Dewberry

ARCHITECTS ENGINEERS CONSULTANTS

Historic Waterford Water Feasibility Study

Loudoun County

Dewberry Project No.: 50079958

March 31, 2022

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ABBREVIATIONS

AACE	American Association of Cost Engineering International
ADD	Average Daily Demand
CAPP	Certificate of Appropriateness
CLOMR	Conditional Letter of Map Revision
CMPT	Commission Permit
Dewberry	Dewberry Engineers, Inc.
DTW	Depth to water
EDM	Engineering Design Manual
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GPD	Gallons per Day
GPM	Gallons per Minute
HDRC	The Historic District Review Committee
LC	Loudoun County
LCHD	Loudoun County Health Department
LOMR	Letter of Map Revision
LW	Loudoun Water
MSL	Mean Sea Level
NEPA	National Environmental Policy Act
NTP	Notice to Proceed
ODW	Office of Drinking Water
OPCC	Opinion of Probable Construction Cost

RPA	Rural Policy Area
SHPO	State Historic Preservation Office
SWPPP	Stormwater Pollution Prevention Plan
TOYR	Time of Year Restrictions
The Program	Community Water and Wastewater Program
US	United States
USACE	US Army Corps of Engineers
VA DEQ	Virginia Department of Environmental Quality
VDCR	Virginia Department of Conservation and Recreation
VDH	Virginia Department of Health
VDHR	Virginia Department of Historical Resources
VDOT	Virginia Department of Transportation
VDWR	Virginia Department of Wildlife Resources
VDOF	Virginia Department of Forestry
VMRC	Virginia Marine Resources Commission
VSMP	Virginia Stormwater Management Program
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The Village of Waterford is a community that is dedicated to preserving its 18th- and 19th-century architecture and landscape, located in a historic district in Loudoun County, Virginia. The village includes 154 lots that are completely within or partially within the study boundary, with 145 lots completely within the study boundary. Many of the community members of Waterford use individual wells as their primary source of water without issue. However, a number of members of the community have been experiencing issues with well yield, which led them to apply to the Water and Wastewater Program (The Program). This application was accepted, and as a result, Dewberry Engineers Inc. (Dewberry), under agreement with Loudoun Water (LW), was tasked with developing an engineering feasibility study.

The purpose of this feasibility study is to evaluate the concerns identified in the community of Waterford's application and to determine the technical feasibility of potential solutions to the community's drinking water issues. This feasibility study reviews the existing conditions of the community, presents the estimated existing and future water demands of the community, provides an analysis of the existing water supply systems and provides an evaluation of the following five (5) options to improve the water systems in Waterford:

1. Upgrade Existing On-Site Systems to Improve Yield on Individual Wells
2. Shared Private Wells
3. Community Water System Owned and Operated by Loudoun Water (Using New Community Wells)
4. Connection to a Nearby, Existing Community System
5. Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System

Prior to analyzing the feasibility of solutions, an analysis of the overall community was performed to better understand the community characteristics such as topography, historical resources, planning and zoning. A technical memorandum was prepared that assessed potential permitting and regulatory conflicts within the Waterford study boundary in regard to the five (5) options, which is included as **Appendix A**. A summary of the potential permits needed for Waterford is provided in the permit register in **Table 2.1**. It should be noted that the exact permitting and regulatory requirements for a particular option will not be able to be fully evaluated until a plan for that option is completed, or advanced with sufficient detail, and submitted to regulatory agencies for review. Based on the historic nature of the community, the permitting and approval process may be involved, however, no limitations were identified that would deem construction of a water system infeasible at this stage of a study. Subsequent phases of this project may include further field investigations, which could drive permitting and approvals that ultimately become a critical path for the project, such as the need for archeological surveys or other detailed studies.

A flow analysis technical memorandum was developed, included as **Appendix B,** which describes the process used to estimate existing and future water demands within the Waterford community. Community demand and minimum yield requirements are dependent on which alternative is selected and is a function of existing community development and potential future community development. Individual systems have different requirements than community systems or municipal connections. As a result of the flow analysis, a community well system serving the existing development would require a well yield of 146 gpm with a potential future yield requirement of 173 gpm based on potential future buildout. Therefore, the recommended demand flow (for the study area) to be used for sizing of a community water distribution piping and well/treatment systems (as needed) for the Waterford community is 173 gpm.

Online health department records, the results of a survey that was sent out to 117 residents regarding water yield, and the groundwater hydrology report prepared by Tetra Tech were studied to determine the existing conditions of the well systems throughout Waterford. The survey letter and summary of results are included in **Appendix C** and the groundwater hydrology report is included in **Appendix D**. This review confirmed that well yield is a concern within pockets of the Waterford community and identified contributing factors to low-yield wells. These problems were documented for approximately 17 to 22 lots out of approximately 145 lots completely within the study boundary (approximately 12% to 15% of the community). In general, groundwater elevations in Waterford wells rose or changed little between 2006 and 2021, and groundwater mining (i.e., withdrawal of water faster than recharge rate) does not appear to be occurring. Although, it should be noted that there is relatively less groundwater in Waterford than is typical within the greater Western Hills Watershed of western Loudoun County, as well as defined areas within the Waterford study boundary that have wells with low yield. In regard to water quality, the groundwater is generally acceptable for a potable water-supply, however; treatment will likely be required for iron and manganese.

Based on the location of the community, condition of the existing systems, and permitting/approval requirements, all five (5) options were evaluated to determine technical feasibility. The result of the evaluation determined that four (4) alternatives are technically feasible and one (1) alternative is not feasible. In summary:

1. <u>Upgrade Existing On-Site Systems to Improve Yield on Individual Wells –</u> Technically feasible alternative that may improve individual systems. Would require hydrofracking on individual wells to improve yield. Long term sustainability of this solution cannot be determined.

2. <u>Shared Private wells –</u> Technically feasible alternative that would require new wells and service connections that would serve up to four (4) residential homes. Challenges associated with maintenance agreements, easements, and building restrictions exist that will need to be addressed.

3. <u>Community Water System Owned and Operated by Loudoun Water (Using New Community Wells) –</u> Feasible alternative requiring new communal well system and treatment facility as well as water distribution system. Wells and treatment facility could be located in or around the existing Waterford community, pending further groundwater hydrology studies.

4. <u>Connection to a Nearby, Existing Community System –</u> The only existing nearby community water systems are Raspberry Falls/Selma Estates and Beacon Hill. However, a connection to Raspberry Falls/Selma Estates is not feasible due to the elevations of the mountain range that separates the community and Waterford .Beacon Hill has existing challenges with well yield. A technically feasible alternative would require expansion of the existing Beacon Hill well system and treatment system as well as installation of a long water transmission main that would convey water from Beacon Hill to Waterford. This solution may be a cost prohibitive alternative.

5. <u>Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System –</u> No municipal systems exist within approximately five (5) miles of the community, making this alternative infeasible.

Therefore, Options 1, 2 and 3 are technically feasible, and Option 4 is only technically feasible for connection to the Beacon Hill community system. A criteria analysis was developed using six (6) criteria, used to score each option on a scale from one (1) to five (5), with 5 being the more favorable scoring. As a result of this matrix, Option 2 or Option 3 are the preferred options for implementation to address Waterford's yield problems.

Option 2 includes a shared private system between residents. This option is limited to residential homes. Multiple shared well systems can exist within the community, as long as Loudoun County Health Department (LCHD) guidelines are followed. In order to remain under the jurisdiction of LCHD, the well must serve less than 15 connections or 25 people. If these numbers are exceeded or met, the well would become public waterworks, as defined by VDH ODW. Per discussions with the VDH ODW and LCHD, the limiting factor on number of connections is population, which is counted by 2 people per bedroom. Based on these discussions and an assumption of three (3) or four (4) bedrooms per home, the maximum number of connections that has been considered for this study is four (4) connections per shared well in order to ensure that the system does not exceed population restrictions as required by LCHD. Each new shared well system would require an existing or new well capable of providing an eight (8) gpm yield, easements, deeds and any additional legal covenants or agreements needed to ensure that the well does not meet the definition of a public waterworks and that responsibility for costs (e.g., well improvements) and violations are clearly defined between property owners.

Option 3 includes a new community system, owned and operated by Loudoun Water, with potentially six (6) community wells located along the periphery of the Waterford study boundary and associated treatment system and distribution piping to convey drinking water to Waterford residents, as shown in **Figure 4.5** and **Figure 4.6**. Attempts to locate and construct high-yield water wells would benefit from (and will require) conducting electrical resistivity survey work to select drilling locations on target parcels. High-yield wells are more likely to be developed in and to the north and east of the Waterford study boundary. The recommended demand flow to be used for sizing of water distribution piping and well/treatment systems (as needed) for the Waterford community is 173 gpm. Based on the information analyzed as a part of this study, a groundwater treatment system is assumed necessary due to iron and manganese levels within Loudoun County, therefore it is assumed that greensand filtration will be required. However, the type of treatment technology to be used, if needed, will need to be confirmed through quality testing once the community wells have been developed.

Class IV preliminary cost estimates, as defined by the American Association of Cost Engineering International's (AACE), were prepared for the recommended options (Options 2 and 3) using 2021 cost factors. Class IV cost estimates have an accuracy range of -20 to +30 percent of the estimated cost. The cost estimates represent a preliminary opinion of probable construction cost (OPCC) and are based on the assumptions outlined throughout this feasibility study. The approximate cost of the project will need to be inflated based on the anticipated implementation schedule.

The preliminary cost of implementing Option 2, which includes drilling a well and running 2-inch distribution piping to each property (4 properties), is estimated to be approximately $159,500 (with a low range of $127,600 and high range of $207,350).

The preliminary cost of implementing Option 3, which includes the design/permitting/surveying for the project, construction of the water distribution system and the water treatment system (assuming one greensand filtration treatment system), individual parcel improvements and road restoration/site work, is estimated to be approximately $10.5 million (with a low range of $8.4 million and high range of $13.6 million). Additional costs associated with Option 3 include O&M costs, to be borne by Loudoun Water, which are estimated to be approximately $108,000 annually (with a low range of $86,000 and high range of $140,000). Finally, a present worth analysis reveals the net present cost of Option 3 to be approximately $11.2 million.

1 PROJECT BACKGROUND

1.1 Waterford Overview

The Village of Waterford is located in a historic district in Loudoun County, Virginia, as shown in **Figure 1.1**. Waterford is a National Historic Landmark, meaning that it is recognized by the United States government for its historical significance, as the village is dedicated to preserving its 18th- and 19th-century architecture and landscape. All of the water provided to the community is through private wells (both shared and individual). Some members of the community have been experiencing issues with well yield, which led the community to apply to the Community Water and Wastewater Program (The Program). The community applied to The Program first in 2018 and then again in 2019 with additional information and a modified boundary, which is shown in **Figure 1.1**. This application was accepted due to the reported issues with well yields and the expanded study area.

Dewberry Engineers Inc. (Dewberry) is under agreement with Loudoun Water (LW) to develop an engineering feasibility study for The Program in order to evaluate the concerns identified in the community of Waterford's application and potential solutions to the community's drinking water issues. The following five (5) options are being evaluated to help improve water conditions within Waterford:

1. Upgrade Existing On-Site Systems to Improve Yield on Individual Wells
2. Shared Private wells
3. Community Water System Owned and Operated by Loudoun Water (Using New Community Wells)
4. Connection to a Nearby, Existing Community System
5. Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System

1.2 Feasibility Study Purpose

The purpose of this study is to determine the technical feasibility of the five (5) potential solutions to Waterford's water issues. This feasibility study is divided into the following sections:

- Project Background
- Overall Community Evaluation
- Preliminary Existing System Analysis
- Current Estimated Water Demand & Potential Future Demand
- Water System Alternatives Evaluation
- Overall Costs
- Summary & Recommendations

It is ultimately the decision of the Waterford community as to which of the five (5) options shall be pursued. Should Options 3, 4 or 5 be chosen, the information in this study may be utilized by the community as a basis for planning and design.

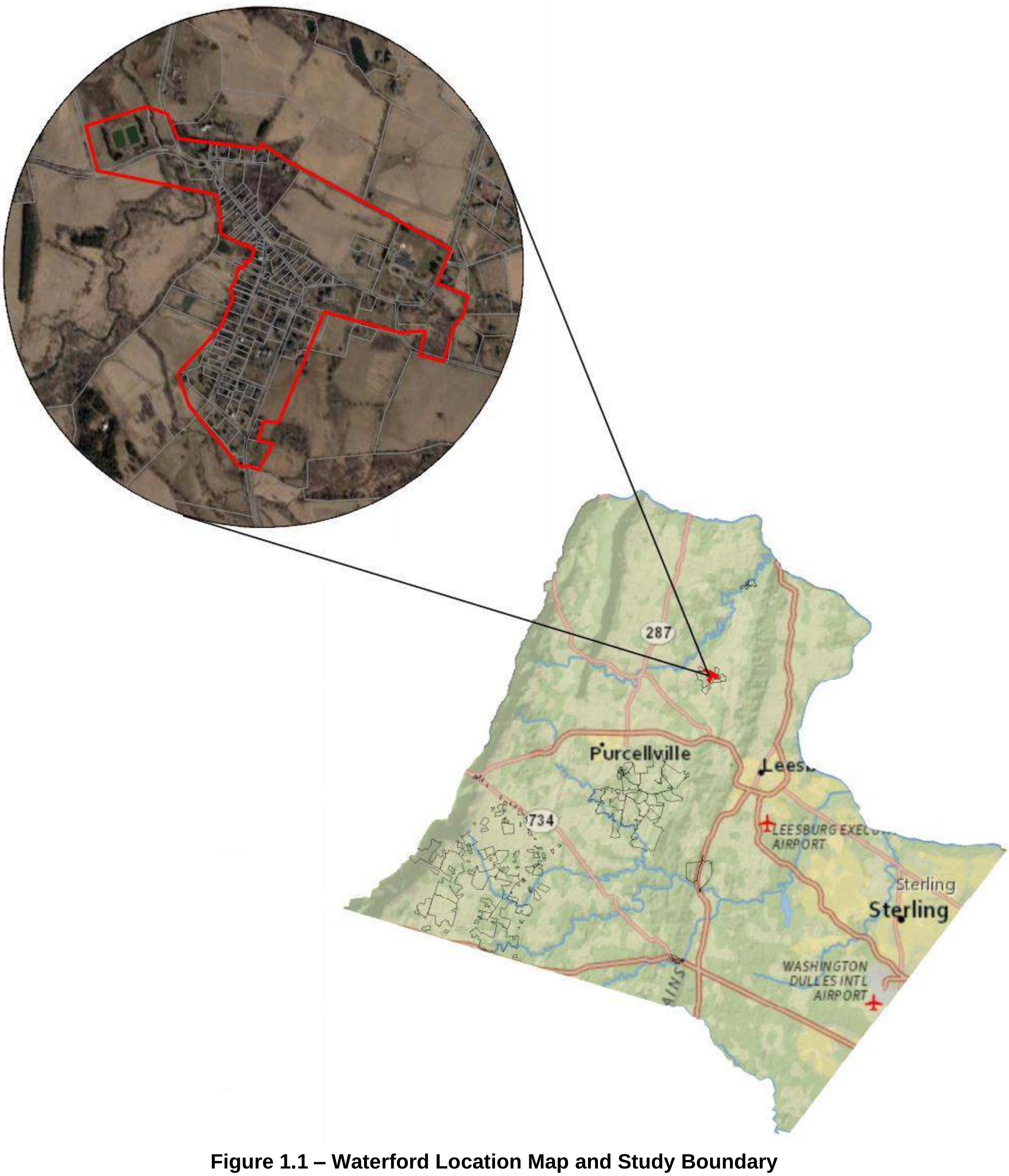


Figure 1.1 – Waterford Location Map and Study Boundary

2 OVERALL COMMUNITY EVALUATION

2.1 Existing Characteristics

Waterford is a small community with 154 lots that are either completely within or partially within the study boundary. The 145 lots that are completely within the study boundary range in size from approximately 0.02 acres to approximately 19 acres. A wastewater treatment plant (WWTP), owned and operated by Loudoun Water, is located at the Northwest corner of the study boundary, and most of the community is served by public sewer, which was installed in the mid- to late- 1970's. It should be noted that public sewer was installed to address a public health need, as wells showed bacterial contamination resulting from private on-site disposal systems. The sewer infrastructure is located under the roads of the community. Waterford is located by the South Fork of Catoctin Creek, as shown in **Figure 2.1**.

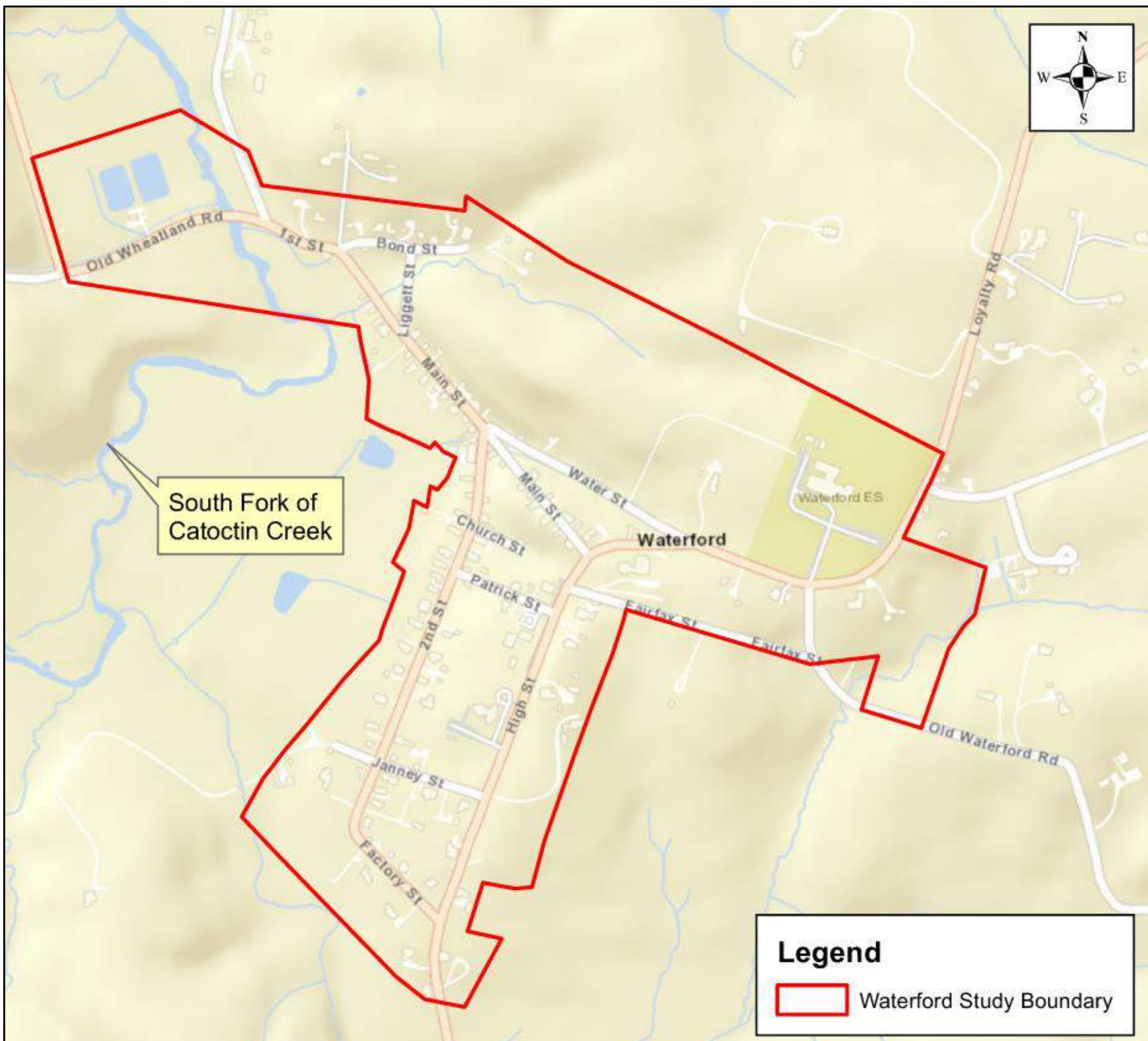


Figure 2.1 – Waterford Village by Catoctin Creek

2.2 General Topography

Waterford has a generally sloping topography throughout the community, with elevations generally decreasing from East to West as the land slopes towards the Catoctin Creek, as shown in **Figure 2.2**. The high point of the community is by the Waterford Elementary School at the Northeast corner of the Waterford study boundary and is approximately 472-feet above Mean Sea Level (MSL). The low point of the community is located to the Northwest of the study area boundary at the Catoctin Creek, which is approximately 340-feet above MSL. To the west of the Catoctin Creek and the WWTP (at the Northwest corner of the boundary), the elevation rises to approximately 360-feet above MSL.

