during high intensity storm events (up to elevation 527 ft NGVD29). Water conservation elevations of 498.0 and 505.0 ft NGVD29 have a small effect on the overall long term deposition in the Basin and SAR. In 2008, the available volume between elevations 498.0 and 505.0 ft NGVD29 was approximately 10,500 acre-feet (af). An average inflow of 5,300 cfs fills this volume in approximately 24 hours. The presence of a Debris Pool, irrespective of water conservation, results in nearly all sand size particles (and larger particles) to deposit within the Basin.

It is important to note that a fundamental water conservation operational objective is to drain the water conservation pool as quickly as possible in order to make storage volume available for subsequent storm flows. Storm conditions do occur that fill the water conservation pools back-to-back; these storm events also produce flows that exceed the water conservation operating rules, and produce WSE's much higher than the 498.0 or 505.0 ft NGVD29 levels. These types of storms result in sediment deposition at much higher elevations in the Basin.

When evaluating the slope of the Dam to Hamner Reach (channel slope is a main factor in sediment transport) the Debris Pool elevation was used as the controlling elevation after 1969. The original SAR streambed elevation in 1938 (at the location of the Dam prior to the construction of the Dam) was approximately 460.0 ft NGVD29. In 1941, the river slope in the vicinity of the Dam upstream to the Hamner Avenue crossing was fairly consistent at approximately 0.0030. The SAR streambed elevation in 2008, at the location of the Debris Pool 1,000 feet upstream from the Dam, was approximately 490.0 ft NGVD29. The overall river slope from the Debris pool upstream to the Hamner Avenue crossing in 2008 was approximately 0.0025. Historical SAR profiles (Figure 3) show us that the Dam to Hamner Reach of the SAR attempts to achieve a stable slope of approximately 0.003.

The overall 2008 SAR slope is somewhat misleading as there is a 10,000 linear foot section of the SAR between elevations 515 to 527 ft NGVD29 where the slope is much flatter than the overall average slope. Approximately 4,000 feet of the SAR in this area had a slope of 0.0004 as of 2008 (Figure 3). Based on debris removal operations, wetland reconstruction operations and SAR channel sediment removal following 2010 storm events, the extent of flattened slope had propagated further upstream. The next Basin survey will provide valuable insight as to the changes in the Basin since 2008.

Figure 3: SAR Profiles



As shown in Figure 3, the rate of aggradation between 1941 and 1960 was much less than after the 1960 survey. Recall that operation of a Debris Pool was established in 1969. The lower sedimentation rates prior to 1960 is likely due to the lower pool elevations during this time (Figure 2), and the operation of ungated outlets which allowed for higher rates of sediment transport through the Dam. Another factor that affected the overall deposition in the Basin during this time period was the generally dryer conditions in the watershed (SAR Watermaster Report, 2008) resulting in overall less run-off.

It can be argued that a much higher rate of sediment transport potential existed in the early years of Prado Dam. The potential was higher because the 1941 to 1960 period was during a time when available source material from the upper watershed would have been more plentiful due to fewer impervious surfaces, and many fewer debris and flood control basins would have existed than what is present today in the upper watershed.

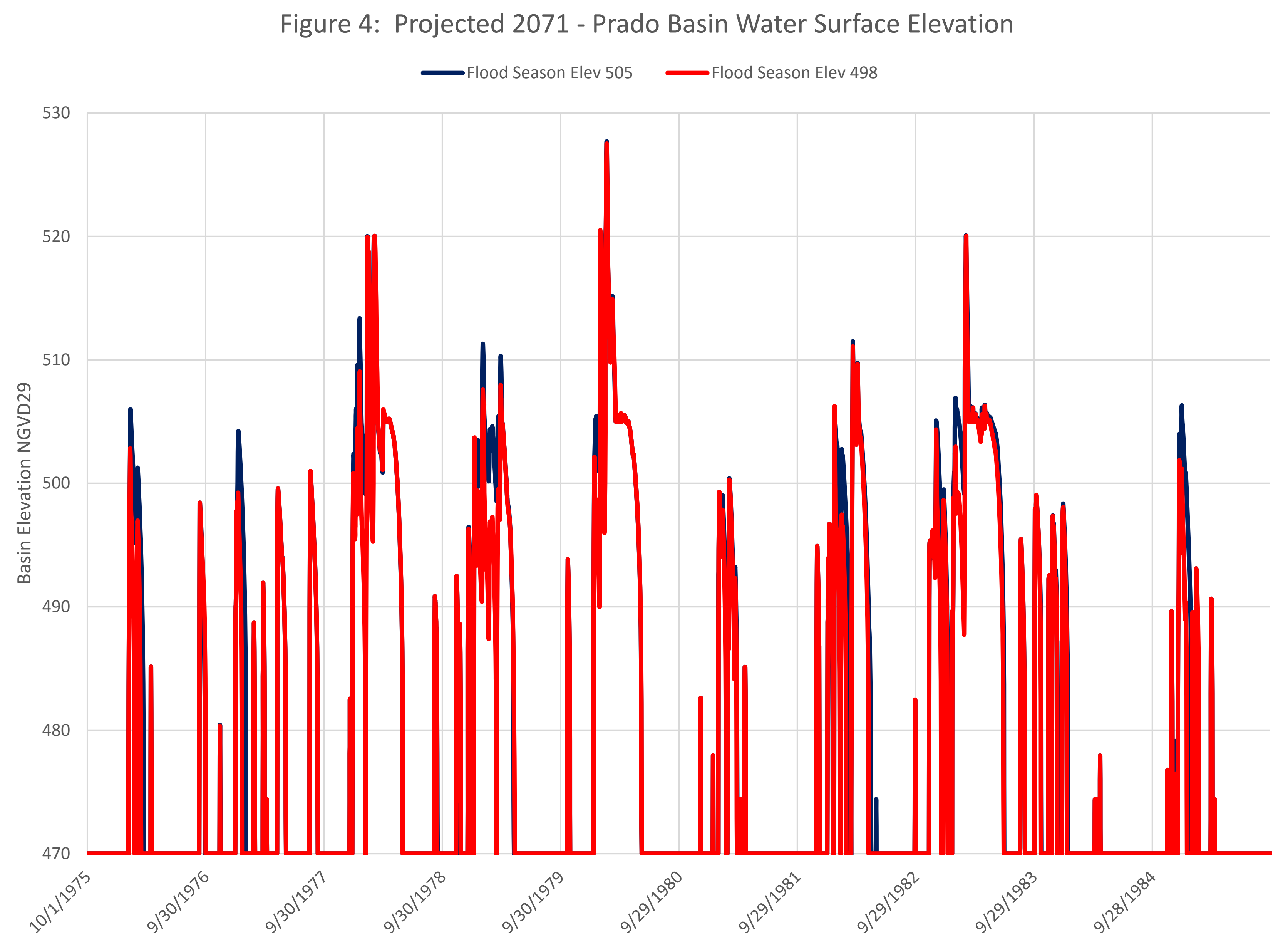
In order to more completely assess the potential effect of increased water conservation a sediment transport model was developed to predict how the riverbed may react to increasing the downstream WSE by 7 feet during the flood season. Under the direction of the U.S. Army Corps of Engineers (USACE) and the Orange County Water District (OCWD), Wildermuth Environmental, Inc. (WEI) developed a 50-year daily inflow hydrograph for Prado Basin for the projected 2021 and 2071 conditions. The hydrograph is based on historical rainfall records, future land use conditions, expected flood control operations, projected recycled water discharges, and water conservation practices in the watershed tributary to the Prado Basin. A representative 10-year time period was selected from the 50-year daily inflow hydrograph (1975-1985) for detailed WSE analysis and detailed sediment transport modeling. A 10-year time period was determined to provide the most reliable model results at the best economy.

The projected Basin hydrograph was then used as input data to OCWD’s groundwater recharge operations model. The operations model takes into account the downstream groundwater recharge capacities, operations and the optimal release rates from Prado Dam to maximize storm water capture and groundwater recharge. The OCWD operations model was then run under the existing condition (elevation 498.0 ft NGVD29 flood season storage level) and under the proposed future condition (elevation 505.0 ft NGVD29 flood season level). These modeling efforts provided an estimate of the maximum WSE elevation in the Basin, the duration of an increased WSE condition and the frequency of which these conditions may occur (Figure 4). Please note that the date range (x-axis) in the following figures relates to the dates of the historical data used to develop the future projections, the data presented in this report is for the projected future conditions.

The representative 10-year time period was selected as input to a HEC-RAS sediment transport model, in-part, to reduce the model run time to less than 1 week. For a complete discussion on the modeling assumptions, inputs and results please refer to the Golder Associates, Inc. technical memo, dated March 26, 2015; Prado Feasibility Study Project – Prado Water Level Analysis Sediment Transport Modeling Results.

It should be noted that the storage and duration projections do not account for the incremental filling of the water conservation pool with sediment. Under current sedimentation rates nearly all storage volume below elevation 505 ft NGVD29 will be lost by 2071. As the Basin fills with sediment it will take much less time to drain the water conservation pool, and impacts from additional water conservation will decrease over time.

Figure 4: Projected 2071 - Prado Basin Water Surface Elevation



The blue trend line in Figure 4 shows the anticipated, heightened, WSEs due to water conservation efforts resulting from the proposed flood season WSE increase. On average there is a 3 to 5 foot WSE increase once per year due the proposed deviation. This WSE data was then used as an input to a HEC-RAS sediment transport model to predict the impacts on the upstream SAR.

The results of the sediment transport model for the existing condition (flood season WSE of 498.0 ft NGVD29, Base 2) indicate that there will be a general trend of aggradation from above the I-15 Freeway crossing, extending downstream into Prado Basin. Aggradation over a 10 year time period is expected to range from 1 to 9 feet in depth. Based on the model results, the river bed around River Road Bridge is expected to experience the most aggradation which is consistent with what has been observed historically (Golder Associates, March 2015 Technical Memo).

The sediment transport model for the increased WSE scenario (flood season WSE of 505.0 ft NGVD29, Base 3) exhibits nearly identical aggradation trends as the existing conditions model. The only expected difference in the sedimentation trends between the two scenarios is a slight increase in deposition within Prado Basin between the 498 ft and 505 ft NGVD29 elevation contours. Based on historical topographic surveys there is approximately 1,000 linear feet between the 498 and 505 contours. If the flood season WSE is increased to elevation 505.0 ft NGVD29, then transient periods of increased aggradation may occur (between elevation 498.0 and 505.0 ft NGVD29) as high flow events coincide with periods of increased WSE. During periods where high flow events coincide with relatively low WSE, the aggradation trends will tend to revert back to historically observed conditions. A portion of the sediment deposited between elevations 498 and 505 ft NGVD29 will be transported below elevation 498 ft NGVD29 when high flow events coincide with relatively low WSE. As mentioned previously, it is important to note that once the water conservation pool is filled to the maximum WSE it is then drained as quickly as possible to create storage volume for subsequent storm flows. This mode of operation reduces the frequency of occurrence when the maximum water conservation WSE coincides with high flow events.

The sediment transport model results also show that there will be no appreciable change to the river bed gradation due to the increased WSE. The general trend for both scenarios is that there will be deposition of primarily fine to medium sand from above the I-15 Freeway crossing, extending downstream into Prado Basin. The overall quantity of sediment and sediment particle size distribution entering Prado Basin will be the same for both WSE scenarios. The alteration to the SAR morphology caused by the proposed flood season increase to the WSE will likely be limited to the spatial distribution of sediments between elevations 498 and 505 ft NGVD29 (Figure 5 and Figure 6).

Figure 5: SAR Channel Elevation Change
498 Flood Season WSE

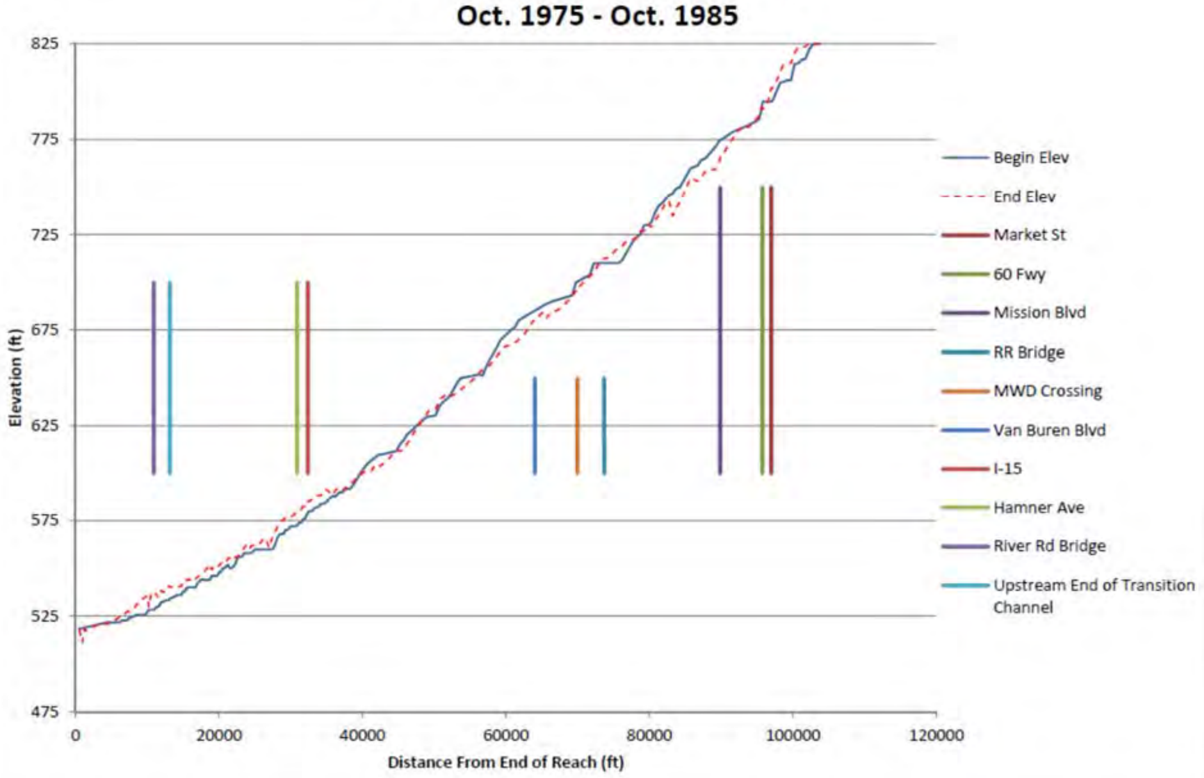
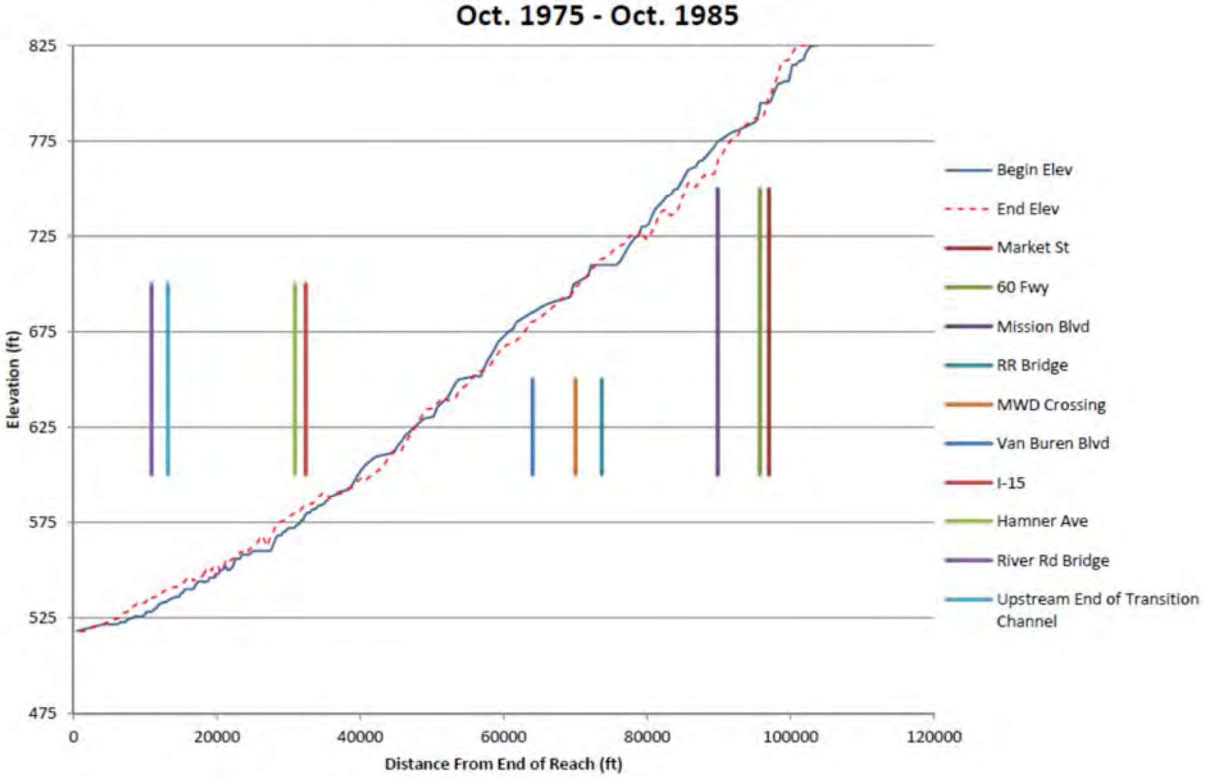


Figure 6: SAR Channel Elevation Change
505 Flood Season WSE

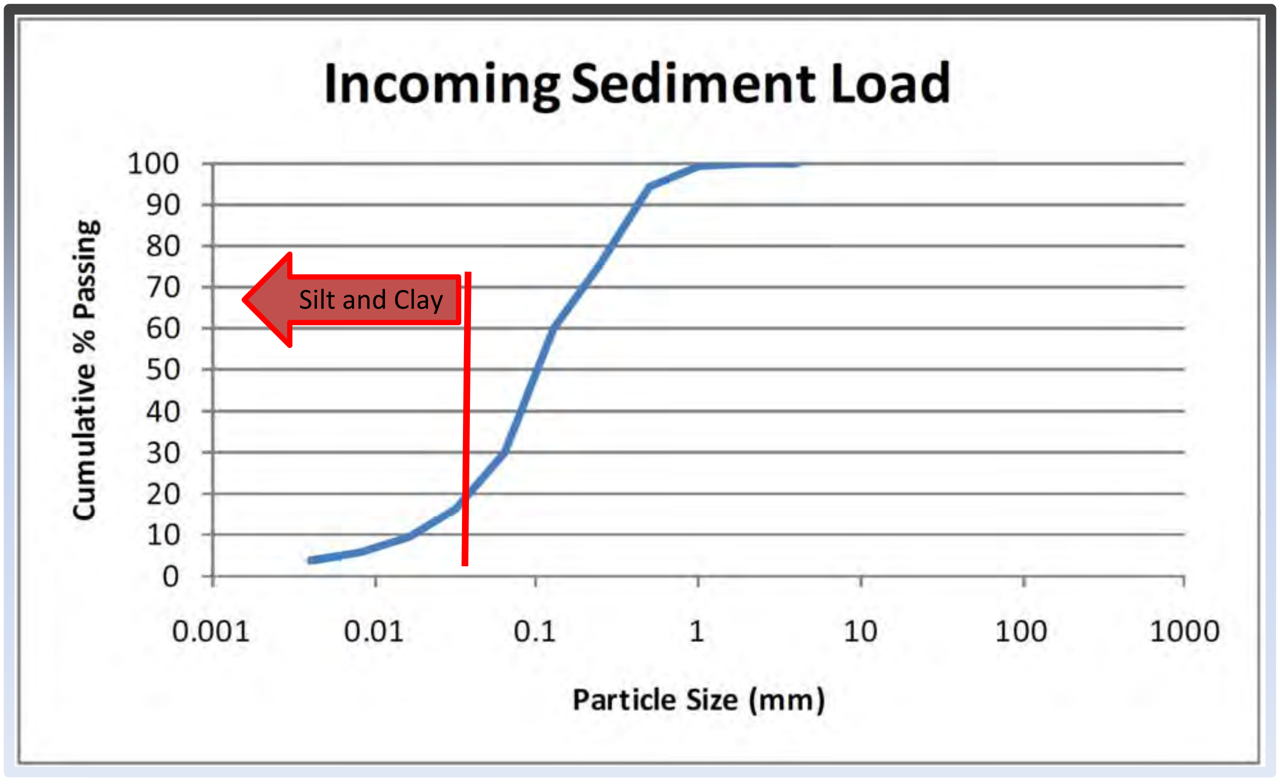


Source: Golder Associates Inc; Prado Feasibility Study Project – Prado Water Level Analysis Sediment Transport Modeling Results, March 26, 2015; Golder Associates Inc.

As discussed previously, nearly all of the sand that enters the Basin will be deposited in the Basin regardless of water conservation WSEs. The sediment removal efficiency of the Basin is estimated to be greater than 95% (Warrick and Rubin 2007, Brownlie and Taylor 1981). This means that the existing residence time of water in the Basin allows for nearly all of the sediment to settle out of the water column. Additional quantities of silt and clay will be deposited in the Basin due to the storage of the increased water volume (for the proposed planned deviation) held for longer durations.

Several soil borings have been performed in the Basin along the SAR to better understand the sediment gradations being introduced and deposited in the Basin. These borings revealed that, on average, approximately 20 percent of the sediment deposited in the Basin is silt and clay (Figure 7). The results of the Golder sediment transport model support this data as well, revealing that approximately 23% of the sediment transported past River Road Bridge is silt and clay.

Figure 7: Average Existing Sediment Gradation in Prado Basin



Source: Orange County Water District; Prado Basin Sediment Management Demonstration Project 100% Engineering Analysis Draft, November 2014; Appendix B HEC-RAS Sediment Transport Modeling Santa Ana River; Golder Associates Inc.

The following assumptions were used to quantify the additional sedimentation in the Basin due to the proposed planned deviation.

1) All sand size particles would deposit in the Basin irrespective of the proposed 7 foot increase to the flood season WSE, leaving a portion of the silt and clay fraction of the incoming sediment for deposition as a potential impact from the proposed planned deviation.
2) The additional 10,500 af of water in the Basin is held for a duration that allows all of the silt and clay particles to settle out of the water column. (Conservative Assumption)
3) The TSS of the Prado storm water inflow is 2,000 mg/L. Historical data shows average Prado storm water inflow TSS to range between 500 to 2,000 mg/L. (Conservative Assumption)
4) Based on soil borings and based on results from sediment transport modeling, the silt and clay portion of the historical sedimentation in the Basin is 20%.
5) The silt and clay deposits across a 1,890 acre area, or the 2008 area of the 505 ft NGVD29 pool.

Calculation of fine grain (silt and clay) deposition volume due to planned deviation:

10,500 af = 12,951,600,000 L

2,000 mg/L = 0.00441 lbs/L

(12,951,600,000 L/af) x (0.00441 lbs/L) = 57,116,556 lbs/10,500 af
(57,116,556 lbs) / (120 lbs/feet^3) = 475,971 feet^3
(475,971 feet^3) / (27 feet^3/yard^3) = 17,629 yard^3

17,629 yard^3 x 20% silt & clay = 3,526 yard^3 silt & clay per 10,500 af water

17,629 yard^3 – 3,526 yard^3 silt & clay = 14,103 yard^3 sand per 10,500 af water

3,526 yard^3 silt & clay per 10,500 af water ≈ 3,500 yard^3 silt & clay per 10,500 af water

On average it is expected that the Basin WSE will reach, or exceed, 505 ft NGVD one time per year (Figure 3). Therefore a volume of 10,500 af has been used as the additional water impounded due to the planned deviaion. The existing sediment removal efficiency of the Basin already removes a portion of the silt and clay that is being attributed to the planned deviation, but in order to be conservative it has been assumed that the entire volume of silt and clay in the10,500 af is deposited due to the planned deviation.

The above set of assumptions result in an additional 3,500 cubic yards of deposition of fine grain (silt and clay) sediments annually in Prado Basin due to the proposed planned deviation (Table 2). The fine grain (silt and clay) sediments disperse over large areas in the Basin due to their ability to stay suspended more easily than coarse (sand) and very coarse sediment (gravel and cobbles). The approximate surface area of the Basin below the 505 ft NGVD29 Basin contour is 1,890 acres (2008 Survey).

Table 2: Annual Prado Basin Sedimentation

Scenario	Flood Season Water Conservation WSE (ft NGVD29)	Total Annual Basin Sedimentation (yards^3/year)	Additional Annual Basin Sedimentation (yards^3/year)	Percent Change in Annual Sedimentation (%)
Existing Condition	498.0	1,200,000	0	0
Planned Deviation	505.0	1,203,500	3,500	0.30
Alternative*	503.9	1,202,900	2,900	0.24

*See page 27 for analysis.

Silt and clay remain suspended relatively easily in flowing water, especially in the high intensity storm flows considered in this analysis. Due to turbulence in the Basin created by wind action and tributary inflow it has been assumed that suspended fine sediments will be distributed somewhat evenly over the pool area in the Basin. If the silt and clay is distributed somewhat evenly across the 1,890 acres, then there would be an average of 0.001 feet per year of deposition. Over 50 years this would equate to 0.05 feet of additional sedimentation. Under existing conditions there is approximately 0.5 to 0.7 feet of sedimentation along the SAR in the Basin. After 50 years nearly all storage below elevation 505 ft NGVD29 would be filled with sediment and the proposed water conservation planned deviation will no longer be a factor in the operation of the Dam.

This calculation suggests that there is approximately 14,000 cubic yards of sand transported into the Basin with each 10,500 af of water. This is not the case as there is a very high volume of sediment transported into the Basin as bed load which is not captured in the above calculation. A fundamental assumption is that all suspended sand and all sediment transported into the Basin as bed load material is heavy enough to be deposited in the Basin regardless of any water conservation operations. Once bed load sediments enter a relatively tranquil body of water the bed load material deposits quickly and relatively close to the high energy stream system which delivered it. This sediment transport process is captured in Basin surveys taken in 1988 and 2008 (Figure 8). The areas of the greatest deposition in the Basin occur where the SAR encounters the 505.0 ft to 524.0 ft NGVD29 WSEs (Figure 8).

The historical annual average volume of sediment deposited in the basin is 1,200,000 cubic yards. The predicted additional sediment deposition in the Basin due to the planned deviation is negligible (3,500 cubic yard per year), representing a 0.3% increase in the annual sedimentation volume.

Topography and Mapping

The change in the SAR slope affects how easily the adjacent flood plain can drain into the low flow channel following a storm event. It is natural and healthy for a river to over-top its banks during a storm event and deposit sediments in the adjacent flood plain. Isolated areas of backwater and marsh habitat should be expected to develop as well under these conditions. The Dam to Hamner Reach of the SAR is no exception to this natural process, however, as the riverbed slope flattens, the backwater areas drain less quickly and completely, and areas of marsh habitat may expand beyond what is typically expected in an un-altered natural riverine system. Backwater pools (some deep at times) create habitat for non-native aquatic species that prey on native fish populations. Historical topographic maps and imagery have been examined to help determine the historical habitat types.

The U.S. Army Corps of Engineers (USACE) constructed Prado Dam 1941, and since that time an average of 770 acre feet per year (afy) (1,200,000 cubic yards (cu yds)) of sediment has deposited within Prado Basin annually (2008 USACE Basin Survey). The most recent Basin survey completed in 2008 revealed that a total of more than 50,000 acre feet (af) (80,600,000 cu yds) of sediment has been deposited in the Basin since 1941 (Table 3).

Surveys of the Basin conducted by the USACE in 1941, 1960, 1988 and 2008 have been used to predict the future sedimentation rates in the Basin (Table 3). The two most recent surveys (1988 and 2008) have been used to graphically demonstrate the topographic change in the Basin during that time period (Figure 8). Basin surveys were also conducted in 1969 and 1980 but GIS data from these two surveys have yet to be located for further analysis. The 1969 and 1980 storage capacity data is presented below in Table 2 along with the aforementioned survey years.

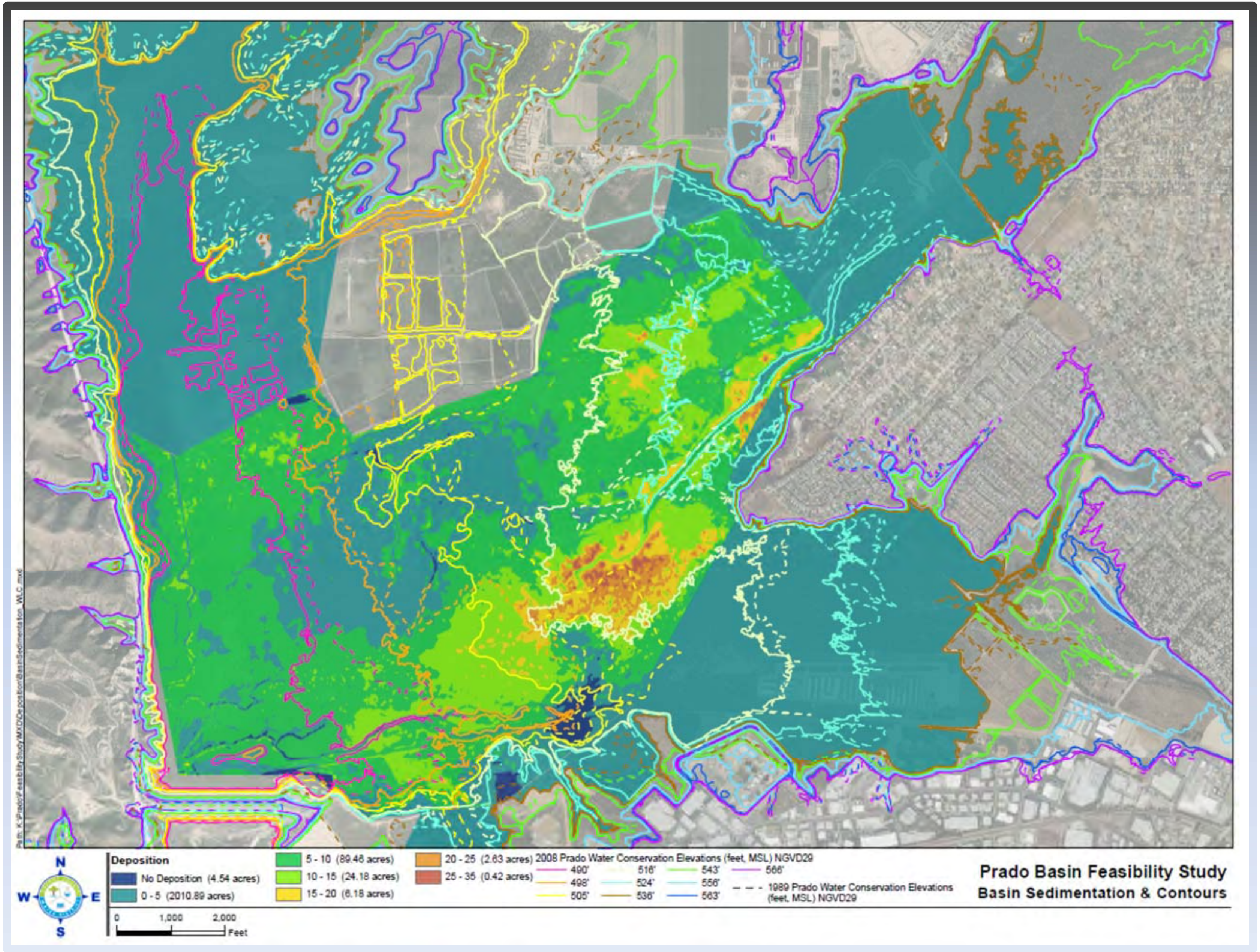
Table 3: Prado Dam Historical Surveys

Prado Dam Storage Capacity

Elevation	2008 Survey	1988 Survey	Storage Loss since 1988		Storage Loss since 1941		1980 Survey	1969 Survey	1960 Survey	1941 Survey	
	ac-ft	ac-ft	ac-ft	%	ac-ft	%	ac-ft	ac-ft	ac-ft	ac-ft	
470	0	7	7	100%	310	100%	8	5	58	310	
471	1	14	13	93%	404	100%	10	6	87	405	
472	5	22	17	77%	525	99%	14	9	128	530	
473	10	34	24	71%	670	99%	18	12	184	680	
474	17	48	31	65%	853	98%	25	18	259	870	
475	24	71	47	66%	1,096	98%	34	25	359	1,120	
476	31	103	72	70%	1,329	98%	46	36	500	1,360	
477	93	147	54	37%	1,587	94%	67	54	687	1,680	
478	121	208	87	42%	1,919	94%	103	99	931	2,040	
479	155	295	140	47%	2,305	94%	159	191	1,245	2,460	
480	196	414	218	53%	2,704	93%	239	305	1,645	2,900	
481	251	573	322	56%	3,349	93%	348	445	2,052	3,600	
482	330	779	449	58%	3,670	92%	488	659	2,540	4,000	
483	442	1,032	590	57%	3,958	90%	664	965	3,119	4,400	
484	581	1,333	752	56%	4,919	89%	883	1,311	3,802	5,500	
485	750	1,705	955	56%	5,750	88%	1,188	1,770	4,604	6,500	
486	954	2,155	1,201	56%	6,746	88%	1,627	2,303	5,435	7,700	
487	1,228	2,674	1,446	54%	6,972	85%	2,183	2,979	6,382	8,200	
488	1,569	3,268	1,699	52%	8,431	84%	2,843	3,753	7,458	10,000	
489	1,988	3,940	1,952	50%	8,512	81%	3,606	4,590	8,674	10,500	
490	2,500	4,688	2,188	47%	10,100	80%	4,474	5,471	10,045	12,600	Top of Debris Pool, Btm. of Buffer Pool
491	3,086	5,508	2,422	44%	10,714	78%	5,442	6,456	11,395	13,800	
492	3,753	6,404	2,651	41%	12,047	76%	6,507	7,565	12,881	15,800	
493	4,498	7,379	2,881	39%	13,502	75%	7,666	8,803	14,514	18,000	
494	5,310	8,435	3,125	37%	13,690	72%	8,915	10,144	16,303	19,000	Flood Season Top Buffer Pool
495	6,194	9,562	3,368	35%	14,806	71%	10,257	11,542	18,259	21,000	
496	7,149	10,758	3,609	34%	15,251	68%	11,693	12,972	20,146	22,400	
497	8,177	12,055	3,878	32%	16,423	67%	13,226	14,490	22,175	24,600	
498	9,278	13,460	4,182	31%	17,722	66%	14,857	16,130	24,353	27,000	Flood Season Water Con. Elev.
499	10,479	14,951	4,472	30%	19,021	64%	16,577	17,923	26,688	29,500	
500	11,760	16,522	4,762	29%	19,240	62%	18,376	19,856	29,187	31,000	
501	13,219	18,185	4,966	27%	20,781	61%	20,281	21,876	31,624	34,000	
502	14,722	19,944	5,222	26%	21,778	60%	22,323	24,061	34,206	36,500	
503	16,302	21,783	5,481	25%	22,898	58%	24,480	26,400	36,937	39,200	
504	18,016	23,712	5,696	24%	23,984	57%	26,732	28,849	39,823	42,000	
505	19,826	25,754	5,928	23%	25,174	56%	29,083	31,410	42,870	45,000	Non-Flood Season Water Con. Elev.
506	21,746	27,910	6,164	22%	26,054	55%	31,536	34,064	45,791	47,800	
507	23,762	30,185	6,423	21%	27,238	53%	34,088	36,808	48,849	51,000	
508	25,878	32,579	6,701	21%	28,122	52%	36,731	39,641	52,047	54,000	
509	28,111	35,084	6,973	20%	28,889	51%	39,466	42,572	55,389	57,000	
510	30,419	37,706	7,287	19%	30,181	50%	42,289	45,564	58,878	60,600	
511	32,818	40,442	7,624	19%	31,182	49%	45,218	48,683	62,229	64,000	
512	35,306	43,290	7,984	18%	32,694	48%	48,270	51,906	65,706	68,000	
513	37,897	46,253	8,356	18%	33,303	47%	51,434	55,194	69,311	71,200	
514	40,611	49,338	8,727	18%	34,389	46%	54,697	58,543	73,048	75,000	
515	43,445	52,534	9,089	17%	35,555	45%	58,067	62,004	76,918	79,000	
516	46,392	55,841	9,449	17%	35,908	44%	61,553	65,543	80,627	82,300	
517	49,505	59,247	9,742	16%	36,995	43%	65,149	69,147	84,451	86,500	
518	52,694	62,750	10,056	16%	37,306	41%	68,852	72,806	88,390	90,000	
519	55,984	66,375	10,391	16%	38,616	41%	72,653	76,514	92,446	94,600	
520	59,568	70,121	10,553	15%	39,432	40%	76,546	80,289	96,622	99,000	
521	63,100	73,966	10,866	15%	40,400	39%	80,535	84,187	100,779	103,500	
522	66,744	77,903	11,159	14%	41,256	38%	84,625	88,239	105,049	108,000	
523	70,516	81,941	11,425	14%	41,484	37%	88,812	92,380	109,432	112,000	
524	74,410	86,084	11,674	14%	42,590	36%	93,092	96,604	113,930	117,000	
525	78,394	90,334	11,940	13%	42,606	35%	97,470	100,905	118,544	121,000	
526	82,501	94,694	12,193	13%	43,699	35%	101,952	105,314	123,070	126,200	
527	86,769	99,162	12,393	12%	42,231	33%	106,534	109,850	127,701	129,000	
528	91,175	103,735	12,560	12%	44,825	33%	111,216	114,493	132,439	136,000	
529	95,722	108,440	12,718	12%	45,278	32%	116,000	119,221	137,285	141,000	
530	100,411	113,291	12,880	11%	45,589	31%	120,888	124,091	142,240	146,000	
531	105,307	118,271	12,964	11%	45,193	30%	125,898	129,107	147,347	150,500	
532	110,289	123,380	13,091	11%	45,711	29%	131,048	134,247	152,568	156,000	
533	115,396	128,607	13,211	10%	45,604	28%	136,330	139,502	157,902	161,000	
534	120,627	133,954	13,327	10%	46,373	28%	141,736	144,867	163,352	167,000	
535	125,976	139,432	13,456	10%	47,024	27%	147,270	150,362	168,917	173,000	
536	131,534	145,038	13,504	9%	46,466	26%	152,936	155,981	174,533	178,000	
537	137,252	150,757	13,505	9%	46,748	25%	158,732	161,706	180,264	184,000	
538	143,062	156,589	13,527	9%	46,938	25%	164,653	167,509	186,110	190,000	
539	149,037	162,549	13,512	8%	47,963	24%	170,698	173,386	192,071	197,000	
540	155,135	168,639	13,504	8%	47,865	24%	176,865	179,376	198,150	203,000	
541	161,458	174,856	13,398	8%	46,842	22%	183,157	185,501	204,364	208,300	
542	167,788	181,201	13,413	7%	48,212	22%	189,578	191,775	210,697	216,000	
543	174,312	187,681	13,369	7%	47,688	21%	196,135	198,222	217,150	222,000	Existing Spillway
544	180,935	194,304	13,369	7%	49,065	21%	202,838	204,820	223,725	230,000	
545	187,735	201,066	13,331	7%	48,265	20%	209,685	211,557	230,422	236,000	
546	194,632	207,968	13,336	6%	48,368	20%	216,678	218,430	237,299	243,000	
547	201,773	215,019	13,246	6%	48,227	19%	223,824	225,426	244,303	250,000	
548	208,981	222,225	13,244	6%	49,019	19%	231,132	232,548	251,435	258,000	
549	216,317	229,595	13,278	6%	49,683	19%	238,598	239,799	258,695	266,000	
550	223,808	237,139	13,331	6%	49,192	18%	246,215	247,176	266,084	273,000	
551	231,480	244,824	13,344	5%	50,520	18%	253,994	254,685	273,542	282,000	
552	239,593	252,656	13,063	5%	50,407	17%	261,946	262,312	281,129	290,000	
553	247,619	260,663	13,044	5%	50,381	17%	270,065	270,037	288,845	298,000	
554	255,744	268,836	13,092	5%	51,256	17%	278,345	277,875	296,691	307,000	
555	264,085	277,196	13,111	5%	48,915	16%	286,810	285,824		313,000	
556	272,513	285,757	13,244	5%	51,487	16%	295,481			324,000	
557	281,164	294,527	13,363	5%	50,836	15%	304,349			332,000	
558	290,025	303,506	13,481	4%	50,975	15%	313,409			341,000	
559	300,555	312,693	12,138	4%	49,445	14%	322,665			350,000	
560	309,784	322,080	12,296	4%	49,216	14%	332,120			359,000	
561	319,214	331,710	12,496	4%	49,786	13%	341,785			369,000	
562	328,855	341,603	12,748	4%	50,145	13%	351,670			379,000	
563	338,676	351,735	13,059	4%	50,324	13%	361,795			389,000	Future Spillway
			avg per year 1988-2008 =	622	avg per year 1941-1988=	776					
594.4											Top of Dam

Data Source: U.S. Army Corps of Engineers; 2008 Survey Data Spread Sheet, Prado Dam Storage Capacity Spread Sheet Disturbed via Email, 2009; USACE, Annotations added by Scheevel Engineering, LLC 2014.

Figure 8: Basin Contours & Sedimentation 1988 - 2008



Sedimentation is expected to continue at a rate equal to, or slightly less than, those experienced between 1988 and 2008. The potential for reduced sedimentation may result from;

1) Less total Basin inflow due to upstream water conservation and recycled water re-use,
2) Lower than historical peak inflows due to upstream storm water capture and recharge,
3) Lower sediment inflow due to urbanization in the upper watershed; and
4) Lower sediment load in the Santa Ana River due to;
    a. Seven Oaks Dam – Controls flow from 177 square miles
    b. San Antonio Reservoir – Controls flow from 27 square miles
    c. Big Bear Lake – Controls flow from 38 square miles
    d. Lake Elsinore – Controls flow from 792 square miles
    e. Small Basins (estimated) – Controls flow from approximately 500 square miles (235 square miles in 1967).

Historical aerial imagery was used to evaluate the historical habitat types along the Dam to Hamner Reach of the SAR. Historical imagery from 1929 (Figure 9) through 1967 (Figure 13) indicates that the Dam to Hamner Reach of the SAR riverbed has always been composed of a large percentage of sand. The resolution of the imagery does not adequately display the likely present gravel and cobble beds, but based on the gradation of sediment in the upper watershed, and the ability of the watershed to produce high flow events, it is very likely that transient areas of gravel and cobble beds were historically present in the Dam to Hamner Reach of the Santa Ana River.

Figure 9: 1929 Prado Dam Area Aerial Imagery

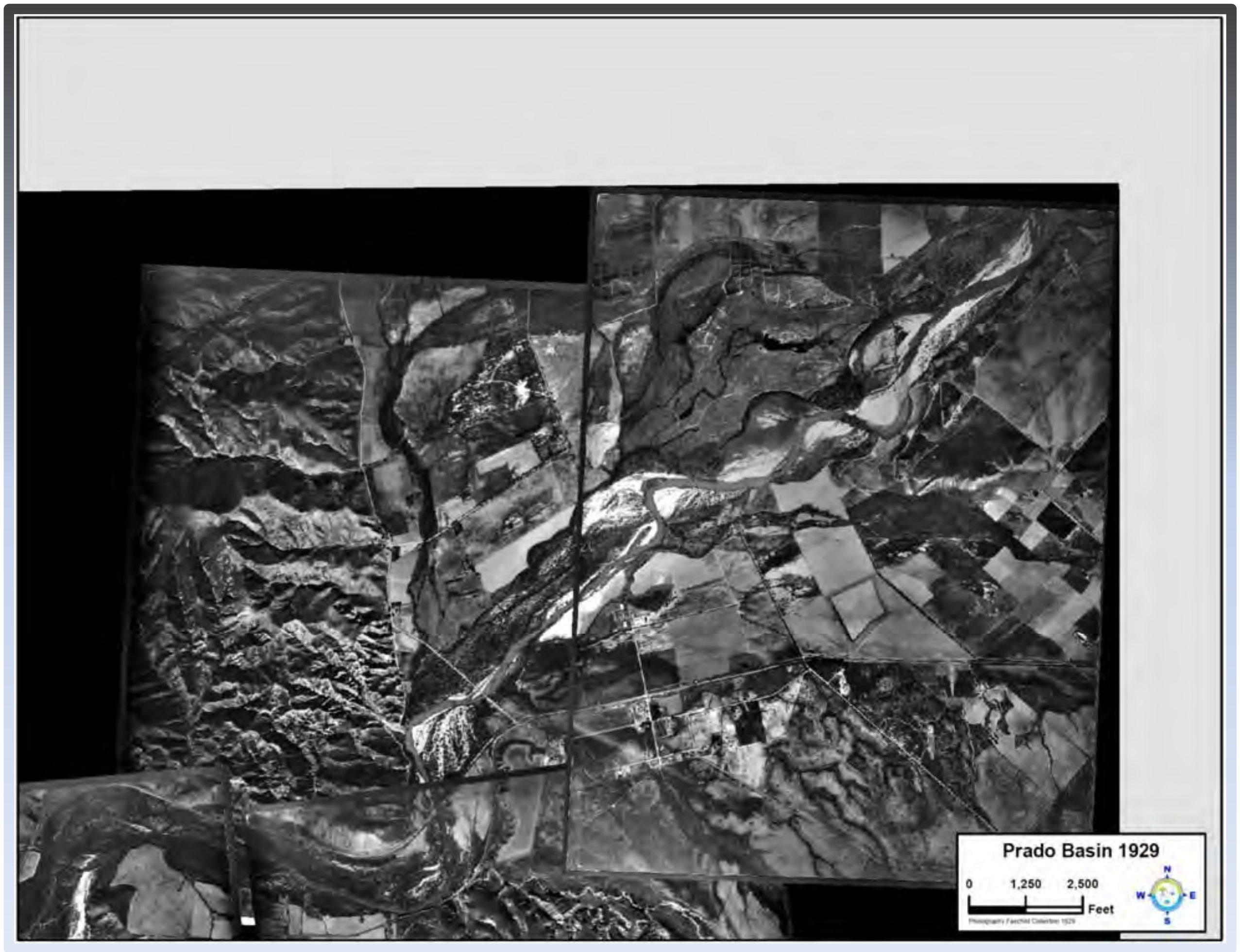


Figure 10: 1938 Prado Dam Area Aerial Imagery

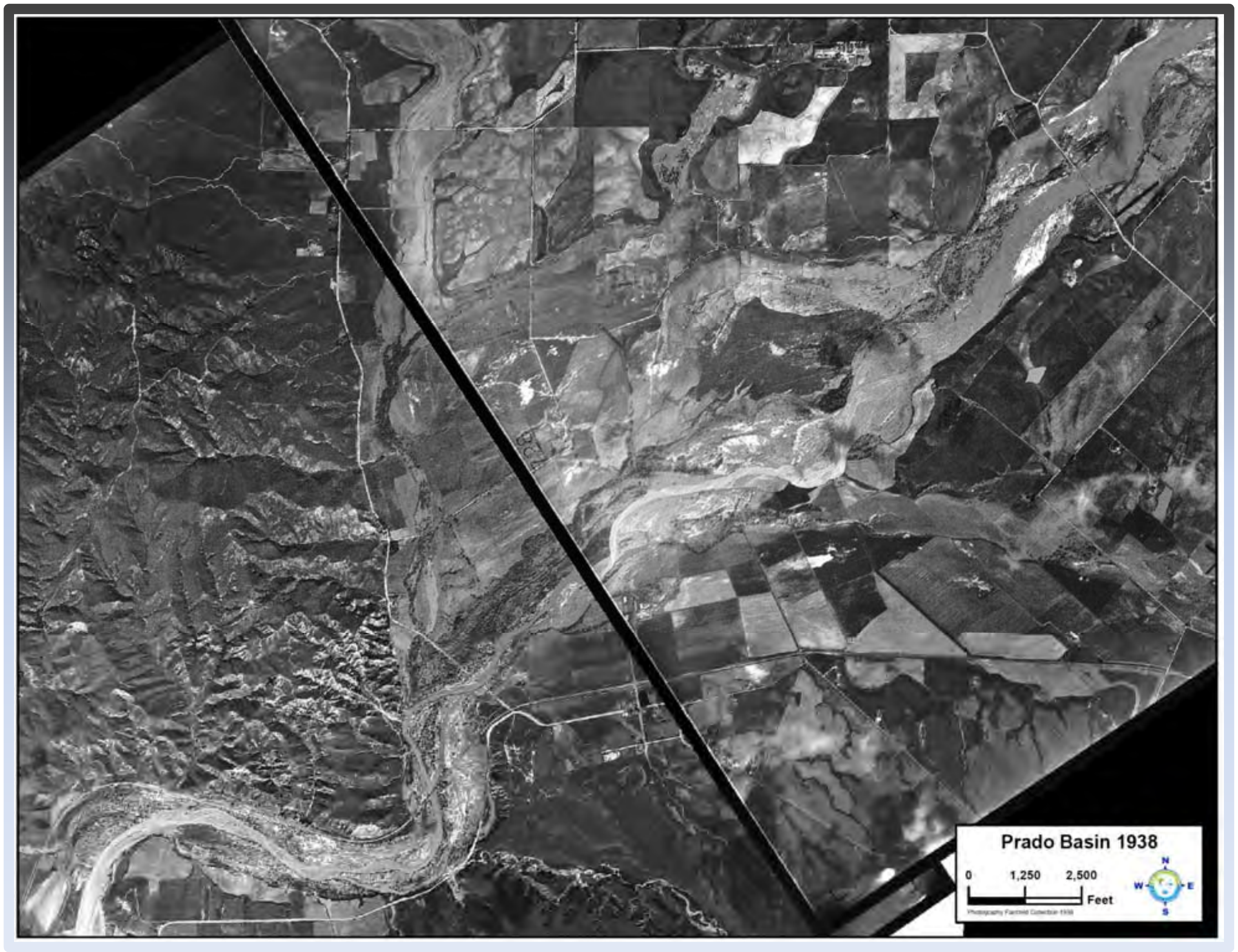


Figure 11: 1947 Prado Dam Area Aerial Imagery

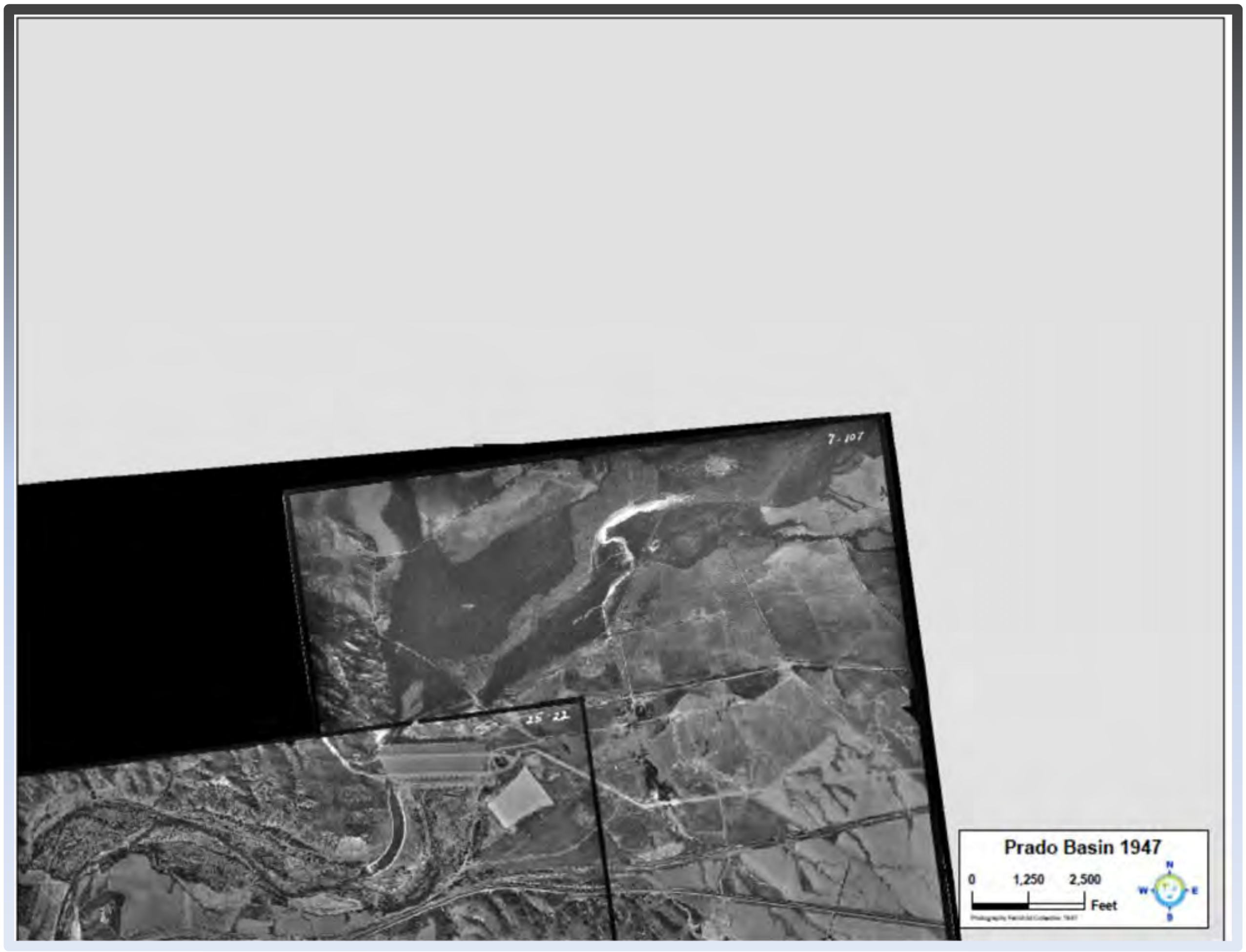


Figure 12: 1950’s Prado Dam Area Aerial Imagery

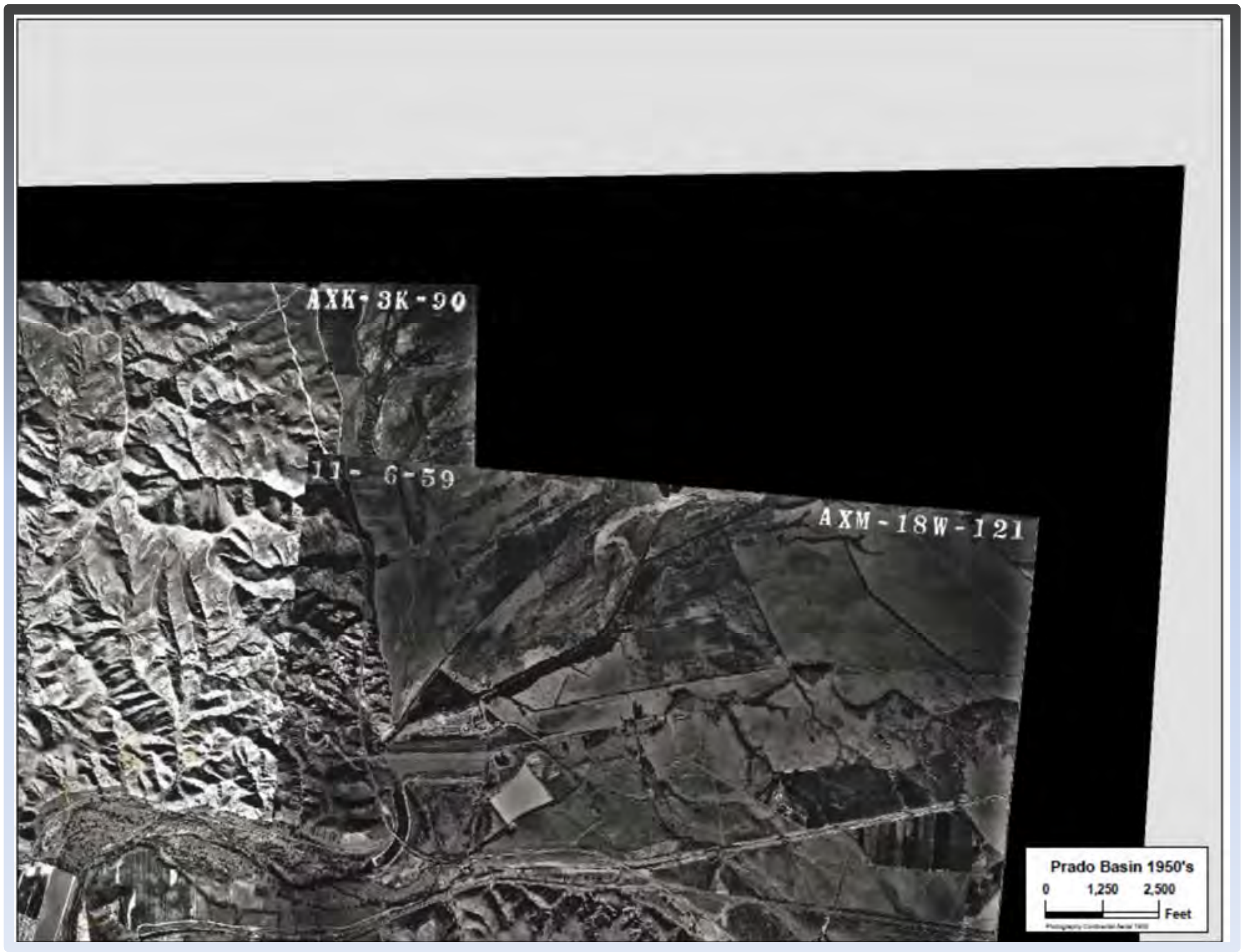
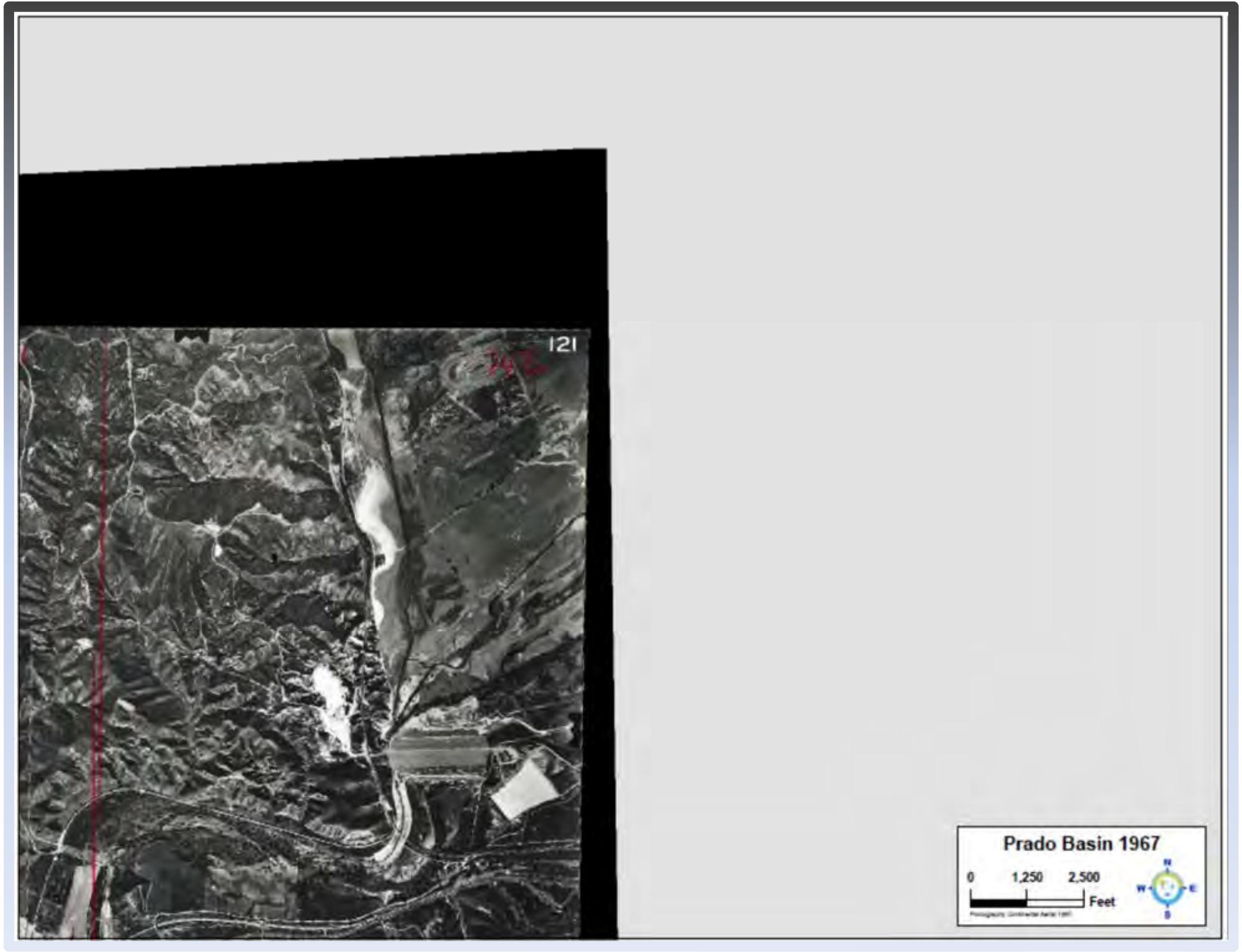


Figure 13: 1967 Prado Dam Area Aerial Imagery



The analysis presented earlier in this report predicts that the planned deviation will have no measurable effect on the SAR habitat types upstream of River Road Bridge and only negligible impacts to the rate of sedimentation in the Basin below elevation 505. Historical data, fundamental sediment transport principles, future water surface elevation predictions and the sediment transport model show that the vast majority of deposition in the Basin will occur irrespective of the planned deviation. Furthermore, the additional sedimentation due to the planned deviation (3,500 cubic yards or a 0.30% increase) is negligible when compared to the overall deposition already occurring (1,200,000 cubic yards annually). The average depth of new sedimentation will be approximately 0.001 feet per year which is expected to have no impact on native riparian habitat below elevation 505 ft NGVD29. The primary grain size of the additional sedimentation will be fine grain (silt and clay), which will disperse over large areas, thereby causing no measurable increase to backwater or marsh habitat along the SAR or in areas where native fish habitat is likely to exist.

Alternative Water Conservation Elevation

An alternative to the proposed flood season water conservation elevation of 505.0 ft NGVD29 would be to increase the elevation to a level between 498.0 ft and 505.0 ft NGVD29. For comparison purposes a flood season water conservation elevation of 503.9 ft NGVD29 has been evaluated.

The same discussion and analysis will apply to the 503.9 ft NGVD29 elevation as was used previously in this report for the 505.0 ft NGVD29 evaluation. The results of the alternative analyzed is summarized below;

1) The flood season water conservation WSE would be 503.9 ft NGVD29
2) The volume of additional captured water would be 8,700 af per year;
3) The additional sediment deposited in the Basin due to the 8,700 af per year of water would be approximately 2,900 cubic yards of sediment (primarily silt and clay);
4) The approximate area of the Basin below elevation 503.9 ft NGVD29 as of 2008 was 1,787 acres;
5) The additional annual average depth of sediment deposition over the 1,787 acres will be approximately 0.001 feet;
6) The 2,900 cubic yards of additional sedimentation represents an increase of 0.24% over the current condition; and
7) The additional deposition over fifty years is expected to be approximately 0.05 feet.

The above alternative will have the same negligible impacts on the SAR channel slope and surrounding habitat as was described for the planned deviation elevation of 505.0 ft NGVD29.

Conclusions

The existing sedimentation rate in the Basin is approximately 1,200,000 cubic yards per year. The estimated additional sediment deposition in the Basin due to the planned deviation is approximately 3,500 cubic yards per year. A volume of 3,500 cubic yards equates to an additional 0.001 feet of sedimentation annually in areas below elevation 505.0 ft NGVD29 (Basin wide) if the planned deviation is implemented. Historically there has been between 0.50 to 0.70 feet of deposition per year (due to TSS and bed load) since 1960 along the SAR in the Basin. The planned deviation represents an annual increase of 0.3 percent in total sediment deposition over the next 50 years, after which time the majority of the storage volume below elevation 505.0 ft NGVD29 will be filled with sediment (due to existing sedimentation conditions) and the proposed planned deviation will no longer be relevant.

The potential impact to habitat along the SAR is limited to a 4,000 foot long stretch of the SAR below elevation 505.0 ft NGVD29. There is currently no clearly defined river channel or native fish habitat at this location in the Basin. This area is primarily braided streams with riparian habitat consisting of cottonwood trees with native understory and some non-native vegetation. The relatively small amount of additional fine grain (silt and clay) sedimentation from the planned deviation will have little or no effect on the current habitat type in this area as the increased rate of aggradation is approximately 0.001 feet per year. This rate of aggradation is considered negligible as the baseline sedimentation rate in this area ranges between 0.5 and 0.7 feet per year.

Sedimentation between elevations 498.0 ft and 505.0 ft NGVD29 will be transient as storm events occur at times when the WSE is higher or lower than the planned deviation. Sediments get deposited at higher elevations in the Basin during periods when high inflow coincide with a high WSE (this typically occurs when there is a storm that lasts several days or longer, or when significant storms occur back-to-back). As subsequent storms occur during periods when the WSE is much lower, portions of the sediment previously deposited high in the Basin will be transport to elevations below the WSE at the time of the inflow.

The propagation of sedimentation and flattening of upstream channel slopes are primarily controlled by the maximum WSE during high inflow events which have historically been as high as elevation 527 ft NGVD29 (22 feet higher than the planned deviation). The storms with the highest intensities and longest durations result in the highest WSE. These same storms transport the highest volumes of sediment (up to 90% of the annual average sediment inflow volume). As these storm events occur there are large volumes of sediment that deposit high in the Basin which then define a new SAR slope for areas above elevation 527 ft NGVD (refer to the 2008 profile plot in Figure 3).

The primary cause of habitat modifications in the Dam to Hamner Reach of the SAR is due to:

1) Reduced gravel and cobble sediment inflow from upstream, due to upstream basins and lower flows in the SAR;
2) Vegetation, debris and non-native habitat restrict sediment transport and cause excessive sedimentation along the Dam to Hamner Reach; and
3) Reduced SAR slopes along the Dam to Hamner Reach are a result of the flood attenuation effects of Prado Dam.

The proposed planned deviation to allow an increase in the flood season WSE will have negligible effects on habitat types along the SAR between the Dam and the Hamner Avenue crossing. The planned deviation will have no effect on habitat types upstream of the Hamner Avenue crossing.

Scheevel Engineering greatly appreciates the opportunity to provide consulting services to OCWD and looks forward to working with OCWD on the next phase of this project. Please don't hesitate to contact me with any questions you might have.

Sincerely,
Scheevel Engineering, LLC

Nate Scheevel, P.E.
Owner/Principal

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References

Brownlie and Taylor; (dated February 1981); Sediment Management for Southern California Mountains, Coastal Plains and Shoreline Part C Coastal Sediment Delivery by Major Rivers in Southern California

Department of the Army, U.S. Army Corps of Engineers Los Angles District; (dated November 8, 1967); Sedimentation Studies for Prado Flood Control Reservoir, Santa Ana River Basin (and Orange Co.), California

Golder Associates, Inc.; (dated March 26, 2015); Prado Feasibility Study Project – Prado Water Level Analysis Sediment Transport Modeling Results

Orange County Water District; (dated November 2014); Prado Basin Sediment Management Demonstration Project 100% Engineering Analysis Draft Report
Santa Ana River Watermaster; (dated April 30, 2008); Orange County Water District V. City Of Chino, Et Al., Case No. 117628--County Of Orange

Scheevel Engineering, LLC; (dated March 26, 2015); Prado Basin Feasibility Study Prado Basin – Projected Sedimentation Trends (Draft)

Scheevel Engineering, LLC; (dated January 21, 2015); Prado Basin Feasibility Study Reach 9 – Projected Sedimentation Trends (Final)

Scheevel Engineering, LLC; (dated April 22, 2015); Prado Dam Water Conservation Prado Basin & Upstream SAR Morphology Trends – Elevation 498 vs. 505

Scheevel Engineering, LLC; (dated March 26, 2015); Prado Basin Feasibility Study Prado Basin – Projected Sedimentation Trends (Draft)

U.S. Department of the Interior, U.S. Geological Survey; (dated 2007); Sources, Dispersal, and Fate of Fine Sediment Supplied to Coastal California; Scientific Investigations Report 2007–5254

U.S. Army Corps of Engineers; (dated 2005); Design, Construction and Seepage at Prado Dam Presentation

U.S. Army Corps of Engineers; (dated December 1, 2005); Letter to State Water Resources Control Board

U.S. Army Corps of Engineers; (dated 2009); Prado Basin Survey Data, Storage Table; Excel spread sheet distributed via email

U.S. Army Corps of Engineers; (dated May 2014); Santa Ana River/Orange County Prado Basin Ecosystem Restoration Feasibility Study, Water Conservation And Sediment Transport Analysis Report, Hydraulics Section Hydrology & Hydraulics Branch, U.S. Army Corps of Engineers, Los Angeles District

Warrick, J.A., and D.M. Rubin; (dated 2007); Suspended-sediment rating curve response to urbanization and wildfire, Santa Ana River, California. Journal of Geophysical Research, Vol. 112.

Wildermuth Environmental, Inc.; (dated December 9, 2013); Prado Basin Daily Discharge Estimates for 2021 and 2071 Using the Wasteload Allocation Model

July 6, 2015

SCHEEVEL
ENGINEERING

Orange County Water District
Attn: Mr. Greg Woodside, P.G., C.HG
Executive Director of Planning and Natural Resources
18700 Ward Street
Fountain Valley, CA 92708

Subject: Prado Dam Planned Deviation
Santa Ana River - Downstream Effects Due to Planned Deviation (Final)

Mr. Woodside:

This technical memo provides an assessment of how increasing the allowable water surface elevation (WSE) at Prado Dam (Dam) during the flood season (October through February) from 498.0 ft National Geodetic Vertical Datum of 1929 (NGVD29) to 505.0 ft NGVD29 may affect the Lower Santa Ana River (LSAR). Note that all elevations referenced in this report are based on the NGVD29. The following analysis will generally cover the LSAR from the Dam downstream to the Pacific Ocean. A more detailed discussion has been provided for a reach of the LSAR from Prado Dam downstream to the Weir Canyon/Santa Ana River crossing. This section of the LSAR is referred to as “Reach 9” for the purposes of this report. Historical topographic surveys, existing sediment transport models, historical data, new hydraulic modeling and prior reports have been used to estimate how additional water conservation may contribute to long-term changes to the river morphology along the LSAR.

Background

The primary purpose of the Dam is to provide flood risk management benefits. A secondary beneficial use of the Dam and Prado Basin (Basin) is water conservation. Water conservation benefits provided by the Dam are possible by using the Dam structure and Basin area to capture, and temporarily impound, storm flows. The captured water is released at rates conducive to downstream groundwater recharge operations. The water conservation volume afforded by the Dam is controlled by the allowable WSE during the flood season and non-flood season (March through September).

In an effort to improve water conservation in the region, an increase to the WCWSE in the Basin during the flood season is being evaluated. The proposed change would increase the flood season WCWSE from 498.0 ft to 505.0 ft. An alternative to the proposed planned deviation would be to increase the flood season WCWSE to 503.9 ft. It is important to note that flood risk management operations take precedence over any water conservation objectives afforded by the Dam.

The Santa Ana River Mainstem Project (SARM) was initiated in 1964 by the United States Army Corps of Engineers (USACE). In September 1980, the USACE completed the General Design Memorandum (GDM) for the SARM. Construction of the SARM was authorized in 1986 as a part of the Water Resources Development Act of 1986. A portion of the SARM includes channel improvements to the LSAR from the Dam to the Pacific Ocean as described in the Santa Ana River Design Memorandum No.1 Phase II GDM on the Santa Ana River Mainstem including Santiago Creek, Volume 3 Lower Santa Ana River.

The primary concern for the LSAR in increasing the flood season WCWSE is that the additional volume of water held for water conservation purposes would create periods of higher discharge rates in order to provide the requisite storage volume for impending storm water inflow to the Basin. The Dam and LSAR have been designed for controlled releases up to 30,000 cubic feet per second (cfs). The currently underway, and planned future construction of Reach 9 channel improvements create a necessity to limit release flow rates to less than 5,000 cfs, until Reach 9 improvements are complete.

Prado Dam Storage Capacity

Prado Dam has a design life of 100 years; made possible by recent and planned future improvements (raising of the Dam, construction of auxiliary embankments and raising of the spillway). The current design life period for the Dam began in 1980 and is estimated to fulfill its functional purpose until approximately 2080. The storage volume of the Basin below the planned future spillway crest (elevation 563.0 ft) was approximately 362,000 acre-feet (af) in 1980. A total of 292,000 af has been allocated for flood risk management and a total of 70,000 af has been allocated for sedimentation (USACE SAR Phase II GDM Volume 2, 1988).

The last survey of the Basin was performed in 2008 by the USACE (Table 1). Between 1980 and 2008 a total of approximately 23,000 af of sedimentation occurred below the planned future spillway crest (elevation 563.0 ft). On other words, 33% of the total storage allocated for sedimentation has been used leaving approximately 47,000 af of volume available for sedimentation. Between the two most recent Basin surveys (1988 and 2008) the annual average sedimentation rate in the Basin was approximately 620 af/yr. As of 2008 there was approximately 72 years remaining of the design life of the Dam. At an annual average sedimentation rate of 620 af/yr there will be an additional 44,640 af of sedimentation in the Basin by 2080, equating to a total storage loss of 67,640 af between 1980 and 2080 (100 years).

Table 1: Prado Dam Historical Surveys

Prado Dam Storage Capacity

Elevation	2008 Survey	1988 Survey	Storage Loss since 1988		Storage Loss since 1941		1980 Survey	1969 Survey	1960 Survey	1941 Survey	
	ac-ft	ac-ft	ac-ft	%	ac-ft	%	ac-ft	ac-ft	ac-ft	ac-ft	
470	0	7	7	100%	310	100%	8	5	58	310	
471	1	14	13	93%	404	100%	10	6	87	405	
472	5	22	17	77%	525	99%	14	9	128	530	
473	10	34	24	71%	670	99%	18	12	184	680	
474	17	48	31	65%	853	98%	25	18	259	870	
475	24	71	47	66%	1,096	98%	34	25	359	1,120	
476	31	103	72	70%	1,329	98%	46	36	500	1,360	
477	93	147	54	37%	1,587	94%	67	54	687	1,680	
478	121	208	87	42%	1,919	94%	103	99	931	2,040	
479	155	295	140	47%	2,305	94%	159	191	1,245	2,460	
480	196	414	218	53%	2,704	93%	239	305	1,645	2,900	
481	251	573	322	56%	3,349	93%	348	445	2,052	3,600	
482	330	779	449	58%	3,670	92%	488	659	2,540	4,000	
483	442	1,032	590	57%	3,958	90%	664	965	3,119	4,400	
484	581	1,333	752	56%	4,919	89%	883	1,311	3,802	5,500	
485	750	1,705	955	56%	5,750	88%	1,188	1,770	4,604	6,500	
486	954	2,155	1,201	56%	6,746	88%	1,627	2,303	5,435	7,700	
487	1,228	2,674	1,446	54%	6,972	85%	2,183	2,979	6,382	8,200	
488	1,569	3,268	1,699	52%	8,431	84%	2,843	3,753	7,458	10,000	
489	1,988	3,940	1,952	50%	8,512	81%	3,606	4,590	8,674	10,500	
490	2,500	4,688	2,188	47%	10,100	80%	4,474	5,471	10,045	12,600	Top of Debris Pool, Btm. of Buffer Pool
491	3,086	5,508	2,422	44%	10,714	78%	5,442	6,456	11,395	13,800	
492	3,753	6,404	2,651	41%	12,047	76%	6,507	7,565	12,881	15,800	
493	4,498	7,379	2,881	39%	13,502	75%	7,666	8,803	14,514	18,000	
494	5,310	8,435	3,125	37%	13,690	72%	8,915	10,144	16,303	19,000	
495	6,194	9,562	3,368	35%	14,806	71%	10,257	11,542	18,259	21,000	
496	7,149	10,758	3,609	34%	15,251	68%	11,693	12,972	20,146	22,400	
497	8,177	12,055	3,878	32%	16,423	67%	13,226	14,490	22,175	24,600	
498	9,278	13,460	4,182	31%	17,722	66%	14,857	16,130	24,353	27,000	Flood Season Water Con. Elev.
499	10,479	14,951	4,472	30%	19,021	64%	16,577	17,923	26,688	29,500	
500	11,760	16,522	4,762	29%	19,240	62%	18,376	19,856	29,187	31,000	
501	13,219	18,185	4,966	27%	20,781	61%	20,281	21,876	31,624	34,000	
502	14,722	19,944	5,222	26%	21,778	60%	22,323	24,061	34,206	36,500	
503	16,302	21,783	5,481	25%	22,898	58%	24,480	26,400	36,937	39,200	
504	18,016	23,712	5,696	24%	23,984	57%	26,732	28,849	39,823	42,000	
505	19,826	25,754	5,928	23%	25,174	56%	29,083	31,410	42,870	45,000	Non-Flood Season Water Con. Elev.
506	21,746	27,910	6,164	22%	26,054	55%	31,536	34,064	45,791	47,800	
507	23,762	30,185	6,423	21%	27,238	53%	34,088	36,808	48,849	51,000	
508	25,878	32,579	6,701	21%	28,122	52%	36,731	39,641	52,047	54,000	
509	28,111	35,084	6,973	20%	28,889	51%	39,466	42,572	55,389	57,000	
510	30,419	37,706	7,287	19%	30,181	50%	42,289	45,564	58,878	60,600	
511	32,818	40,442	7,624	19%	31,182	49%	45,218	48,683	62,229	64,000	
512	35,306	43,290	7,984	18%	32,694	48%	48,270	51,906	65,706	68,000	
513	37,897	46,253	8,356	18%	33,303	47%	51,434	55,194	69,311	71,200	
514	40,611	49,338	8,727	18%	34,389	46%	54,697	58,543	73,048	75,000	
515	43,445	52,534	9,089	17%	35,555	45%	58,067	62,004	76,918	79,000	
516	46,392	55,841	9,449	17%	35,908	44%	61,553	65,543	80,627	82,300	
517	49,505	59,247	9,742	16%	36,995	43%	65,149	69,147	84,451	86,500	
518	52,694	62,750	10,056	16%	37,306	41%	68,852	72,806	88,390	90,000	
519	55,984	66,375	10,391	16%	38,616	41%	72,653	76,514	92,446	94,600	
520	59,568	70,121	10,553	15%	39,432	40%	76,546	80,289	96,622	99,000	
521	63,100	73,966	10,866	15%	40,400	39%	80,535	84,187	100,779	103,500	
522	66,744	77,903	11,159	14%	41,256	38%	84,625	88,239	105,049	108,000	
523	70,516	81,941	11,425	14%	41,484	37%	88,812	92,380	109,432	112,000	
524	74,410	86,084	11,674	14%	42,590	36%	93,092	96,604	113,930	117,000	
525	78,394	90,334	11,940	13%	42,606	35%	97,470	100,905	118,544	121,000	
526	82,501	94,694	12,193	13%	43,699	35%	101,952	105,314	123,070	126,200	
527	86,769	99,162	12,393	12%	42,231	33%	106,534	109,850	127,701	129,000	
528	91,175	103,735	12,560	12%	44,825	33%	111,216	114,493	132,439	136,000	
529	95,722	108,440	12,718	12%	45,278	32%	116,000	119,221	137,285	141,000	
530	100,411	113,291	12,880	11%	45,589	31%	120,888	124,091	142,240	146,000	
531	105,307	118,271	12,964	11%	45,193	30%	125,898	129,107	147,347	150,500	
532	110,289	123,380	13,091	11%	45,711	29%	131,048	134,247	152,568	156,000	
533	115,396	128,607	13,211	10%	45,604	28%	136,330	139,502	157,902	161,000	
534	120,627	133,954	13,327	10%	46,373	28%	141,736	144,867	163,352	167,000	
535	125,976	139,432	13,456	10%	47,024	27%	147,270	150,362	168,917	173,000	
536	131,534	145,038	13,504	9%	46,466	26%	152,936	155,981	174,533	178,000	
537	137,252	150,757	13,505	9%	46,748	25%	158,732	161,706	180,264	184,000	
538	143,062	156,589	13,527	9%	46,938	25%	164,653	167,509	186,110	190,000	
539	149,037	162,549	13,512	8%	47,963	24%	170,698	173,386	192,071	197,000	
540	155,135	168,639	13,504	8%	47,865	24%	176,865	179,376	198,150	203,000	
541	161,458	174,856	13,398	8%	46,842	22%	183,157	185,501	204,364	208,300	
542	167,788	181,201	13,413	7%	48,212	22%	189,578	191,775	210,697	216,000	
543	174,312	187,681	13,369	7%	47,688	21%	196,135	198,222	217,150	222,000	Existing Spillway
544	180,935	194,304	13,369	7%	49,065	21%	202,838	204,820	223,725	230,000	
545	187,735	201,066	13,331	7%	48,265	20%	209,685	211,557	230,422	236,000	
546	194,632	207,968	13,336	6%	48,368	20%	216,678	218,430	237,299	243,000	
547	201,773	215,019	13,246	6%	48,227	19%	223,824	225,426	244,303	250,000	
548	208,981	222,225	13,244	6%	49,019	19%	231,132	232,548	251,435	258,000	
549	216,317	229,595	13,278	6%	49,683	19%	238,598	239,799	258,695	266,000	
550	223,808	237,139	13,331	6%	49,192	18%	246,215	247,176	266,084	273,000	
551	231,480	244,824	13,344	5%	50,520	18%	253,994	254,685	273,542	282,000	
552	239,593	252,656	13,063	5%	50,407	17%	261,946	262,312	281,129	290,000	
553	247,619	260,663	13,044	5%	50,381	17%	270,065	270,037	288,845	298,000	
554	255,744	268,836	13,092	5%	51,256	17%	278,345	277,875	296,691	307,000	
555	264,085	277,196	13,111	5%	48,915	16%	286,810	285,824		313,000	
556	272,513	285,757	13,244	5%	51,487	16%	295,481			324,000	
557	281,164	294,527	13,363	5%	50,836	15%	304,349			332,000	
558	290,025	303,506	13,481	4%	50,975	15%	313,409			341,000	
559	300,555	312,693	12,138	4%	49,445	14%	322,665			350,000	
560	309,784	322,080	12,296	4%	49,216	14%	332,120			359,000	
561	319,214	331,710	12,496	4%	49,786	13%	341,785			369,000	
562	328,855	341,603	12,748	4%	50,145	13%	351,670			379,000	
563	338,676	351,735	13,059	4%	50,324	13%	361,795			389,000	Future Spillway
			avg per year 1988-2008 =	622	avg per year 1941-1988=	776					
594.4											Top of Dam

The distribution of sediment deposition is not uniform over the Basin area. The location of deposited sediment is also transient within the Basin. This is because as the WSE changes, and high flow events occur, the previously deposited sediments are redistributed to different locations within the Basin. Typically sediments move from higher elevations to lower elevations within the Basin, thereby, infilling the lowest storage volume first. If the majority of deposited sediments move into the lowest elevations of the Basin over the 100 year life of the Dam, then nearly all water storage volume would be infilled with sediment up to elevation 515.0 ft.

The annual average sedimentation rate below elevation 505.0 ft is approximately 300 af/yr. Of the total 300 af/yr of sedimentation, 190 af/yr of deposition occurs between elevation 490.0 ft and 505.0 ft. The remaining 110 af/yr deposits below elevation 490 ft. As of 2008 there was approximately 6,800 af of storage between the top of the debris pool (elevation 490.0 ft) and the top of the flood season buffer pool (elevation 498.0 ft).

Based on the same 2008 survey there was an additional 10,500 af of storage volume between the top of the flood season buffer pool (elevation 498.0 ft) and the top of the proposed flood season planned deviation WSE of 505.0 ft. As of 2008 there was approximately 17,300 af of available water storage volume between elevation 490.0 ft and 505.0 ft.

At current sedimentation rates (190 af/yr) the approximate storage volume remaining between the top of the debris pool (elevation 490.0 ft) and the top of the proposed flood season planned deviation WSE (505.0 ft) in 2015 is 15,970 af. The available storage volume below elevation 505.0 ft will continue to decline as sedimentation occurs into the future (Table 2).

Table 2: Prado Basin Volume Projections

Elevation	Sediment-ation Rate	Surveyed Volume		Estimated Volume												
(ft NGVD29)	(af/yr)	(af of water)		(af of water)												
		1988	2008	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075
Below 505.0	300	25,800	19,800	17,700	16,200	14,700	13,200	11,700	10,200	8,700	7,200	5,700	3,475	1,975	475	0
Between 505.0 and 490.0	190	21,100	17,300	15,970	15,020	14,070	13,120	11,700	10,200	8,700	7,200	5,700	3,475	1,975	475	0
Between 505.0 and 498.0	90	12,300	10,500	9,870	9,420	8,970	8,520	7,875	7,150	6,425	5,700	4,975	3,475	1,975	475	0
Between 498.0 and 490.0	100	8,800	6,800	6,100	5,600	5,100	4,600	3,825	3,050	2,275	1,500	725	0	0	0	0
Below 490.0	110	4,700	2,500	1,730	1,180	630	80	0	0	0	0	0	0	0	0	0

The potential to impact the LSAR from the proposed planned deviation is dependent upon the Dam release flow rate and duration. Flood risk management operations dictate the release rate from the Dam when the water surface elevation is above the current buffer pool elevations (498.0 ft during the flood season and above elevation 505.0 ft during the non-flood season). Once basin WSEs are within the buffer pool elevations, the release rates are typically reduced to help facilitate groundwater recharge operations downstream. The exception to this mode of operations is if there is a significant forecasted storm event while there is still water in the buffer pool. If this occurs the USACE may release water at a higher rate to evacuate the buffer pool to create storage volume for forecasted inflows. In general, the USACE uses forecast models and storm water runoff models to predict the Basin inflow and resultant WSE of a given storm/storm system, then the USACE adjusts the release rate to achieve certain WSEs before, during and after a given storm event. Please refer to the Prado Dam Water Control Manual dated September 1994 and the Prado Dam Interim Water Control Plan dated may 2003 for complete details.

The need to rapidly evacuate the buffer pool occurs when there is a forecasted storm event of significant intensity that has the potential to exceed flood risk management operational WSEs. Historically, the time allotted to drain the buffer pool has been 24 hours (Prado Dam WCM 1994). This time allotment was partially based on forecast model capabilities at the time the water control manual was written. Storm system forecasting has improved with the development of advance weather forecast modeling, and in practice the available time to drain the buffer pool is often greater than 24 hours.