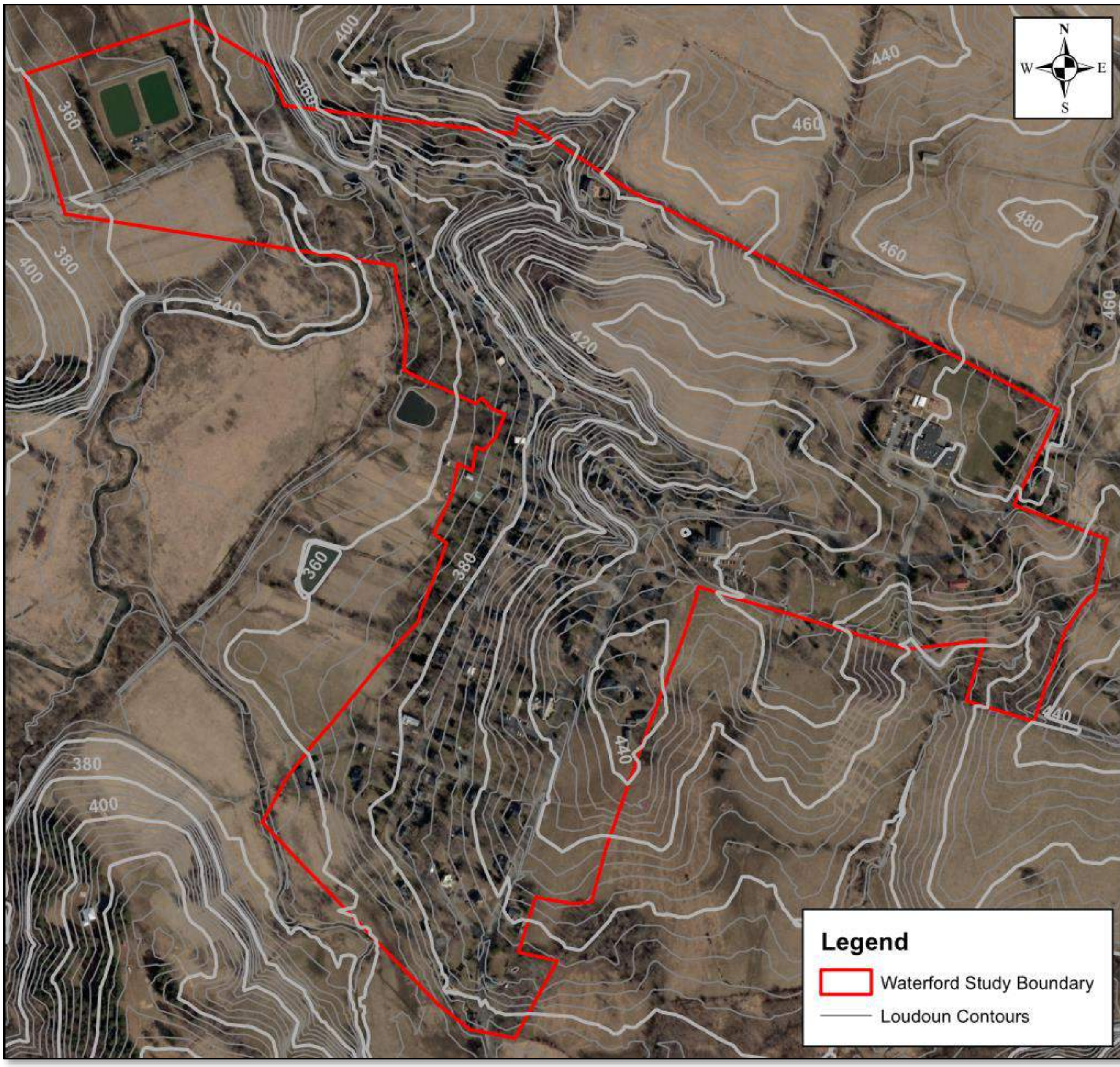


Figure 2.2 – Waterford Topography

2.3 Permitting/Policy Considerations, Regulatory Requirements & Right-of-Way Constraints

As previously described, the Village of Waterford has a rich historical background. The Village of Waterford with its well-preserved 18th and 19th century architecture and rural landscape is designated as a National Historic Landmark (ID#69000256), as well as a Loudoun County Historic and Cultural Conservation Site. Waterford is also included on the Virginia Historic Landmarks Register (ID#401-0123) and the National Register of Historic Places (ID#69000256). Furthermore, per the Loudoun County 2019 General Plan (2019 GP), Waterford is within the Rural Policy Area (RPA) in the Rural North Place Type and is designated as a Rural Historic Village. The 2019 GP policies for the RPA are aimed at protecting existing community characteristics and landscape, preserving heritage resources, developing agricultural and rural economy uses while limiting residential development. The 2019 GP policies also support the construction of community water systems in rural historic villages, as the document states, "public water and wastewater facilities are encouraged to provide services to the villages."

Due to the historic nature of the village, conflicts may arise with permitting considerations and regulatory requirements for each of the five (5) previously listed options to improve well yield problems in Waterford. This includes, but is not limited to, jurisdictional determinations, right-of-way (ROW) and easement constraints, policy considerations, and working in a National Historic Landmark.

A Technical Memorandum (TM) was prepared to assess potential permitting and regulatory conflicts within the Waterford study boundary in regard to the five (5) previously listed options, which is included as **Appendix A**. There are potential Federal, state and local permitting processes that need to be undertaken for all options. The permitting processes and regulatory requirements for each of the five (5) options were divided into four (4) different categories and are discussed in the following sections of the TM: Historical Permitting, Planning and Zoning Permitting, Health Department Permitting and Environmental Permitting. In each section, a description of relevant permit processes and regulatory requirements, as well as the options that they are applicable to, is provided.

The exact permitting and regulatory requirements for a particular option will not be able to be fully evaluated until a plan for that option is completed, or advanced with sufficient detail, and submitted to regulatory agencies for review. Should Options 3, 4 or 5 be chosen, the water main alignment will drive many of the permitting requirements, therefore; it should be noted that each permit needs to be considered as the alignment selection process is advanced.

A summary of the potential permits needed for Waterford is provided in the permit register in **Table 2.1**. The permit register was developed to consider all five (5) options. This list may not be all-inclusive and should be revisited and updated as appropriate (i.e., as the project scope and design proceeds and options are further assessed). All permits, regulatory requirements, and authorizations, such as Section 106 of the National Historic Preservation Act (NHPA), are further detailed in **Appendix A**.

Table 2.1 – Waterford Permit Register (August 2, 2021)

Permit/Authorization	Agency
Historical	
Section 106 authorizations, easement encroachments, and appropriate mitigation as necessary	VDHR SHPO
Section 106 / Landmarks Effect Determination	National Park Service (National Landmark Coordinator)
Certificate of Appropriateness (CAPP)	HDRC
Phase 1 archaeological survey approval	VDHR; Loudoun County Planning and Zoning
Planning and Zoning	
Commission Permit (CMPT)	Loudoun County
Special Exception (SPEX)/Minor Special Except (SPMI)	
Site Plan	
Grading Permit	
VDOT Utility Plan	VDOT
Detour/Traffic Management Plan	
VSMP/SWPPP	VA DEQ
Health Department	
Private Well Construction Permit (Single family or shared well not meeting the definition of a Public Waterworks)	LCHD
Chapter 1042.02 Application for Public Waterworks (15 connections or 25 people served, or greater)	
Abandonment Permits	
Construction and Operation Permits	VDH ODW
Construction Permit	LW
Connection Permit	
Environmental	
NEPA Document (if federally funded)	TBD; dependent on involvement of Federal agencies
Clean Water Act Section 404 Permit	USACE
Wetland Delineation Report and Jurisdictional Determination Request	
Clean Water Act Section 401 Virginia Water Protection Permit	VA DEQ
Virginia Stormwater Management Program Permit	
Hazardous Materials & Due Diligence Compliance	
Emergency Generator or Concrete Batch Plant Permit	VA DEQ
Permit to construct in Virginia Tidal Wetlands and Subaqueous bottoms.	Virginia Marine Resources Commission
Permit for timber sale	VA Department of Forestry
Virginia Scenic River Program Designation	Catoctin Creek Scenic River Advisory Committee
Preparation and submittal of a Conditional Letter of Map Revision (CLOMR)	Loudoun County/FEMA
Once constructed, prepare and submit a Letter of Map Revision (LOMR)	

3 CURRENT ESTIMATED WATER DEMAND & POTENTIAL FUTURE DEMAND

A Flow Analysis TM was prepared, which describes the process used to estimate existing and future water demands within the Waterford community and summarizes the results of this analysis. Community demand and minimum yield requirements are dependent on which alternative is selected and is a function of existing community development and potential future community development. Individual systems have different requirements than community systems or municipal connections. Analysis results were used to determine the recommended amount of flow, in gallons per minute (gpm), to be used for sizing of water distribution piping and well/treatment systems for the Waterford community, should they be necessary (i.e., if Option 3 was chosen). These estimates were developed to be as accurate as possible while adhering to Loudoun Water's Engineering Design Manual (EDM) and VDH ODW standards and requirements. Details can be found in the Flow Analysis TM, which is included as **Appendix B**.

For existing development demand estimates, the demands for residential homes, commercial buildings and schools were estimated using EDM standards. For commercial and industrial buildings, the number of employees for each business was determined either by contacting the businesses or by online research. Demands for churches and auditoriums were determined to best match the "theaters" category of the VDH ODW standards. These facilities were contacted to determine the number of persons expected at events. The total minimum required demand was also calculated per LW requirements, which require that a demand of 1.2 gpm be provided per connection to a community well (assumed 122 existing connections).

The potential future demand estimates were developed by assuming that all 154 parcels in the Waterford study boundary, except for ten (10) parcels that were excluded due to zoning restrictions or lack of anticipated water use, are occupied and require water service. The total minimum required demand was also calculated per Loudoun Water requirements, which require that a demand of 1.2 gpm be provided per connection to a community well (assumed 144 future connections).

Based on the analysis described above, a community well system serving the existing development would require a well yield of 146 gpm with a potential future yield requirement of 173 gpm based on potential future buildout. Therefore, the recommended demand flow (for the study area) to be used for sizing of a community water distribution piping and well/treatment systems (as needed) for the Waterford community is 173 gpm. It should be noted that requirements for fire protection is not included as part of this assessment. Loudoun County Facility Standards Manual regulations state that community water systems within the rural policy area do not require providing fire flow and pressures throughout the system. Fire protective devices, such as drafting hydrants, can be used to provide additional water storage for fire protection.

4 WATER SYSTEM EVALUATION

4.1 Review of Existing Data

Waterford is located in the Northeast portion of the Western Hills Watershed of western Loudoun County, which includes the North Fork Catoctin Creek and South Fork Catoctin Creek major watershed area. There have been approximately 190 individual private wells installed in the Waterford study boundary since the 1950's, including 147 individual wells (WWIN and WWTS types), 25 shallow dug wells (WWDU), 11 "dry hole" wells (WWDH), three (3) non-community water-supply wells (WWNC), three (3) heat pump wells (WWHP), three (3) springs and one (1) community well (WWCO), as shown in **Figure 4.1**. Approximately 131 wells are currently active, and most shallow dug wells have either been abandoned in accordance with LCHD regulations or are not pumped. Some residences rely on more than one (1) well to provide an adequate water supply. Some of these additional wells may be shallow dug wells.

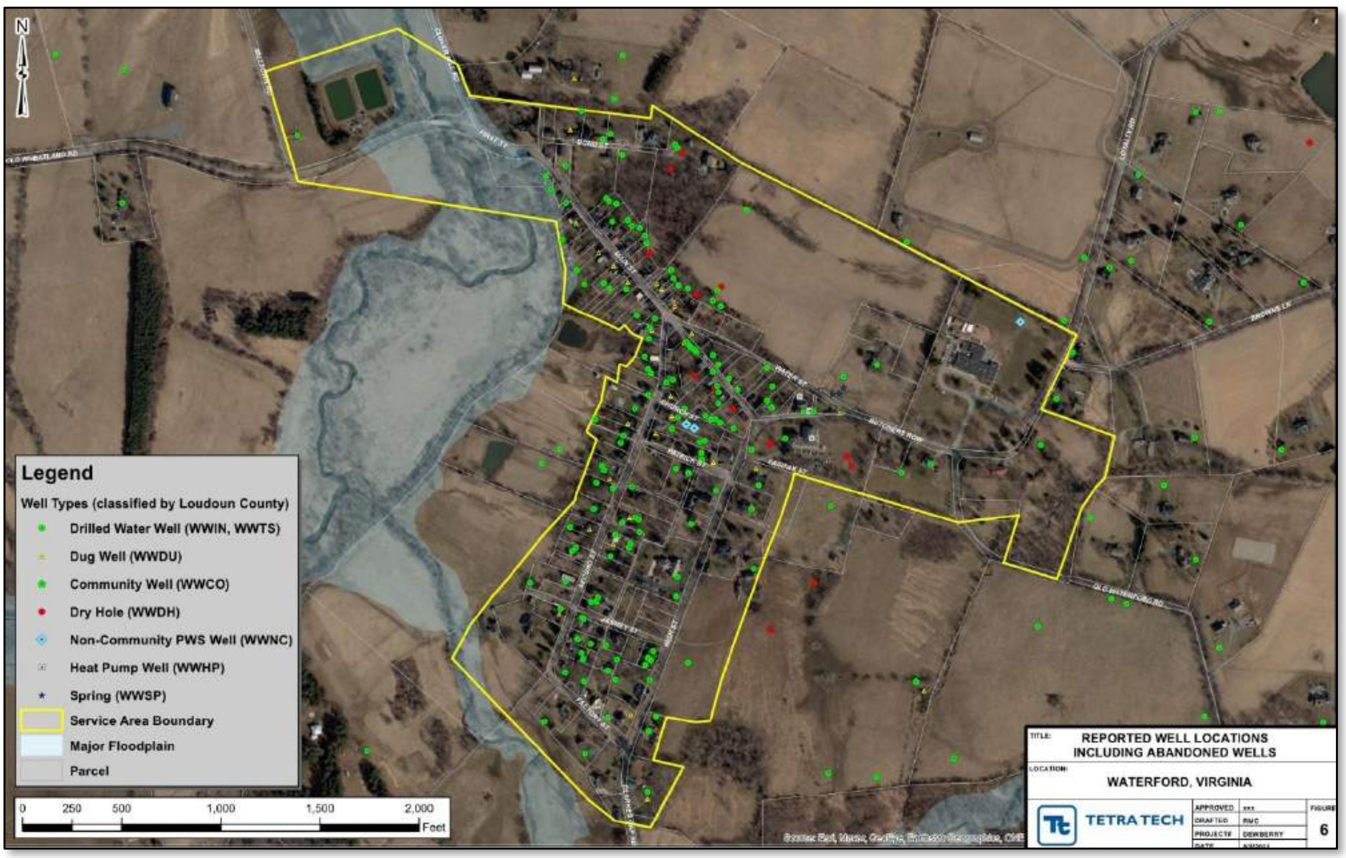


Figure 4.1 – Waterford Wells

This section reviews a 1966 feasibility study prepared by Dewberry, the Waterford application and existing well and groundwater data, which have been evaluated from health department records, survey results and a groundwater hydrology report prepared by Tetra Tech.

4.1.1 Previous Feasibility Study

Dewberry previously completed a feasibility study for water and sewerage facilities for the community of Waterford in August 1966. A survey conducted for this report found that more than 50% of the water supplies were not acceptable for domestic use. However, it was noted that the unsanitary health conditions were caused by the malfunctioning of a majority of the individual septic systems, which contaminated several of the well supply systems. The report recommended a centrally operated water and sewer distribution system. A sewer distribution system was installed in the late 1970's following this report and subsequent design.

The recommended water distribution system consisted of transmission mains, an elevated storage tank and source of supply from drilled underground wells. It was determined that well supply was the most economical and feasible method of obtaining water for a small community, as connection to a nearby municipality (Leesburg) was deemed economically infeasible and the costs (including land, construction operating and treatment costs) of obtaining a potable water supply from a stream (surface water) is much greater than that of a drilled well. The report noted that the required water demand of the community could be satisfied from drilled wells, and it was anticipated that the water would be of good chemical quality.

4.1.2 Waterford Application

The community of Waterford applied to The Program first in 2018 and then again in 2019 with a new study boundary. The 2019 Waterford application was accepted due to the reported issues with well yields and the expanded study area. It should be noted that "the majority of those who did not sign are worried about the possible cost and uncertainty about The Program and the threat of development should water be more readily available."

The application states that "18 homes are having serious quantity problems but can't afford to drill again and/or current technical options are limited on their small, marshy, or steep lots; others have periodic challenges, where the well goes 'dry' or the pressure drops so low, water can't be obtained." The application highlights thirteen (13) residential properties that have significant yield problems, which are described below:

- One (1) property is empty due to a lack of water
- Owners of one (1) property have to purchase 5,000 gallons of water every two (2) weeks to meet household needs
- One (1) property with three (3) wells that likely cannot drill more
- One (1) property owner that had a well go dry but fears digging a new well
- Five (5) properties "where residents must closely monitor and often forego showers, flushing toilets, running dish washer, etc."
- Four (4) properties that "have wells that run 'dry' periodically or measures have to be taken to prevent water shortages when guests arrive."

The application also notes that having water or improved water at several buildings could benefit business in the community.

4.1.3 Review of Health Department Records/Official Online Records

Existing health department records were reviewed through VDH ODW's open-information online database, Online Responsible Management Entity (RME). The database includes records of well and sewer system applications, such as well permits and Water Well Completion Reports submitted by well drillers, as well as inspections and results. It should be noted that inspections are not routine and occur following complaints, prior to real-estate transfer and following connection to a newly constructed well. Due to the lack of routine inspection, some wells could have become non-compliant since last inspection. It should also be noted that records of some parcels are non-existent, as older wells do not have records. Furthermore, there are inconsistencies in records, such as lots being identified as “septic with gravity” despite records showing septic had been abandoned. Therefore, the information presented in this section is not comprehensive.

Records were available for 48 of the 145 parcels completely within the Waterford study boundary. Of these parcels, 15 (approximately 10%) contained documentation of yield problems and/or a dry well, and 16 (approximately 11%) contained documentation of an unsatisfactory well sample and/or a complaint regarding water quality. It should be noted that, due to the previously described lack of records, these numbers do not necessarily reflect the full extent of existing community well conditions.

Despite the lack of records and inconsistencies, there appeared to be strong evidence that well yield is a historical and continuing problem within the Waterford community. Several documents indicated that yield problems in Waterford are common knowledge. A letter dated 8/1/2010 states, “the water situation in Waterford makes it very unwise to abandon any well with a measurable return." Another letter dated 7/13/2000 states, "as you know, Waterford suffers from many instances of wells going dry.” A letter dated 5/1/2000 introduces Waterford as “a village with a long history of water problems." The online records also provided specific examples of problems encountered by Waterford residents. A letter dated 6/11/1994 states, “Our well runs dry approximately once a week despite our best efforts to be frugal with water use...Our current water supply is so scarce that we fear any decrease in well yield will effectively leave us with no water at all." Another letter dated 8/17/2010 states, "I was distressed to hear of your difficulty to find sufficient water to serve your home in Waterford." Overall, records as recent as 2010 detail yield problems within Waterford, with ten (10) lots containing documentation of yield problems and seven (7) lots containing records of dry wells, which date back to 1983. Therefore, the records indicate that well yield is a reoccurring and current problem in Waterford.

There was not strong evidence that water quality is a current issue in the community. However, there have been past instances where water quality was of concern. There was an underground storage tank release in the late 1980’s. The issue is described in a letter dated 1/13/1989, which states, "recently, this office was informed of petroleum contamination to a private drinking water well in the vicinity of a previously investigated pollution incident resulting from an underground storage tank release…this office requires the Waterford Foundation to conduct further investigation and complete corrective action requirements." The contamination affected the groundwater aquifer, which affected wells in two (2) neighboring lots. This issue was resolved, as the wells were tested and the results revealed that the measured contaminant levels were not considered a threat to health. This resolution is documented in a letter dated 6/29/1989, which states, "In response to your complaint, the Loudoun County Department of Health collected a water sample from your residence on November 15, 1988. In consideration of the maximum contaminant levels published for regulated chemicals listed in the Safe Water Drinking Act, concentration levels of 12 ppb naphthalene, and 11 ppb ethyltoluene identified in your well water, are not considered to be a threat to your health." All other instances of past water quality issues (e.g., sewage drainage into water from since abandoned drainfields, water quality issues from naturally occurring leachate, odor/taste complaints and unsatisfactory tests) also appeared to be resolved. Overall, the majority of records containing water quality issues occurred from the 1970’s to the early 1990’s. The lack of recent records may be due to the fact that testing and reporting are not required after the initial construction of a well, and a small number of wells have recently been constructed in Waterford. Furthermore, various water quality issues may have been resolved following the implementation of a public sewer system in the late 1970's and subsequent abandonment of individual sewage systems over time as members of the community chose to connect to the public sewer system.

Additional, official documentation of well yield problems in Waterford can also be found online. Several reports developed by community members address these problems and potential solutions. The "2011 Community Water Supply For Waterford: What Would It Take Report" states, "an unusually high proportion of the wells in the Village have low or very low yields in comparison to other areas in western Loudoun County." Furthermore, the "Status of the Water Supply on Waterford Foundation Properties" (October 2011) report states, "The Waterford Foundation Board of Directors (BOD) established the Ad-Hoc Water Supply Committee in September 2010. The decision to create this committee was made after several wells in the village went dry during the previous summer."

4.1.4 Well Yield Survey Results Summary

A survey was sent out to 117 residents of the Waterford community in March 2021. The purpose of the survey was to obtain feedback from the community regarding any issues experienced with well yield. The survey asked seven (7) questions. Questions 1, 2, 3 and 5 were quantitative questions (with the option to provide additional comments), and questions 4 and 7 were qualitative questions. In order to identify if certain areas in Waterford experience more well yield problems than others, while maintaining anonymity, survey responders were asked (in question 6) to indicate which "zone," out of five (5) zones, that their residence is located in, based on a map provided with the survey. The survey letter and results, as well as the map showing the different zones, can be found in **Appendix C**. The survey questions can be found on the next page.

1. Do you encounter problems with the amount of water your well provides?

If you answered 'Yes' please explain problems encountered below:

____

____

____

2. Do you encounter these quantity problems only at certain times of the year? Yes _____ No _____

If you answered 'Yes' please place an X over every typical month(s) when quantity problems occur below:

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC

Please provide additional explanation below, if needed:

____

____

____

3. For the well problems noted in question 2, if they occur on a regular frequency, please indicate the frequency below:

Indicate the number of hours and times DAILY__________,

Indicate the number of days WEEKLY__________,

Or Indicate the number of weeks MONTHLY______?

4. For the well problems noted in question 2, if they occur on an intermittent frequency, please describe below:

____

____

____

5. Have you observed a noticeable decrease in the amount of water provided by your well within the last five years (since 2016)? Yes _____ No _____

If you answered 'Yes' please explain below:

____

____

____

6. Using the figure provided with this survey, please indicate the geographical area, by zone number, where your well is located. The purpose of this information is to provide general location information for well quality concerns without identifying a specific parcel or well's location:

Zone ____

7. Please provide any additional information or comments:

____

____

____

A total of 82 responses to the survey were received as of May 20, 2021 (70% response rate). Quantitative responses are summarized in **Table 4.1**, which shows both the number of responses and the percentage of responses within each zone and overall.

Table 4.1 – Well Yield Survey Quantitative Results

Zone	#[1] / %[2]	Question 1		Question 2		Question 3				Question 5	
		Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
1	#	1	10	0	11	1	0	1	10	0	11
	%	9%	91%	0%	100%	9%	0%	9%	91%	0%	100%
2	#	2	13	0	15	0	0	0	15	0	15
	%	13%	87%	0%	100%	0%	0%	0%	100%	0%	100%
3	#	8	17	1	24	0	0	0	25	4	21
	%	32%	68%	4%	96%	0%	0%	0%	100%	16%	84%
4	#	1	14	0	15	0	0	1	14	0	15
	%	7%	93%	0%	100%	0%	0%	7%	93%	0%	100%
5	#	5	10	1	14	0	0	0	15	2	13
	%	33%	67%	7%	93%	0%	0%	0%	100%	13%	87%
Overall	**#**	**17**	**65**	**2**	**80**	**1**	**0**	**2**	**80**	**6**	**76**
	%	**21%**	**79%**	**2%**	**98%**	**1%**	**0%**	**2%**	**98%**	**7%**	**93%**

[1]Number of responses

[2]Percentage of responses

Overall, 21% of survey responders indicated that they have problems with well yield (Question 1). The highest number of well yield problems was reported in Zone 3. It is inferred that the majority of well yield problems occur in the central area of the Waterford study boundary around Main Street. However, well yield problems appear to occur throughout the entire study area. Based on investigation by tetra tech, lowest yielding wells, which are those with flows less than or equal to 2 gpm, are prevalent throughout the community. It should also be noted that the number of responses that indicated well yield problems within each zone did not correspond to the number of wells with yields from 0-2 gpm in each zone, as shown in **Figure 4.2**.

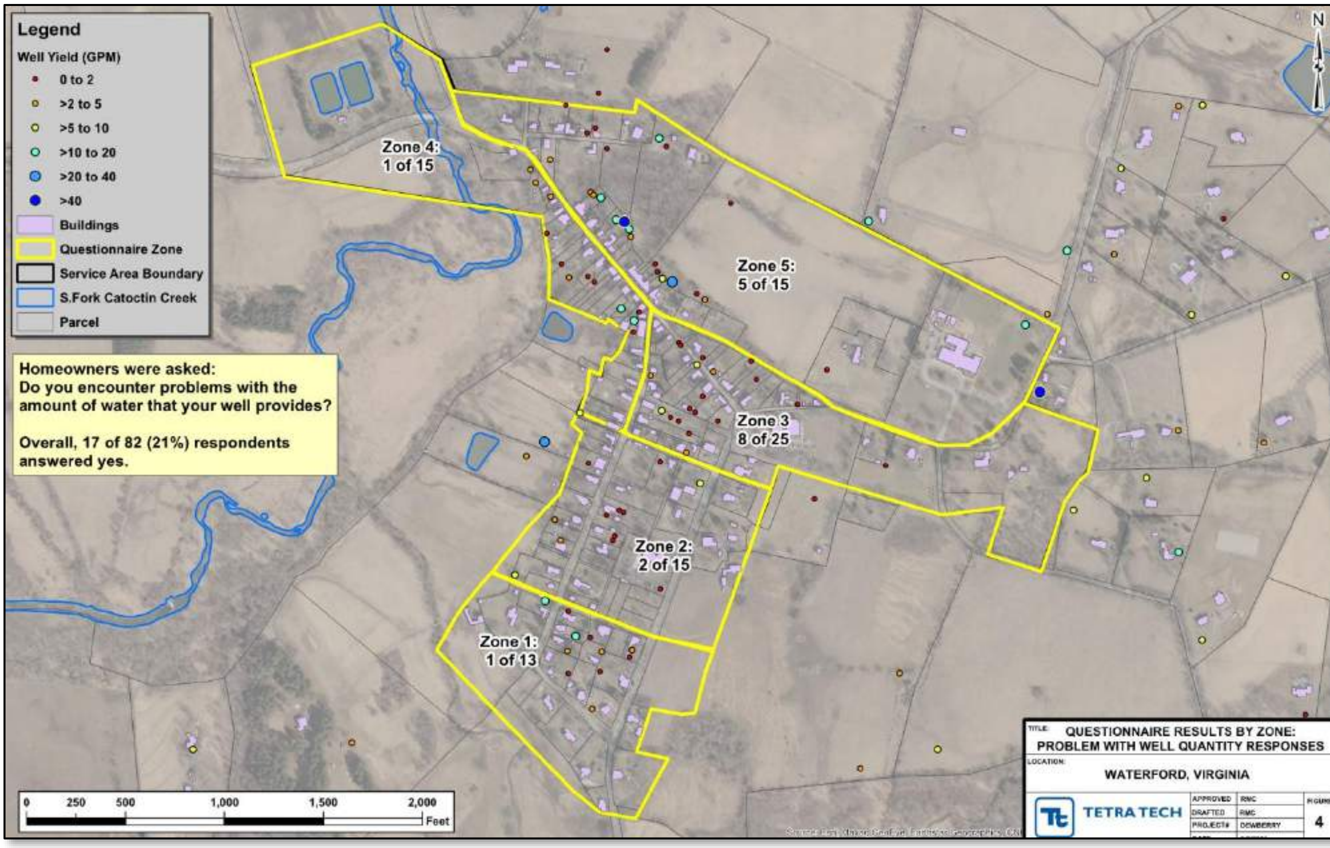


Figure 4.2 – Survey Responses (Question 1) versus Well Yields

Survey responders were also provided the chance to share thoughts in qualitative questions and space for comment on quantitative questions. Many responses noted that their well(s) ran dry if used for a prolonged period of time (e.g., watering grass, hosting large event, running laundry/dishwasher, washing car, etc.). Several responses noted that their well(s) ran dry during a drought or dry weather. Numerous responses indicated that well yield problems did not occur during a certain time of the year, but rather all year-round. Some comments acknowledged that they are not aware of the full extent of their well yield problems, as they currently practice several methods of conserving and storing water. A very concerned response wrote, “We have struggled with water for 20+ years in Waterford. In 2017, our second well went dry. Our new well only provides a pint of water every 45 minutes, about 6 gallons a day. The new well is >700-feet deep. We truck water in on our own truck and tank every 3-5 days from a local municipality. Our problems have been every month for 20+ years.” Another concerned response wrote, “I have to haul 5-gallons of bottled water to bathe. It's hard to lift bottles up 3 flights of stairs. It's been going on for 2 years now.” These comments confirm that members of the Waterford community are currently experiencing well yield issues and have historically experienced these issues.

It should also be noted that five (5) responses indicated concerns regarding water quality. Three (3) responses indicated the need to treat water for iron. Responses also noted black grit, sulfur and high acid content in water. A very concerned response wrote, “I’m also very unhappy with the water quality. I failed county water quality for coliform bacteria and had a UV water purification system installed. We only drink bottled water and notice skin problems in the warmer months.” These responses suggest that water quality is a current concern within pockets of the Waterford community.

Based on both the quantitative and qualitative responses, it is estimated that between 17 and 22 lots out of the 145 lots completely in the study boundary (approximately 12% to 15%) have challenges with their water systems, including approximately nine (9) lots (approximately 6%) facing critical challenges.

4.1.5 Groundwater Hydrology Report

Tetra Tech conducted a study that evaluated the groundwater conditions of the Waterford community and produced a report titled "Groundwater Resource Evaluation Waterford, Virginia," dated September 16, 2021, which is included as **Appendix D**.

As a part of the study, Tetra Tech solicited permission from property owners within the study boundary, as well as several property owners outside of the boundary, to measure depth to water (DTW) in wells on their properties. Tetra Tech also monitored hydraulic head changes in select private wells caused by residential pumping stresses. Furthermore, Tetra Tech reviewed available data and literature, such as aquifer test data and the results of a survey that was sent out regarding depth to water in wells. Tetra Tech used this information to determine DTW and groundwater elevation (hydraulic head) in wells in the Waterford area in May 2021, to compare measured water levels to those measured in Spring 2006, to estimate local formation transmissivity and to estimate groundwater flow directions. Long term well-monitoring results are included as part of this report. It should be noted that individual assessments of wells were excluded from this scope of work.

As a result of the study, Tetra Tech found that groundwater flow through bedrock in Waterford is primarily from east to west. Tetra Tech identified the median bedrock well yield in Waterford to be less than 2 gpm, which is significantly lower than the reported range of yield (8 gpm to 12 gpm) in the Western Hills Watershed. However, groundwater elevations in Waterford wells rose or changed little between 2006 and 2021. Furthermore, although variable drawdown has occurred since before well pumping began, groundwater mining (i.e., withdrawal of water faster than recharge rate) is not occurring.

The median well depth in Waterford is approximately 550-feet. There is a negative (weak) correlation between well yield and well depth because well drilling generally continues to greater depths until a satisfactory yield is achieved. Statistically in western Loudoun County, yield is increased by drilling wells deeper. However, it should be noted that the mean yield per depth interval drilled declines from 4.4 gpm between 300- and 400-feet to 1.0 gpm between 700- and 800-feet. DTW in wells on the west and east sides of the Waterford study boundary is much shallower (e.g., 15- to 50-feet deep) than in active pumping wells apparently completed in poorly transmissive rock in areas of greater well density (where DTW in wells exceeds 100-feet at 12 locations). Particularly in low-yield wells, DTW is sensitive to both well pumping rates, which vary with time and use, and formation transmissivity. Data collected by Loudoun County from 2005 to 2017 from a well just south of the Waterford study boundary showed a seasonal pattern of hydraulic head fluctuation, with lower DTW realized in the winter and higher DTW realized in the summer. High-yield wells are more likely to be found at the Northeast end of the Waterford study boundary.

Tetra Tech noted the following three (3) main factors that contribute to the low yield of wells in Waterford:

1. Relatively unfractured, poorly transmissive bedrock
2. High density and small separation between wells on small lots
3. Reduced recharge to groundwater after septic drainfields were replaced by public sewer, which was installed to resolve a public health issue

Figure 4.3 shows low yield areas and well yields within Waterford. The "red" zones, which have yields less than two (2) gpm, are considered to be low yield areas. 49 lots fall completely or partially within a low yield area. 37 lots fall completely within a low yield area and are completely or majority within the study boundary. Therefore, based on the hydrology study, approximately 26% of lots are within a low yield area. This is similar to the results of the resident survey, which indicated that 21% of the community experiences low well yield.

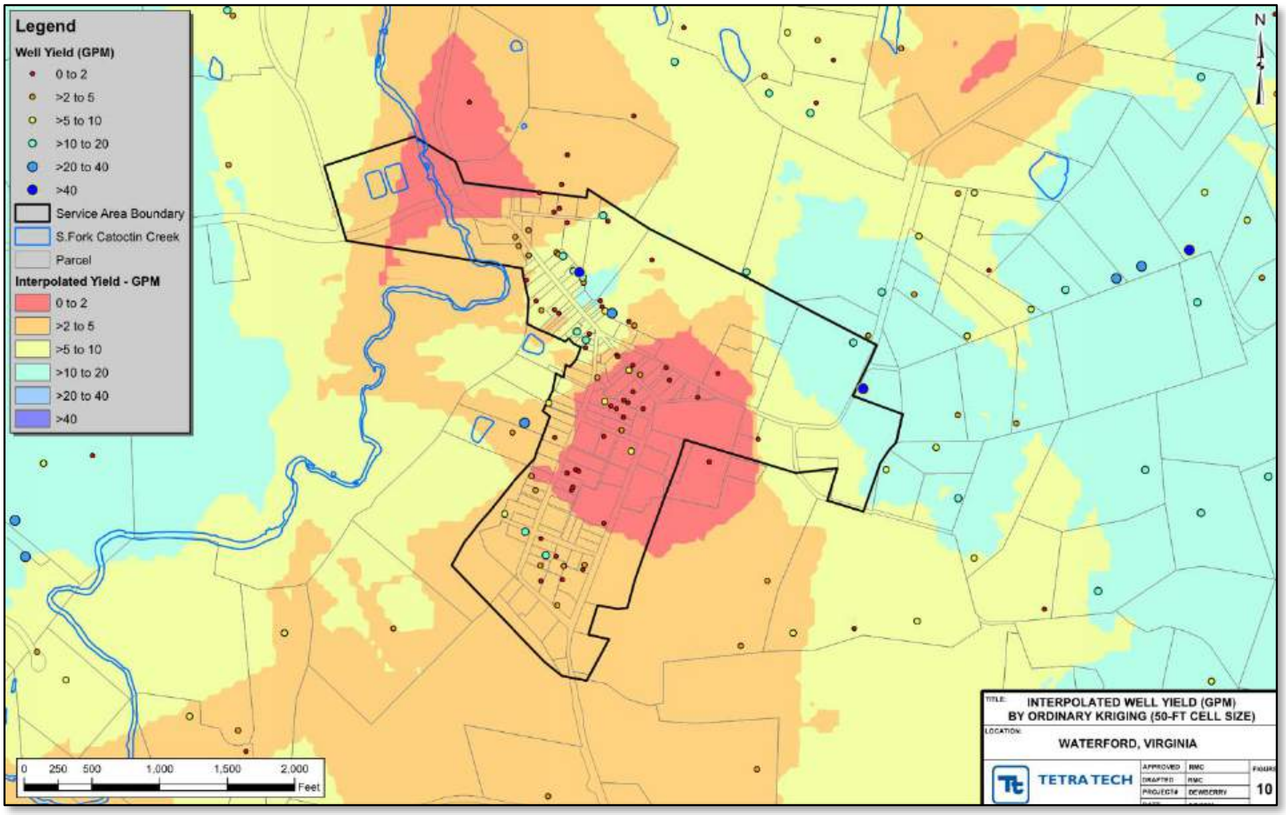


Figure 4.3 – Waterford Well Yields

Tetra Tech also evaluated groundwater quality. Groundwater samples were taken within and near Waterford and tested for chemical constituents. The results of the chemical analysis showed that the groundwater is generally acceptable for a potable water-supply. However, treatment will likely be required for iron and manganese since these metals are frequently detected in western Loudoun County groundwater above their Secondary Maximum Concentration Levels. Also, as previously noted, several survey responses noted issues with iron in their water supply.

4.2 Overview of Options

The technical feasibility of five (5) different options were evaluated to improve water systems in Waterford, which are listed and described below.

1. Option 1 – Upgrade Existing On-Site Systems to Improve Yield on Individual Wells

   Involves private property owners making individual improvements to their system by means such as hydraulic fracturing of rock (hydrofracking), construction of a new well or wells, or well deepening.

2. Option 2 – Shared Private wells

   Consists of connecting two or more homes to a private well, therefore implementing a shared well system. This option is limited to residential homes. Multiple shared well systems can exist within the community, as long as LCHD guidelines are followed. Each new shared well system would require an existing or new well capable of providing 8 gpm yield, easements, deeds, and maintenance agreements. Costs would be divided by four (4) homes.

3. Option 3 – Community Water System Owned and Operated by Loudoun Water (Using New Community Wells)

   Consists of the construction of a community well system and associated treatment system for the entire community. This option would require that a well or several wells be sited to meet the potential future demand of the community (173 gpm, or 1.2 gpm per connection).

4. Option 4 – Connection to a Nearby, Existing Community System

   Requires connecting to a nearby community system with sufficient capacity to serve its residents and the community of Waterford.

5. Option 5 – Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System

   Involves connecting to a nearby municipal system with sufficient capacity to serve its residents and the community of Waterford.

The following sections expand upon considerations for each option in more detail.

4.2.1 Option 1 – Upgrade Existing On-Site Systems to Improve Yield on Individual Wells

Based on the review of existing information described above, there are approximately 17 to 22 lots that need well improvements in Waterford (with up to 37 lots potentially needing improvements, based on the map in **Figure 4.3**). Potential improvements to individual wells include hydraulic fracturing of rock (hydrofracking), drilling a new well, or well-deepening, which are further described below.

Hydrofracking involves injecting water under pressure to open or clean out existing rock fractures and thereby increase well yield, and typically takes one (1) day to complete. For hydrofracking, Loudoun County requires that potable water be used and LCHD recommends zone tracking. Hydrofracking cannot be performed in the top 120-feet of the well, and the upper packer, which acts as a seal between layers within a well, must be placed below the casing and grout zones. Loudoun County requires that the hydrofracking contractor be licensed by LCHD to install water supply systems. Although this is technically feasible, there has been limited documentation of success with hydrofracking in Loudoun County, and the feasibility of hydrofracking as a long-term solution (i.e., sustainability of yield increases) is still unknown. There is no guarantee that hydrofracking will be successful. For example, one response to the well yield survey noted, “We had our well "fracked," which increased flow, but after 3 to 4-years, problems returned.” Additionally, few contractors perform hydrofracking in Loudoun County. Details regarding hydrofracking procedures in Loudoun County are not well-documented. Hydrofracking also poses risks to nearby wells and the environment. Further explanation of hydrofracking can be found in the hydrology report in **Appendix C**.

Another solution to improve yield on a private property is to drill an additional well or wells. However, due to setback requirements and other permitting and regulatory requirements, this option may not be feasible. An additional challenge for individual properties may be lack of access for necessary drilling equipment due to small parcel size and density of structures. The majority of lots in need of improvement are located in areas where it would be difficult to construct a new well based on either lot size and/or the surrounding characteristics (i.e., structures, old drainfields and other lots). For example, one response to the well yield survey noted, “Because of small lot size, old septic field, near sewer line or property line there is no place to drill a new well.” Furthermore, there is no guarantee that newly drilled wells will provide adequate yield.

Well deepening involves drilling in an existing well. There has been some success of well deepening within Waterford, as one (1) responder to the well yield survey wrote, “well was deepened 10 years ago, from 540' to 700' and flow went from 2 QT/min to 5.5 gal/min.” Although this improvement is technically feasible and has improved well yield in some instances, there is no guarantee that it will be successful, and the effectiveness of well deepening as a long-term solution (i.e., sustainability of yield increases) is uncertain.

Private property owners are entirely responsible for the costs of any improvements to existing wells or the construction of new wells.

4.2.2 Option 2 – Shared Private wells

If fifteen (15) connections (or more) are made to one well, or if 25 people (or more) are served by one well (for at least 60 days out of the year), the system meets the definition of a public “Waterworks” and would be required to meet VDH ODW public water supply system standards. Per discussions with VDH ODW, the limitation for a shared well is driven mainly by the number of connections, and the maximum number of connections (15) is rarely approved, as it is difficult to prove that the number of people connected will not exceed the definition of public water works. There are numerous ways to help guarantee the number of people connected to a shared well doesn't go over 25, such as looking at how many people occupy each home and the ages of occupants. However, should the results of a census reveal that the number of people connected to a shared well is over 25, VDH ODW would be notified. Based on discussions with the LCHD, the number of people in a house can be estimated by the number of bedrooms and accounting for two (2) people per bedroom. Therefore, based on an assumption of three (3) or four (4) bedrooms per home, approximately four (4) homes can be connected to an individual shared well system. A shared well with four (4) connections should have an approximate yield of eight (8) gpm.

Although Option 2 is technically feasible, it is a challenge and comes with restrictions that need to be considered during design/preliminary engineering. As previously described, one of the main challenges is ensuring that the shared system does not meet the definition of a public waterworks. In order to ensure this, legal covenants may be needed. For example, a legal covenant could prevent a newly built house from connecting to the shared well. Furthermore, legal determinations that limit the number of people allowed to live in each home could be developed.

Another challenge is the determination of responsibility for each owner connected to the shared well. Responsibility for costs (e.g., well improvements) and violations should be clearly defined between property owners that are connected to the well in an agreement, in order to avoid litigation. In addition, property sale and agreements may be required by mortgage companies associated with each home.

A third challenge is the uncertainty of the specific individual lots that are experiencing issues. Each new shared well system would require an existing well or new well capable of providing an eight (8) gpm yield.

Since the exact locations of all lots experiencing issues are unknown, Dewberry cannot explicitly determine if any of the following conditions exist in order to ensure adequate supply for a shared well system:

- Nearby existing wells with yield > 8 gpm
- Nearby existing wells with yield that could potentially provide > 8 gpm with improvements (such as hydrofracking)
- Ability to construct a new well that could potentially provide > 8 gpm

As previously noted, it is expected that the majority of well-yield problems can be found in the central area of the Waterford study boundary around Main Street. Implementing shared well systems in this area may be difficult due to the density of residential homes (i.e., difficulty meeting setback requirements for the construction of new wells) and the well yields currently realized within the area (i.e., the majority of well yields in this area are less than 2 gpm).

Although there is flexibility with piping and layout, it is assumed that a new well will be drilled for each shared well system. New wells do not have to be drilled on site and may be drilled outside of the Waterford study boundary. Distribution piping may run under road for necessary distances in the community. However, since yield problems were noted throughout the community boundary, implementation of this option would need to be phased to target different areas of the community.

It should be noted that high-yield wells are sometimes drilled by chance, and actual sustainable groundwater extraction rates can only be determined by well drilling and testing. Attempts to locate and construct high-yield water wells would benefit from electrical resistivity survey work to select drilling locations on target parcels. Furthermore, there has been some success of shared wells within Waterford, according to multiple responses to the well yield survey. One (1) response wrote, "we share a well with our neighbor since this property does not have a well. Never had a problem 26 years," and another response wrote, "I share a well with the neighbors…and so far I have not encountered problems."

Based on existing information, it is estimated that at least six (6) total shared well systems are needed in Waterford, in the four (4) general areas shown in **Figure 4.4**. However, several factors, such as property and well locations, may change the number of shared well systems needed. Note that the shared wells may not be placed in these areas and may be placed elsewhere (such as outside the study boundary) as needed to obtain the required yield. The areas circled indicate approximately where service from a shared well would be needed.

Overall, each new shared well system would require an existing or new well capable of providing 8 gpm yield, easements, deeds, mortgages and costs to drill and connect to a new well, which would be divided by private property owners of the four (4) homes.

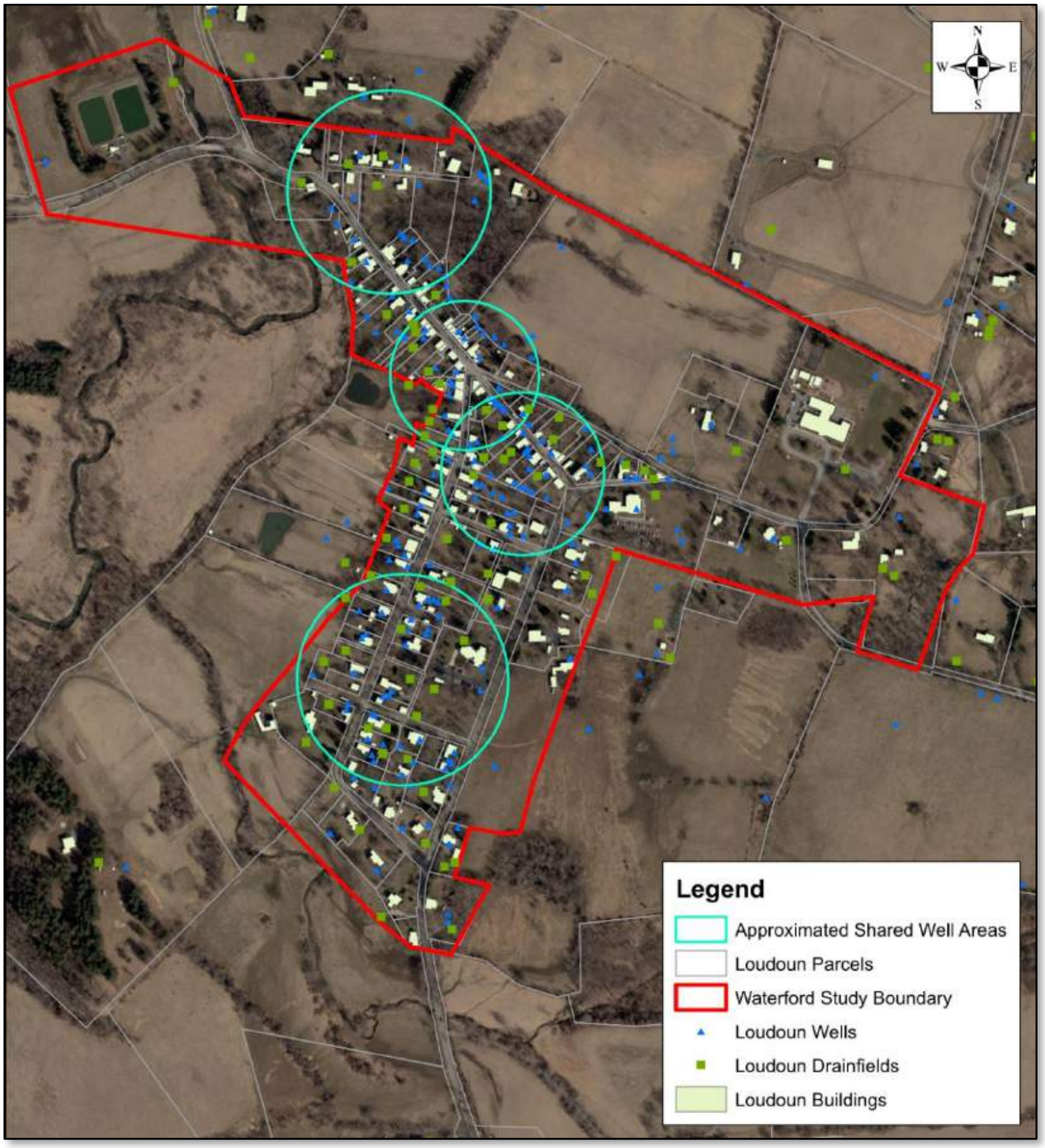


Figure 4.4 – Potential Shared Well Areas

4.2.3 Option 3 – Community Water System Owned and Operated by Loudoun Water (Using New Community Wells)

For a community system, a well system will need to be designed and constructed to convey the minimum required flow of 146 gpm for the existing condition and 173 gpm for the future condition. Furthermore, LW requires that systems having more than 50 connections shall provide either:

1. Three (3) wells with required easements, including two (2) wells in service and one (1) backup well, producing at least 0.6 gpm per connection (which is equal to 73.2 gpm per well for 122 connections and 86.4 gpm per well for 144 connections), or

2. Four (4) or more wells with required easements, including a backup well that has undergone initial hydro geological testing, the two (2) smallest of which shall combined produce at least 0.6 gpm per connection with the smallest producing at least 0.12 gpm per connection.