The duration required to drain the buffer pool is based on the beginning storage volume, Basin inflow and Basin outflow. Each storm event is different, but in general the Basin inflow after the storm systems has passed (and after the peak of the inflow hydrograph occurs) tends to reach 200 to 400 cfs within 1 to 3 days and then continues to decline over time until the next storm event occurs. In order to calculate the average time to evacuate the buffer pool an inflow of 300 cfs has been used as the Basin inflow rate. Two Basin outflow release rates have been analyzed to provide a range of buffer pool evacuation durations. A Dam release rate of 2,500 cfs was selected because it has been the historical (pre-Reach 9 improvements) targeted maximum release rate that has been considered non-damaging for Reach 9 (Prado Dam WCM 1994). A Dam release rate of 5,000 cfs was selected for analysis because it has been identified as the rate that would have minimal impacts during the various Reach 9 improvement projects and is considered non-damaging from a riparian habitat standpoint (additional analysis and discussion is provided later in this report regarding this statement). Accounting for sedimentation over the design life of the Dam, and given the above inflow and outflow assumptions, two long term projections were developed to estimate the time required to evacuate the buffer pool from elevation 505.0 ft to 490.0 ft (Table 3 and Table 4).

The two buffer pool evacuation models assume that a second significant storm occurs immediately after an initial storm that fills the buffer pool volume, in reality this is a rare occurrence. It is important to note that a fundamental water conservation operational objective is to drain the water conservation pool as quickly as possible in order to make storage volume available for subsequent storm flows. This objective reduces the recurrence interval of instances when the full buffer pool volume must be evacuated due to a subsequent storm event. As shown in Table 3, the most conservative buffer pool evacuation duration scenario occurs at a release rate of 2,500 cfs with the WCWSE at 505.0 ft. This scenario would require approximately 4 days of flow at a rate of 2,500 cfs. The buffer pool evacuation duration can be reduced by increasing the flow rate as shown in Table 4.

Table 3: Buffer Pool Evacuation Durations At 2,500 cfs Outflow

	Available Water Storage Volume Between Elev. 490.0 to 505.0	**Basin Inflow**	**Basin Outflow**	**Days to Drain Water Conservation Volume From Elev. 505.0 to 490.0**
Year	(af)	(cfs)	(cfs)	(days)
1988	21,100	300	2,500	4.8
2008	17,300	300	2,500	4.0
2015	15,970	300	2,500	3.7
2020	15,020	300	2,500	3.4
2025	14,070	300	2,500	3.2
2030	13,120	300	2,500	3.0
2035	11,700	300	2,500	2.7
2040	10,200	300	2,500	2.3
2045	8,700	300	2,500	2.0
2050	7,200	300	2,500	1.7
2055	5,700	300	2,500	1.3
2060	3,475	300	2,500	0.8
2065	1,975	300	2,500	0.5
2070	475	300	2,500	0.1

Table 4: Buffer Pool Evacuation Durations At 5,000 cfs Outflow

	Available Water Storage Volume Between Elev. 490.0 to 505.0	**Basin Inflow**	**Basin Outflow**	**Days to Drain Water Conservation Volume From Elev. 505.0 to 490.0**
Year	(af)	(cfs)	(cfs)	(days)
1988	21,100	300	5,000	2.3
2008	17,300	300	5,000	1.9
2015	15,970	300	5,000	1.7
2020	15,020	300	5,000	1.6
2025	14,070	300	5,000	1.5
2030	13,120	300	5,000	1.4
2035	11,700	300	5,000	1.3
2040	10,200	300	5,000	1.1
2045	8,700	300	5,000	0.9
2050	7,200	300	5,000	0.8
2055	5,700	300	5,000	0.6
2060	3,475	300	5,000	0.4
2065	1,975	300	5,000	0.2
2070	475	300	5,000	0.1

LSAR Habitat & Sediment Transport Characteristics

The LSAR extends from Prado Dam to the Pacific Ocean. The design capacity of the LSAR provides protection for a storm event with a 190-year recurrence interval. The Dam has been designed for a maximum controlled release rate of 30,000 cfs. The LSAR channel has also been designed to provide protection from a 190-year event and the channel capacity increases downstream to provide capacity for local inflow. Table 5 provides a summary of the channel capacity at various locations along the LSAR (USACE SAR Phase II GDM Volume 3, 1988).

Table 5: LSAR Channel Design Capacity

Crossing Location	Design Flow Rate
	(cfs)
Prado Dam Outflow	30,000
Imperial Highway	38,000
Carbon Canyon Diversion Channel	40,000
Santiago Creek	46,000
Pacific Ocean	47,000

The LSAR from the Weir Canyon crossing downstream to the Pacific Ocean has improved channel walls (rip-rap, grouted stone or concrete), invert grade stabilizers, drop structures and concrete lined inverts at some locations. This section of the LSAR has experienced flows in excess of 10,000 cfs on one occasion and flows of 2,500 to 5,000 cfs on multiple occasions with little to no damage. Because the design capacity in this section of the LSAR is greater than 37,000 cfs, and the maximum proposed discharge resulting from the proposed planned deviation is 5,000 cfs or less, it can reasonably be expected that no negative impacts will occur in this section of the LSAR. Only the LSAR from Prado Dam to Weir Canyon (Reach 9) will be evaluated further in this report.

Reach 9 improvement projects have been completed, and are underway, to increase the capacity of hydraulically inadequate sections of Reach 9. Channel modifications and bank protection improvements will provide the requisite 30,000 cfs conveyance capacity and will contain flows up to 6,000 cfs within low flow channel sections of Reach 9 where frequent flood plain inundation is undesirable.

The primary hydraulic variable which causes damaging flows to a river system is the velocity of the flowing water. The primary components which control the flow velocities are the cross sectional area of the channel, the slope of the channel, the roughness of the channel and the total flow passing through a given cross sectional area. The proposed planned deviation has the potential to affect the total flow of the LSAR system and no physical modifications (cross sectional area, slope, and roughness) to the channel or floodplain are being proposed. Ultimately the flow velocity's effect on sediment transport characteristics determine how much erosion or deposition will occur in a given section of the LSAR. The LSAR has been analyzed and modeled multiple times for various studies and projects. This report utilizes past efforts to estimate the effect of the proposed planned deviation on riverbed morphology.

In general, Reach 9 of the LSAR has incised and coarsened since the Dam was constructed in 1941. The riverbed material through Reach 9 is primarily a mixture of coarse sand, gravel, cobbles and boulders (Tetra Tech Scour Study SAR 2010). This coarse gradation of riverbed material provides erosion protection at low to moderate flows.

Two independent studies have identified the flow velocities which can create erosion of coarse sediments (gravel and cobbles), and that are potentially damaging to habitat in Reach 9.

In a 2001 Biological Opinion prepared for the Prado Mainstem and SAR Reach 9 Project it was noted that the USACE determined (through fixed bed modeling) that flow velocities greater than 6 feet per second (ft/sec) in Reach 9 could have a damaging effect on riparian habitat. Furthermore it was determined that flow releases from Prado Dam of 5,000 cfs or less were generally not capable of creating velocities greater than 6 ft/sec in Reach 9 (USFWS BO 2001).

In 2014 OCWD employed Golder Associates to perform a sediment transport model of the LSAR in conjunction with the Prado Basin Sediment Management Demonstration Project (SMDP). The Reach 9 portion of the analysis revealed that flow velocities greater than 4 ft/sec may cause gravel to mobilize and flows greater than 10 ft/sec may cause cobbles to mobilize (Golder SMDP 2014).

Given the above analysis it has been assumed that any flow velocities greater than 5 ft/sec may cause erosion and riparian habitat damage through Reach 9. A HEC-RAS hydraulic model was developed for this report to determine the worst case scenarios for a Prado Dam release rate of 2,500 cfs and 5,000 cfs for the proposed planned deviation. The most current Reach 9 channel geometry was obtained from the USACE which includes Reach 9 improvements completed through 2013. Channel cross sections were analyzed at 200 ft intervals through Reach 9 (209 cross sections total).

The average velocity in Reach 9 at a flow rate of 2,500 cfs is 3.7 ft/sec and the average velocity in Reach 9 at a flow rate of 5,000 cfs is 4.2 ft/sec.

Given the current coarse gradation of the Reach 9 riverbed, the recent Reach 9 improvements, the recurrence interval of rapid buffer pool evacuation events, and the anticipated current and future release rates and durations required to evacuate the buffer pool elevation, no measurable negative impacts to habitat or are expected to occur from the proposed planned deviation. The extent of riverbed incision and riverbank erosion from the proposed planned deviation will likely not exceed the LSAR incision and erosion rates of the existing condition.

Civil Infrastructure Considerations

Several civil infrastructure assets exist along the LSAR. Multiple bridge crossings, bank stabilization features and utility crossings exist between Prado Dam and the Pacific Ocean. The majority of these assets have not been affected by historical releases from Prado Dam, however, there are some assets that have created cause for concern in the recent past. Civil infrastructure and other assets (in Reach 9) that warrant additional consideration are listed below. All of the following assets have been improved by the USACE, or are in the planning and design phase for improvements.

Improvement Area	USACE Project Reference
1) Santa Ana Regional Interceptor (SARI) Pipeline	(Reach 9 Phase 3, 4)
2) Burlington North Santa Fe (BNSF) Railroad Bridge	(Reach 9 Phase 2A, 4)
3) Green River Housing Estates	(Reach 9 Phase 2A)
4) Green River Mobile Home Park	(Reach 9 Phase 2B)
5) Green River Golf Course	(Reach 9 Phase 2B)
6) SR-91 Freeway	(Reach 9 Phase 1, 2A, 2B, 3, 4)
7) Miscellaneous Embankments	(Reach 9 Phase 4, 5A, 5B)

SARI Pipeline – Historically the SARI pipeline has been threatened by channel incision in Reach 9. The SARI pipeline carries brine discharge and raw sewage from Riverside and San Bernardino counties into Orange County. A project was completed in 2015 to protect and relocate the SARI pipeline/SAR crossing along Reach 9.

A Reach 9 scour report was prepared by Tetra Tech and HDR in 2010 to provide analysis and recommendations for the new locations and depths of the SARI pipeline relocation. A sediment transport analysis was performed by Tetra Tech which utilized a 100 year flow series to estimate the total maximum scour at the SARI pipeline locations of interest. Included in the analysis were multiple (approximately 18) 5,000 cfs release events and two 30,000 cfs release events. The report concluded that the pipeline should be relocated to depths greater than 9 feet in order to protect it from future channel incision and bank erosion.

The proposed planned deviation would result in flows equal to or less than 5,000 cfs, which will produce negligible channel incision at the SARI pipeline locations. Based on the SARI pipeline's new protective cover depths no long-term negative impacts to the SARI pipeline are expected to occur from the proposed planned deviation.

BNSF Bridge – The BNSF Railroad Bridge consists of 3 separate bridges, each bridge carries one set of tracks. The first bridge was constructed in 1938 as a relocation of an existing bridge, and was done as a part of the original Prado Dam construction. The other 2 bridges (immediately downstream of the 1938 bridge) were constructed in 1995.

The bridges were designed for Prado Dam release flows (up to 30,000 cfs) but were not originally designed for the rate of scour occurring in Reach 9. Once it was determined that the scour in Reach 9 was advancing faster than expected a new maximum targeted release rate from Prado Dam was set. A maximum targeted release rate of 5,000 cfs was originally set as a non-damaging release rate for the original SARI line (USACE EIR, 2013). Flows less than 5,000 cfs are also expected to be non-damaging to the existing BNSF Bridge.

Improvements to the BNSF Bridge are currently being designed and would be under construction in 2015 – 2017. The targeted maximum release rate during the construction period (as with other Reach 9 construction projects) would be set at 5,000 cfs with efforts to keep flows from damaging downstream construction activities. The planned deviation would not cause release flows in excess of 5,000 cfs, and therefore is not expected to increase the risk of damaging flows in the LSAR.

Green River Housing Estates, Mobile Home Park and Golf Course – The Green River Housing Estates, Mobile Home Park and Golf Course projects include various forms of channel geometry modification and bank stabilization. The majority of these improvements have been completed (or will be complete by the 2015 storm season) within the areas potentially affected by a 5,000 cfs (or less) releases. The planned deviation would not cause release flows in excess of 5,000 cfs, and therefore is not expected to increase the risk of damaging flows in the LSAR.

SR-91 Freeway – The SR-91 Freeway parallels the LSAR at several locations along Reach 9. The LSAR embankments nearest to the SR-91 Freeway have been improved by modifying the channel geometry, adding rip rap, sheet pile, grouted stone and derrick stone. The release rates proposed by the planned deviation are well below the design flows (up to 30,000 cfs) of the SR-91 improvements. No negative impacts to the SR-91 are expected to occur from the planned deviation.

Additional SR-91 embankment improvements (Phase 4) are currently being designed and would be under construction in 2015 – 2017. The targeted maximum release rate during the construction period (as with other Reach 9 construction projects) would be set at 5,000 cfs with efforts to keep flows from damaging downstream construction activities. The planned deviation would not cause release flows in excess of 5,000 cfs, and therefore is not expected to increase the risk of damaging flows in the LSAR.

Miscellaneous Embankments – Embankment improvements along roadways, the SAR Trail, industrial and commercial development, and residential housing in the City of Yorba Linda (Phase 5A, 5B) are currently being designed and would likely be under construction during the planned deviation. The targeted maximum release rate during the construction period (as with other Reach 9 construction projects) would be set at

5,000 cfs with efforts to keep flows from damaging downstream construction activities. The planned deviation would not cause release flows in excess of 5,000 cfs, and therefore is not expected to increase the risk of damaging flows in the LSAR.

Alternative Water Conservation Elevation 503.9

An alternative to the proposed flood season WCWSE of 505.0 ft would be to increase the elevation to 503.9. The same discussion and analysis will apply to 503.9 ft elevation as was used previously in this report for the 505.0 ft evaluation. The results of the alternative analyzed is summarized below;

1) The flood season WCWSE would be 503.9 ft;
2) The available storage volume between 498.0 ft and 503.9 ft is approximately 8,700 af;
3) The resultant Dam release flows and durations would be less than the proposed planned deviation; and
4) Because the proposed planned deviation is expected to result in negligible impacts, no measurable difference can be ascertained between a flood season WCWSE of 503.9 and 505.0.

Table 6: Buffer Pool Evacuation Durations At 2,500 cfs Outflow (503.9 Alternative)

Year	Available Water Storage Volume Between Elev. 490.0 to 503.9 (af)	Basin Inflow (cfs)	Basin Outflow (cfs)	Days to Drain Water Conservation Volume From Elev. 503.9 to 490.0 (days)
1988	18,990	300	2,500	4.4
2008	15,570	300	2,500	3.6
2015	14,373	300	2,500	3.3
2020	13,518	300	2,500	3.1
2025	12,663	300	2,500	2.9
2030	11,808	300	2,500	2.7
2035	10,530	300	2,500	2.4
2040	9,180	300	2,500	2.1
2045	7,830	300	2,500	1.8
2050	6,480	300	2,500	1.5
2055	5,130	300	2,500	1.2
2060	3,128	300	2,500	0.7
2065	1,778	300	2,500	0.4
2070	428	300	2,500	0.10

Table 7: Buffer Pool Evacuation Durations At 5,000 cfs Outflow (503.9 Alternative)

	Available Water Storage Volume Between Elev. 490.0 to 503.9	Basin Inflow	Basin Outflow	Days to Drain Water Conservation Volume From Elev. 503.9 to 490.0
Year	(af)	(cfs)	(cfs)	(days)
1988	18,990	300	5,000	2.0
2008	15,570	300	5,000	1.7
2015	14,373	300	5,000	1.5
2020	13,518	300	5,000	1.5
2025	12,663	300	5,000	1.4
2030	11,808	300	5,000	1.3
2035	10,530	300	5,000	1.1
2040	9,180	300	5,000	1.0
2045	7,830	300	5,000	0.8
2050	6,480	300	5,000	0.7
2055	5,130	300	5,000	0.6
2060	3,128	300	5,000	0.3
2065	1,778	300	5,000	0.2
2070	428	300	5,000	0.05

The above alternative will have the same negligible impacts on the LSAR and surrounding habitat as was described for the planned deviation elevation of 505.0 ft.

Conclusions

The proposed planned deviation will have no measurable impact on the LSAR and habitat communities along Reach 9. Based on existing reports, analysis, modeling and recently completed analysis the following conclusions can be supported;

1) Prado Basin will continue to fill with sediment thereby reducing the storage volume of the proposed planned deviation.
2) Buffer pool evacuation release rates and durations will decline over time as Prado Basin fills with sediment.
3) Present day storm forecast models typically provide more than 24 hour advance notice for significant storm events affecting the tributary area and inflow to Prado Basin.
4) The LSAR has been designed for release flows up to 30,000 cfs.
5) Historical release rates of 2,500 cfs have been identified as non-damaging to habitat and civil infrastructure prior to any Reach 9 improvements.
6) Reach 9 improvements will provide more than adequate protection for flows equal to or less than 5,000 cfs.
7) Release rates of 5,000 cfs or less result in flow velocities less than those required to cause damaging erosion in Reach 9.
8) It would take approximately 3.7 days to drain the buffer pool at a release rate of 2,500 cfs
9) It would take approximately 1.7 days to drain the buffer pool at a release rate of 5,000 cfs
10) The SARI pipeline will not be adversely affected by Prado Dam release flows resulting from the proposed planned deviation.
11) No measureable deference can be ascertained in the LSAR between the proposed planned deviation of flood season WCWSE of 505.0 and the alternative WCWSE of 503.9 ft.

The proposed planned deviation to allow an increase in the flood season WCWSE will have negligible effects on the river bed and habitat types along the LSAR between Prado Dam and the Pacific Ocean.

Scheevel Engineering greatly appreciates the opportunity to provide consulting services to OCWD and looks forward to working with OCWD on the next phase of this project. Please don’t hesitate to contact me with any questions you might have.

Sincerely,
Scheevel Engineering, LLC

Nate Scheevel, P.E.
Owner/Principal

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References

Department of the Army, U.S. Army Corps of Engineers Los Angles District; (dated November 8, 1967); Sedimentation Studies for Prado Flood Control Reservoir, Santa Ana River Basin (and Orange Co.), California

Orange County Water District; (dated November 2014); Prado Basin Sediment Management Demonstration Project 100% Engineering Analysis Draft Report, Appendix B, HEC-RAS Lower Santa Ana River Sedimentation Modeling by Golder Associates

Scheevel Engineering, LLC; (dated March 26, 2015); Prado Basin Feasibility Study Prado Basin – Projected Sedimentation Trends (Draft)

Scheevel Engineering, LLC; (dated January 21, 2015); Prado Basin Feasibility Study Reach 9 – Projected Sedimentation Trends (Final)

Tetra Tech & HDR, Prepared for the County of Orange; (dated January 2010); Scour Study of Santa Ana River Below Prado Dam, SARI Pipeline Relocation Project

U.S. Army Corps of Engineers, Los Angles District; (dated August 1988); Santa Ana River Design Memorandum No.1 Phase II GDM on the Santa Ana River Mainstem including Santiago Creek, Volume 2 Prado Dam

U.S. Army Corps of Engineers, Los Angles District; (dated August 1988); Santa Ana River Design Memorandum No.1 Phase II GDM on the Santa Ana River Mainstem including Santiago Creek, Volume 3 Lower Santa Ana River

U.S. Army Corps of Engineers, Los Angles District; (dated August 1988); Santa Ana River Design Memorandum No.1 Phase II GDM on the Santa Ana River Mainstem including Santiago Creek, Volume 7 Hydrology

U.S. Army Corps of Engineers, Los Angles District; (dated August 1988); Santa Ana River Design Memorandum No.1 Phase II GDM on the Santa Ana River Mainstem including Santiago Creek, Appendix B Geotechnical Appendix

U.S. Army Corps of Engineers, Los Angles District; (dated September 1994); Water Control Manual, Prado Dam & Reservoir Santa Anan River, Orange County California

U.S. Army Corps of Engineers, Los Angele District; (dated May 2003); Interim Water Control Plan (During Construction), Prado Dam & Reservoir Santa Anan River, Orange County California

U.S. Army Corps of Engineers, Los Angles District; (dated 2009); Prado Basin Survey Data, Storage Table; Excel spread sheet distributed via email

U.S. Army Corps of Engineers, Los Angles District; (dated March 2013);Final Supplemental Environmental Assessment and Addendum to Environmental Impact Report (EIR) 583 Santa Ana River: Reach 9 Phase 3

U.S. Department of the Interior, U.S. Fish and Wildlife Service; (dated December 5, 2001); Biological Opinion on the Prado Mainstem and Santa Ana River Reach 9 Flood Control Projects and Norco Bluffs Stabilization Project, Orange, Riverside, and San Bernardino Counties, California

APPENDIX B
HEC-RAS SEDIMENT TRANSPORT MODELING

Santa Ana River

APPENDIX B

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Distribution: HDR Engineering
Orange County Water District

July 14, 2014 **1300314**

Table of Contents

List of Tables

List of Figures

List of Attachments

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1.0 INTRODUCTION

Orange County Water District (OCWD), through HDR Engineering, Inc. (HDR), commissioned Golder Associates (Golder) to perform sediment transport modeling for the Prado Dam Sediment Management Demonstration Project Engineering Analysis. A one-dimensional sediment transport model was developed to address the following primary questions related to reaching the primary project goals:

1. What is the anticipated spatial and temporal distribution of deposited, sand-sized replenishment materials in the Lower Santa Ana River (LSAR)?
2. Could the proposed project replenish beach sand?
3. How does the proposed project affect riparian habitat in the LSAR?
4. Could the proposed sediment augmentation project change the gradation of the LSAR bed material in the groundwater recharge reach?

Issues of secondary interest, to be evaluated by the sediment transport modeling, include the following:

1. Do the silt- and clay-sized sediments move through the LSAR?
2. Could the proposed project increase flooding potential, particularly downstream of I-405
3. Would the project result in increased maintenance requirements at diversion structures?
4. Could the proposed project lessen the effects of channel degradation at Featherly Park?
5. Could the project result in increased scour potential at the levees in the LSAR?
6. What are the measurable effects at critical structures within the LSAR?
7. Could the proposed project result in increased river degradation at the Santa Ana River Interceptor (SARI)?

This report appendix is a revision to the appendix submitted by Golder in February 2011 (Golder 2011). This revision is required due to channel improvements made in the upstream reach of the LSAR. A new HEC-RAS geometry file was created to reflect the channel improvements and provided to Golder in April 2014.

Due to the lack of measured sediment discharge and geometric data over time, the model cannot be fully calibrated to historic conditions. The model was calibrated to the extent practical based on observations during a geomorphic assessment (Attachment A) and information contained in previous reports. However, the model represents what Golder expects will happen in the river during the scenarios modeled and the model can be used to identify areas of potential risk that can be monitored during the demonstration project. The model can be calibrated to observed conditions during sediment re-entrainment at a later date.

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2.0 METHOD AND ASSUMPTIONS

The US Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) Version 4.1 released January 2010 was chosen to aid in this analysis. The study used both the hydraulic and the sediment transport modules within this software.

The basic requirements for hydraulic calculations in HEC-RAS are channel cross sectional geometry, Manning's n-values for the cross sections, riverbank locations, and distances between the cross sections, flow information, and flow boundary information. Additional information is required to model bridges and weirs. The HEC-RAS sediment transport module calculates transport capacity for non-cohesive and cohesive soils using hydraulic variables (velocity, flow depth, and shear stress) and sediment properties.

2.1 Geometry

Two geometries have been modeled for this project. The original input geometry used in the 60% design report submitted in February 2011 was obtained from the USACE (Golder 2011). This geometry was broken into two reaches that the USACE developed into two HEC-RAS models to study the effects of different flood events. One model incorporated the reach from Prado Dam downstream to Weir Canyon Road, and the second model continued from Weir Canyon Road to the Pacific Ocean. Golder combined the two existing model reaches to create a continuous model from Prado Dam to the Pacific Ocean. The second geometry was updated due to construction in Reach 9.

Due to construction of channel improvements in Reach 9 downstream of Prado Dam, the geometry was updated to reflect the changes in the upper reach of the HEC-RAS model. Golder obtained the updated geometry in April 2014 and updated the modeling using the new geometry.

Both geometries evaluated were similar. Over the entire reach, 37 bridges are present, ranging from small pedestrian, bicycle, and railroad bridges to multi-lane major freeway bridges. Based on available aerial imagery, the geometry of the existing USACE models appear accurate, except for three structures. The project team added two inflatable rubber dam structures built in 1993, as well as a small grade control structure within the Riverview Golf Course.

The channel generally has three distinct geomorphic reaches shown in Figure B-1 and Table B-1. The first geomorphic reach commences near Prado Dam and ends at North Weir Canyon Road. It is a natural channel with braided and meandering patterns, and a relatively steep longitudinal slope when compared to the remainder of the LSAR. The overbanks are fully vegetated, indicating possible vegetation encroachment after the dam was constructed. Manning's n values for this reach vary from 0.034 to 0.040 for the main channel and from 0.05 to 0.070 for the overbanks in this reach.

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Table B-1 River Station Boundaries of the Three Geomorphic Reaches

Geomorphic Reach	River Station Boundaries
Upper Reach	162302-120325
Recharge Reach	120325-59930
Lower Reach	59930-760

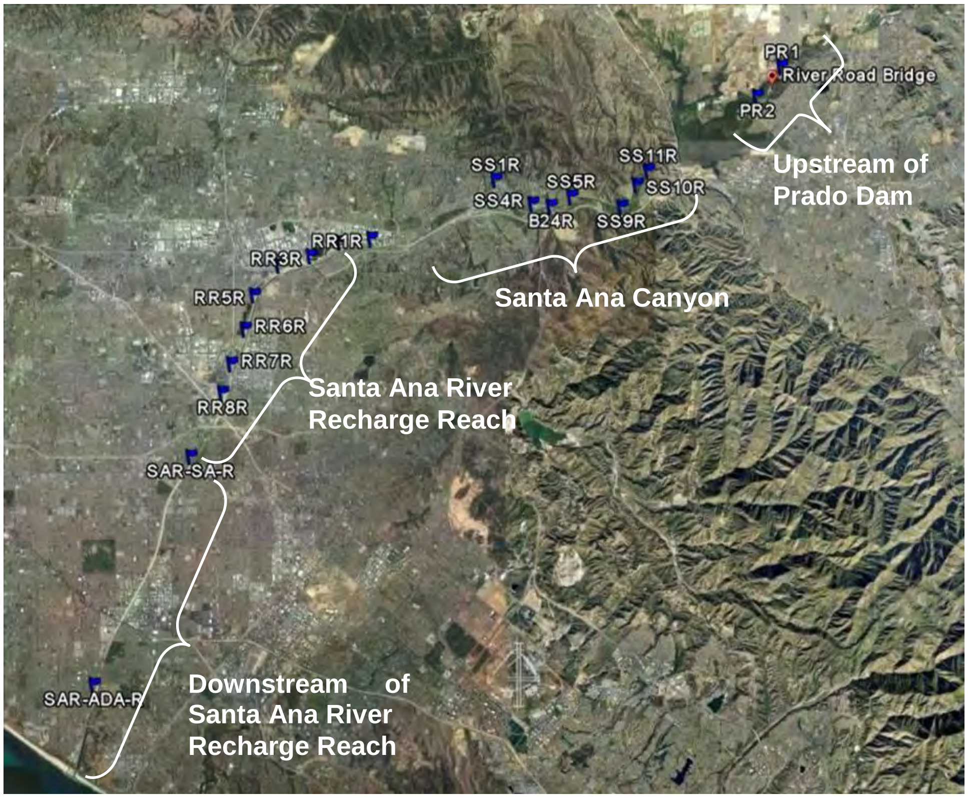

Figure B-1 Location Map

The second geomorphic unit is the groundwater recharge reach, extending from North Weir Canyon Road to the Garden Grove Freeway. This section has a natural bed, but its banks have been significantly modified. The river in this reach is contained within a regular, trapezoidal channel with a bottom-width of about 325 feet. Several drop and grade-control structures were constructed in this reach to maintain the river slope and prevent undue degradation. Temporary T&L, named for the shape of the levees resembling the letters “T” and “L”, and “racetrack” levees constructed by OCWD to enhance infiltration of water into the riverbed (Figure B-2) are also present in the recharge reach. These temporary structures are designed to slow down low flows and allow more infiltration. They are washed away during high flows and were therefore not incorporated in the HEC-RAS model.

Flow diversion structures located in this river reach divert flows to adjacent infiltration ponds. Two of these structures are inflatable rubber dams that were built in 1993 near stations 103085 and 85000. They are approximately 7’ high when inflated. These dams are fully inflated during the storm season when flows are less than 500 cfs. When flows are between 500 and 2,000 cfs they will be partially inflated, and when flows exceed 2,000 cfs they are fully deflated removing the obstruction to the flow in the river. However, water is still allowed to be diverted through open gates. The HEC-RAS model geometry is broken at these inflatable dams to allow for a rating curve to be used to simulate the operation of the dams to properly analyze the sediment transport at these locations. Infiltration and other small diversion points are modeled throughout this reach as well.

The Carbon Canyon Diversion Channel flows into the Santa Ana River in this reach, just downstream of North Glassell St. Currently the flow magnitudes corresponding to the modeled outflows from Prado Dam from this channel are unknown. Other small inflow points along this reach convey flows back to the river from the adjacent infiltration ponds. Numerous storm drains are present along the lower stretches of this reach. Again, the flow contributions corresponding to the modeled flows are unknown. The Manning’s n value is set at 0.030 for the majority of the sections and 0.050 for sections representing the drop structures.

Figure B-2 Example of T&L Levees

The final geomorphic reach is located between the downstream end of the recharge reach (downstream of the State Highway 22) and the Pacific Ocean. This reach has a mild, longitudinal slope and much of the channel geometry has been modified. From just upstream of 17th Street to just upstream of I-405, the channel has a trapezoidal shape with concrete lined sides and bottom. Downstream of this point to just upstream of Adams Street the channel changes to a rectangular channel with concrete lined sides and bottom. Downstream of this point to the PCH the channel takes on a natural soft bottom with concrete lined levees. The extreme downstream reach of the Santa Ana River between the PCH and the Pacific Ocean has natural sides and bottom and is prone to periodic sediment deposition.

Santiago Creek enters the Santa Ana River at the beginning of this reach, and one more major ditch discharges water into the river near the end of the reach, just downstream of the Victoria St. Bridge. The reach has one grade control structure that was not present in the original USACE version of the model. The model used in this study contains this structure. The exact geometry of the grade control structures is not known at this time. Therefore, its geometry was assumed. It has been located near the beginning of this reach just downstream of the Santiago Creek confluence. The Manning's n value for the channel bed is set at 0.030. At the drop structures, it is set at 0.050. The Manning's n value for the concrete-lined section was set at 0.014.

2.2 Hydrology

The flow from Prado Dam, controlled by USACE, is the only inflow hydrology used in the HEC-RAS model. Inflows from the catchment downstream of Prado Dam have not been included in the model at this point. Tetra Tech and HDR (2010) indicate that the watershed area contributing to the Santa Ana River downstream of the dam is two orders of magnitude smaller than the watershed area upstream of Prado Dam. Neglecting flows from the downstream part of the catchment is therefore deemed reasonable.

Historical daily flow data from Prado Dam is available from 1980 through the beginning of 2010. These flow records were analyzed to establish five pulse flow scenarios. The pulse flows will be used to model sediment re-entrainment downstream of the dam to augment sediment loads in the SAR. These sediments will be dredged from the Prado Basin and will be placed just downstream of the dam prior to re-entrainment. It is assumed for the purpose of this report that when the pulse flows are released from the reservoir the augmentation sediment will be introduced into the river for conveyance downstream. The pulse flow magnitudes that were selected are 500, 750, 1250, 2,000 and 5,000 cfs. They will be released under controlled conditions over periods of several days until all the augmentation sediment has been re-entrained. In order to determine the fate of the augmented sediment after it has been re-entrained into the river by the pulse flows it was necessary to develop representative flow records in the river for use after the augmentation period simulation.

The historical daily flow data were therefore further analyzed to identify water years representing 75% (Wet), 25% (Dry), and 50% (Median) exceedance water years from October 1 to September 30. The flow records successively representing these conditions are the water years 2002/2003 (wet), 1987/88 (dry), and 1999/2000 (median).The corresponding flow records are shown in Figure B-3 through Figure B-5 below. These flows were added after the pulse flows to create one year of historic daily flow data for use in the simulations. Each of the flow series covers a period of a little over one year, commencing with a pulse flow followed by the full year of average annual daily flow series. The flow and sediment time series used in the various HEC-RAS simulations are contained in Figures B.B.16 to B.B.57, attached to this appendix.

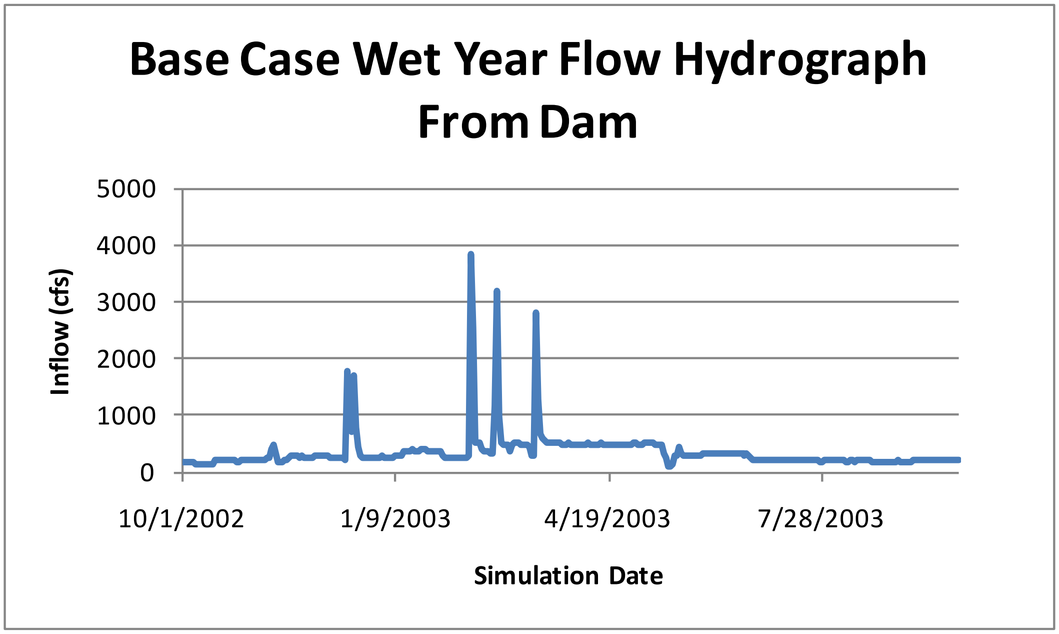

Figure B-3 **Wet Year Flow Hydrograph**

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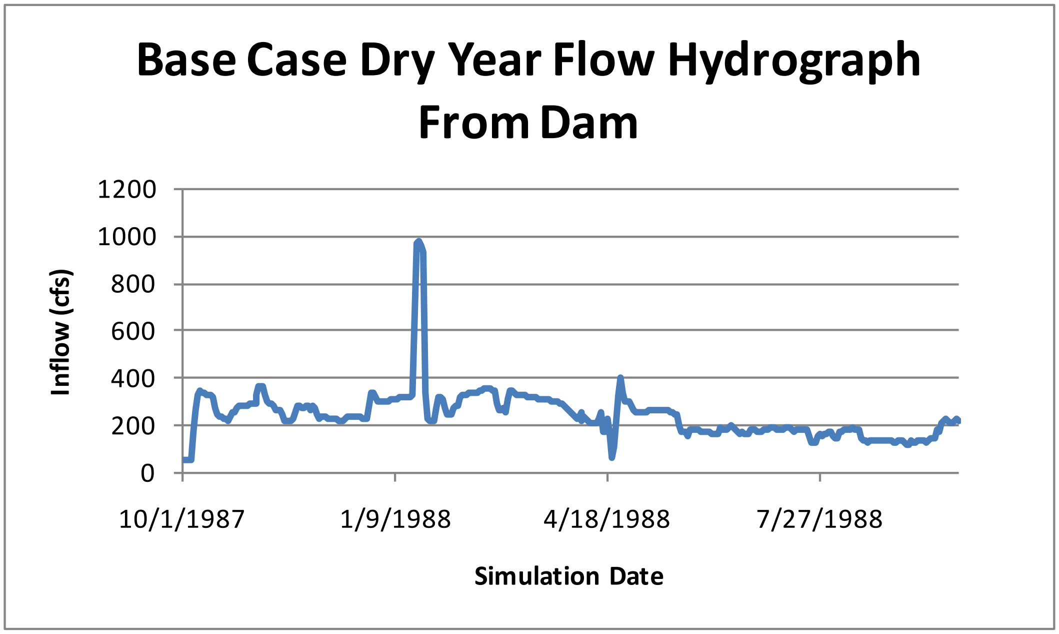

Figure B-4 Dry Year Flow Hydrograph

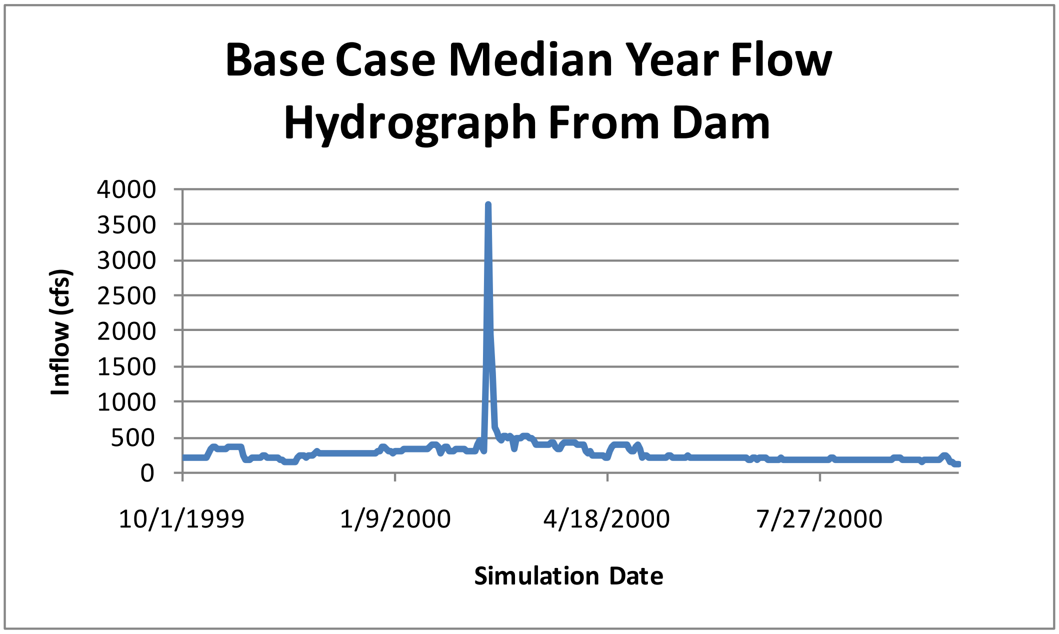

Figure B-5 Median Year Flow Hydrograph

Operating procedures for the inflatable dams previously mentioned leads to the diversion of all flow in the river when the flow from Prado Dam is less than 500 cfs. As shown in Figure B-3 through Figure B-5 there are very few times throughout the year where there will be flow in the river below the recharge reach in all three flow scenarios modeled.

2.3 Sediment

The sediment file provides the model with sediment data required for execution of the sediment transport simulations. It contains the properties of both bed material and incoming sediment loads. Sediment grain sizes, grain size distributions, sediment mass density, porosity of deposited sediment, bed material properties, and sediment loads flowing into the river are contained in the input files. For this study, the natural sediment load and sediment augmentation load were expressed in tons per day. The magnitude of the natural sediment load into the system was specified using a rating curve relating water flow and sediment load. The augmentation load was specified as a percent concentration in the flowing water.

Cohesive soils are simulated using either non-cohesive sediment transport assumptions (i.e., using the same equations to estimate cohesive sediment transport as are used to estimate non-cohesive sediment transport) or by making use of equations developed by Krone (1962) and Parthanadias (1962), which specifically addresses cohesive sediment erosion, deposition and transport properties. When using the cohesive sediment transport equations by Krone and Parthanadias it is usually necessary to perform specialized testing. In this study, it was assumed that the cohesive sediments can be simulated using non-cohesive sediment transport equations. It is noted that this approach may significantly overestimate the transport of cohesive sediments.

Several equations are available in HEC-RAS to calculate sediment transport, bed sorting, and fall velocity. The equation used in the model is selected on the sediment input screen. Bed sorting calculations are required to simulate how the bed material composition may change over time. For example, if the bed material becomes coarser due to the preferential removal of fine material it may become armored. Once armored it protects the sub-surface sediments and limits the amount of sediment that can be removed from the riverbed for transportation. The fall velocity of the sediment is required to determine its mobility, i.e., how easy is it to settle the material and to re-entrain it once settled on the riverbed.

For this analysis the Engelund-Hansen sediment transport function, the Exner sorting equation, and the Rubey fall velocity equation were selected. The Engelund and Hansen (1967) total load equation was selected because of its simplicity and suitability to calculate sediment transport in sandy river conditions. The equation is a stream-power based relationship using commonly available parameters (e.g., grain size, flow velocity and bed shear stress). It has been identified as one of the most accurate total load sediment transport equations for a wide range of non-cohesive sand sizes (HEC-RAS 2010). Annandale

(2007) showed that the Engelund and Hansen (1967) equation responds appropriately as a total load predictor to changes in total turbulence as opposed to only responding to changes in near-bed turbulence (bed load) or only to turbulence in the water column above the near-bed region (suspended load).

The Exner sorting equation is effective in predicting armoring of the bed material. For this reason, it was selected for the Santa Ana River where armoring has already been found to occur in some river reaches. The Rubey fall velocity method is suitable for silt, sand, and gravel sizes with specific gravities of around 2.65, similar to materials found in the Santa Ana River.

One of the limitations of the HEC-RAS sediment transport modeling software is that specification of only one sediment gradation per cross section is allowed. This means for example that differing gradations cannot be specified for the surface layer and the sub-surface layer at one particular cross-section. This is an important observation because the sediment properties on the surface and sub-surface often differ especially if the channel has armored.

2.4 Quasi-Unsteady Flow

The quasi-unsteady flow file is used to define a flow hydrograph for the HEC-RAS model. The flows are entered as a flow series for a specified duration and are the upstream model boundary condition. A 24-hour duration was used to represent the daily flows. This means that the daily discharges were held constant for periods of 24 hours. Therefore, one year of daily flow data consists of 365 (or 366 in a leap year) different daily flow values.

The computational increment is specified as part of the flow series. This increment determines how often calculations are performed. For example, a computational increment of one hour means that a computation is carried out every simulated hour. Therefore, the calculations are repeated 24 times for every simulated day if the computational increment is one hour. The model is extremely sensitive to this parameter. Long increments can result in model instability, while very short increments may result in more stable models but require very long run times. This parameter was used in model calibration, which is discussed in the next section.

The tide elevation at the Santa Ana River/Pacific Ocean interface was set as the downstream boundary condition. The temperature of the river water must be specified for calculating sediment particle fall velocities. A constant water temperature of 55 degrees Fahrenheit was used for all simulations.

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3.0 MODEL CALIBRATION

Due to the lack of measured sediment discharge and geometric data over time, the model cannot be fully calibrated to historic conditions. The model was calibrated to the extent practical based on observations during a geomorphic assessment (Attachment A) and information contained in previous reports. However, the model represents what Golder expects will happen in the river during the scenarios modeled and the model can be used to identify areas of potential risk that can be monitored during the demonstration project. The model can be calibrated to observed conditions during sediment re-entrainment at a later date.

Before baseline and predictive analyses can be performed, the HEC-RAS model must be calibrated for existing conditions to ensure the model is capable of predicting natural conditions in the river. For this calibration many different scenarios were modeled, combining different computational increments, flows, tidal influences, sediment concentration, incoming sediment gradation, geometry specifications, bed material gradations, allowable depths of scour, and boundary conditions. The project team developed approximately 200 models before developing a calibrated simulation. It should be noted that calibration was conducted on the model before improvements to Reach 9 were made. The new geometry obtained in April 2014 did not affect model calibration results.

Mathematical models that are used to forecast morphologic behavior of rivers are based on numerous assumptions. A systematic approach to model development and calibration is therefore required. The project team employed a three level approach to address these needs, consisting of a geomorphic assessment (Attachment A), basic hydraulic and sediment analyses, and detailed sediment transport modeling supported by a sensitivity analysis. In honoring this approach, the HEC-RAS sediment model development for this project commenced with a field trip to investigate river characteristics. This was followed by basic hydraulic and sediment transport analyses, which was accompanied by systematic model development.

The criterion used to calibrate the HEC-RAS model is based on the Santa Ana River morphology between Prado Dam and the Pacific Ocean. Aerial imagery, field observation, channel geometry and bed material data was used to assess its morphologic stability, which indicated a “quasi-equilibrium” condition. This means that the river experiences only minor morphologic channel changes.

The objective function thus established reflects the present degree of stability of the river. This means that the model parameters that were finally selected were those that reasonably produce a model representing a quasi-equilibrium condition.

3.1 Computational Increment Sensitivity Analysis

As previously stated, model stability is very sensitive to the computational increment. For the calibration runs, computational increments ranged from 15 minutes to 24 hours. It was determined that a 30-minute computational increment provided the best balance between model stability and run time.

3.2 Flow Analysis

After analyzing the historical flow data, a hydrologic year from March 23, 1980 to March 22, 1981 was chosen for the calibration runs. This year was selected because it contains higher than average flows for approximately the first month of the hydrologic year, which is useful for introducing sediment to the system. This flow series was only used in the model calibration. As stated previously, there is not enough data over time to perform a typical calibration using long-term water flow, sediment flow, and geometric data. This flow series is used to ensure the model represents the quasi-equilibrium conditions observed in the river. As discussed in the Hydrology section above, statistical analysis was performed to determine a wet, dry, and median water year to be used in the base and predictive case model runs that are discussed in Sections 4.0 and 5.0 below.

3.3 Tidal Influences

Multiple tide elevations were simulated to determine its effect on erosion and deposition in the lower reaches of the Santa Ana River. Stages of 0, 2, 4, and 8 feet above mean sea level were analyzed. The sensitivity analysis revealed that tidal elevations indicate that the tides have a significant impact on sediment deposition in the most downstream reach of the river. However, when viewed in terms of the total amount of sediment transported through the system it is deemed to have fairly minor effects. The difference in sediment deposition over this tidal range is about 500 tons (Figure B-10) which is a very small percentage of the total re-entrained sediment load. This finding led to the selection of a constant tide level of 0 feet. This was used in both the baseline and predictive analyses.

3.4 Sediment Load

The natural sediment load in the river was calculated using the USACE rating curve from Figure 4.1 in the GDM (USACE 1988). The relevant equation is: $Q_s = 0.003Q_w^{1.42}$. Select paired water and sediment flows are shown below in Table B-2.

Table B-2 Paired Water and Sediment Flows

Q_w (cfs)	Q_s (tons/day)
100	2.1
250	7.6
500	20.4
1,000	54.6
2,000	146.1
5,000	536.6

The rate by which augmented sediment can be introduced into the river was estimated by conducting a sensitivity analysis. Concentrations of augmented sediment introduced into the river were analyzed for 0.25%, 0.5%, 0.75%, and 1%. No significant difference in the sediment transport characteristics was observed. It was therefore decided to assume that the augmented sediment can be introduced into the Santa Ana River at a concentration of 1%. This allowed calculation of the amount of pulse flow water needed to re-entrain 500,000 yd^3 of sediment into the Santa Ana River.

3.5 Incoming Sediment Gradation

An incoming sediment gradation was calculated by taking the average of the two samples collected for each of the three boreholes (B3, B12, and B16) for a total of six samples taken from Prado Basin in March 2010. The percent passing for each size fraction was averaged across the six samples to develop the incoming sediment gradation. This gradation is classified as fine sand and is assumed to be the material that will be dredged from the Prado Basin and re-entrained to the Santa Ana River downstream of Prado Dam. Figure B-6 shows the assumed gradation for the calibration, natural, and augmented sediment load. It is recommended that additional samples are taken in the recommended dredging area using continuous sampling techniques to obtain a better representation of sediment that will be dredged and re-entrained downstream.

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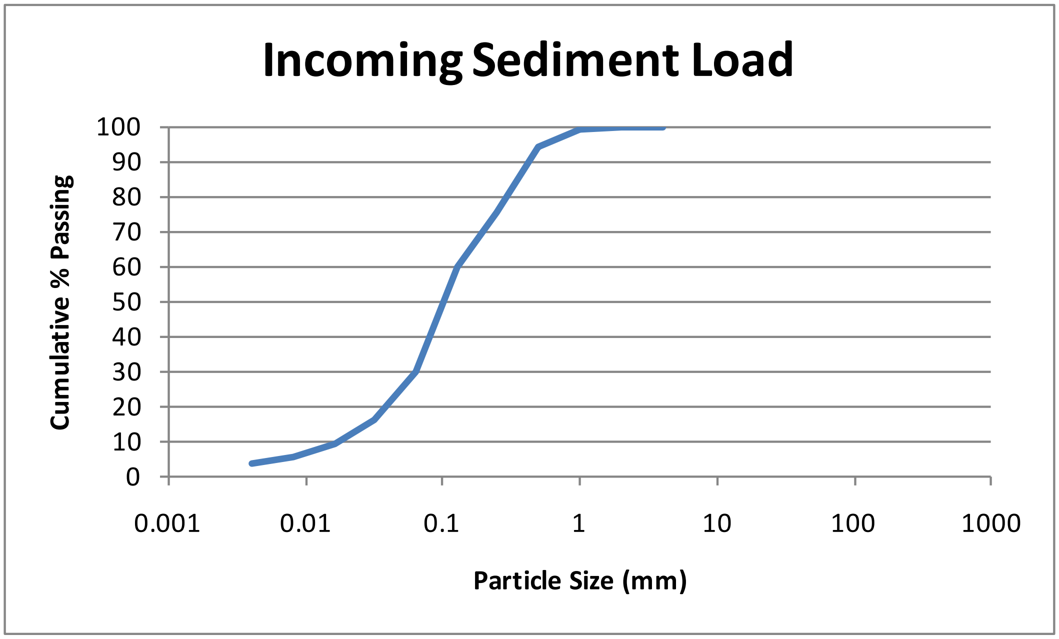

Figure B-6 Incoming Sediment Load Gradation

3.6 Geometry Specifications

The model calibration required sensitivity analyses related to model geometry. The geometric sensitivity analysis considered interpolated cross sections and development of sediment pass-through nodes. The models originally developed by the USACE and obtained in April 2014 used several interpolated cross sections throughout the length of the study reach. For steady flow computations (without sediment transport), this can increase model stability. However, for sediment transport computations major instabilities can occur when multiple interpolated cross-sections are used in reaches with constant slopes and cross sectional geometry. Therefore, most of the interpolated sections were removed from the model.

Pass-through nodes can be valuable when analyzing sediment transport systems, because they prevent sediment from depositing or eroding. During model calibration, several locations were experiencing large deposition rates that did not reflect conditions observed in the field. In some cases, these deposition areas led to model run failure. As such, pass-through nodes were added to reflect observed quasi-equilibrium conditions. Locations where implementation of this approach was necessary usually included areas near bridges or drop structures. Several pass-through nodes were used in the final calibration of the model and remain in the base case and predictive assessments.

3.7 Bed Material Gradations

Several sediment samples in the Santa Ana River below Prado Dam were collected in 2008. These samples and the resulting gradations were used in the calibration analysis. It is noted that the HEC-RAS model allows specification of only one gradation per cross section. It was therefore necessary to select one sample at cross sections where more than one gradation was available. In such cases, to be consistent, Golder selected the sample gradation that was taken in the thalweg (i.e., the deepest part of the river channel). Table B-3 relates sample points and the corresponding cross sections (also see Figure B-1). The gradations of the sediment collected at each sample point are presented in Attachment B.

Table B-3 Sample Point Number and River Station

Sample Point	River Station
SS10R	152780
SS9R	147873.3
SS5RSur	139329.3
SS4RSur	132453.7
SSER	124611.3
RR1RSur	102000
RR2RSur	97200
RR3RSur	92300
RR4RSurThal	87400
RR5RSurThal	80700
RR6RSur	74969
RR7RSur	69346
RR8RSur	56947
SARSAR	53330
SARADAR	19400

3.8 Allowable Depths of Scour and Erodible Bed Limits

HEC-RAS allows a set of maximum scour depths and erodible bed limits (horizontal extents of allowable scour) to be input that may be applied during any one simulation. This can be used as a calibration factor to ensure that the simulated bed scour depths resemble observed scour. A sensitivity analysis was conducted for the SAR model to determine the value of the maximum allowable simulated scour depth for each simulation. The scour depth limits that were tested ranges from 0 to 6 feet. The bank stations were used as boundaries for the erodible bed limits.

In all the sensitivity runs conducted, the maximum selected scour depth was achieved at many locations within a short amount of time. This implies that the model calculates scour depths of up to 6 feet within a year. Field observations reveal that the river has not historically degraded at a rate of 6 feet per year in any location, which indicates that the simulated scour depths from these sensitivity model runs do not represent actual field observations.

The Tetra Tech and HDR (2010) scour study of the SARI indicates an average observed scour depth of 6.7 feet over 30 years, implying an average annual rate of about 0.25 feet per year. Golder therefore used this value, i.e., 0.25 feet per year, as the maximum allowable scour depth that could be applied at any location for the simulations conducted (duration = 1 year). No scour was allowed in the concrete lined sections or in the sections representing drop structures. It is understood that “forcing” the model to a maximum allowable depth of scour does not necessarily represent model calibration, however, as previously mentioned, the goal of the calibration is to replicate the quasi-equilibrium condition observed in the field. The bank stations remain as the erodible bed limits throughout the base case and predictive model runs.

3.9 Calibration Summary

The sediment model was calibrated to the extent possible using available information taking the following into account:

- The flow data used for calibration is represented by flows for the hydrologic year 1980.
- The computational increment was set at 30 minutes, balancing the need for model stability and run-time requirements.
- Many interpolated cross-sections were removed from the original USACE models to improve model stability for sediment transport simulations.
- Based on the sensitivity analysis it was decided to set the average tide elevation at the Pacific Ocean at 0 feet.
- The cross sections along channelized portions of the river channel are trapezoidal with flat beds. Therefore, no minor channels, bars, islands, or other geomorphic features are included in those reaches.
- The temporary T&L levees and “racetrack” levees in the recharge reach, constructed of sand, were not simulated. These features fail rapidly during large flow events and are not considered to affect sediment discharge.
- Hydraulic structures such as bridges and drop structures were defined as pass-through features. This means that sediment was not allowed to deposit at these structures. If this was not done the Exner equation would have incorrectly calculated unrealistic values of scour or deposition that has not been observed.
- Based on the history of the Santa Ana River since construction of Prado Dam, the scour limit was set at 0.25 feet. This means that the maximum calculated scour allowed at any cross-section is 0.25 feet for the entire simulation period. Erodible bed limits were set using bank stations from the model.
- The natural sediment load was calculated using a sediment-rating curve developed by the USACE for the SAR.
- The gradation of sediments originating from Prado Dam was determined using the samples collected by Golder from three boreholes in the Prado Basin during March 2010.
- The bed-material sediment gradations specified at each section represent sediment properties of the bed in the thalweg of the river (i.e., the lowest cross-sectional elevation).
- The magnitude of the augmentation load and the amount of water required to re-entrain the sediment into the river were determined by assuming a 1% sediment concentration.
- The Engelund and Hansen equation is used to estimate the sediment transport capacity; the Ruby equation to calculate fall velocities, and the Exner equation to calculate bed sorting.
- Lateral inflows and diversion of flows to OCWD’s infiltration ponds have been omitted. The project team believes that such omission does not significantly affect the simulation results as it relates to transport of the augmented sediment.

Following the demonstration project, the model will be updated with data obtained during sediment re-entrainment.

3.10 Calibration Results

3.10.1 Upstream Geomorphic Reach

The upstream reach is located between River Stations 160818 and 120325 Currently, Prado Dam acts as a sediment trap resulting in only suspended, fine-grained sediment released into the downstream reach. This creates sediment-hungry water, which has led to river degradation. Although the river channel in the upstream segment historically experienced incision, conditions have stabilized somewhat due to channel armoring. The channel is deemed to be in a quasi-equilibrium condition as reflected by the model result presented in Figure B-7, indicating no substantial net degradation or aggradation.

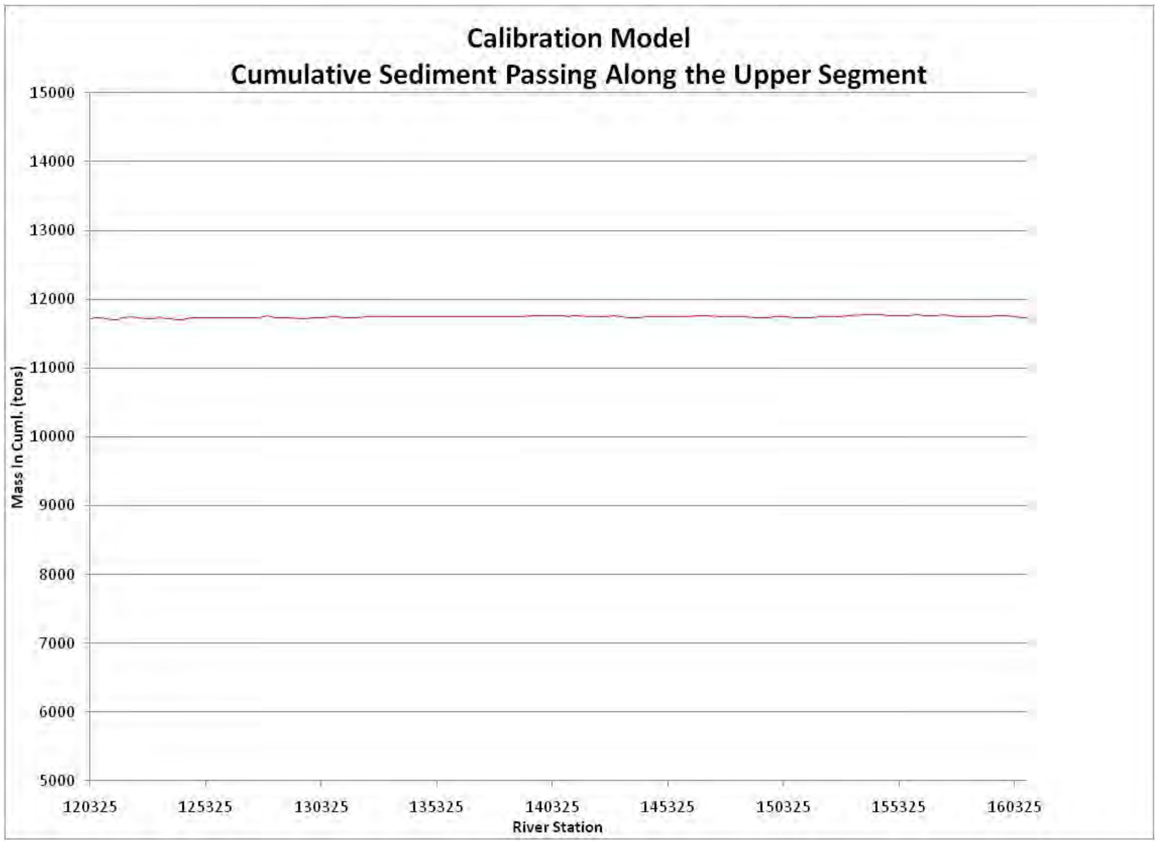

Figure B-7 Cumulative Sediment Passing Along the Upper Segment

3.10.2 Recharge Reach

The recharge reach is located between River Station 120325 and 59930. The sediment transport capacity in the recharge reach is large compared to the natural sediment supply, indicating potential degradation. However, the grade control structures and, in particular, the drop structure constructed in 1993 retain a measure of quasi-equilibrium in this reach. The rubber dam structures, when inflated, ponds water, and results in large amounts of deposited sediment upstream of it. The captured sediment sizes range from silt to gravel with the highest amount of deposition by weight occurring with very fine to medium sand size fractions. During model calibration, it was assumed that the existing rubber dam was fully inflated throughout the model run. Therefore, it may lead to greater amounts of deposited sediment throughout the recharge reach. Figure B-8 is an overview of the entire section illustrating the significant deposition of sediment just upstream of the rubber dam structure for the calibration run[1].

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[1] Note: For the graphs representing hydraulics and sediment transport characteristics, the abscissa represents the upstream end of the river to the right and the downstream end to the left. Therefore, if the amount of cumulative sediment is lower on the left hand side of the graph than on the right hand side, it means that sediment must have deposited (or removed) within the reach. Negative slopes of curves on the graph indicate erosion of the riverbed or addition of sediments, while positive slopes of curves on the graph represent deposition of transported sediment or removal of sediments.

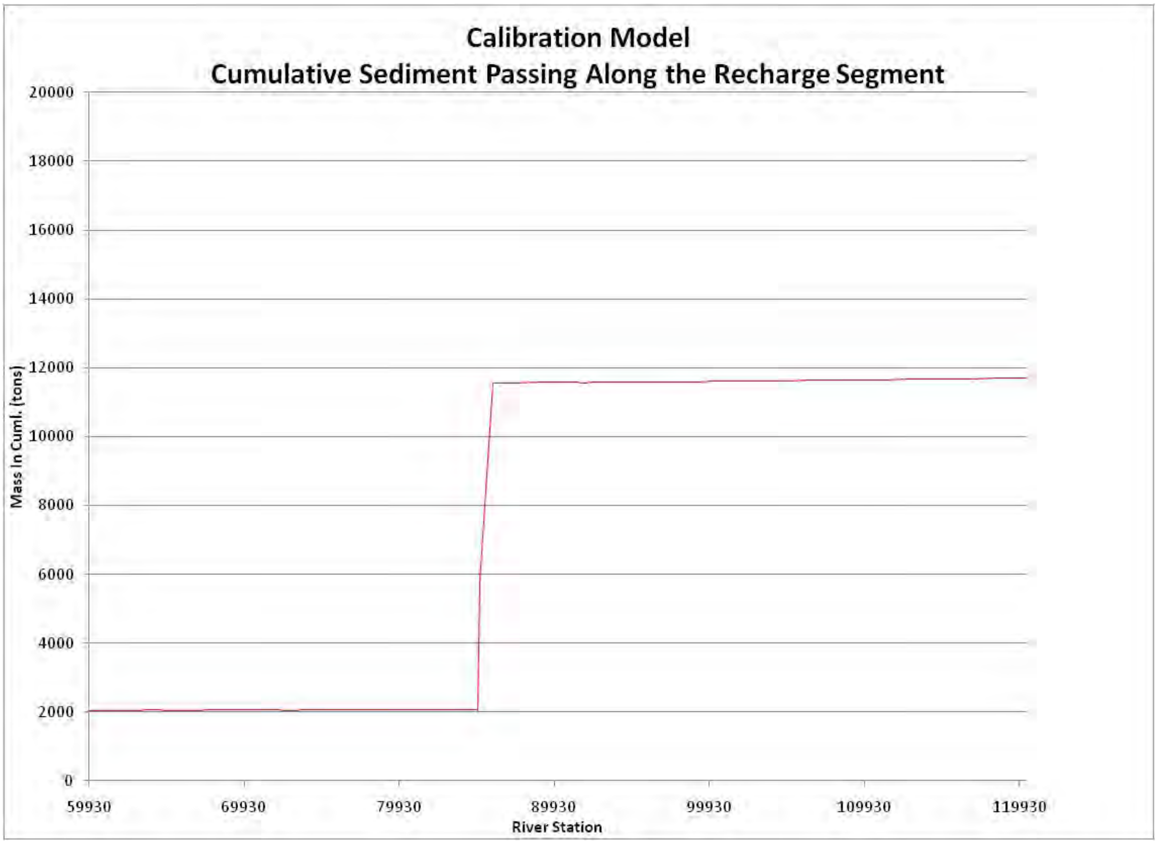

Figure B-8 Reduction in Sediment Load near the Inflated Rubber Dam Structure

3.10.3 Lower Geomorphic Reach

The lower geomorphic reach is located between River Stations 59930 and 760. The section between station 53380 and station 19400 is concrete-lined. At section 22050, the slope of the channel changes and becomes milder.

Excess sediment transport capacity exists in the reach upstream of section 22050. This is evidenced by the almost horizontal slope of the mass cumulative sediment curve upstream of the slope change (i.e., to the right of the note indicating the slope change on Figure B-9) and by the bare concrete channel bed throughout that reach as observed in the field. Downstream of section 22050 sediment deposition occurs (evidenced by the positive slope of the cumulative mass plot to the left of the note indicating the slope change location in Figure B-9). This deposition is due to the natural reduction in riverbed slope, continuing up to about station 6656. Downstream of this station tidal influence significantly affects sediment transport. Figure B-10 illustrates that, for assumed zero tidal elevation, significant sediment deposition is evidenced by the sudden drop in cumulative sediment mass. Such deposition of sediment is observed in the field, confirming the model result. Figure B-10 illustrates the effect of the tide elevation on sediment deposition downstream of section 22050 for other tidal surface elevations of 0, 4, and 8 feet.

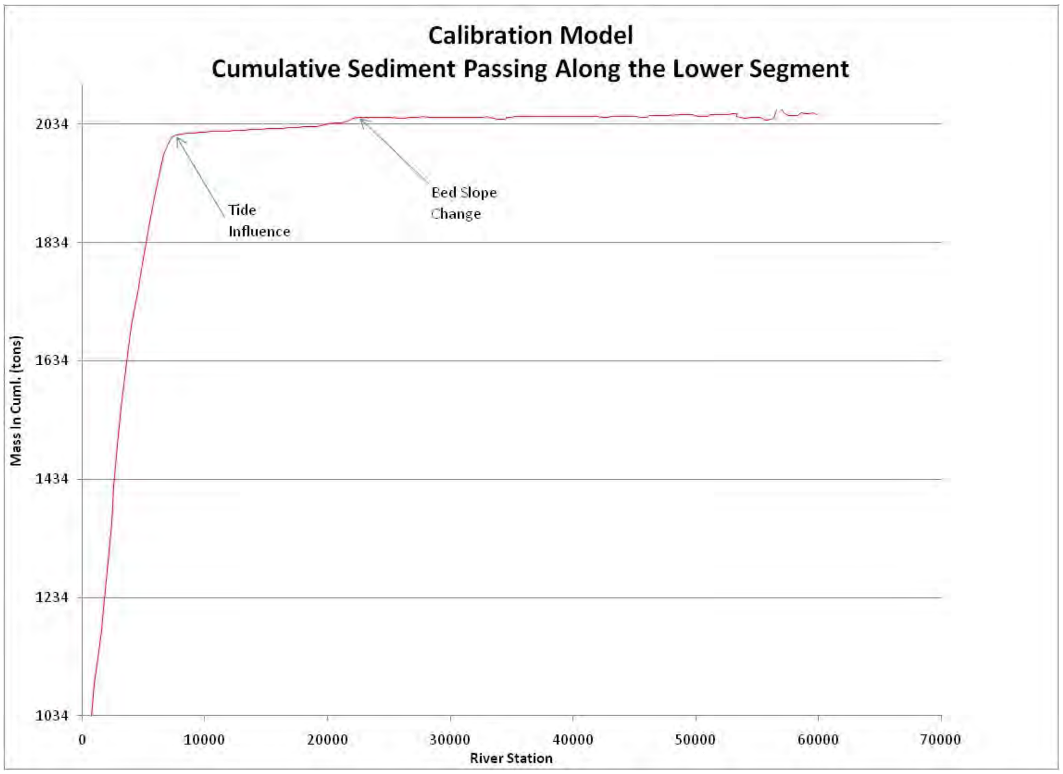

Figure B-9 Cumulative Sediment Passing Along the Lower Segment

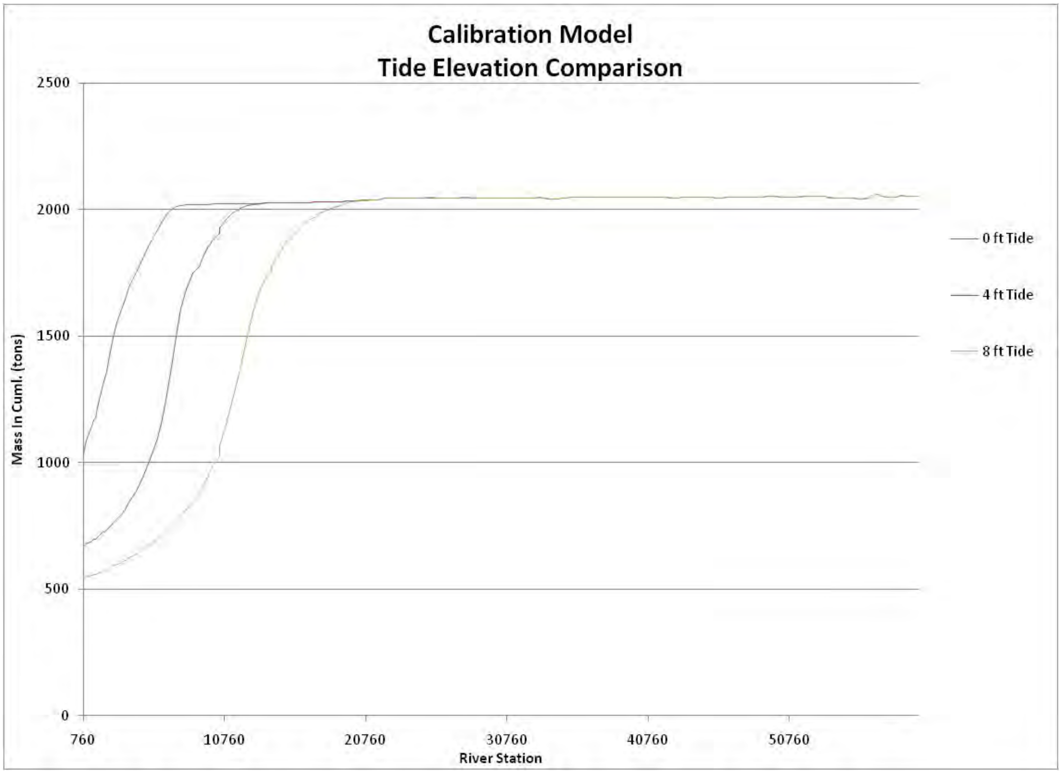

Figure B-10 Effect of Different Tide Elevation on Sediment Deposition

3.11 Hydraulics

A riverbed will degrade or aggrade depending on the relative balance between sediment transport capacity and the amount of sediment available for transport. If the sediment transport capacity is greater than the amount of sediment within the river, the riverbed will erode and, therefore, degrade. If the sediment transport capacity of the flowing water is not large enough to transport the available sediment, sediment in the water column will fall out and could lead to aggradation of the riverbed. This process is not dictated by a single flow, but is a cumulative effect of multiple flows within the river.

One way of expressing the relative magnitude of the sediment transport capacity of the flowing water is to relate it to flow velocity, which can be quantified by making use of the Hjulstrom Curve (Hjulstrom 1935). From that curve, it is possible to identify ranges of flow velocities that will mobilize varying sediment sizes. Figure B-11 and Figure B-12 illustrate potentials to erode and deposit different particle sizes along the Santa Ana River reach.

Figure B-11 illustrates that gravel is expected to mobilize for all the simulated flows in the concrete channel in the lower geomorphic reach. For flows greater than 5,000 cfs, cobbles will erode in the concrete reach. The conditions in the recharge reach are different, and gravel will erode when flows are greater than approximately 250 cfs. Velocities are not high enough to erode cobbles for any of the modeled flow in the recharge reach. In the canyon reach, the erosion potential varies by cross section. However, in many locations mobilization of gravels may occur for all modeled flow events.

Anticipated sediment deposition form an important part of this study. Its characteristics may be gleaned from Figure B-12, which indicates that the potential for gravel and cobbles to deposit in the recharge reach is greater than in the upstream and lower geomorphic reaches. However, it is noted that finer materials, i.e., finer than medium gravel-sized material, are not likely to deposit in this reach. This observation provides a guideline on how the recharge reach might be managed to maximize sediment deposition.

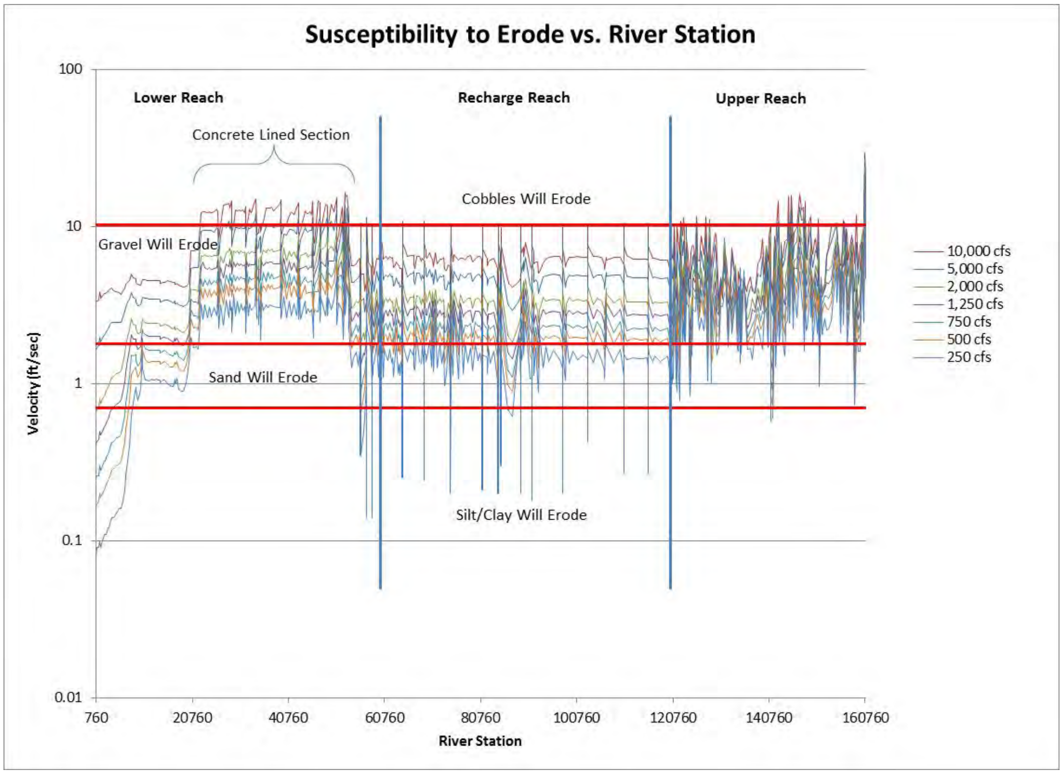

Figure B-11 **Susceptibility to Erode Based on Steady Flows**

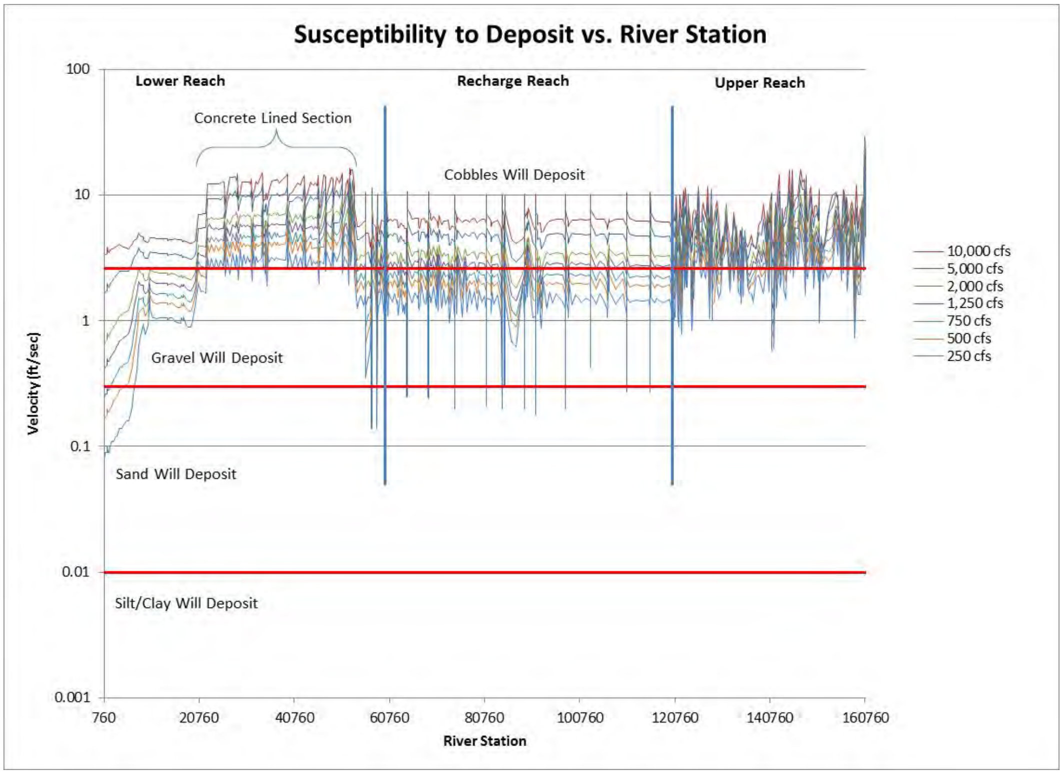

Figure B-12 **Susceptibility to Deposit Based on Steady Flows**

Figure B-13 illustrates Froude Number vs. river station to assist in better understanding the flow regime. Froude numbers in excess of 1 represents super-critical or shooting flow, while those less than one represent sub-critical or tranquil flow. It is noted that the river sections with natural erodible riverbeds are generally sub-critical, with the average Froude number in the recharge reach approximating about 0.4. The evenly spaced peaks in Froude number in the recharge reach represent flow conditions at the grade control structures and are localized. Some of the peaks in the other sections may occur in the general vicinity of bridges.

The Froude number in the concrete channel approaches and even exceeds critical flow conditions for most discharges. It averages about 0.75 to 0.80 in the concrete channel reach, indicating unstable and dangerous flow conditions. High Froude numbers in the concrete channel exceed values of 2, indicating very rapid flows with high sediment transport capacity.

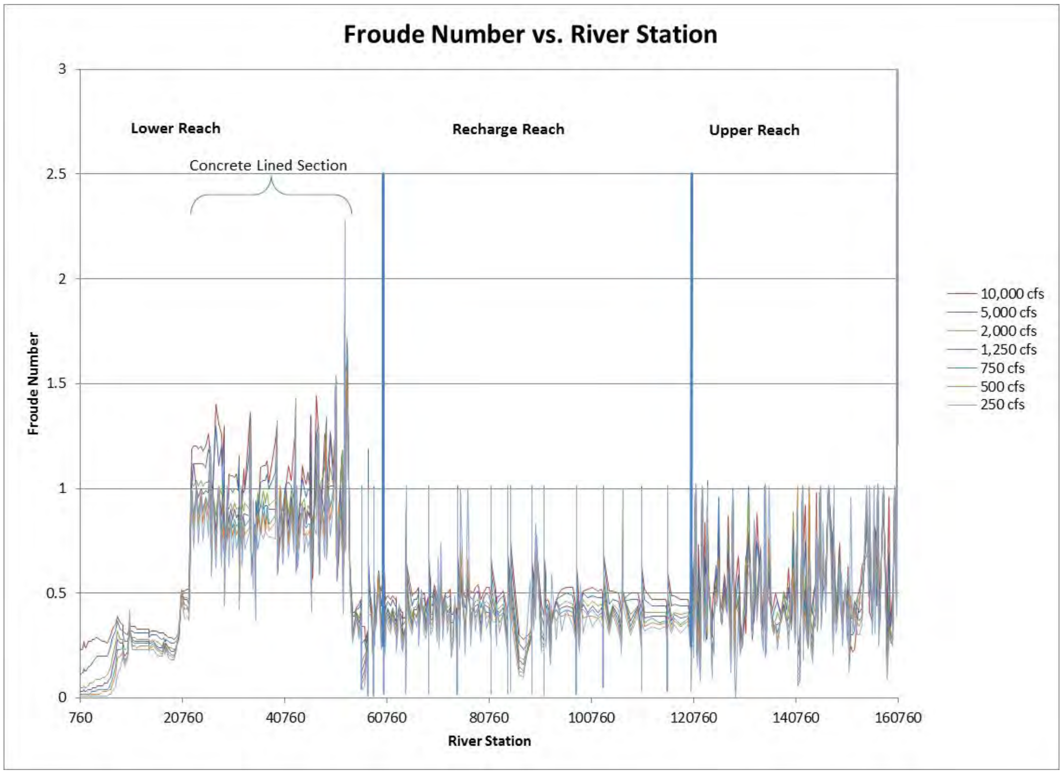

Figure B-13 Froude Number Summary Based on Steady Flows

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4.0 BASELINE ASSESSMENT DOWNSTREAM OF PRADO DAM

Using the calibrated model parameters set forth above, baseline scenarios were simulated to develop understanding of system characteristics. The baseline model consists of the following:

- Geometry: Calibrated model geometry
- Hydrology: The three selected hydrologic sequences, representing dry, median and wet years
- Sediment: Sediment loads were calculated using the rating curve developed by the USACE (1988) for each of the three water year flow series analyzed

For the base case, pulse flows that will be used to re-entrain sediment were not modeled. Therefore, only the three water year flow series were used in the simulations to analyze base case conditions. The sediment load used is only the natural sediment load coming from Prado Dam during these three flow series. The inflow hydrographs and sediment loads used for the wet year base case scenario is presented in Attachment B (Figure B.B.16 and B.B.17). The dry year is shown in Figures B.B.28 and B.B.29 and the median year is shown in Figures B.B.40 and B.B.41.

4.1 Results

4.1.1 Cumulative Mass

For each of the three baseline models the cumulative mass flowing into each section vs. river station was plotted by particle size at the end of the year. Those plots are shown in Attachment C (Figure B.C.1 to Figure B.C.3). The three plots are vastly different in volumes of sediment being carried through the system; however, locations where deposition or erosion occurs are generally consistent between the three models. Three main deposition points are present in each model for all size fractions. One is an inverse slope just upstream of Weir Canyon Rd. (station 121000), another is an inverse slope just downstream of the Talbert Ave. Bridge (station 29000), and the third is the tidal zone.

The model results indicate that, in general for the wet year model, the sand load continues to increase in a downstream direction until approximately the end of the recharge reach with a major deposition at the inverse slope at Weir Canyon Road. From the end of the recharge reach onward, the sand load roughly remains constant until the inverse slope at the Talbert Ave. Bridge. The sand load increases again until it eventually reaches the tidal zone, where it deposits.

For the dry year model, sand moving through the system follows the same pattern as far as deposition areas as the wet year model except that the maximum sand load occurs upstream of the rubber dam at the Five Coves. From this point, it gradually deposits to the end of the recharge reach and stays fairly constant until it encounters the inverse slope at the Talbert Ave. Bridge. The median year model is very similar to the wet year model as far as sand load pattern and depositional areas but is much lower in volume.

For all three base models, the gravel load increases downstream of the Weir Canyon Rd. and remains fairly constant throughout the recharge reach before gradually depositing throughout the lower geomorphic reach.

Cobbles are only transported in the upstream geomorphic reach in all models. Silt particles in suspension remain consistent in the upstream and recharge reaches and gradually deposit throughout the lower reach. About the same volume of silt particles incoming to the upstream reach are transported to the ocean. Clay particles are transported throughout the entire reach, although the volume is relatively small.

4.1.2 Degradation and Aggradation

Total erosion and deposition for the three base case models is shown in Figure B-14 through Figure B-16 for the base case scenarios. From an overall point of view, it is noted that the general trend within and upstream of the recharge reach resembles degradation for the wet, dry, and median year scenario. The upstream geomorphic reach shows erosion hovering around the 0.25-foot degradation limit input to the model. Deposition occurs in all three models between Gypsum Canyon Rd. and a local road at the Green River Golf club in the upstream reach at station 147000. Deposition in this area is not apparent from the cumulative mass figures described in Section 4.1.1. Locally sediment deposits of between 0.5 and 1.5 feet occur in the recharge reach, depending on the run. The concrete lined channel experiences no simulated scour (as expected). Deposits occur in the downstream reach again with depositions of 1 to 3.5 feet at the Talbert Avenue Bridge. Tidal influences cause another deposit of less than 1.0 foot.