It should be noted that there are no reported wells in the Waterford study boundary with a yield greater than 50 gpm. The closest well to Waterford (not including wells associated with public water-supply systems) having a yield of at least 100 gpm is approximately 2.5 miles away. However, new wells do not have to be drilled on site and may be drilled outside of the Waterford study boundary. Tetra Tech determined the best potential community well sites, which are shown in **Figure 4.5.** According to Tetra Tech, it may be possible to sustain production of 86,000 to 212,000 gallons per day (gpd) (60 to 147 gpm) from six (6) wells located along the periphery of the Waterford study boundary, and high-yield wells are more likely to be developed in and to the north and east of the boundary.

The potential to achieve this goal is uncertain, as actual sustainable groundwater extraction rates to support a community water supply system in Waterford can only be determined by well drilling and testing. It should be noted that due to the complex, heterogenous distribution of water-bearing fractures in the metamorphic rocks of western Loudoun County, dry holes may be drilled in areas with statistically high yields, and vice versa. Extreme high-yield wells are sometimes drilled by chance. Attempts to locate and construct high-yield water wells would benefit from (and will require) conduct of electrical resistivity survey work to select drilling locations on target parcels.

Community wells would be owned and operated by LW and would pump groundwater to a treatment facility, as needed. The facility would be designed to treat the raw groundwater to required standards prior to distribution. This option would also require that a conveyance system be installed to distribute water from the treatment facility to individual homes. A preliminary layout of the conveyance system is shown in **Figure 4.6**. A baseline assumption for the size of the distribution piping is 6-inches to 10-inches in diameter. Per the LW EDM, raw water lines 4-inch and larger for a community system shall be ductile iron pipe AWWA C151, Class 52 or better, with AWWA C153 MJ fittings.

A small treatment facility may be necessary prior to the distribution system to convey treated water. Prior to deciding the final treatment requirements, well development and testing would be completed to determine water quality. These systems could range from simple disinfection to membrane treatment for contaminants. Based on experience in the area and similar facilities in the region, the most common water quality issue that requires treatment is heavy metals, such as iron. The most cost-effective approach to treat wells with heavy metal is the use of a manganese greensand filtration system. For the purpose of this report, the facility is shown on the Elementary School parcel and a manganese greensand filtration system has been assumed. However, the location of the treatment facility could be located anywhere near the distribution system. Should the treatment facility be moved further away from the community or distribution system, the cost of the project will increase to accommodate additional piping.

It is anticipated that any kind of water storage tank or similar facility required for this project will need to meet the requirements of Chapter 3 of the Waterford Loudoun County Historic District Guidelines. The most relevant requirements of this chapter, which addresses the addition of Site Elements to the community, will be those guidelines for Landforms and Features (Part B), Siting (Part C) and Accessory Structures and Breezeways (Part F). Designs for water storage facilities and appurtenances will be designed in accordance with the District Guidelines to preserve the community landforms, vegetation, viewsheds and structure siting patterns to the greatest extent practicable. A viewshed analysis for any proposed structure(s) is anticipated to be necessary to evaluate the potential of the project to impact historic viewsheds for the community. Part I, which deals with Mechanical and

Utility Screenings, will be utilized as appropriate if screenings might be useful in mitigating the potential for any proposed water facility to impact the character of the historic district. Part E, addressing archaeological sites, is expected to be addressed through agency permitting reviews.

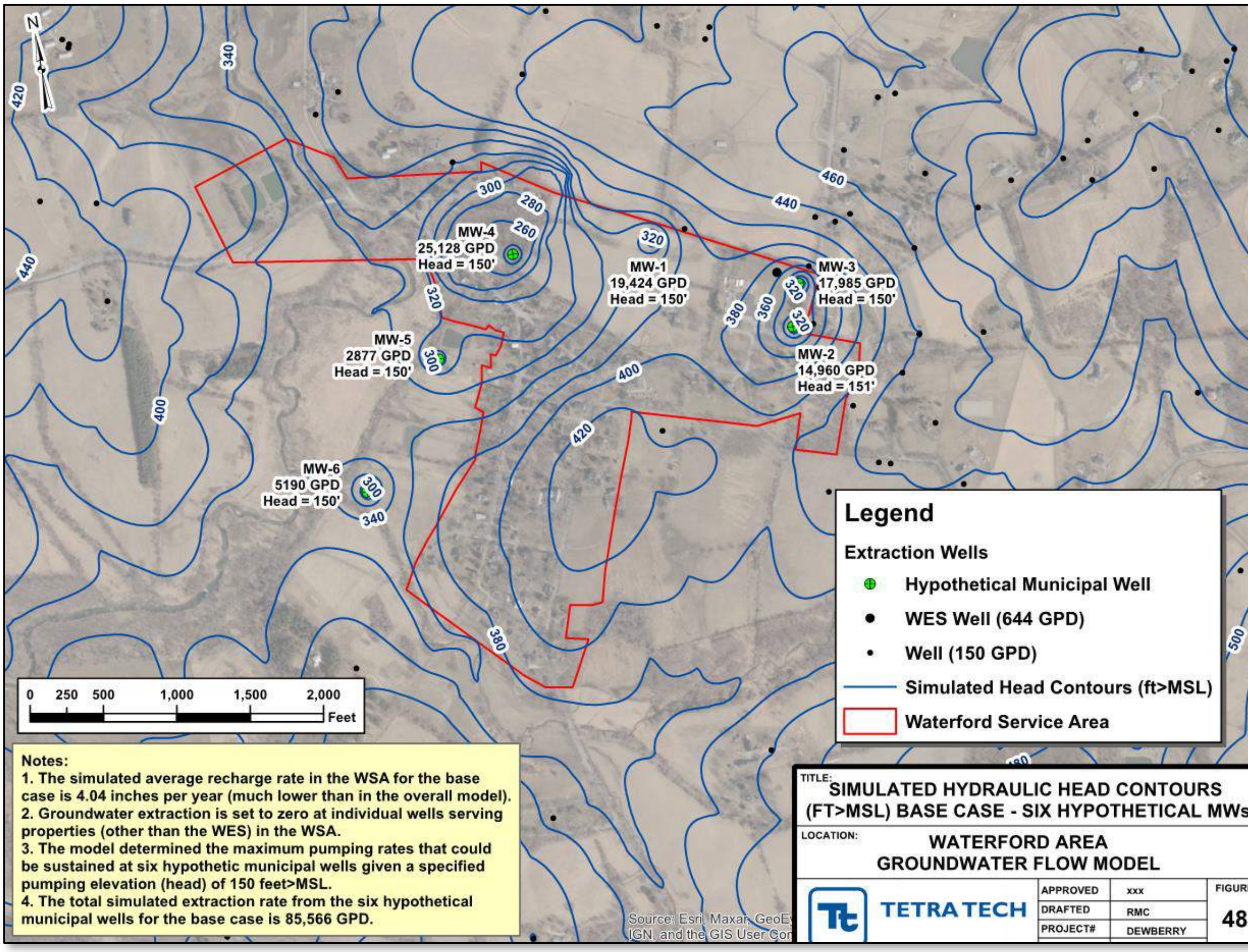


Figure 4.5 – Potential Community Well Sites

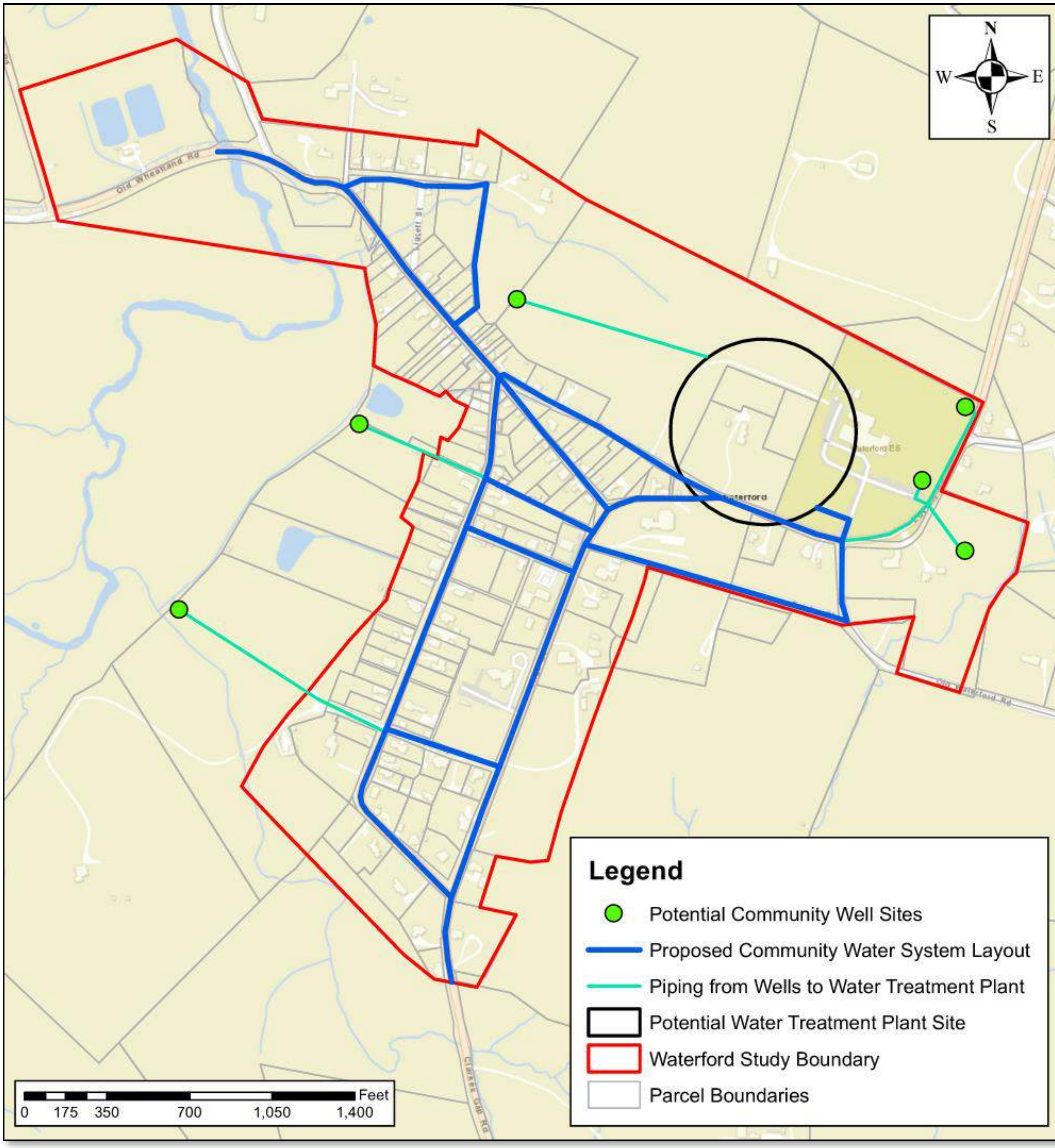


Figure 4.6 – Preliminary Water Main Layout

Each community well will need to be tested and monitored per the Virginia Waterworks Regulations (12-VAC-590). The water treatment technology will depend of the water quality of the well drilled. **Table 4.2** shows the primary and secondary Maximum Contaminant Levels (MCL) for several water quality measurements from the VDH ODW. Primary standards are legally enforceable, and secondary standards are non-mandatory but are recommended for aesthetic purposes. A full list of standards can be found in **Appendix E**.

Table 4.2 – Primary and Secondary MCLs for Water Quality

Primary	
Substance	**MCL (mg/L) VDH ODW**
Total Coliforms (including fecal coliform and E. Coli)	Positive repeat sample
Arsenic	0.010
Copper	1.3
Lead	0.015
Nitrate (measured as Nitrogen)	10
Secondary	
Substance	**MCL (mg/L) VDH ODW**
Chloride	250.0
Iron	0.3
Manganese	0.05
pH	6.5-8.5
Sulfate	250.0
Total Dissolved Solids (TDS)	500

During well drilling and testing, water samples will be taken and tested for water quality parameters. Based on the results of the water quality tests, water treatment may be required.

Water may be treated by conventional or direct filtration, slow sand filters, diatomaceous earth (DE) filters, or alternative filtration technology. Applying granular filtration removes turbidity and suspended solids. It will not remove any harmful bacteria. Alternative filtration, such as membrane filters, is capable of removing harmful bacteria in the water. Several additional common water treatment technologies which may be required are described below:

- Microfiltration Membranes: Microfiltration uses semi-permeable membranes with small pores to filter and remove bacteria, Giardia, and Cryptosporidium. This treatment technology reduces the amount of chlorine dosage needed for disinfection but is not effective in removing dissolved contaminates.
- Greensand Filtration: Greensand filtration uses filters made from glauconite greensand with a special coating of manganese oxide in order to oxidize iron and manganese. As the water flows through the greensand filter, these elements form solids that are filtered out of the water. The filters are capable of removing dissolved solids but are unable to remove bacteria.
- Activated Carbon Filters: Activated carbon filters are typically made of coconut shells, wood, or coal and are capable of removing organic contaminates, as they are effective for removing heavy metals such as copper, lead and mercury since these chemicals adsorb to the carbon. These filters are not able to remove dissolved solids, coliform, bacteria and arsenic.

It is assumed that greensand filtration will be needed since iron and manganese are frequently detected in western Loudoun County groundwater above their Secondary Maximum Concentration Levels and since three (3) well yield survey responses indicated the need to treat water for iron. However, the type of treatment technology to be used, if needed, will need to be confirmed through water quality testing once the community wells have been developed.

For the purposes of this feasibility study, it is also assumed that there will be one (1) treatment system for all wells. Similar to the potential well locations, the treatment system may also be located outside of the study boundary.

Another alternative for supplying water to the community is a surface water withdrawal from a nearby waterway. Surface water withdrawal permits are managed by VDEQ and the State Water Control Board. In addition, the Virginia Marine Resources Commission (VMRC) will be coordinated through the permit process to confirm no adverse impact from a new withdrawal structure. Permit applications for new withdrawals on streams are managed through the joint permit application (JPA) process. Surface withdrawal regulations are outlined in Chapter 210 of the Virginia Administrative Code (9VAC25-210). An extensive public outreach process is required as part of any new surface water withdrawal application for any proposed withdrawal above 10,000 gallons per day (GPD). In addition, new surface withdrawal systems need to be coordinated with local and regional water supply planning as outlined in Virginia Administrative Code (9VAC25-780) and may result in the development of a new Water Supply Program for the region.

Surface withdrawal permit applications require evaluations of numerous criteria of the proposed stream withdrawal including the availability of any alternatives considered, interconnectivity of water supply systems, environmental reviews of state and federally listed threatened and endangered species, water quality monitoring and proximity to point source discharges. Several challenges exist for installing a new surface water withdrawal system near the Waterford Boundary, including:

- The Waterford WWTP has a discharge in the creek within close proximity to the community. This point source discharge may require any new withdrawal be placed a significant distance up or downstream. Detailed water quality modeling is required to confirm feasible locations for a new withdrawal structure.
- Portions of the Catoctin Creek and its forks are 'impaired'. Depending on the results of water quality sampling, withdrawals may not be feasible.
- The feasibility of withdrawal locations depends on normal stream flow as well as drought creek flows and elevations. Seasonal fluctuations in flow and stream levels for Catoctin Creek and its tributaries make standard withdrawals challenging. In areas where stream flow is insufficient, impoundments (i.e. dams or other structures) can be installed to store water for withdrawal. However, due to the topography of the area, sensitivity of the watershed and existing flows, an impoundment may not be practical.

Based on a desktop review of streams around the community, a new surface withdrawal will be challenging but may be technically feasible. The JPA process through the state requires that, prior to proposing a surface withdrawal for water, the applicant has determined that other alternatives for providing the necessary water demand have been thoroughly studied and deemed infeasible. Based on the hydrology report prepared as part of this study, a communal well system may be able to meet the demand requirements. Therefore, a phase 2 groundwater study, including test wells, drawdown testing and yield testing, will be required prior to requesting a surface withdrawal facility.

Once it has been determined that no groundwater source is available to the community, a petition to the state through the JPA can be initiated. Siting and locating a new withdrawal will require further analysis of waterways in the area, including sampling, water quality modeling and environmental reviews. At a minimum, coordination and/or developing a Local Water Supply Plan and a more robust treatment system (i.e. Membrane) would be required, in addition, an intake structure would need to be included and an impoundment created. The new raw water intake and treatment system would still distribute water into the same water distribution piping proposed with a communal well system. Due to the complexity of getting a new surface water intake approved and permitted, there will be significant schedule impacts should this be required. The permitting process for a new surface withdrawal could extend the project schedule by two to three years. In addition to schedule, the cost of the project will be significantly impacted. Depending on the location of the withdrawal, the cost for a surface facility could be as much as 80% - 100% higher than a communal groundwater well system. Lastly, long term O&M costs for a surface water treatment facility will be significantly higher, increasing overall lifecycle cost of the solution.

In summary, a surface withdrawal system should only be considered should the groundwater alternatives be deemed infeasible after well testing has been completed.

4.2.4 Option 4 – Connection to a Nearby, Existing Community System

Several potential connections points to be considered include:

- Beacon Hill
- Raspberry Falls/Selma Estates

The locations of these service areas relative to Waterford are shown in **Figure 4.7**.

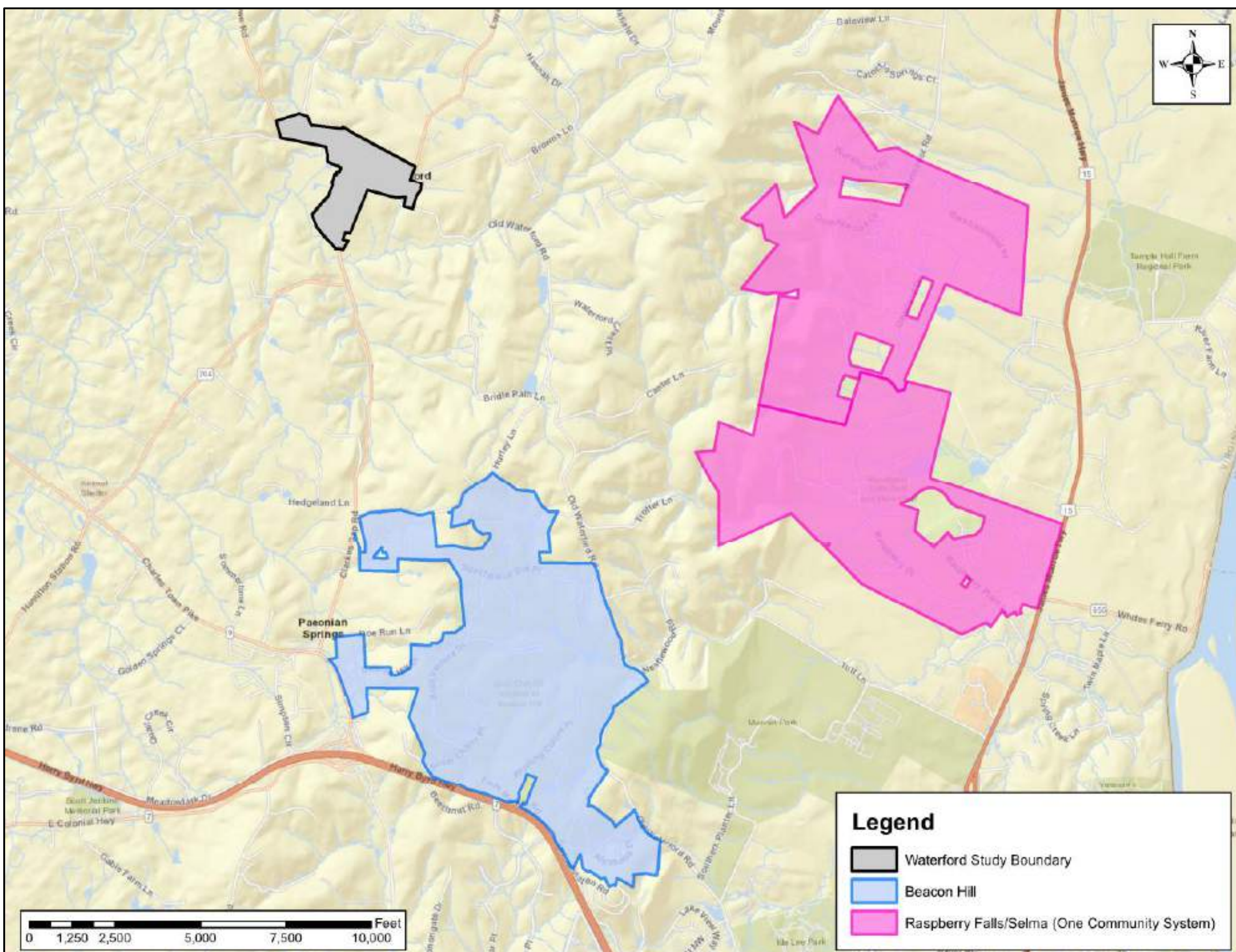


Figure 4.7 – Potential Neighboring Community Water System Connections

Connection to these systems would require sufficient well and treatment capacity to serve Waterford. Additionally, a water main would need to be installed to convey potable water from the existing systems to the community.

Installation of a water main from Raspberry Falls/Selma Estates to Waterford is not technically feasible due to elevation, as there is a mountain range between the two communities. **Figure 4.8** shows potential paths for installation between the two communities (with green lines indicating where the path lacks roadway), however; all potential paths cross the mountain range and have elevation changes similar to that shown in the elevation profile in **Figure 4.9** for the shortest path. For this path, the starting elevation at Raspberry Falls/Selma Estates is approximately 280-feet and the end elevation at Waterford is approximately 470-feet, and the path covers a distance of approximately 3.89 miles. Since the elevation at Waterford is higher than the starting elevation at Raspberry Falls/Selma Estates, there is an overall negative slope between the communities, meaning that pumping will be required for the majority of the conveyance system. Furthermore, the mountain range in the middle of the distance between the communities' peaks at an elevation of approximately 700-feet. Slopes along the mountain side reach up to 11%, which is not acceptable for conveying flow. This option is also not practicable, as there are constructability challenges with the installation of approximately 3.89 miles of water main, and there is concern with the age of the water once it reaches Waterford (due to the time it takes to travel the length of the water main). Furthermore, based on preliminary discussions with LW, Raspberry Falls/Selma does not have spare capacity (well or treatment) to serve the Waterford community.

However, it is technically feasible to install a water main from Beacon Hill to Waterford based on location and elevation. As shown in **Figure 4.10**, the elevation from Beacon Hill to Waterford slopes downhill about 0.38%, from approximately 537-feet at Beacon Hill to approximately 470-feet at Waterford over approximately 3.33 miles. At the low point elevation between the communities, which is at an elevation of 400-feet at a distance of 2.49 miles from Beacon Hill and 0.84 miles from Waterford, the downward slope from Beacon Hill to the low point is approximately 1.0% and the upward slope from the low point to the high point at Waterford is approximately 1.6%. Since the majority of the path follows a downward slope and the slope percentages are relatively low, it is technically feasible to install piping between the communities in order to convey water from Beacon Hill to Waterford. The cost of implementing this option is significantly higher than other options. Furthermore, based on preliminary discussions with LW, Beacon Hill does not have spare capacity (well or treatment) to serve the Waterford community. It should also be noted that since this community is located in the RPA, approvals through the Board of Supervisors would be required for connection.

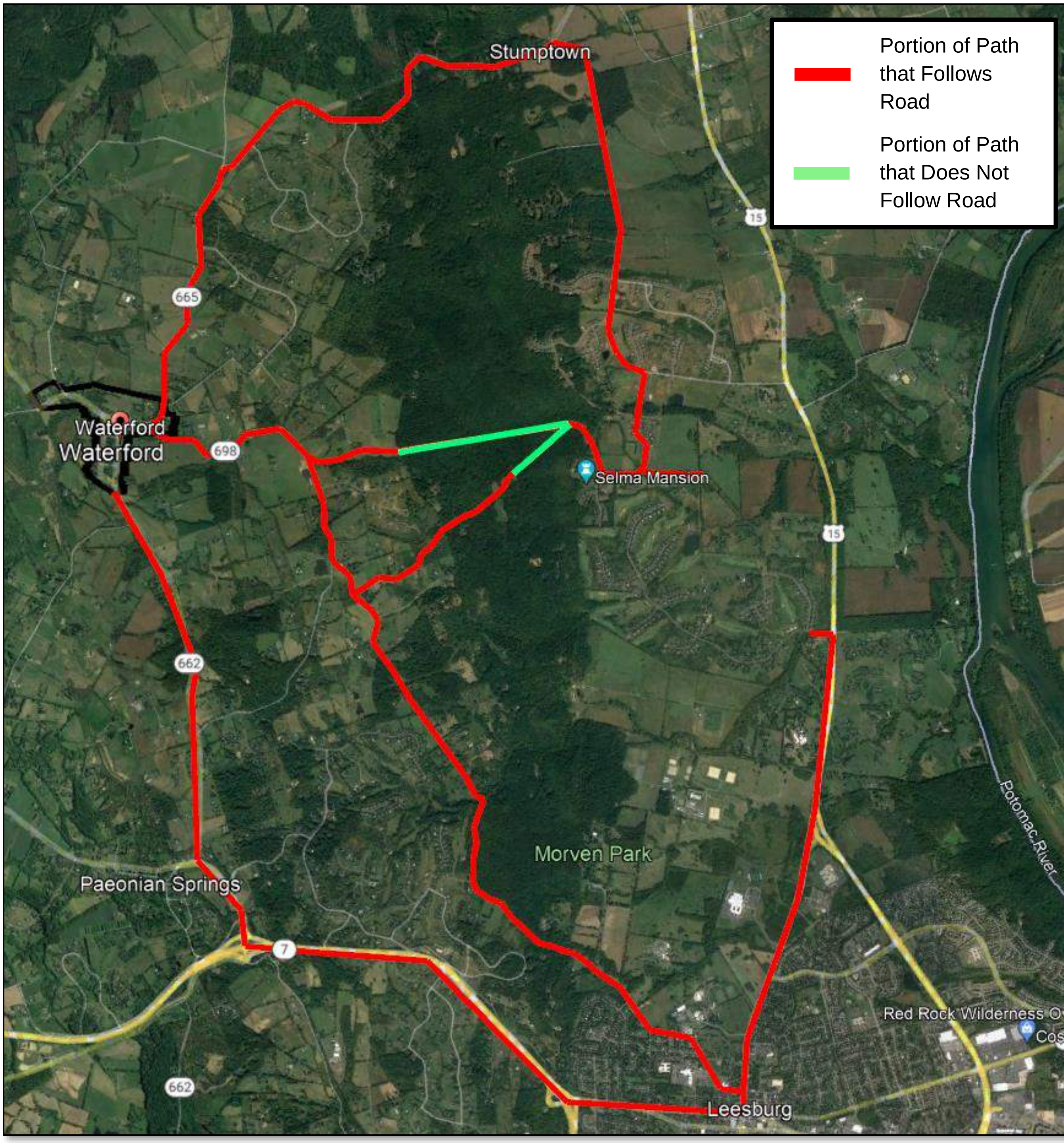


Figure 4.8 – Potential paths from Waterford (Left) to Raspberry Falls/Selma Estates (Right), Photo Courtesy of Google Earth

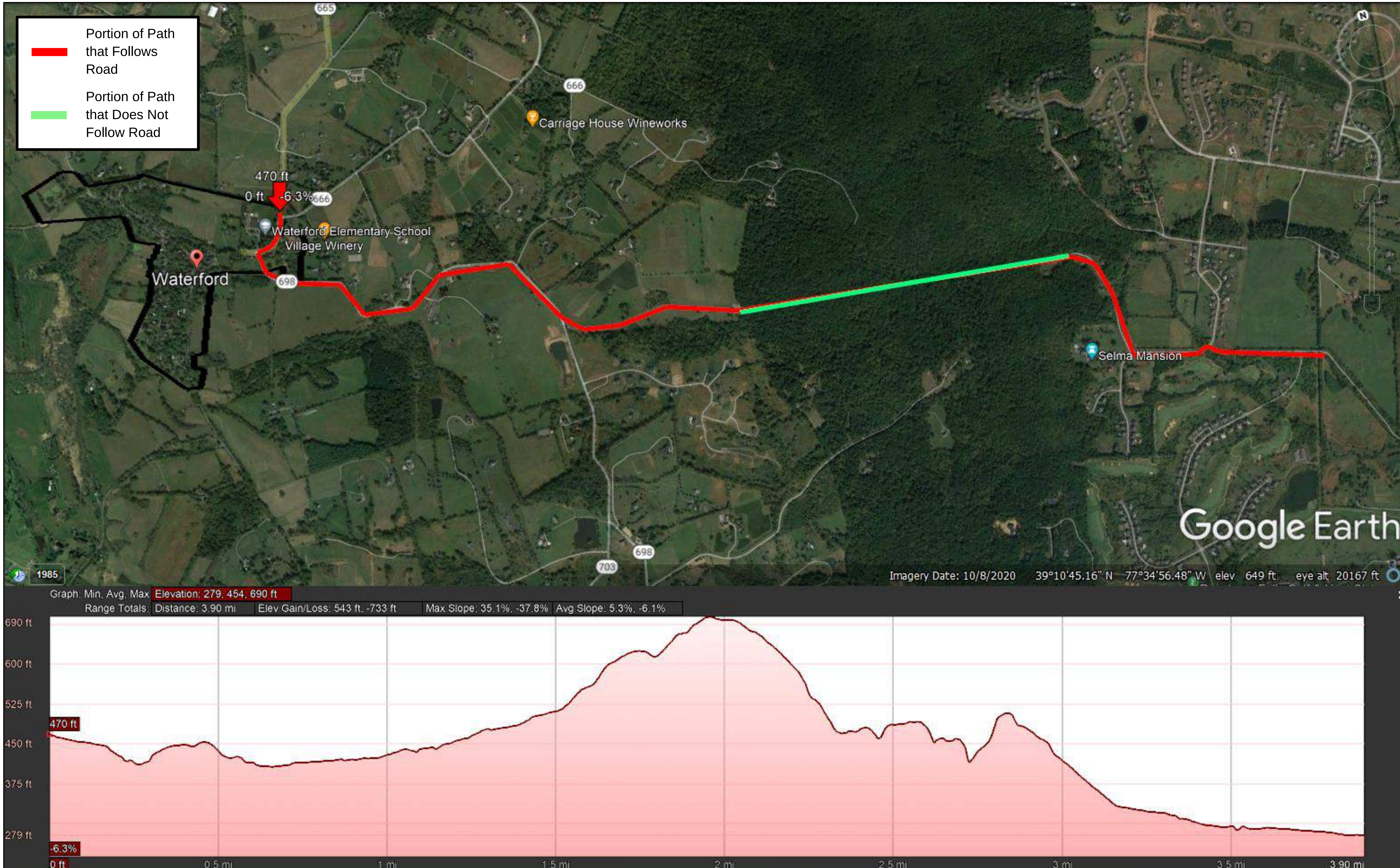


Figure 4.9 – Elevation Profile of Shortest Pat h from Waterford (Left) to Raspberry Falls/Selma (Right), Photo Courtesy of Google Earth

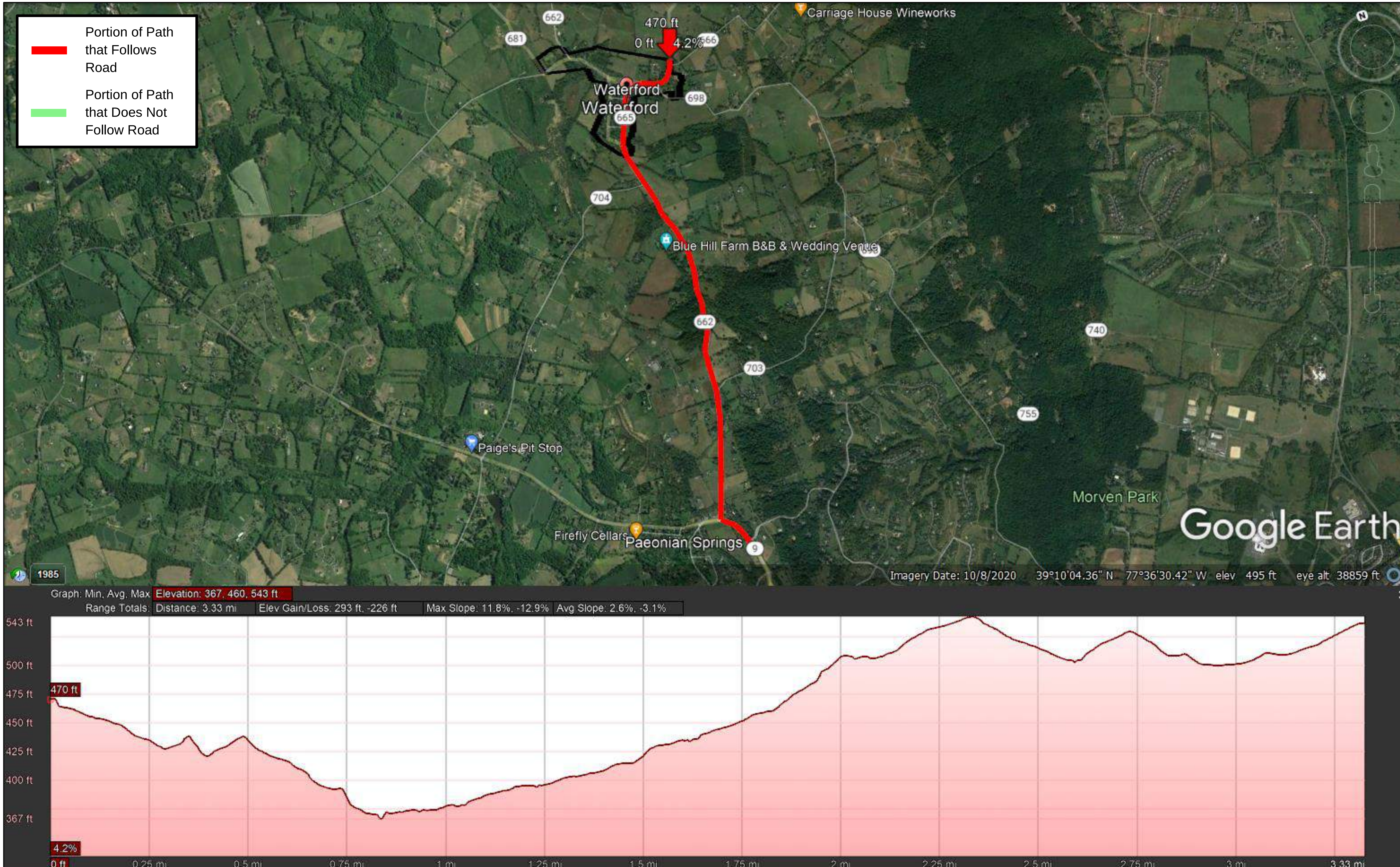


Figure 4.10 – Elevation Profile from Waterford (North) to Beacon Hill (South), Photo Courtesy of Google Earth

4.2.5 Option 5 – Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System

Several potential connections points to be considered include:

- Purcellville
- Hamilton
- Town of Leesburg

The locations of these service areas relative to Waterford are shown in **Figure 4.11**.

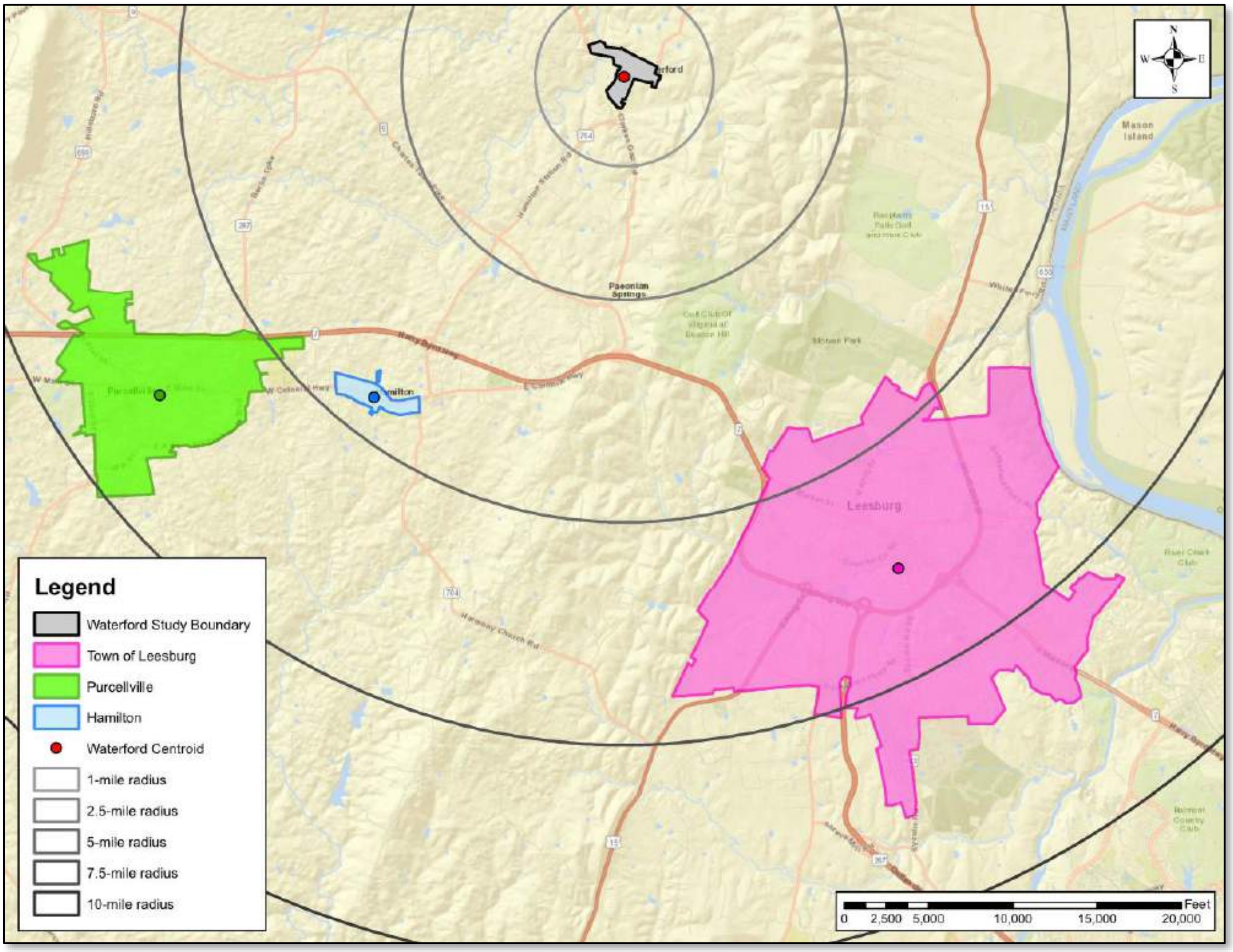


Figure 4.11 – Potential Neighboring Municipal Water System Connections

Connection to these systems would require sufficient well and treatment capacity to serve Waterford. Additionally, a water main would need to be installed to convey potable water to the community. The distance from the centroid of the community to the centroids of the nearby municipal systems ranges from approximately 4.5 miles (Hamilton) to approximately 6.3 miles (Leesburg and Purcellville). However, since water mains generally follow roadways, the length of the water main from Waterford to the Town of Leesburg would be approximately 6.3 miles (from Route

662 to Route 9 to Route 7), to Hamilton approximately 5.4 miles (from Route 662 to Route 704 to Route 7) and to Purcellville approximately 8.5 miles (from Route 662 to Route 704 to Route 7). While technically feasible, connection to any of these municipalities would not be practical, as this would require an extensive water main and supplemental support appurtenances, such as a booster pump. Construction of the water main would be challenging since it would run through existing developments and a major thoroughfare, Harry Byrd Hwy (Route 7). Therefore, this option is associated with the highest cost. Furthermore, there is concern with the age of the water once it reaches Waterford due to the time it takes for water to travel the length of the main. It should also be noted that since this community is located in the RPA, approvals through the Board of Supervisors would be required for connection.

4.3 Options Matrix

A simple options matrix was developed to analyze the five (5) potential options relative to recommendation criteria. The purpose of the matrix is to better present and compare the options, in order to recommend a water system. The options were considered based on six (6) criteria, which are listed below:

- Constructability
- Public Impacts
- Costs
- Approval/Acceptance
- Environmental Impacts
- Operations & Maintenance

The criteria for each option was then rated on a scale from one (1) to five (5), with the larger number being more favorable, as shown in **Table 4.3**.

Table 4.3 – Scoring Breakdown

Rating Score	
5	Very Good
4	Good
3	Fair
2	Poor
1	Very Poor

The full matrix is included as **Table 4.4**. As a result of the analysis, two (2) options are most practical for further analysis to address the water yield concerns within the Waterford community:

- Option 2 (Shared Private Wells), or
- Option 3 (Community Water System Owned and Operated by Loudoun Water)

For Option 2, it is estimated that approximately six (6) shared well systems are needed in Waterford. It is recommended that a new well be drilled for each shared well system, and 2-inch piping be used to distribute the water to the connected properties. The well sites, piping and treatment system (if necessary) may be located outside of the Waterford study boundary. Easements, deeds, mortgages, permits and costs to drill and connect to a new well would be divided by private property owners of the four (4) homes for each new shared well system. Not all systems will be the same cost. Agreements should be developed between property owners regarding responsibility for any necessary maintenance or future well improvements.

Option 3 includes the implementation of a water distribution and treatment system. Six (6) potential well sites, as shown in **Figure 4.5**, have been identified that may provide adequate yield to convey the estimated future demand of 173 gpm to Waterford. It should be noted that no discussions took place with property owners regarding potential well sites. The well sites are shown conceptually for the purpose of this feasibility study and to show potential water infrastructure alignments. Per the preliminary layout shown in **Figure 4.6**, approximately 13,350 LF of 6-inch ductile iron pipe (DIP) is recommended to convey the water. Greensand filtration is the recommended treatment system due to the presumed presence of iron and manganese in the water. For the purposes of this feasibility study, it is also assumed that there will be one (1) treatment system for all wells. All well sites, piping and treatment system locations are shown preliminarily for conceptual purposes and some infrastructure may ultimately be located outside of the Waterford study boundary.