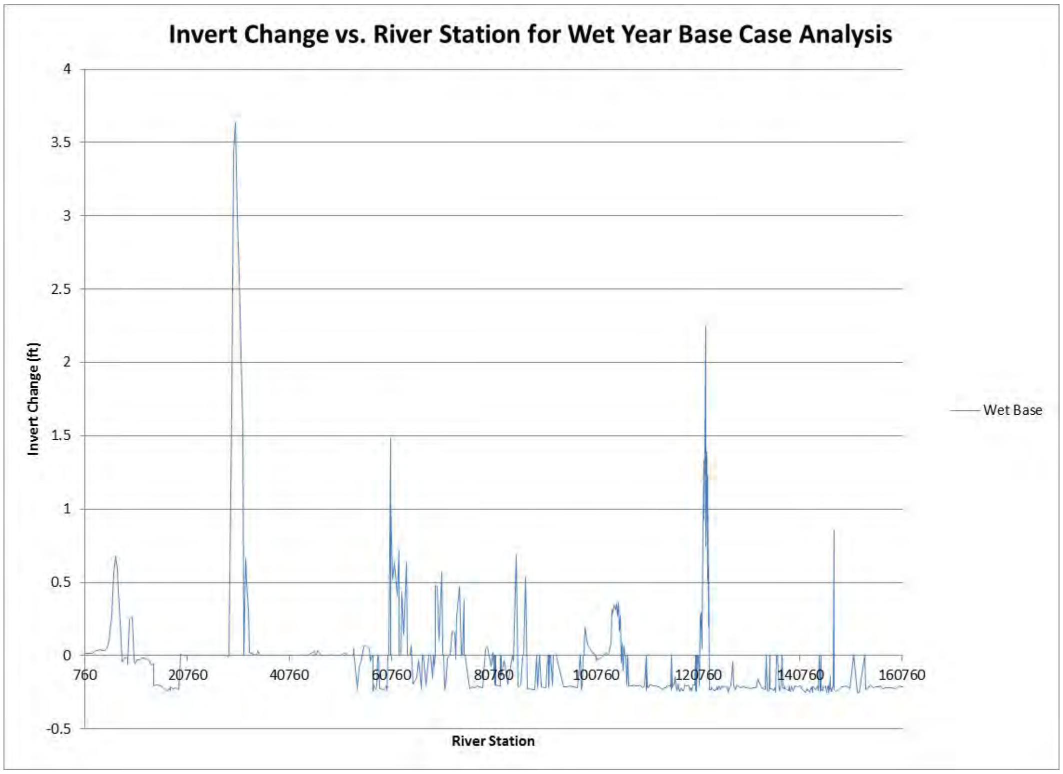

Figure B-14 Total Erosion or Deposition for the Wet Year Base Case

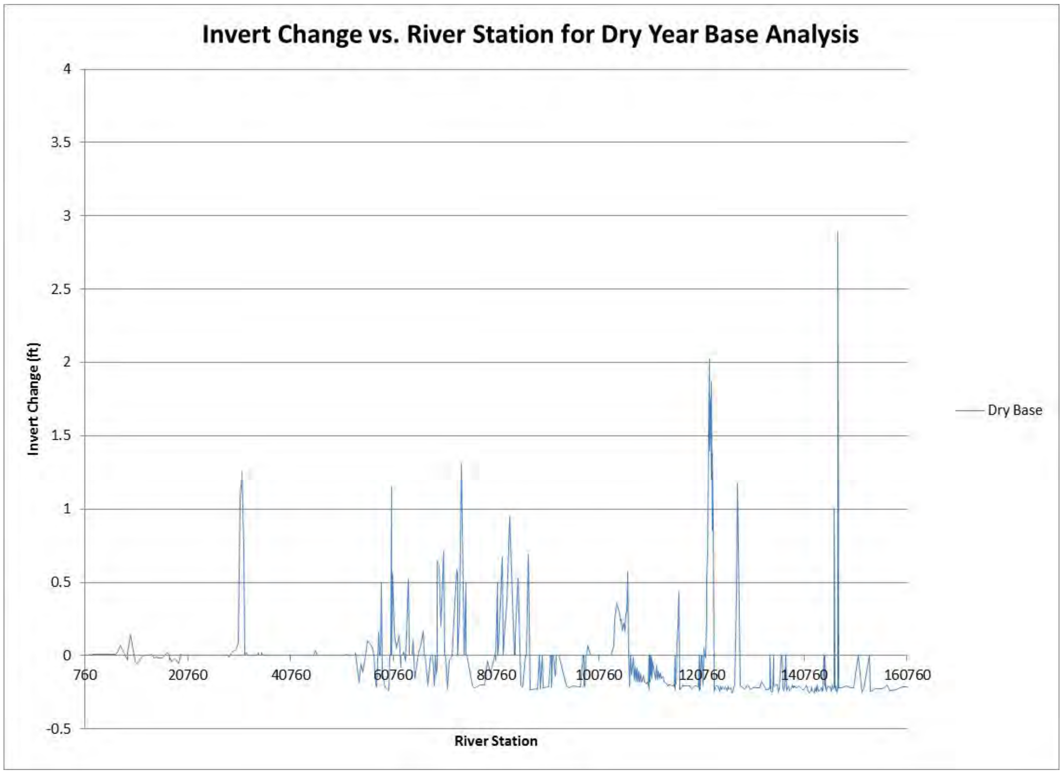

Figure B-15 Total Erosion or Deposition for the Dry Year Base Case

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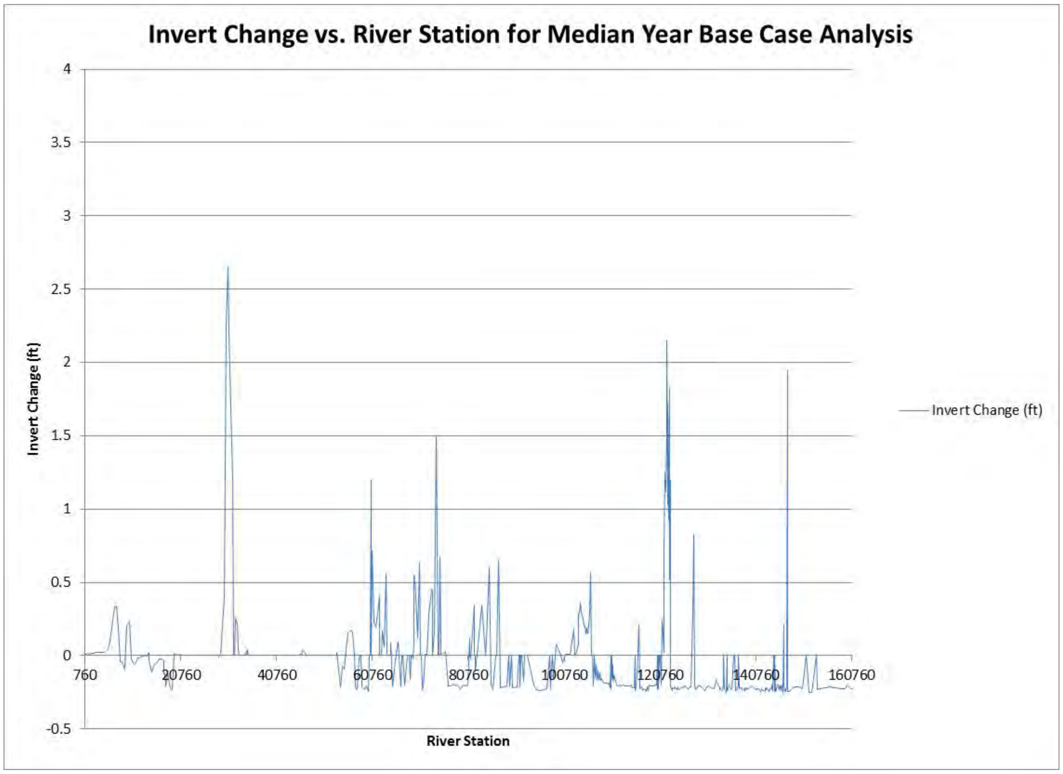

Figure B-16 Total Erosion or Deposition for the Median Year Base Case

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5.0 PREDICTIVE ASSESSMENT

The predictive assessment was used to evaluate the effects of augmenting sediment loads by introducing 500,000 yd^3 of sediment into the SAR.

5.1 Location of Sediment Introduction

Locations and methods to introduce the augmented sediment load are still under consideration. From a modeling point of view, it is assumed that the sediment will be introduced into the SAR at a location just downstream of Prado Dam.

5.2 Sediment Concentration

The sensitivity analysis revealed that minor changes in depositional patterns occurred when using alternative initial sediment concentrations of 0.25%, 0.50%, 0.75%, and 1% at the point where the sediment is introduced. Based on engineering judgment, it was deemed reasonable to assume that a sediment concentration of 1% would be appropriate for the re-introduction of sediment. This is a conservative assumption, based on engineering judgment, of a sediment concentration that will not cause sediment to fall out of suspension immediately after re-entrainment and create a dam in the river. As this assumption may affect acceptable levels of sediment concentration in the river water it may be varied to optimize the project.

5.3 Hydrology and Sediment Augmentation

The historical flows range between 100 and 5,000 cfs. The hydrology used for the predictive runs are the same years of data run for the three respective base case models with the addition of the pulse flows and corresponding durations added to the beginning of each run when sediment augmentation is assumed to take place. At this time, the pulse flow range that was used in the simulations varies: 500, 750, 1,250, 2,000, and 5000 cfs. It should be noted that OCWD does not anticipate dam operations will be modified to provide pulse flows as modeled here. Sediment re-entrainment will take place throughout normal dam operations as flows allow for a period of 72 hours followed by a period of 24 hours without re-entrainment. The pulse flows with re-entrainment were modeled to show the minimum amount of time re-entrainment can take place and the effects on the re-entrained sediment after a reasonable amount of time of normal flow conditions. The natural sediment load is still assumed to be flowing from the dam during re-entrainment flows and is added to augmented sediment loads.

The duration of these flows was dictated by the time required to re-entrain 500,000 yd^3 of sediment at a 1% concentration by weight. The corresponding sediment load rates in tons/day, assuming a 1% concentration by weight, are provided in Table B-4. The estimated times required to transport 500,000 yd^3 of sediment for each of the discharges, following the 72 hours on/24 hours off re-entrainment schedule, are shown in Table B-5.

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Table B-4 Sediment Load at 1% Concentration by Weight

Discharge (cfs)	Sediment Load at 1% Concentration by Weight (tons/day)
500	13,620
750	20,430
1,250	34,050
2,000	54,480
5,000	136,200

Table B-5 Durations to Deplete 500,000 yd³ of Sediment for Six Selected Discharges

Discharge (cfs)	Duration (days)
500	57.4
750	37.9
1,250	22.4
2,000	13.8
5,000	5.3

The graphs relating incoming sediment versus time are presented in Attachment B (alternate graphs in Figure B.B.16 to Figure B.B.51).

5.4 Results

5.4.1 Cumulative Mass

The simulation results are contained in Attachment D. Figure B.D.1 to Figure B.D.15 illustrates the mass balance of sediment discharge over the entire length of the SAR downstream of Prado Dam. From those graphs, it is seen that the general progression of the cumulative sediment mass differs from the base case and is fairly consistent between the three yearly flow scenarios. For the base case, the simulated sediment load generally increases between the dam and the end of the recharge reach, except for the silt and clay load that remains constant throughout the model and for the cobble load that only exists over a relatively small distance along the upstream end of the SAR.

5.4.1.1 Sand Load

From Figure B.D.1 to Figure B.D.15 for the predictive case it is seen that the cumulative load of sand gradually decreases through the upstream reach with a large deposit at the inverse slope at Weir Canyon Road for all scenarios.

The wet year model sand load generally remains consistent through the recharge reach with discreet deposition points downstream of the Imperial Highway Rubber Dam (station 102000), upstream of the Lincoln Ave. Bridge (station 84400), and at the Garden Grove Freeway. Bridge (station 60000). In the lower reach, the sand load remains constant through the concrete lined reach and then deposits in the tidal zone.

The sand load in the dry year models gradually decreases throughout the recharge reach with less noticeable discreet deposition points than the wet model. Like the wet year model, the dry year model sand load remains constant through the concrete lined section and deposits in the tidal zone. The sand load through the recharge reach in the median year model is similar to the dry year model with a gradual reduction in load. A large deposition area is present downstream of the Imperial Highway Rubber Dam (station 102000) in the median year model. In general, the lower the pulse flow at the beginning of the run for all water years, the more sand is deposited in the recharge reach and the less is transported through to the tidal zone.

5.4.1.2 Other Sediment Size Fractions

In general, the silt load remains consistent through all wet year scenarios with small discreet depositions in lower pulse flow models downstream of the Imperial Highway Rubber Dam (station 102000). The dry and median year models show a more gradual deposition in the silt load through the recharge reach at lower pulse flows. Higher pulse flows do not result in much deposition through the recharge reach. As with the sand load, the silt load remains constant through the concrete lined reach and deposits in the tidal zone with a portion of the load flowing through to the ocean. Clay, gravel, and cobble loads behave similar to the base load models.

5.4.2 Degradation and Aggradation

Total changes in invert elevations along the river for the predictive case are shown in Figure B-17 through Figure B-19. Major deposition areas in the predictive models include:

- An area between Gypsum Canyon Rd. and a local golf course road (station 148000) with depositions around 4 feet maximum in the wet year models and 2.5 feet maximum in the dry and median year models
- Upstream of Weir Canyon Rd. (station 121000) with depositions of about 3 to 3.5 feet maximum in all model years
- Between the SPT Railroad Bridge and the Katella Ave. Bridge at a transition from a 320 to 270 feet channel bottom width (station 72000) of about 3.5 feet maximum for the wet year model and about 6.5 feet maximum for the dry and median year models
- Upstream of the Garden Grove Freeway. Bridge (station 60000) with depositions of about 5 feet maximum for the wet and dry year and 7 feet maximum for the median year
- At the inverse slope downstream of the Talbert Ave. Bridge (station 29000) of about 5 feet maximum for all three model years.

Other areas of deposition are estimated to be present throughout the modeled reach but are generally limited to 2.5 feet or less.

Some locations of deposition are present in both the base case and in the predictive scenarios. It can be assumed, from analyzing Figures B-14 to B-16 against Figures B-17 to B-19, that the sediment re-entrainment is not responsible for the total deposition shown at these particular locations. The difference between these figures is the sediment added to the system through re-entrainment. A normal process of any river is active deposition and erosion in a balanced manner. Therefore, it is likely a geomorphic trend that at locations where significant deposition takes place, there would be some degree of deposition under normal water and sediment flow conditions.

Deposition levels could be considered conservative due to several assumptions made in the model setup. These include:

- The sediment re-entrainment site and storage at the re-entrainment. This is calculated from available borehole data. There is a possibility that there will be more fines in the sediment for re-entrainment that will be passed through the system more readily than sand size particles.
- The presence of sediment passes through nodes. By using pass through nodes to aid in stability, the model does not show deposition in some areas that would likely see deposition in reality. This could lead to more deposition in other locations than may occur in the field.

Even though deposition levels reported may be conservative, the model can provide guidance in selecting deposition-monitoring points during the demonstration project.

5.4.3 Sediment Concentration

The simulated sediment concentrations immediately after sediment augmentation (October 1), at March 1, and at the end of simulation (September 30) are shown in Figure B-20 through Figure B-28. Within the upstream and recharge reaches the concentrations hover around 10,000 mg/l for all modeled flow scenarios immediately after sediment re-entrainment. The concentration on October 1 steadily drops off in the lower reach before dropping to near 0 downstream of the end of the recharge reach. As the models progress through the year, the general trend of the sediment concentration through the reach remains the same but the concentration decreases as time goes on.

5.4.4 Spatial and Temporal Distribution of Deposited Sediment

The simulated temporal and spatial distributions of deposited sand for the predictive case are presented in Figure B.D.16 to Figure B.D.45. These figures shows the distribution of sand-sized sediment particles in tons for each River Station on October 1 (just after augmentation) and on September 30 (at the end of the simulation). These figures indicate that generally sand deposits throughout the LSAR immediately after re-entrainment but is transported out of the recharge reach during the period of only the natural sediment load. Sediment that has deposited in the upstream geomorphic reach as well as in the tidal zone immediately after re-entrainment is generally observed to remain throughout the model run. In general, the lower the pulse flow at the beginning of the model run, the more sediment remains in the recharge reach after the model run.

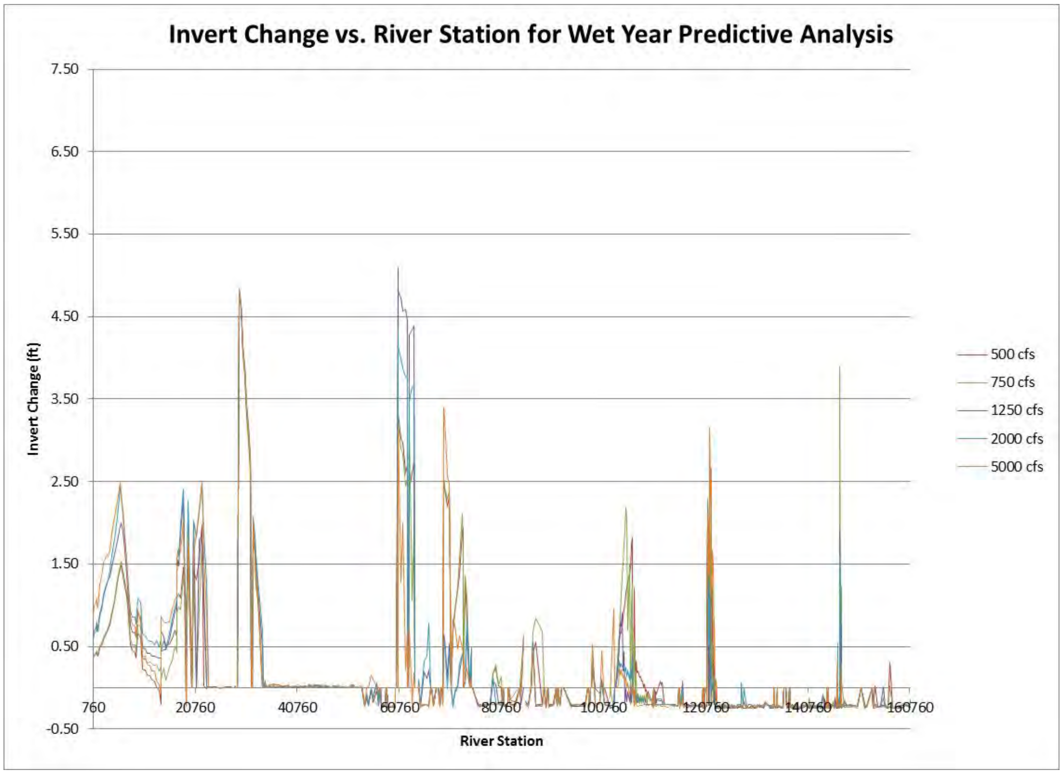

Figure B-17 Total Erosion or Deposition for the Wet Year Predictive Scenarios

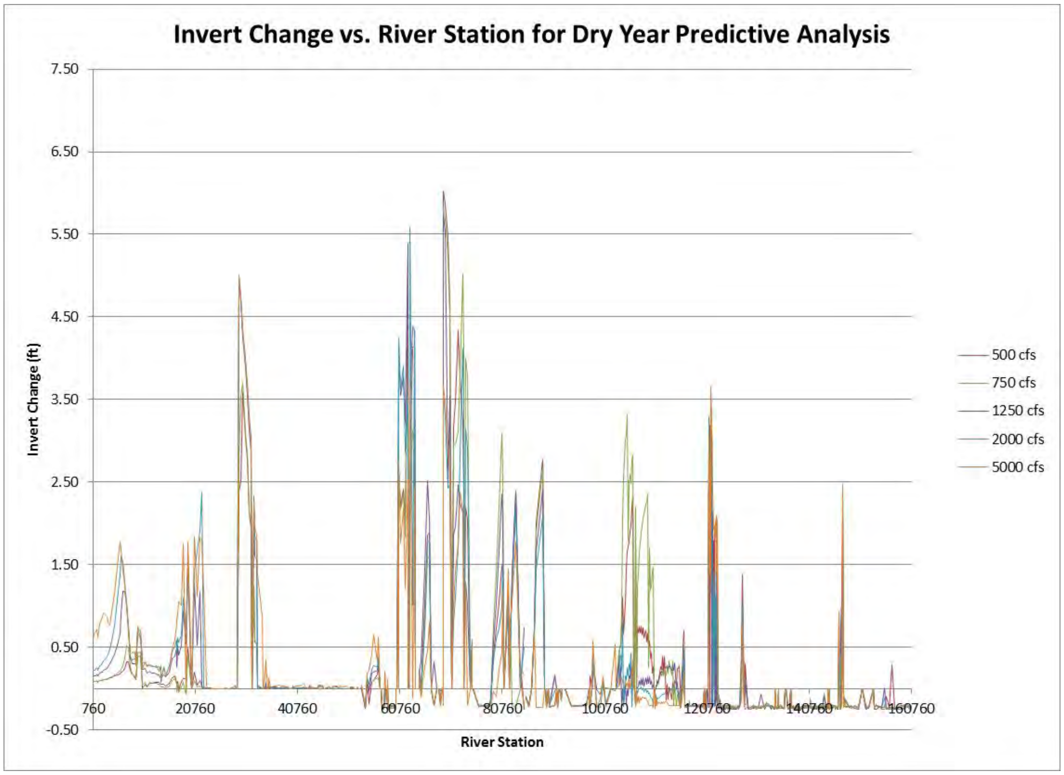

Figure B-18 Total Erosion or Deposition for the Dry Year Predictive Scenarios

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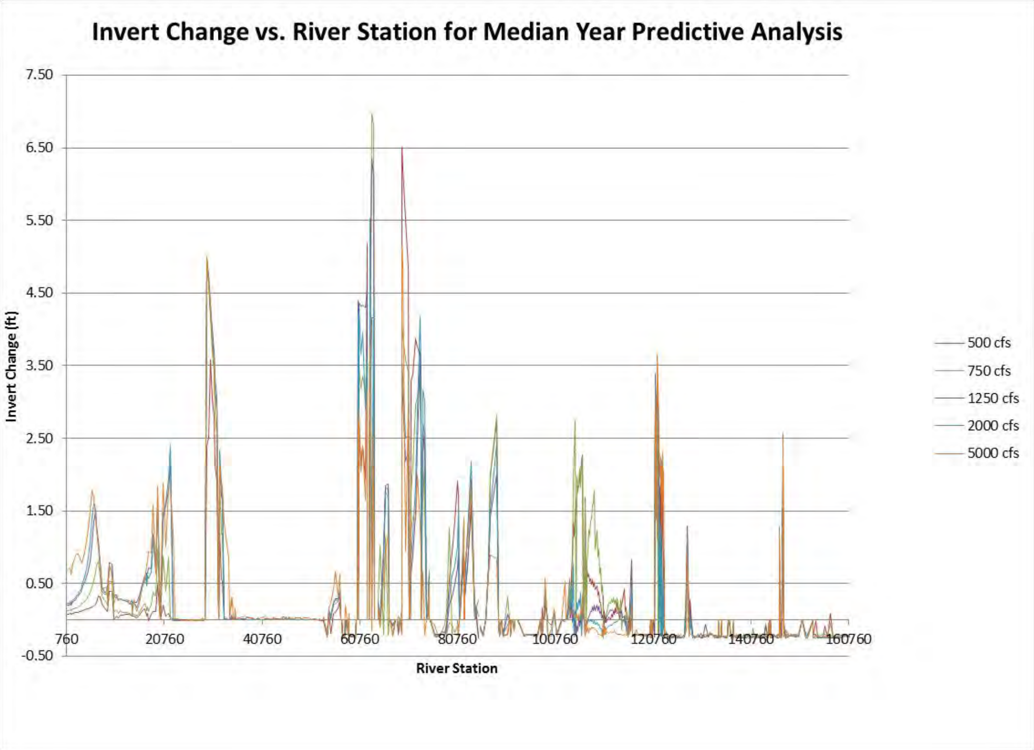

Figure B-19 Total Erosion or Deposition for the Median Year Predictive Scenarios

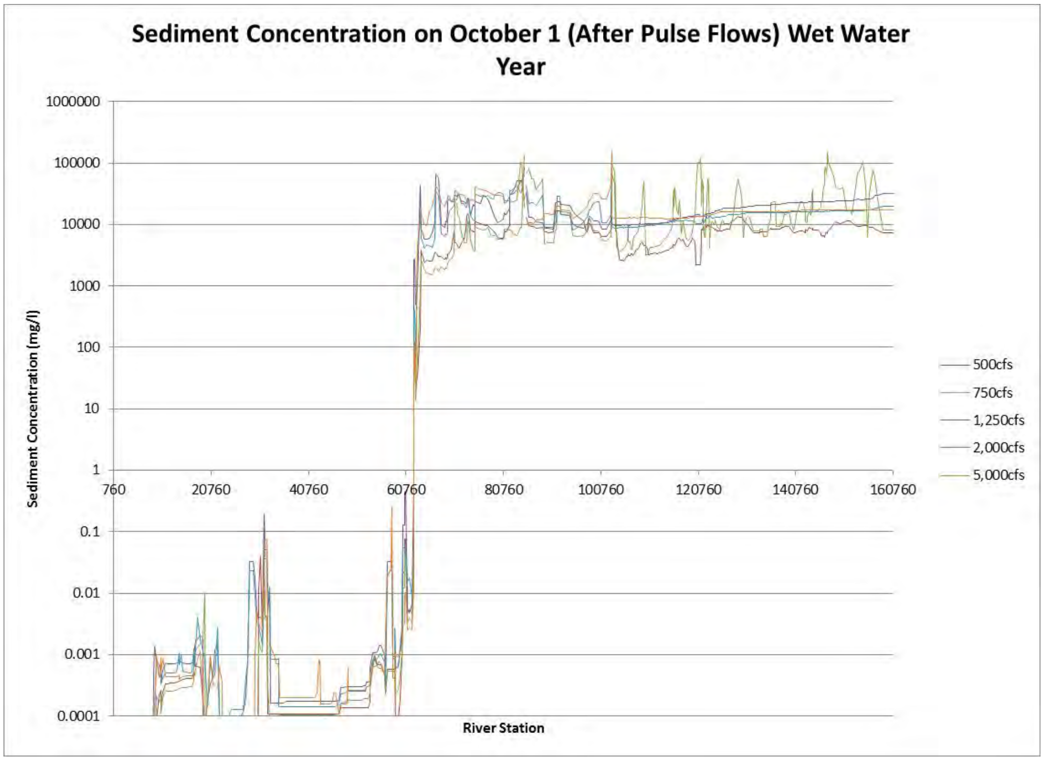

Figure B-20 Sediment Concentration Immediately After Introduction of Sediment for the Wet Year Predictive Scenarios

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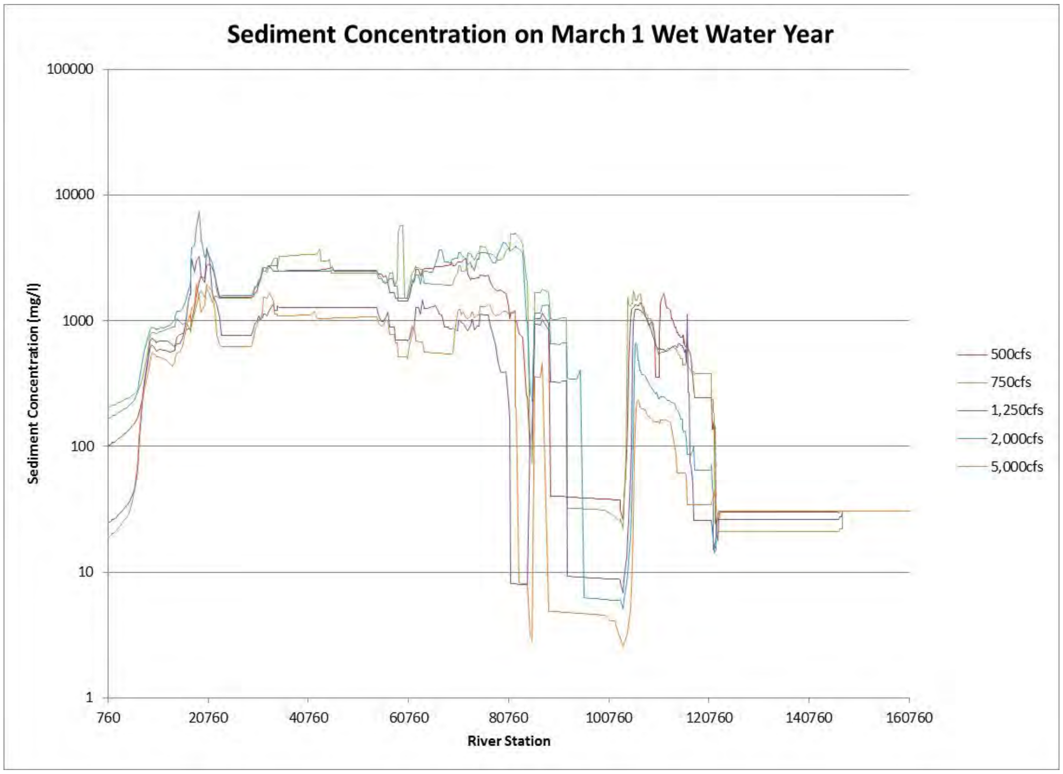

Figure B-21 Sediment Concentration at March 1 for the Wet Year Predictive Scenarios

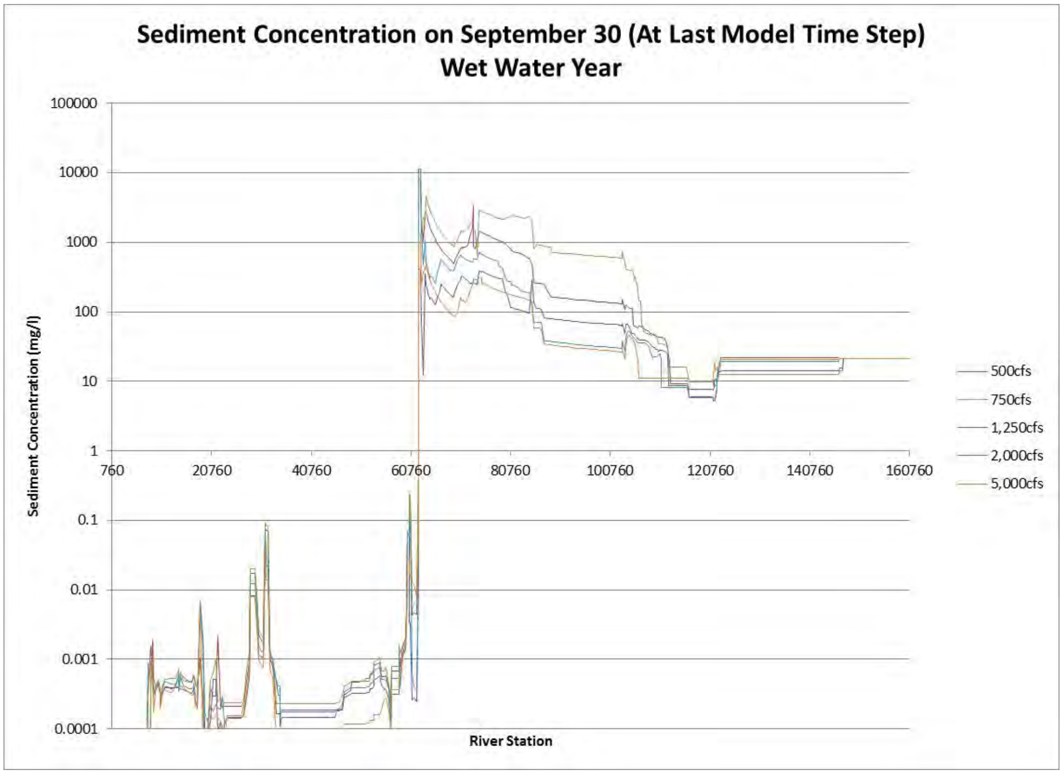

Figure B-22 Sediment Concentration at End of Simulation for the Wet Year Predictive Case

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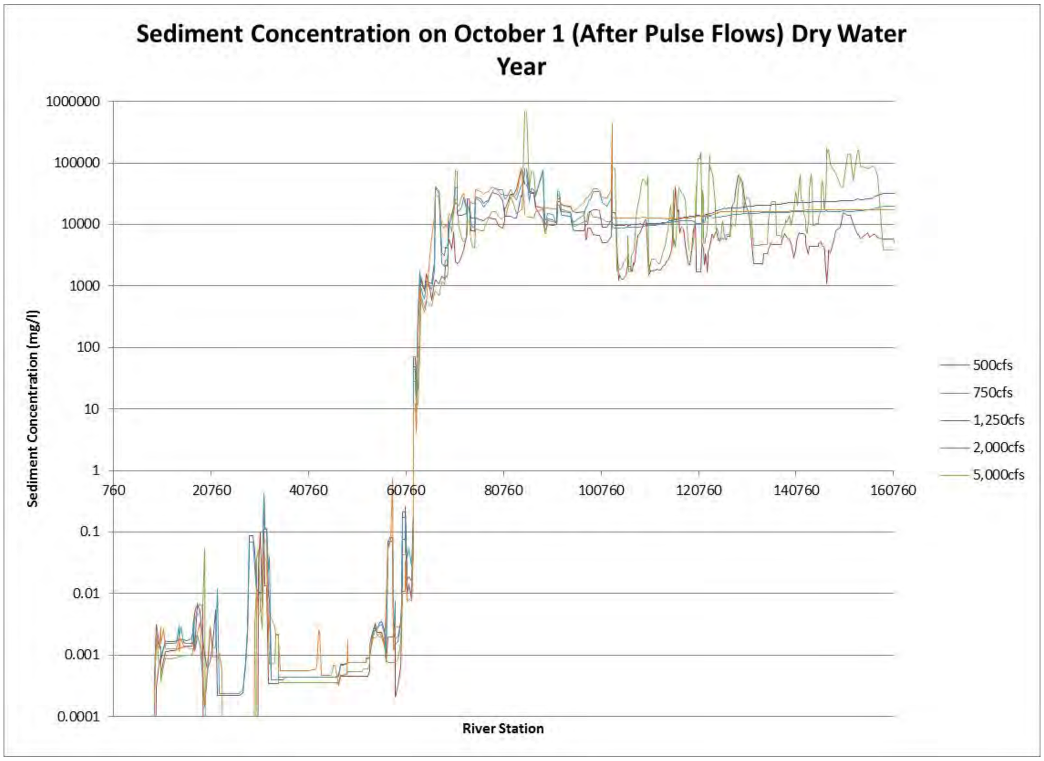

Figure B-23 Sediment Concentration Immediately After Introduction of Sediment for the Dry Year Predictive Case

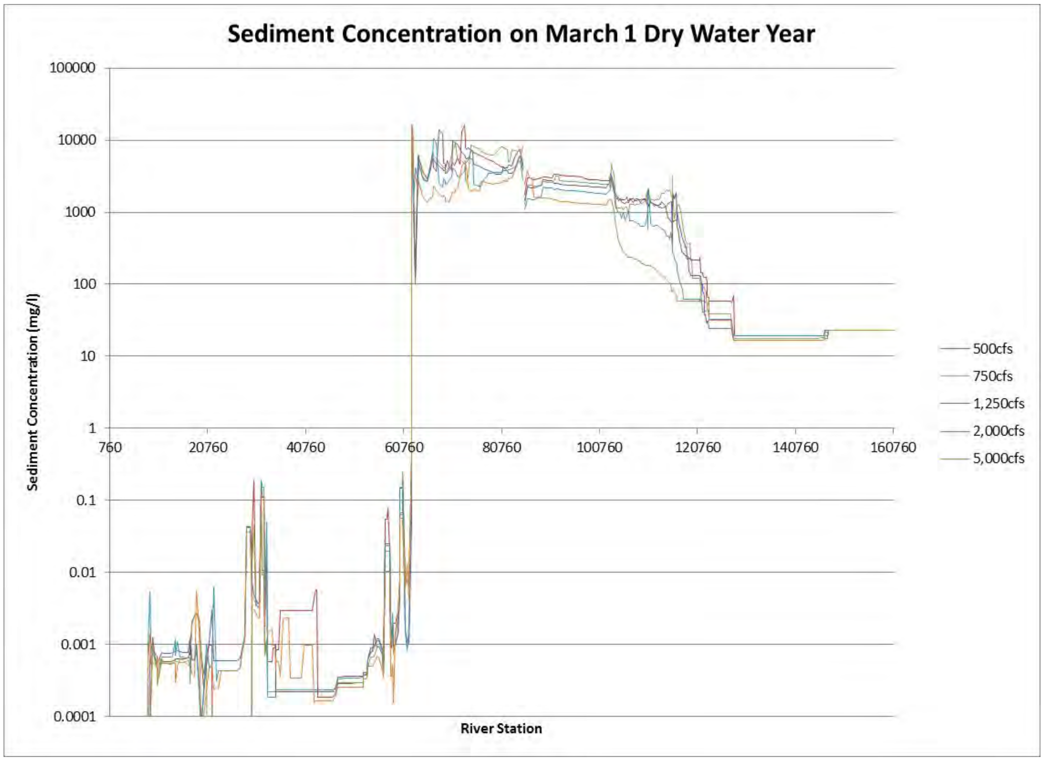

Figure B-24 Sediment Concentration at March 1 for the Dry Year Predictive Scenarios

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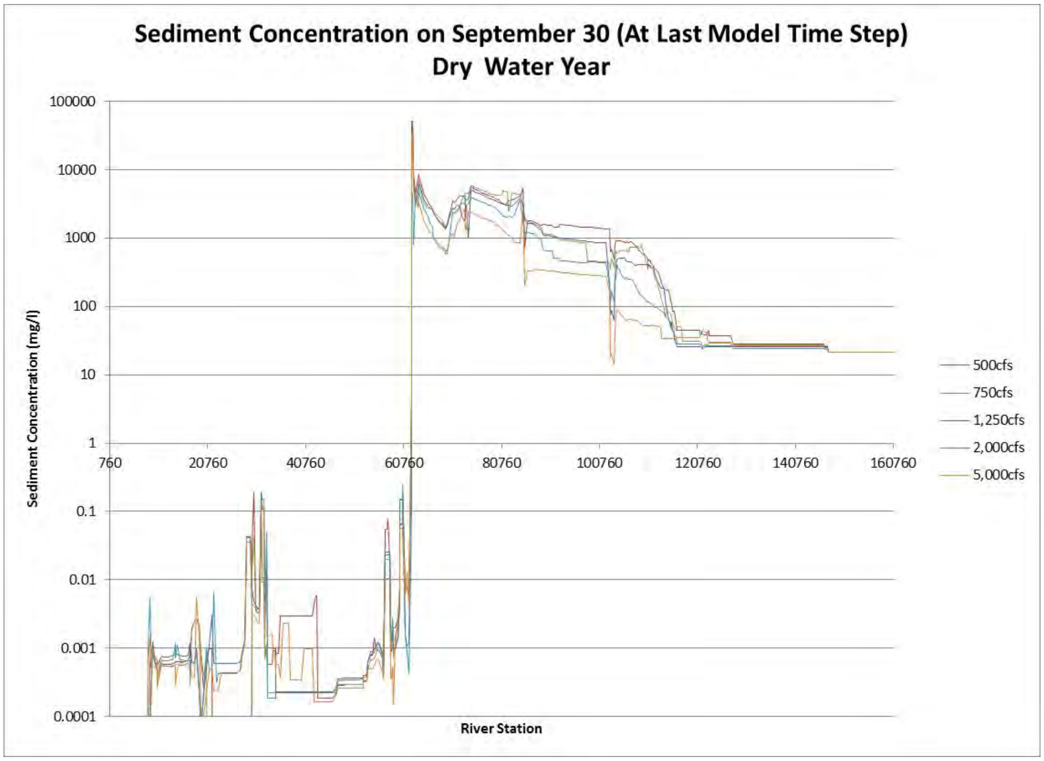

Figure B-25 Sediment Concentration at End of Simulation for the Dry Year Predictive Case

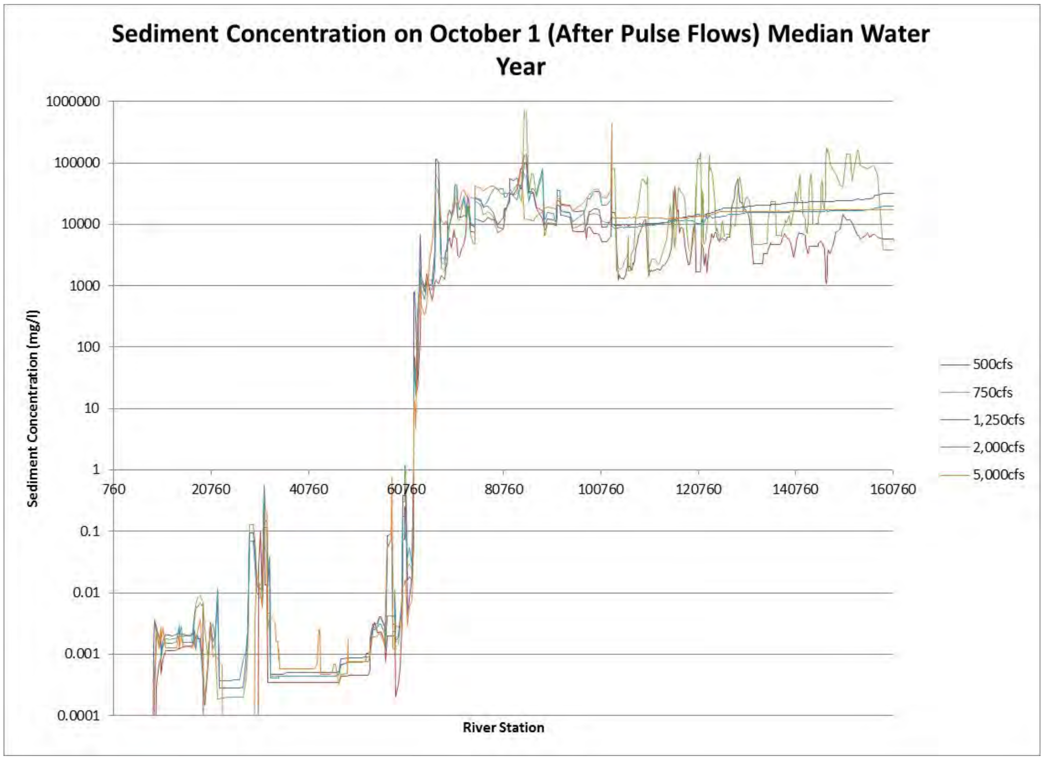

Figure B-26 Sediment Concentration Immediately After Introduction of Sediment for the Median Year Predictive Case

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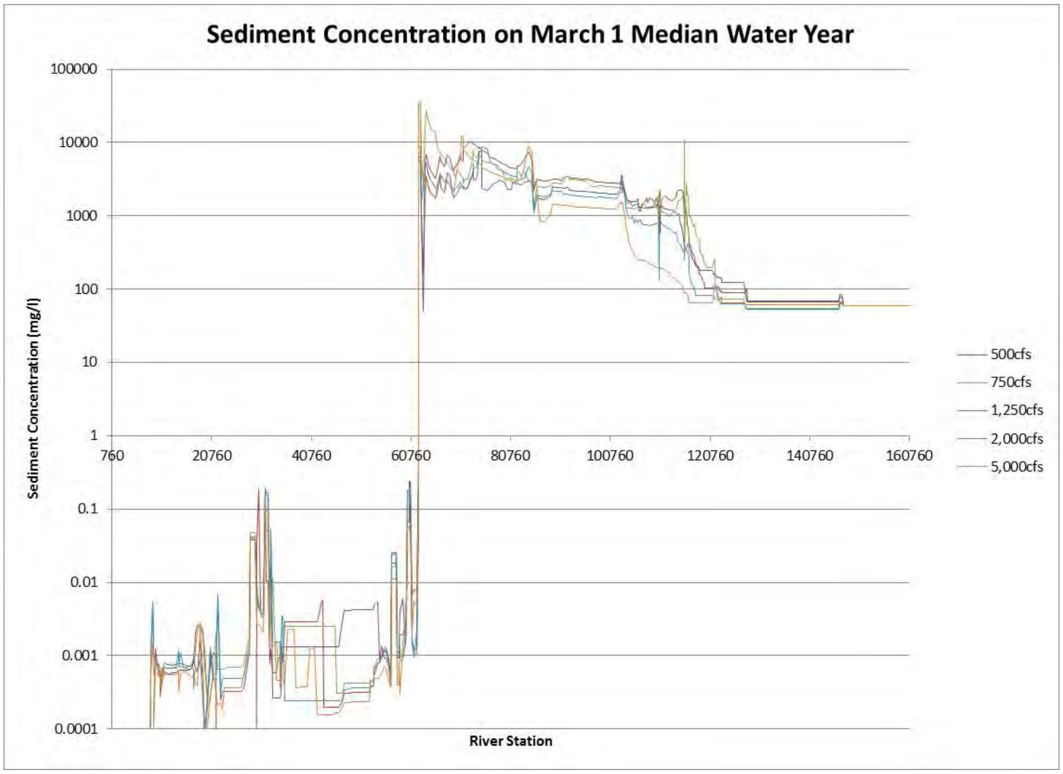

Figure B-27 Sediment Concentration at March 1 for the Median Year Predictive Scenarios

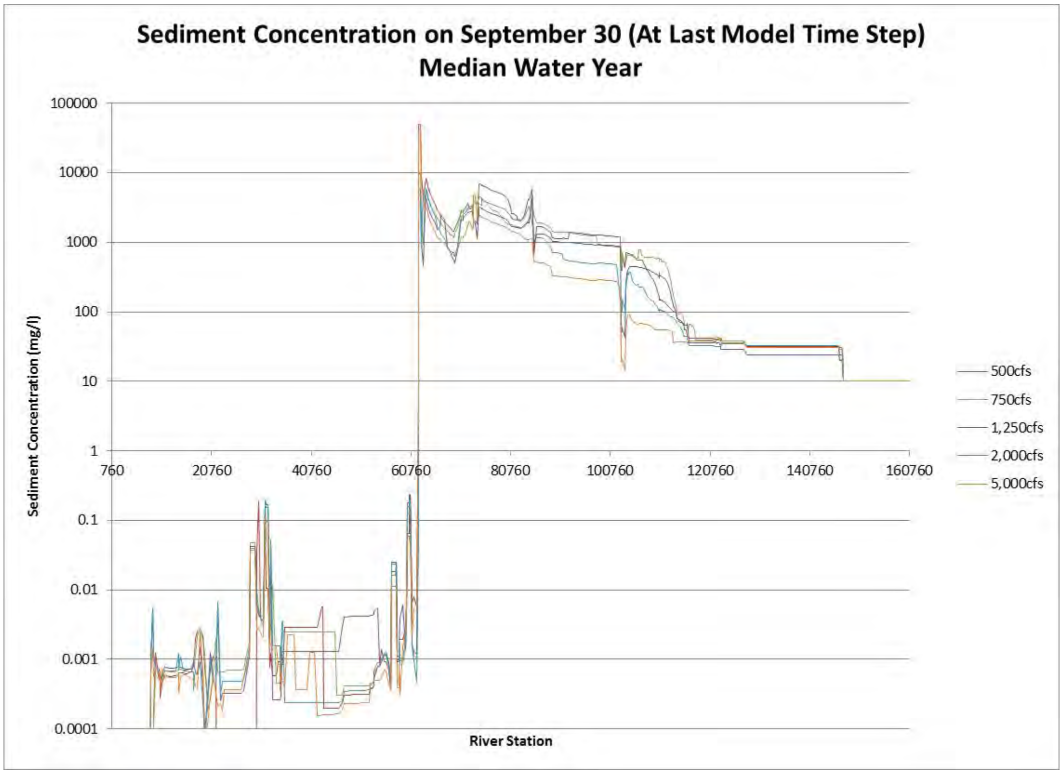

Figure B-28 Sediment Concentration at End of Simulation for the Median Year Predictive Case

5.4.5 Releases of Fines to the Ocean

Figure B-29 to Figure B-31 indicates that fine-grained sediment remains consistent throughout the modeled reach until reaching the tidal zone for the wet year model with a few discreet depositions and releases between 100,000 and 150,000 tons of fines to the ocean. The median and dry year models show a more gradual deposition of fines throughout the modeled reach with releases to the ocean of between 25,000 and 100,000 tons.

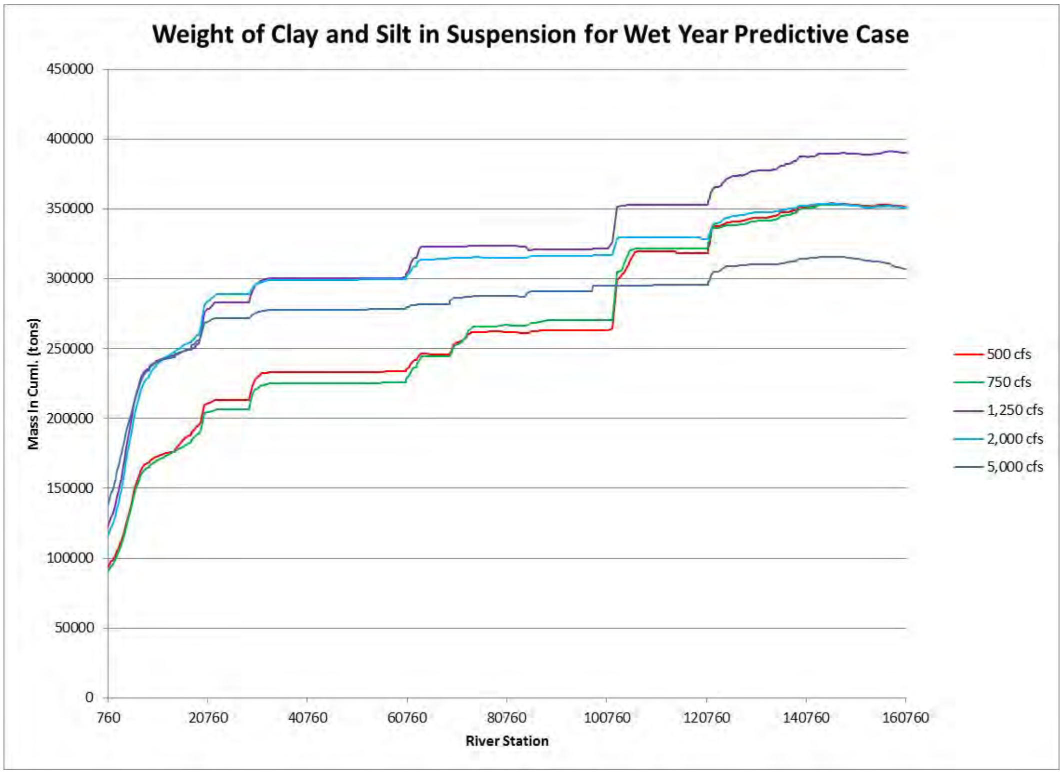

Figure B-29 Weight in Tons of Clay and Silt in Suspension for the Wet Year Predictive Case

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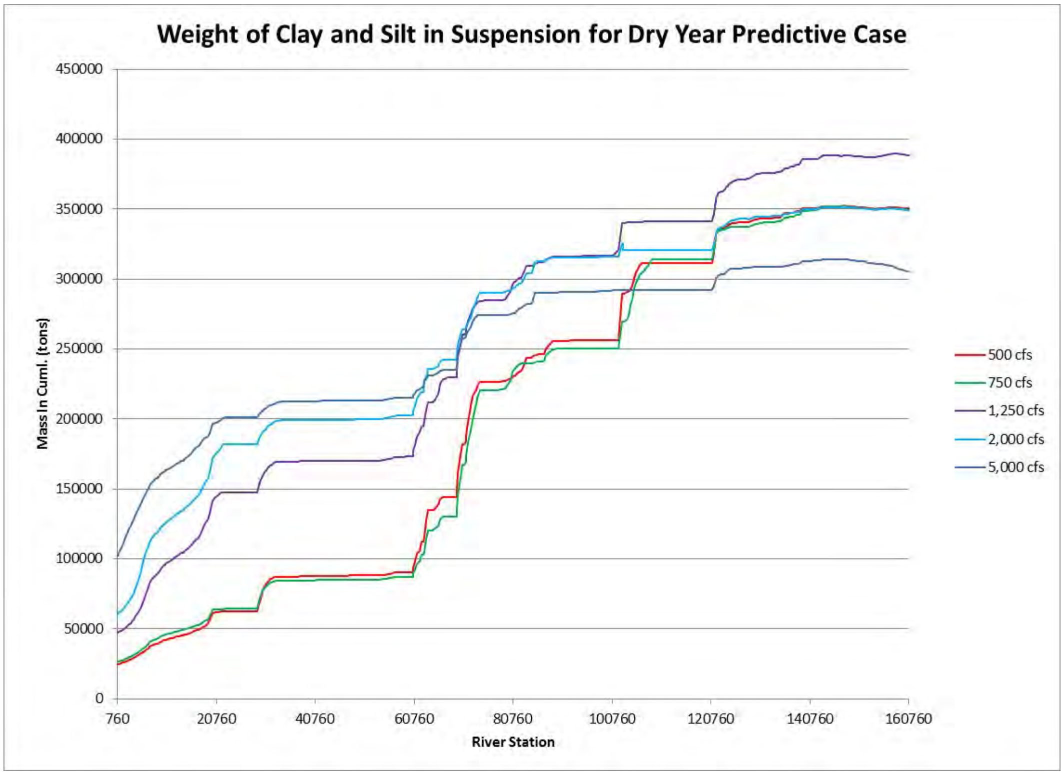

Figure B-30 Weight in Tons of Clay and Silt in Suspension for the Dry Year Predictive Case

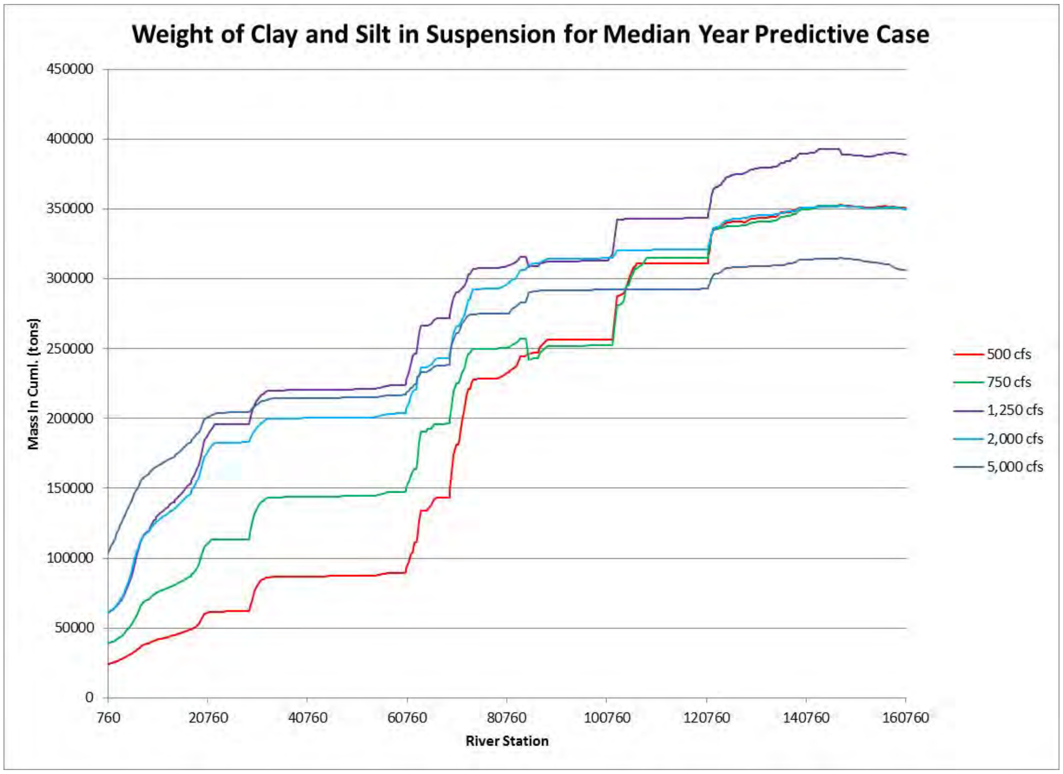

Figure B-31 Weight in Tons of Clay and Silt in Suspension for the Median Year Predictive Case

5.4.6 Flood Potential

The increased flood potential resulting from the proposed project was considered by simulating floods through the system prior to and after implementation of the augmentation project. The simulations incorporate two worst-case assumptions, and are therefore very conservative. The first assumption is that the flood will occur immediately after termination of the pulse flows. The second assumption is that no sediment transport will occur during the flood. The first assumption is statistically conservative. The second assumption is technically unrealistic and is therefore very conservative. Figures B.D.46 to B.D.60 show the effect of the new bed geometry, i.e., incorporating the changes due to aggradation and degradation resulting from sediment augmentation, on the water surface elevation (WSEL) for the sections with levees of the LSAR (i.e., downstream of River Station 120810). It also shows the locations and magnitude of negative freeboard in the sections with levees.

The cross section geometry used is the resulting geometry just after sediment augmentation, i.e., immediately after termination of the pulse flows. This is a conservative scenario as it is deemed unlikely that a major flood will occur concurrently with sediment augmentation activities. The information in these figures was created by running the design flow through the LSAR with existing geometry to establish a baseline and with the altered geometry immediately after sediment augmentation. The design flow used for the flood potential simulations is shown below in Table B-6:

Table B-6 Design Flow used for Flood Potential Simulations

River Station	Discharge (cfs)
162302.5	30000
161331.7	31000
160675.5	32000
156544.8	33400
152402.5	33500
150463.6	34500
144546.3	35000
142790.3	35500
136191.2	36000
127783.7	36500
121986.6	37000
106494.2	38000

In both cases, i.e., for the base case and the predictive case, it is assumed that the river has rigid boundaries (bed and banks), as is normally done in flood studies. Flood simulations were completed for conditions after each of the pulse flows that were considered (i.e., pulse flows of 500, 750, 1,250, 2,000, and 5,000 cfs).

The maximum WSEL increase in the levee reach is between 4.0 and 6.0 feet at a few locations including downstream of Weir Canyon Rd. (station 120300), near the bicycle bridge and road bridge at the Imperial Highway (station 105000), near the Five Coves rubber dam (station 86000), between Interstate 5 and the Garden Grove Freeway (station 61000), between the Warner Ave. bridge and the Slater Ave. bridge (station 33000), and at a slope change downstream of the Interstate 405 bridge (station 23000). WSEL increases are generally more in the downstream reach and less in the upstream reach as pulse flows become larger. Locations where it is estimated that water could potentially flow out of the channel banks are:

- Station 116498 between Weir Canyon Rd. and the Imperial Hwy.
- Station 106987 Upstream of a bicycle bridge
- Station 85999 At a flat slope downstream of the Glassell St. Bridge
- Station 61000 Between Interstate 5 and the Garden Grove Freeway

In general, the pulse flow of 500 cfs may increase flooding risk only in the upstream reach (stations 116498 and 106987). Pulse flows of 750 and 1,250 cfs may increase the greatest flooding risk throughout the four locations where flooding is seen. Pulse flows of 2,000 cfs have a decreased risk of flooding in all locations, and pulse flows of 5,000 cfs do not create a flooding risk.

As described above, the flood risk modeling is conservative and likely over-estimating flood risks due to several factors including:

- All 500,000 yd^3 of sediment are re-entrained in a short amount of time (less than one season)
- The extreme event would occur immediately after sediment re-entrainment before normal flows would redistribute deposited sediment throughout the reach
- The extreme event would not redistribute deposited sediment during the event

The simulations are designed to provide information regarding where to monitor for the development of conditions that could increase flood risks and decision makers to take corrective actions. That said, the locations mentioned above with an increased risk of flooding after sediment deposition will be monitored more closely during the demonstration project for increased deposition and the potential for water surface elevation increases.

6.0 CONCLUSION

This report appendix is a revision to the appendix submitted by Golder in February 2011 (Golder 2011). This revision was required due to channel improvements made in the upstream reach of the LSAR. A new HEC-RAS geometry file was created to reflect the channel improvements and provided to Golder in April 2014. Generally, the revision did not affect the sediment transport throughout the LSAR. As previously discussed, the model was not calibrated to historic data in the traditional sense. However, the model does reflect the quasi-equilibrium condition of the river as observed during field visits. The model can be used as a means to help guide monitoring location decisions. After conducting monitoring during the demonstration project, data collected can be used to verify and update the model where required. As discussed in the Introduction, there are four primary and seven secondary questions to be addressed by the sediment transport model results.

1. **What is the anticipated spatial and temporal distribution of deposited sand-sized replenishment materials in the LSAR?**

   The simulated spatial distribution of deposited sand-sized sediment changes with time. The currently simulated spatial distribution of deposited sand immediately after sediment augmentation differs from the distribution at the end of one year.

   For all simulated flow scenarios, immediately following the augmentation period, sand-sized particles are simulated to deposit in several reaches along the LSAR. This includes a large amount of deposited sand in the recharge reach. However, during the course of a year with the river subject to average flows the simulation indicates that sand initially deposited in the recharge reach will likely move to the far downstream reach, i.e., the tidal zone of the LSAR. This is the case even though the total number of days where there is flows capable of carrying sediment farther downstream is small.

   It is pointed out that these results may not reflect actual long-term conditions. The reason or this is that only one year of flows was simulated. Golder is of the opinion that the Santa Ana River will reach a new equilibrium condition with continued sediment augmentation in the long term and that it might lead to a complete change in the composition of the sand-sized material in the LSAR.

2. **Could the proposed project replenish beach sand?**

   Sand sized particles are currently predicted to ultimately deposit in the far downstream reaches of the LSAR. The preliminary model indicates that the sand-sized particles might not reach the beach. However, it is noted that the current model only reflects one year of flow and not long-term conditions.

   It is Golder’s opinion that long-term sediment augmentation will likely result in a new equilibrium river state. Over the long-term such a new equilibrium state will likely lead to more sand moving down the river towards the beach as sediment augmentation operations continue. In such a case, it is possible that the augmentation project could replenish beach sand.

3. **How does the project affect riparian habitat in the LSAR?**

   The current preliminary simulations indicate that clay and silt move through the LSAR to the ocean. Sand-sized particles deposit throughout the river reach, with current simulations indicating that much of it ends up in the upstream reach and the tidal zone at the end of the simulation period. Gravel is more evenly distributed throughout the system, while cobbles are mainly deposited in the upper reaches of the river.

Generally, silt- and clay-sized particles are often undesirable for riparian habitat. The current simulations indicate that clay-sized particles will be transported to the ocean and will not deposit over a wide area. More desirable particle sizes like sand and gravel may be more prevalent under augmentation conditions. More sand may be present in the recharge reach and in the tidal zone and the amounts of gravel throughout the river reach will likely increase.

4. **Could the proposed sediment augmentation project change the gradation of the LSAR bed material in the groundwater recharge reach?**

   The model results show that between 2 and 3 feet of additional sand will likely deposit within the recharge reach immediately after sediment re-entrainment. This sand could change the overall particle size distribution of the bed material in the recharge reach. The modeling indicates that some re-entrainment flows may provide better performance than others. One aim might be to minimize the amount of sediment deposited in the flat river reach downstream of station 22050 (towards the ocean) and maximize the amount of sediment deposited in the recharge reach (between stations 120325 and 60129). Another objective might be to minimize flood impacts. The final selection of a desirable range of re-entrainment flows will likely also have to consider the desire of OCWD to minimize the amount of sediment deposition in the settling ponds adjacent to the river. Consideration of the results presented in this Appendix and its Annexure can be used to select preferred re-entrainment flow magnitudes.

   Golder is of the opinion that sediment augmentation can lead to a more favorable particle size distribution that can result in increased permeability if an appropriate sediment augmentation strategy is followed. Optimization of such a strategy is the subject of the demonstration program.

The replies to the secondary questions are as follows:

1. **Do the silt- and clay-sized sediments move through the LSAR?**

   Fines (clay and silt sized particles) experience very little deposition as they move through the LSAR. Under augmentation conditions, it is predicted that about one quarter to one third of the fines introduced to the LSAR will be released to the Pacific Ocean in the wet year model and between 10 and 15% in the dry and median year models. The fines that do deposit generally gradually deposit throughout the entire modeled reach. The wet year models suggest that about 100,000 to 150,000 tons of fine-grained sediment will be released to the ocean. The dry and median year models predict releases somewhere around 25,000 to 100,000 tons over the model year.

2. **Could the proposed project result in increased flooding potential, particularly downstream of I-405**

   Given the conservative assumptions used in this assessment, the maximum increase in water surface elevation for the design flood in the levied reach is about 4 to 6 feet and occurs at a few locations within this reach. The larger increases in WSEL in the upstream and recharge reaches occur under lower pulse flows and under larger pulse flows for the largest WSEL increases seen in the lower reach. Downstream of I-405, WSEL increases after sediment re-entrainment are up to 6 feet under high pulse flow scenarios but the increase in WSEL does not lead to any flooding. Other locations between Weir Canyon Rd. and the Imperial Highway do experience flooding due to WSEL increases after sediment re-entrainment.

3. **Would the project result in increased maintenance requirements at diversion structures?**

   Maintenance requirements considered include bank protection, scour downstream of structures, sedimentation and riverbank / levee overtopping. The potential for increased maintenance depends on the magnitudes of the flows that will be used to re-entrain the augmented sediment. If the selected flows are much higher than flows normally occurring in the LSAR, it might result in greater maintenance requirements due to increased scour at some structures and possible bank erosion in some river reaches.

   Adding additional sediment to the river might also result in increased maintenance needs. This is particularly true if flows with high sediment concentrations are diverted to the infiltration ponds operated by OCWD. Some of the drop structures might also accumulate more sediment, but it is deemed unlikely that the amounts of deposited sediment will be so much greater as to result in significantly higher maintenance cost at the latter.

   The increased amounts of deposited sediment in the most downstream river reach, i.e., the lower geomorphic reach, may lead to increased maintenance cost if it is deemed necessary to remove such deposits. Currently, the prediction is that the amount of freeboard in this river reach is more than enough to prevent flooding during design flows except at the few locations discussed above. This implies that it may not be necessary to remove the increased amounts of deposited sediment from this reach except where the risk of flooding is greater. Alternatively, levee protection or other flood protection measures can be provided where there is flooding potential.

4. **Could the proposed project lessen the effects of channel degradation at Featherly Park be reversed?**

   The model shows continued degradation occurring in Featherly Park in unlined portions of the LSAR.

5. **Could the project result in increased scour potential at the levees in the LSAR?**

   At this stage, the potential for increased scour at the levees has not been calculated. The scour limit of 0.25 feet set in the simulation model prevents realistic assessment of levee scour potential. However, it is Golder’s opinion, at this stage, that it is unlikely that increased scour would be experienced, except if very high re-entrainment flows are selected. If the range of the selected re-entrainment flows resemble flow conditions normally experienced in the LSAR, it is unlikely that increased scour would occur. Rather, the increased amounts of sediment introduced into the LSAR will likely decrease the potential for levee scour.

6. **What are the measurable effects at critical structures within the LSAR?**

   There are a few areas where measurable results can provide feedback as to the success of the demonstration project. These areas include:

   A. Cannot have excessive deposition which leads to increased flood risks especially downstream of I-405

   B. No more than 8 feet of deposition can be allowed at Rock Canyon Weir

   C. The deposition of sand can be measured at the Pacific Coast Highway bridge

   D. Degradation at Featherly Park can be observed

7. **Could the proposed project result in increased river degradation at the SARI line?**

   The current constraints used in the simulation model might not fully account for maximum possible scour. At this stage, it is not deemed reliable to make conclusions from the simulation model to predict scour at the SARI line. However, based on professional experience, it is Golder’s opinion that such scour will not be exacerbated if the selected re-entrainment flows remain within the ranges normally experienced in the river. If this requirement can be satisfied, it is likely that the scour will actually decrease. This is because the sediment load in the river will increase when the sediment loads are augmented. Such an increase in the sediment load is likely to lead to aggradation of the riverbed rather than degradation.

7.0 CLOSING

Golder appreciates the opportunity to be of service on this project.

GOLDER ASSOCIATES INC.

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Principal

CPB/GWA/rjg

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8.0 REFERENCES

Annandale, G.W. 2007. Scour Technology: Mechanics and Engineering Practice. New York: McGraw-Hill.

Engelund, Frank, and Eggert Hansen. 1967. A Monograph on Sediment Transport in Alluvial Streams. Monogr, Denmark Tech Univ., Hydraul Lab, 62 pp, 30 figures, 2 tables, 31 references.

Golder Associates Inc. (Golder) 2011. Appendix B – HEC-RAS Sediment Transport Modeling Santa Ana River. Project 093-81947. Submitted February 11.

Hjulstrom, Filip. 1935. Studies of the Morphological Activity of Rivers as Illustrated by the River Fyris. Bull. Geol. Inst. University of Upsala, Vol. XXV, 221-527.

Krone, R.B. 1962. Flume Studies of the Transport of Sediment in Estuarial Shoaling Processes. Final report prepared for Army Engineer District, San Francisco, June. 110 pp, 35 figures, 3 tables, 23 references, 2 appendices. DA-04-203 CIVENG-59-2.

Parthanadias, E. 1965. “Erosion and Deposition of Cohesive Soils,” *Journal of the Hydraulics Division, Proceedings of the ASCE*, vol. 91, no. HY I, January, pp. 105-1 39.

Tetra Tech and HDR. January 2010. The Santa Ana Regional Interceptor Pipeline Relocation Project: Scour Study of Santa Ana River below Prado Dam – Final Report.

U.S. Army Corps of Engineers (USACE). 1988. Santa Ana River Design Memorandum No. 1: Phase II GDM on the Santa Ana River Mainstem Including Santiago Creek, Volume 3: Lower Santa Ana River (Prado Dam to Pacific Ocean)

U.S. Army Corps of Engineers (USACE). 2010. *HEC-RAS River Analysis System User’s Manual*. Version 4.1. January.

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ATTACHMENT A
GEOMORPHIC RECONNAISSANCE

1.0 SITE VISIT ASSESSMENT

A site visit was conducted on February 2010 at the Prado Dam Basin and the Santa Ana River downstream of Prado Dam to the Pacific Ocean. The objective was to obtain information pertaining to the present hydraulic, sediment, and geomorphic conditions of the system. The observations and collected data were also used to develop sediment transport simulation models.

1.1 Prado Basin

The Prado Dam Basin is characterized by significant sedimentation and encroachment of vegetation (Figure A-1). Some vegetation has been cleared, principally for agricultural use. The bed material of tributaries flowing into the reservoir consists mostly of sand-sized material. Additionally, large quantities of debris including garbage, uprooted trees, and branches were observed just upstream of the River Road Bridge (Figure A-2).

Figure A-1: Prado Basin Vegetation Encroachment

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Figure A-2: Dense Vegetation and Debris near the River Road Bridge Looking Upstream

1.2 Downstream of Prado Dam

The objective of visiting the river downstream of Prado Dam was to obtain baseline information for the hydraulics, sediments, and geomorphic conditions. During the site visit, three sub-reaches were identified:

- The upstream reach extending from the Prado Dam to the recharge area;
- The recharge area; and
- The lower reach between the end of the recharge area and the Ocean.

Each of these reaches is described below.

1.2.1 Upstream reach.

The upstream reach has several sections with distinctive characteristics. The upstream section, from the dam outlet structure to the golf course property line, has a relatively flat slope compared to the remainder of the upstream reach. The floodplain is covered with riparian vegetation; the banks are moderately incised and vegetated islands dot the main channel. No significant bed forms were identified in this reach. The bed material could not be inspected due to flow releases from Prado Dam at the time of the site visit. However, bed material analyses have been performed by Engineering and Hydrosystems and Golder Associates in 2007 and 2009.

The river bed slope increases in the next segment extending along the entire length of the golf course. This section is characterized by significant river bed incision, and during the site visit the water was confined inside the main channel banks. The river valley is crossed by a high railroad bridge and two access bridges to the golf course. River bank stabilization was under construction during the field trip. The construction activities extended both upstream and downstream of the access bridge to the Golf Course along the Santa Ana River. Hydraulic controls identified along this reach include man-made and natural bed controls. Figure A-3 illustrates the general condition and shape of the river in this area and the general bank and hydraulic characteristics of the reach.

Figure A-3: Santa Ana River Looking Upstream from Entrance Road to Green River Golf Course

The river section between the golf course and the upstream end of the recharge area contains a large floodplain, with several flow splits forming natural islands. Riparian vegetation is mostly concentrated near the river bank. Overbank sediment deposits were frequently observed, which indicates overtopping of the river banks with water flowing onto the floodplain during flood events. This reach ends at a drop structure a short distance downstream of Weir Canyon Road. The river bed upstream of the drop structure is silted-in up to the top of the drop structure.

No flow diversions were detected throughout this reach. However several storm drainages into the river have been identified on both sides of the river. An important drainage is located on the left bank of the Santa Ana River commencing just downstream of the Prado Dam outlet structures. This tributary may produce significant inflow of both water and sediment during extreme events

1.2.2 Recharge Area Reach

The recharge area reach extends from the drop structure immediately downstream of the Weir Canyon Road Bridge to the drop structure immediately downstream of California 22 Highway. Several man made hydraulic structures were identified throughout the recharge area that confines and controls the water and sediment flow. The structures include:

- Bank stabilization with concrete and / or riprap;
- Drop structures constructed with concrete
- Two inflatable rubber dam structures;
- Small grade control structures;
- Storm drainage;
- Diversion dams;
- Infiltration ponds adjacent to the main channel, and
- Temporary, small detention ponds between T&L levees to enhance infiltration

During the field trip it was observed that all flows from Prado Dam and urban runoff were either diverted to infiltration ponds adjacent to the river or temporarily dammed in the Santa Ana River for infiltration into the river bed. The principal diversion structures are located downstream of Imperial Highway Bridge and downstream of Glassell St. Bridge (Figure A-4). At the diversion structure downstream of Glassell St. the flow was completely diverted. It appeared that part of the diverted flow was returned to the Santa Ana River to be infiltrated further downstream.

The rubber dam structures downstream of the Imperial Highway and Glassell St. were constructed in 1993 and currently have only minor deposition of sediment on their upstream sides (Figure A-5). The inflatable dams may be partially lowered during flows greater than 500 cfs to enable downstream transport of sediment and to reduce the amount of solids flowing into the off-channel infiltration ponds. At flows greater than 2,000 cfs, the inflatable dams are fully deflated. Above 2,000 cfs additional intertie tubes through the SAR levees divert small amounts of flow.

Downstream of the diversion structures the flow is significantly reduced (Figure A-6). The bed material consisted predominantly of sand with small amounts of cobbles. The bed material contains insignificant amounts of silt and clay (Figure A-7).

Figure A-4: Rubber Dam Structure Downstream of Glassell St.

Figure A-5: Sediment Deposition Downstream of Glassell St. and Upstream of the Rubber Dam Structure

Figure A-6: Recharge Area Downstream of Orangewood Ave. Looking Downstream Showing Remaining Flow in River Detained by T&L Levees

Figure A-7: Upstream of Chapman Ave. Bridge Looking Downstream Showing Mostly Sand Bed Material

1.2.3 Lower Reach

The lower reach (i.e. from the downstream end of the recharge reach to the ocean) has segments with distinctive geomorphic and hydraulic characteristics. The river reach between the Highway 22 drop structure and the Santa Ana River Trail pedestrian bridge is unlined. Floods are controlled by levees and several grade control structures are present along the reach. The Riverview Golf Course is located in part of this river reach, within the main channel and floodplain. Bed material is mostly sandy with small percentages of gravel (Figures A-8 and A-9). The main channel bed forms predominantly consist of dunes (Figure A-8). Bank erosion was also identified.

Figure A-8: Bed Material Upstream of Memory Ln. Bridge Looking Downstream

Figure A-9: Bed material is mostly sandy, with some gravel

Both the river bed and banks are lined with concrete between the Riverview Golf Course and the Mesa Verde Country Club (Figure A-10). The channel has a trapezoidal shape and contains a low-flow channel. No significant sediment deposition was observed throughout this reach, indicating high sediment transport capacity. However, sediment deposition was observed downstream of I-405, near the Mesa Verde Country Club.

Figure A-10: Lined Channel Section at W. Edinger Ave. Looking Downstream

Downstream of Mesa Verde Country Club the Santa Ana River continues with concrete lined banks and a natural, unlined channel bed. The channel bed consists mostly of sand, with a frequent presence of bars. The change in river bed morphology from dunes to bars is deemed to be associated with the reduction in river bed slope and the influence of tides. As the Santa Ana River flows into the ocean downstream of the West Coast Highway, the channel becomes narrow and the river bed becomes incised due to a large amount of sediment deposition at the beach (Figure A-11).

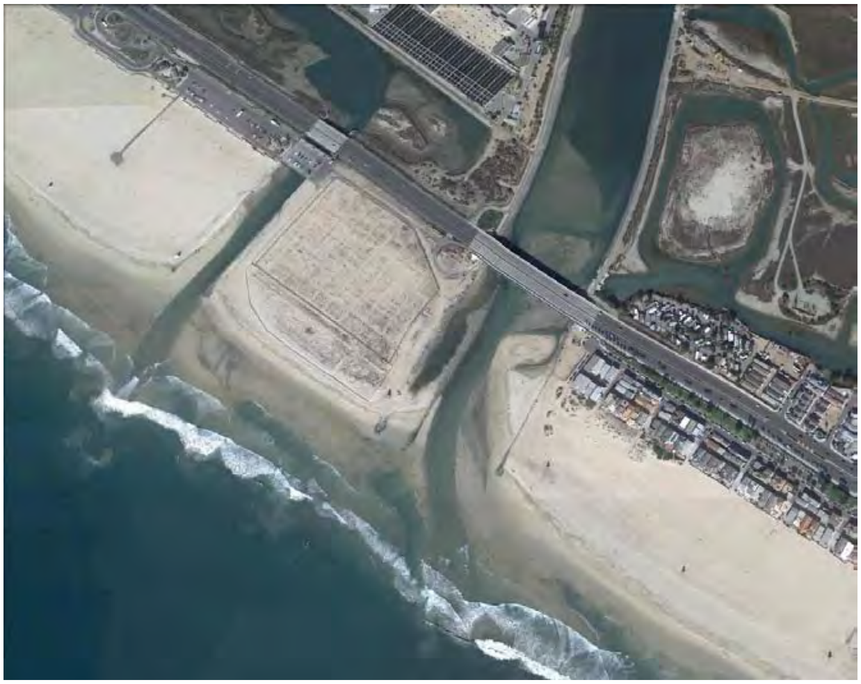
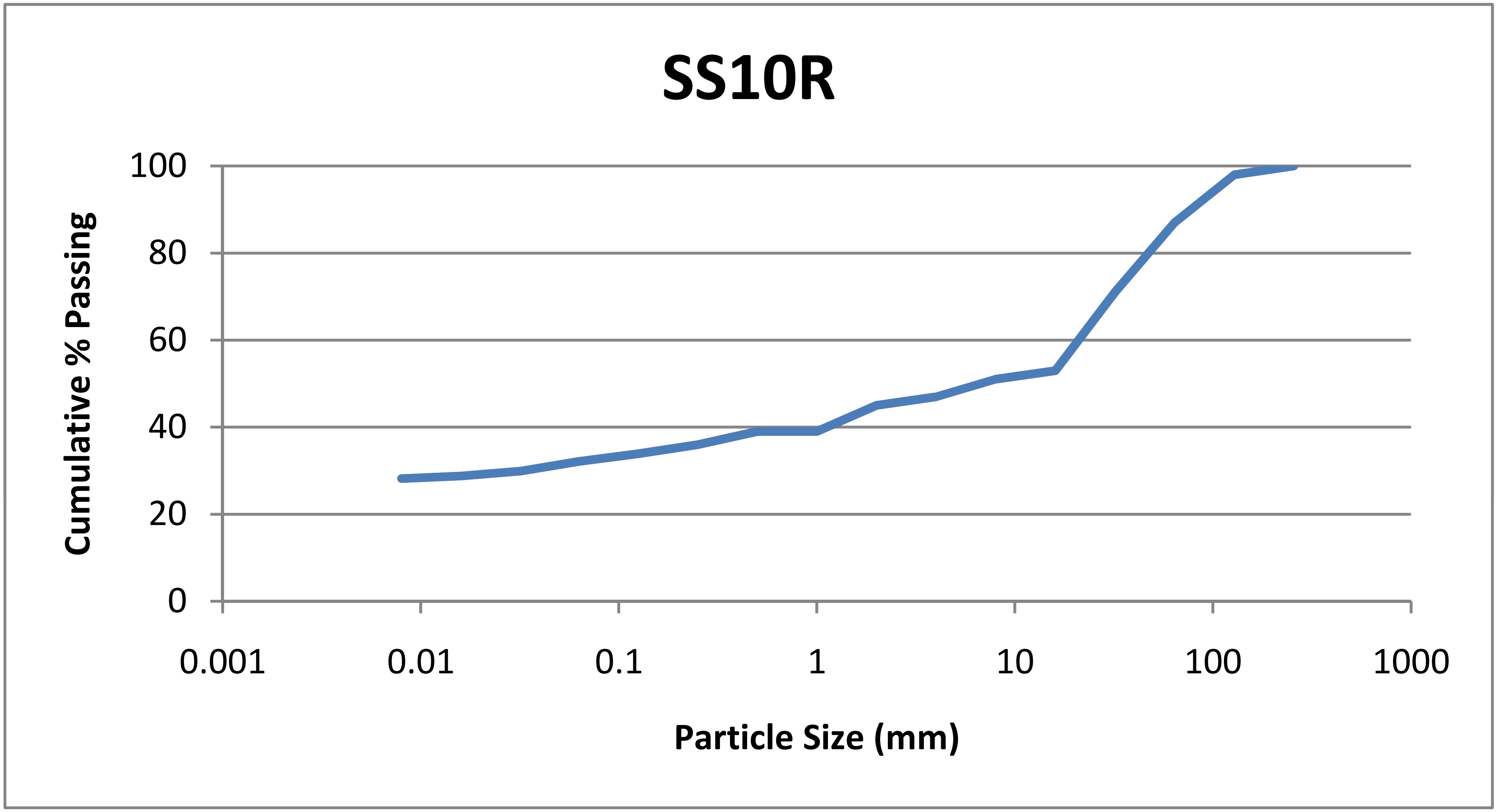


Figure A-11: Aerial View of Santa Ana River at the Pacific Ocean

ATTACHMENT B
INPUT PARAMETER/PROJECT BACKGROUND FIGURES AND TABLES


SS10R
Cumulative % Passing
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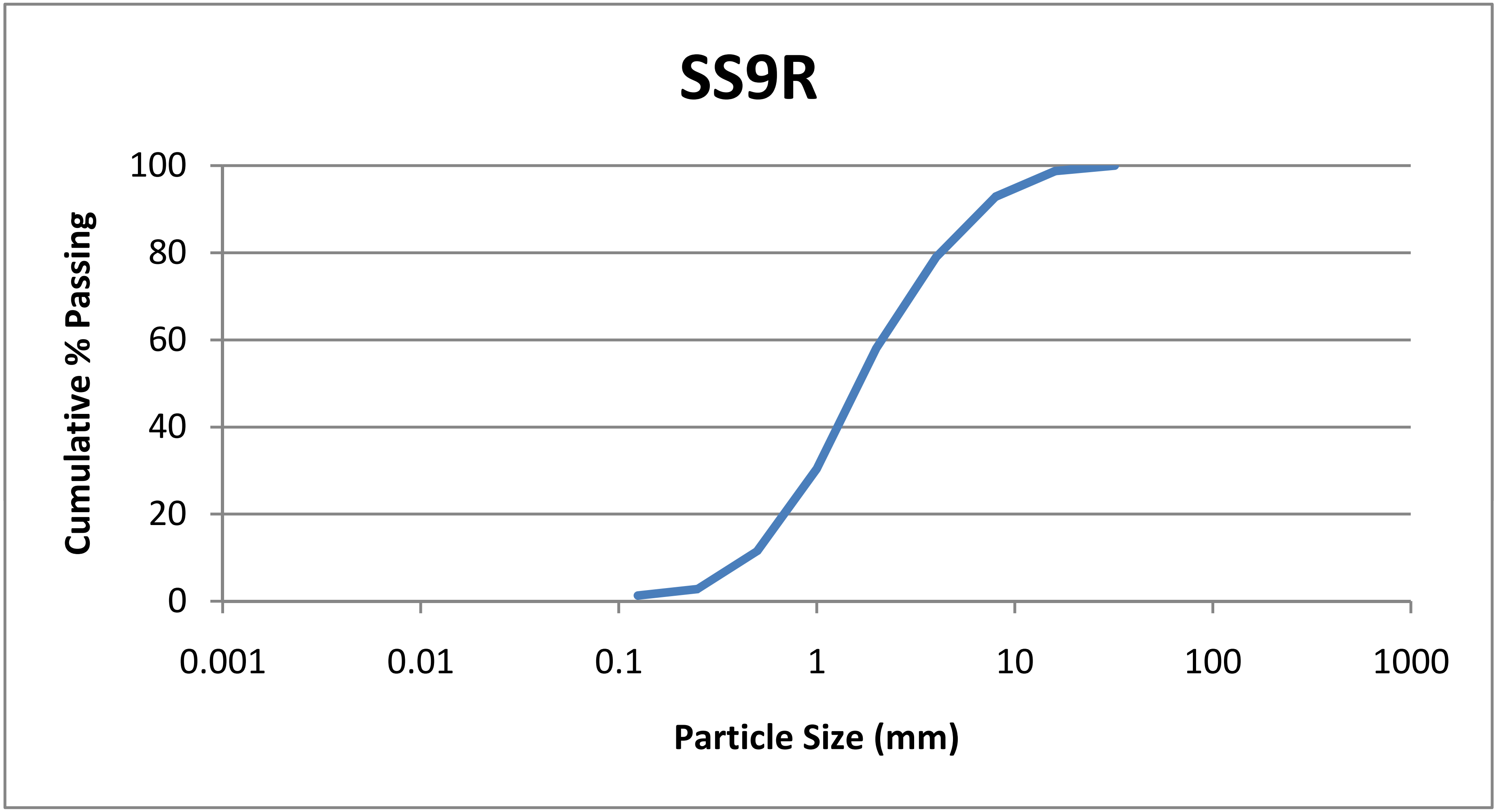
80
60
40
20
0
0.001
0.01
0.1
1
10
100
1000
Particle Size (mm)

Figure B.B.1


SS9R
Cumulative % Passing
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0.01
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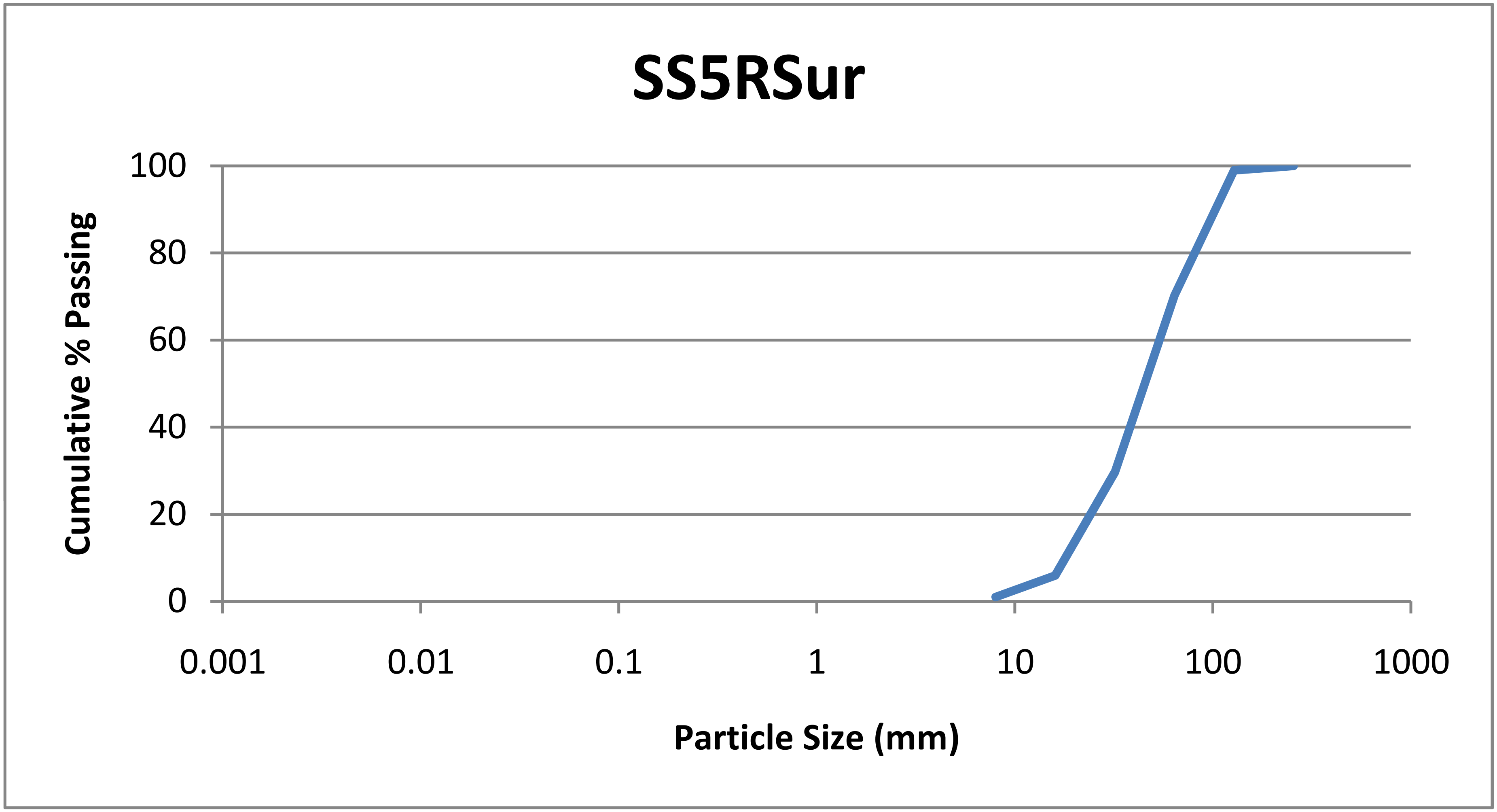
1000
Particle Size (mm)