Table 4.4 – Waterford Options Matrix

Waterford Options Matrix							
Alternative Number	**Constructability**	**Public Impacts**	**Costs**	**Approval/Acceptance**	**Environmental Impacts**	**Operations & Maintenance**	**Average Score**
Option 1 **Upgrade Existing On-Site Systems to Improve Yield on Individual Wells**	Community may have issues with new well construction based on parcel sizes and setback requirements.	Upgrade of existing systems not guaranteed to address issues with poor yield. Long-term effectiveness of hydrofracking unknown.	Upgrade of existing systems would have lower initial capital costs. Long term O&M costs would be the responsibility of the property owner.	Existing wells may need to be repaired or replaced. No need for additional land acquisition. Minor permitting approvals.	Water usage, potential contamination and potential impacts to nearby wells from hydrofracking (if used).	Continued homeowner O&M. Yearly inspections and upkeep.	**2.5**
Raw Score	2	1	4	3	3	2	
Option 2 **Shared Private Wells**	Locating new wells with sufficient yield may be challenging based on hydrology study. Access to lots may be challenging.	Shared wells will require extensive agreements between homeowners for proper access and maintenance. May impact long term ownership and sale/transfers.	Should sufficient yield be discovered for shared wells, costs will be reasonable and distribution system will be limited. Costs would be the responsibility of the property owners.	Shared well system do not need to meet public water work regulations. Approvals from several property owners will be required. Limitations on number of connections and residents for each system.	Limited environmental impacts. New wells may remove older non-yielding well systems.	Continued homeowner O&M. Yearly inspections and upkeep. Shared wells expense is divided amongst several owners.	**2.8**
Raw Score	1	2	4	3	3	4	
Option 3 **Community Water System Owned and Operated by Loudoun Water (Using New Community Wells)**	Requires new community well system and treatment facility. Extensive road restoration and community impacts for long construction durations.	Elimination of existing wells will provide more sustainable community solution. Public impacts during construction of distribution systems with road works and extended impacts.	High initial capital costs and connection fees.	Easements and land acquisitions necessary for well/treatment facility and distribution system. Extensive permitting due to historic nature of community.	Communal well would eliminate numerous old wells from community. Historic nature requires permitting, however, minimum environmental concerns.	New community system that will need O&M in accordance with VDH ODW requirements. Ongoing water fees.	**3.0**
Raw Score	3	4	2	1	4	4	
Option 4 **Connection to a Nearby, Existing Community System**	Requires road work and restoration. Consideration for crossing Catoctin Creek. Significant impacts due to extended water main in rural policy area and distance from Waterford to nearest community system.	Public impacts during construction. Elimination of existing wells will provide more sustainable community solution.	Highest initial capital costs and connection fees due to extensive piping required and work within major thorough fares and required coordination/ negotiation with nearby communities	Board of Supervisors approval required. Easement and land acquisitions most likely necessary. Need to prove existing community system has capacity to provide additional water to Waterford.	Potential tributary impacts with seasonal streams for distribution piping. Larger land disruption.	No additional treatment facility for maintenance. Ongoing water fees for residents.	**2.0**
Raw Score	1	4	1	1	1	4	
Option 5 **Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System**	Requires road work and restoration. Consideration for crossing Catoctin Creek. Significant impacts due to extended water main on busy roads and distance from Waterford to nearest community system.	Public impacts during construction. Greatly reduce risk of ongoing public health impacts due to connection to nearby system.	Highest initial capital costs and connection fees due to extensive piping required and work within major thorough fares and required coordination/ negotiation with nearby communities	Board of Supervisors approval required. Easement and land acquisitions most likely necessary. Need to prove existing municipal system has capacity to provide additional water to Waterford.	Potential tributary impacts with seasonal streams for distribution piping. Larger land disruption.	No additional treatment facility for maintenance. Ongoing water fees for residents.	**2.0**
Raw Score	1	4	1	1	1	4	

5 OVERALL COSTS & SCHEDULE

A Class IV preliminary cost estimate for the recommended options (Options 2 and 3) to solve yield problems in Waterford has been prepared using 2021 cost factors. A Class IV preliminary cost estimate is defined by the Cost Estimate Classification System of the American Association of Cost Engineering International (AACE) and has an accuracy range of -20 to +30 percent of the estimated cost. The cost estimates represent a preliminary opinion of probable construction cost (OPCC) and are based on the assumptions outlined throughout this feasibility study. The approximate cost of the project will need to be inflated based on the anticipated implementation schedule.

A schedule was prepared for Option 3, as this would be a capital project. A schedule is not provided for Option 2 since work for this option would be at the discretion of the property owners.

5.1 Option 2 – Shared Well Systems

Assuming that one (1) well is drilled per shared well system and that approximately 1,000 LF of piping is needed per shared well system, the total cost for each shared well system is approximately $159,500 with a low range estimate (-20%) of approximately $127,600 and a high range estimate of approximately $207,350. Divided by four (4) properties, the cost per property (i.e., per connection) is approximately $40,000. Costs for operations and maintenance as necessary shall be agreed upon between property owners.

Table 5.1 – Shared Well Costs

Shared Well Costs				
Item	**Units**	**Quantity**	**Unit Price**	**Total**
Drill Well	EA	1	$ 35,000	$ 35,000
2” Piping	LF	1,000	$ 85	$ 85,000
Road Restoration (5' Sawcut and Full Road Overlay)	SF	2,500	$ 11.00	$ 27,500
County Well and Site Plan Approvals	EA	1	$ 12,000	$ 12,000
			Total	**$ 159,500**
			Low Range Estimate (-20%)	**$ 127,600**
			High Range Estimate (+30%)	**$ 207,350**

5.2 Option 3 – New Community Water System

5.2.1 Water Conveyance and Treatment Capital Costs

As described above, the community water system will require distribution piping and a treatment system. For the purpose of the cost estimate, it is assumed that all community wells will pump to one (1) treatment system and that a greensand filtration system will be used. It is also assumed that one (1) greensand filtration system is sufficient for treatment. However, upon drilling the wells, it may be determined that a treatment system is not necessary. This system does not take into consideration fire or irrigation flows. The preliminary capital cost estimate is summarized in **Table 5.2**. The total preliminary capital cost for the water system is approximately $9.1 million, with a low range of $7.3 million and high range of $11.8 million.

Table 5.2 – Water System Capital Costs

Water System Capital Costs				
Item	**Units**	**Quantity**	**Unit Price**	**Total**
Furnish and Install 6" DIP Water Main	LF	13,350	$ 300.00	$4,005,000.00
Water Meter and Service Installation	EA	122.00	$ 3,250.00	$ 396,500.00
Blow Off Valve	EA	5.00	$ 2,750.00	$ 13,800.00
Air Release Valve	EA	5.00	$ 2,750.00	$ 13,800.00
Road Restoration (5' Sawcut and Full Road Overlay)	SF	66,750	$ 22.50	$1,501,900.00
Groundwater Well (Six 8-inch Wells and Casing)	EA	6.00	$ 49,500.00	$ 297,000.00
Water Treatment System (greensand filtration, disinfection, pressurization, SCADA, etc…)	EA	1.00	$2,750,000.00	$2,750,000.00
Land Acquisition for Well and Treatment Facility	ACRES	3.00	$ 40,000.00	$ 120,000.00
			Total	**$ 9,100,000**
			Low Range Estimate (-20%)	**$ 7,300,000**
			High Range Estimate (+30%)	**$ 11,800,000**

[1]This cost includes drilling, water quality report, logging for test wells and conversion to production wells after completion

The scope of this project will include service lines from the water main to a new water meter that will be installed for each connection. Homeowners will be responsible for making the connection to the new water meter. This work may include installation of new service line piping, well abandonment, internal piping modifications and site restoration. The cost for this work is not included as part of this cost estimate. It should be noted that Loudoun Water review fees are calculated as 2.5% of the construction bond estimate and are paid at the first plan submission and then reassessed at plan approval. It should also be noted that individual wells shall be abandoned per VDH ODW requirements, which requires an abandonment permit by LCHD, unless the well is converted to an irrigation well. The cost of this permit is $300; however, this fee is refunded upon request when replacing existing wells or springs, or when replacing a new well drilled dry. Furthermore, this fee is waived if the well is located on the owner's primary residence.

The capital costs outlined reflect current 2022 market conditions. Year of year price escalations due to inflation, market demand and other factors will increase the cost of the project through future years. Historically, a 3-5% yearly increase has been realized for similar projects. However, over the past 12-24 months, influence from COVID and other supply chain issues have caused significant increases in construction costs. For the purpose of estimating future costs of the project, a 6% yearly escalation can be used for budgeting purposes. **Table 5.3** below shows approximate costs over time with a 6% escalation. It should be noted that current market volatility significantly impacts future costs, and these estimates should be confirmed during preliminary design.

Table 5.3 – Water System Capital Costs Over Time

Water System Capital Costs Inflation			
Year	**Total**	**Low Range Estimate (-20%)**	**High Range Estimate (+30%)**
2022	$ 9,100,000.00	$7,300,000.00	$11,800,000.00
2023	$ 9,646,000.00	$7,716,800.00	$12,539,800.00
2024	$10,224,760.00	$8,179,808.00	$13,292,188.00
2025	$10,838,245.60	$8,670,596.48	$14,089,719.28
2026	$11,488,540.34	$9,190,832.27	$14,935,102.44
2027	$12,177,852.76	$9,742,282.20	$15,831,208.58

Taking into consideration the design, permitting and surveying required prior to construction, as well as necessary improvements to individual parcels (e.g., service lateral and meter), the overall preliminary costs for implementing a community system were determined and are summarized in **Table 5.4**. The total preliminary cost of the water system is approximately $10.5 million, with a low range of $8.4 million and high range of $13.6 million.

Table 5.4 – Water System Summary

Water System Summary	
Item	**Total**
Design, Permitting, & Surveying	$ 1,364,700.00
Water Distribution System	$ 4,429,100.00
Water Treatment System	$ 3,047,000.00
Road Restoration & Site Work	$ 1,501,900.00
Land Acquisition for Well and Treatment Facility	$ 120,000.00
Total Capital Costs	**$10,463,000.00**
Low Range Estimate (-20%)	**$ 8,370,000**
High Range Estimate (+30%)	**$ 13,602,000**

5.2.2 Loudoun Water Operation and Maintenance Cost

Following construction completion, there is additional effort for the operation and maintenance (O&M) of the facilities, as there are costs associated with upkeep of the treatment system. These costs are summarized in **Table 5.5**. The total preliminary estimated yearly cost for O&M is approximately $108,000, with a low range of $86,000 and high range of $140,000. The operation and maintenance costs would be the responsibility of Loudoun Water and would be included as part of the quarterly usage fees assessed for each property.

Table 5.5 – Operation and Maintenance Costs

Estimated Maintenance Costs		
Item	**Unit**	**Cost**
Maintenance Parts (consumables/repair)	$/year	$ 2,750
General Equipment Maintenance[1]	$/year	$ 9,100
Facility Maintenance[2]	$/year	$ 2,150
Estimated Operational Costs		
Item	**Unit**	**Cost**
Standard Operating Personnel[3]	$/year	$ 67,018
Routine Maintenance[4]	$/year	$ 10,400
Power Cost[5]	$/year	$ 9,500
Chemicals	$/year	$ 7,000
Total		**$ 108,000**
Low Range Estimate (-20%)		**$ 86,000**
High Range Estimate (+30%)		**$ 140,000**

[1]Includes costs associated with monthly, annual and semi-annual maintenance of equipment

[2]Includes maintenance costs associated with the well area including leaf removal, grass trimming, etc…

[3]The cost of 1 operator for three (3) four (4) hour visits per week at $107.40 per hour

[4]Time spent in addition to standard maintenance to maintain technology specific equipment. Assumes 2 hour per week at $107.40 per hour

[5]Assumes 200 kWh/day at $0.13/kWh

5.2.3 Present Worth Analysis

A present worth analysis was also performed for the water system, which is summarized in **Table 5.6**. The total net present cost of implementing a community system in Waterford is approximately $11.2 million.

Table 5.6 – Present Worth Analysis

Present Worth Analysis	
Disposal Method	**Cost**
Initial Capital Cost	$ 9,100,000.00
Yearly O&M Costs	$ 108,000.00
Lifecycle (years)	30
Interest Rate	3%
Net Present Cost	**$ 11,200,000**

5.3 Cost Summary

The overall costs of Options 2 and 3 are summarized in **Table 5.7**.

Table 5.7 – Costs of Feasible Options

Option	Cost	Low Range Estimate (-20%)	High Range Estimate (+30%)
2 (Shared Wells)	$ 159,500 [1]	$ 127,600 [1]	$ 207,350 [1]
3 (New Community Water System)	$ 10,463,000.00 [2]	$ 8,370,000 [2]	$ 13,602,000 [2]

[1]Per shared well system, to be divided by four (4) homes

[2]Includes design/permitting/survey, water distribution and treatment system and road/site work

When divided by four (4) homes, the cost of Option 2 to each property owner, and therefore the cost of connection, is approximately $40,000. There are also O&M costs associated with Option 3, which are approximately $108,000 (with a low range of $86,000 and high range of $140,000). Finally, a present worth analysis reveals the net present cost of Option 3 to be approximately $11.2 million.

5.4 Schedule

A schedule was not developed for Option 2 since work for this option would be at the discretion of the decisions between property owners. The following sequence of actions are anticipated for this option:

- Develop agreement between shared well users
- Develop easements and land agreements as necessary
- Obtain contractor
- Contractor to submit shared well plan to health department
- Install shared well and service piping
- Perform well testing and obtain certification from health department

The approximate schedule for implementing Option 3 is shown in **Figure 5.1**.

The legislative approval process covers the special exception and commission permit (CMPT) process, which includes extensive public comment periods and board approvals.

Implementation Schedule for Option 3

Task	
Chartering (County, public, project)	8 Months
Project Scoping/Procurement	4-6 Months
Planning/Basis of Design/PER	6-9 Months
Legislative/Land use approvals	12 Months
Project Scoping/Procurement	4-6 Months
Notice to Proceed (NTP) Design	0 Months
Design	12-18 Months
Permitting	12-24 Months
Construction Procurement	3-4 Months
Water Treatment and Distribution Construction	24-30 Months
System Startup and Functional Testing	3 Months

Figure 5.1 – Implementation Schedule for Option 3 (New Community Water System)

6 SUMMARY & RECOMMENDATIONS

6.1 Summary

This feasibility study evaluated the concerns identified by the community of Waterford and the technical feasibility of potential solutions to the community's drinking water issues. This feasibility study reviewed the existing conditions of the community, estimated the existing and future demands of the community, analyzed the existing systems and evaluated a total of five (5) options.

Prior to analyzing the feasibility of solutions, an analysis of the overall community was performed to better understand the community characteristics such as topography, historical resources, planning and zoning. A technical memorandum was prepared that assessed potential permitting and regulatory conflicts within the Waterford study boundary in regard to the five (5) options. Based on the historic nature of the community, the permitting and approval process may be challenging, however, there were no limitations that were identified that would deem construction of a new water system infeasible at this stage of a study. Subsequent phases of this project may include further field investigations that could drive permitting and approvals and ultimately become critical path for the project, such as the need for archeological surveys or other detailed studies.

A flow analysis technical memorandum was developed, which describes the process used to estimate existing and future water demands within the Waterford community. As a result of the flow analysis, a community well system serving the existing development would require a well yield of 146 gpm with a potential future yield requirement of 173 gpm based on potential future buildout. Therefore, the recommended demand flow (for the study area) to be used for sizing of a community water distribution piping and well/treatment systems (as needed) for the Waterford community is 173 gpm.

A review of online health department records, the results of a survey that was sent out to 117 residents regarding water yield and the groundwater hydrology report prepared by Tetra Tech were studied to determine the existing conditions of the well systems throughout Waterford. This review confirmed that well yield is a concern within pockets of the Waterford community and identified contributing factors to low-yield wells. These problems were documented for approximately 17 to 22 lots out of approximately 145 lots completely within the study boundary (approximately 12% to 15% of the community). In general, groundwater elevations in Waterford wells rose or changed little between 2006 and 2021, and groundwater mining (i.e., withdrawal of water faster than recharge rate) is not occurring. Although, it should be noted that there is relatively less groundwater in Waterford than in the Western Hills Watershed of western Loudoun County, as well as defined areas within the Waterford study boundary that have wells with low yield. In regard to water quality, the groundwater is generally acceptable for a potable water-supply, however; treatment will likely be required for iron and manganese.

Based on the location of the community, condition of the existing systems, and permitting/approval requirements, all five (5) options were evaluated to determine technical feasibility. The result of the evaluation determined that four (4) alternatives are technically feasible and one (1) alternative is not feasible. In summary:

1. Upgrade Existing On-Site Systems to Improve Yield on Individual Wells – Technically feasible alternative that may improve individual systems. Would require hydrofracking on individual wells to improve yield. Long term sustainability of this solution cannot be determined.

2. Shared Private wells – Technically feasible alternative that would require new wells and service connections that would serve up to four (4) parcels. Challenges associated with maintenance agreements, easements, and building restrictions exist that will need to be addressed.

3. Community Water System Owned and Operated by Loudoun Water (Using New Community Wells) – Feasible alternative requiring new communal well system and treatment facility as well as water distribution system. Wells and treatment facility would be located in or around the existing Waterford community, pending further groundwater hydrology studies.

4. Connection to a Nearby, Existing Community System – The only existing nearby community water system is Beacon Hill. However, Beacon Hill has existing challenges with well yield. A technically feasible alternative would require expansion of the existing Beacon Hill well system and treatment system as well as installation of a long water transmission main that would convey water from Beacon Hill to Waterford. This solution may be a cost prohibitive alternative.

5. Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System – No municipal systems exist within approximately five (5) miles of the community, making this alternative infeasible.

Therefore, Options 1, 2 and 3 are technically feasible, and Option 4 is only technically feasible for connection to the Beacon Hill community system. A weighted criteria analysis was developed using six (6) criteria, used to score each option on a scale from one (1) to five (5), with 5 being the more favorable scoring. As a result of this matrix, Option 2 or Option 3 are the preferred options for implementation to address Waterford's yield problems.

6.2 Recommendations

Based on the evaluation presented in this feasibility study and summarized above, Option 2 and Option 3 were determined to be the preferred options to address Waterford's yield problems.

Option 2 includes a shared private system between residents. This option is limited to residential homes. Multiple shared well systems can exist within the community, as long as Loudoun County Health Department (LCHD) guidelines are followed. In order to remain under the jurisdiction of LCHD, the well must serve less than 15 connections or 25 people. If these numbers are exceeded or met, the well would become public waterworks, as defined by VDH ODW. Based on discussions with the VDH ODW and LCHD and an assumption of three (3) or four (4) bedrooms per home, the maximum number of connections that has been considered for this study is four (4) connections per shared well in order to ensure that the system does not exceed population restrictions as required by LCHD. Based on these discussions, the maximum number of connections that has been considered for this study is four (4) connections per shared well in order to ensure that the system does not exceed population restrictions. Each new shared well system would require an existing or new well capable of providing an eight (8) gpm yield, easements, deeds and any additional legal covenants or agreements needed to ensure that the well does not meet the definition of a public waterworks and that responsibility for costs (e.g., well improvements) and violations are clearly defined between property owners. The preliminary cost of this option, which includes drilling a well and running 2-inch distribution piping to each property, is approximately $159,500 (with a low range of $127,600 and high range of $207,350) and would be divided by four (4) properties to be approximately $40,000 per property.

For Option 3, which involves a new community system owned and operated by Loudoun Water, six (6) community wells located along the periphery of the Waterford study boundary and associated treatment system(s) and distribution piping to convey drinking water to Waterford residents is recommended, as shown in **Figure 4.5** and **Figure 4.6**. Attempts to locate and construct high-yield water wells would benefit from (and will require) conduct of electrical resistivity survey work to select drilling locations on target parcels. High-yield wells are more likely to be developed in and to the north and east of the Waterford study boundary. The recommended demand flow to be used for sizing of water distribution piping and well/treatment systems (as needed) for the Waterford community is 173 gpm. Based on the information analyzed as a part of this study, a groundwater treatment system is assumed necessary due to iron and manganese levels within Loudoun County, therefore it is assumed that greensand filtration will be required. However, the type of treatment technology to be used, if needed, will need to be confirmed through quality testing once the community wells have been developed. The preliminary cost of this option, which includes the design/permitting/surveying for the project, construction of the water distribution system and the water treatment system (assuming one greensand filtration treatment system), individual parcel improvements and road restoration/site work, is approximately $10.5 million (with a low range of $8.4 million and high range of $13.6 million). Additional costs associated with Option 3 include O&M costs, which are approximately $108,000 (with a low range of $86,000 and high range of $140,000). Finally, a present worth analysis reveals the net present cost of Option 3 to be approximately $11.2 million.

Appendix A
Permitting Approval Technical Memorandum

Date: March 15, 2022

To: Andrew Beatty, P.E.

From: Paul Longo, P.E.

Subject: FINAL - Waterford Permitting Approval Technical Memorandum

Introduction

Project Background

The Village of Waterford is located in a historic district in Loudoun County, Virginia. Waterford is a National Historic Landmark, meaning that it is recognized by the United States government for its historical significance, as the village is dedicated to preserving its 18th- and 19th-century architecture and landscape. All of the water provided to the community is through private wells (both shared and individual). Some members of the community have been experiencing issues with well yield, which led the community to apply to the Water and Wastewater Program (The Program). The community applied to The Program first in 2018 and then again in 2019 and was accepted into The Program. A map of Waterford, which shows the study boundary, is included as **Figure 1**.

Dewberry Engineers Inc. (Dewberry) is under agreement with Loudoun Water (LW) to develop an engineering feasibility study for Waterford in order to evaluate the concerns identified in the community of Waterford's application and potential solutions to the community's drinking water issues. The following five (5) options are being evaluated to help improve water conditions within Waterford:

1. Upgrade Existing On-Site Systems to Improve Yield on Individual Wells
2. Shared Private wells
3. Community Water System Owned and Operated by Loudoun Water (Using New Community Wells)
4. Connection to a Nearby, Existing Community System
5. Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System

Technical Memorandum Purpose

The purpose of this Technical Memorandum (TM) is to assess potential permitting and regulatory conflicts within the study boundary in regard to the five (5) options listed above.

Conflicts may arise due to permitting considerations and regulatory requirements including, but not limited to, jurisdictional determinations, right-of-way and easement constraints, policy considerations, and working in a National Historic Landmark (ID#69000256). The exact permitting requirements for a particular option will not be able to be fully evaluated until a plan for that option is completed, or advanced with sufficient detail, and submitted to regulatory agencies for review. Within this TM we will outline the expected permitting process for each option and discuss any anticipated impacts to the overall project implementation schedule for each option due to the requirements and approvals which may be needed. The TM is divided into the following sections:

- Introduction
- Historical Permitting
- Planning and Zoning Permitting
- Health Department Permitting
- Environmental Permitting
- Summary & Conclusions

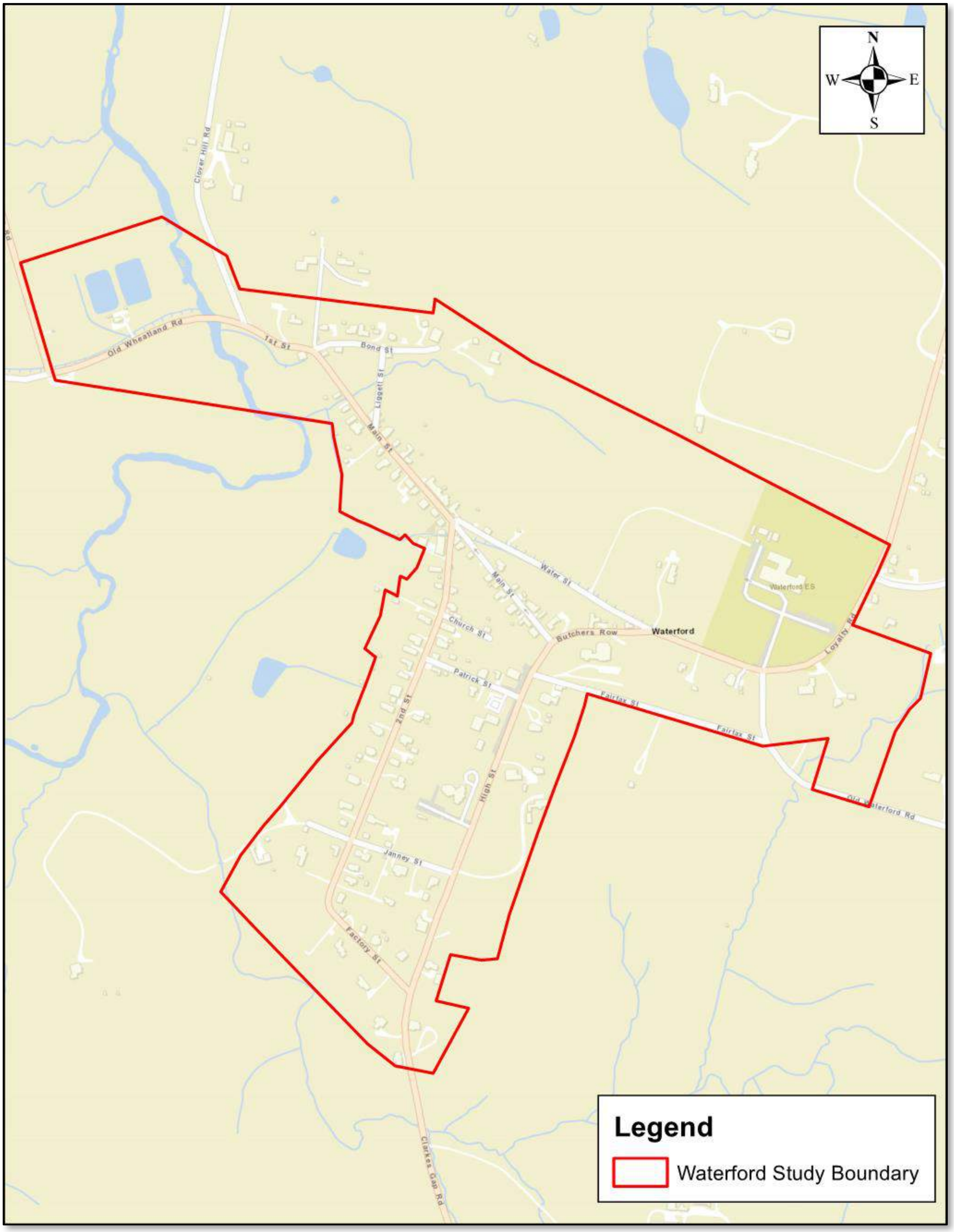


Figure 1 – Waterford Study Boundary

Historical Permitting

As previously described, the Village of Waterford is a National Historic Landmark (ID#69000256). Waterford is also a Loudoun County Historic and Cultural Conservation Site as well as on the Virginia Historic Landmarks Register (ID#401-0123) and the National Register of Historic Places (ID#69000256). Furthermore, per the Loudoun County 2019 General Plan, Waterford is within the Rural Policy Area (RPA) in the Rural North and is designated as a Rural Historic Village. Due to the historic nature of the village, there are potential Federal, state and local permitting processes that need to be undertaken for all options. Utility alignment will drive many of the permitting requirements, so each permit needs to be considered as the alignment selection process is advanced.

Federal

Compliance with Section 106 of the National Historic Preservation Act (NHPA) is required for all undertakings that involve a federal action, which might include an activity on properties owned, leased, or controlled by the Federal government, undertakings which require Federal licenses, permits, or approvals, or actions that are assisted by Federal funds, including grants. Section 106 consultation is the responsibility of the agency performing the relevant federal action. When submitting projects, if multiple federal agencies are involved, it will be necessary to determine which Federal agency will be the lead agency reviewing the project for Section 106 . This review is applicable to all options.

Dewberry has identified three (3) potential Federal actions which may trigger a Section 106 review for all five of the study options:

- Use of federal funds and/or application for a federal grant
- Permitting of impacts to Waters of the U.S. (wetlands and streams) Clean Water Act Permits (depends on selected alternative and alignment)
- Evaluation of potential impacts to identified archaeological resources within or adjacent to the Historic District

The National Landmark Program's regional coordinator is to be consulted any time a federal action will potentially have an adverse effect on a National Historic Landmark. In addition, because Waterford is also recognized as a "Preserve America Community" as part of the Preserve America Communities Initiative, the Advisory Council on Historic Preservation (ACHP) that administers the program and supports community efforts to preserve cultural and natural heritage will also be involved in any Section 106 Review process required by the project. Regardless of if the project involves a federal action, the project designer may request a Technical Assistance Review from the National Landmark Program to aid in determining the necessary requirements for the project to avoid adversely affecting the National Historic Landmark status of the community.

Should Section 401/404 Clean Water Act permits be required for a specific alignment determined during the design phase of the project (for Options 2, 3, 4 and 5), the ACHP and National Landmark Program's regional coordinator will be required to consult on the project as part of the required Section 106 review coordinated through the U.S. Army Corps of Engineers (USACE) during the permitting process.

State

Within the Commonwealth of Virginia, Section 106 reviews for effect on cultural resources are primarily conducted by the Virginia Department of Historical Resources (VDHR). If the project will involve a Federal action, a VDHR review of activities such as ground disturbance or construction of above-ground structures that have the potential to affect known or suspected historically significant cultural resources, historical areas, or buildings, will be coordinated through the federal agency approving or funding the project. These types of actions are anticipated for all options.

In addition, VDHR administers existing historical preservation easements within the community of Waterford that are held by the State Historic Preservation Office (SHPO). Conservation and preservation easements are shown in **Figure 2**.

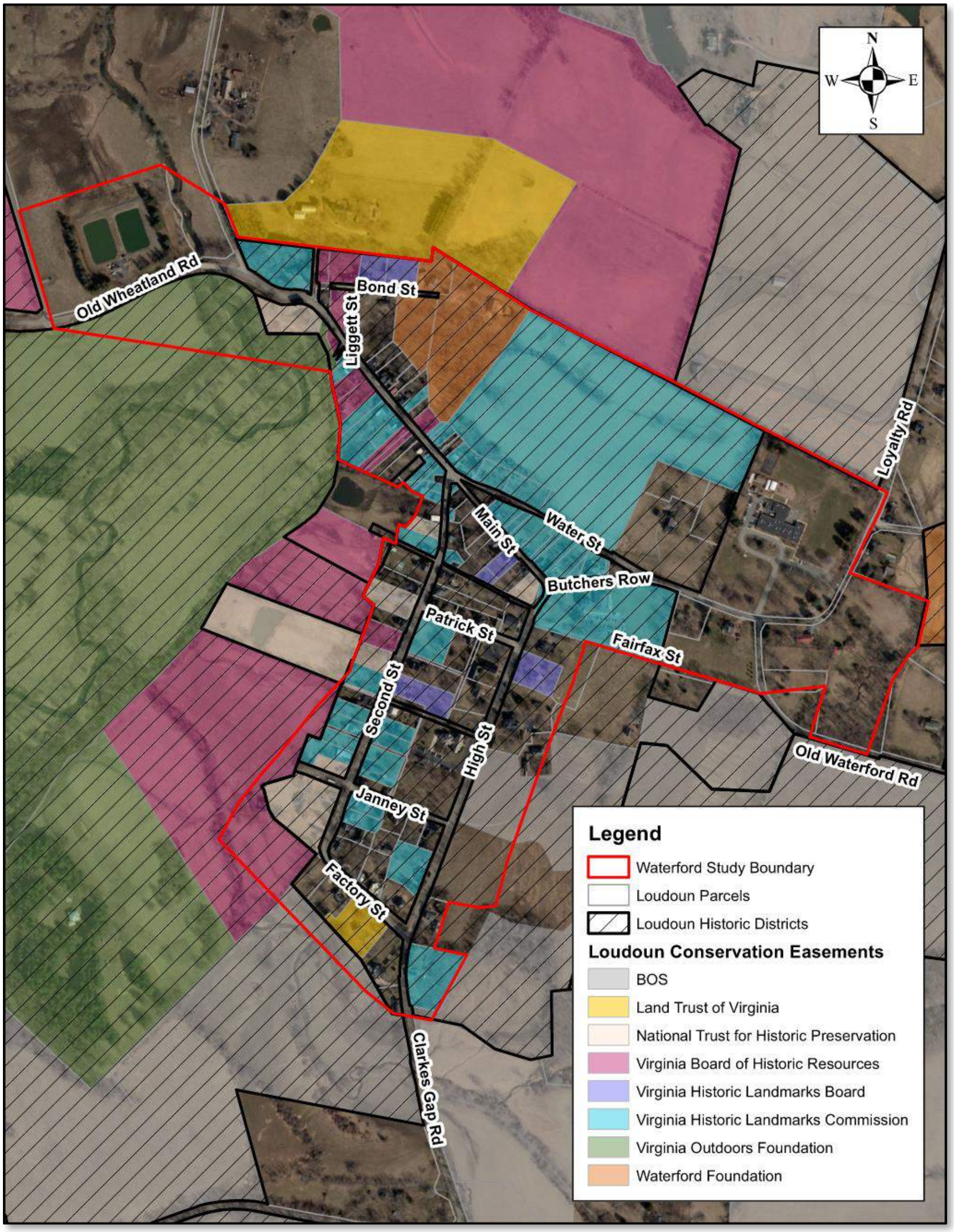


Figure 2 – Conservation and Preservation Easements

A review would be completed for each parcel that is affected within an option, as VDHR Waterford historical easements are recorded by parcel. By law, this review cannot be conducted for any project in the absence of consultation with the property owner. There must be proof of discussion with the property owner and approval from the property owner in order to obtain approval for any submission that affects historical easements. It should be noted that VDHR Waterford historical easements cover different criteria for each parcel. For example, certain easements exist to protect structures and character defining features. Furthermore, not all easements allow for auxiliary structures, which are considered to be both above and below ground, that serve anything other than their property. VDHR is required to work within the language in each easement, however; as in the case of a health/safety issue, flexibility may be maximized to allow for exceptions to these easements to alleviate such issues. These issues will be reviewed on a case-by-case basis. Considerations will need to be made within all of the options to adhere to this historical easement review requirement.

For installation of underground utilities, existing roadways should be utilized where possible. VDHR does not review Virginia Department of Transportation (VDOT) projects where a VDOT Land Use Permit is used and work is confined to the roadway right of way (ROW). However, some property owners in Waterford may own up to the middle of the road. In such a case, requirements for which agency is responsible and must be involved during consultation depends on the chronology in which easements or ROWs were recorded, as the oldest easement governs. This is applicable to Options 2, 3, 4 and 5.

The project designer may request a Technical Assistance Review from VDHR to aid in determining the necessary requirements of the project. This Technical Assistance Review is completed prior to submitting a full application for review and assists in identifying features/easements which may be impacted, permits that will be required, and frameworks within which mitigation activities may be required. Due to the state-level permits that may be required, it is strongly recommended that a Technical Assistance Review be completed for the chosen option prior to submitting the design for formal review.

Local

Waterford is subject to the requirements of the Historic District Guidelines and Village Conservation Overlay District regulations within Loudoun County. The Historic District Review Committee (HDRC) also has jurisdiction to review projects within the County. Projects in these districts are subject to these reviews to ensure that the historic character of the area is maintained. Typically, this review is focused on architectural elements. This will require consideration when designing any structures that may be needed for treatment or distribution within Options 2, 3, 4, and 5. Dewberry has identified four (4) local permitting processes which may require review with respect to the study options:

- Section 6-1800 Zoning Ordinance
- Section 6-1900 Zoning Ordinance
- Section 6-300 Zoning Ordinance
- Section 7.810 Loudoun County Facilities Standards Manual

Section 6-1800 of the Zoning Ordinance requires compliance with land use regulations and architectural guidelines, which are defined in the Waterford Historic District Guidelines. This is applicable to all options.

Actions changing or adding vertical structures (i.e., any structure that is built within a Loudoun County Historical District, including fences, signs, etc.) will require application and receipt of a Certificate of Appropriateness (CAPP) through HDRC, per Section 6-1900 of the Zoning Ordinance. A CAPP is not required for sidewalks or driveways. Loudoun County encourages getting a letter of approval from VDHR first before applying for the CAPP, but the CAPP process can be done concurrently with a Section 106 review. Loudoun County also encourages that a pre-submittal meeting be scheduled prior to application submission, and applications must be submitted approximately one (1) month prior to the next scheduled HDRC meeting. CAPP applicants should use the Waterford Historic District Guidelines for guidance since the approval of a CAPP does not guarantee issuance of a zoning permit and the HDRC considers the criteria outlined in these guidelines to determine permitting. This is applicable to Options 2, 3, 4 and 5.

It should be noted that in addition to the Waterford Historic District Guidelines, the Heritage Preservation Plan may be referenced to aid in project design. This plan outlines policies and strategies to preserve heritage resources. Permits do not require implementation of this plan, however; the Loudoun County Heritage Commission and Loudoun County Planning and Zoning monitor the implementation of this Plan countywide.

Once a project is designed and the construction plans are submitted, any subsurface disturbance will require a Phase 1 archaeological survey through Loudoun County Planning and Zoning, within the limits of disturbance of the project (per the Loudoun County Facilities Standards Manual, Section 7.810.C). If one has already been completed as part of another agency's review process, and/or the area has been subject to previous disturbances that would have degraded existing archaeological resources, then documentation would need to be submitted to the County as part of the Site Plan approval process to justify an exemption to the requirement for a Phase 1 survey. This is applicable to all options.

Planning and Zoning Permitting

In Options 3, 4, and 5, a Commission Permit (CMPT) is required. A Commission Permit will define the "service area". For the purposes of this feasibility study, Loudoun Water and Loudoun County staff have suggested that the water service area boundary should be the same as the already-established wastewater service area (which was the basis for this Water Study Area). Ultimately the service area will be determined by the Board of Supervisors through the legislative review process for the Commission Permit. The Commission Permit process is defined in Section 6-1100 of the Revised 1993 Loudoun County Zoning Ordinance (Zoning Ordinance) and is required for any public utility. Zoning in the Waterford Study area is depicted in **Figure 3**.

The majority of the Water Study Area is zoned Countryside Residential 1 (CR1) and Countryside Residential 2 (CR2) as defined in section 2-500 and 2-600, respectively, of the Zoning Ordinance. CR-1 and CR-2 zoned parcels are parcels that were originally zoned Agricultural Rural-1 (AR-1) and Agricultural Rural-2 (AR-2) under the 1972 zoning ordinance and where the properties are arranged in a hamlet style pattern. The Zoning Ordinance states that public water and sewer facilities are encouraged in these areas. A water pumping station, as regulated under Section 5-621 of the Zoning Ordinance, is a by-right use in CR-1 and CR-2. Water storage tanks and water treatment plants are listed as special exception uses. Regardless of zoning district, all public utility facilities will be required to obtain a Commission Permit, per section 6-1100 of the Zoning Ordinance. Additional legislative requirements (special exceptions, modifications) can be processed and approved as part of the required Commission Permit application.

There are also a few parcels zoned Rural Commercial (RC), defined in section 2-900 of the Zoning Ordinance. RC zoning has the same by-right uses and special exception uses listed above in CR-1 and CR-2 zoning.

Some parcels along the boundary of the Water Study Area are zoned AR-1. Municipal water wells, municipal drinking water reservoir, and water pump stations are permitted uses in AR-1 zoning. Water treatment plants and water storage tanks will require a special exception, along with required Commission Permit.

The water source for Options 2, 3, 4, and 5 can be located outside of the service area boundary. However, for public utilities to cross the rural policy area, a "public health" need will need to be established and the utility will need restrictive easements. It was indicated during an initial project discussion with Loudoun County Planning and Zoning staff that establishing a public health need for Options 2, 3, 4 and 5 will require increased justification other than locating the water source relatively adjacent to Waterford.

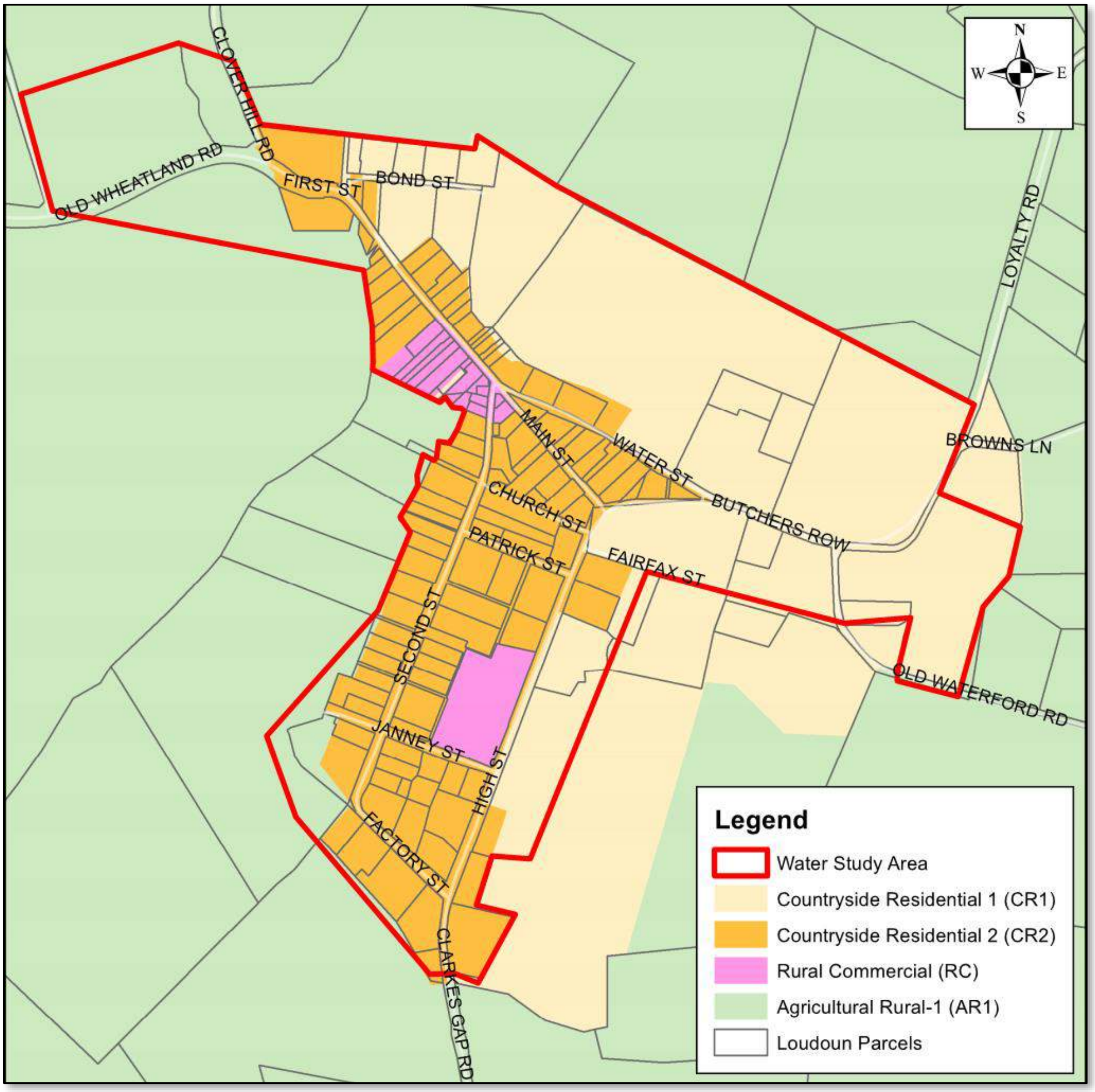


Figure 3 – Waterford Zoning Map

Loudoun County Building and Development

Any construction needed for structures, site access for the wells or treatment or distribution buildings will require a Loudoun County site plan approval, Loudoun County grading permit and Loudoun Water easements. Based on the potential work items within all five options, these permits will apply to all five of the study options. Site plans for the work items under all five options will likely be considered simple site plans but there is potential to have several different sites depending on the water source or sources and water characteristics. Any stormwater management criteria required will also be included with the site plan. A Virginia Stormwater Management Program (VSMP) Construction General Permit and Stormwater Pollution Prevention Plan (SWPPP) is also necessary for site plan approval. A grading permit is required prior to any construction. The design and profiles for the water distribution network throughout Waterford will be submitted to Loudoun Water for review and approval but are not required for Loudoun County review.

For Options 2 and 3, Loudoun County Codified Ordinance Chapter 1042.01 will require Board of Supervisors approval for any water system supplying water to three (3) or more connections. The chapter states, "no new water system to serve, or to be capable of serving, three or more connections shall be established and no extension of a previously approved water system shall be made until a detailed plan of such proposed new system or of such proposed extension, with proof of capacity to serve, has been filed with, and a permit therefor has been obtained from, the Board of Supervisors."

VDOT

The construction plans will be submitted to VDOT in order obtain the necessary land use and utility permits to do work in a VDOT right-of-way. Options 2, 3, 4, and 5 have the potential to need VDOT land use and utility permits, but exact requirements will not be known until alignments have been further developed. **Figure 4** shows that most of the roads in Waterford are VDOT-designated roads. Detour and traffic management plan approval from VDOT will be needed for any watermain construction in the right-of-way.

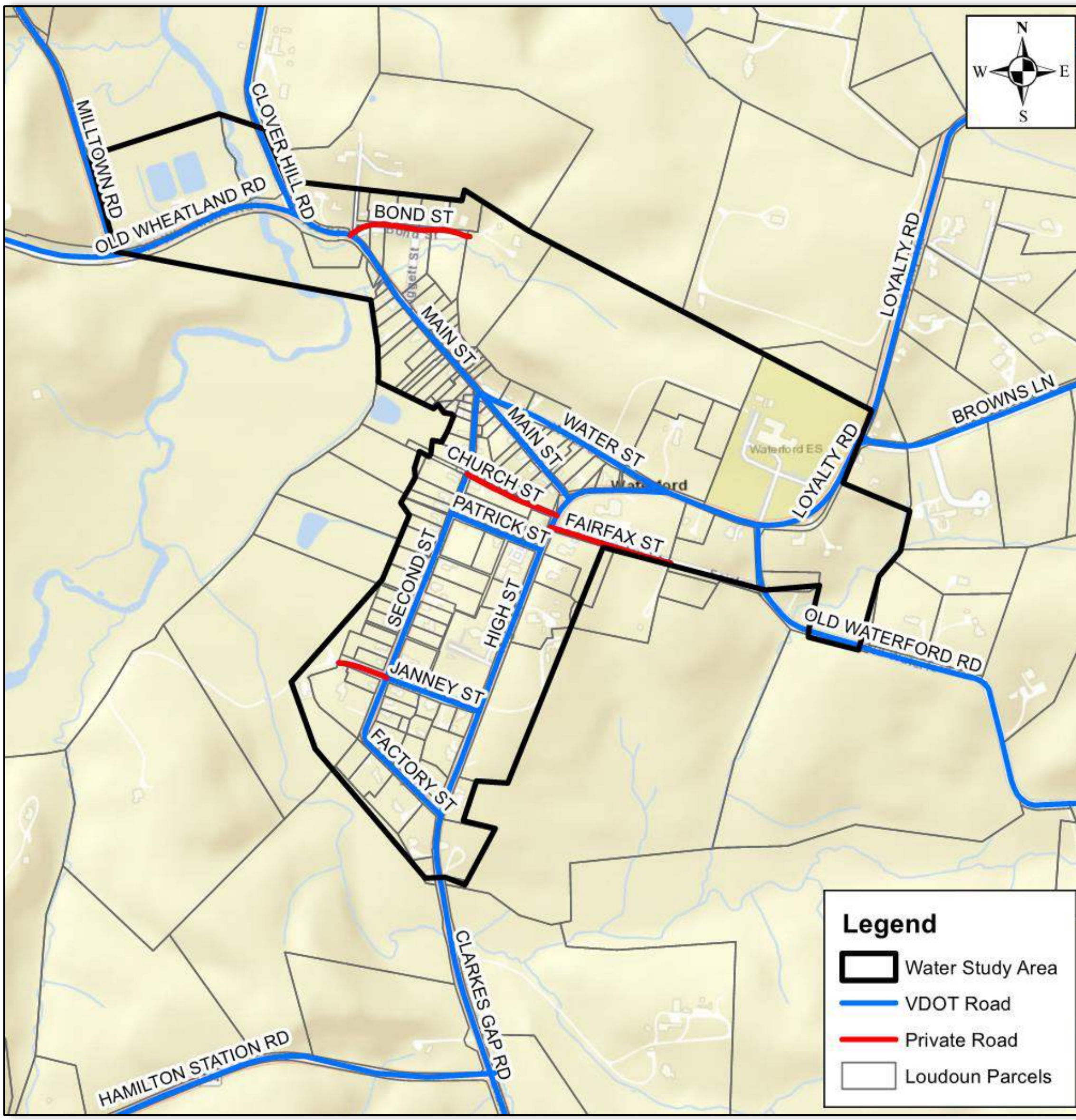


Figure 4 – VDOT Roads

Design Considerations
Many of the parcels lack consistently defined right-of-way and depending on the alignment, easements may be required on private property throughout the community. Encroachment agreements will be needed to impact and/or cross existing easements. Titles should be obtained on properties that will be encumbered by construction and existing utility designations obtained prior to design in order to avoid potential conflicts. The community also has many historic structures, such as homes and stone walls, very close to right-of-way. Care should be taken when designing the water main alignment and location of water meters, or other necessary appurtenances, to not impact historic structures.