Figure B.B.2


SS5RSur
Cumulative % Passing
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0
0.001
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1
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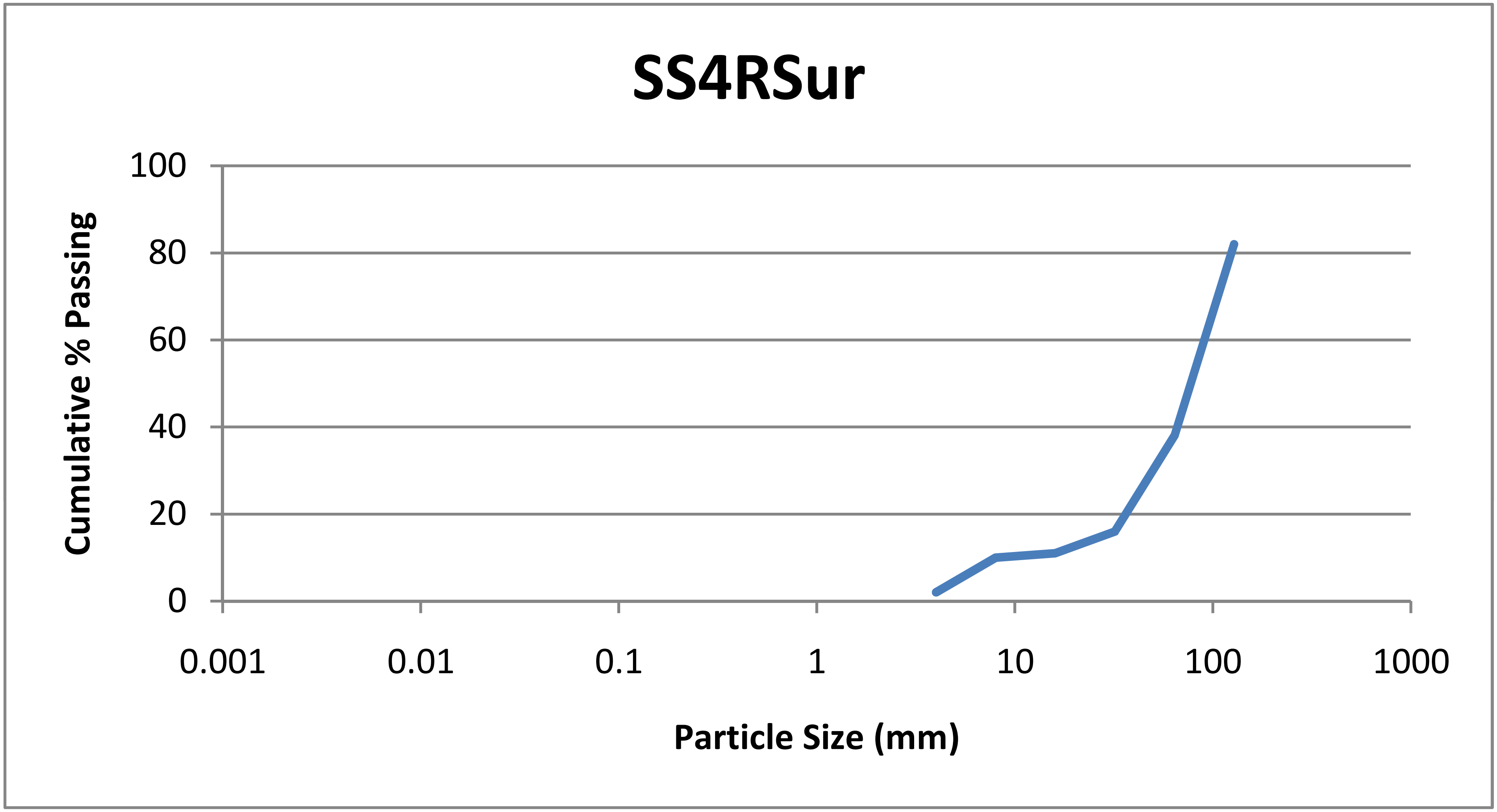
1000
Particle Size (mm)

Figure B.B.3


SS4RSur
Cumulative % Passing
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0.1
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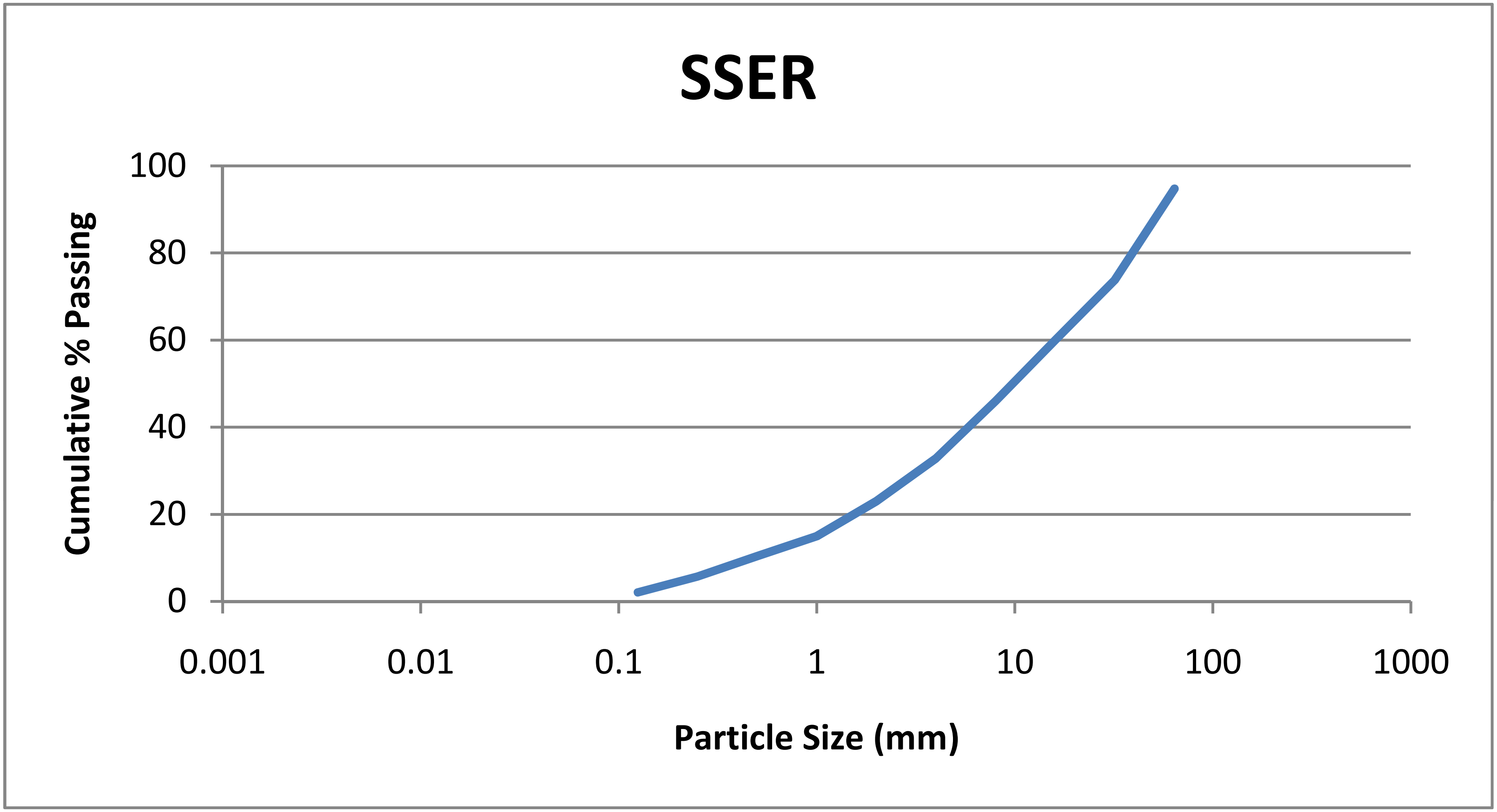
1000
Particle Size (mm)

Figure B.B.4


SSER
Cumulative % Passing
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0.01
0.1
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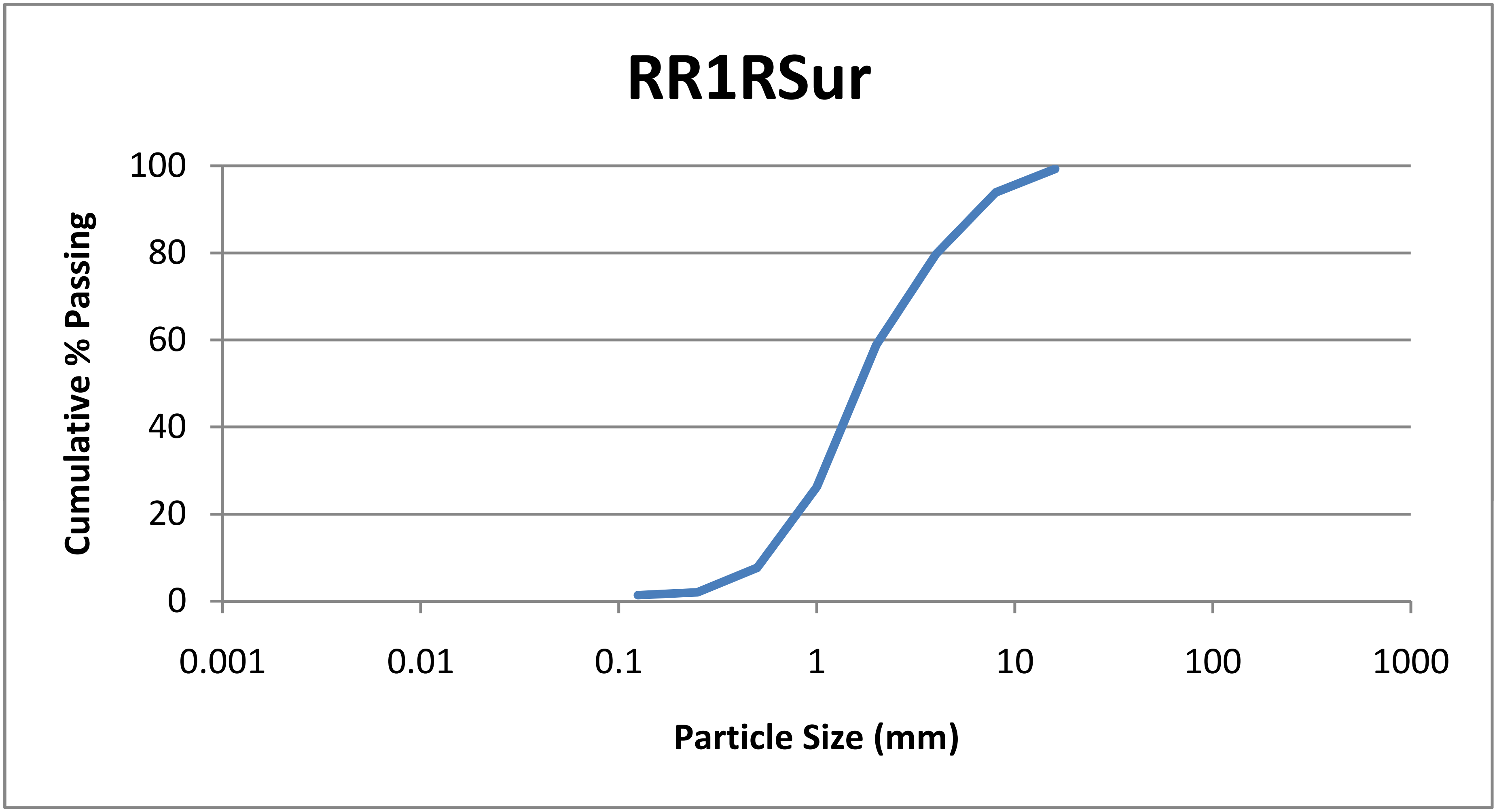
10
100
1000
Particle Size (mm)

Figure B.B.5


RR1RSur
Cumulative % Passing
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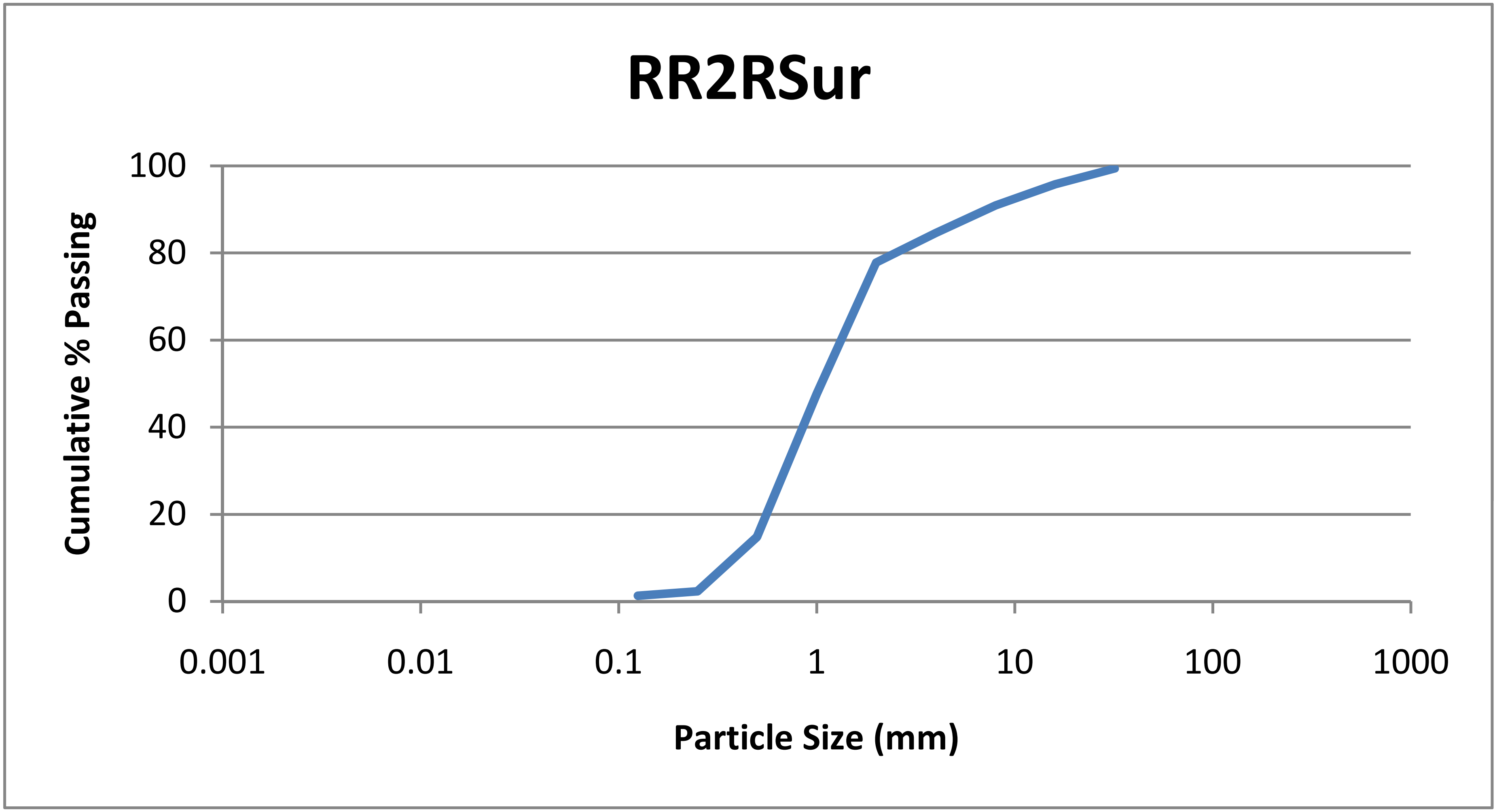
0.01
0.1
1
10
100
1000
Particle Size (mm)

Figure B.B.6


RR2RSur
Cumulative % Passing
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0.1
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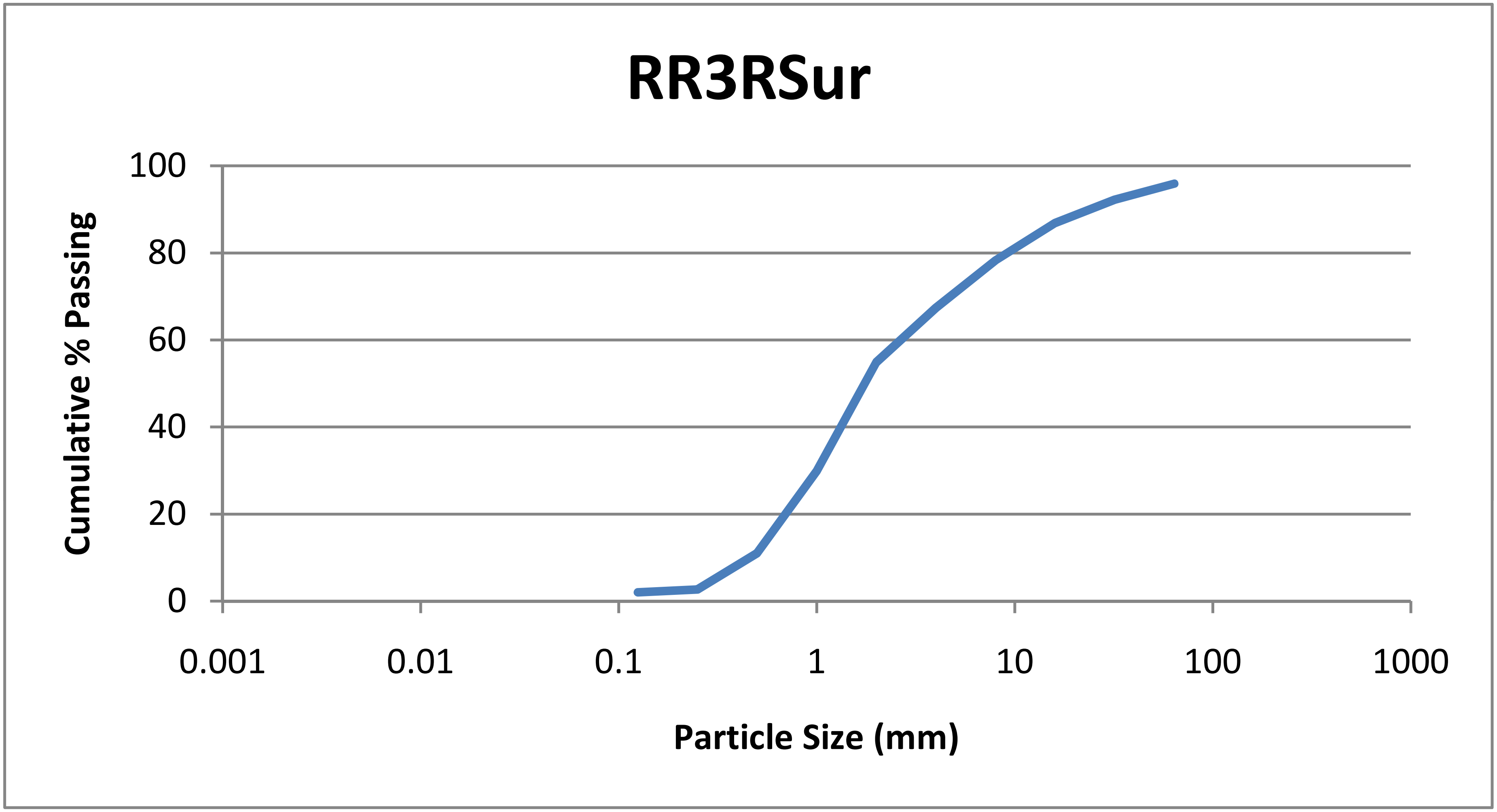
10
100
1000
Particle Size (mm)

Figure B.B.7


RR3RSur
Cumulative % Passing
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60
40
20
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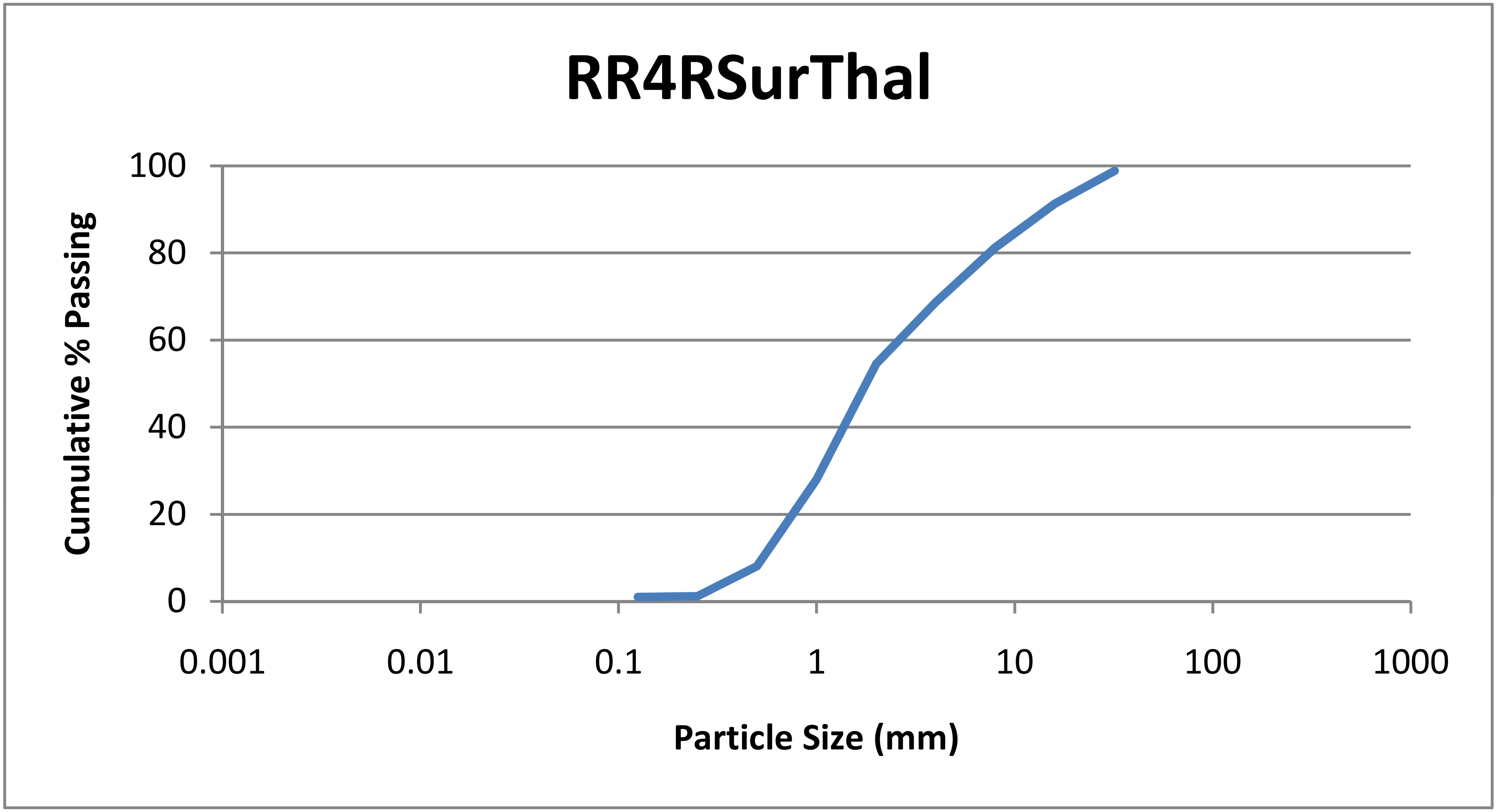
0.001
0.01
0.1
1
10
100
1000
Particle Size (mm)

Figure B.B.8


RR4RSurThal
Cumulative % Passing
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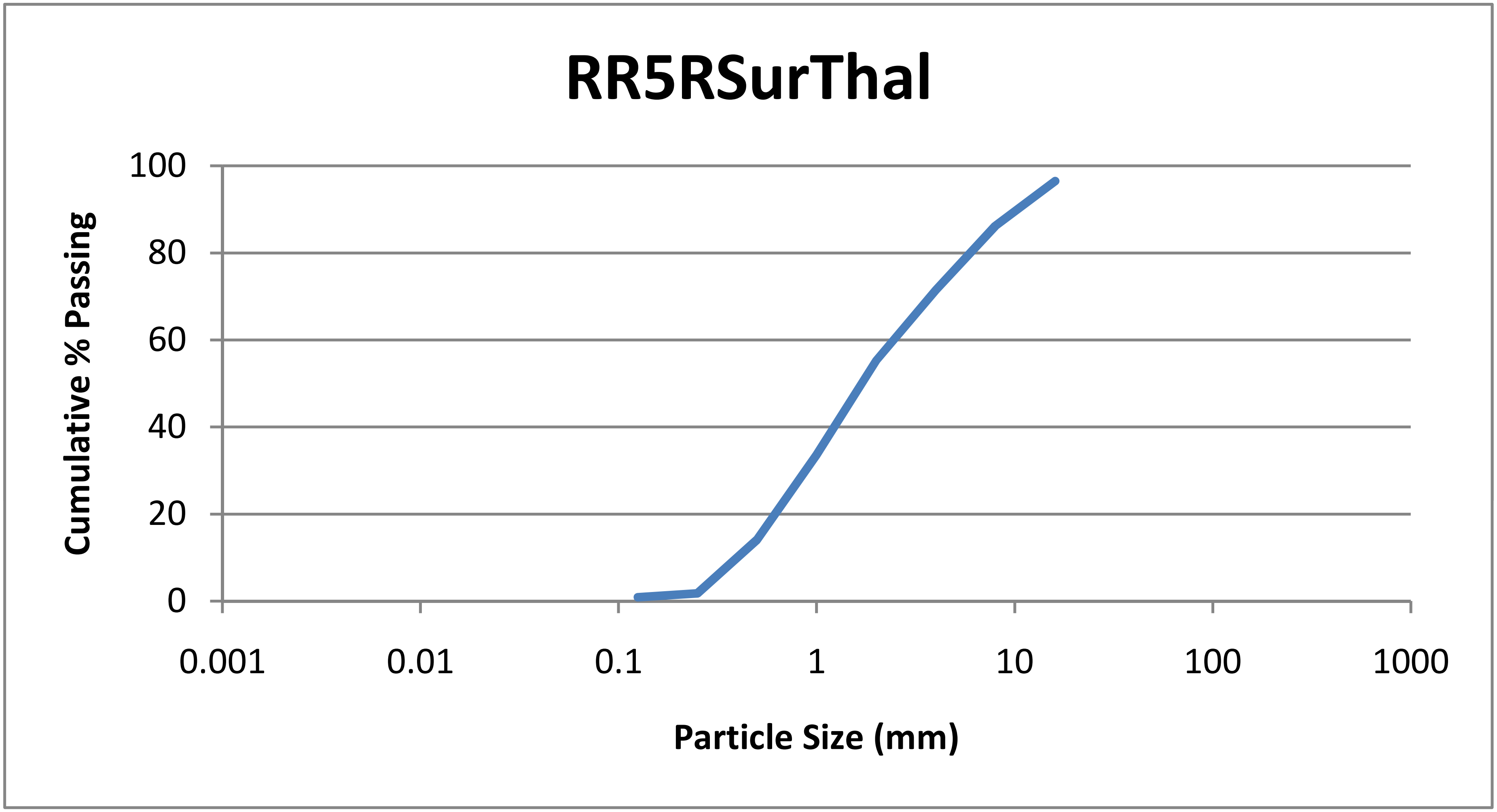
10
100
1000
Particle Size (mm)

Figure B.B.9


RR5RSurThal
Cumulative % Passing
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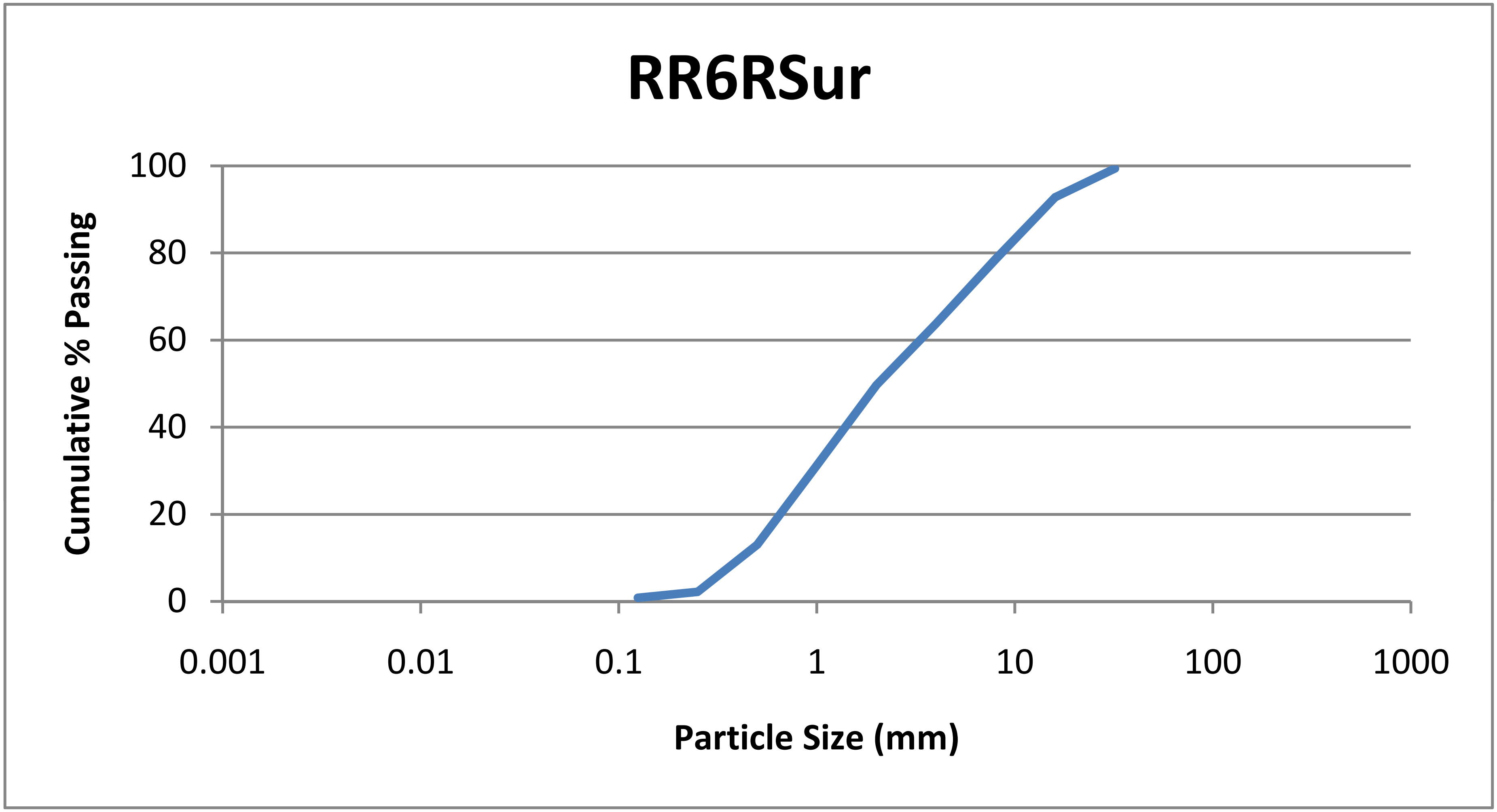
20
0
0.001
0.01
0.1
1
10
100
1000
Particle Size (mm)

Figure B.B.10


RR6RSur
Cumulative % Passing
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0.01
0.1
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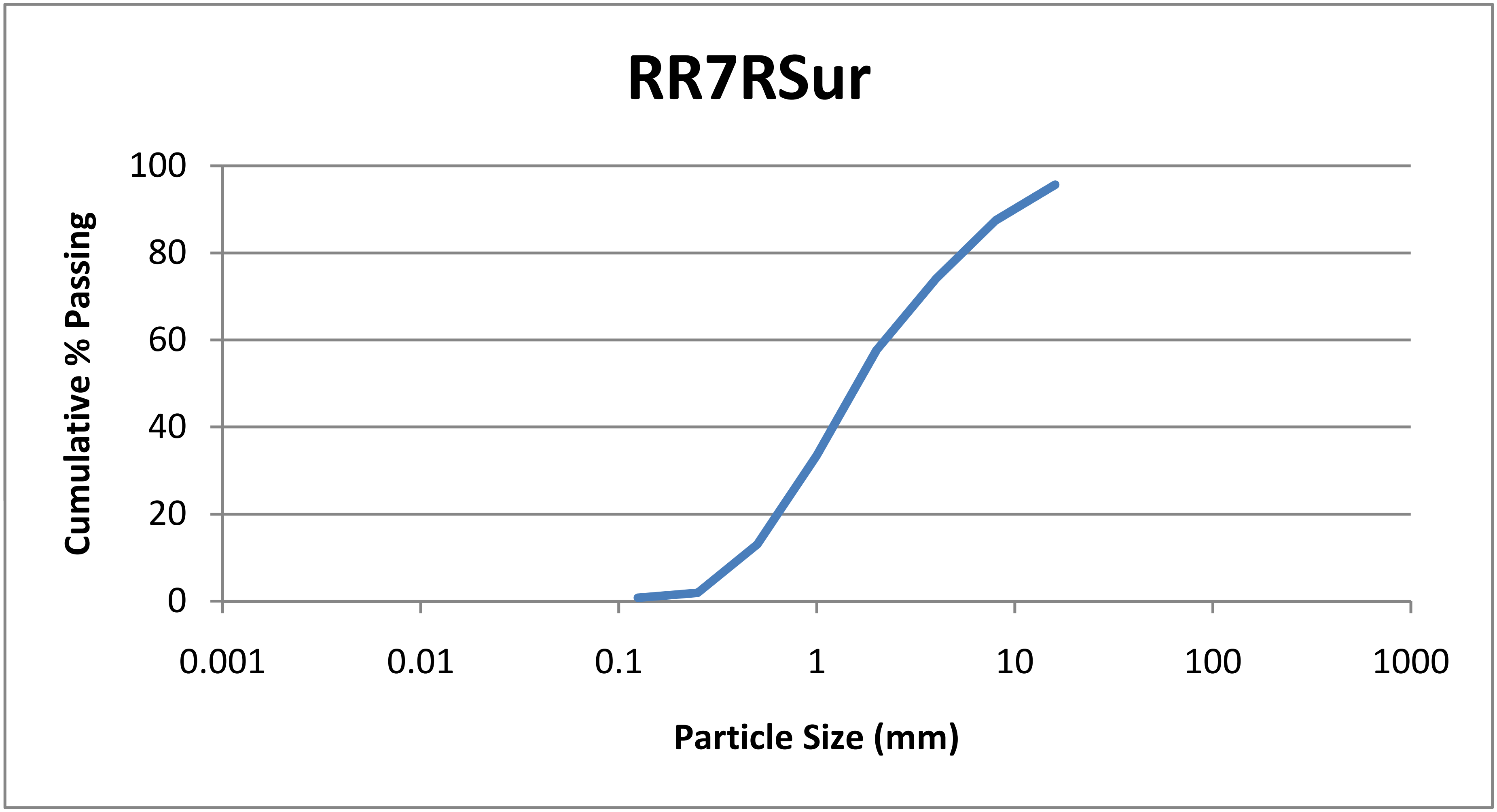
100
1000
Particle Size (mm)

Figure B.B.11


RR7RSur
Cumulative % Passing
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80
60
40
20
0
0.001
0.01
0.1
1
10
100
1000
Particle Size (mm)

Figure B.B.12

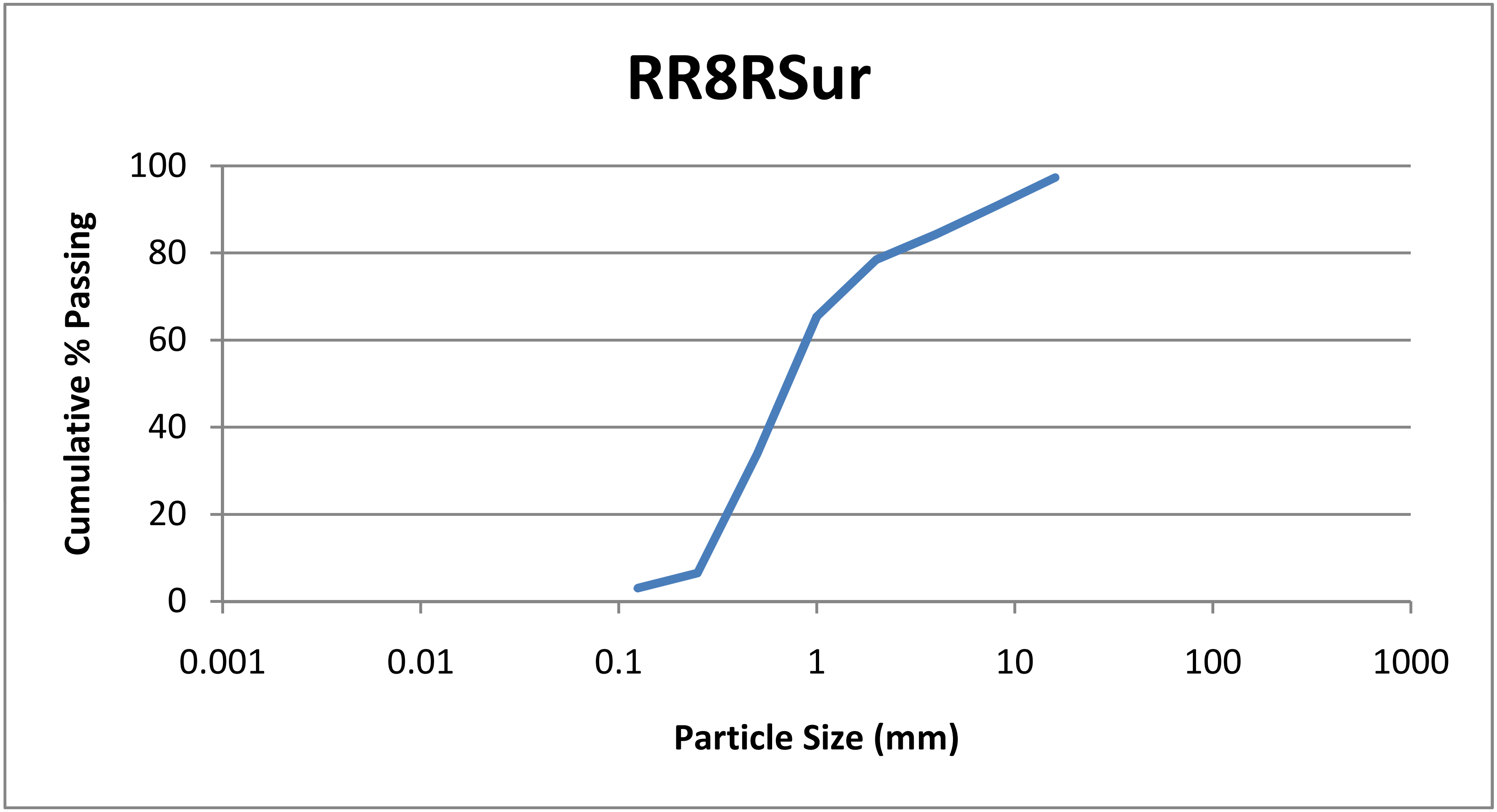
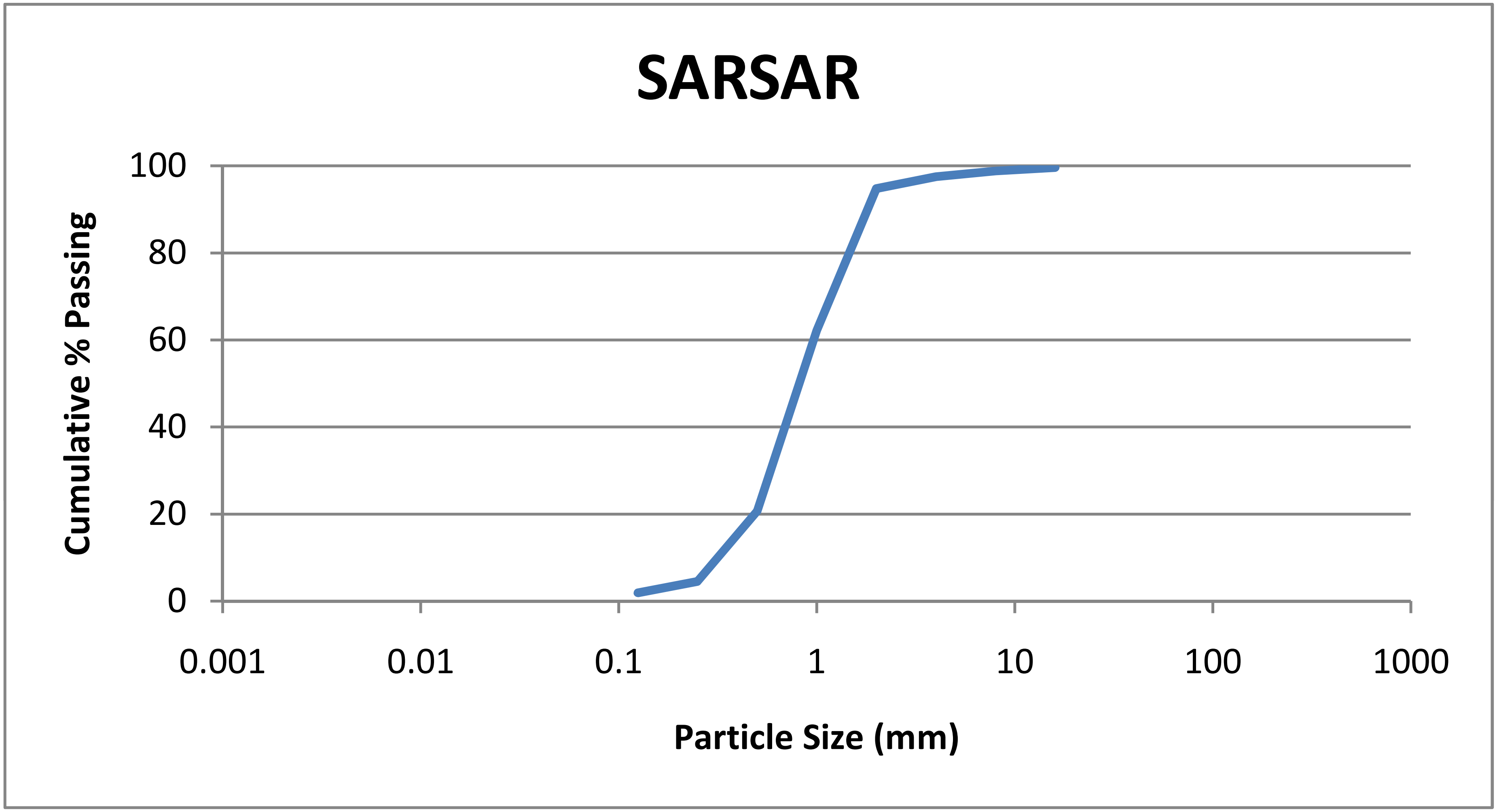

RR8RSur
Cumulative % Passing
100
80
60
40
20
0
0.001
0.01
0.1
1
10
100
1000
Particle Size (mm)

Figure B.B.13


SARSAR
Cumulative % Passing
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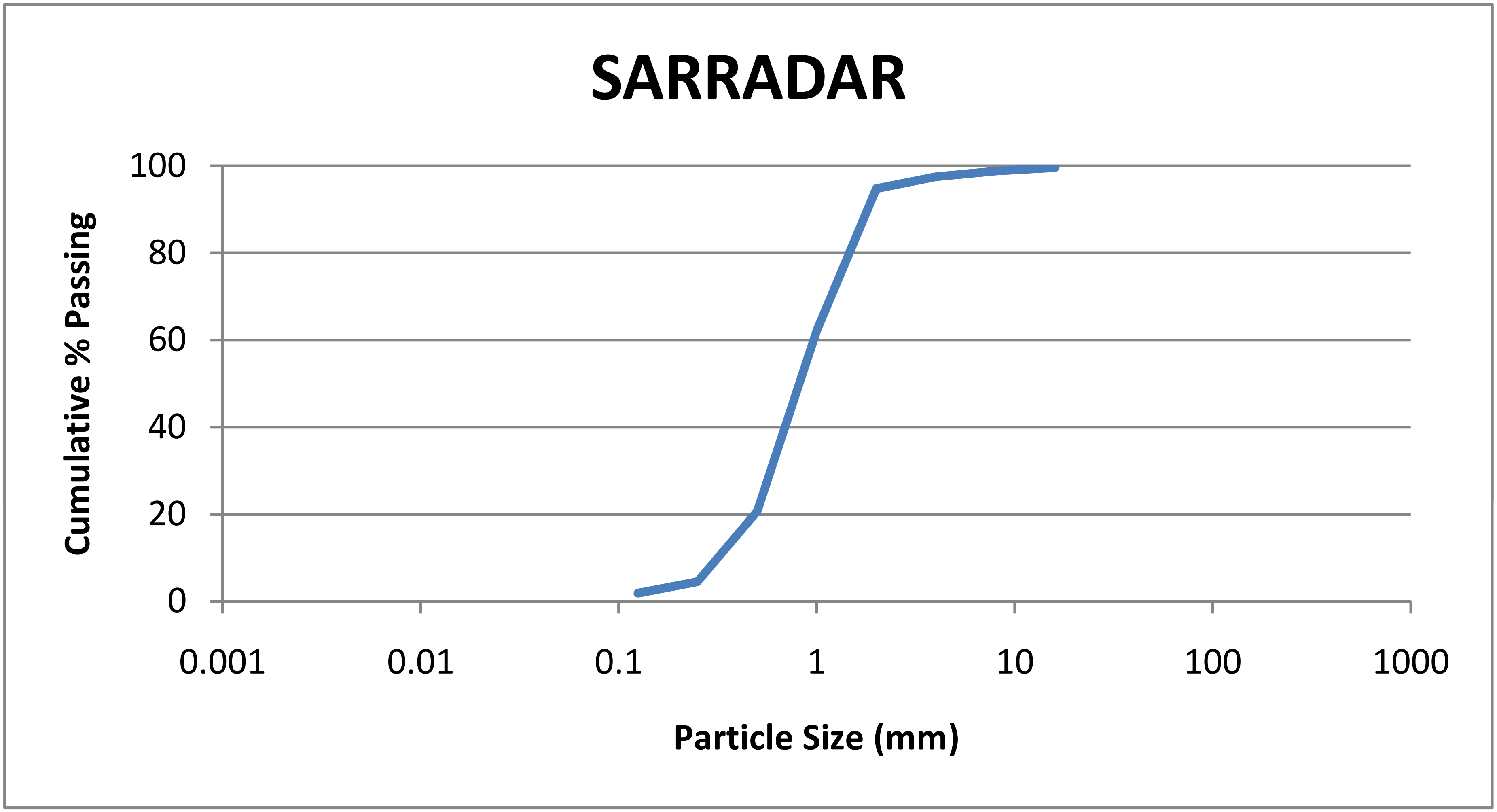
60
40
20
0
0.001
0.01
0.1
1
10
100
1000
Particle Size (mm)

Figure B.B.14


SARRADAR
Cumulative % Passing
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80
60
40
20
0
0.001
0.01
0.1
1
10
100
1000
Particle Size (mm)

Figure B.B.15

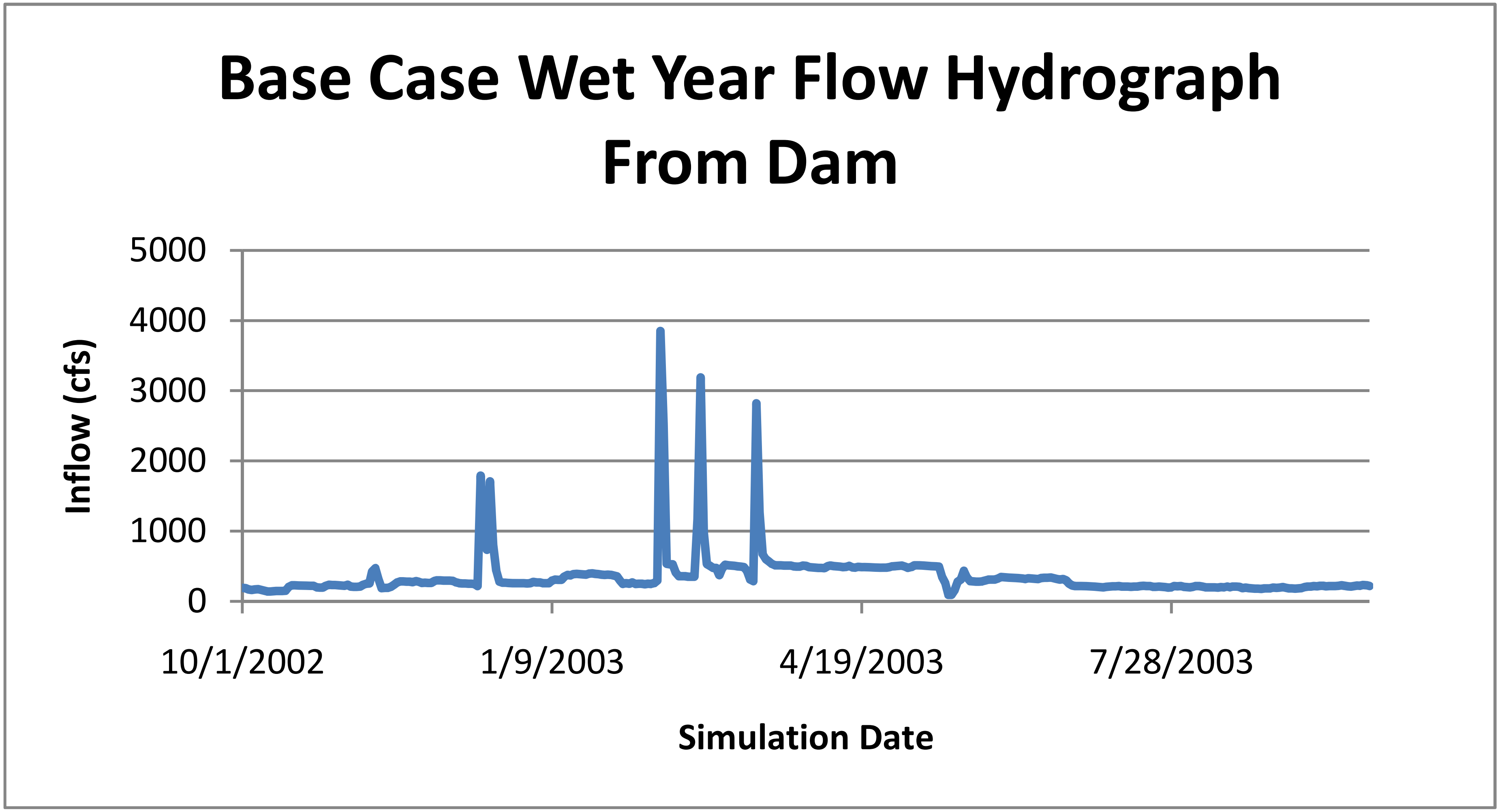

Base Case Wet Year Flow Hydrograph From Dam
Inflow (cfs)
5000
4000
3000
2000
1000
0
10/1/2002
1/9/2003
4/19/2003
7/28/2003
Simulation Date

Figure B.B.16

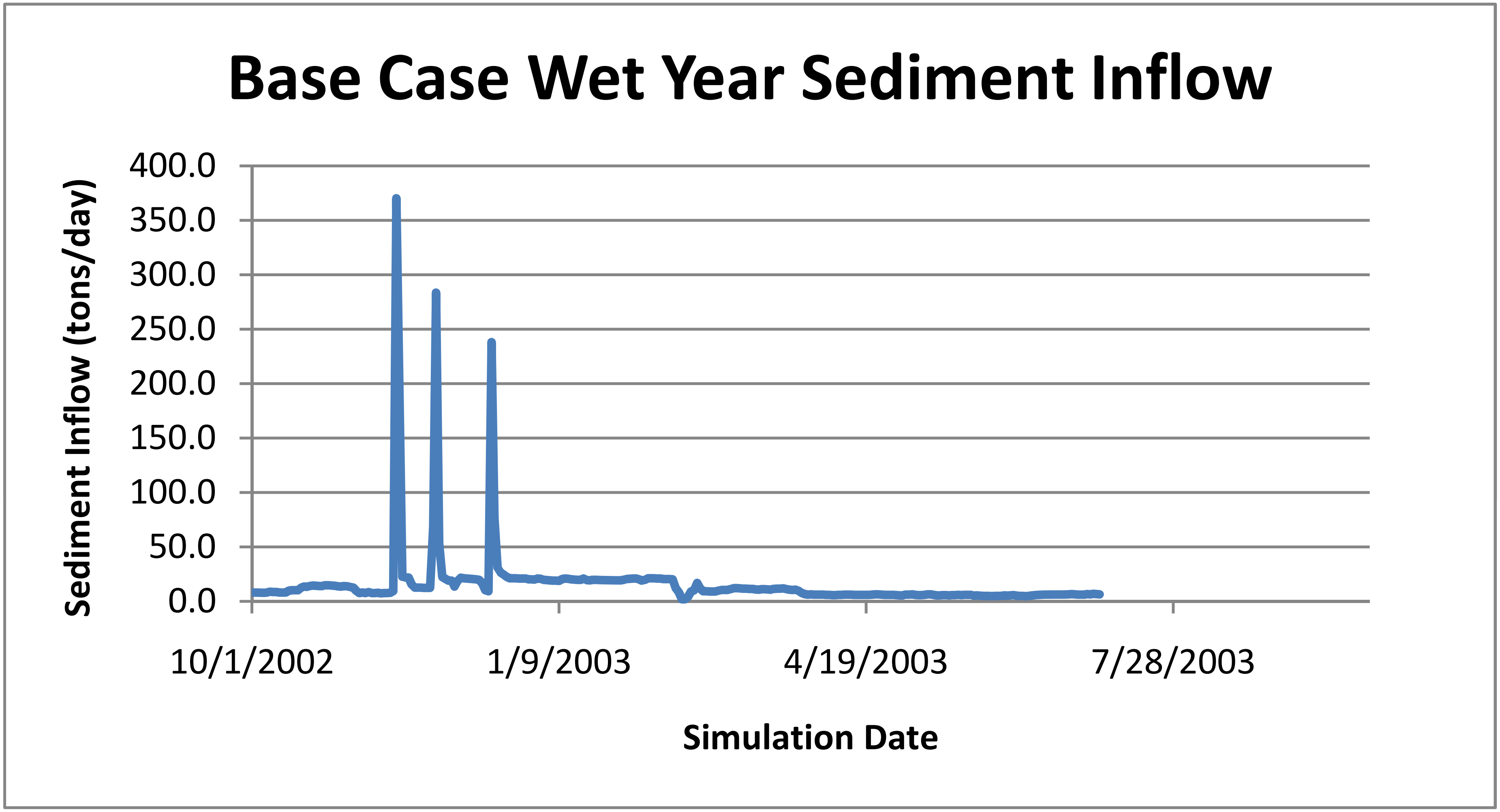

Base Case Wet Year Sediment Inflow
Sediment Inflow (tons/day)
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
10/1/2002
1/9/2003
4/19/2003
7/28/2003
Simulation Date

Figure B.B.17

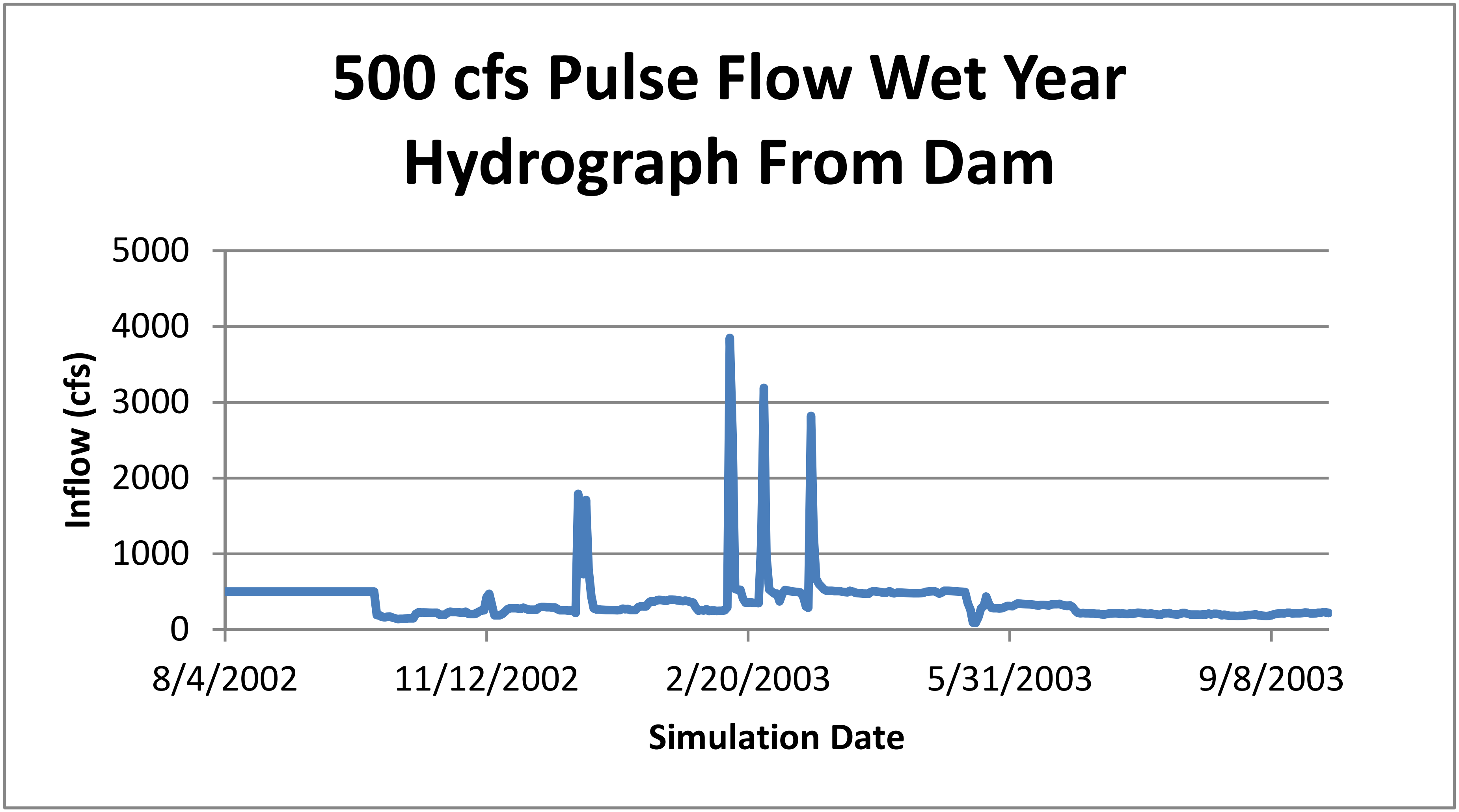

500 cfs Pulse Flow Wet Year
Hydrograph From Dam
5000
4000
3000
2000
1000
0
Inflow (cfs)
8/4/2002
11/12/2002
2/20/2003
5/31/2003
9/8/2003
Simulation Date

Figure B.B.18

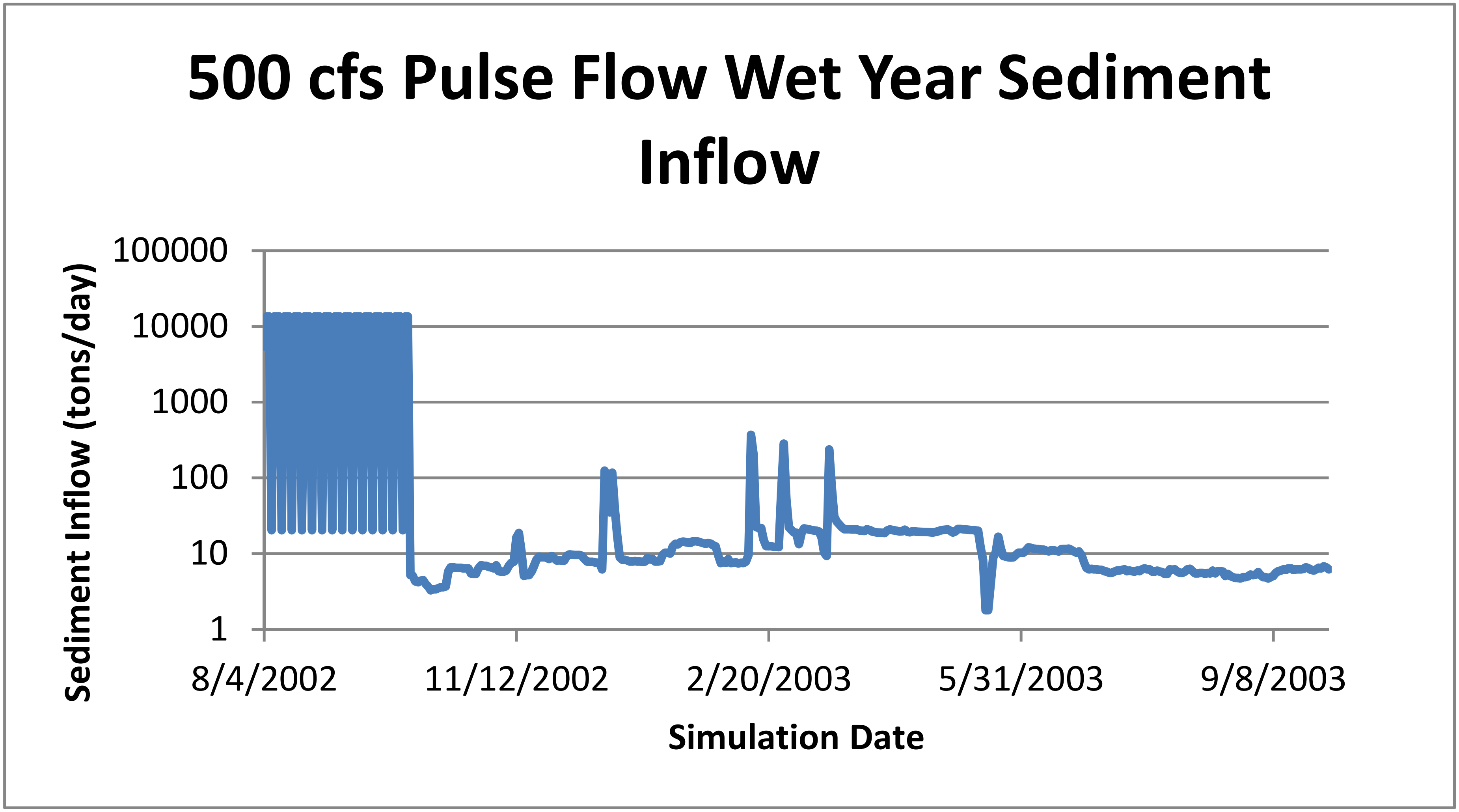

500 cfs Pulse Flow Wet Year Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
8/4/2002
11/12/2002
2/20/2003
5/31/2003
9/8/2003
Simulation Date

Figure B.B.19

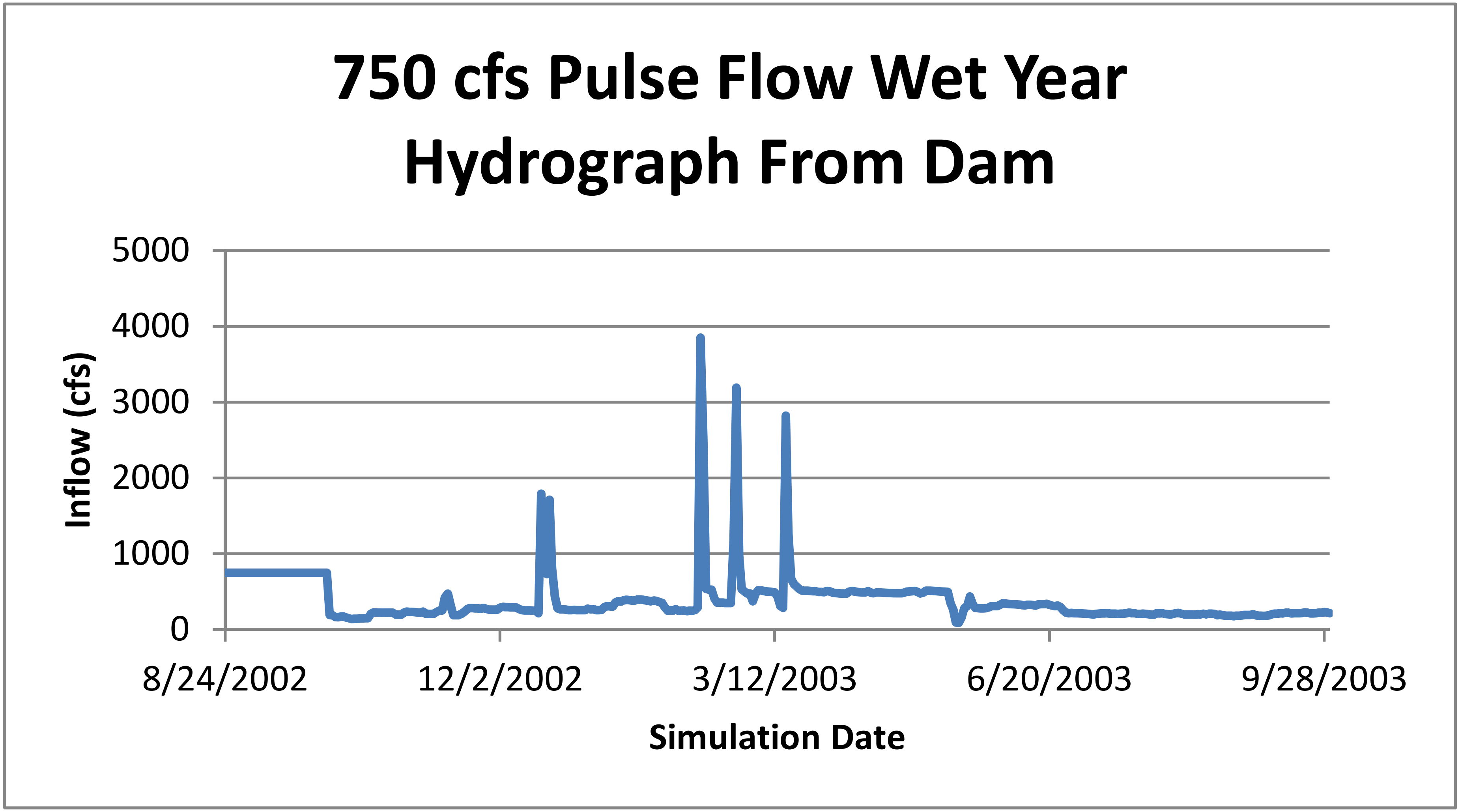

750 cfs Pulse Flow Wet Year
Hydrograph From Dam
Inflow (cfs)
5000
4000
3000
2000
1000
0
8/24/2002
12/2/2002
3/12/2003
6/20/2003
9/28/2003
Simulation Date

Figure B.B.20

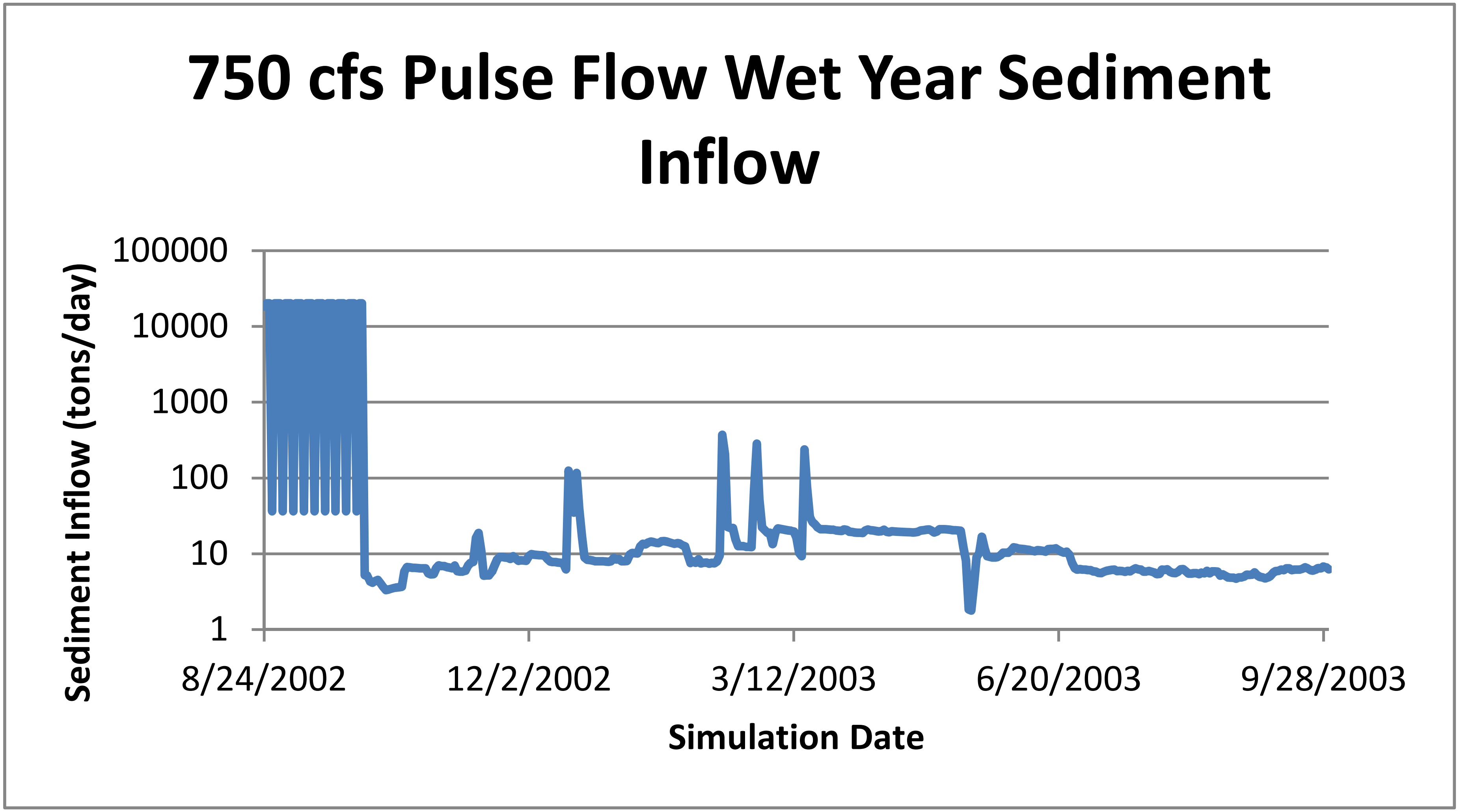

750 cfs Pulse Flow Wet Year Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
8/24/2002
12/2/2002
3/12/2003
6/20/2003
9/28/2003
Simulation Date

Figure B.B.21

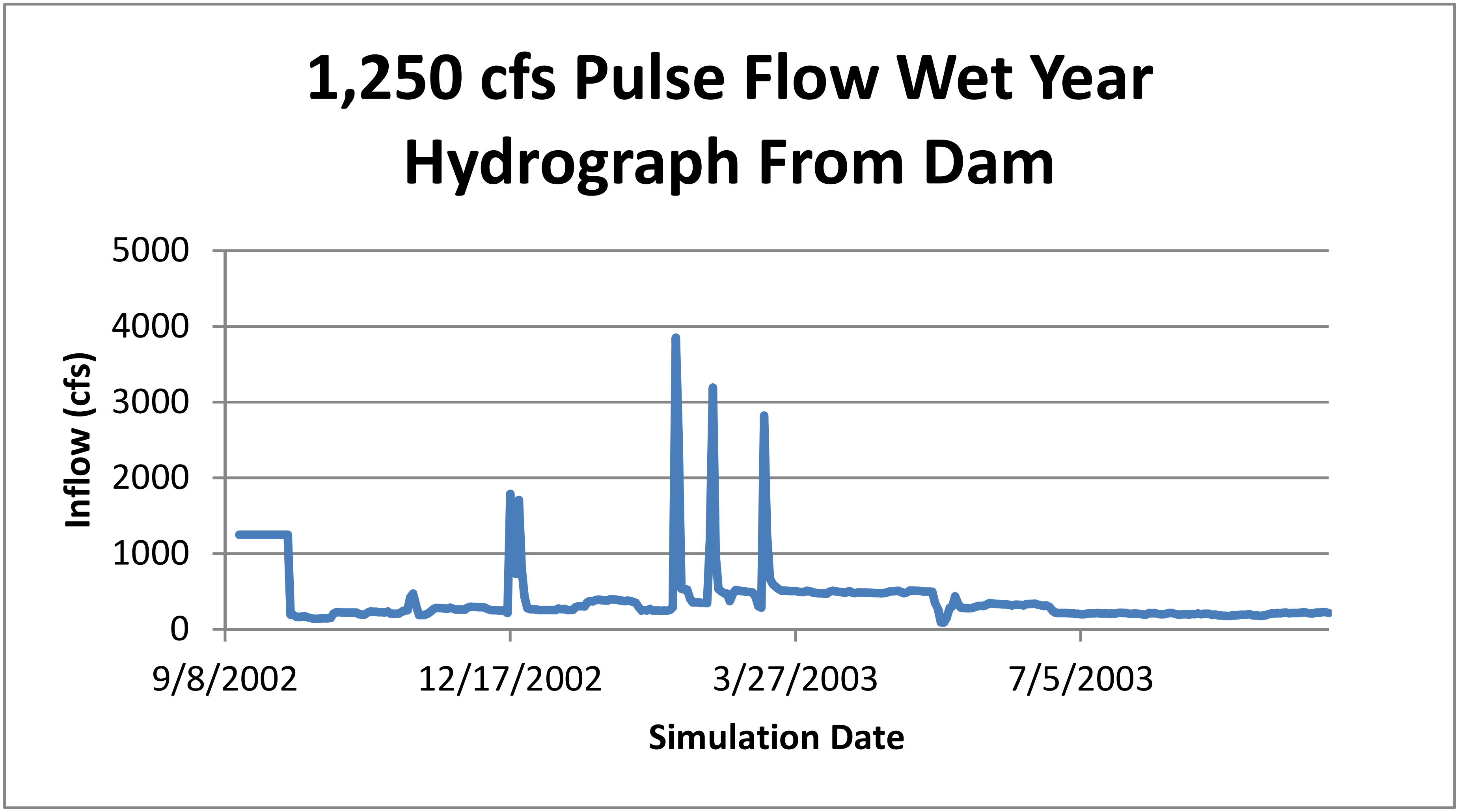

1,250 cfs Pulse Flow Wet Year Hydrograph From Dam
Inflow (cfs)
5000
4000
3000
2000
1000
0
9/8/2002
12/17/2002
3/27/2003
7/5/2003
Simulation Date

FIgure B.B.22

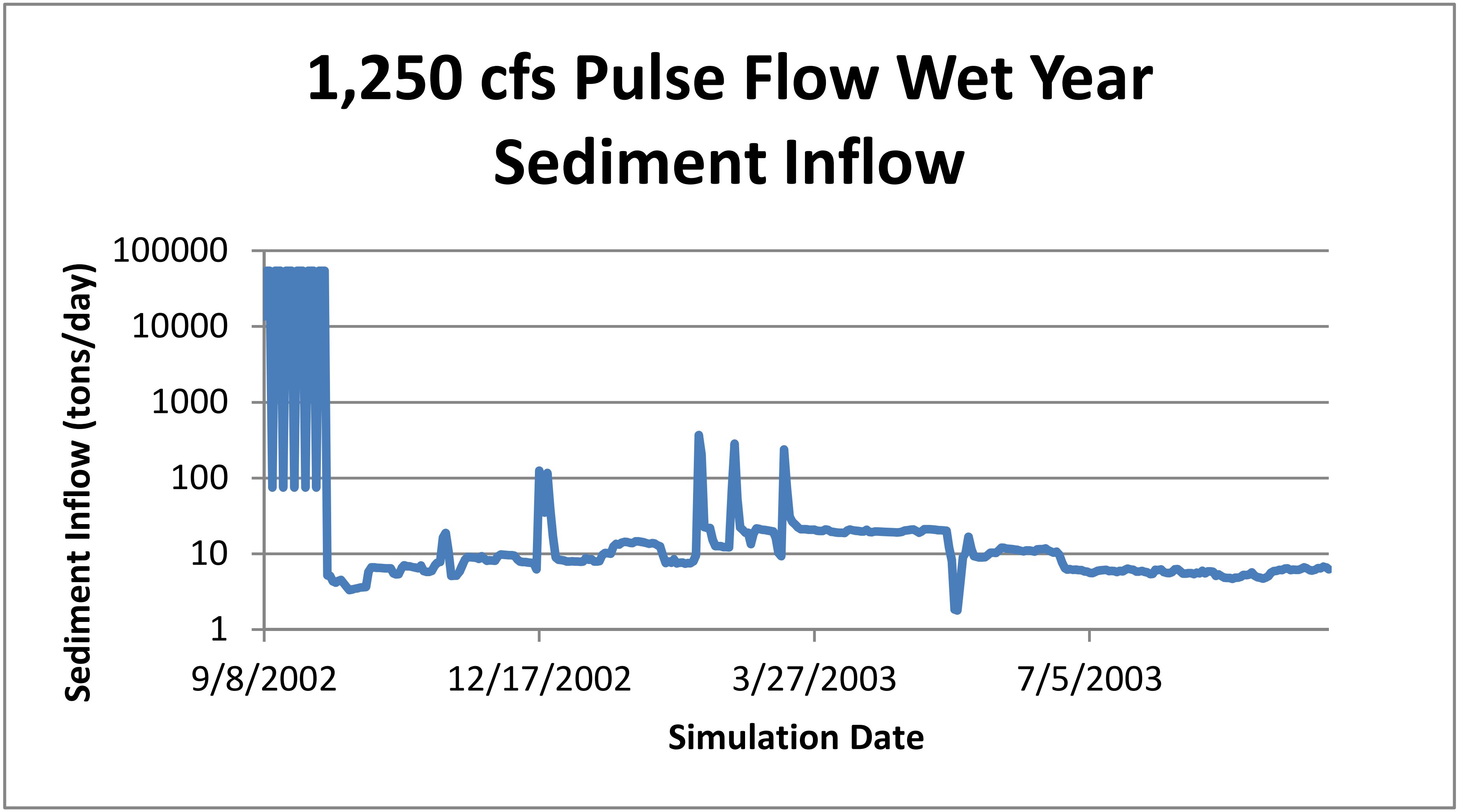

1,250 cfs Pulse Flow Wet Year
Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
9/8/2002
12/17/2002
3/27/2003
7/5/2003
Simulation Date

Figure B.B.23

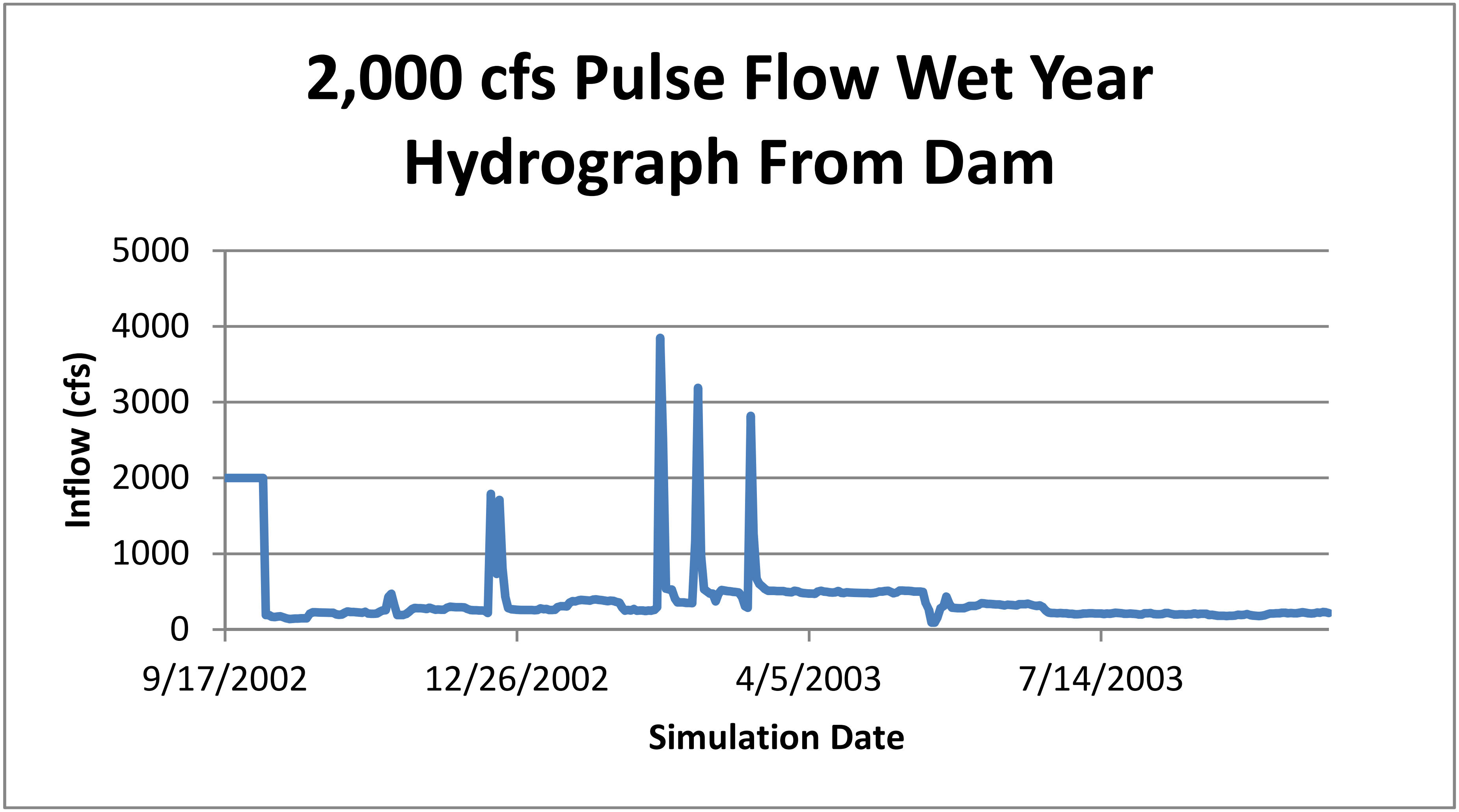

2,000 cfs Pulse Flow Wet Year Hydrograph From Dam
Inflow (cfs)
5000
4000
3000
2000
1000
0
9/17/2002
12/26/2002
4/5/2003
7/14/2003
Simulation Date

Figure B.B.24

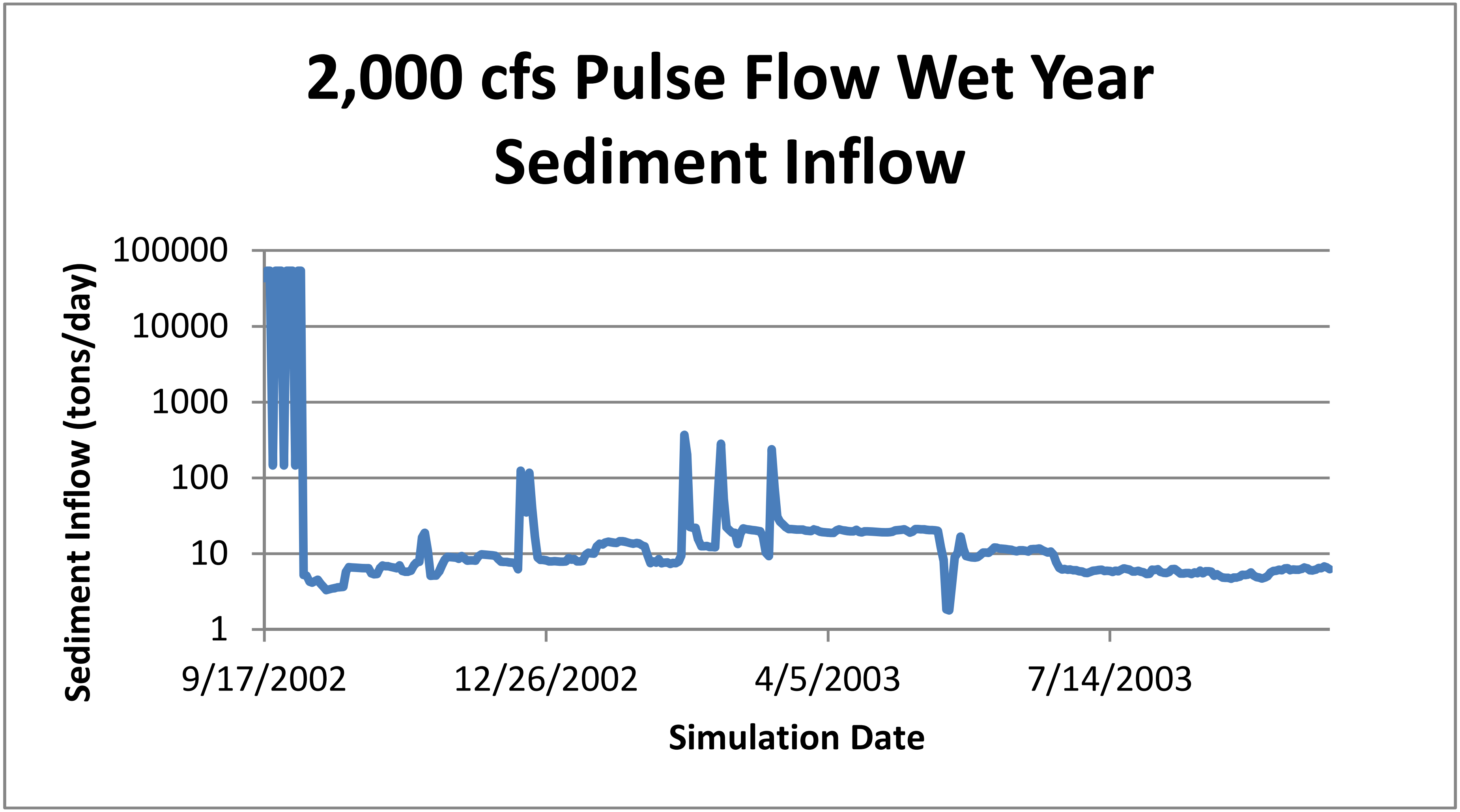

2,000 cfs Pulse Flow Wet Year
Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
9/17/2002
12/26/2002
4/5/2003
7/14/2003
Simulation Date

Figure B.B.25

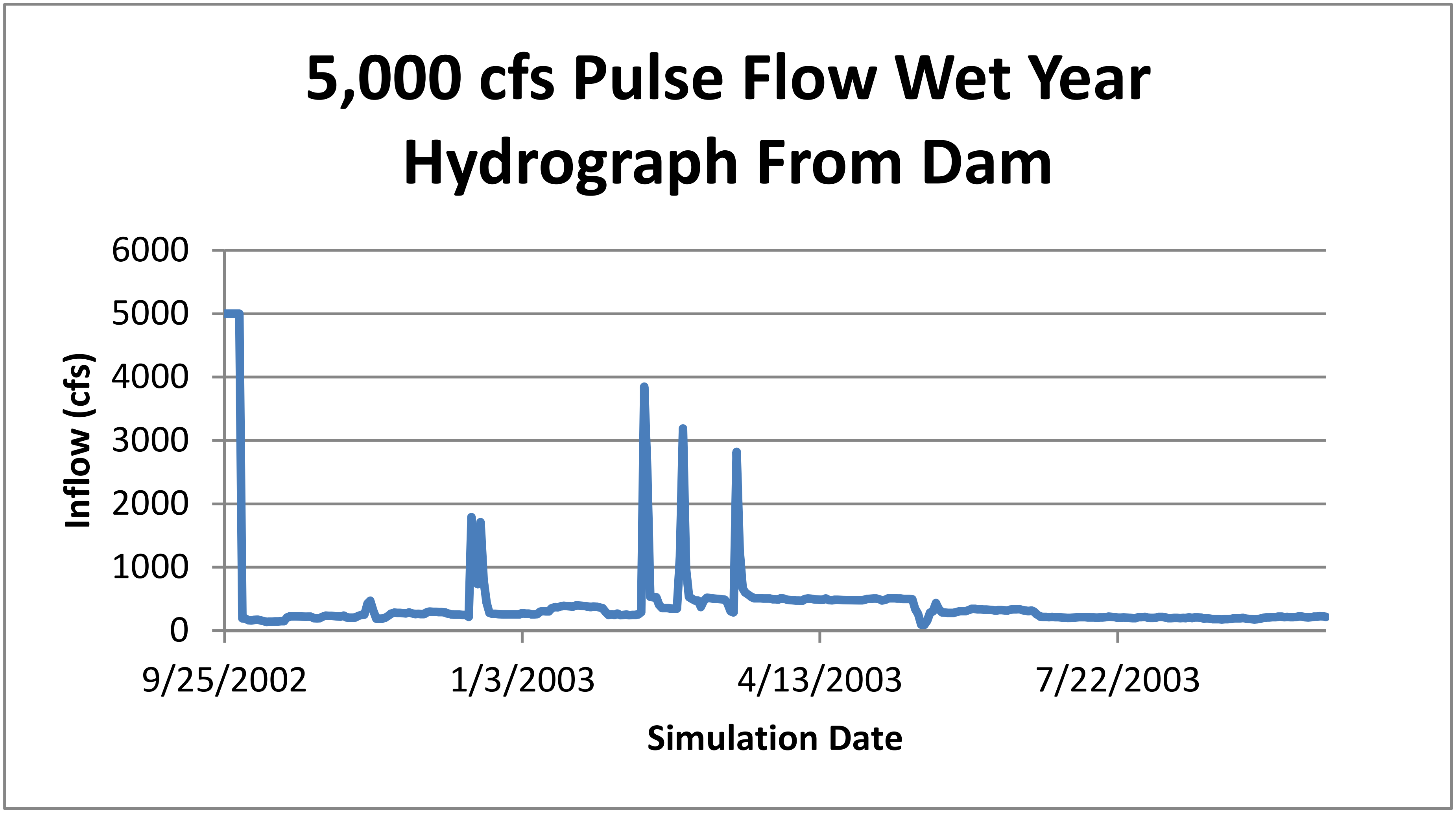

5,000 cfs Pulse Flow Wet Year
Hydrograph From Dam
Inflow (cfs)
6000
5000
4000
3000
2000
1000
0
9/25/2002
1/3/2003
4/13/2003
7/22/2003
Simulation Date

Figure B.B.26

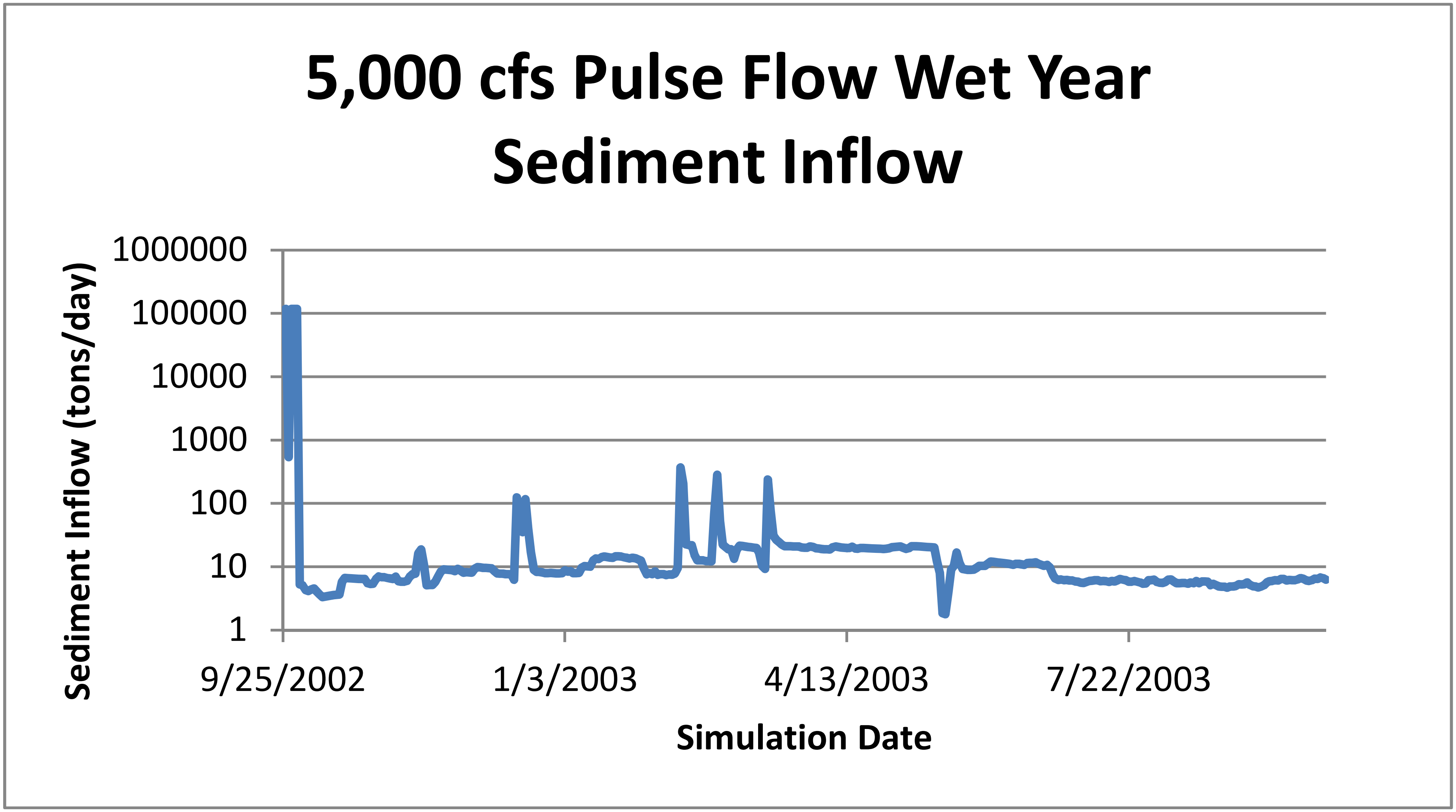

5,000 cfs Pulse Flow Wet Year
Sediment Inflow
Sediment Inflow (tons/day)
1000000
100000
10000
1000
100
10
1
9/25/2002
1/3/2003
4/13/2003
7/22/2003
Simulation Date

Figure B.B.27

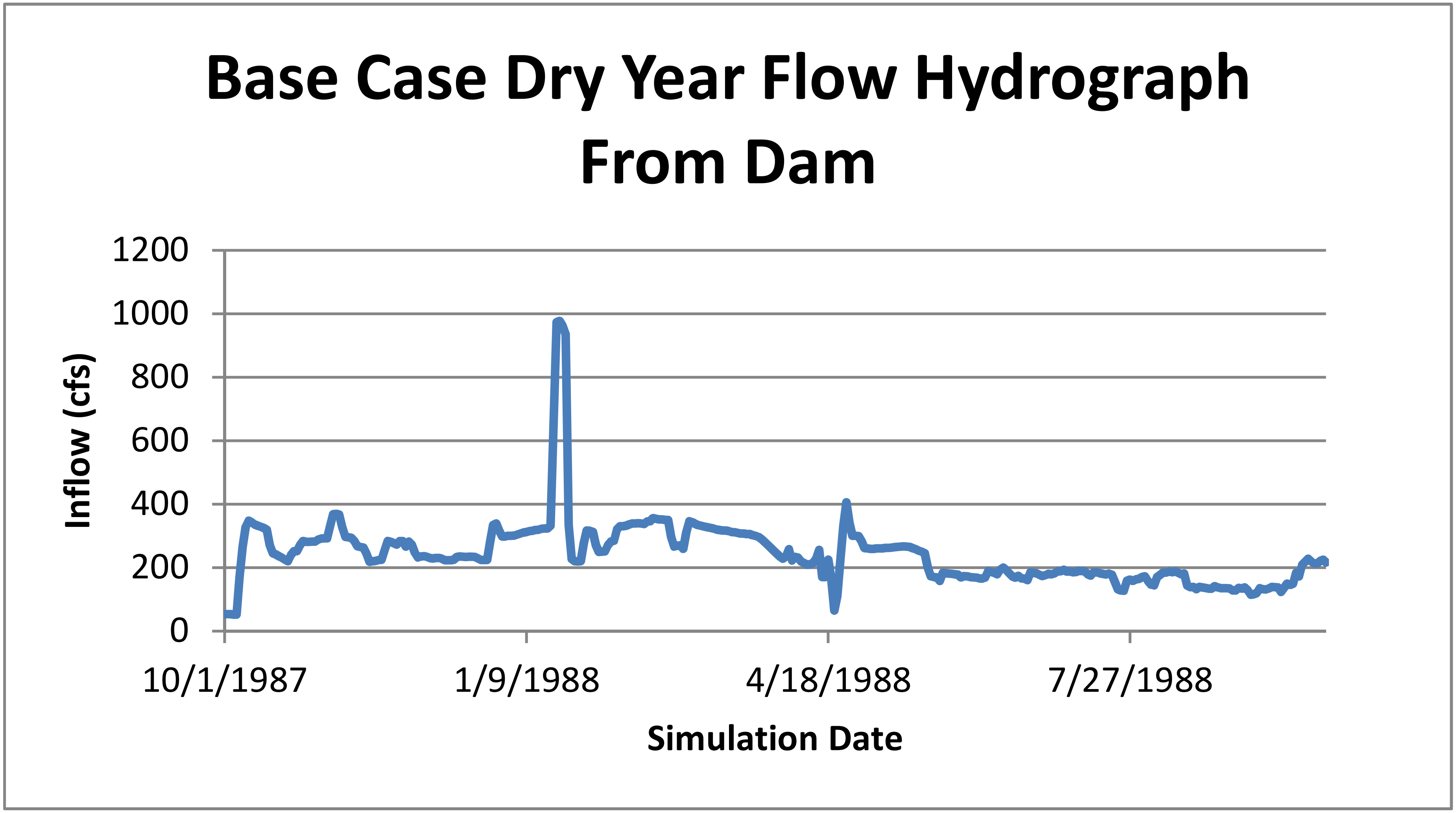

Base Case Dry Year Flow Hydrograph From Dam
Inflow (cfs)
1200
1000
800
600
400
200
0
10/1/1987
1/9/1988
4/18/1988
7/27/1988
Simulation Date

Figure B.B.28

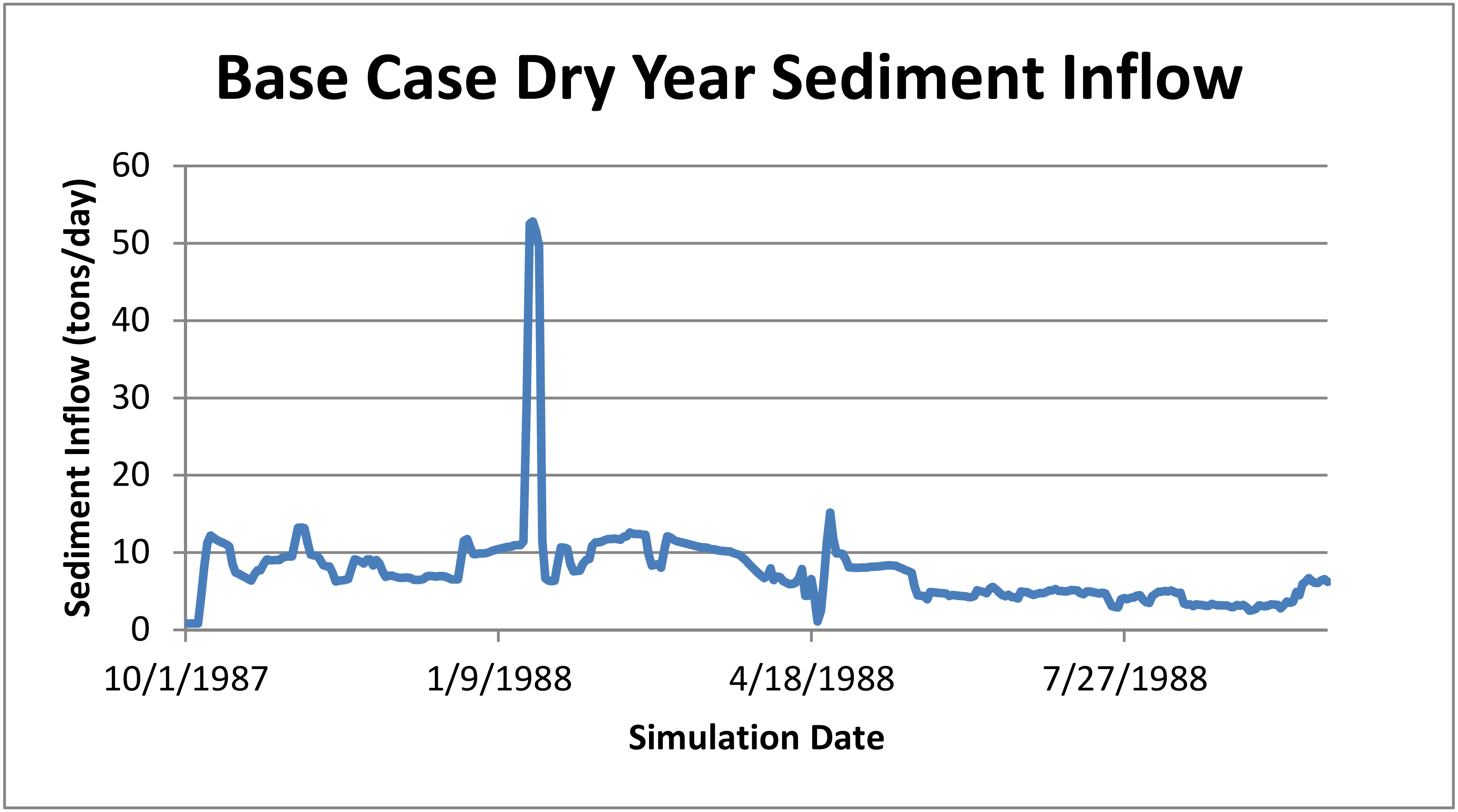

Base Case Dry Year Sediment Inflow
Sediment Inflow (tons/day)
60
50
40
30
20
10
0
10/1/1987
1/9/1988
4/18/1988
7/27/1988
Simulation Date

Figure B.B.29

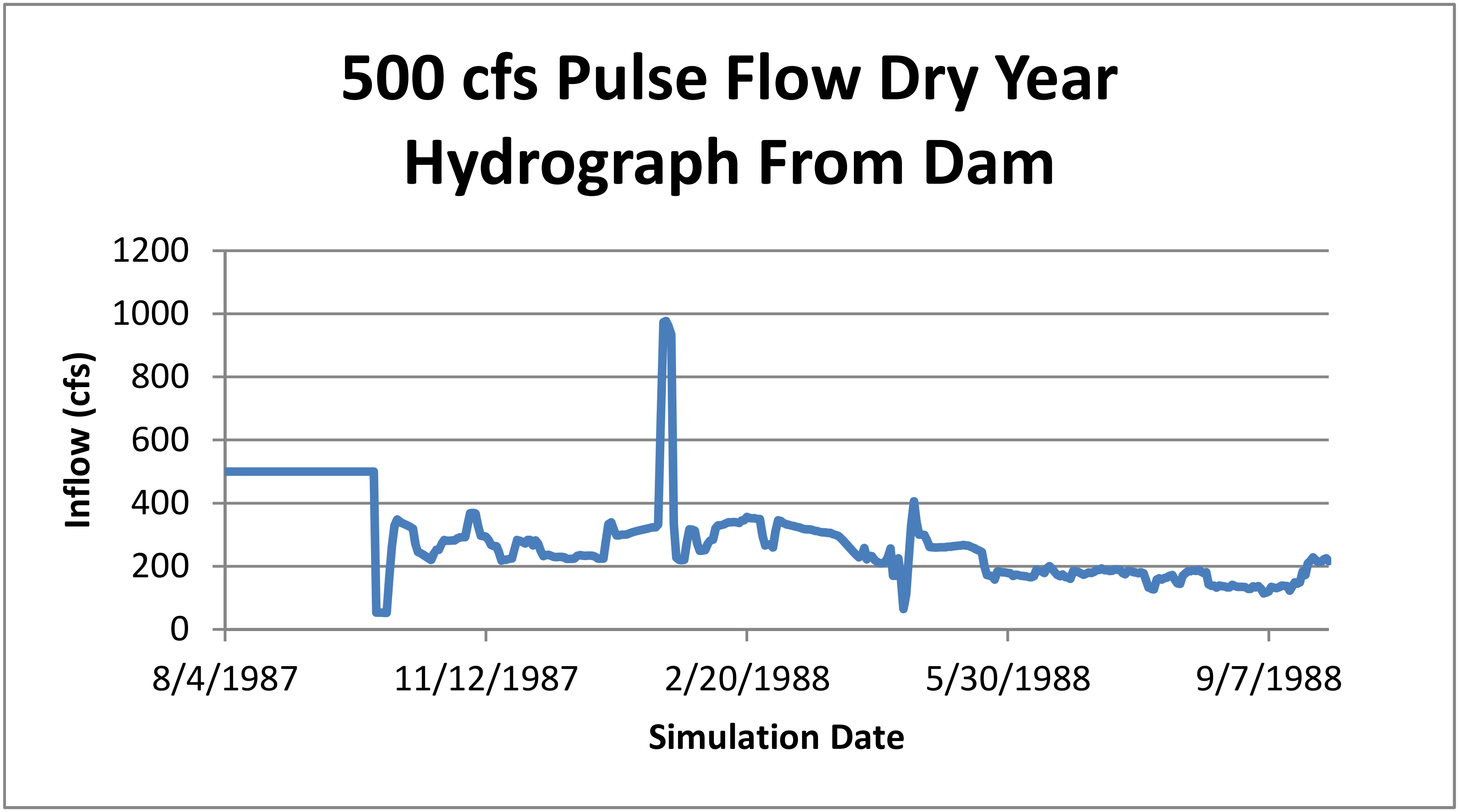

500 cfs Pulse Flow Dry Year Hydrograph From Dam
Inflow (cfs)
1200
1000
800
600
400
200
0
8/4/1987
11/12/1987
2/20/1988
5/30/1988
9/7/1988
Simulation Date

Figure B.B.30

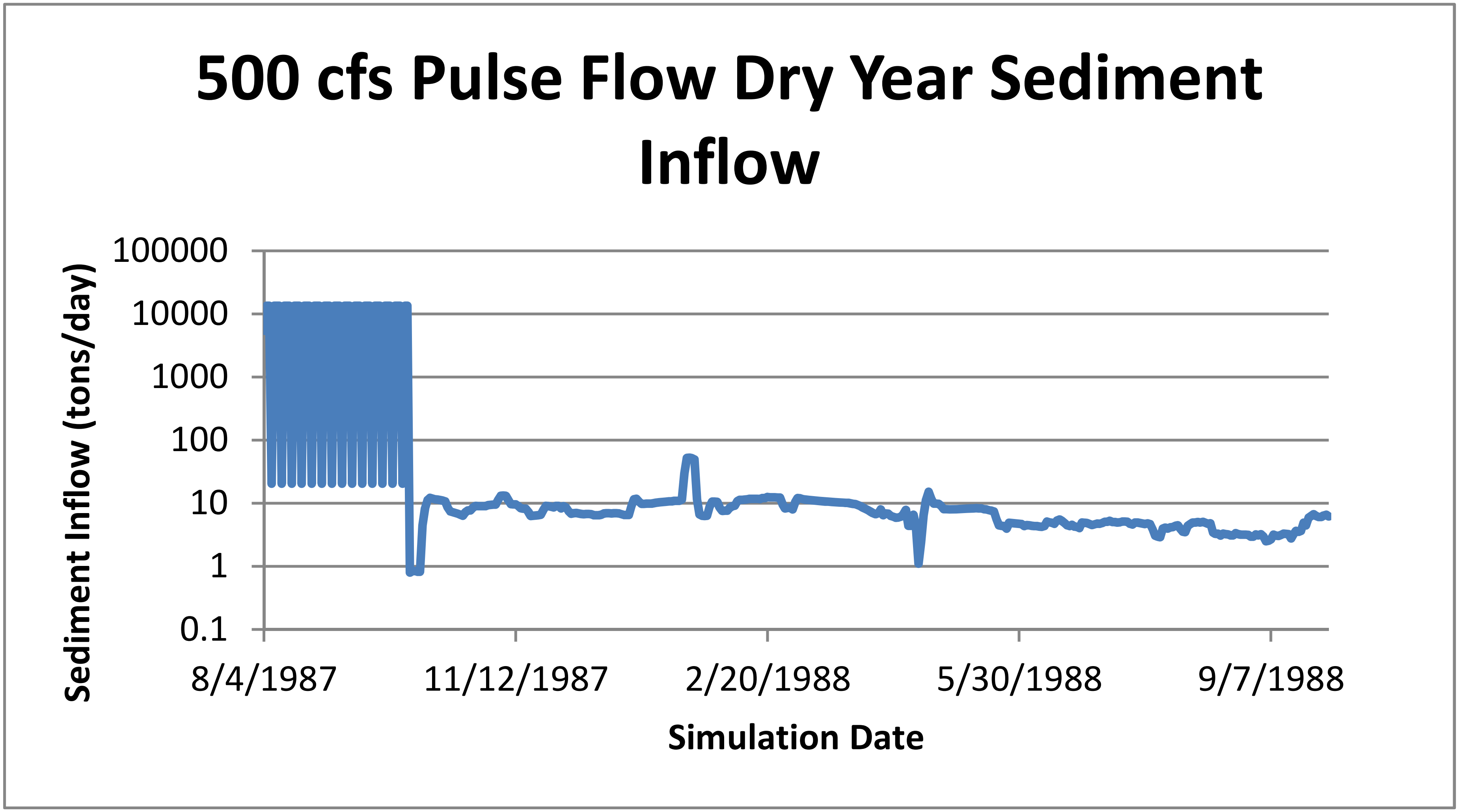
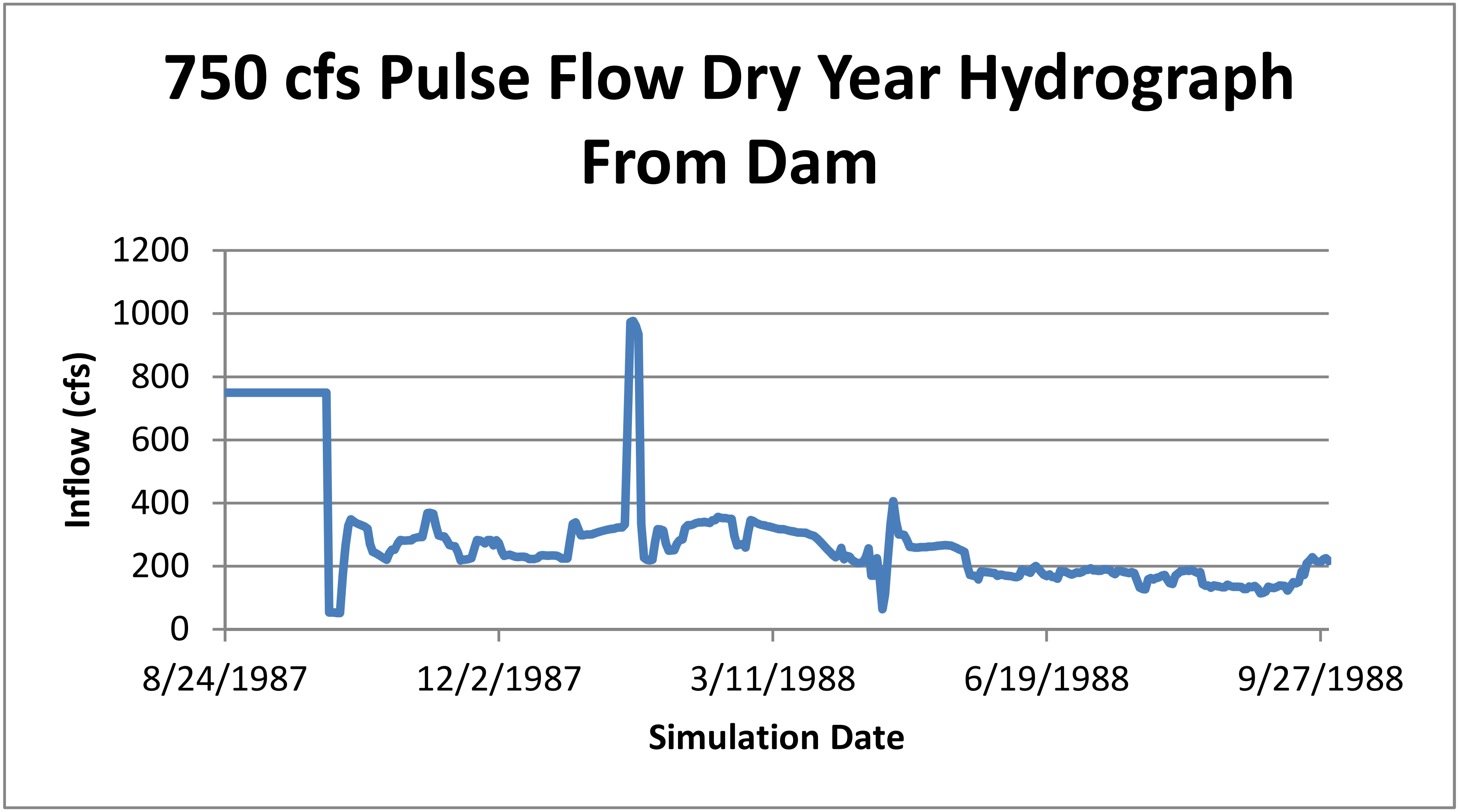

500 cfs Pulse Flow Dry Year Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
0.1
8/4/1987
11/12/1987
2/20/1988
5/30/1988
9/7/1988
Simulation Date

Figure B.B.31



750 cfs Pulse Flow Dry Year Hydrograph From Dam

Figure B.B.32

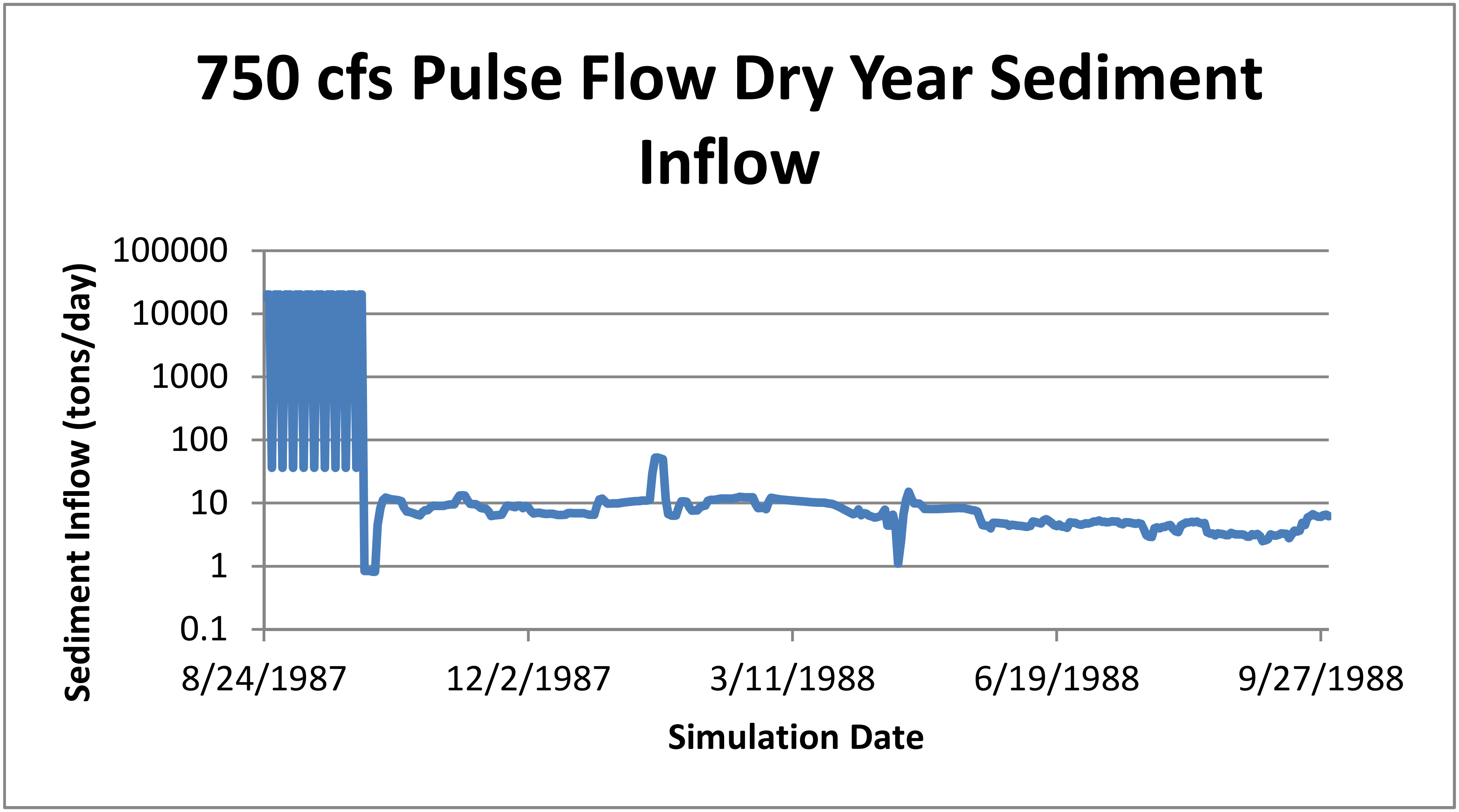

750 cfs Pulse Flow Dry Year Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
0.1
8/24/1987
12/2/1987
3/11/1988
6/19/1988
9/27/1988
Simulation Date

Figure B.B.33

1,250 cfs Pulse Flow Dry Year Hydrograph From Dam

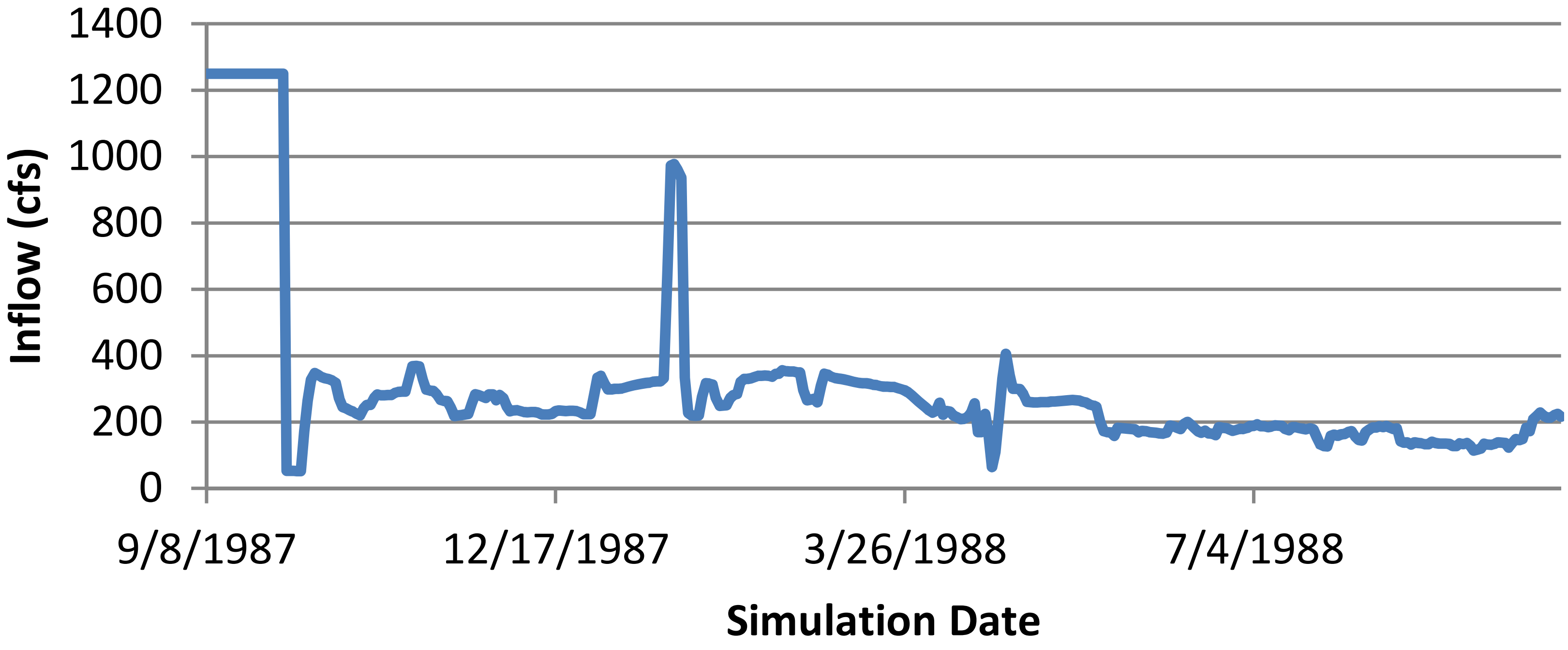
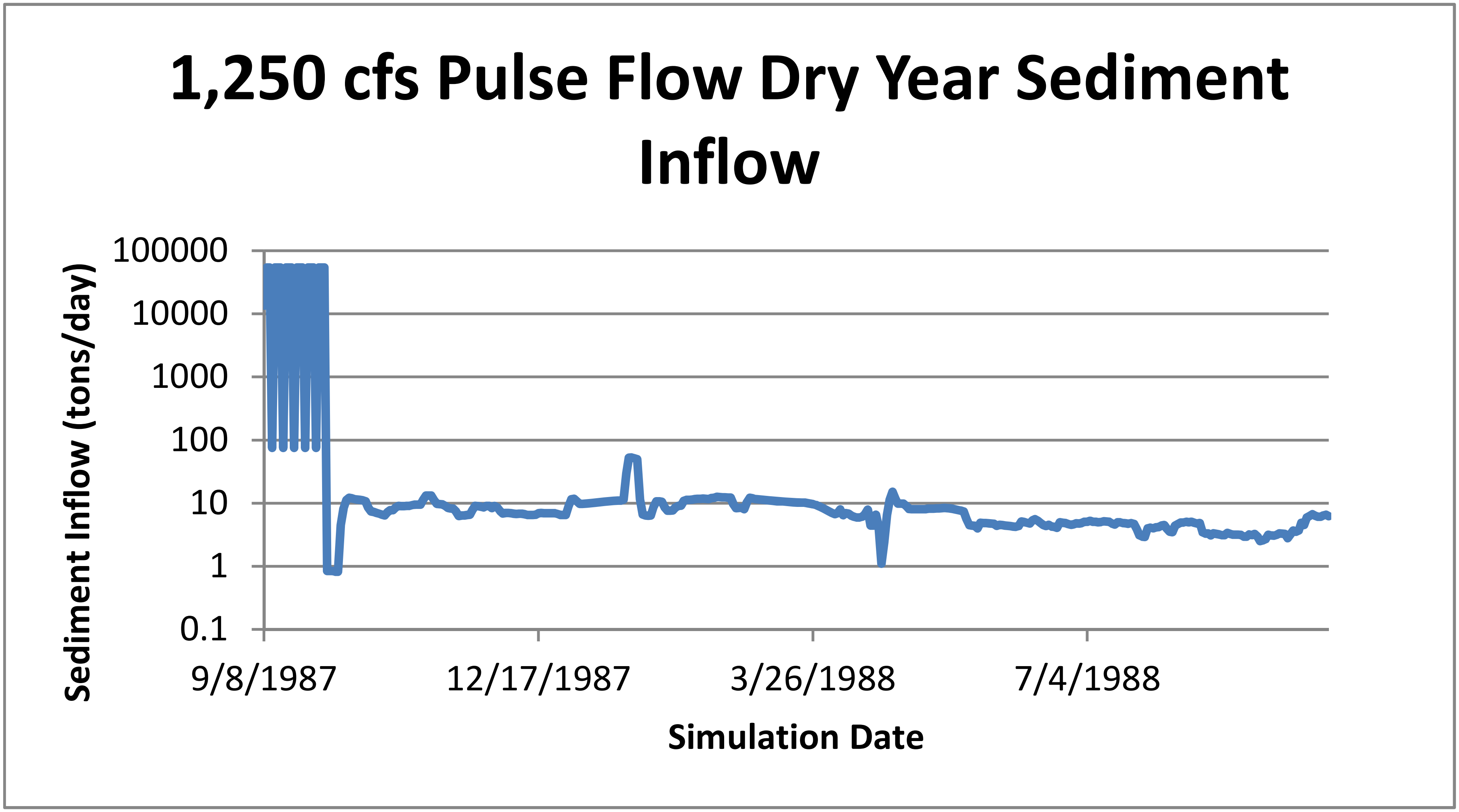


Figure B.B.34



1,250 cfs Pulse Flow Dry Year Sediment Inflow

Figure B.B.35

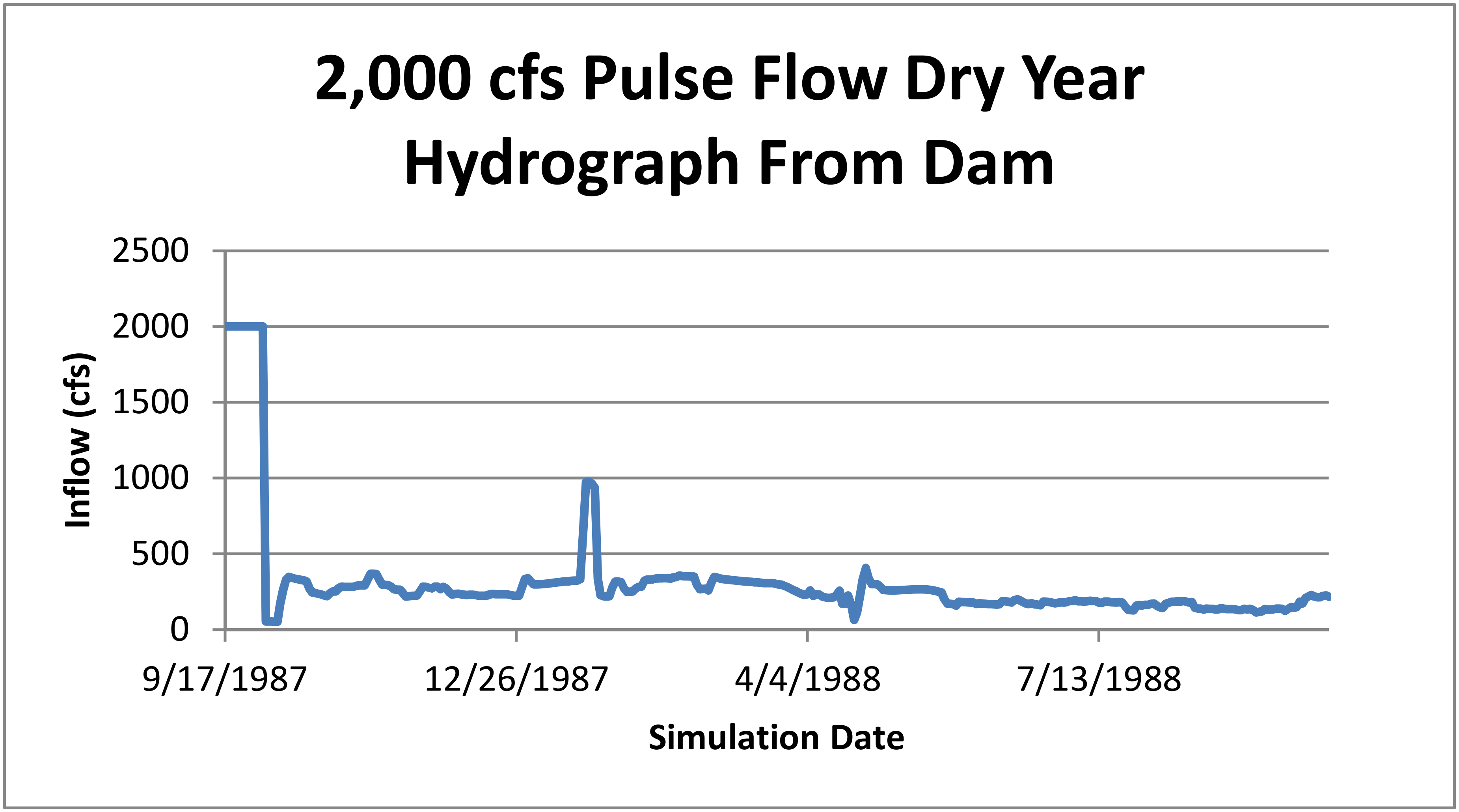

2,000 cfs Pulse Flow Dry Year Hydrograph From Dam
Inflow (cfs)
2500
2000
1500
1000
500
0
9/17/1987
12/26/1987
4/4/1988
7/13/1988
Simulation Date

Figure B.B.36

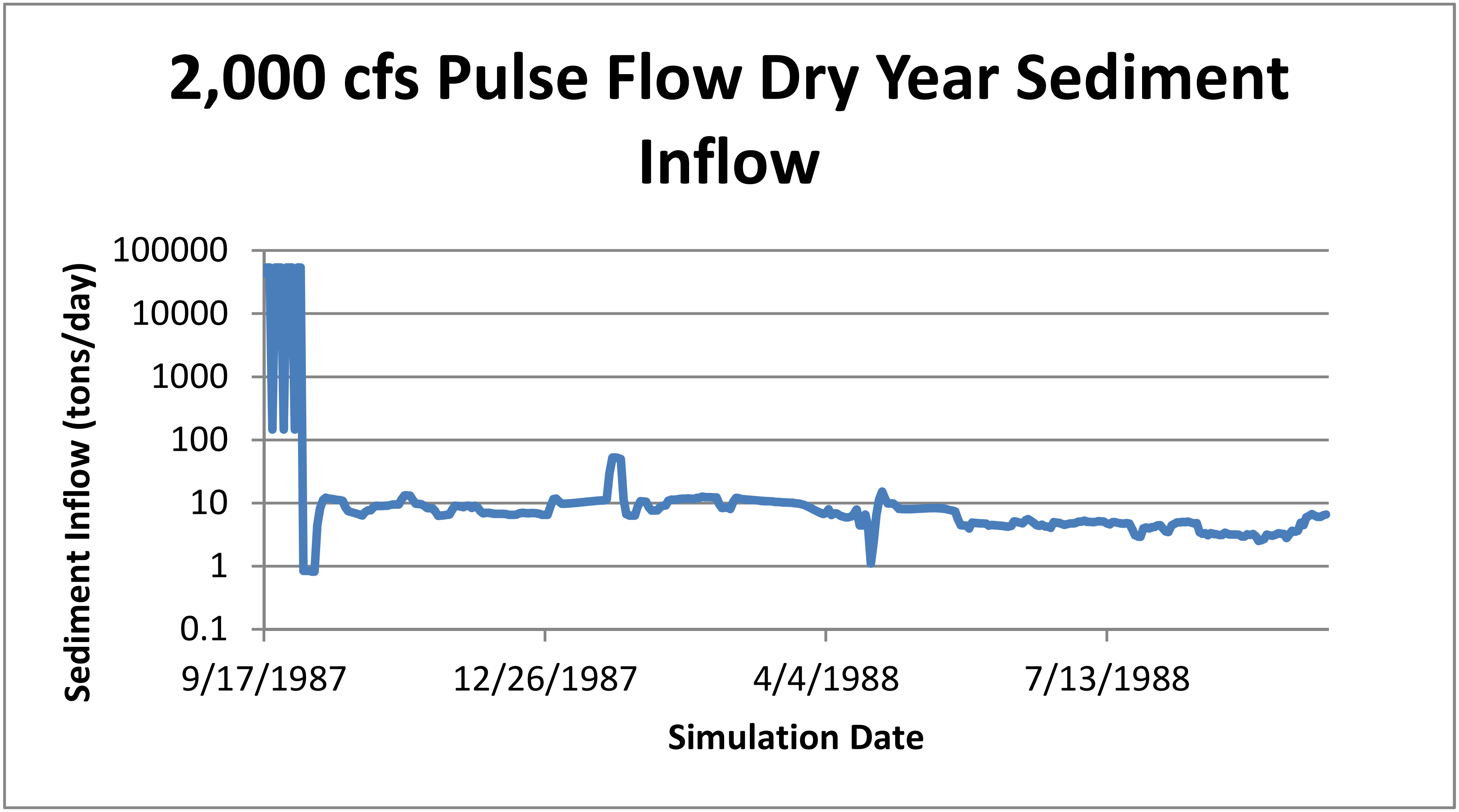

2,000 cfs Pulse Flow Dry Year Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
0.1
9/17/1987
12/26/1987
4/4/1988
7/13/1988
Simulation Date

Figure B.B.37

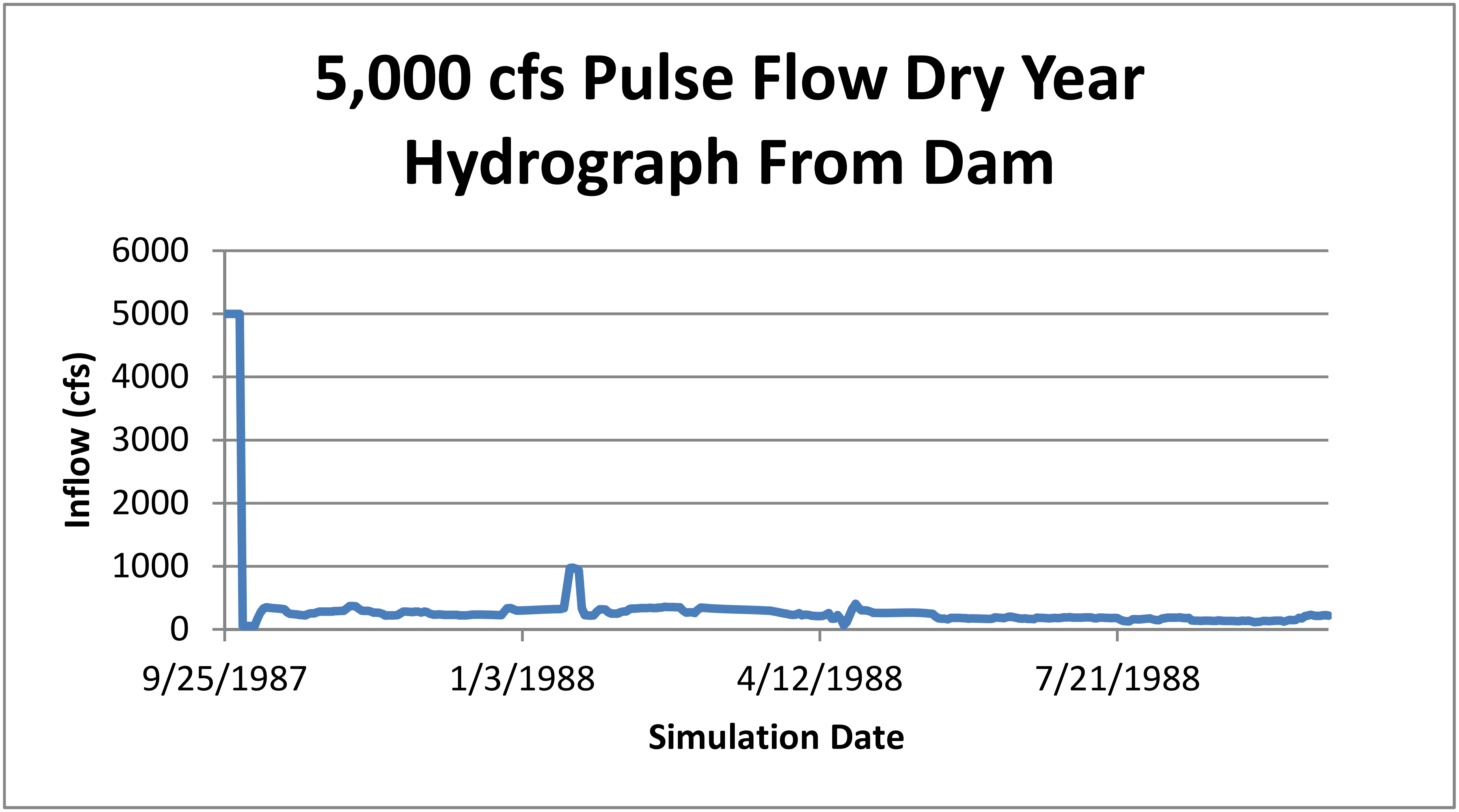

5,000 cfs Pulse Flow Dry Year
Hydrograph From Dam
6000
5000
4000
3000
2000
1000
0
Inflow (cfs)
9/25/1987
1/3/1988
4/12/1988
7/21/1988
Simulation Date

Figure B.B.38

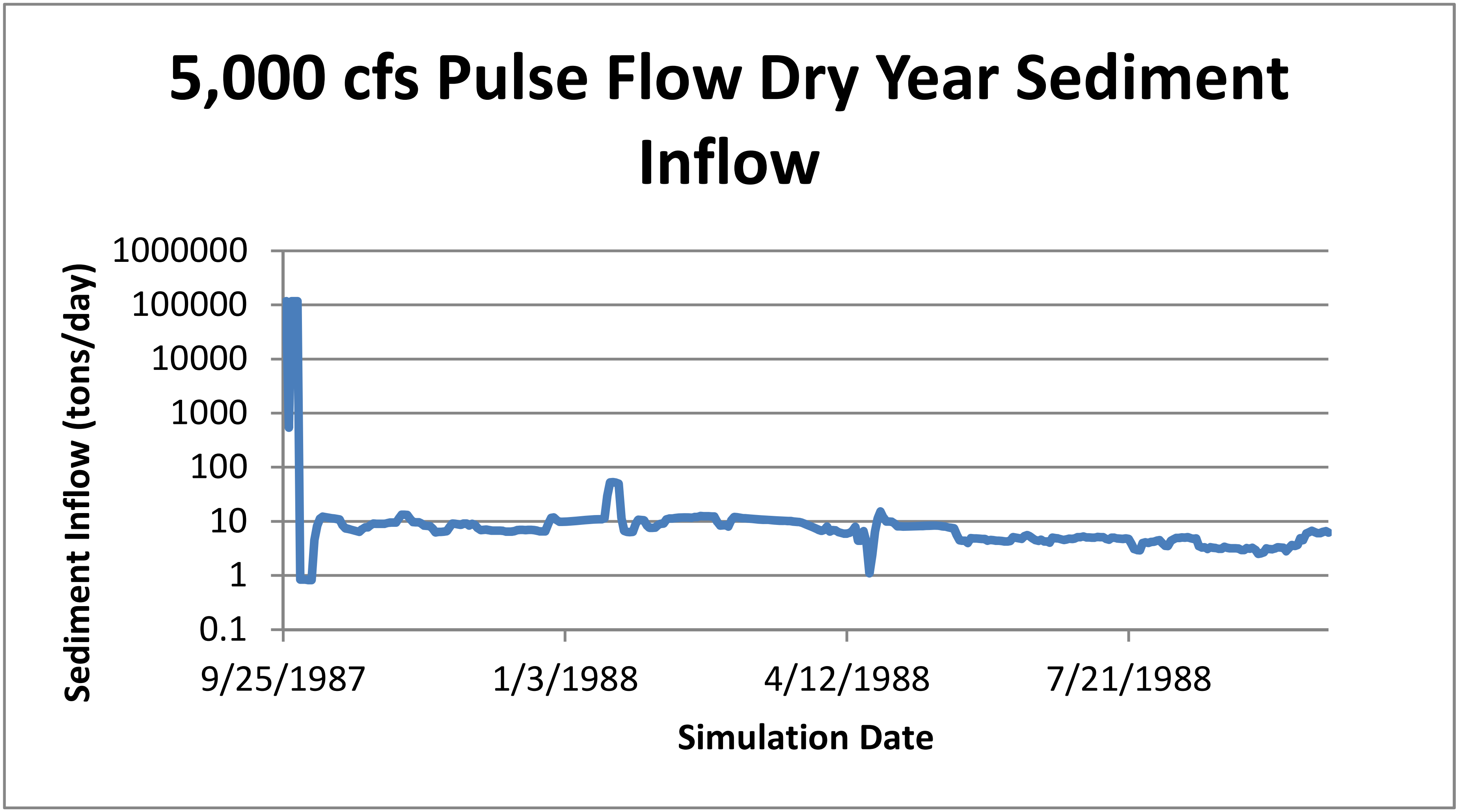
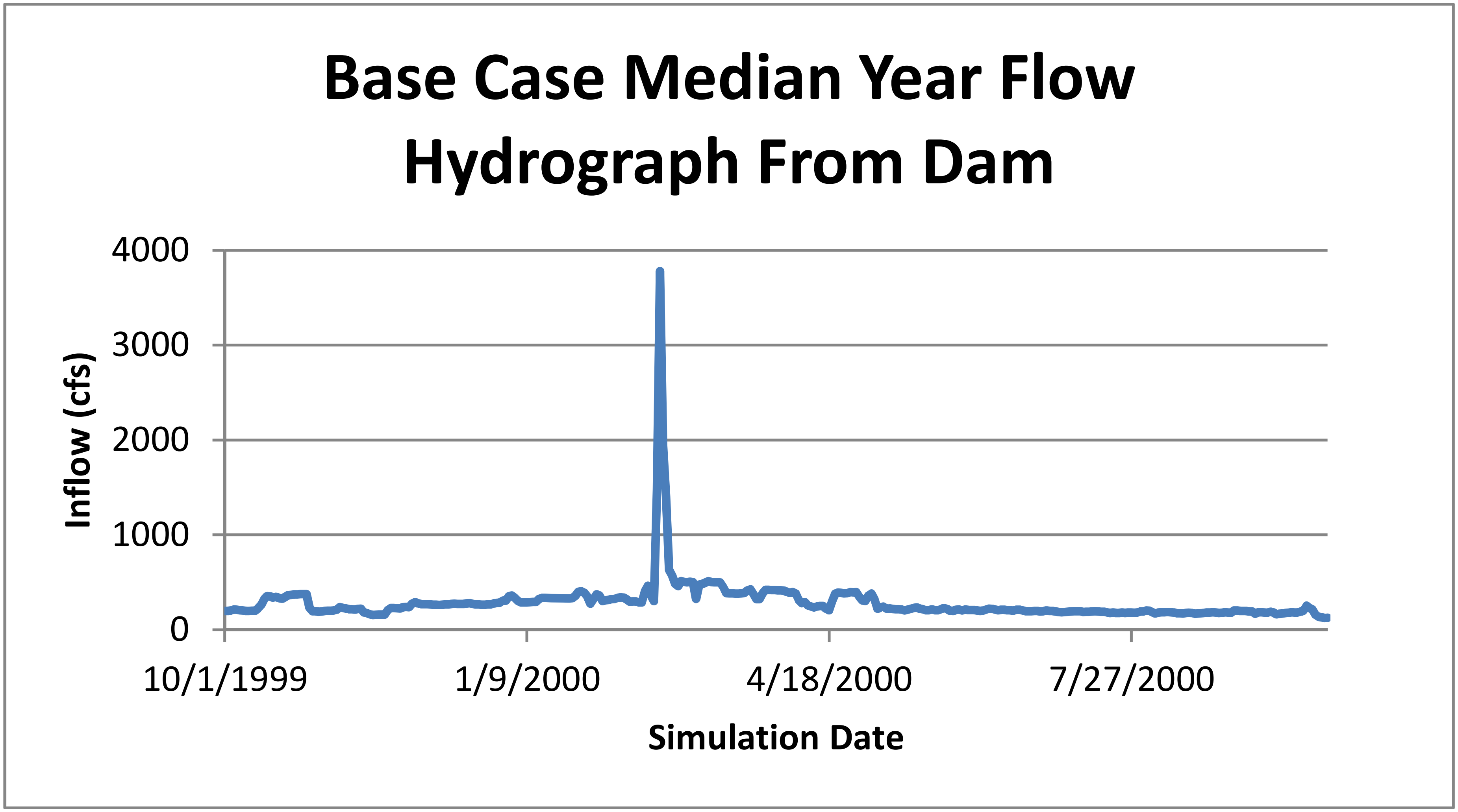

5,000 cfs Pulse Flow Dry Year Sediment Inflow
Sediment Inflow (tons/day)
1000000
100000
10000
1000
100
10
1
0.1
9/25/1987
1/3/1988
4/12/1988
7/21/1988
Simulation Date

Figure B.B.39



Base Case Median Year Flow Hydrograph From Dam

Figure B.B.40

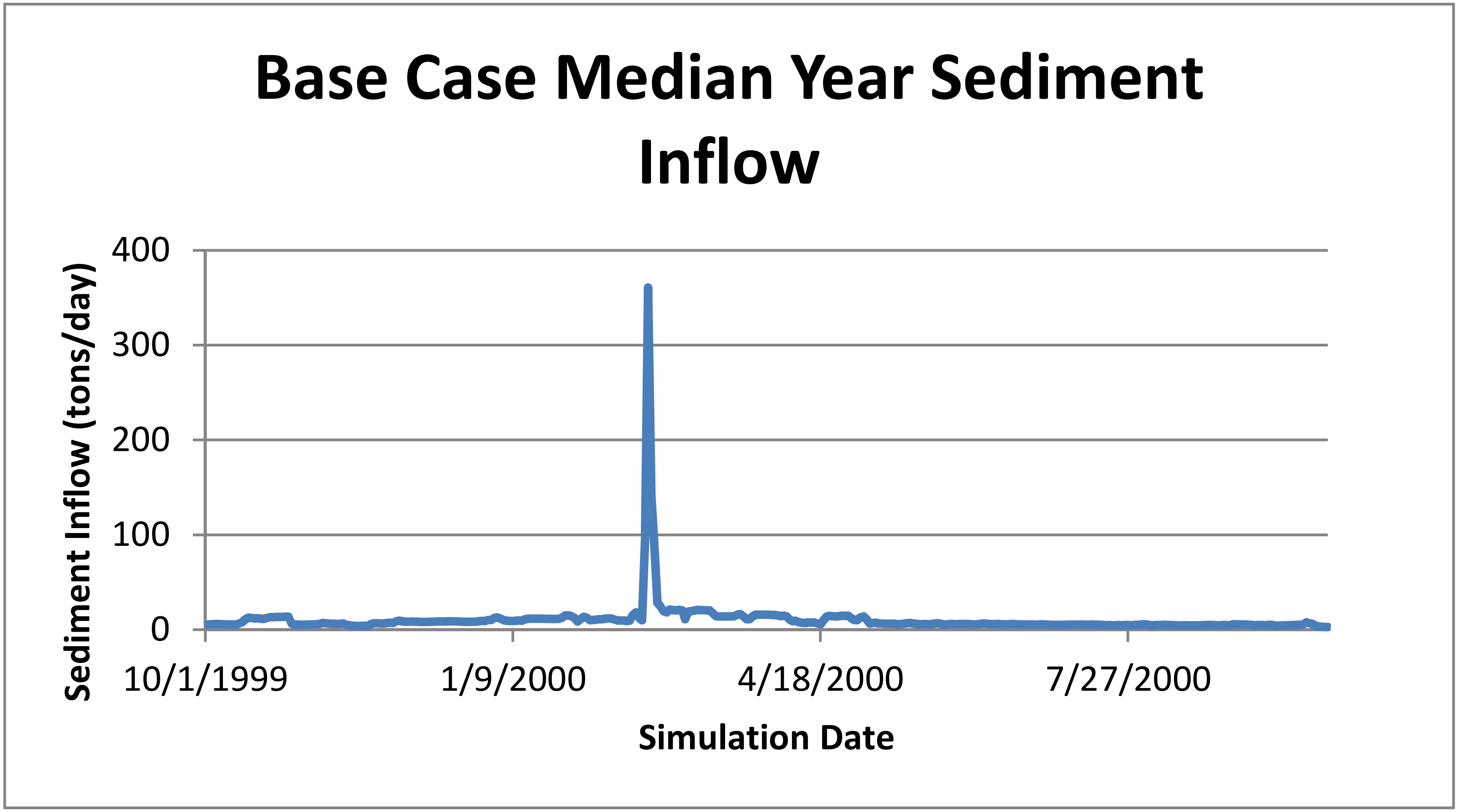

Base Case Median Year Sediment Inflow
400
300
200
100
0
Sediment Inflow (tons/day)
10/1/1999
1/9/2000
4/18/2000
7/27/2000
Simulation Date

Figure B.B.41

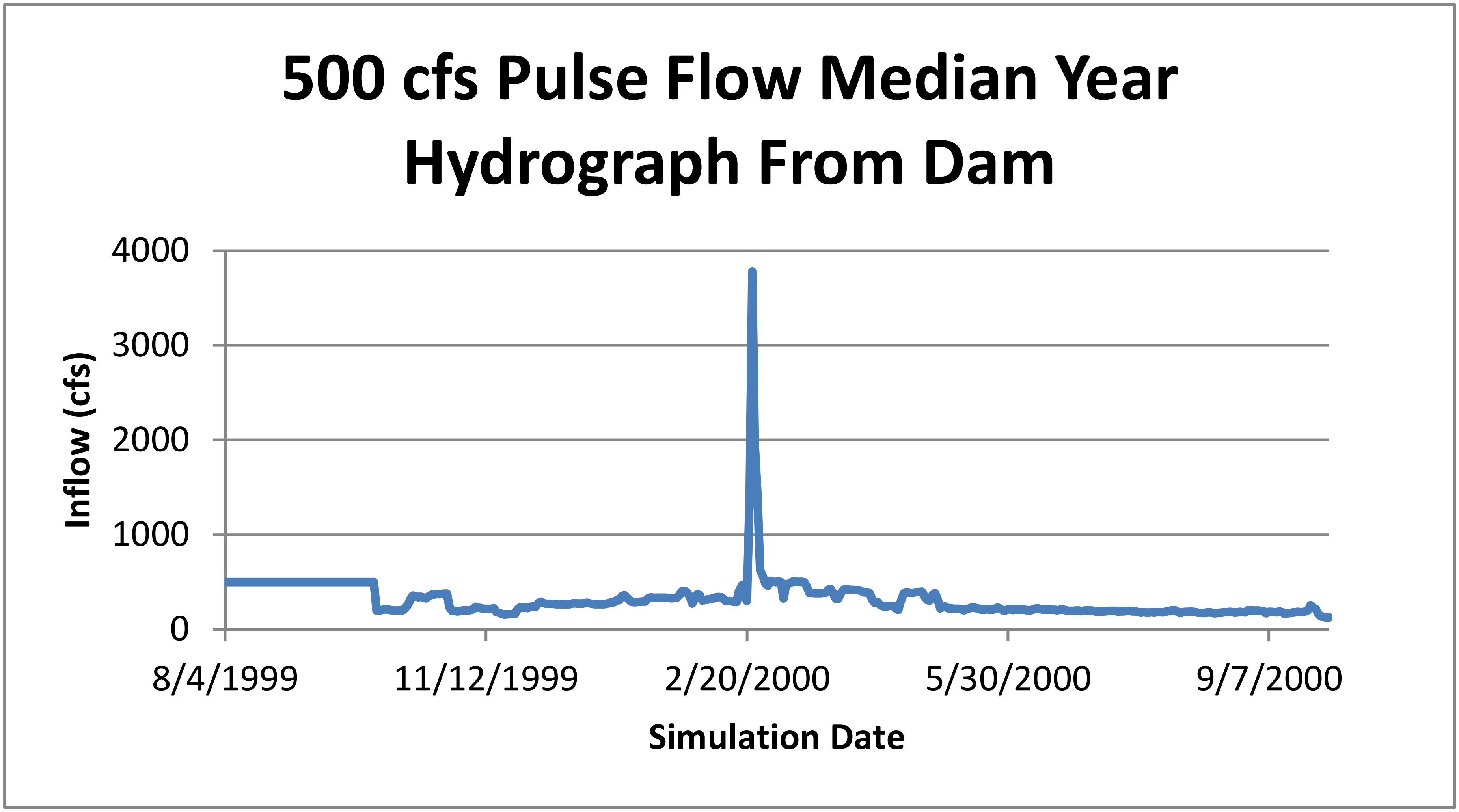

500 cfs Pulse Flow Median Year
Hydrograph From Dam
Inflow (cfs)
4000
3000
2000
1000
0
8/4/1999
11/12/1999
2/20/2000
5/30/2000
9/7/2000
Simulation Date

Figure B.B.42

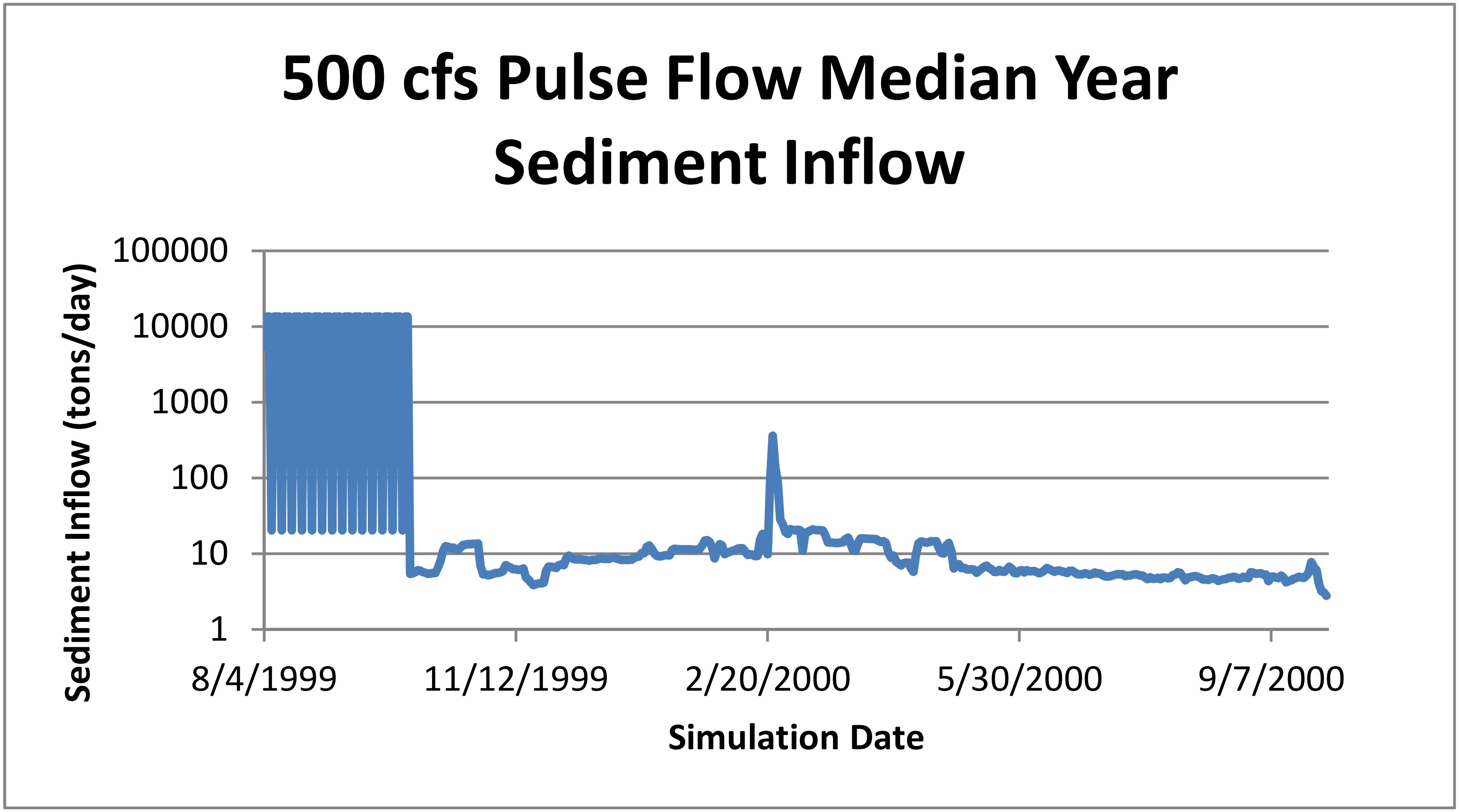

500 cfs Pulse Flow Median Year
Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
8/4/1999
11/12/1999
2/20/2000
5/30/2000
9/7/2000
Simulation Date

Figure B.B.43

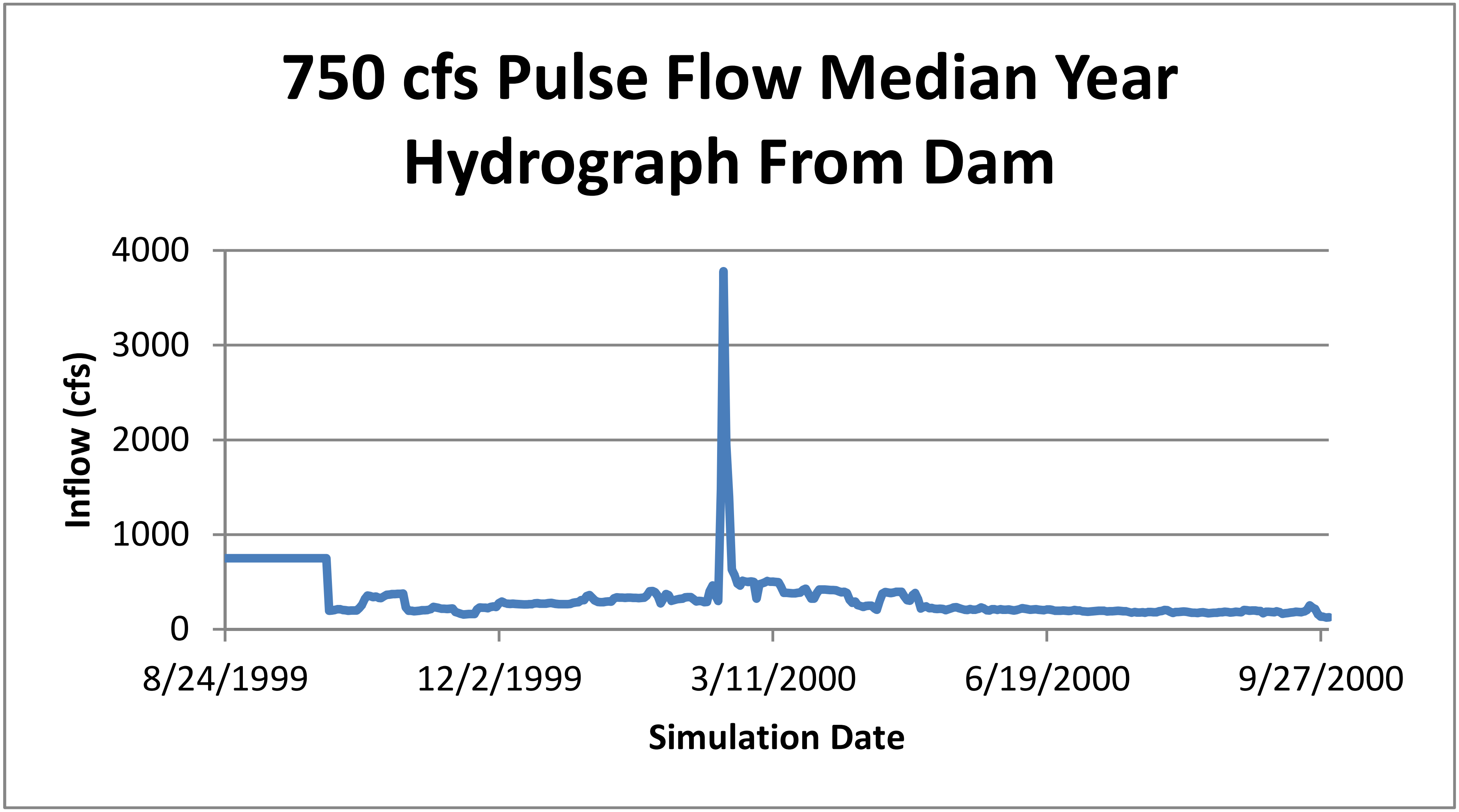

750 cfs Pulse Flow Median Year Hydrograph From Dam
Inflow (cfs)
4000
3000
2000
1000
0
8/24/1999
12/2/1999
3/11/2000
6/19/2000
9/27/2000
Simulation Date

Figure B.B.44

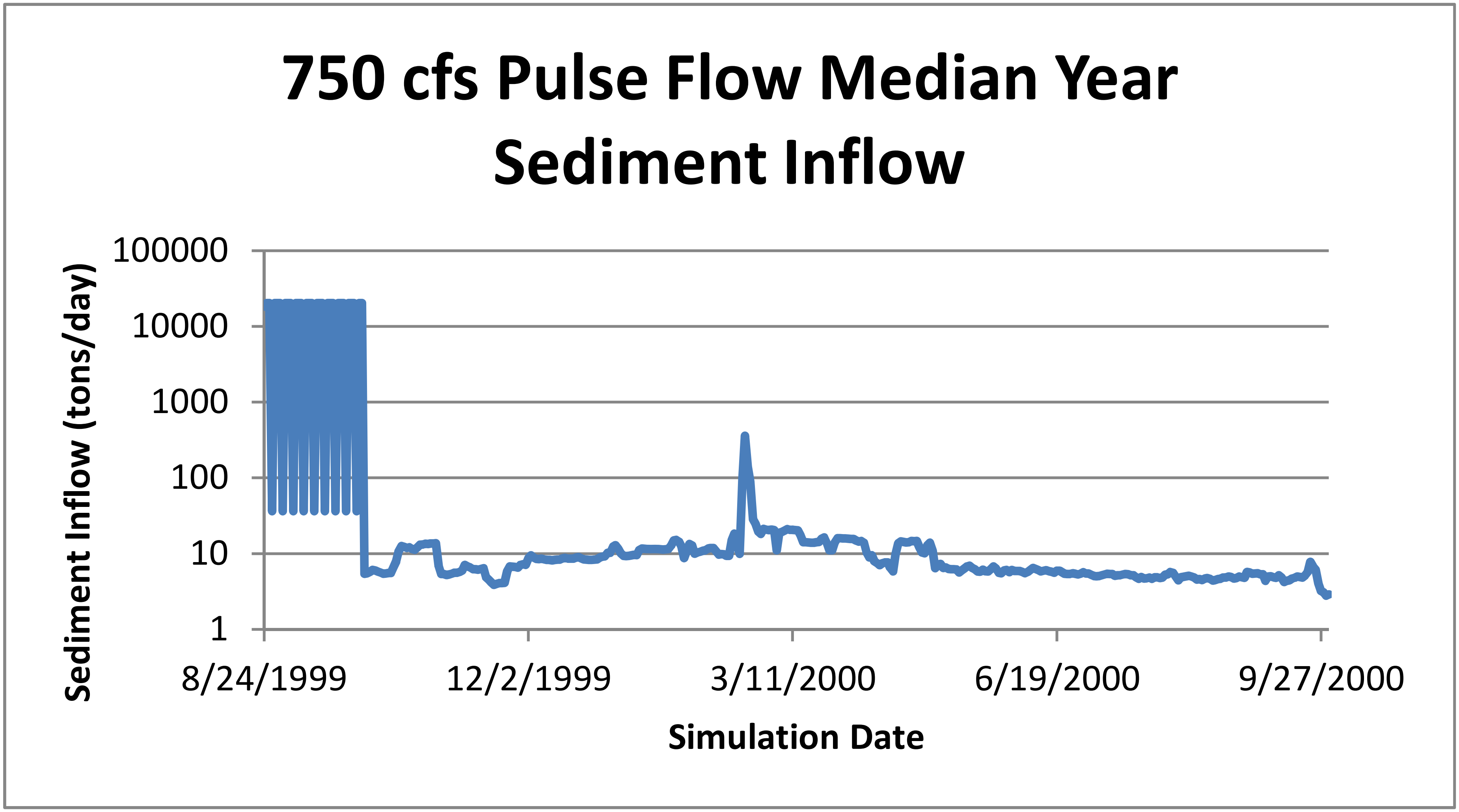

750 cfs Pulse Flow Median Year
Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
8/24/1999
12/2/1999
3/11/2000
6/19/2000
9/27/2000
Simulation Date

Figure B.B.45

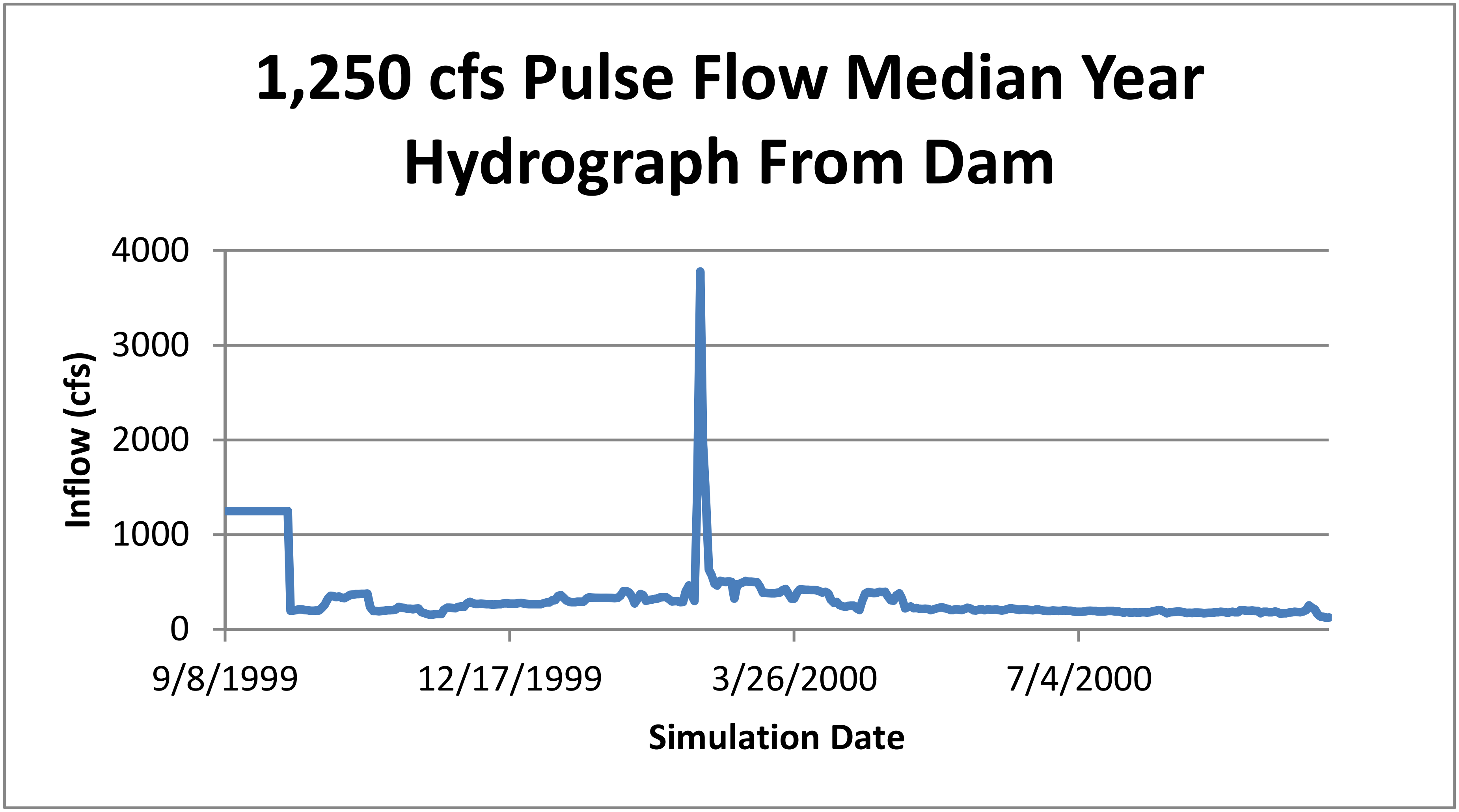

1,250 cfs Pulse Flow Median Year Hydrograph From Dam
Inflow (cfs)
4000
3000
2000
1000
0
9/8/1999
12/17/1999
3/26/2000
7/4/2000
Simulation Date

Figure B.B.46

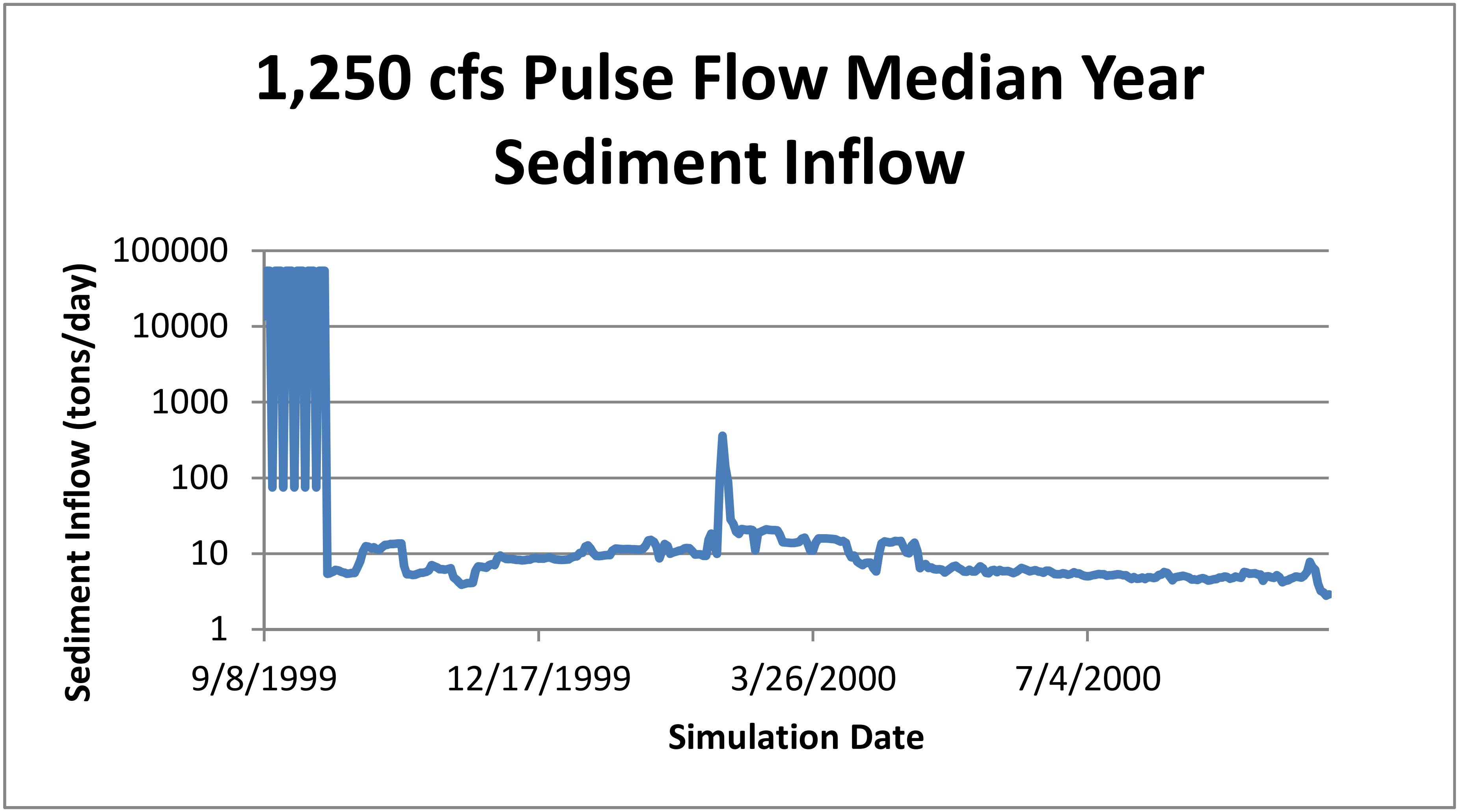
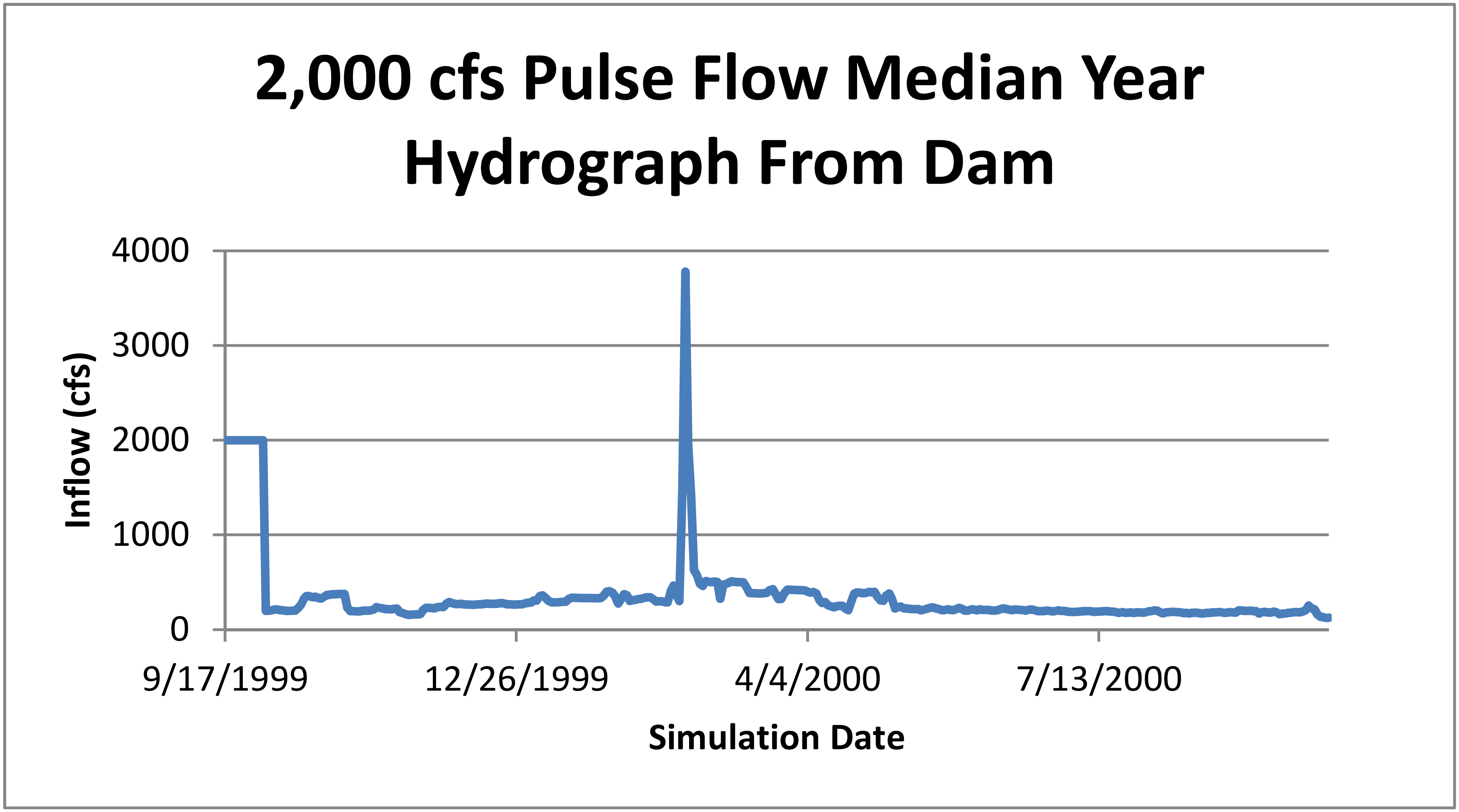

1,250 cfs Pulse Flow Median Year
Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
9/8/1999
12/17/1999
3/26/2000
7/4/2000
Simulation Date

Figure B.B.47



2,000 cfs Pulse Flow Median Year Hydrograph From Dam
Inflow (cfs)
4000
3000
2000
1000
0
9/17/1999
12/26/1999
4/4/2000
7/13/2000
Simulation Date

Figure B.B.48

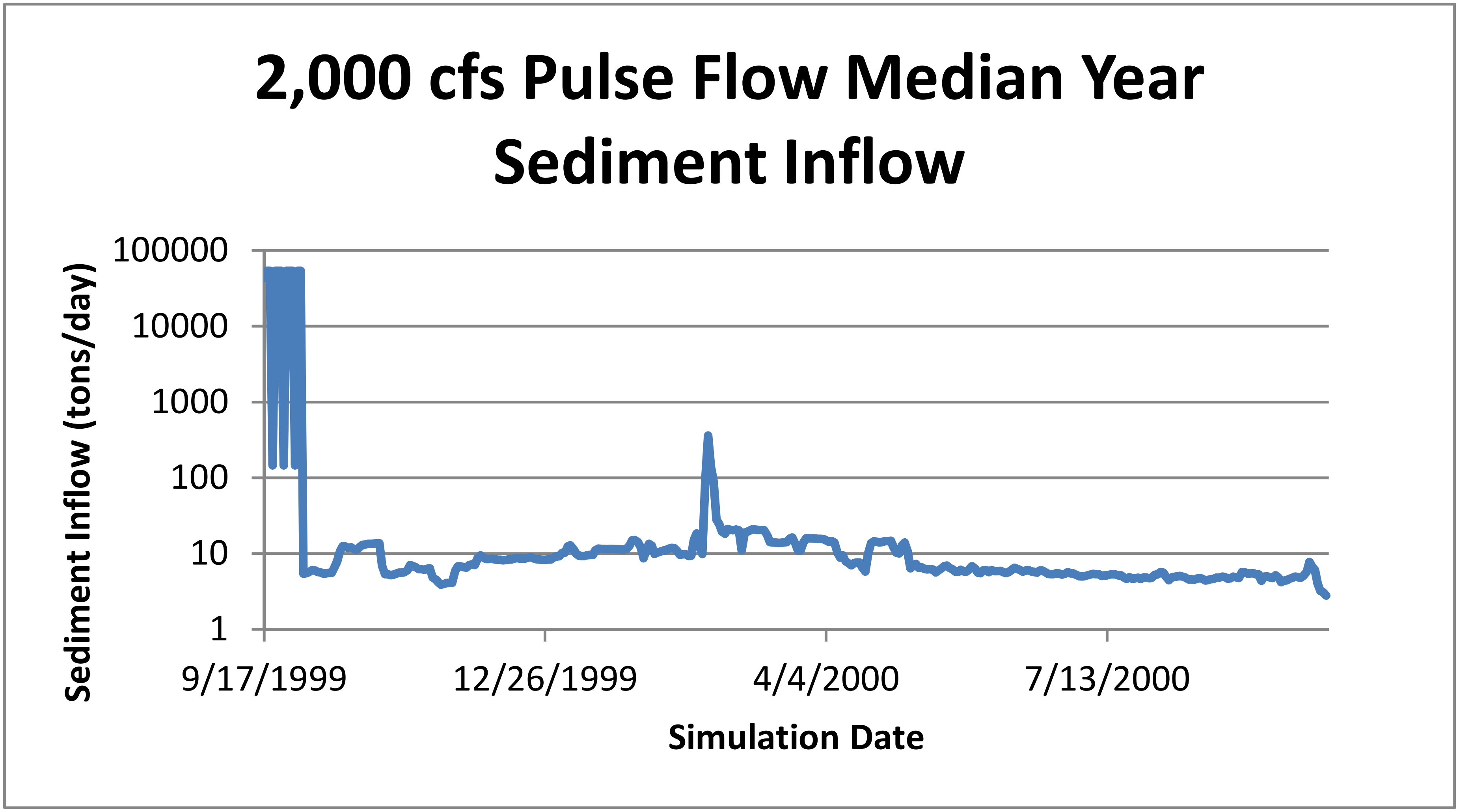

2,000 cfs Pulse Flow Median Year
Sediment Inflow
Sediment Inflow (tons/day)
100000
10000
1000
100
10
1
9/17/1999
12/26/1999
4/4/2000
7/13/2000
Simulation Date

Figure B.B.49

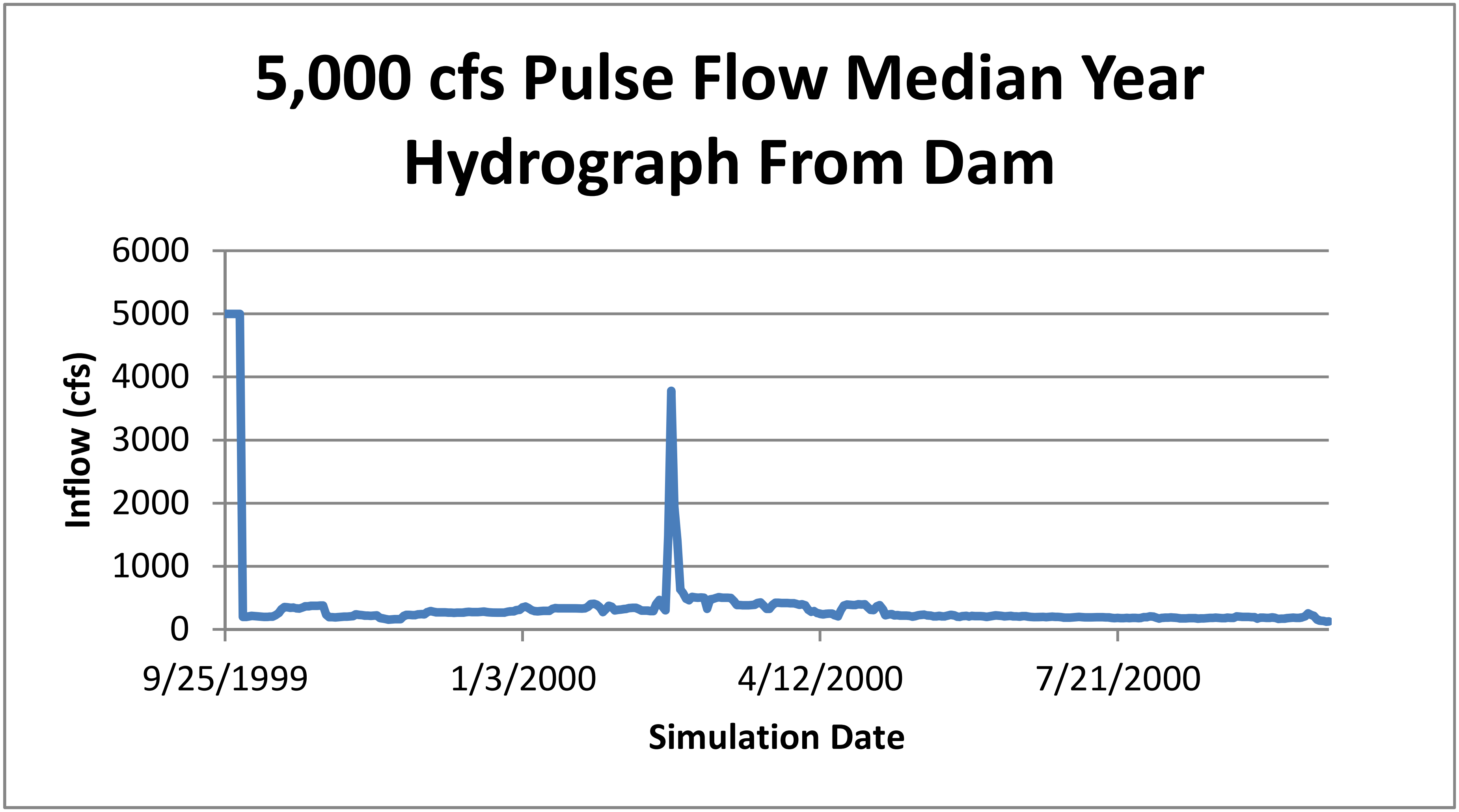

5,000 cfs Pulse Flow Median Year Hydrograph From Dam
Inflow (cfs)
6000
5000
4000
3000
2000
1000
0
9/25/1999
1/3/2000
4/12/2000
7/21/2000
Simulation Date

Figure B.B.50

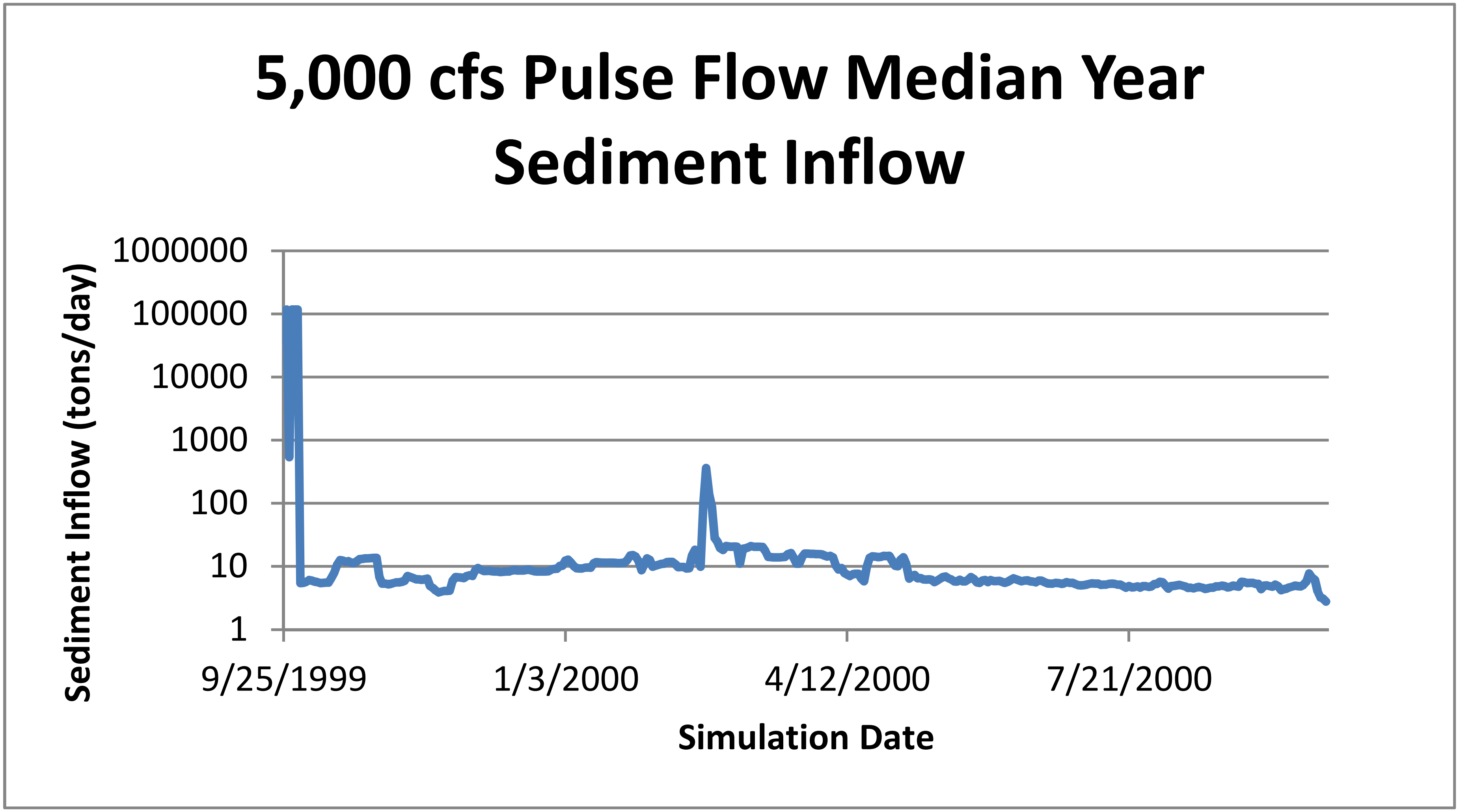

5,000 cfs Pulse Flow Median Year
Sediment Inflow
Sediment Inflow (tons/day)
1000000
100000
10000
1000
100
10
1
9/25/1999
1/3/2000
4/12/2000
7/21/2000
Simulation Date

Figure B.B.51

ATTACHMENT C
BASELINE ASSESSMENT FIGURES

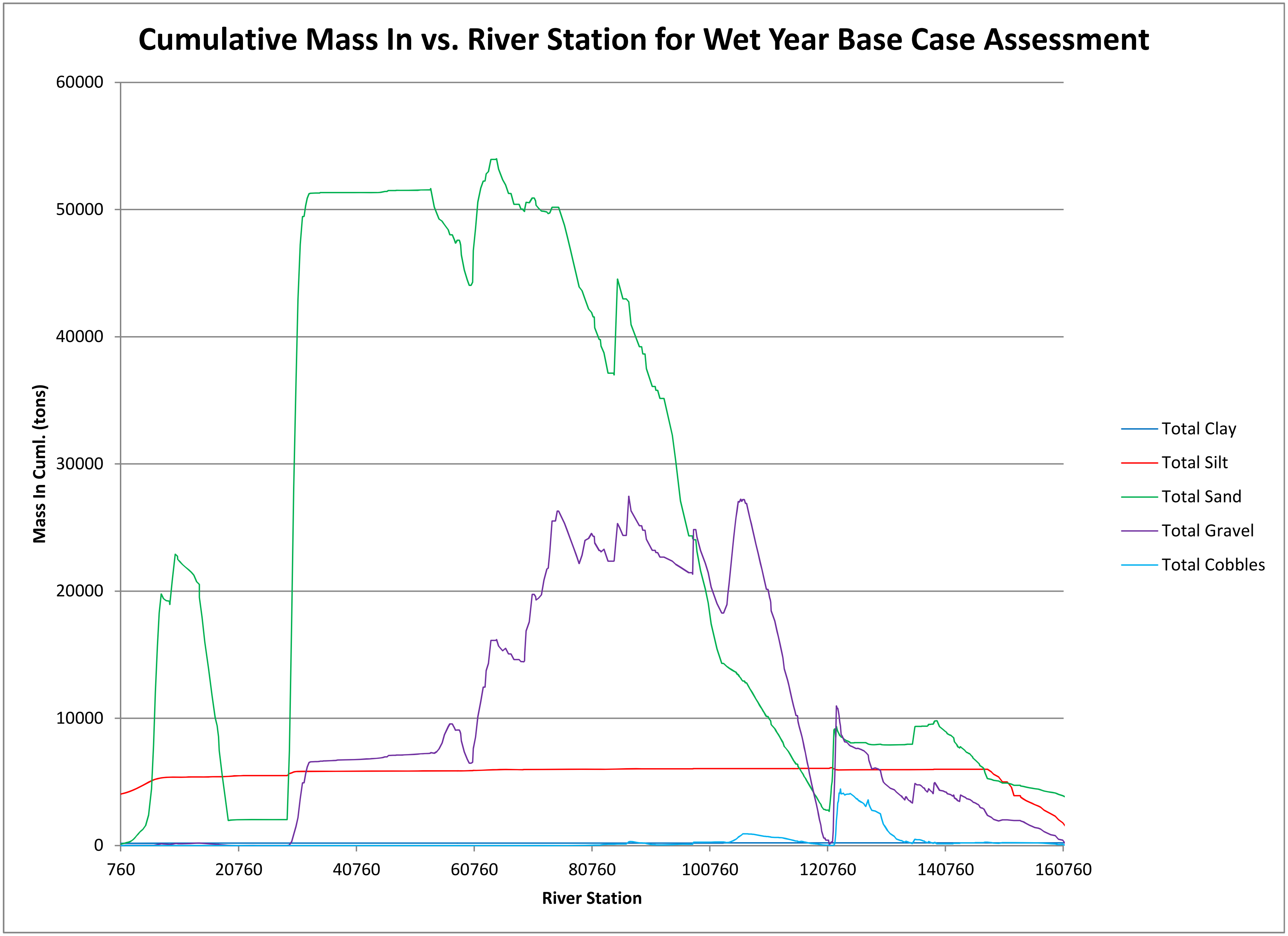

Cumulative Mass In vs. River Station for Wet Year Base Case Assessment
60000
50000
40000
30000
20000
10000
0
Mass In Cuml. (tons)
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Total Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.C.1

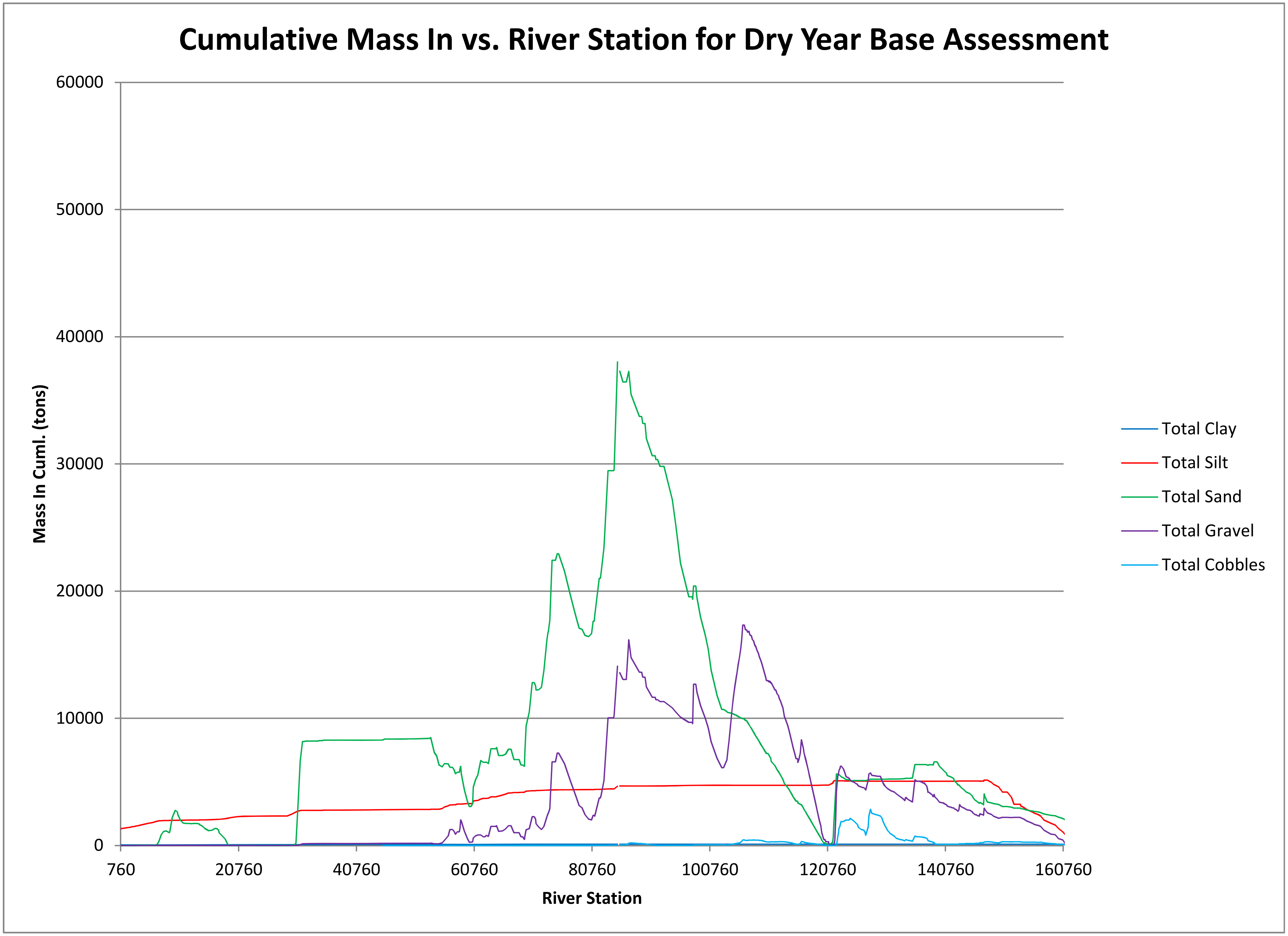

Cumulative Mass In vs. River Station for Dry Year Base Assessment
Mass In Cuml. (tons)
60000
50000
40000
30000
20000
10000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Total Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.C.2

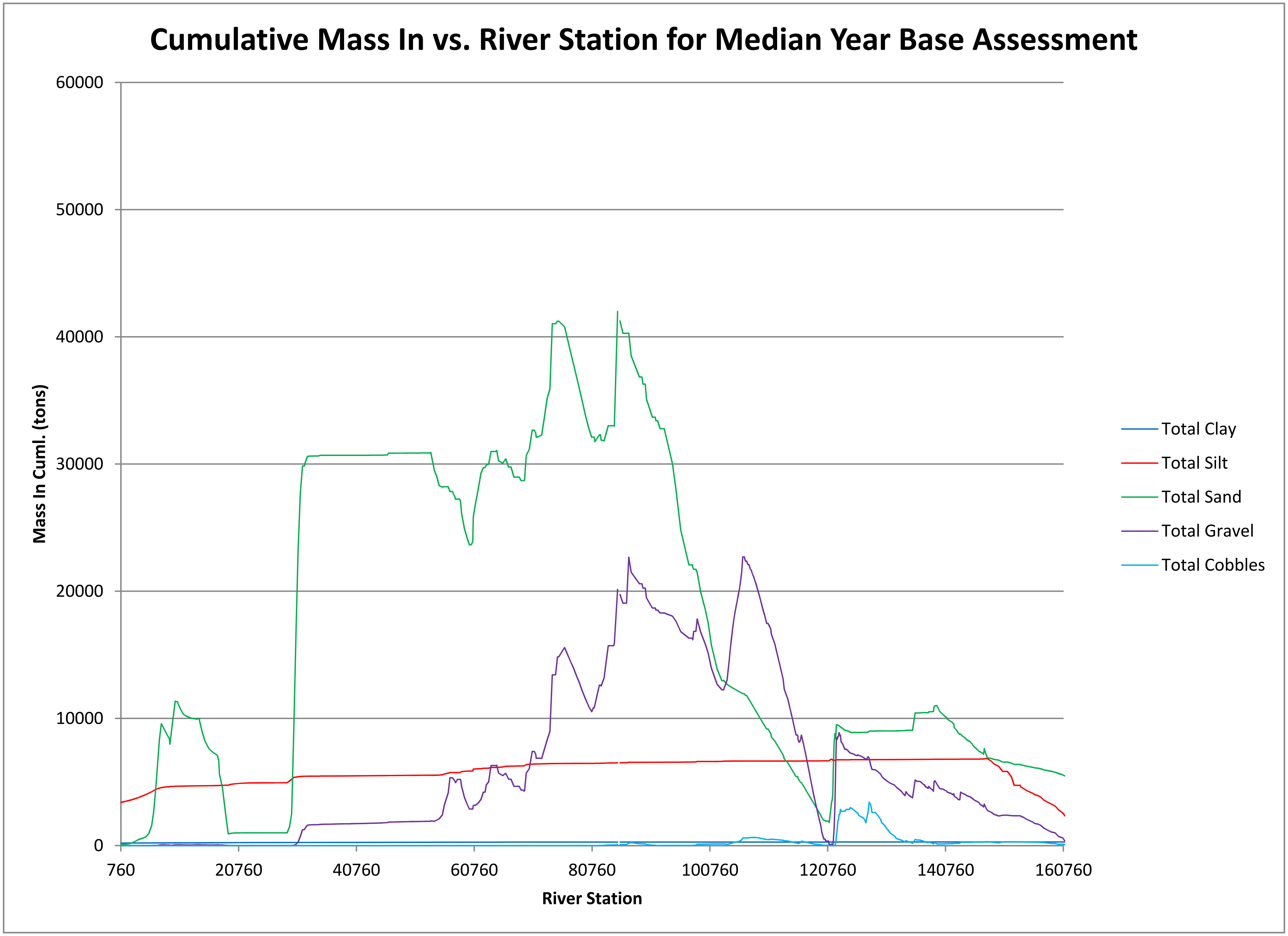

Cumulative Mass In vs. River Station for Median Year Base Assessment
60000
50000
40000
30000
20000
10000
0
Mass In Cuml. (tons)
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Total Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.C.3

ATTACHMENT D
PREDICTIVE ASSESSMENT FIGURES

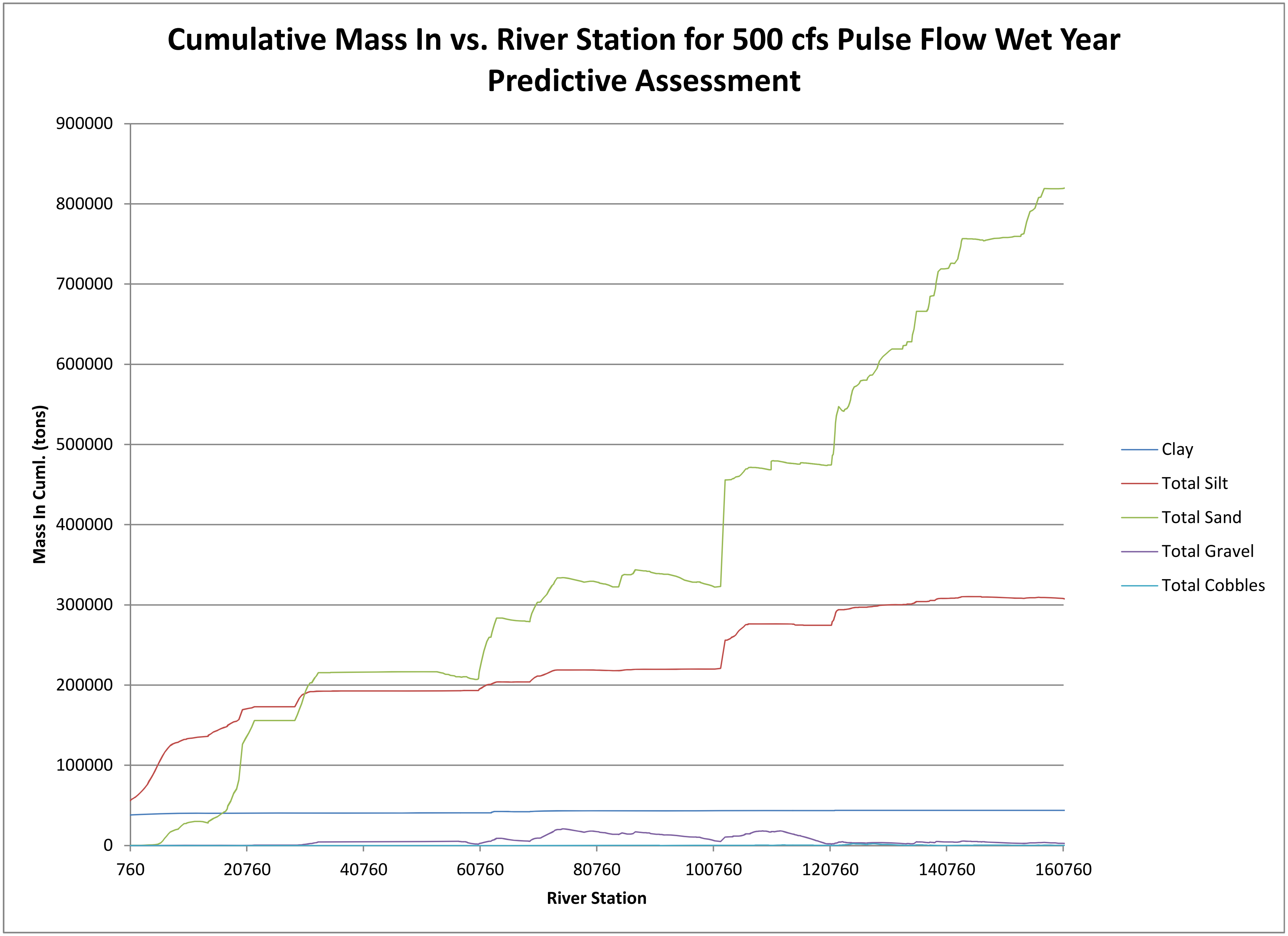

Cumulative Mass In vs. River Station for 500 cfs Pulse Flow Wet Year Predictive Assessment
Mass In Cuml. (tons)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.1

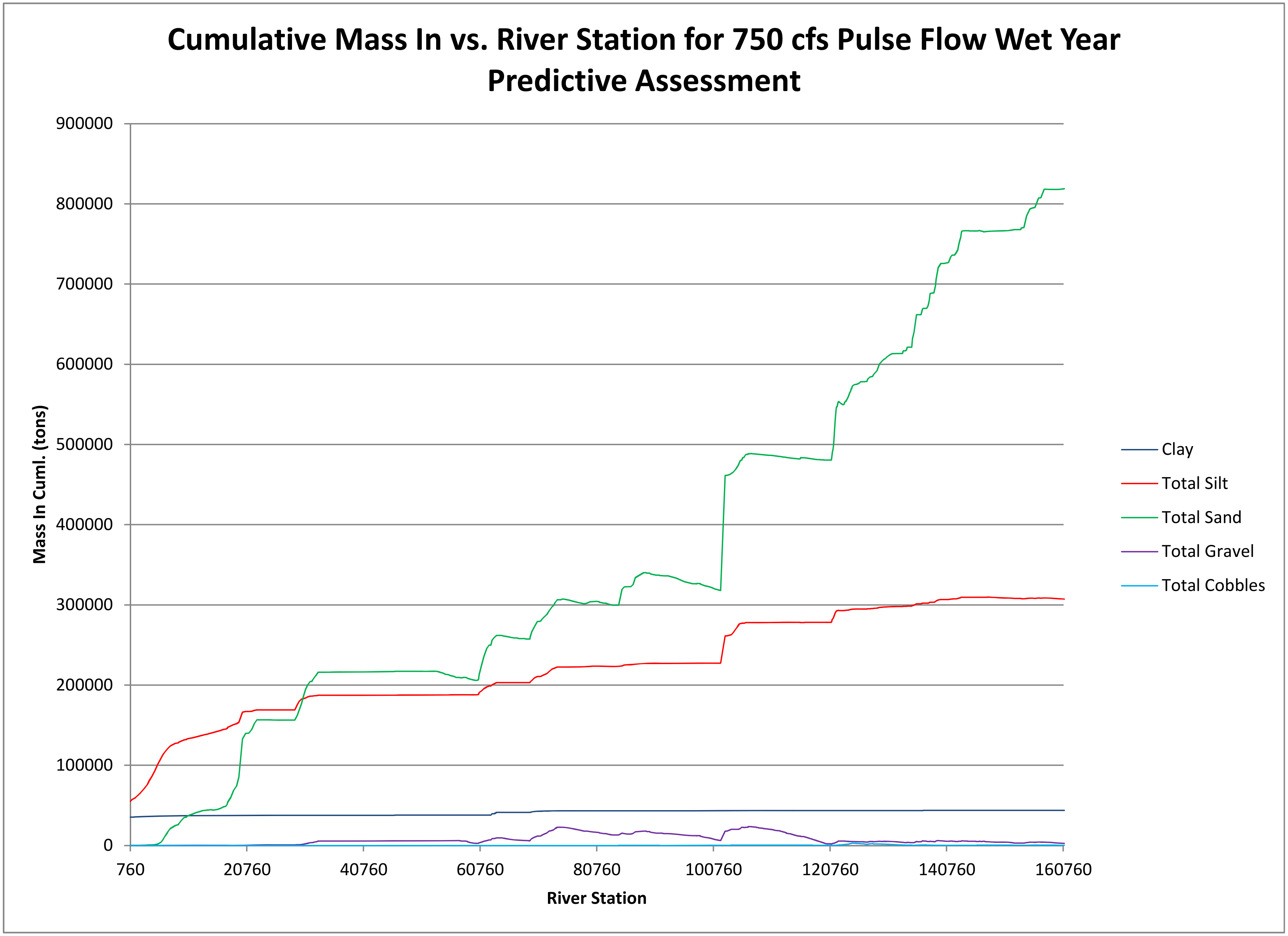

Cumulative Mass In vs. River Station for 750 cfs Pulse Flow Wet Year Predictive Assessment
Mass In Cuml. (tons)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.2

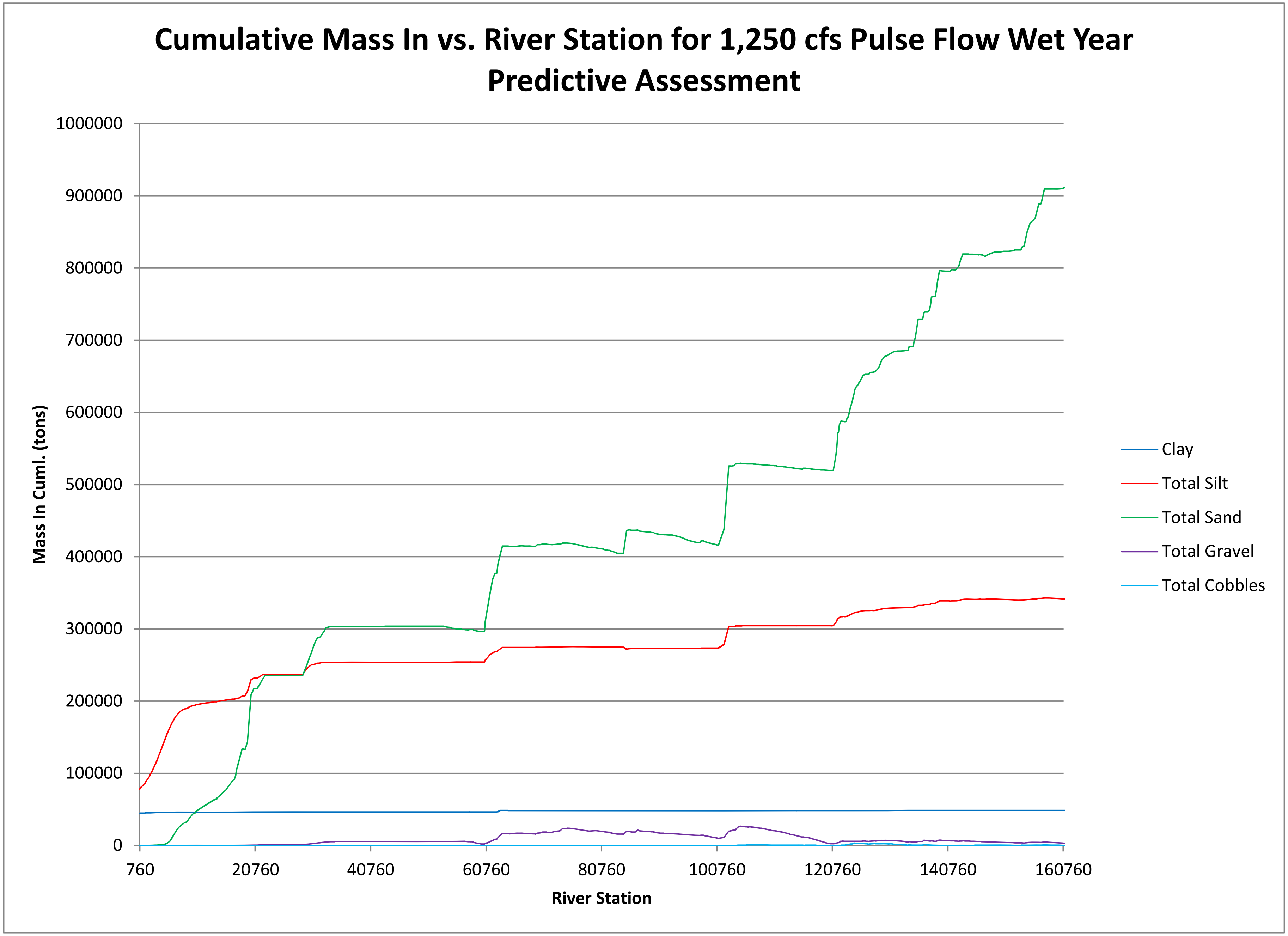

Cumulative Mass In vs. River Station for 1,250 cfs Pulse Flow Wet Year Predictive Assessment

Figure B.D.3

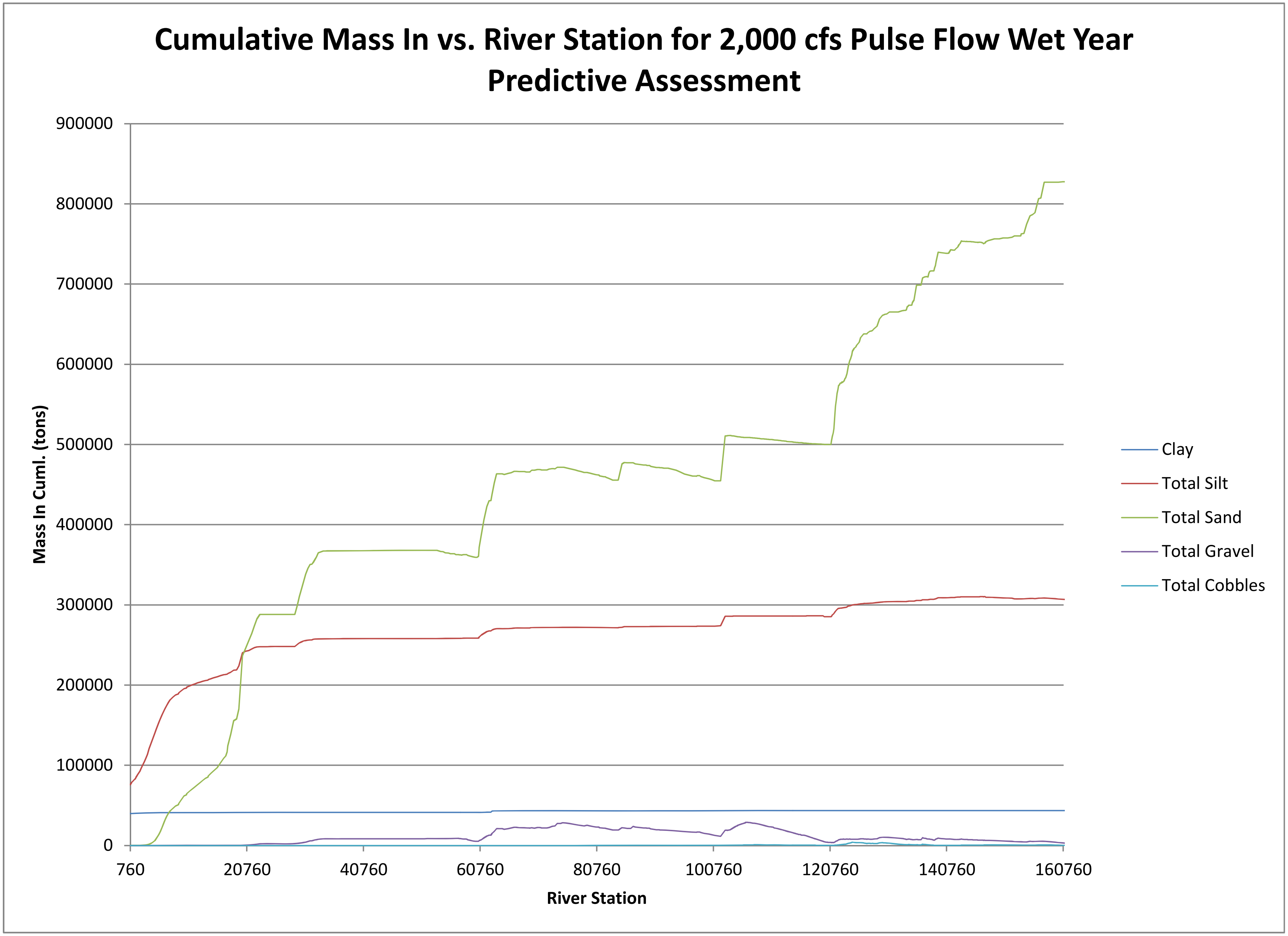

Cumulative Mass In vs. River Station for 2,000 cfs Pulse Flow Wet Year Predictive Assessment
Mass In Cuml. (tons)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.4

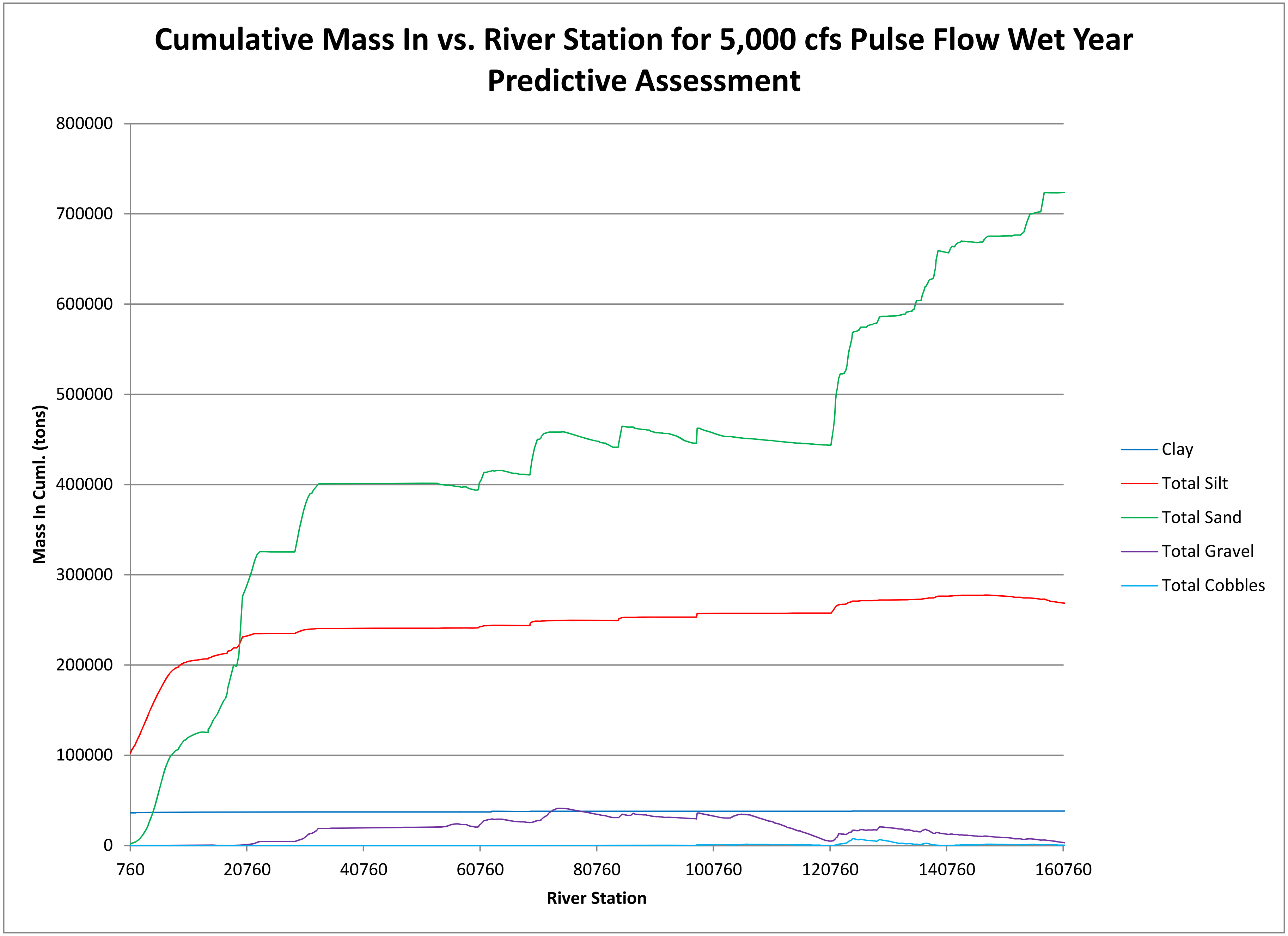

Cumulative Mass In vs. River Station for 5,000 cfs Pulse Flow Wet Year
Predictive Assessment
Mass In Cuml. (tons)
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.5

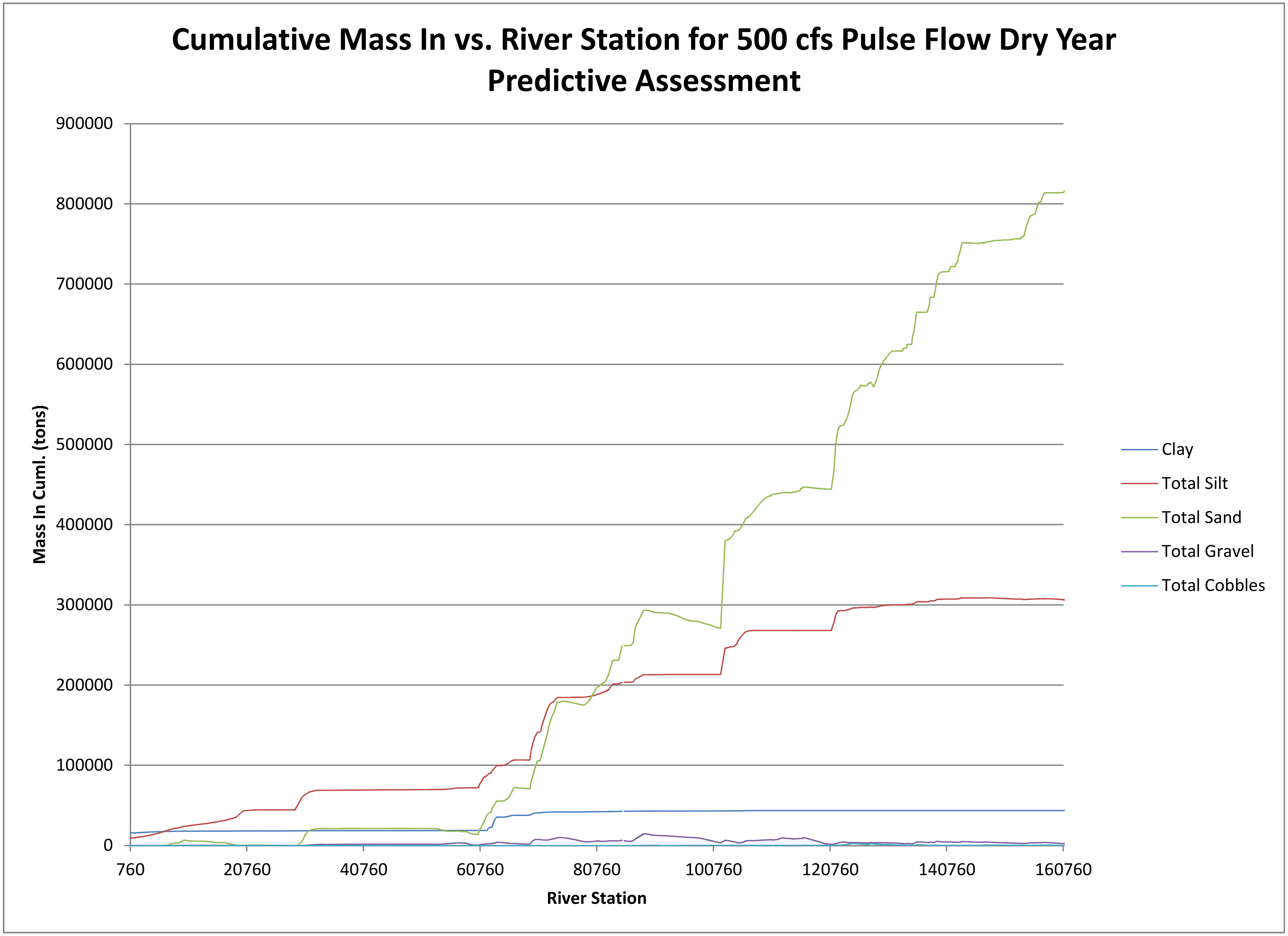
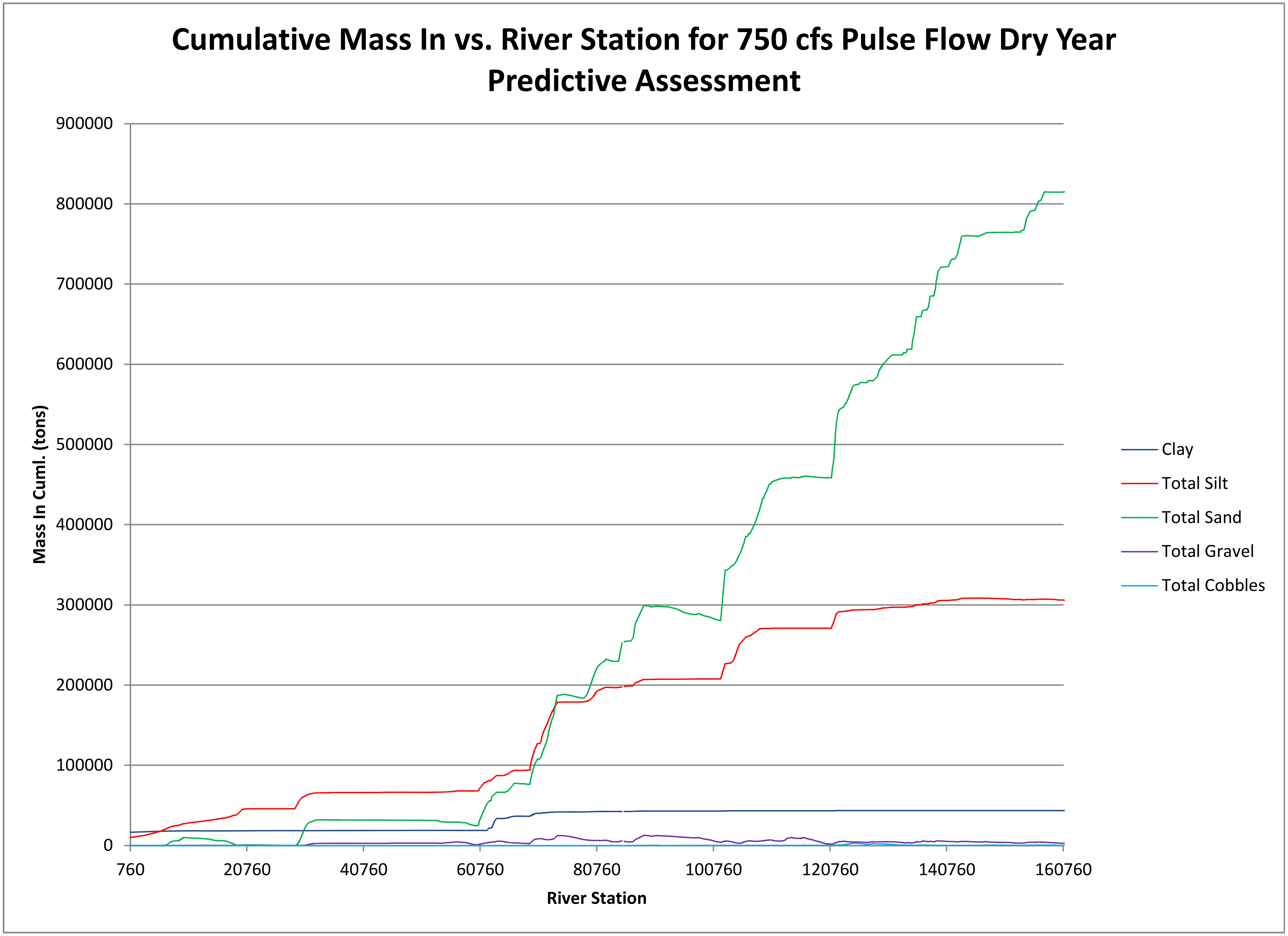

Cumulative Mass In vs. River Station for 500 cfs Pulse Flow Dry Year Predictive Assessment
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Mass In Cuml. (tons)
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.6



Cumulative Mass In vs. River Station for 750 cfs Pulse Flow Dry Year Predictive Assessment
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Mass In Cuml. (tons)
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.7

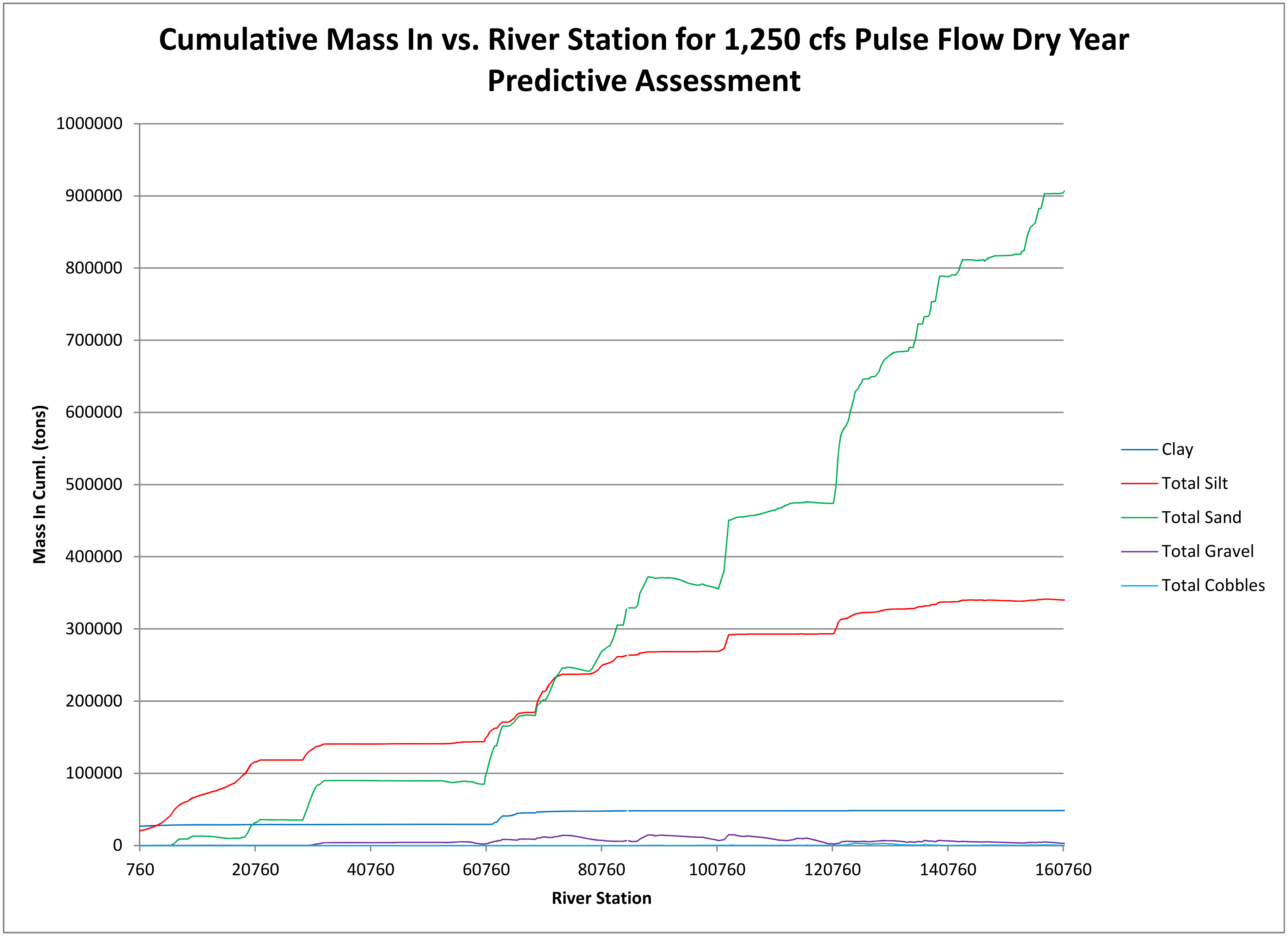

Cumulative Mass In vs. River Station for 1,250 cfs Pulse Flow Dry Year Predictive Assessment
Mass In Cuml. (tons)
1000000
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.8

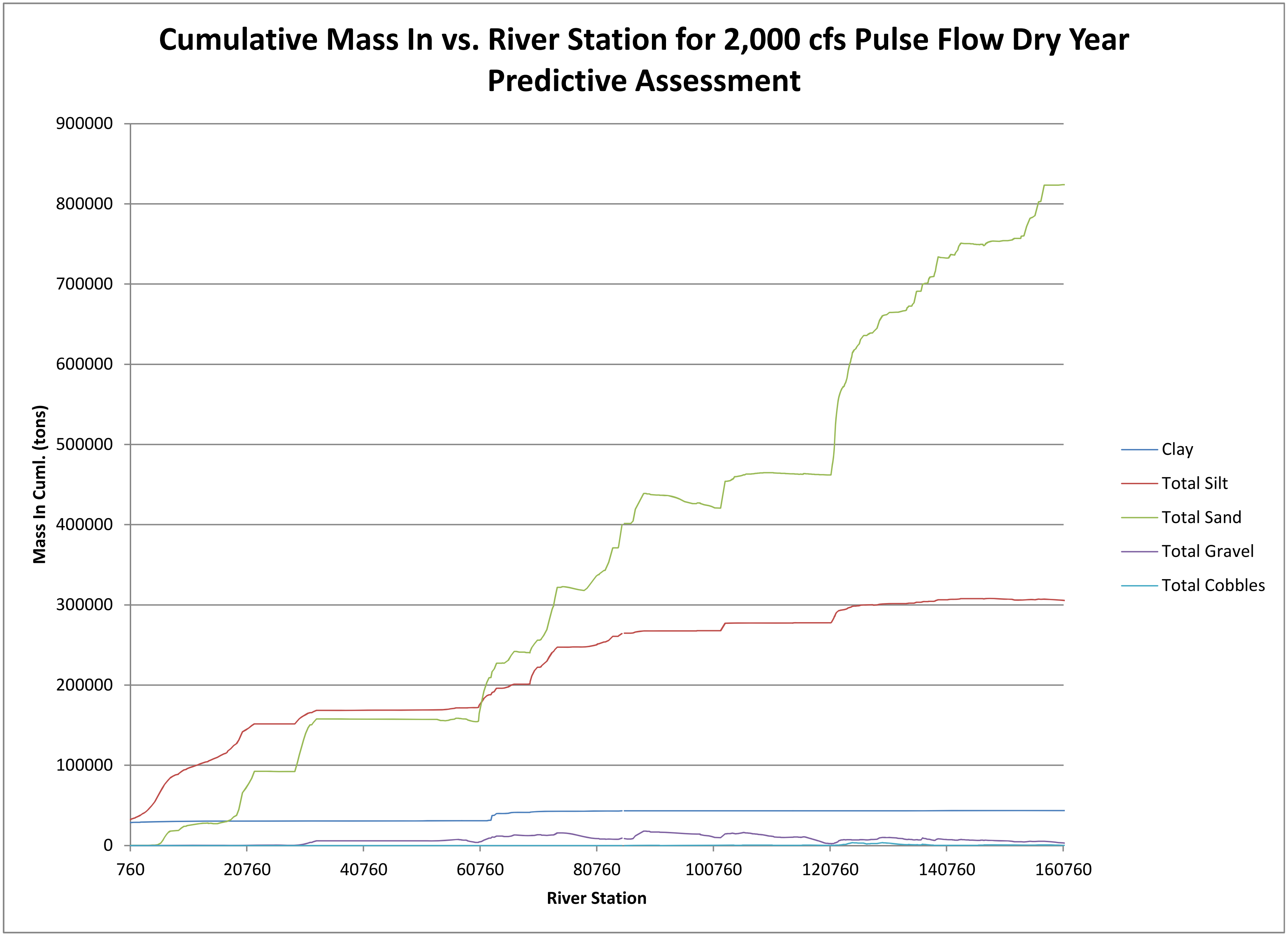

Cumulative Mass In vs. River Station for 2,000 cfs Pulse Flow Dry Year Predictive Assessment
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Mass In Cuml. (tons)
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.9

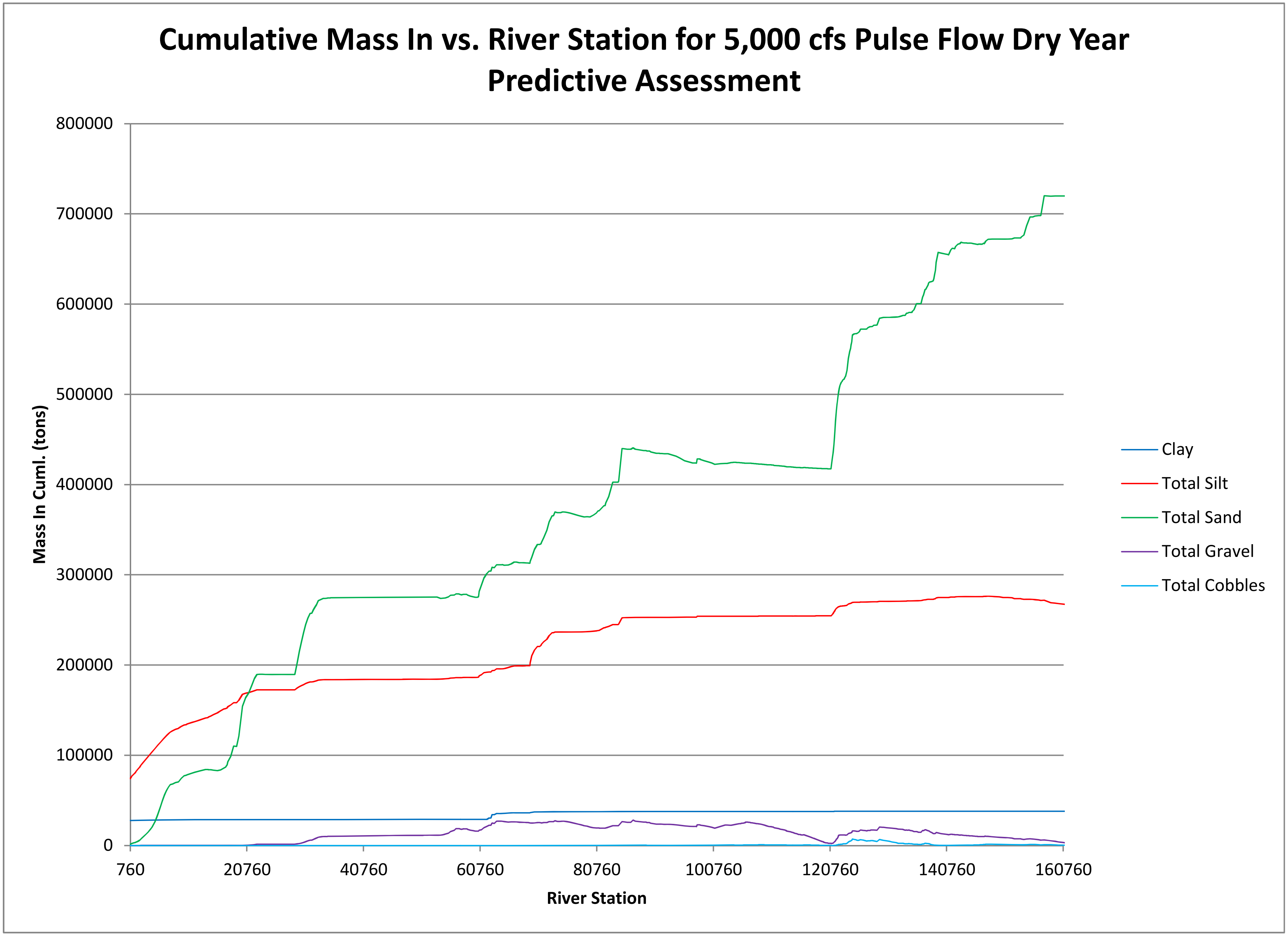

Cumulative Mass In vs. River Station for 5,000 cfs Pulse Flow Dry Year Predictive Assessment
Mass In Cuml. (tons)
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.10

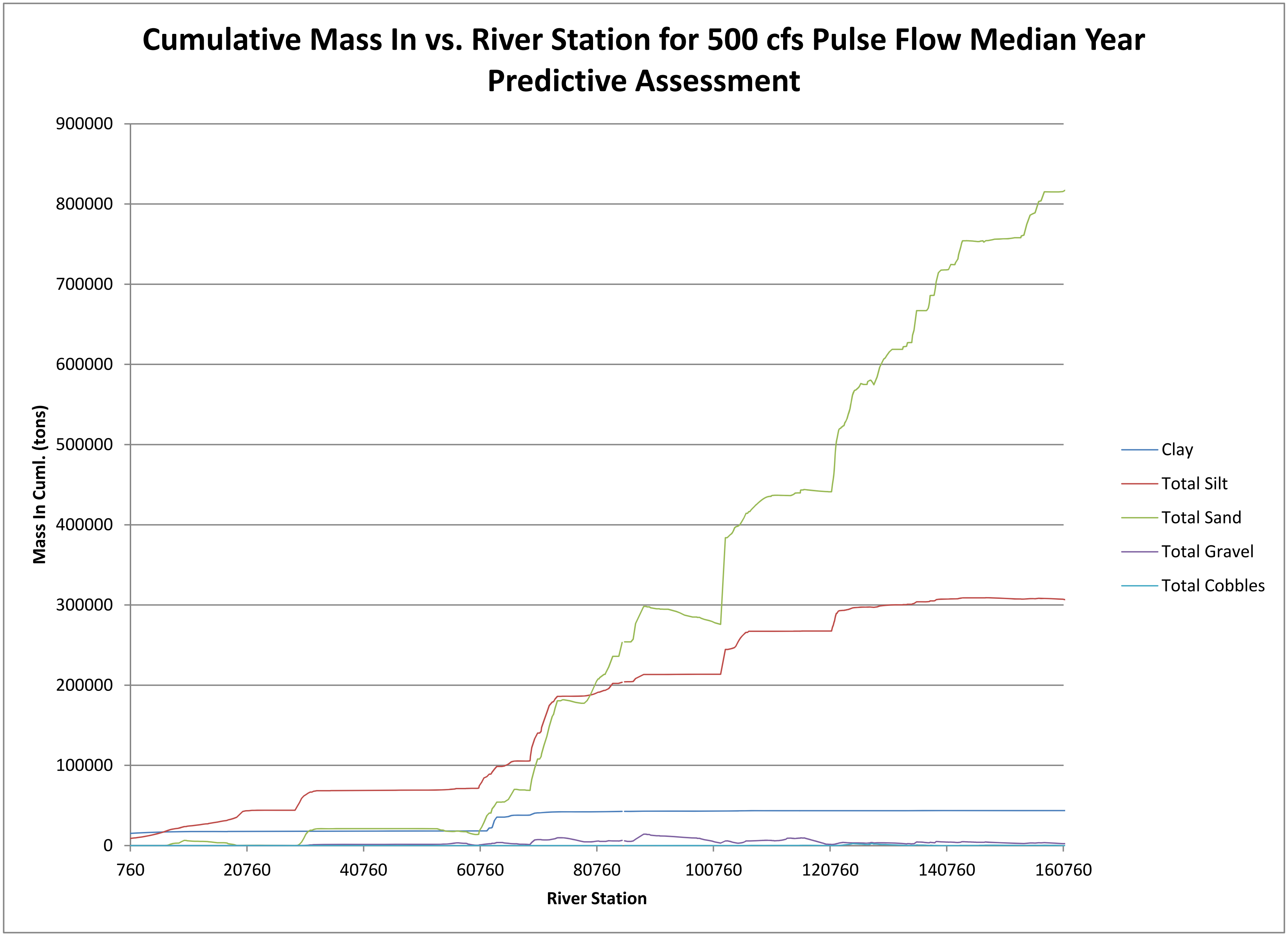

Cumulative Mass In vs. River Station for 500 cfs Pulse Flow Median Year Predictive Assessment
Mass In Cuml. (tons)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.11

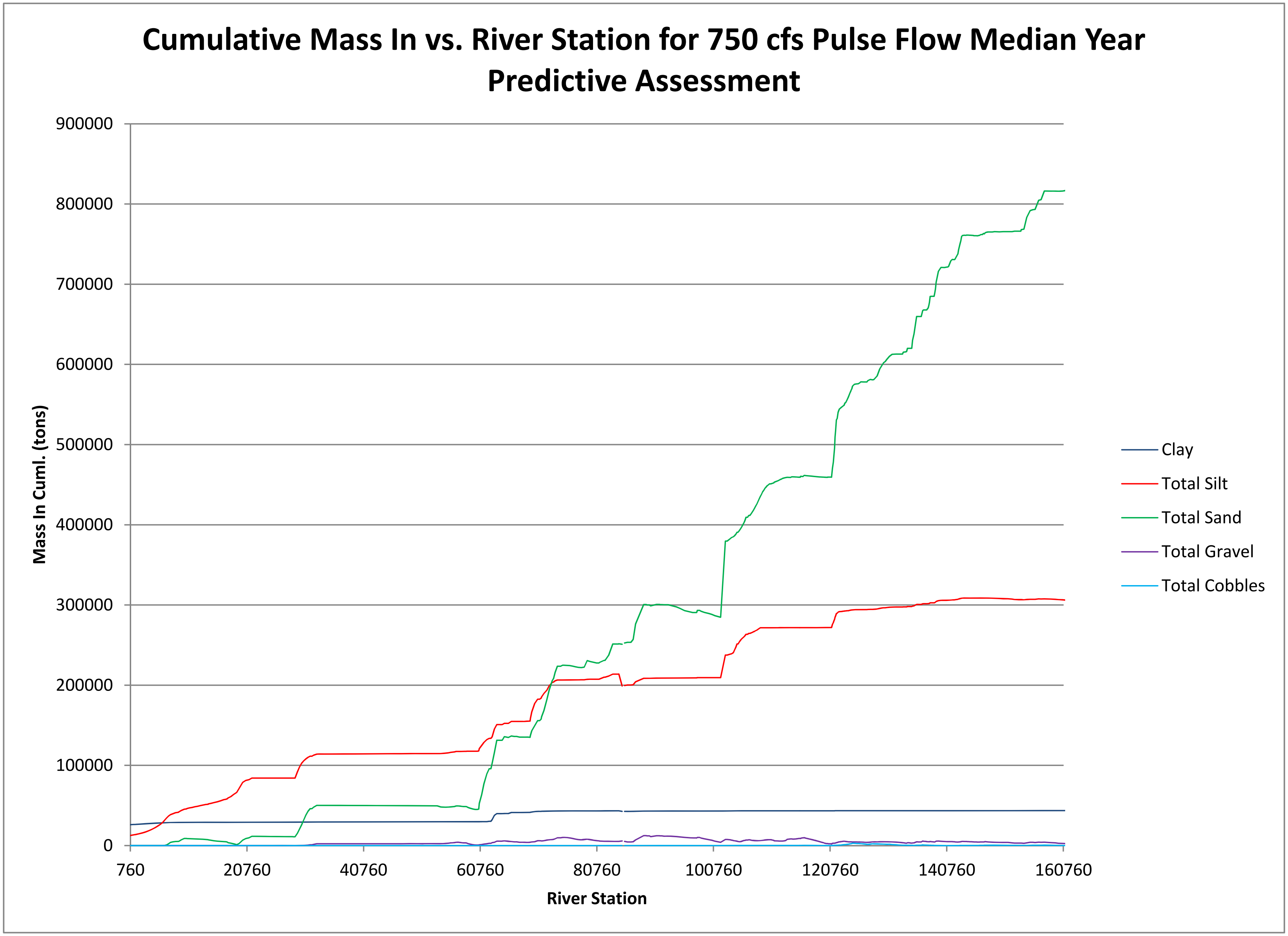

Cumulative Mass In vs. River Station for 750 cfs Pulse Flow Median Year Predictive Assessment
Mass In Cuml. (tons)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.12

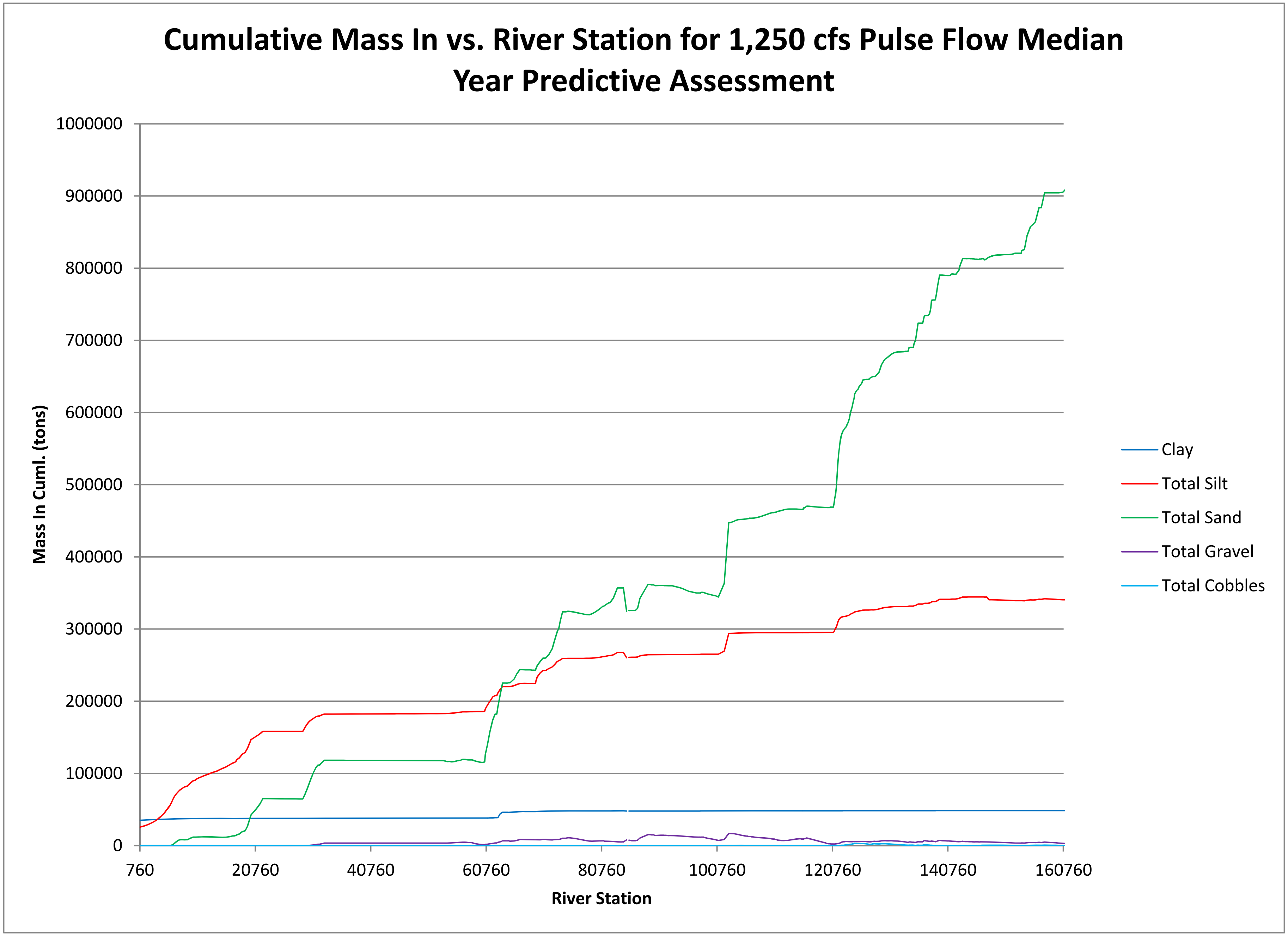

Cumulative Mass In vs. River Station for 1,250 cfs Pulse Flow Median Year Predictive Assessment
1000000
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Mass In Cuml. (tons)
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.13

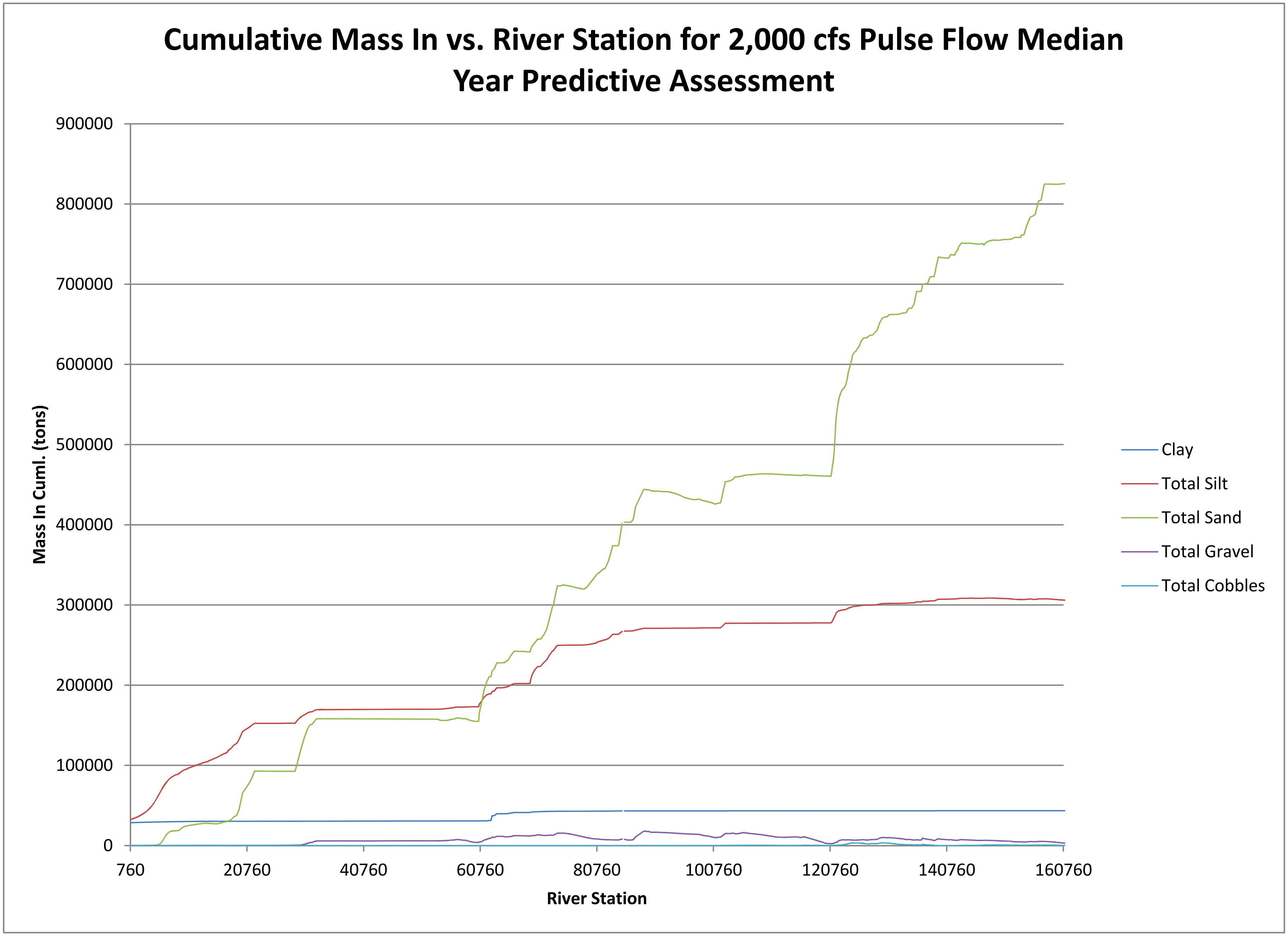

Cumulative Mass In vs. River Station for 2,000 cfs Pulse Flow Median Year Predictive Assessment
Mass In Cuml. (tons)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.14

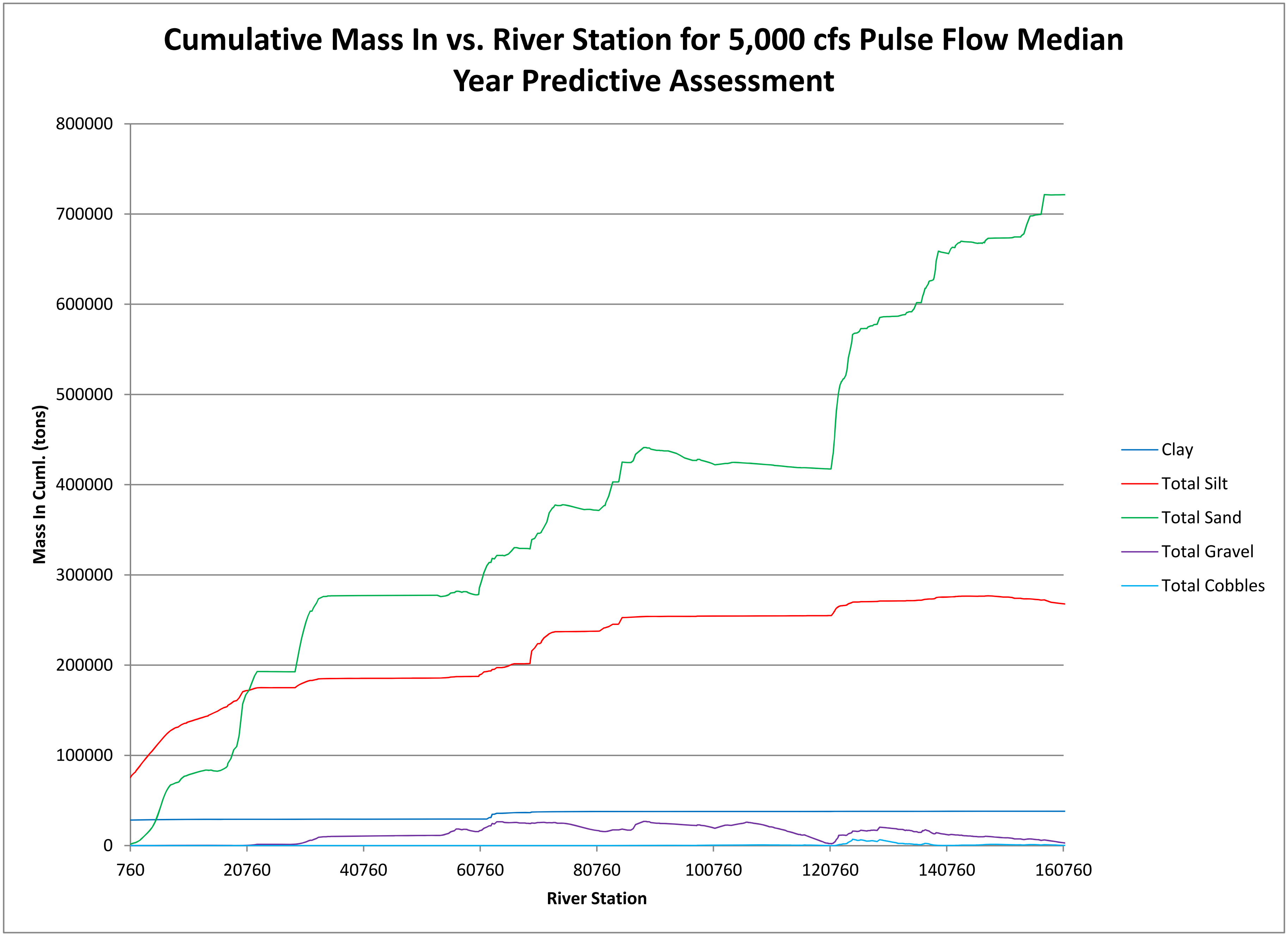
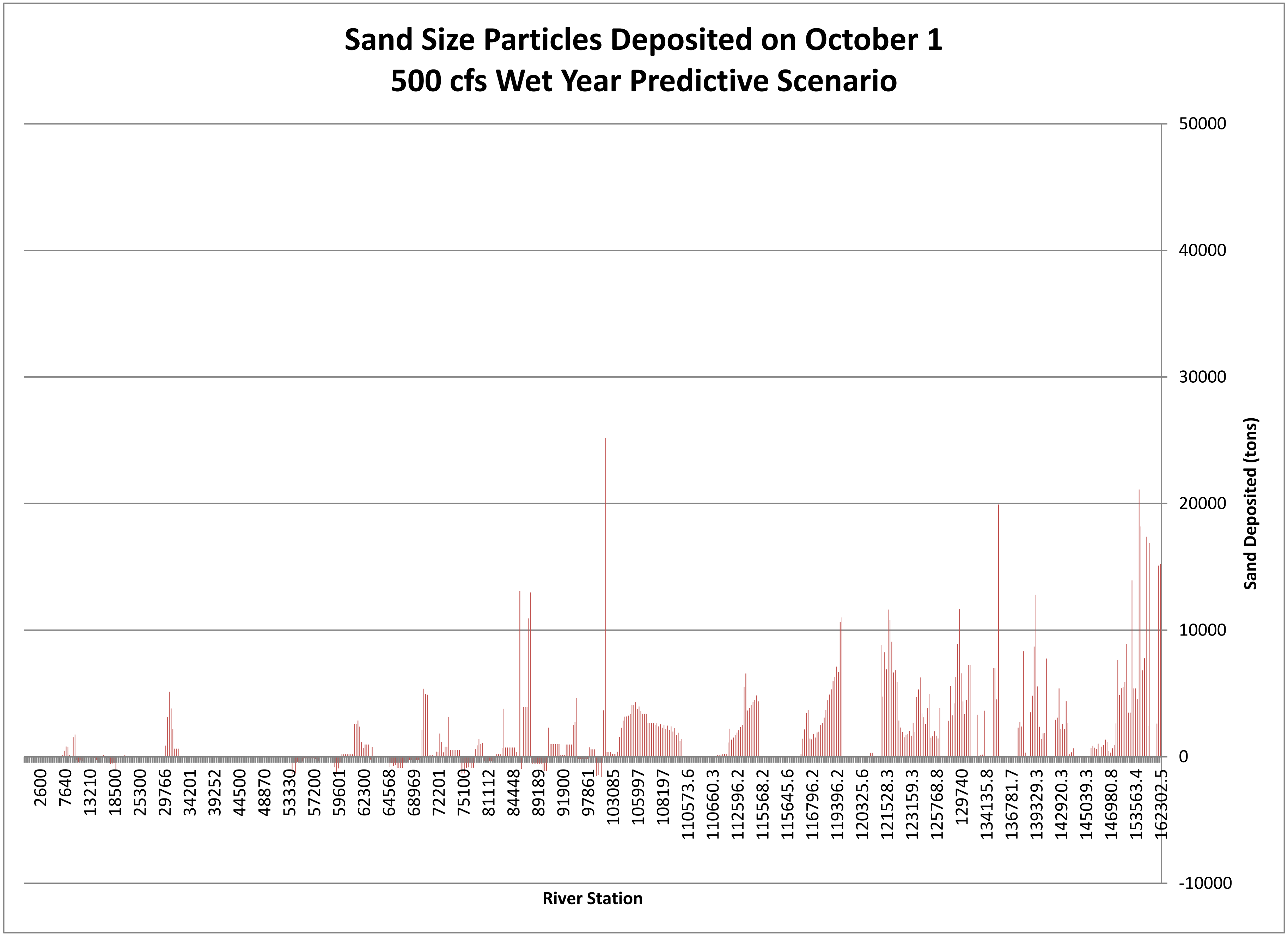

Cumulative Mass In vs. River Station for 5,000 cfs Pulse Flow Median Year Predictive Assessment
Mass In Cuml. (tons)
800000
700000
600000
500000
400000
300000
200000
100000
0
760
20760
40760
60760
80760
100760
120760
140760
160760
River Station
Clay
Total Silt
Total Sand
Total Gravel
Total Cobbles

Figure B.D.15



Sand Size Particles Deposited on October 1
500 cfs Wet Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.16

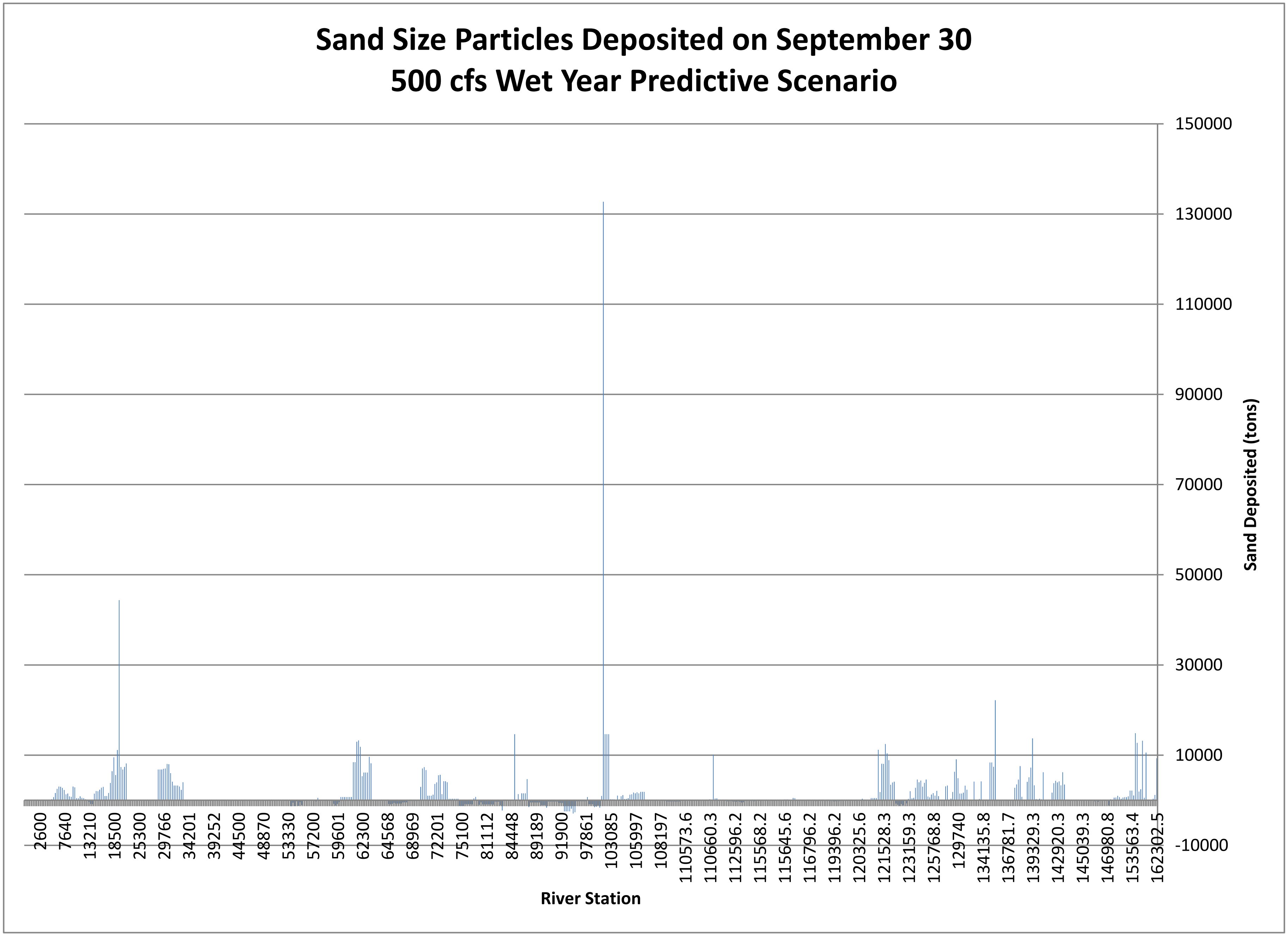

Sand Size Particles Deposited on September 30
500 cfs Wet Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.17

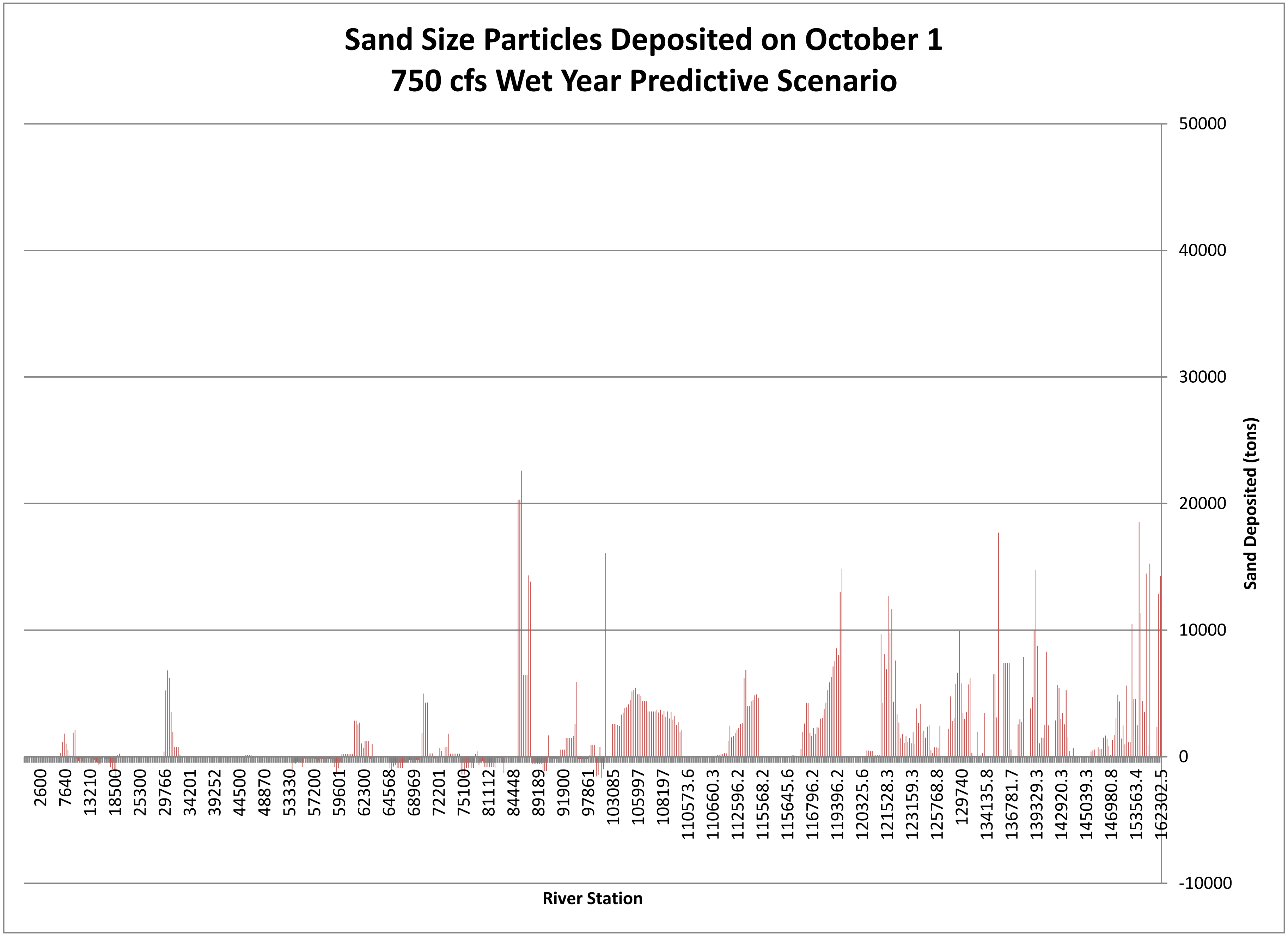

Sand Size Particles Deposited on October 1
750 cfs Wet Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.18

Sand Size Particles Deposited on September 30
750 cfs Wet Year Predictive Scenario

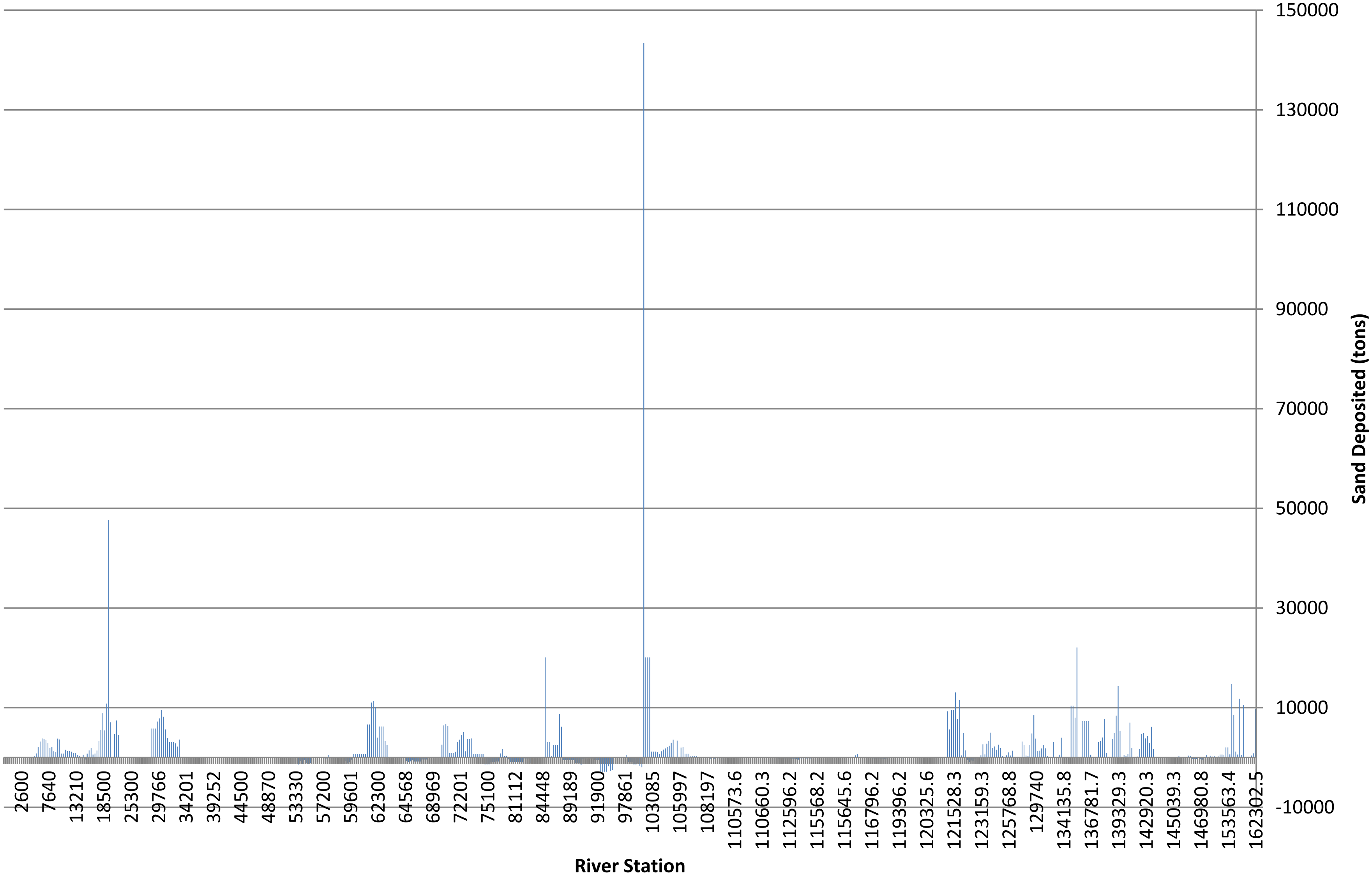
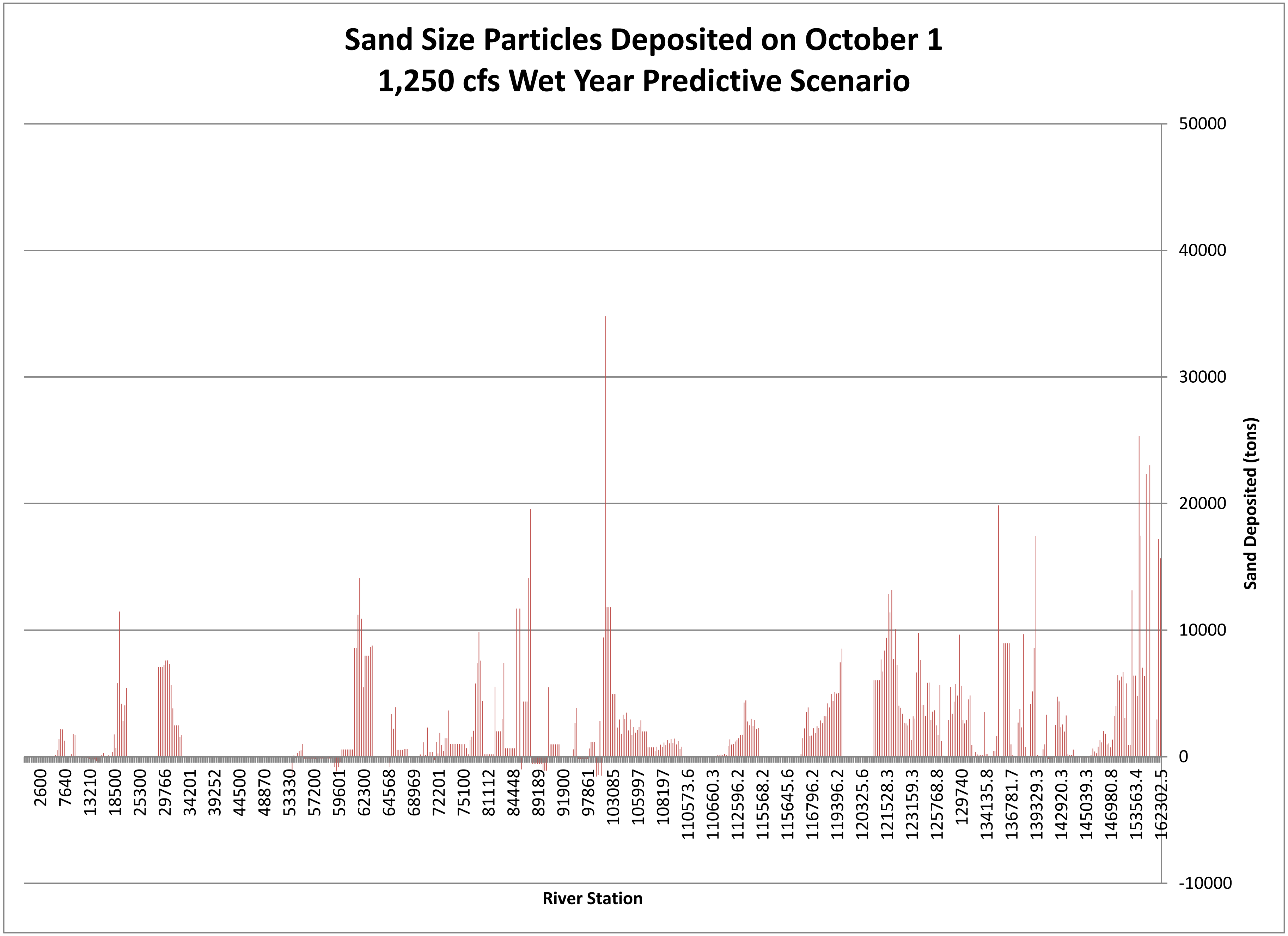
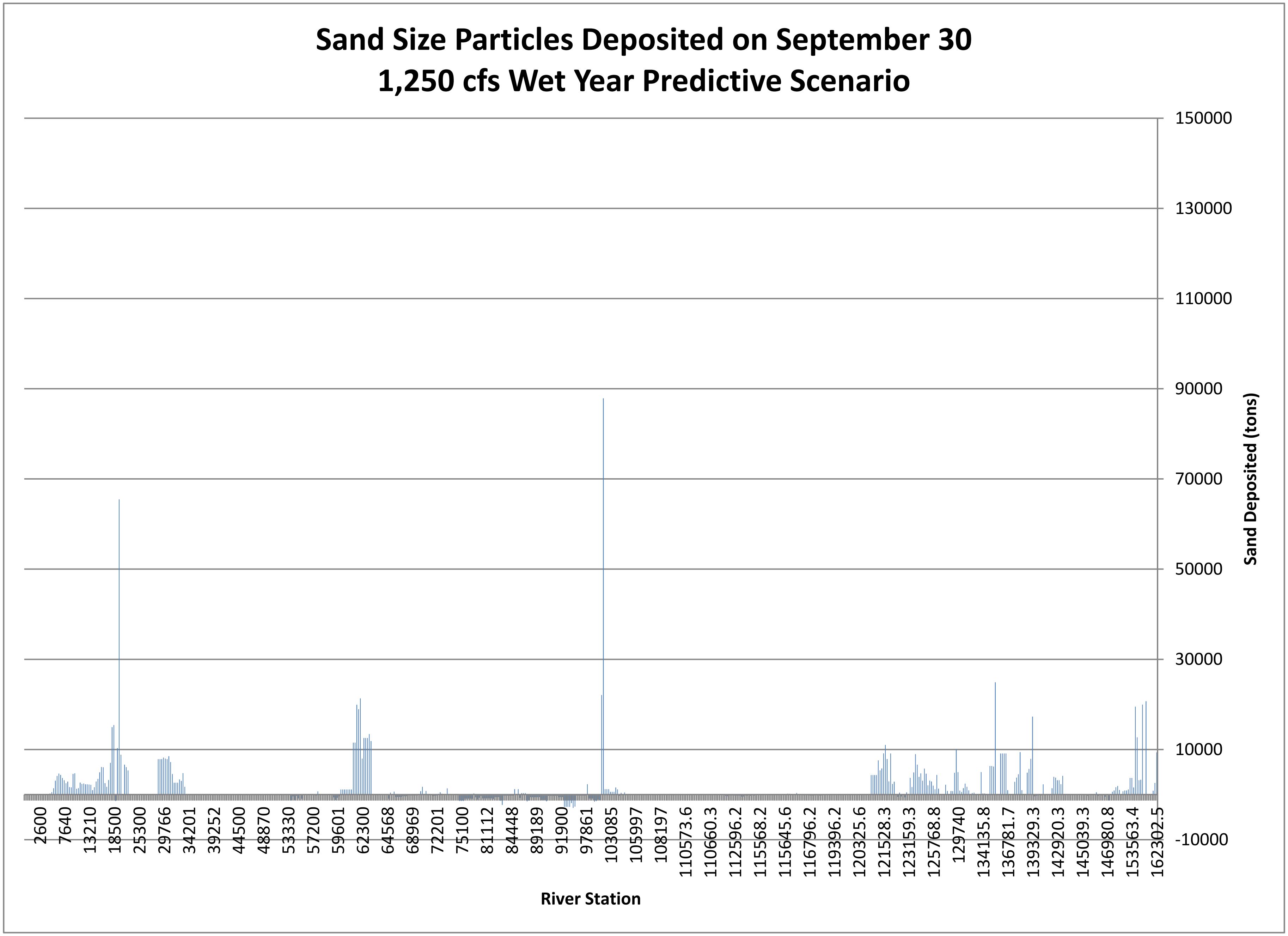


Figure B.D.19



Sand Size Particles Deposited on October 1
1,250 cfs Wet Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.20



Sand Size Particles Deposited on September 30
1,250 cfs Wet Year Predictive Scenario

Figure B.D.21

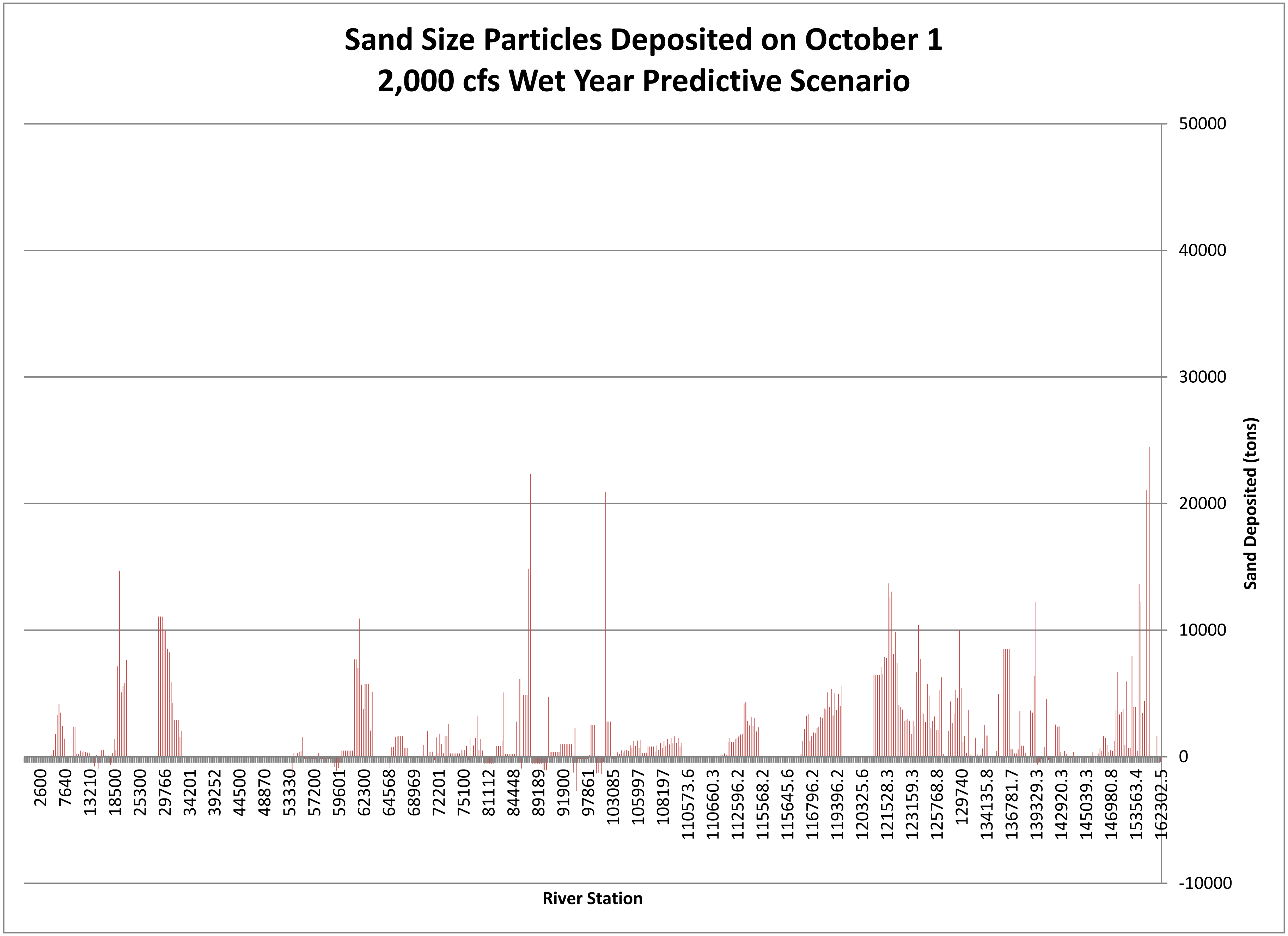
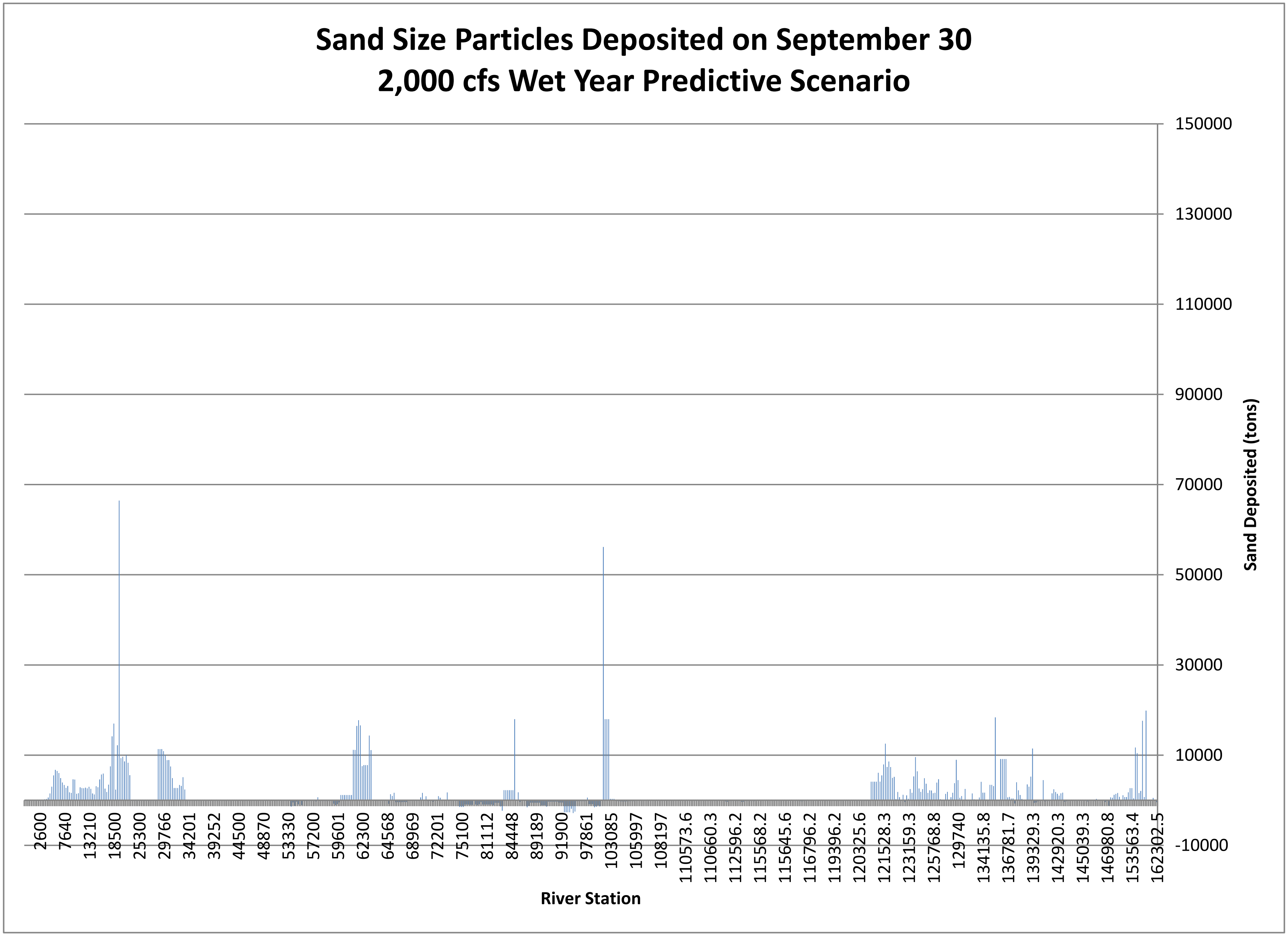

Sand Size Particles Deposited on October 1
2,000 cfs Wet Year Predictive Scenario
Sand Deposited (tons)
50000
40000
30000
20000
10000
0
-10000
River Station
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5

Figure B.D.22



Sand Size Particles Deposited on September 30
2,000 cfs Wet Year Predictive Scenario

Figure B.D.23

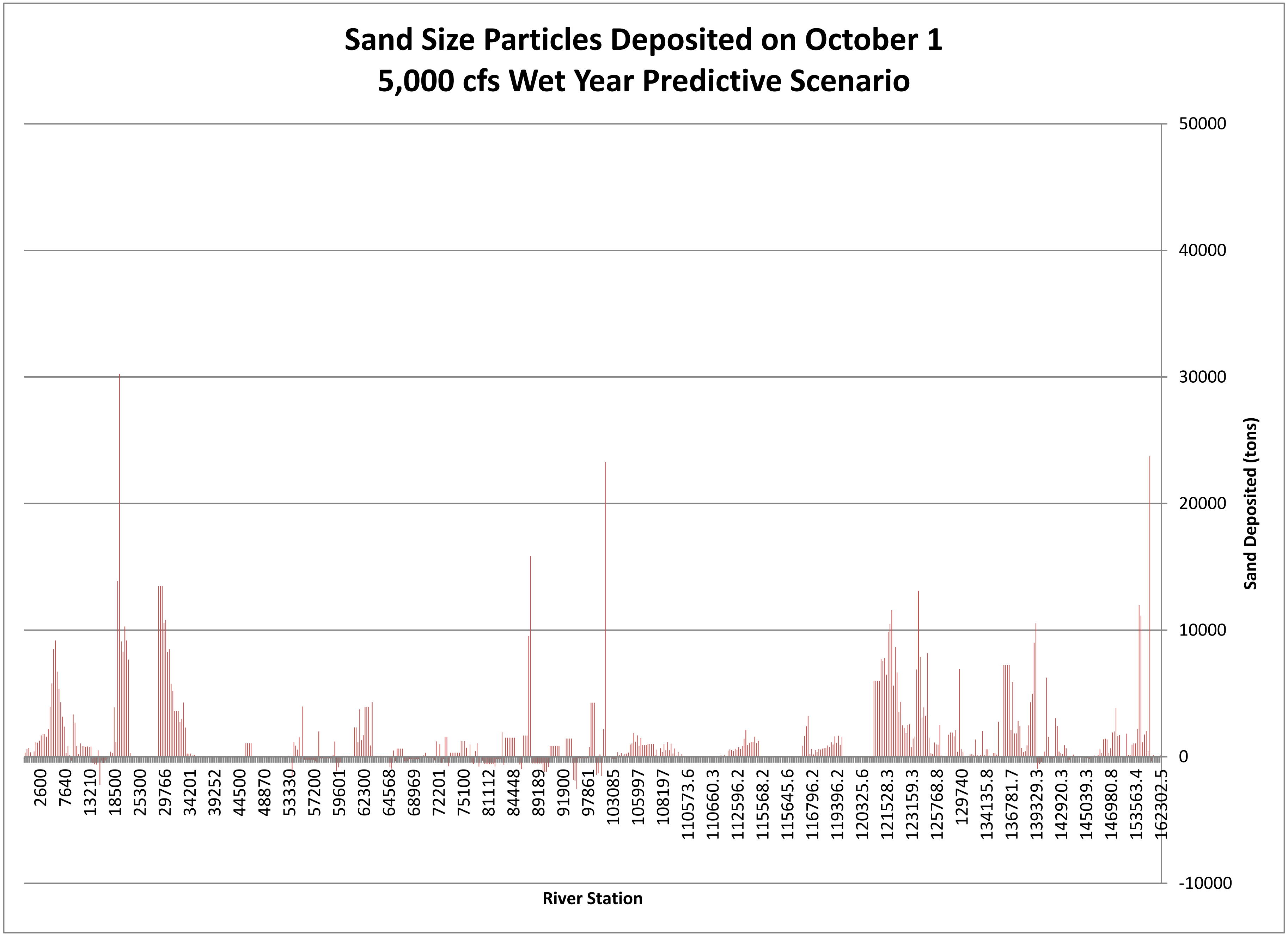

Sand Size Particles Deposited on October 1
5,000 cfs Wet Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.24

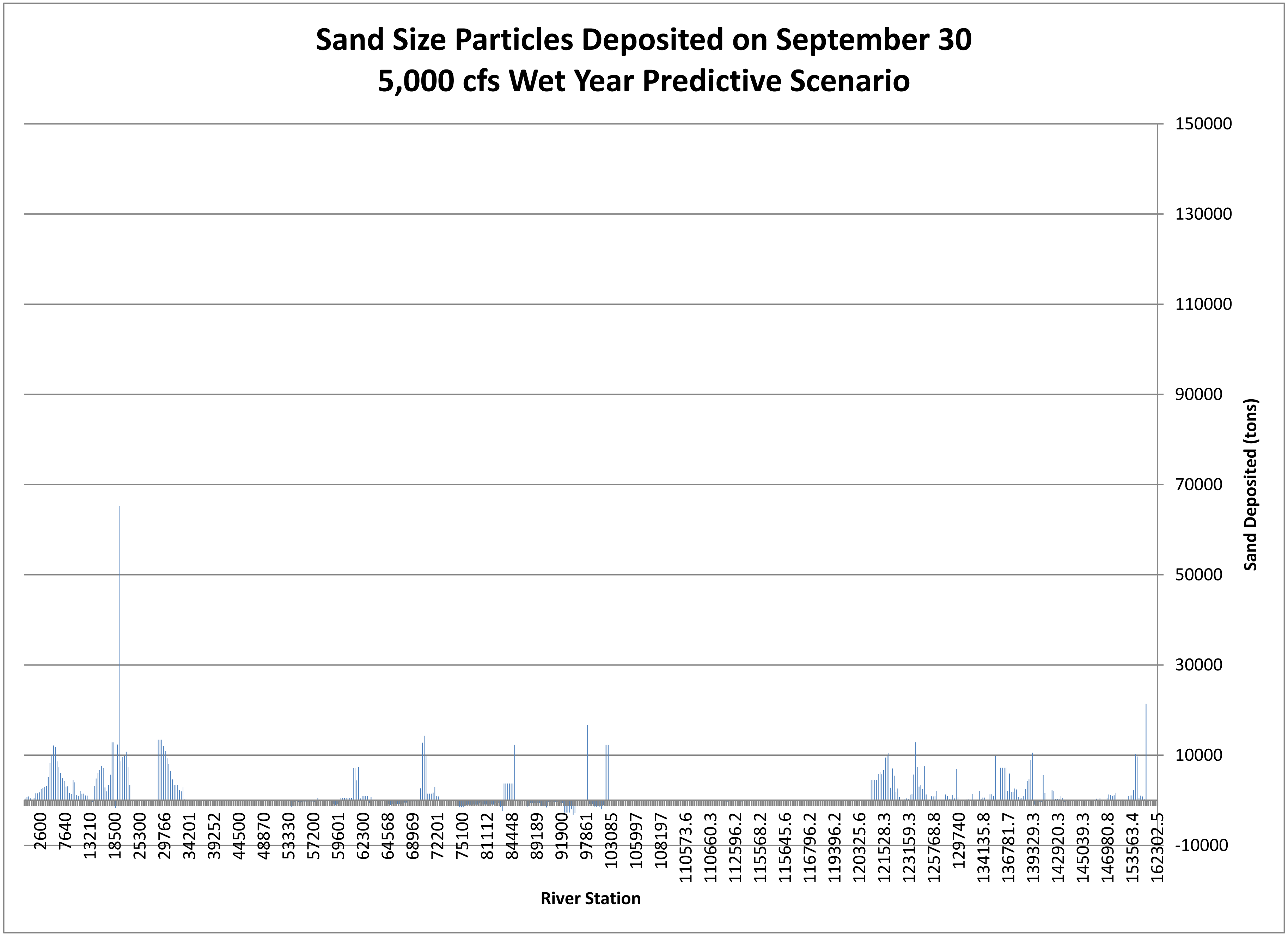
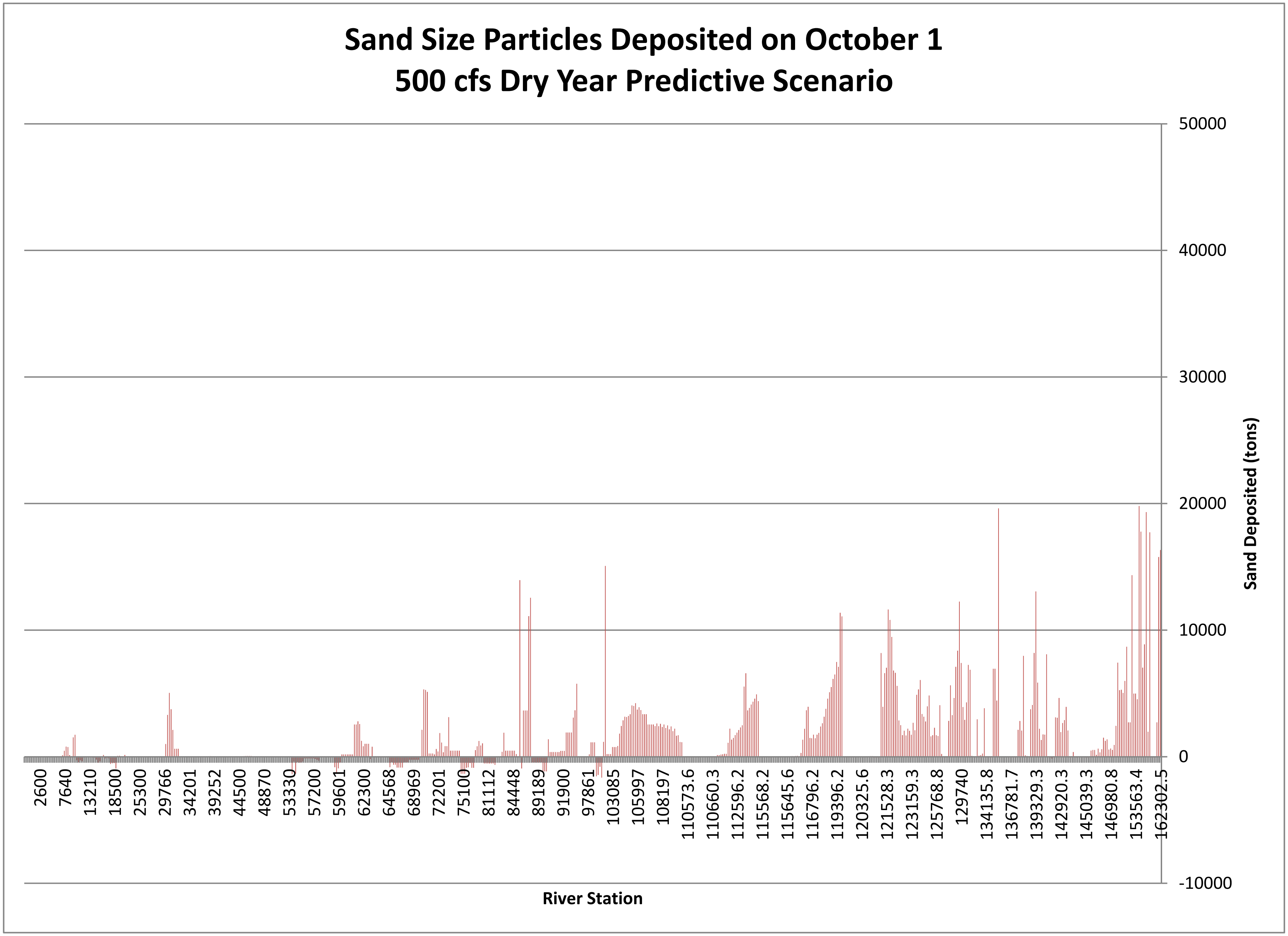

Sand Size Particles Deposited on September 30
5,000 cfs Wet Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.25



Sand Size Particles Deposited on October 1
500 cfs Dry Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.26

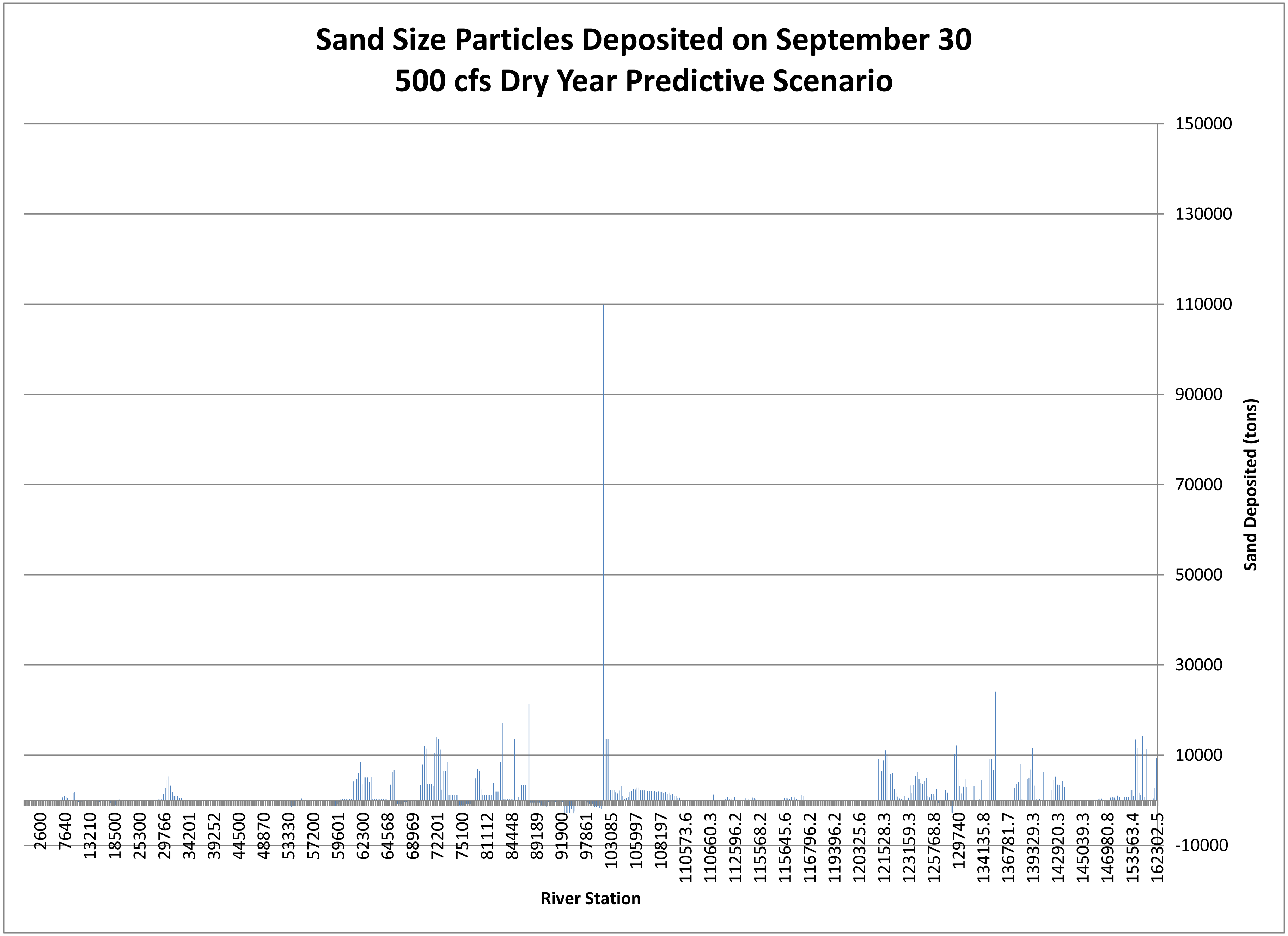

Sand Size Particles Deposited on September 30
500 cfs Dry Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.27

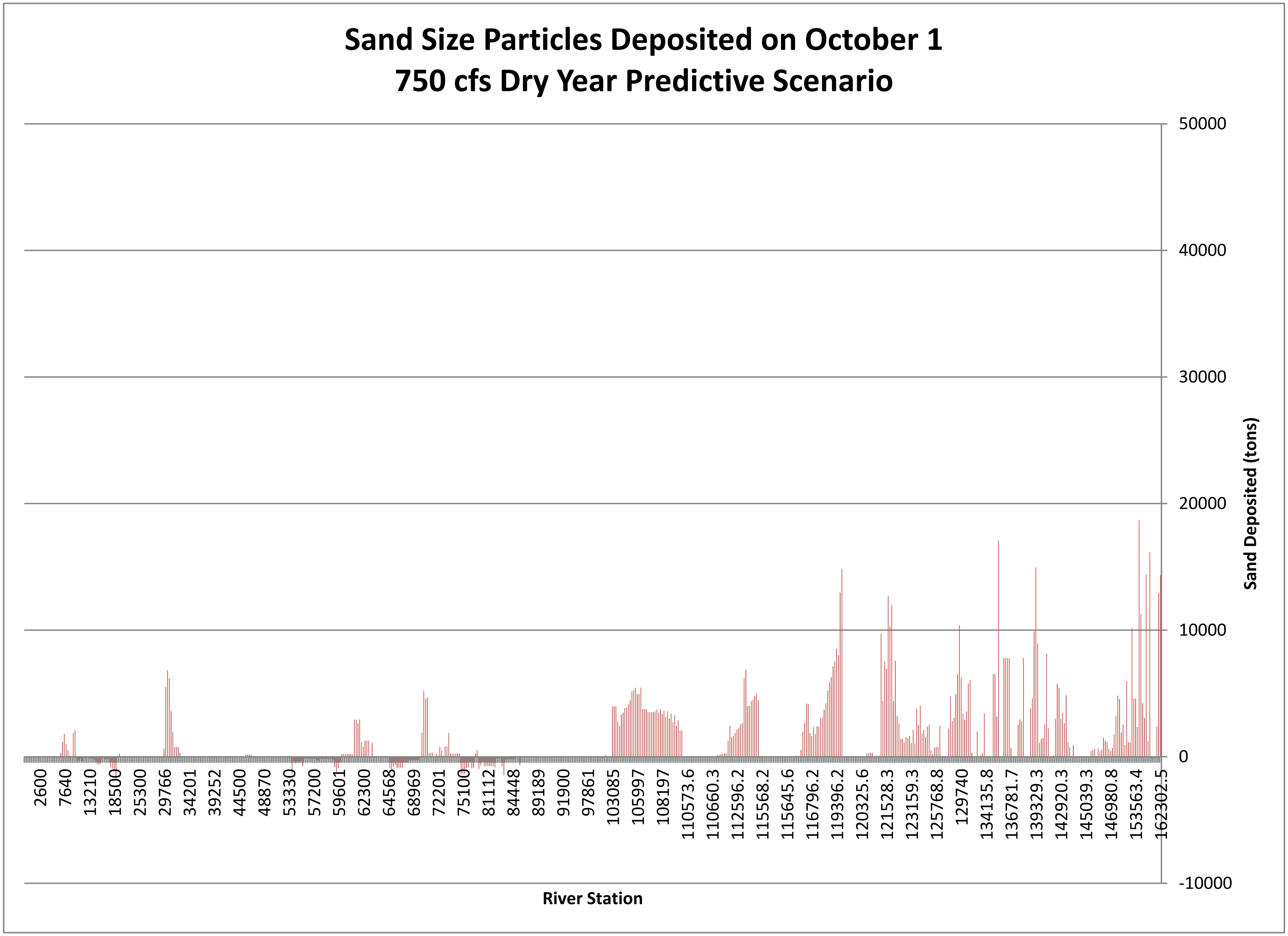

Sand Size Particles Deposited on October 1
750 cfs Dry Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.28

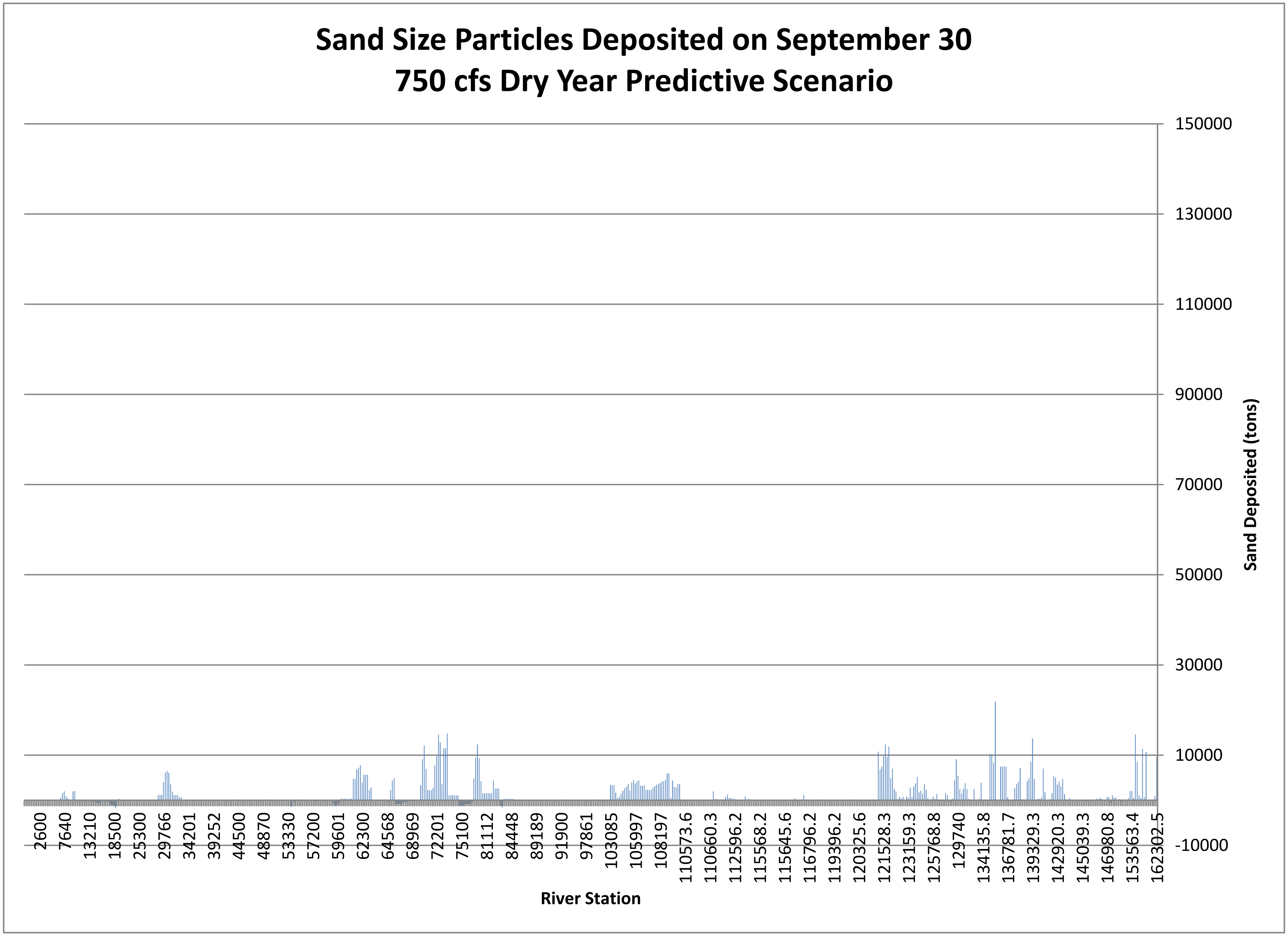

Sand Size Particles Deposited on September 30
750 cfs Dry Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.29

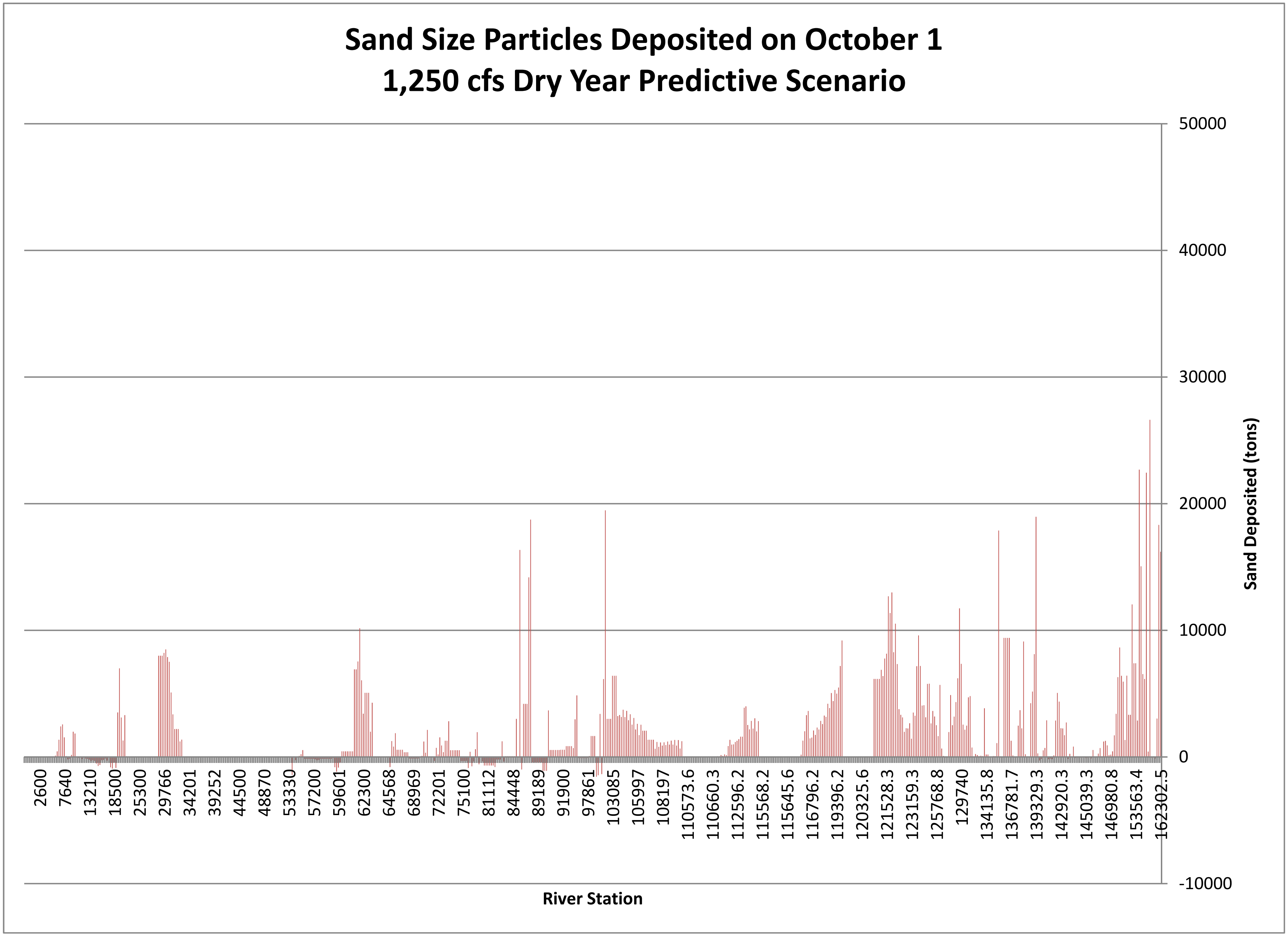

Sand Size Particles Deposited on October 1
1,250 cfs Dry Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.30

Sand Size Particles Deposited on September 30
1,250 cfs Dry Year Predictive Scenario

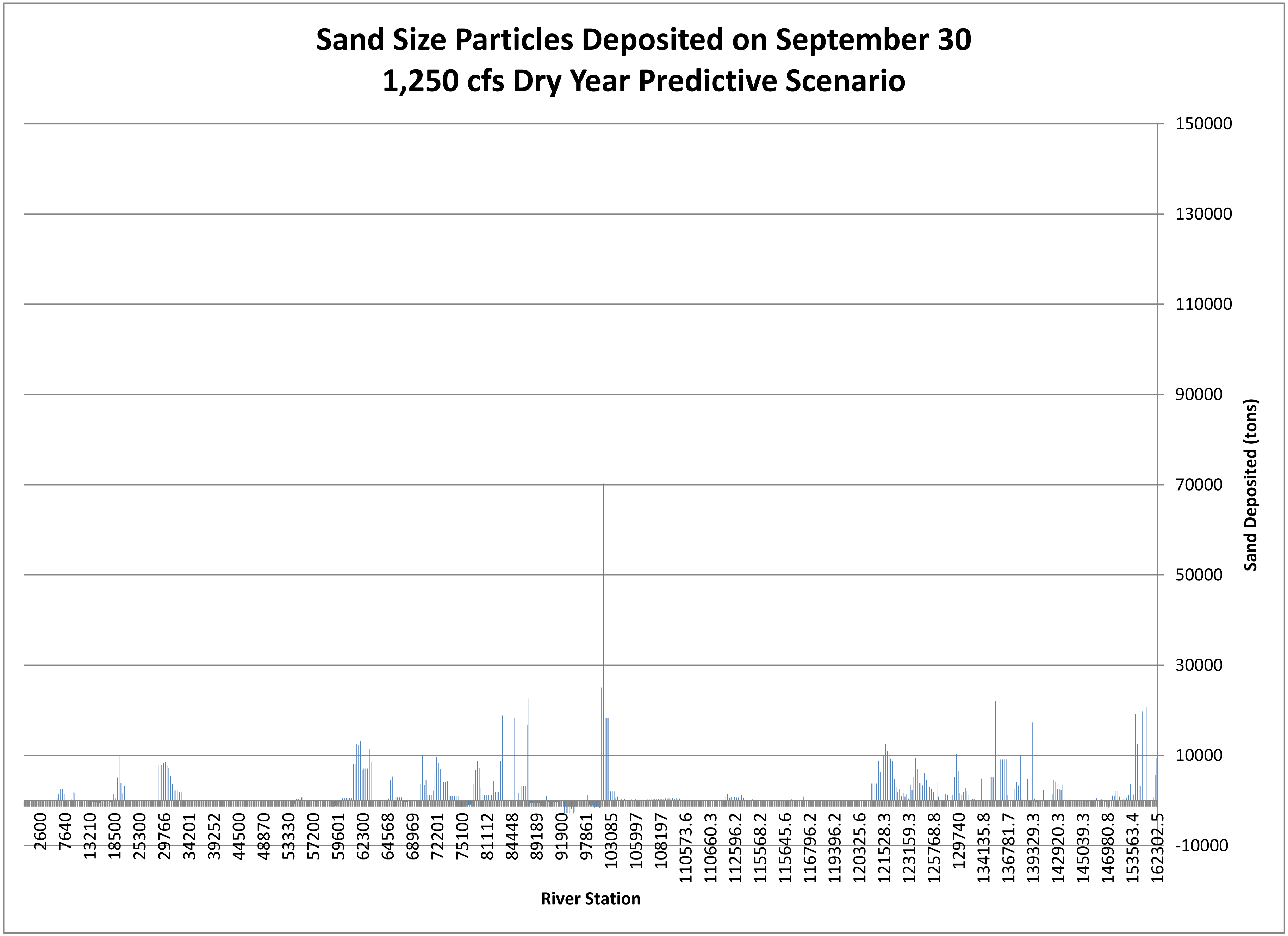


Figure B.D.31

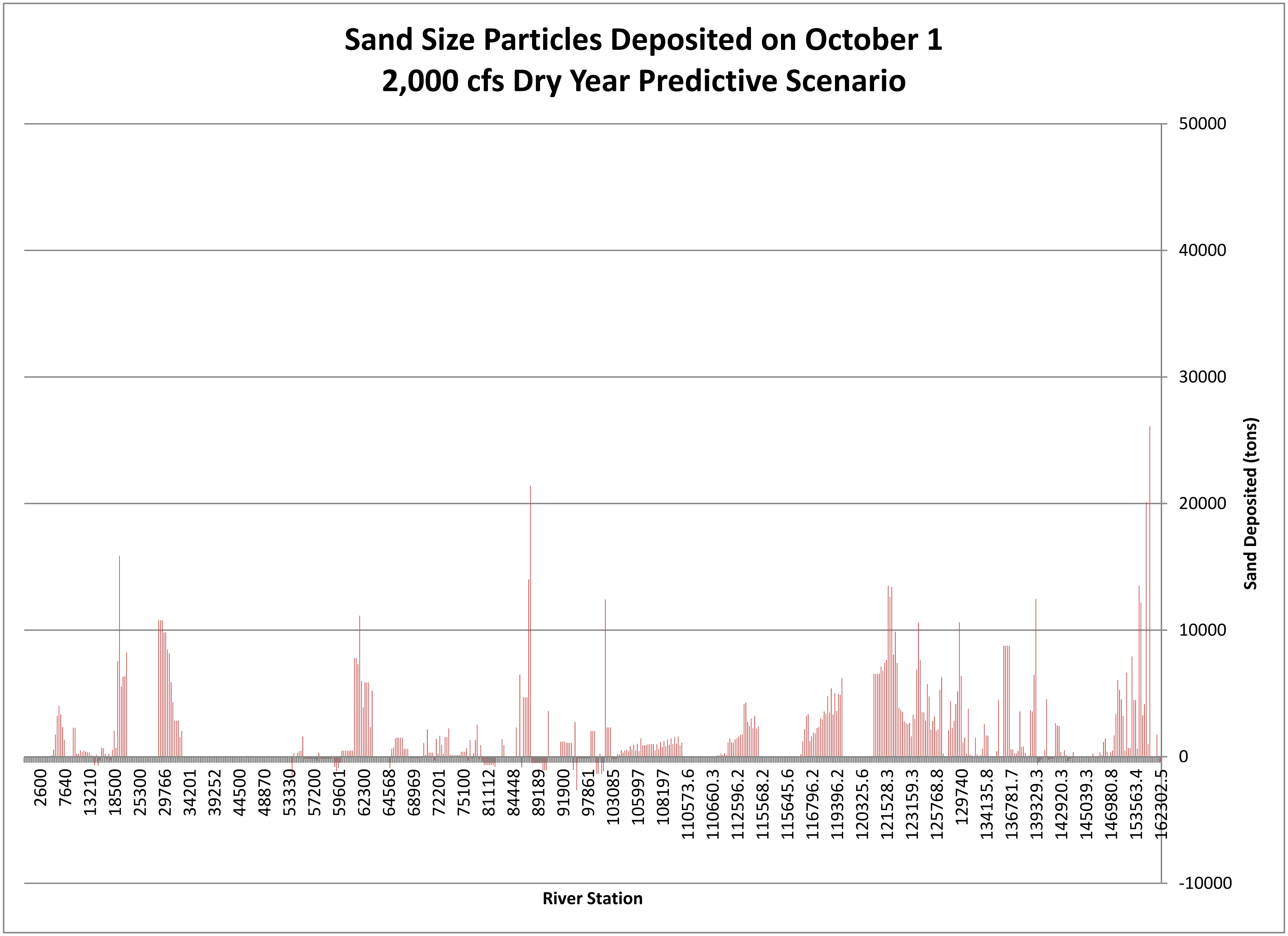

Sand Size Particles Deposited on October 1
2,000 cfs Dry Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.32

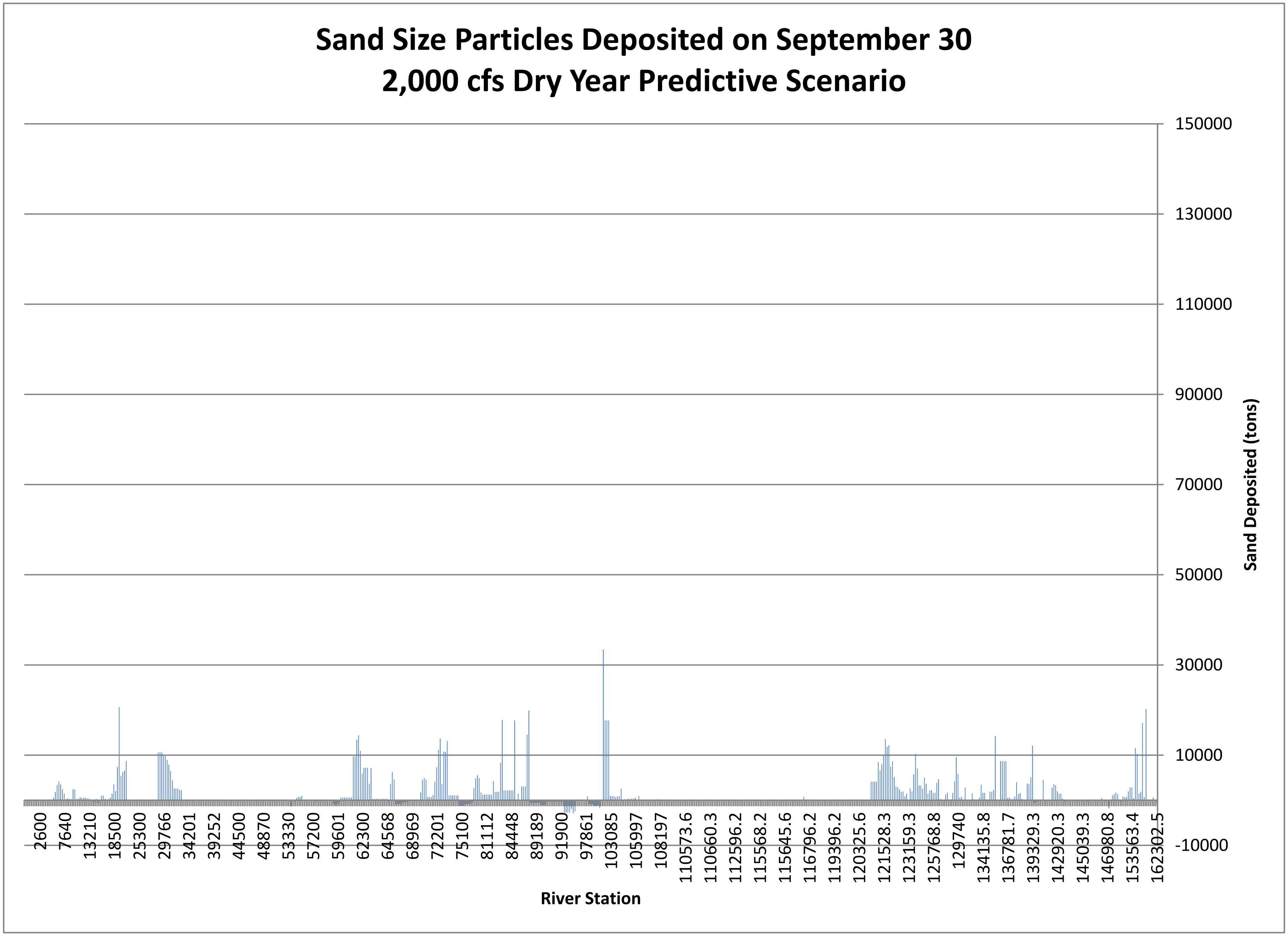

Sand Size Particles Deposited on September 30
2,000 cfs Dry Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.33

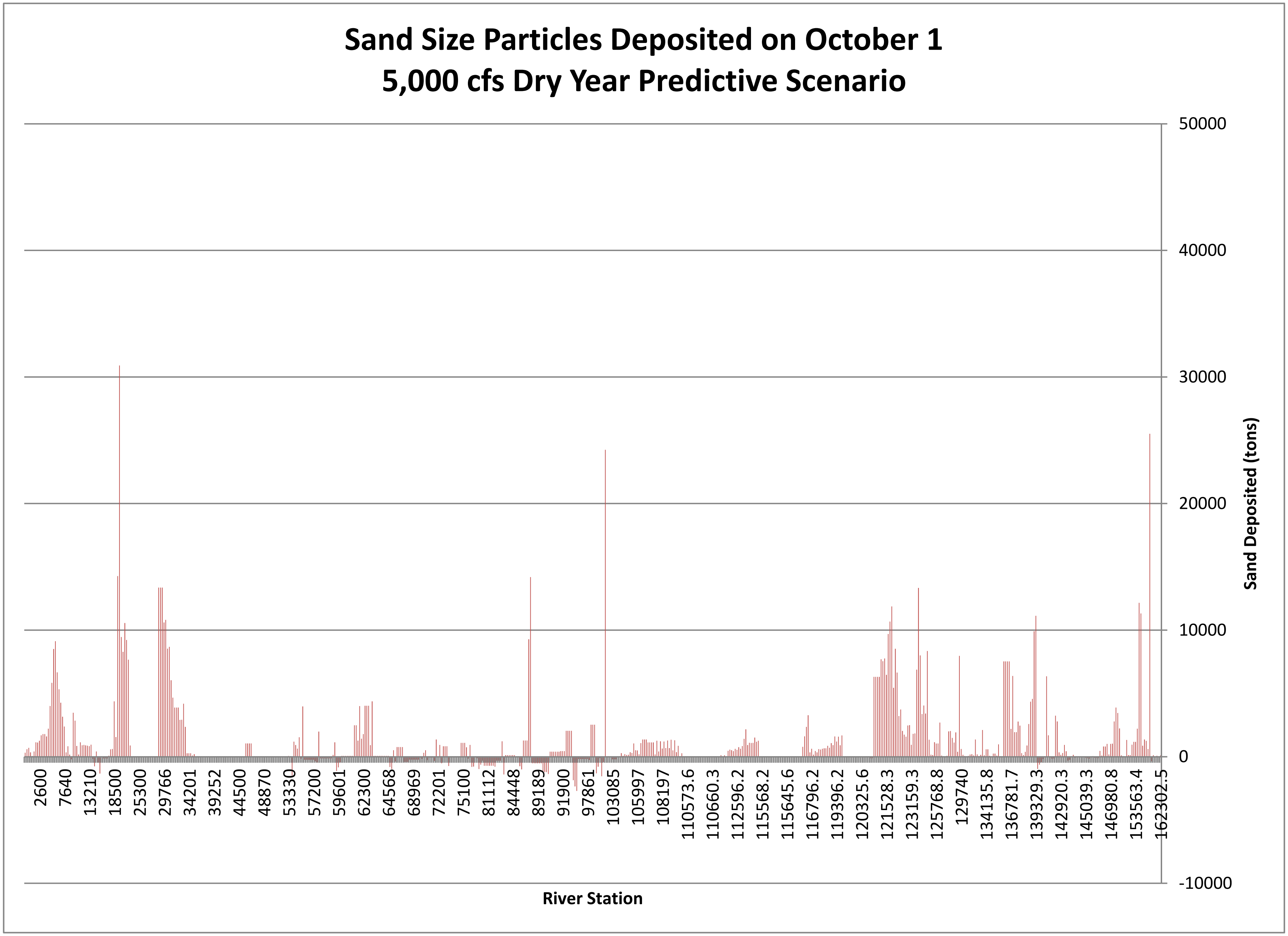

Sand Size Particles Deposited on October 1
5,000 cfs Dry Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.34

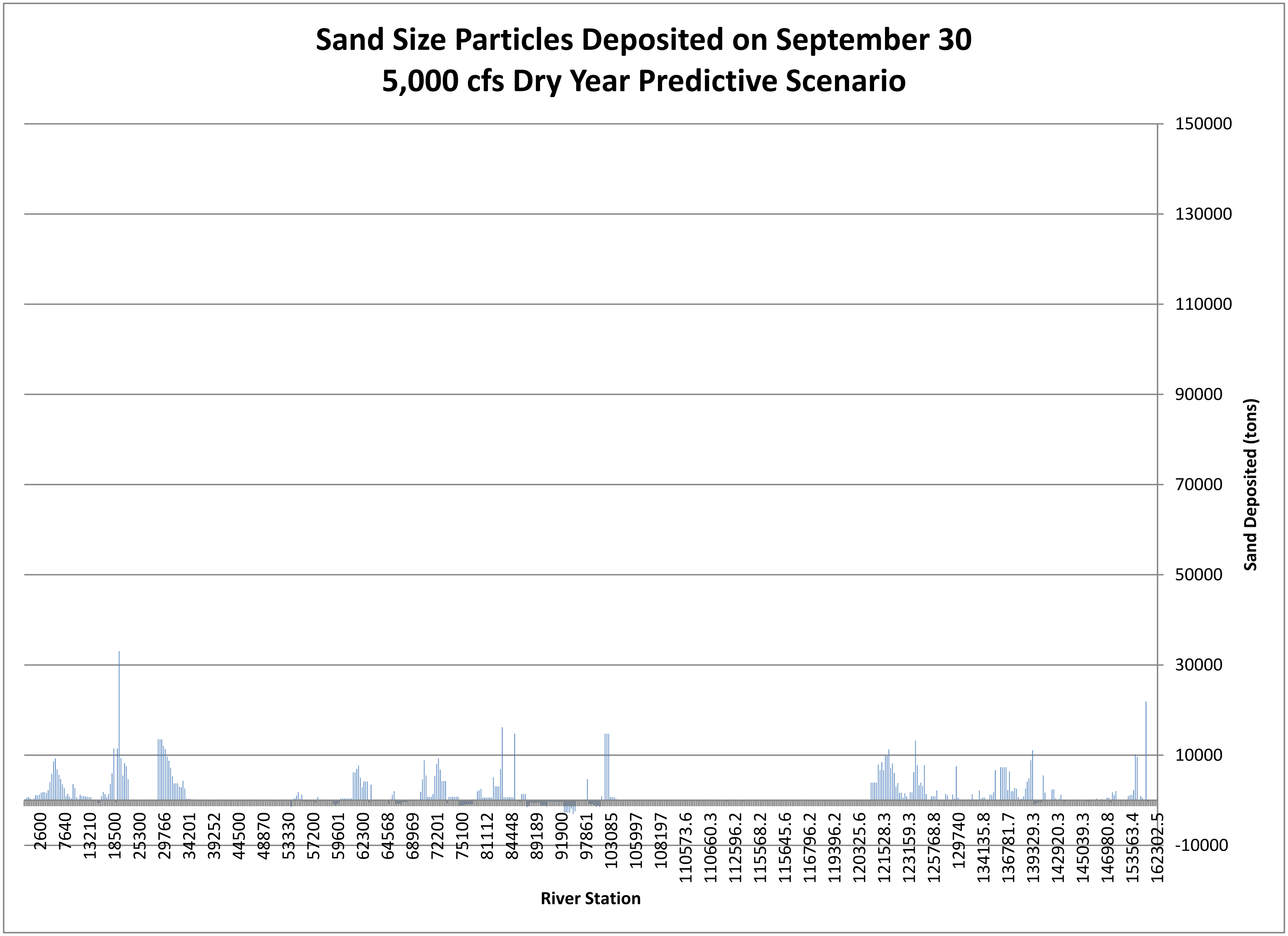

Sand Size Particles Deposited on September 30
5,000 cfs Dry Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.35

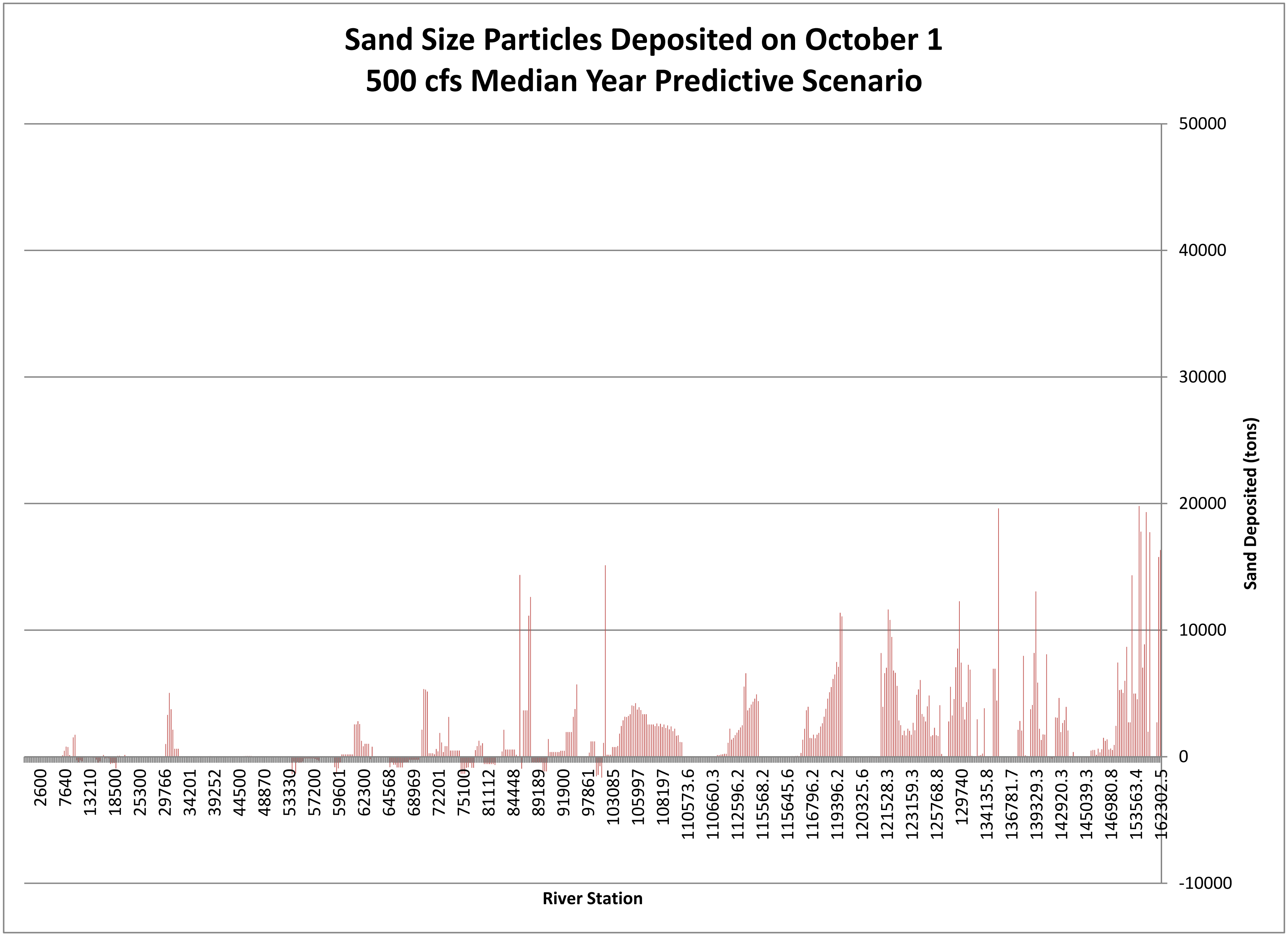

Sand Size Particles Deposited on October 1
500 cfs Median Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.36

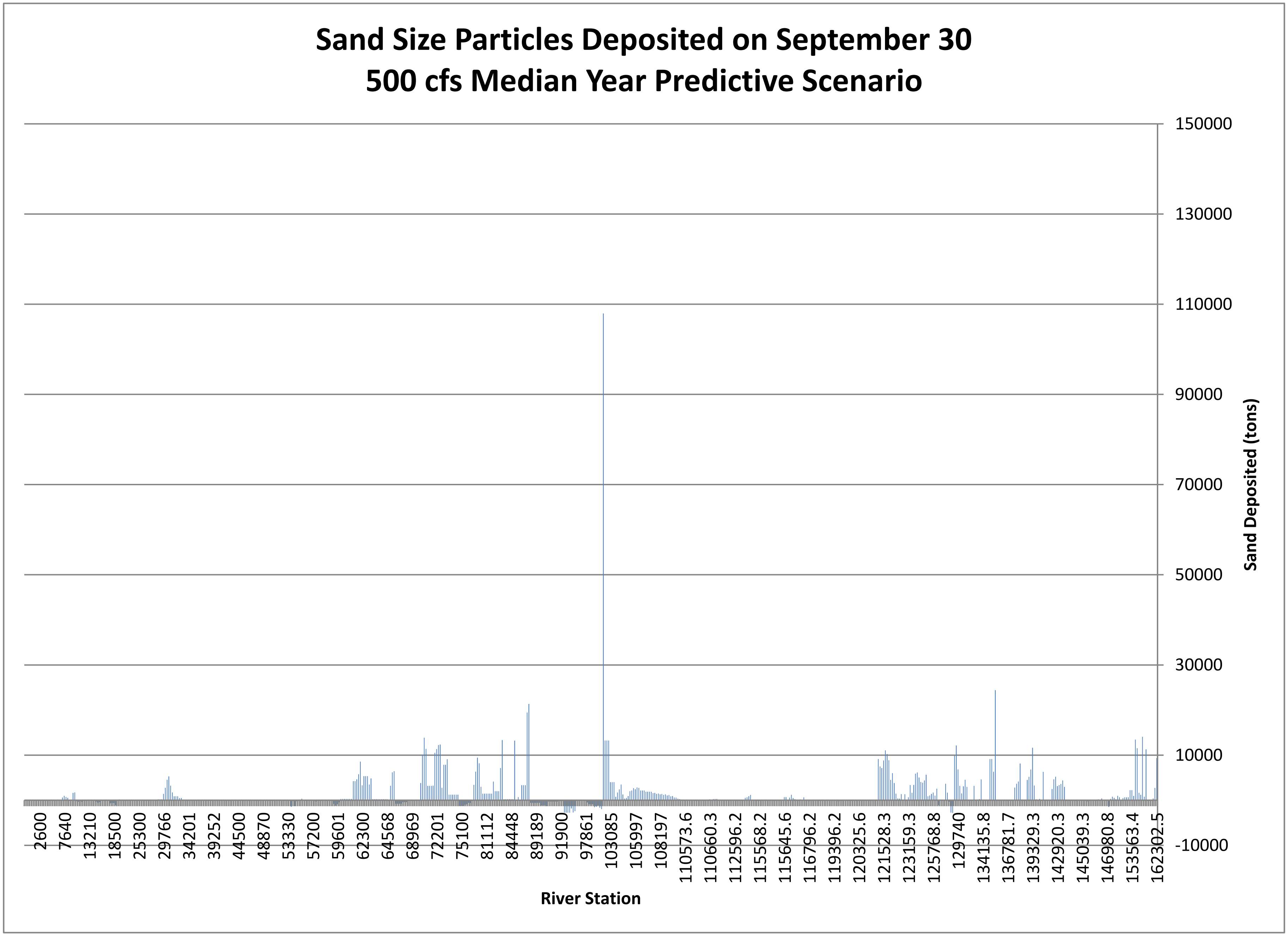

Sand Size Particles Deposited on September 30
500 cfs Median Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.37

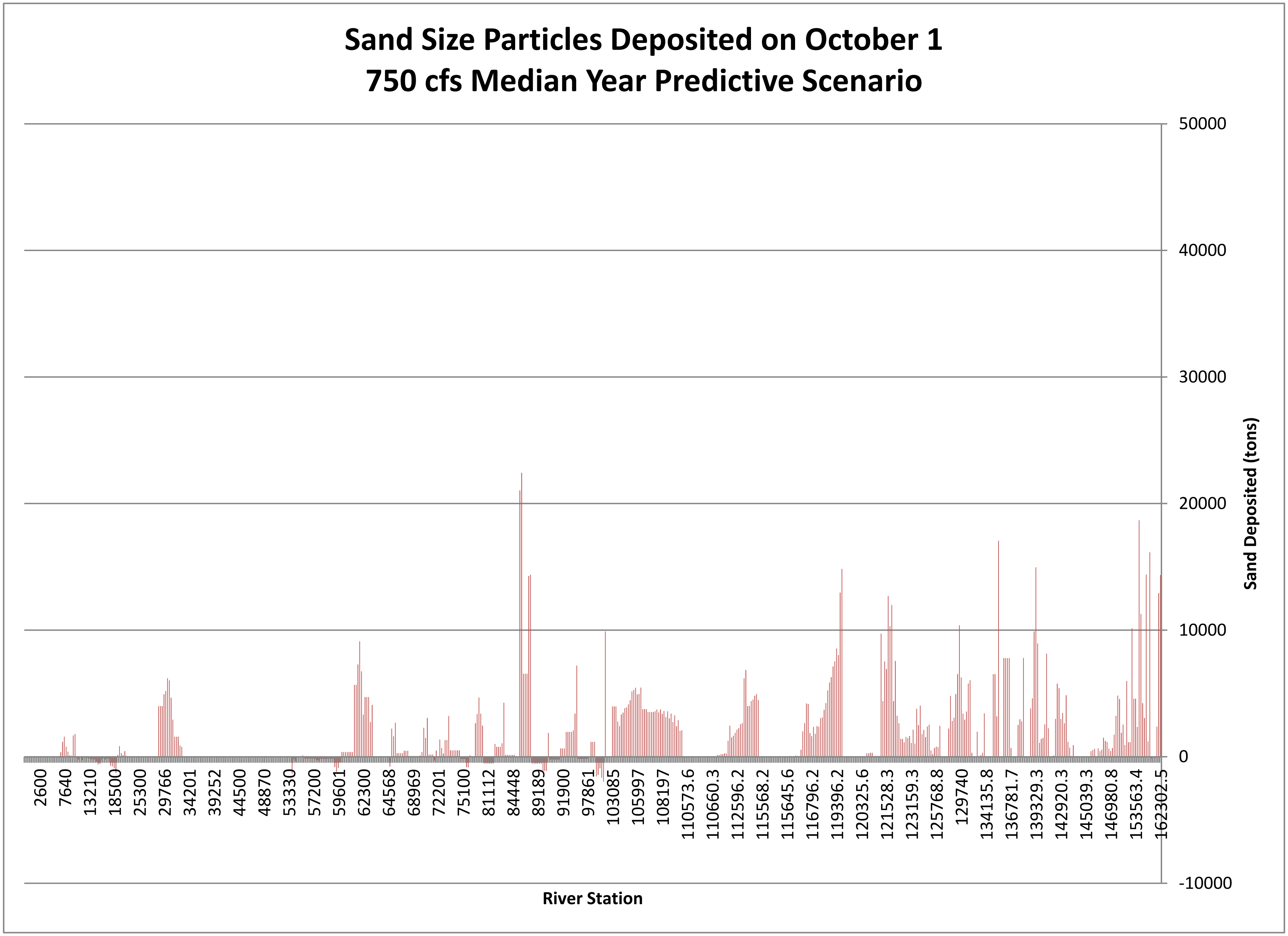

Sand Size Particles Deposited on October 1
750 cfs Median Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.38

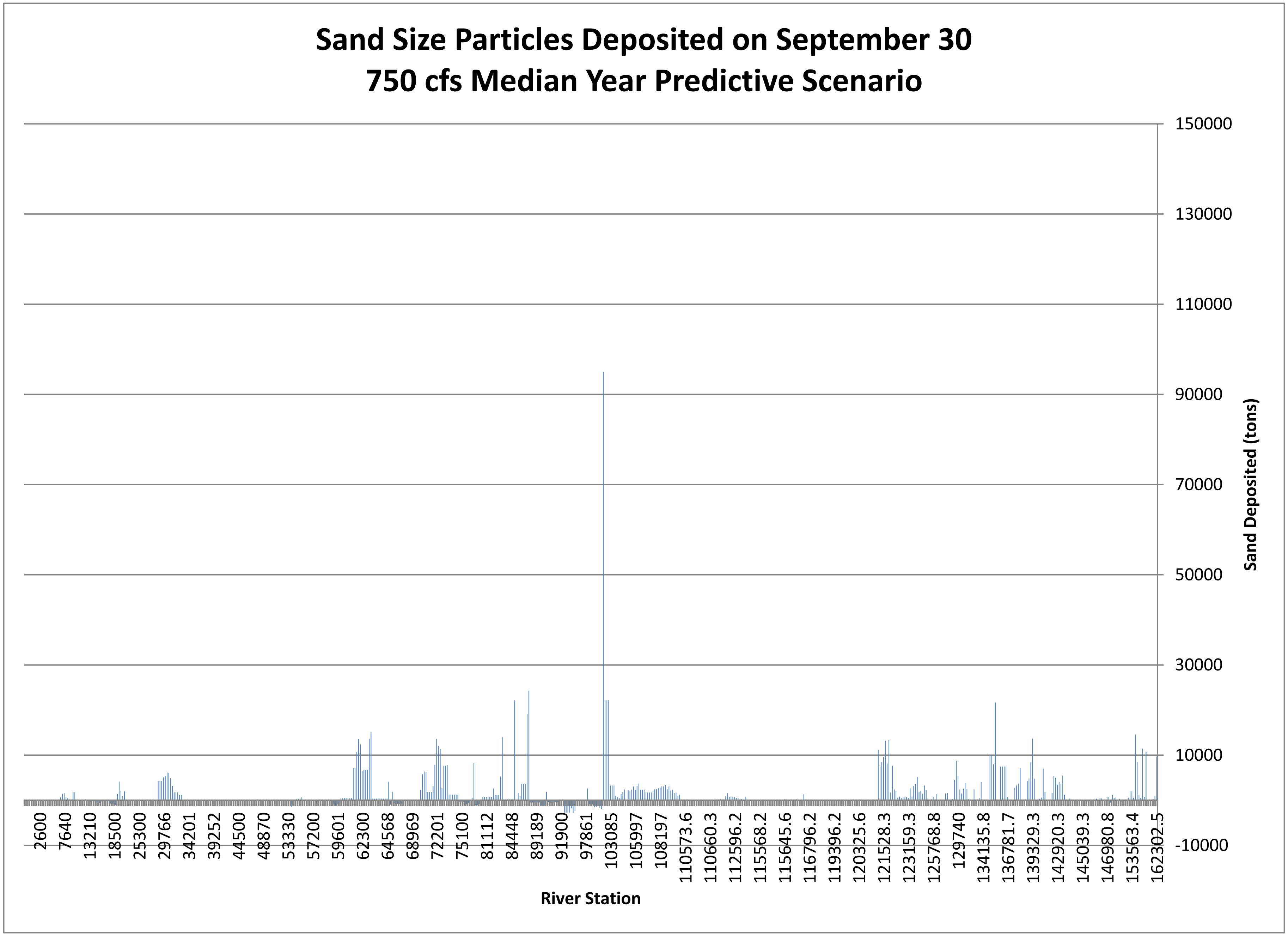

Sand Size Particles Deposited on September 30
750 cfs Median Year Predictive Scenario

Figure B.D.39

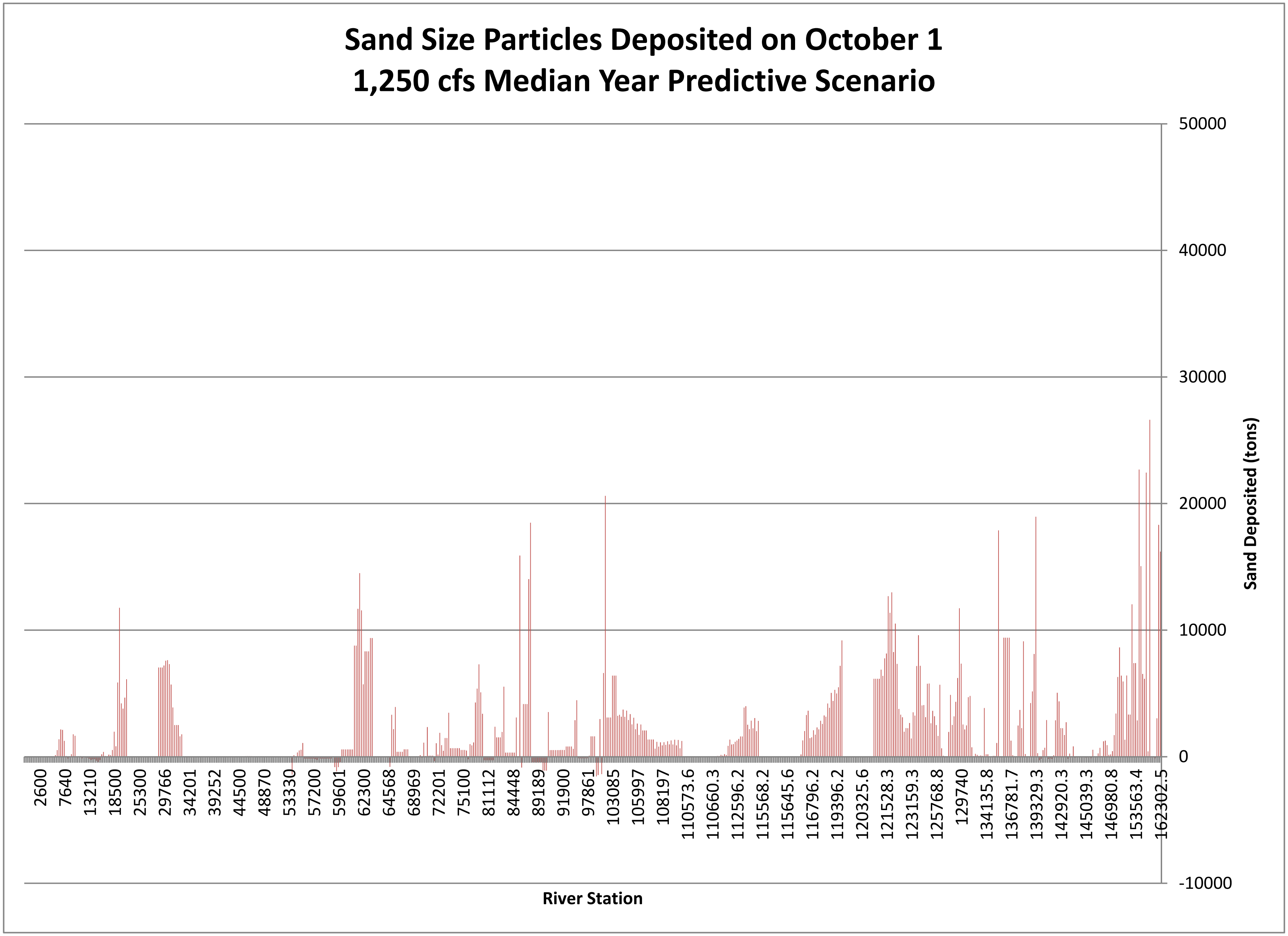

Sand Size Particles Deposited on October 1
1,250 cfs Median Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.40

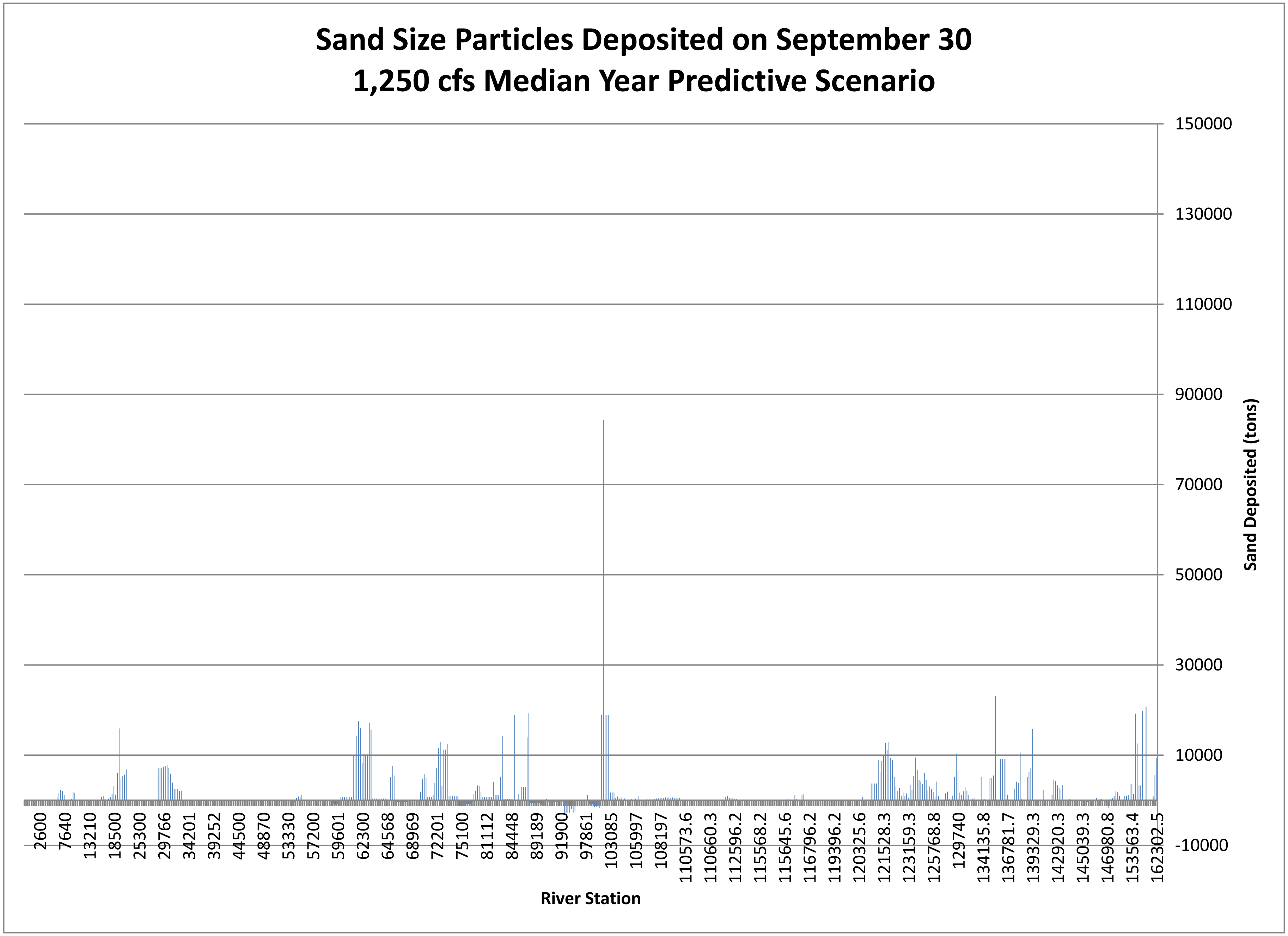

Sand Size Particles Deposited on September 30
1,250 cfs Median Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.41

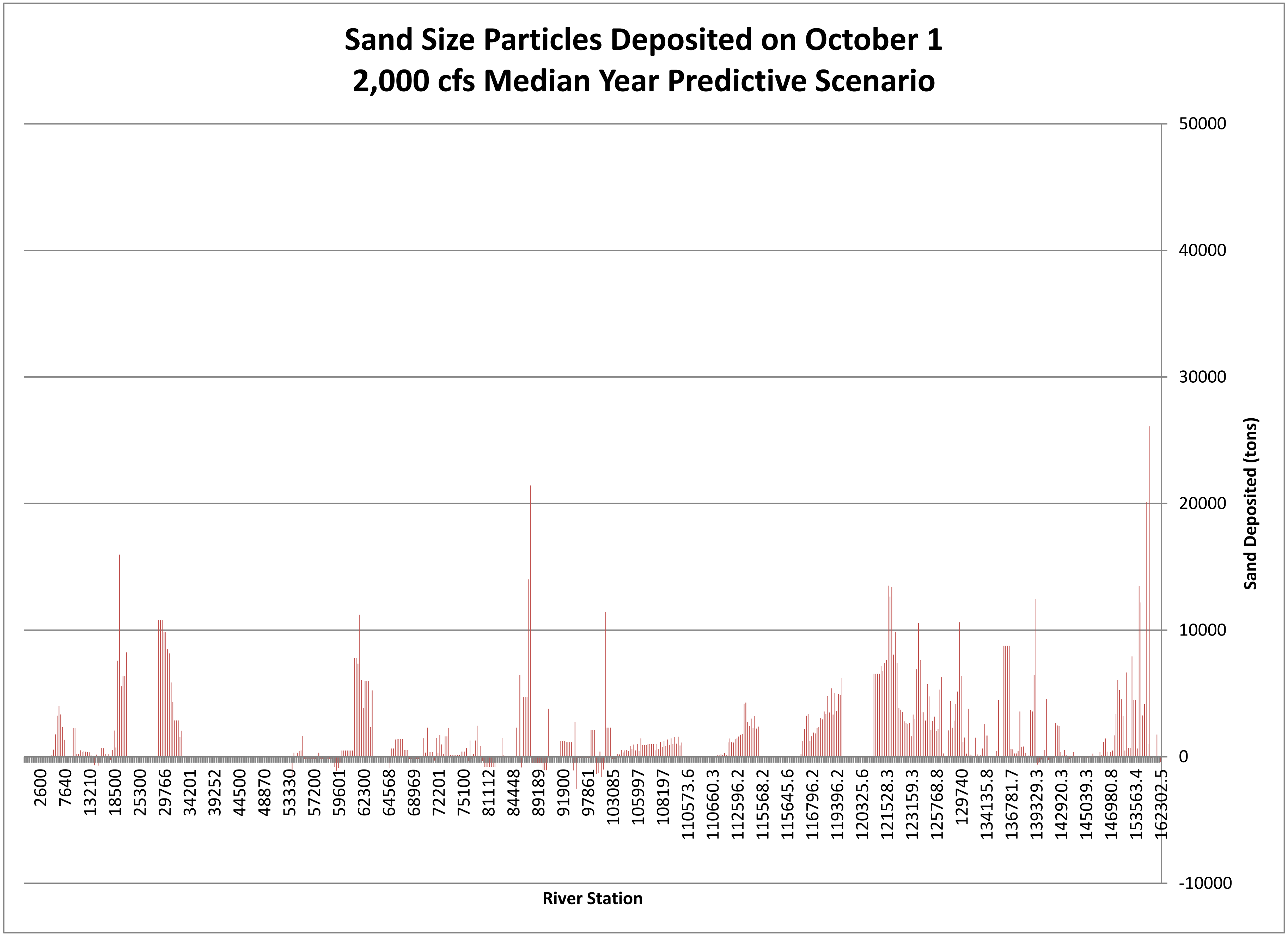

Sand Size Particles Deposited on October 1
2,000 cfs Median Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.42

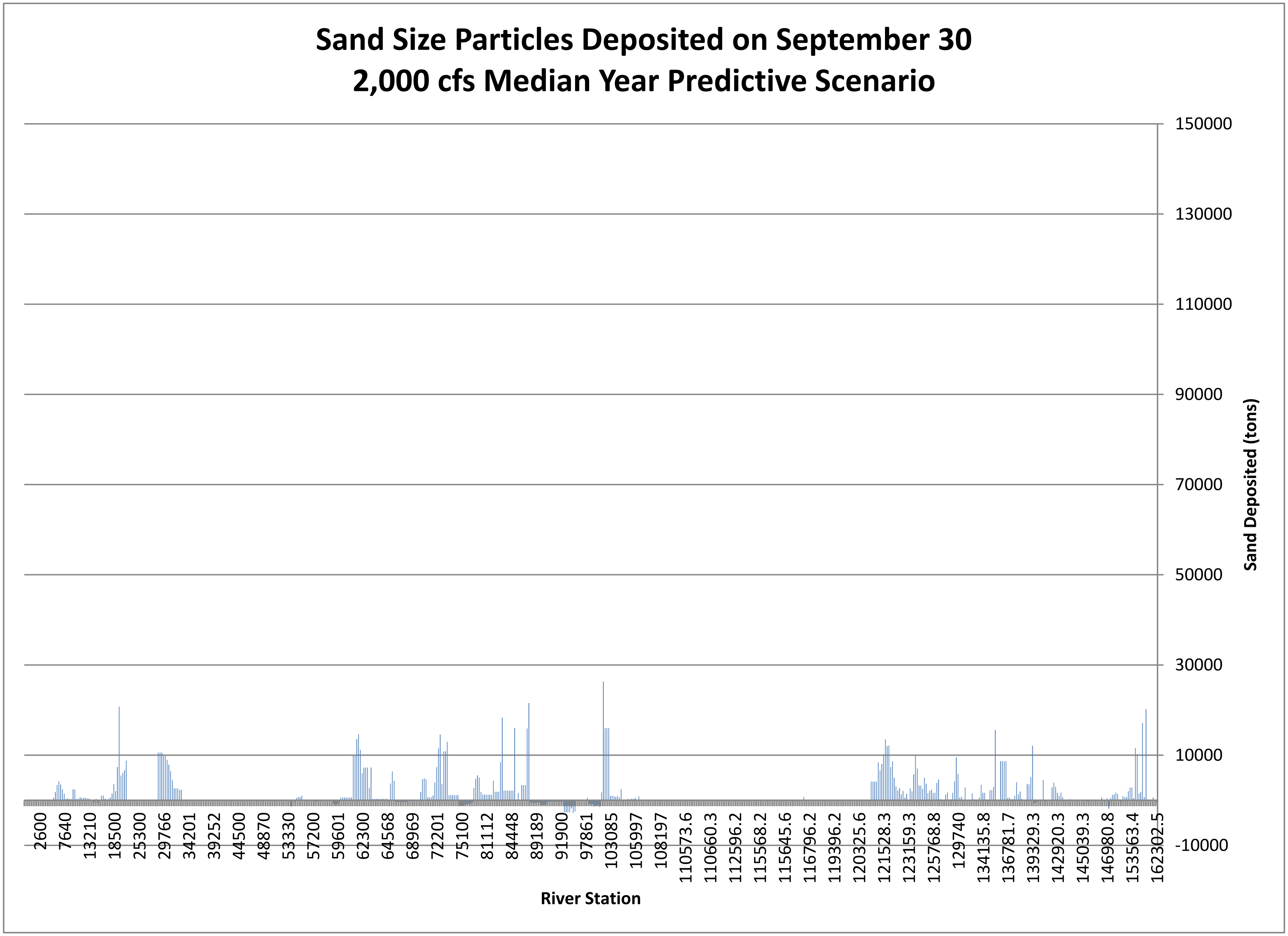

Sand Size Particles Deposited on September 30
2,000 cfs Median Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.43

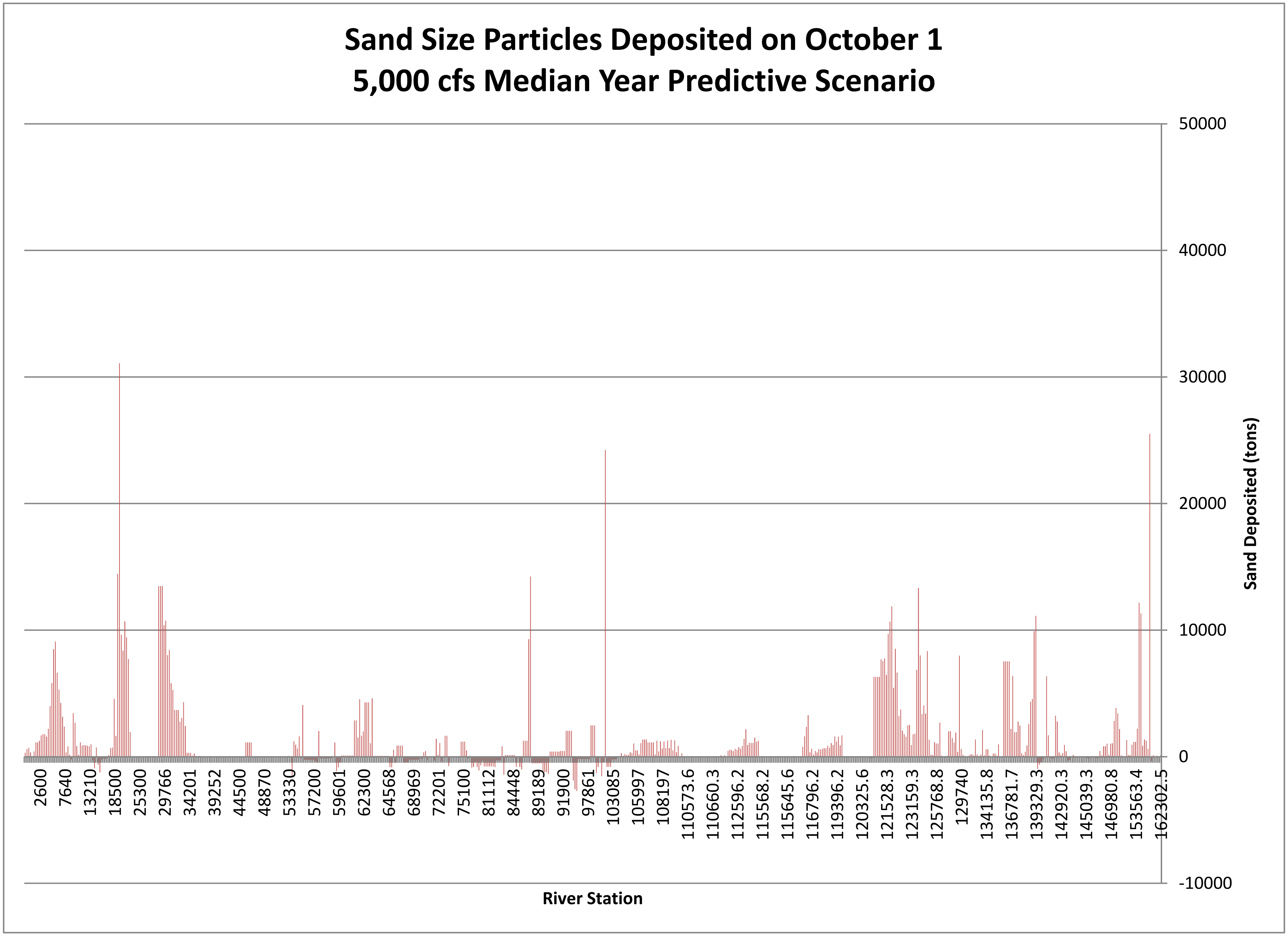

Sand Size Particles Deposited on October 1
5,000 cfs Median Year Predictive Scenario
50000
40000
30000
20000
10000
0
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.44

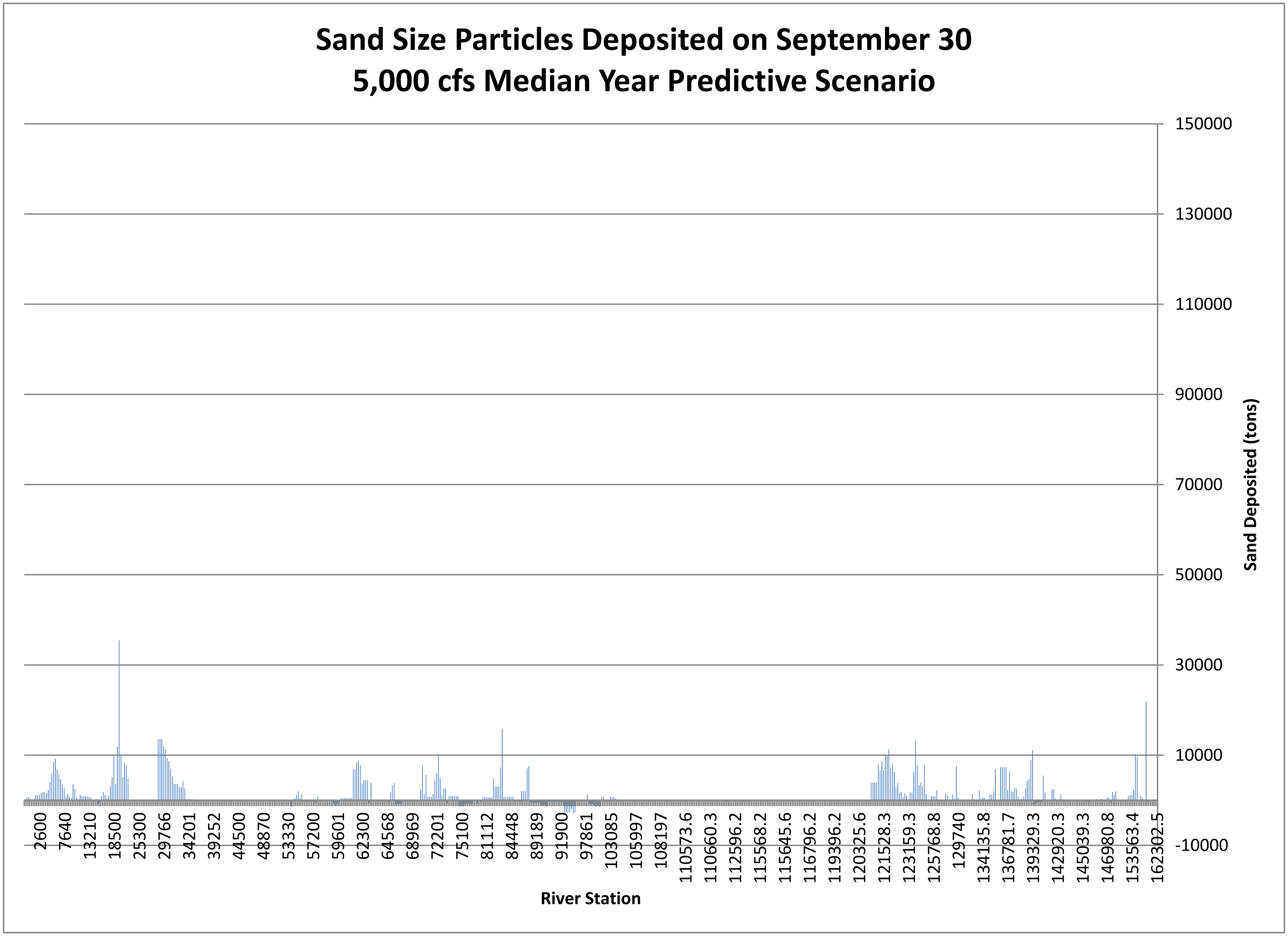

Sand Size Particles Deposited on September 30
5,000 cfs Median Year Predictive Scenario
150000
130000
110000
90000
70000
50000
30000
10000
-10000
Sand Deposited (tons)
2600
7640
13210
18500
25300
29766
34201
39252
44500
48870
53330
57200
59601
62300
64568
68969
72201
75100
81112
84448
89189
91900
97861
103085
105997
108197
110573.6
110660.3
112596.2
115568.2
115645.6
116796.2
119396.2
120325.6
121528.3
123159.3
125768.8
129740
134135.8
136781.7
139329.3
142920.3
145039.3
146980.8
153563.4
162302.5
River Station

Figure B.D.45

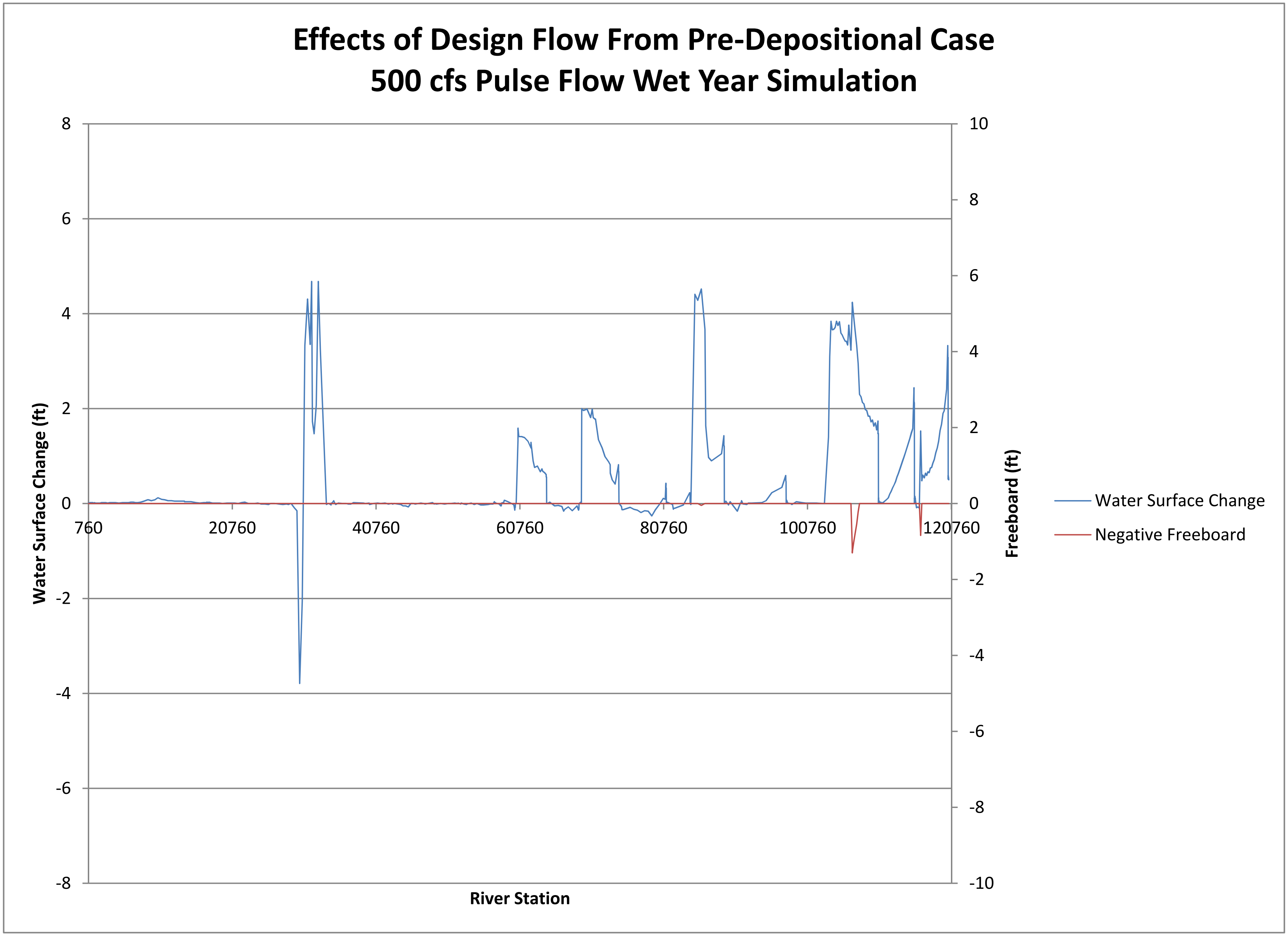

Effects of Design Flow From Pre-Depositional Case
500 cfs Pulse Flow Wet Year Simulation
8
6
4
2
0
-2
-4
-6
-8
10
8
6
4
2
0
-2
-4
-6
-8
-10
760
20760
40760
60760
80760
100760
120760
Water Surface Change (ft)
Freeboard (ft)
River Station
Water Surface Change
Negative Freeboard

Figure B.D.46

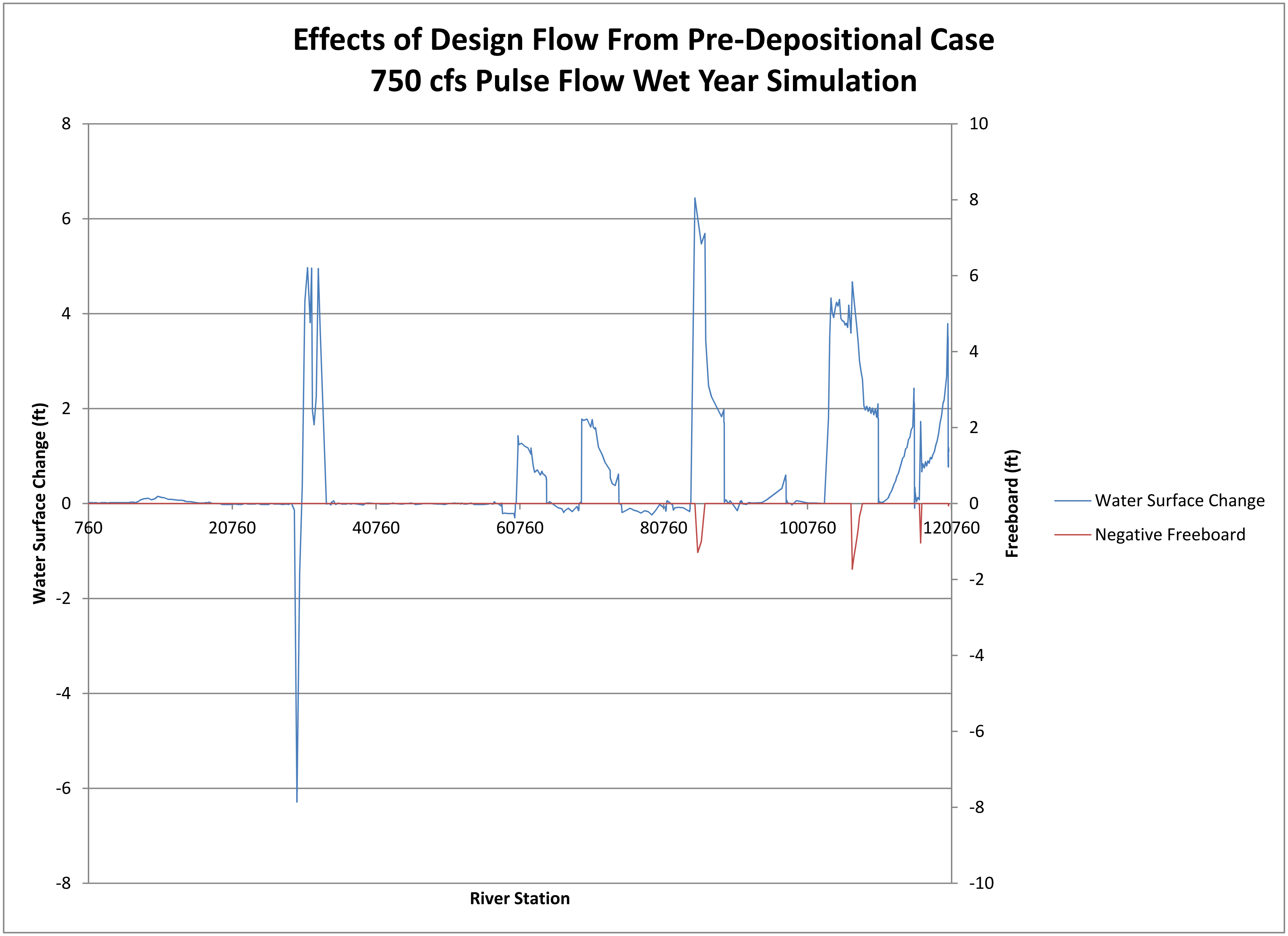

Effects of Design Flow From Pre-Depositional Case
750 cfs Pulse Flow Wet Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
760
20760
40760
60760
80760
100760
120760
River Station
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Water Surface Change
Negative Freeboard

Figure B.D.47

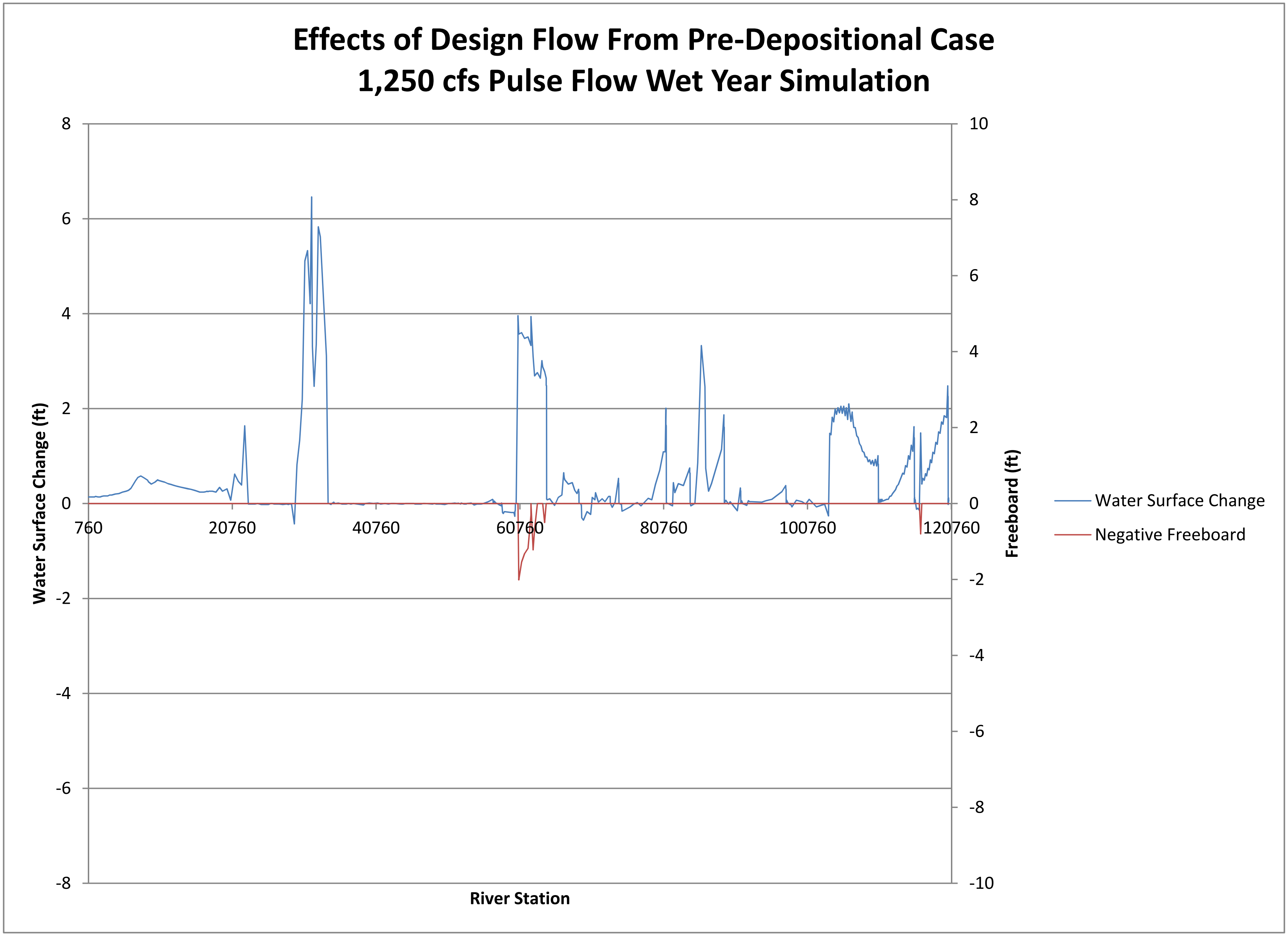

Effects of Design Flow From Pre-Depositional Case
1,250 cfs Pulse Flow Wet Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
760
20760
40760
60760
80760
100760
120760
River Station
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Water Surface Change
Negative Freeboard

Figure B.D.48

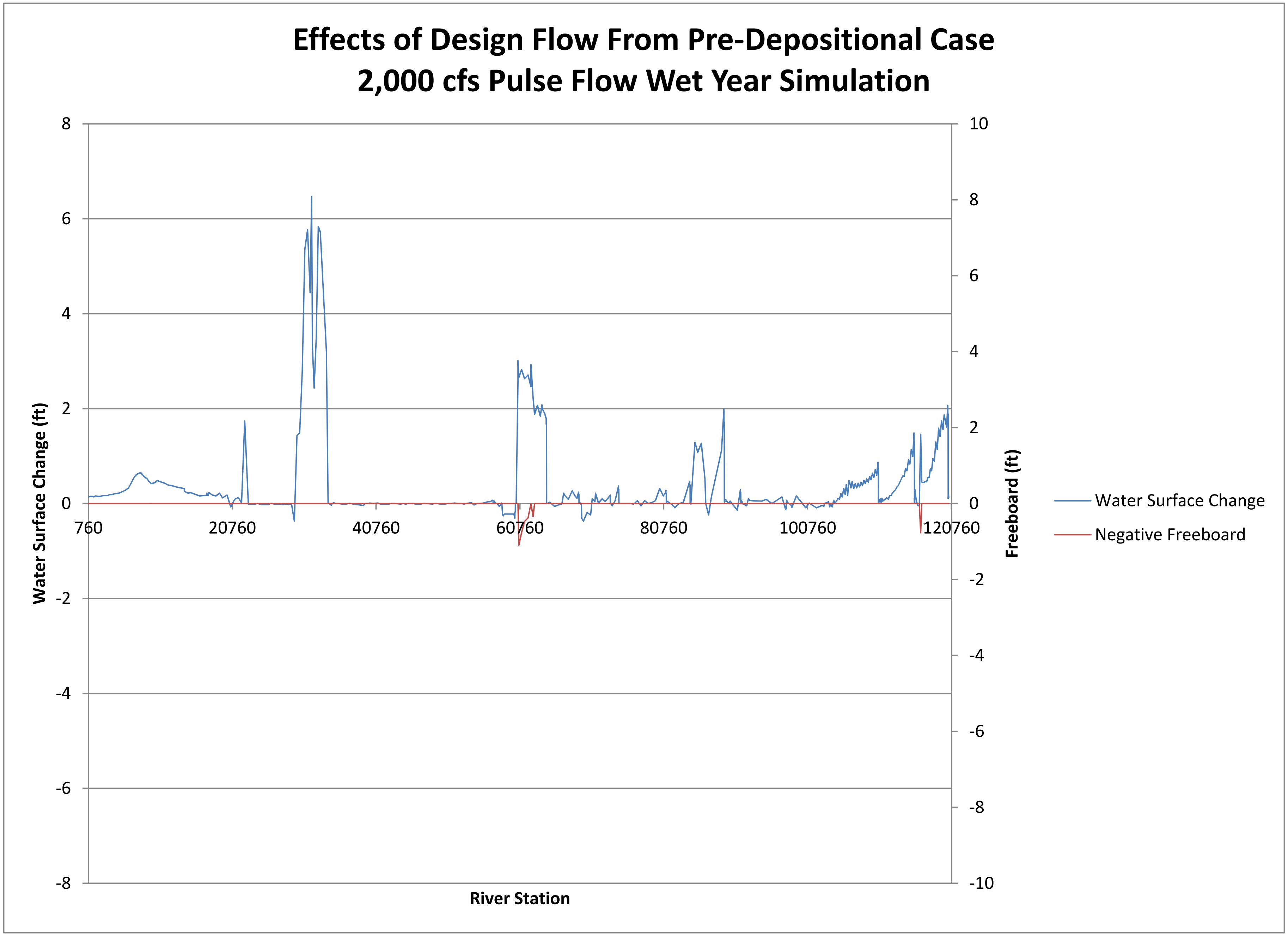

Effects of Design Flow From Pre-Depositional Case
2,000 cfs Pulse Flow Wet Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
760
20760
40760
60760
80760
100760
120760
River Station
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Water Surface Change
Negative Freeboard

Figure B.D.49

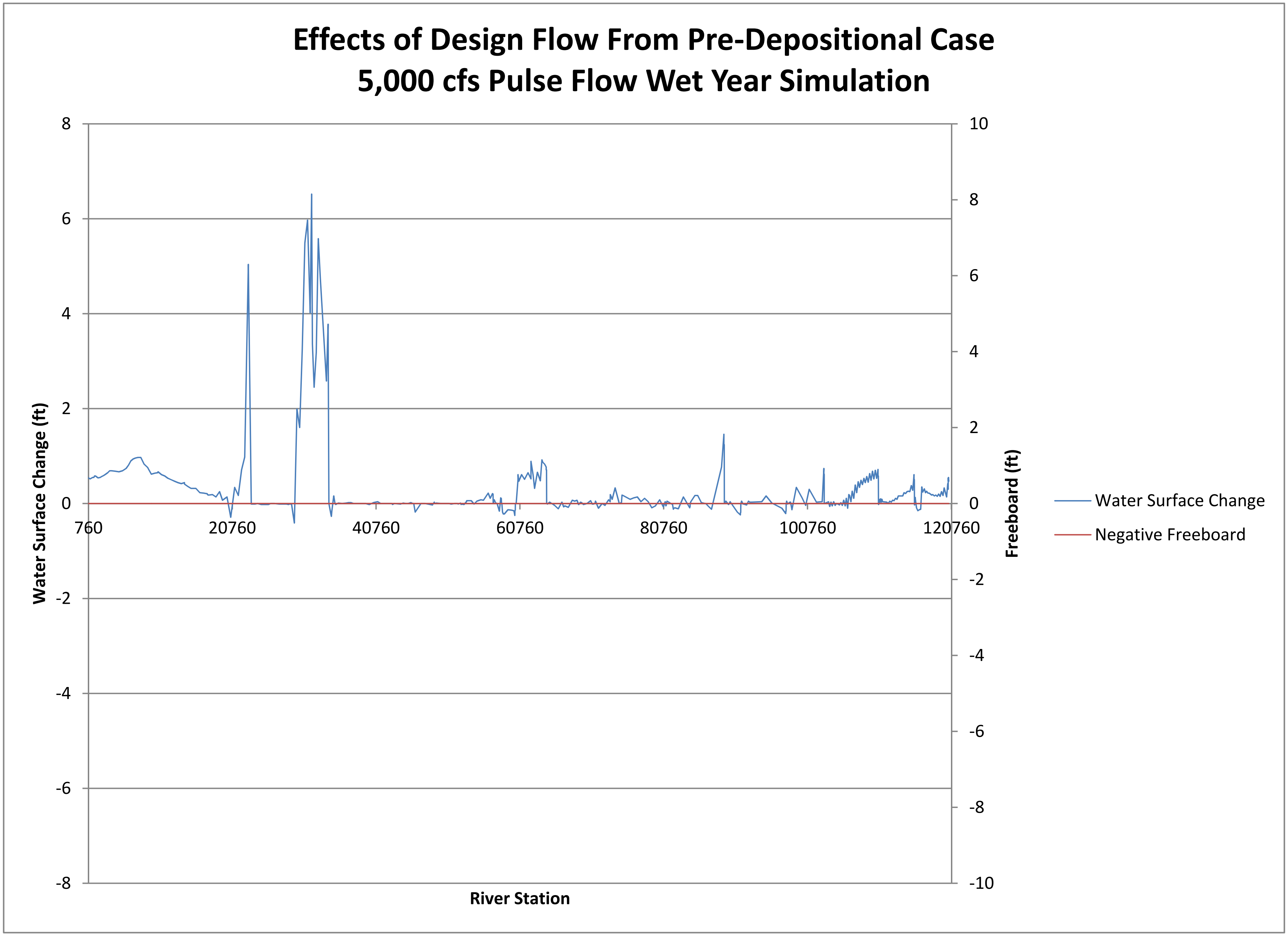
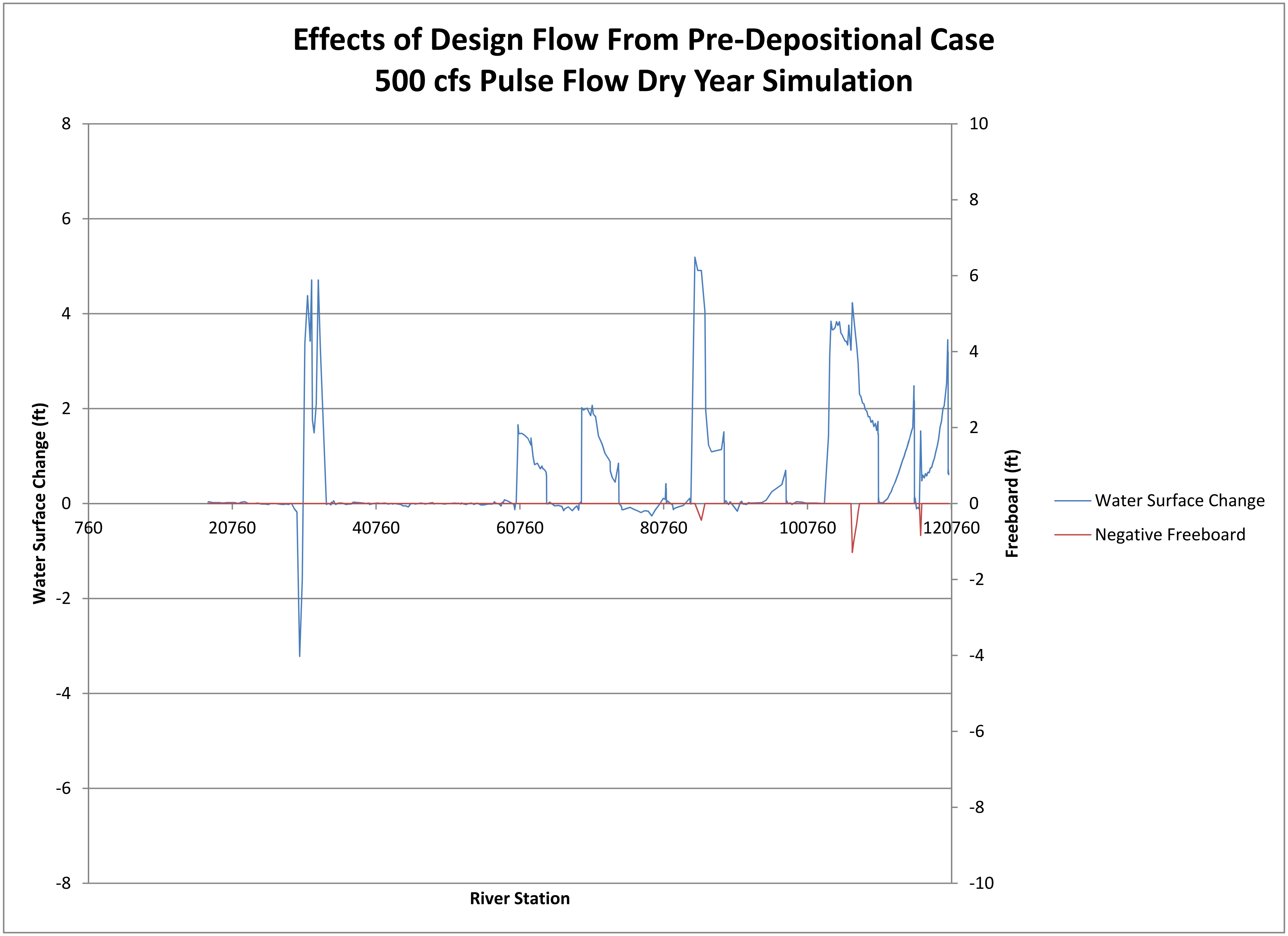

Effects of Design Flow From Pre-Depositional Case
5,000 cfs Pulse Flow Wet Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
760
20760
40760
60760
80760
100760
120760
River Station
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Water Surface Change
Negative Freeboard

Figure B.D.50



Effects of Design Flow From Pre-Depositional Case
500 cfs Pulse Flow Dry Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
760
20760
40760
60760
80760
100760
120760
River Station
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Water Surface Change
Negative Freeboard

Figure B.D.51

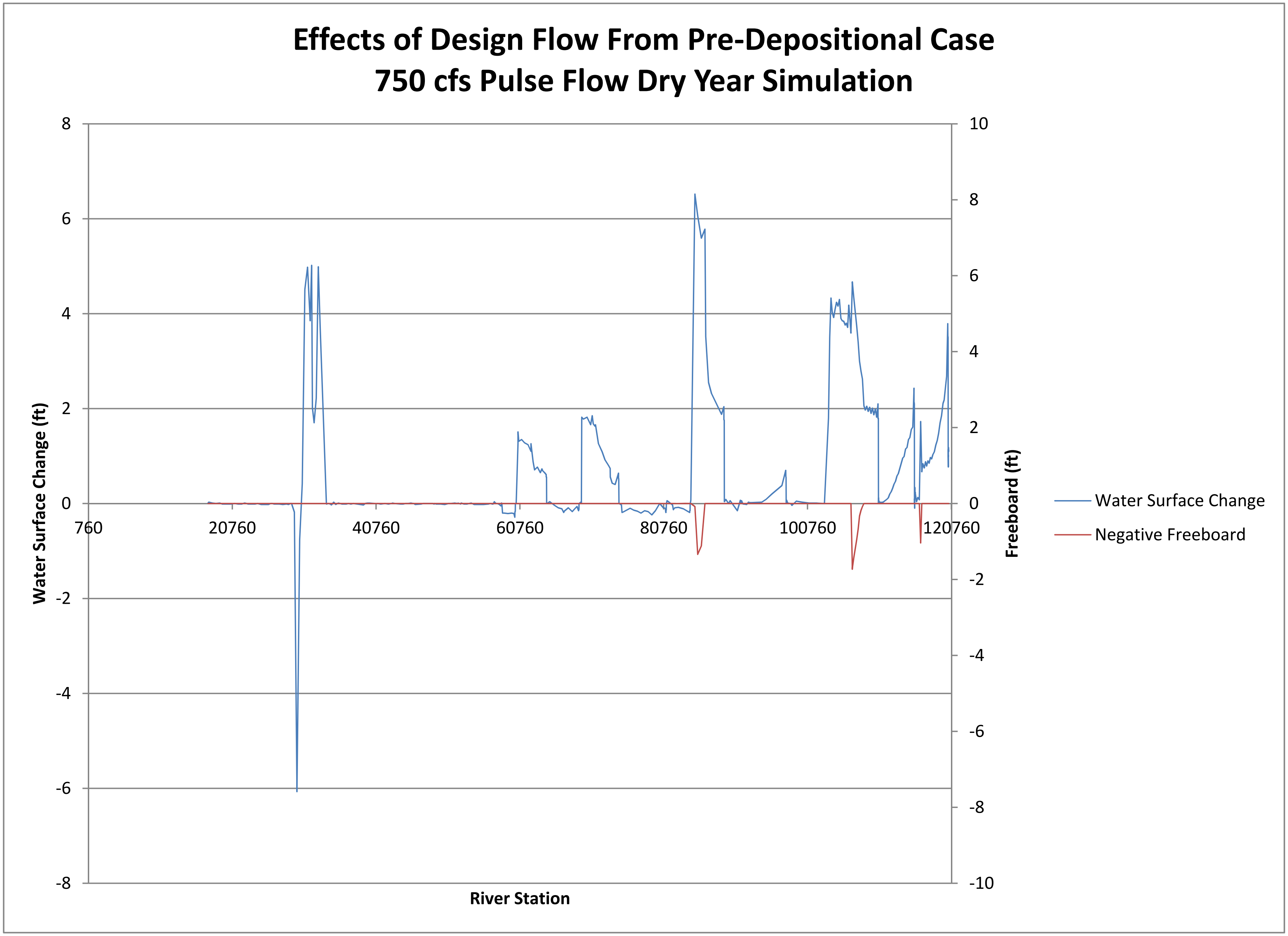

Effects of Design Flow From Pre-Depositional Case
750 cfs Pulse Flow Dry Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
760
20760
40760
60760
80760
100760
120760
River Station
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Water Surface Change
Negative Freeboard

Figure B.D.52

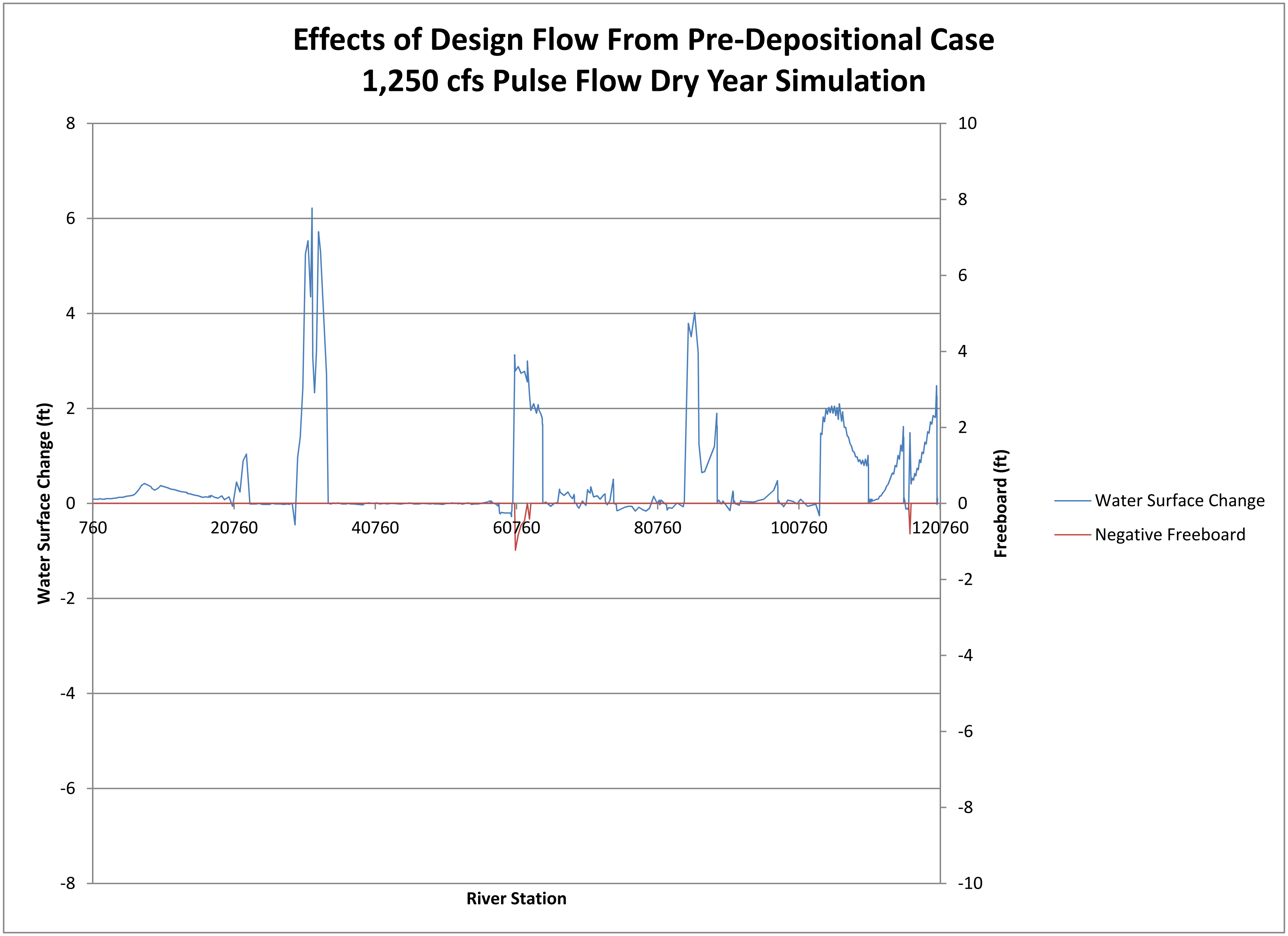

Effects of Design Flow From Pre-Depositional Case
1,250 cfs Pulse Flow Dry Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
760
20760
40760
60760
80760
100760
120760
River Station
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Water Surface Change
Negative Freeboard

Figure B.D.53

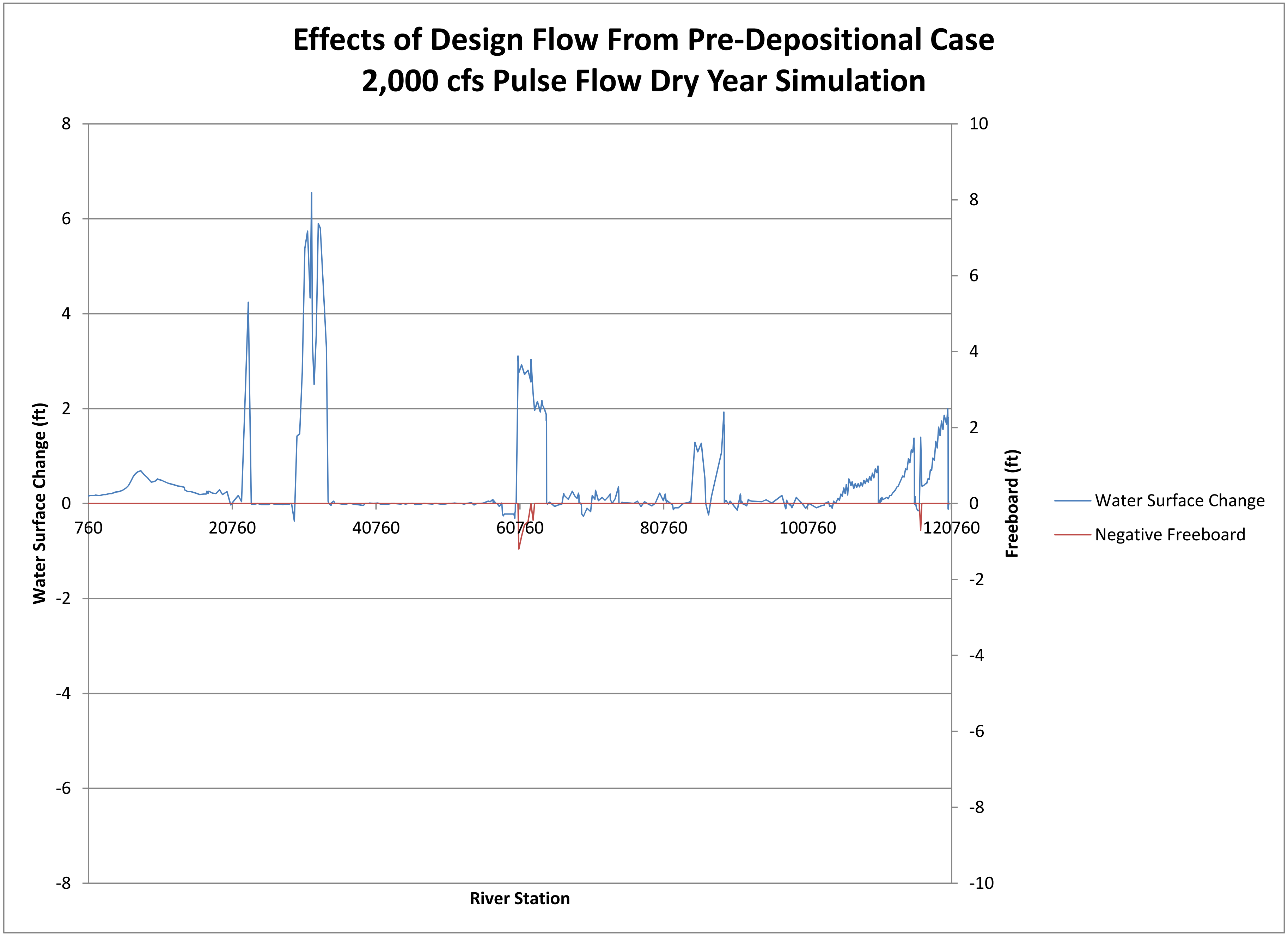

Effects of Design Flow From Pre-Depositional Case
2,000 cfs Pulse Flow Dry Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
760
20760
40760
60760
80760
100760
120760
River Station
Water Surface Change
Negative Freeboard

Figure B.D.54

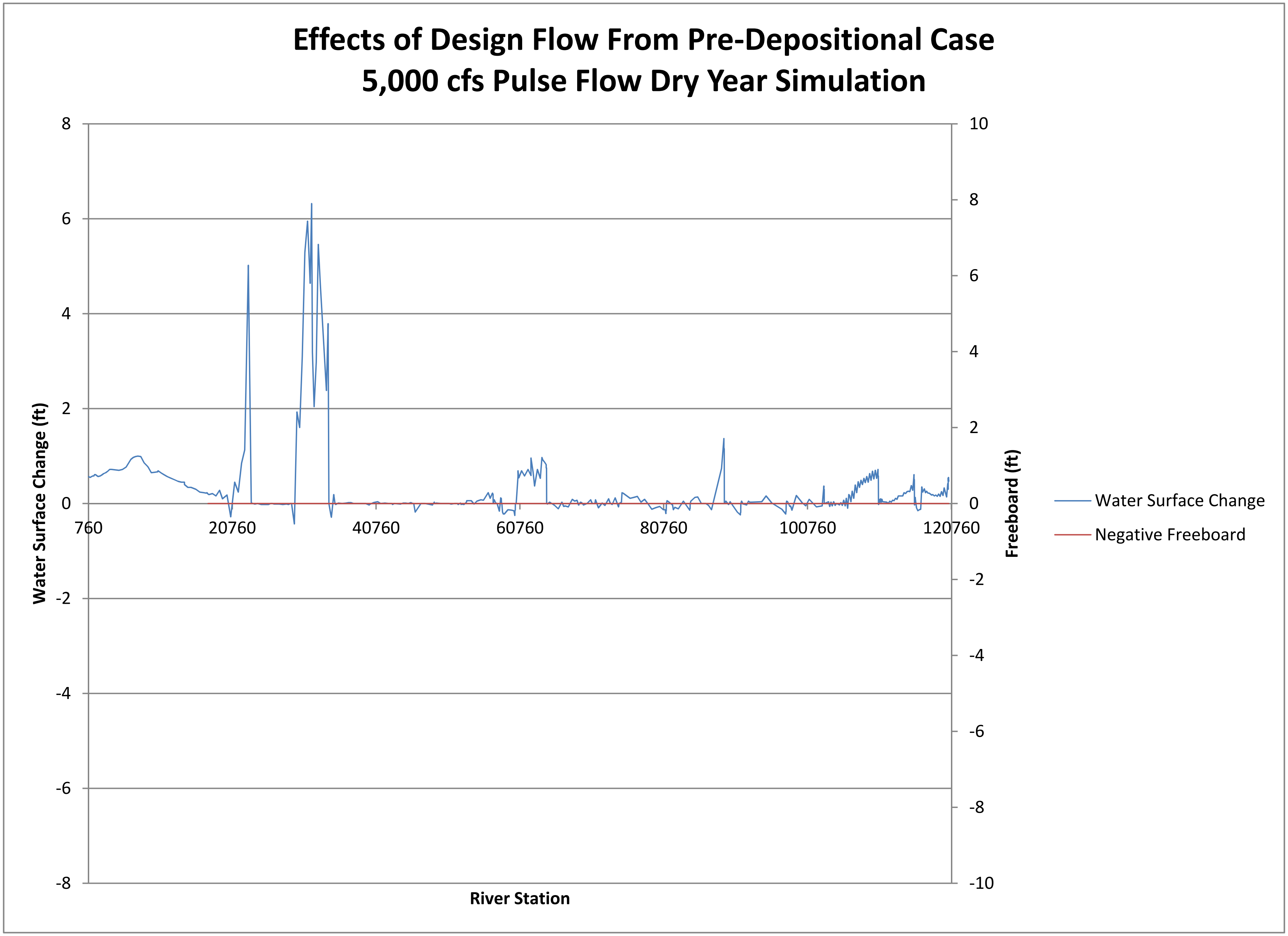

Effects of Design Flow From Pre-Depositional Case
5,000 cfs Pulse Flow Dry Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
760
20760
40760
60760
80760
100760
120760
River Station
Water Surface Change
Negative Freeboard

Figure B.D.55

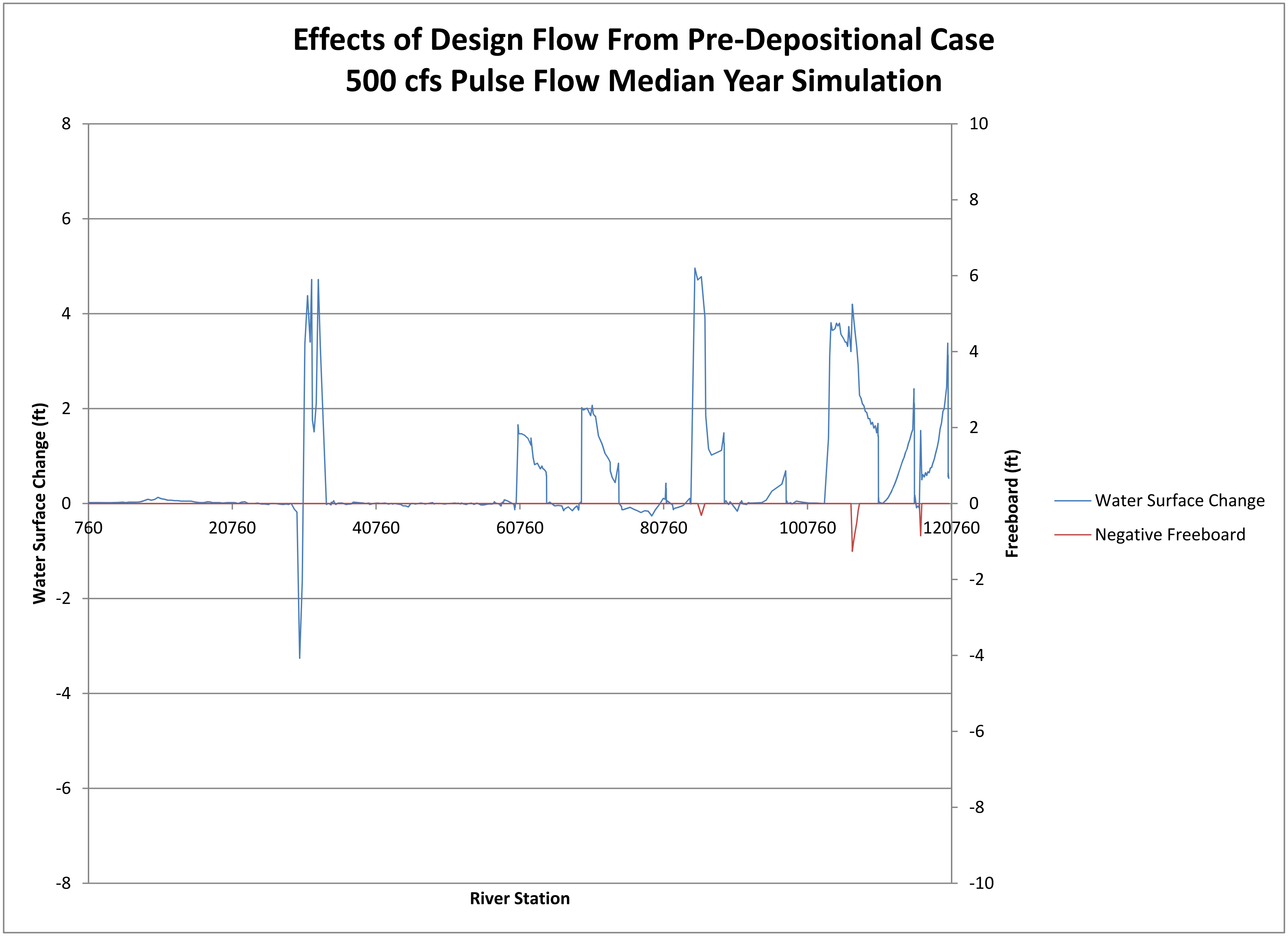

Effects of Design Flow From Pre-Depositional Case
500 cfs Pulse Flow Median Year Simulation
Water Surface Change (ft)
Freeboard (ft)
River Station
8
6
4
2
0
-2
-4
-6
-8
10
8
6
4
2
0
-2
-4
-6
-8
-10
760
20760
40760
60760
80760
100760
120760
Water Surface Change
Negative Freeboard

Figure B.D.56

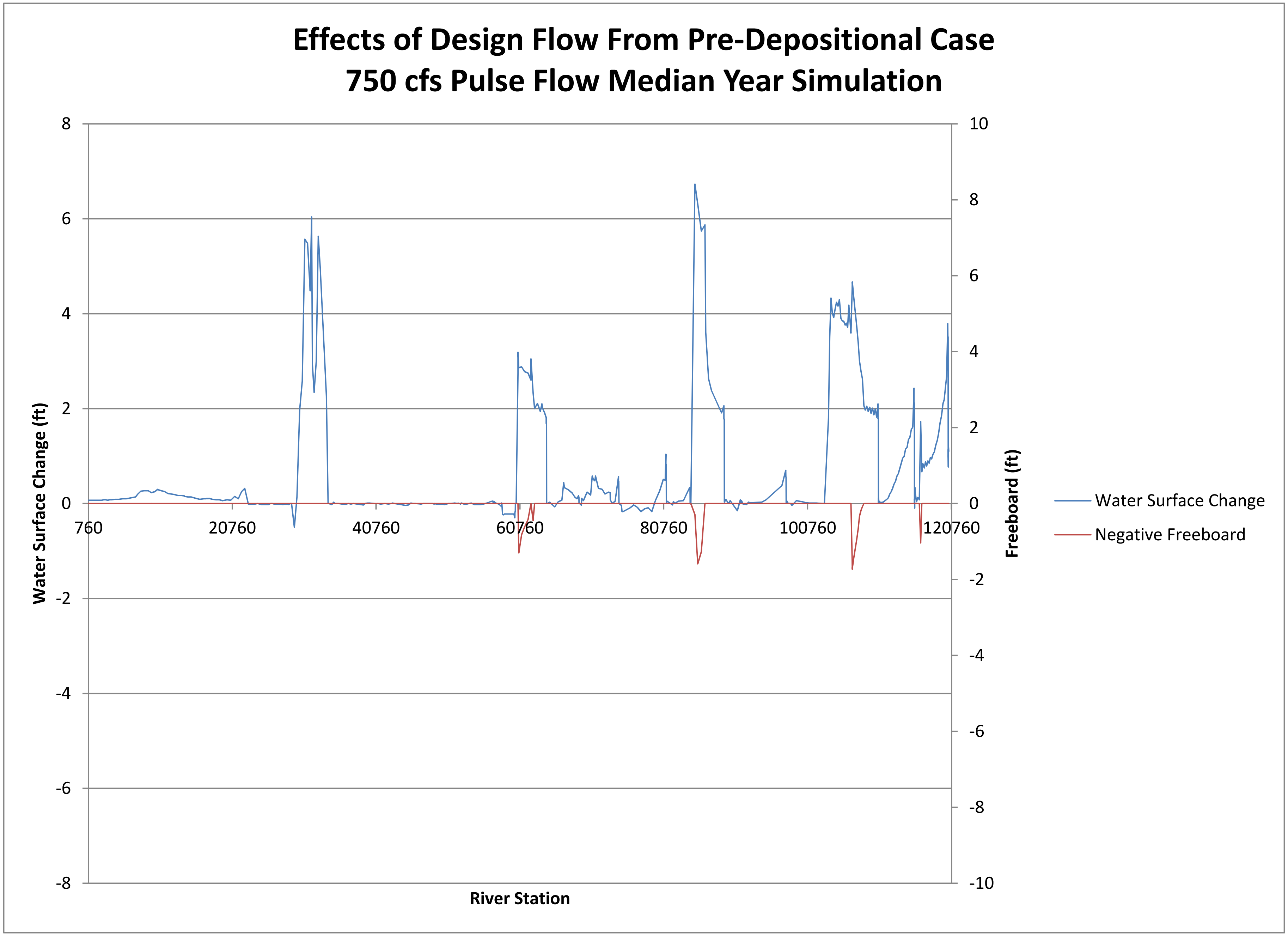

Effects of Design Flow From Pre-Depositional Case
750 cfs Pulse Flow Median Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
760
20760
40760
60760
80760
100760
120760
River Station
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Water Surface Change
Negative Freeboard

Figure B.D.57

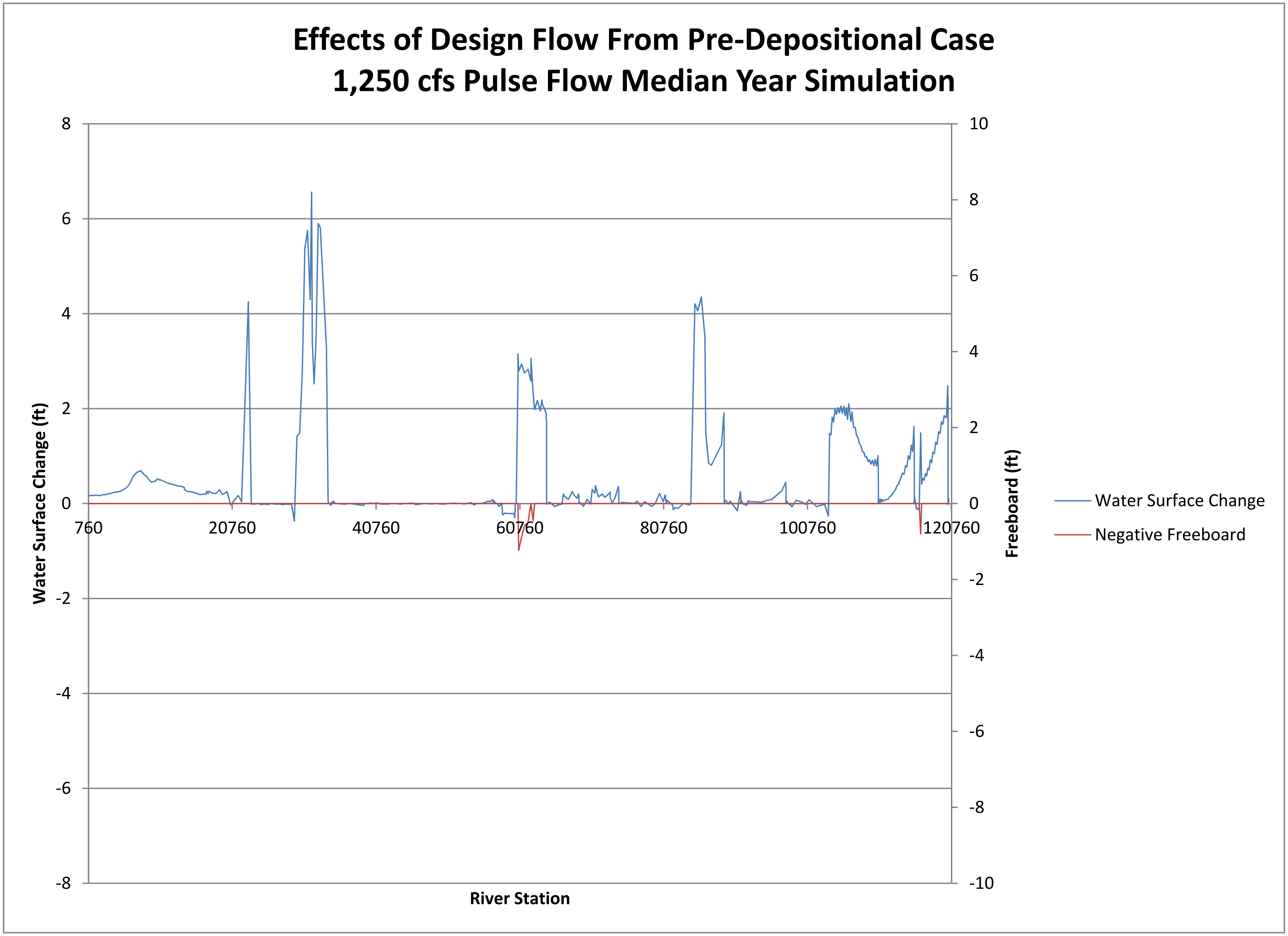

Effects of Design Flow From Pre-Depositional Case
1,250 cfs Pulse Flow Median Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
760
20760
40760
60760
80760
100760
120760
River Station
Water Surface Change
Negative Freeboard

Figure B.D.58

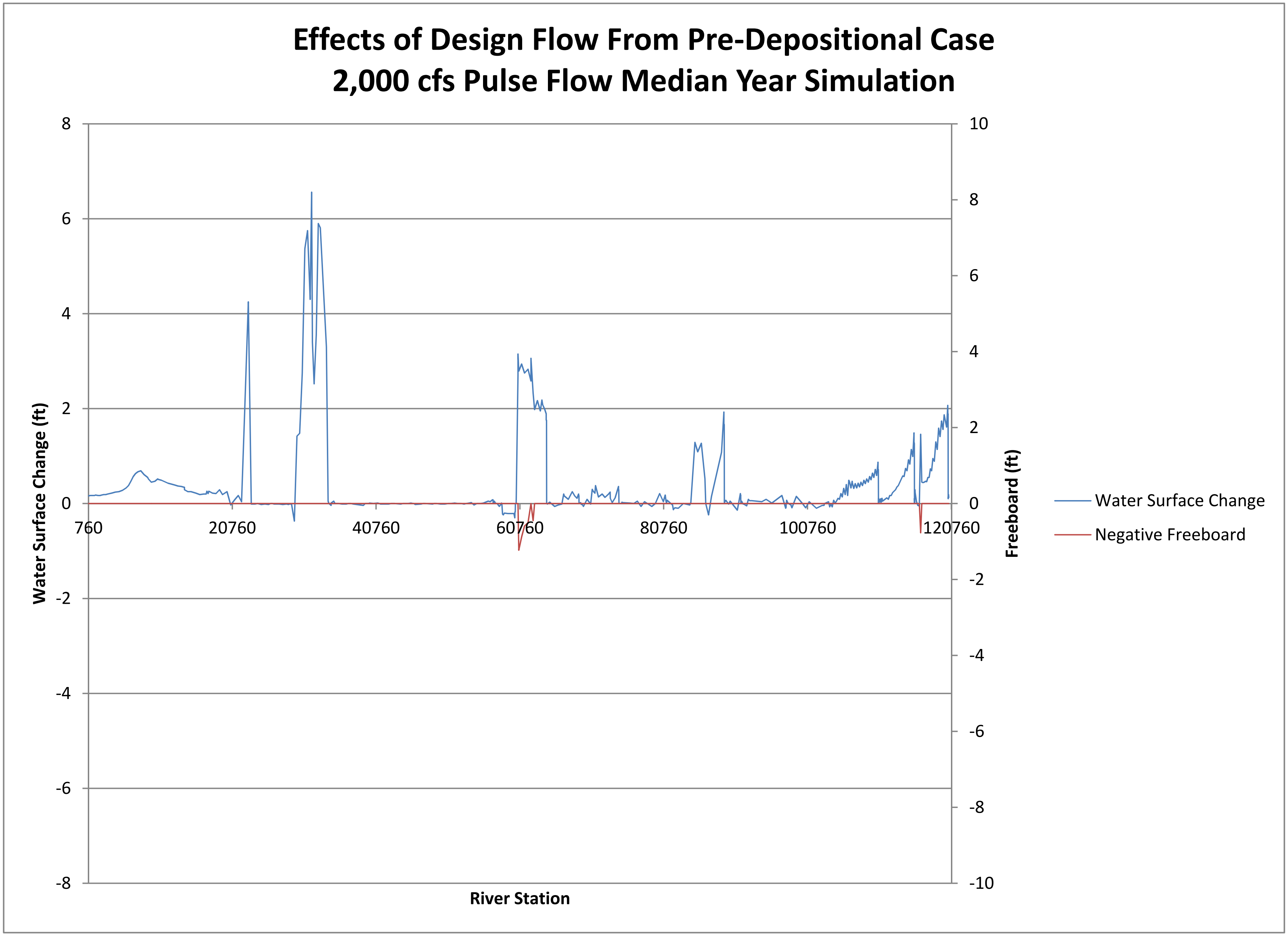

Effects of Design Flow From Pre-Depositional Case
2,000 cfs Pulse Flow Median Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
760
20760
40760
60760
80760
100760
120760
River Station
Water Surface Change
Negative Freeboard

Figure B.D.59

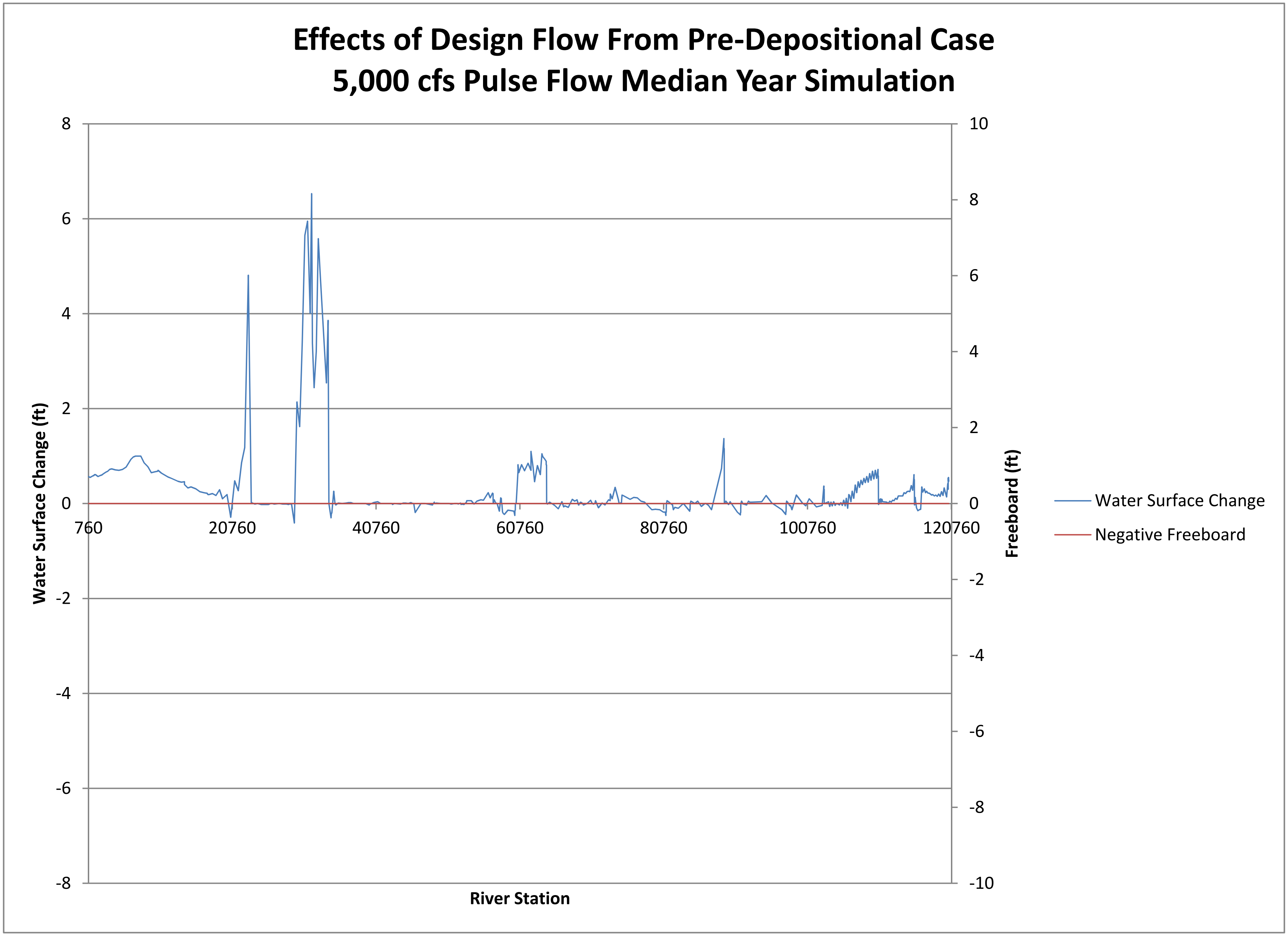

Effects of Design Flow From Pre-Depositional Case
5,000 cfs Pulse Flow Median Year Simulation
Water Surface Change (ft)
8
6
4
2
0
-2
-4
-6
-8
Freeboard (ft)
10
8
6
4
2
0
-2
-4
-6
-8
-10
760
20760
40760
60760
80760
100760
120760
River Station
Water Surface Change
Negative Freeboard

Figure B.D.60

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

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