Health Department Permitting

There are several agencies that regulate groundwater and well requirements in the community of Waterford, which include the Loudoun County Health Department (LCHD), the Virginia Department of Health (VDH) Office of Drinking Water (ODW) and Loudoun Water (LW).

Option 1
If Option 1 was to be pursued, requirements would depend on the type of upgrade. If an existing well is replaced or deepened, a LCHD well permit would be required. Well tests are not required for irrigation wells, replacement wells, or for wells that have been drilled but not connected.

However, if the upgrade within Option 1 requires the construction of a new well, then LCHD regulate this process, and a well permit would need to be obtained from LCHD. Furthermore, if an existing well were to be abandoned, an abandonment permit would need to be obtained from LCHD. A 25-feet setback distance from any part of a sewage disposal system or future systems is required for all wells properly abandoned.

For the construction of a new well, the current setback requirements, as determined by LCHD, are 50-feet from pollution sources (e.g., drain field, old drain field, wood structure treated for termites, old privy, etc.) and 10-feet from property lines. For older, existing wells, setbacks from pollution sources have been from 50-feet to 100-feet. Setbacks are evaluated on a case-by-case basis, and local codes may be waived in the case of an emergency, such as an out-of-water situation. It should be noted that VDH ODW allows borate-based termite treatment to be applied directly to structures rather than spray or chemical injection. If this treatment is used, a waiver may be requested through LCHD to allow the well to be as close as 15-feet to the structure that has been directly-treated. There are no additional requirements by LCHD to test a new well past its first test report. It should also be noted that Waterford is mostly located in a Limestone Overlay District and that all wells within a Limestone Overlay District shall be installed in accordance with the setback provisions in Chapter 1040 of the Loudoun County Public Health Ordinances. Furthermore, it should be noted that per the LW Engineering Design Manual (EDM), there should exist a minimum horizontal separation of 50-feet between sewer and all potable wells. However, per Chapter 1040 of the Loudoun County Public Health Ordinances, this separation may be reduced to as little as 35-feet where the sewer is constructed of pressure pipe, tested in place.

Storage tanks are only approved by LCHD with the addition of a new well. Minimum yield requirements of a new well are one (1) gallon per minute (gpm) and the ability to produce 500 gallons within a two (2) hour period. If a well is not capable of meeting this yield then the calculated difference between what the well can produce in two (2) hours and 500 gallons is required to be made up by adding a storage tank of that size. It should be noted that VDH ODW requires a higher demand per connection (3 gpm) for private wells (individual and shared), assuming no storage.

A water well completion report would not need to be submitted to the Virginia Department of Environmental Quality (VA DEQ) since Waterford is not located in a Groundwater Management Area (GWMA).

Option 2
If Option 2 was to be pursued, LCHD would need to approve the location and construction of any new wells. Although VDH ODW has regulations regarding the construction of new wells, these regulations would not

apply because LCHD regulations are more restrictive. Well requirements would be the same as outlined above for Option 1.

If fifteen (15) connections (or more) are made to one well, or if 25 people (or more) are connected to one well (for at least 60 days out of the year), the system meets the definition of a public "Waterworks" and would be required to meet VDH ODW public water supply system standards. Wells considered to be public Waterworks would be regulated by VDH ODW and would be required to undergo annual monitoring (12VAC5-590-374, Table 374.1).

Per discussions with VDH ODW, the limitation for a shared well is driven mainly by the number of connections, and the maximum number of connections (15) is rarely approved, as it is difficult to prove that the number of people connected will not exceed the definition of public water works. There are numerous ways to help guarantee the number of people connected to a shared well doesn't go over 25, such as looking at how many people occupy each home and the ages of occupants. However, should the results of a census reveal that the number of people connected to a shared well is over 25, public waterworks would be notified. Therefore, it is generally safe to not exceed four (4) connections per well. The well would fall under local regulations administered by LCHD. Shared wells are allowed by LCHD as long as they meet LHCD requirements. Some local requirements are not regulated or administered by LCHD. Therefore, the Loudoun County Facility Standards Manual (FSM) and other ordinances should be checked regarding additional requirements. A shared well with four (4) connections should have an approximate yield of eight (8) gpm.

Regarding water withdrawal, Waterford is not located within a GWMA and therefore does not need groundwater withdrawal permitting through the Virginia Department of Environmental Quality (VA DEQ).

As with Option 1, if an existing well were to be abandoned, an abandonment permit would need to be obtained from LCHD. A 25-feet setback distance from any part of a sewage disposal system or future systems is required for all wells properly abandoned.

Option 3

If Option 3 was to be pursued, LCHD and VDH ODW would be involved in the location and construction of the community wells. These wells would be considered a public "Waterworks," which is defined by VDH ODW as "a system that serves piped water for human consumption to at least 15 service connections or 25 or more individuals for at least 60 days out of the year" (12VAC5-590-10).

Since the well would be considered a public Waterworks, VDH ODW would also be involved in regulation and testing of the well throughout construction and the life of the well. A Waterworks Permit Application for construction (construction permit) should be submitted through VDH ODW prior to construction of well(s) and distribution mains, unless a general permit for distribution mains is granted (12VAC5-590-300). All requests for a construction permit are directed initially to VDH ODW. Following completion of construction, a Waterworks Permit Application for operation (operation permit) should be submitted through VDH ODW. For the duration of the life of the well, VDH ODW requires that the well undergo annual monitoring (12VAC5-590-374, Table 374.1).

Additional requirements by LCHD for the construction of the wells depends on the class of the well. Well classes are defined in Loudoun County Public Health Ordinances Chapter 1040 – Water Wells. LCHD defines two (2) classes of public wells: Class I and Class II. According to LCHD, Class I wells are "for public multi-user water supply systems," and Class II wells are "for public individual water supply systems and private water supply systems construction on lots three acres or less." Based on these definitions, a Class I public well would be required for this option. Water supply systems shall not be located in ground swale areas or flood plains which are subject to surface run-off and/or flooding. LCHD shall also approve a hydrogeologic study, which is required for groundwater sources.

Chapter 7 of the LW EDM also details requirements for "Community Water Systems." The Community Water System shall be approved by LW, and the procedure for reviews and approval by LW can be found in Appendix D of the EDM in the chart titled "Community Systems Design Review Process." Per the EDM, Loudoun Water will only consider for approval groundwater systems not influenced by surface water.

Loudoun Water also requires that all groundwater systems shall provide the number of wells that are anticipated to be capable of continuously pumping no less than 1.2 gpm per connection for 60 consecutive days and that systems having more than 50 connections shall provide either:

1. Three (3) wells with required easements, including two (2) wells in service and one (1) backup well, producing at least 0.6 gpm per connection, or

2. Four (4) or more wells with required easements, including a backup well that has undergone initial hydro geological testing, the two (2) smallest of which shall combined produce at least 0.6 gpm per connection with the smallest producing at least 0.12 gpm per connection.

Furthermore, LW requires a minimum 100-feet radial or a 200-feet by 200-feet square for each well. A computerized hydraulic analysis of the distribution system shall be submitted to Loudoun Water for review and approval. Like with LCHD requirements, wells shall not be located within any major 100-year flood plain and shall be Class I.

Also, as previously noted with Option 1, Waterford is mostly located in a Limestone Overlay District. All wells within a Limestone Overlay District shall be installed in accordance with the setback provisions in Chapter 1040 of the Loudoun County Public Health Ordinances.

Regarding water withdrawal, Waterford is not located within a GWMA and therefore does not need groundwater withdrawal permitting through VA DEQ.

Options 4 and 5

If Option 4 or Option 5 were to be pursued, VDH ODW would regulate the actions taken since the Waterford community would be connected to an existing, permitted public Waterworks already regulated by VDH ODW. Design and construction standards of the community/Town and LW requirements also shall be met.

As previously described for Option 3, a construction permit will be needed for the distribution system, unless a general permit for distribution mains is granted (12VAC5-590-300). All requests for a construction permit are directed initially to VDH ODW but will also need to be in compliance with the permit issued for the community system being connected to (Option 4) or the utility distribution system being connected to (Option 5). This means that the system design will need to be reviewed by the licensed operator of the existing public Waterworks for conformance to the existing system's requirements prior to submitting the request for a construction permit to VDH ODW. Following completion of construction, an amended Waterworks Permit Application for operation (operation permit) would need to be submitted through VDH ODW.

Individual wells shall be abandoned per VDH ODW requirements, which requires an abandonment permit by LCHD, unless the well is converted to an irrigation well. A 25-foot setback distance from any part of a sewage disposal system or future systems is required for all wells properly abandoned.

As with Options 1 and 3, because Waterford is not located within a GWMA, groundwater withdrawal permitting through VA DEQ is not required.

Environmental Permitting

Waterford is located by the South Fork of Catoctin Creek, as shown in **Figure 5**.

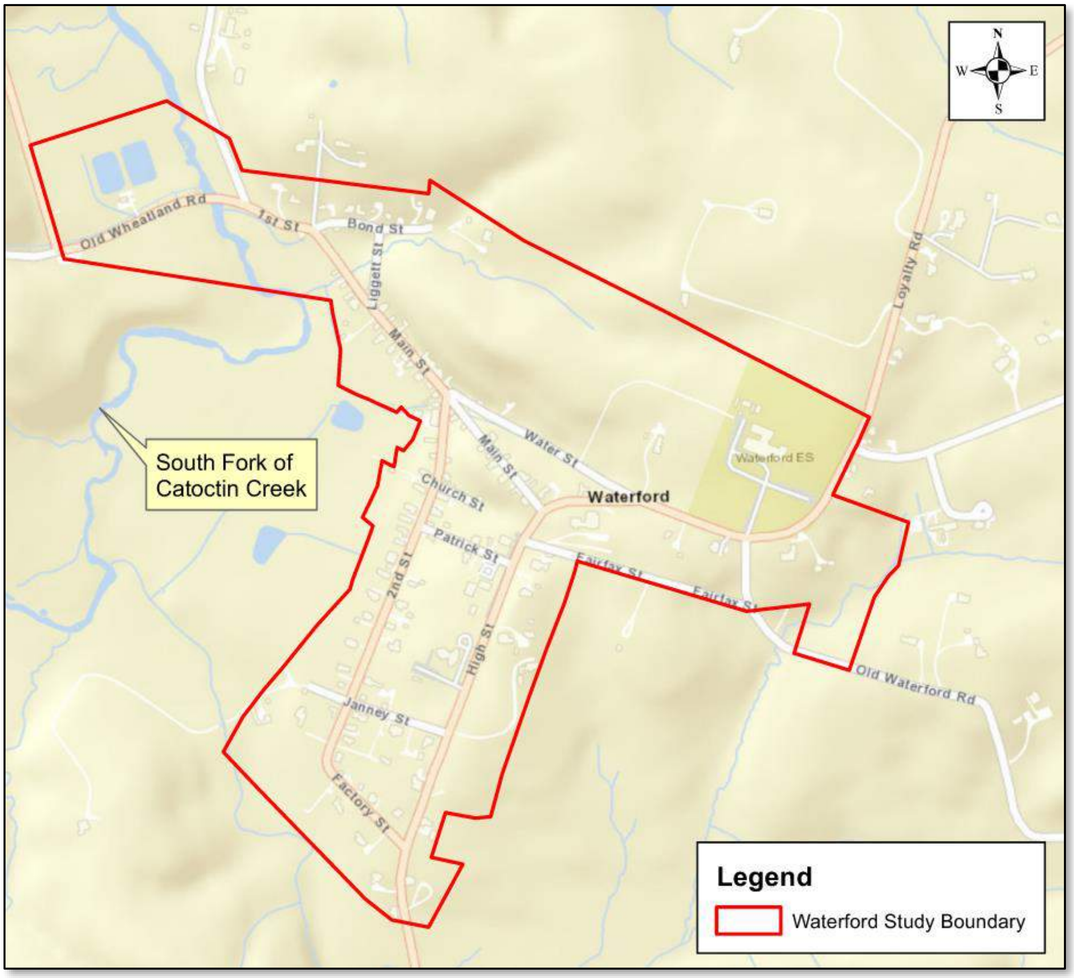


Figure 5 – Waterford Village by Catoctin Creek (Google Maps)

Due to Waterford's location by the creeks, and several other factors that may affect options that require installation of underground utilities in the area, there are several Federal, state and local environmental permitting considerations that need to be accounted for, which are discussed below. Each of these considerations will be dependent on the alignment selection.

Federal

If the project is federally funded, it may be necessary to perform a National Environmental Policy Act (NEPA) review of the project. Determining who the lead review agency would be for the project, in addition to determining what level of NEPA document might be required will be dependent on the option selected and the anticipated significance of environmental impacts for the work. A NEPA review would require cataloguing the potential for the project to impact numerous environmental resources, including (but not limited to) streams and wetlands, floodplains, threatened and endangered species, hazardous materials sites, environmental justice populations and land use patterns. If the proposed project requires a more involved Environmental Assessment document, this will necessitate more extensive coordination with the lead Federal Agency and a public hearing. This is potentially applicable to all options.

A wetland delineation and Jurisdictional Determination for the project area would need to be completed and submitted to USACE to determine if the location and extent of jurisdictional waters within the project area. If the project impacts Waters of the U.S. (WOUS), including jurisdictional wetlands and stream channels, either temporarily or permanently, a Section 404 permit under the Clean Water Act would need to be issued by the US Army Corps of Engineers (USACE) to allow for construction activities to commence. This is applicable to all options.

State

VA DEQ Section 401 permitting requirements will be dependent upon alignment selection, impacts or crossings of jurisdictional waters and the type of USACE permit required for the project (some USACE permits do not require a separate review/permit from DEQ). A Virginia Water Protection (VWP) Permit would be required through VA DEQ for any impacts to state waters and wetlands that requires a USACE permit without a Section 401 certification, which may apply to Options 2, 3, 4 and 5. A Virginia Stormwater Management Program (VSMP) Construction General Permit and Stormwater Pollution Prevention Plan (SWPPP) may be required by VA DEQ if limits of disturbance are in excess of 1 acre, which is potentially applicable to Options 3, 4 and 5. VA DEQ permit processes should also be followed for any hazardous materials issues and/or air quality impacts caused by a project (for all options) and any need for an Emergency Generator or Concrete Batch Plant Permit, which is applicable to Options 3, 4 and 5.

A permit to construct in Virginia tidal wetlands and subaqueous bottoms, as issued by the Virginia Marine Resources Commission (VMRC), may be required if the proposed alignment crosses the South Fork of Catoctin Creek or a tributary with over a five (5) square-mile drainage area. This is applicable to Options 3, 4 and 5.

Permitting review processes for any project effects to state threatened and endangered species, as well as game and non-game species (including insects), will be conducted by the Virginia Department of Wildlife Resources (DWR) and the Virginia Department of Conservation Resources (DCR) as coordinated by the relevant permitting agencies (i.e., USACE and/or DEQ). Permits will be needed for any timber sales through the Virginia Department of Forestry. These measures are applicable to all options.

Local

The Catoctin Creek Scenic River Advisory Committee may require a Virginia Scenic River Program Designation for crossings or encroachments on the South fork of Catoctin Creek near the Mill and downstream. This is applicable to Options 3, 4 and 5.

The Loudoun County Stormwater Management Program will need to be consulted for measures regarding construction site runoff control and post-construction runoff control. Loudoun County manages floodplains in accordance with the Federal Emergency Management Agency (FEMA) regulations and Section 4-1500 of the Zoning Ordinance. Therefore, preparation and submittal of a Conditional Letter of Map Revision (CLOMR) will be required through Loudoun County prior to construction of a distribution main. Following construction, preparation and submittal of Letter of Map Revision (LOMR) will be required. This is applicable to Options 3, 4 and 5.

Summary & Conclusions

The Village of Waterford has a rich historical background. Waterford is located in a historic district and is considered to be a National Historic Landmark and a Loudoun County Historic and Cultural Conservation Site and is also on the Virginia Historic Landmarks Register and the National Register of Historic Places. All of the water provided to the community is through private wells (both shared and individual), and some members of the community have been experiencing issues with well yield. Due to the historic nature of the village, as well as general requirements for any construction project, there are numerous permits to consider for the five (5) options being considered to improve well yield in Waterford.

The permitting processes for each of the five (5) options were divided into four (4) different categories and discussed in the corresponding sections of this TM: Historical Permitting, Planning and Zoning Permitting, Health Department Permitting and Environmental Permitting. In each section, a description of relevant permit processes and the options that they are applicable to was provided.

A summary of the potential permits needed for Waterford is provided in the permit register in **Table 1**. The permit register was developed to consider all five (5) options to be evaluated in the Waterford Feasibility Study. This list may not be all-inclusive and should be revisited and updated as appropriate, and as the project scope and design proceeds and options are further assessed.

Table 1 – Waterford Permit Register (August 2, 2021)

Permit/Authorization	Agency	Option 1	Option 2	Option 3	Option 4*	Option 5*
Historical						
Section 106 authorizations, easement encroachments, and appropriate mitigation as necessary	VDHR SHPO	X	X	X	X	X
Section 106 / Landmarks Effect Determination	National Park Service (National Landmark Coordinator)	X	X	X	X	X
Certificate of Appropriateness (CAPP)	HDRC		X	X	X	X
Phase 1 archaeological survey approval	VDHR; Loudoun County Planning and Zoning	X	X	X	X	X
Planning and Zoning						
Commission Permit (CMPT)	Loudoun County			X	X	X
Special Exception (SPEX)/Minor Special Except (SPMI)	Loudoun County	X	X	X	X	X
Site Plan	Loudoun County	X	X	X	X	X
Grading Permit	Loudoun County	X	X	X	X	X
VDOT Utility Plan	VDOT		X	X	X	X
Detour/Traffic Management Plan	VDOT		X	X	X	X
VSMP/SWPPP	VA DEQ	X	X	X	X	X
Heath Department						
Private Well Construction Permit (Single family or shared well not meeting the definition of a Public Waterworks)	LCHD	X	X			
Chapter 1042.02 Application for Public Waterworks (15 connections or 25 people served, or greater)	LCHD		X	X		
Abandonment Permits	LCHD	X	X	X	X	X

Permit/Authorization	Agency	Option 1	Option 2	Option 3	Option 4*	Option 5*
Heath Department (Continued)						
Construction and Operation Permits	VDH ODW		X	X	X	X
Construction Permit	LW			X		
Connection Permit				X	X	X
Environmental						
NEPA Document (if federally funded)	TBD; dependent on involvement of Federal agencies	X	X	X	X	X
Clean Water Act Section 404 Permit	USACE	X	X	X	X	X
Wetland Delineation Report and Jurisdictional Determination Request		X	X	X	X	X
Clean Water Act Section 401 Virginia Water Protection Permit	VA DEQ		X	X	X	X
Virginia Stormwater Management Program Permit				X	X	X
Hazardous Materials & Due Diligence Compliance		X	X	X	X	X
Emergency Generator or Concrete Batch Plant Permit	VA DEQ			X	X	X
Permit to construct in Virginia Tidal Wetlands and Subaqueous bottoms.	Virginia Marine Resources Commission			X	X	X
Permit for timber sale	VA Department of Forestry	X	X	X	X	X
Virginia Scenic River Program Designation	Catoctin Creek Scenic River Advisory Committee			X	X	X
Preparation and submittal of a Conditional Letter of Map Revision (CLOMR)	Loudoun County/FEMA			X	X	X
Once constructed, prepare and submit a Letter of Map Revision (LOMR)				X	X	X

*These options will need to meet the requirements of the potential connection location (i.e., Purcellville, Hamilton, Leesburg, Loudoun Water)

Appendix B
Flow Analysis Technical Memorandum

Date: November 23, 2021

To: Andrew Beatty, P.E.

From: Paul Longo, P.E.

Subject: DRAFT - Waterford Demand Analysis Technical Memorandum

Introduction

Project Background

The Village of Waterford is located in a historic district in Loudoun County, Virginia. Waterford is a National Historic Landmark, meaning that it is recognized by the United States government for its historical significance, as the village is dedicated to preserving its 18th- and 19th-century architecture and landscape. All of the water provided to the community is through private wells (both shared and individual). Some members of the community have been experiencing issues with well yield, which led the community to apply to the Water and Wastewater Program (The Program). The community applied to The Program first in 2018 and then again in 2019 and was accepted into The Program. A map of Waterford, which shows the study boundary, is included as **Figure 1**.

Dewberry Engineers Inc. (Dewberry) is under agreement with Loudoun Water (LW) to develop an engineering feasibility study for The Program in order to evaluate the concerns identified in Waterford's application and develop potential solutions to the community's drinking water issues. The following five (5) options are being evaluated to help improve water conditions within Waterford:

1. Upgrade Existing On-Site Systems to Improve Yield on Individual Wells
2. Shared Private wells
3. Community Water System Owned and Operated by Loudoun Water (Using New Community Wells)
4. Connection to a Nearby, Existing Community System
5. Wholesale Purchase of Water from, or Connection to, a Nearby Municipal System

Technical Memorandum Purpose

The purpose of this technical memorandum (TM) is to present the current and future water demand estimates developed by Dewberry for the Waterford community and to provide a recommendation for the demand to be used when evaluating sizing of water distribution piping and well/treatment systems for the Waterford community, should they be necessary. Fire flow demands are excluded from this analysis, as they are not required within the rural policy area based on Loudoun County Requirements. The TM is divided into the following sections:

- Introduction
  - Purpose of TM
  - Project Background
- Demand Study
  - Existing Development Demand Estimates
  - Existing Development Demand Estimates Summary
  - Potential Future Demand Estimates
  - Potential Future Demand Estimates Summary
- Conclusion

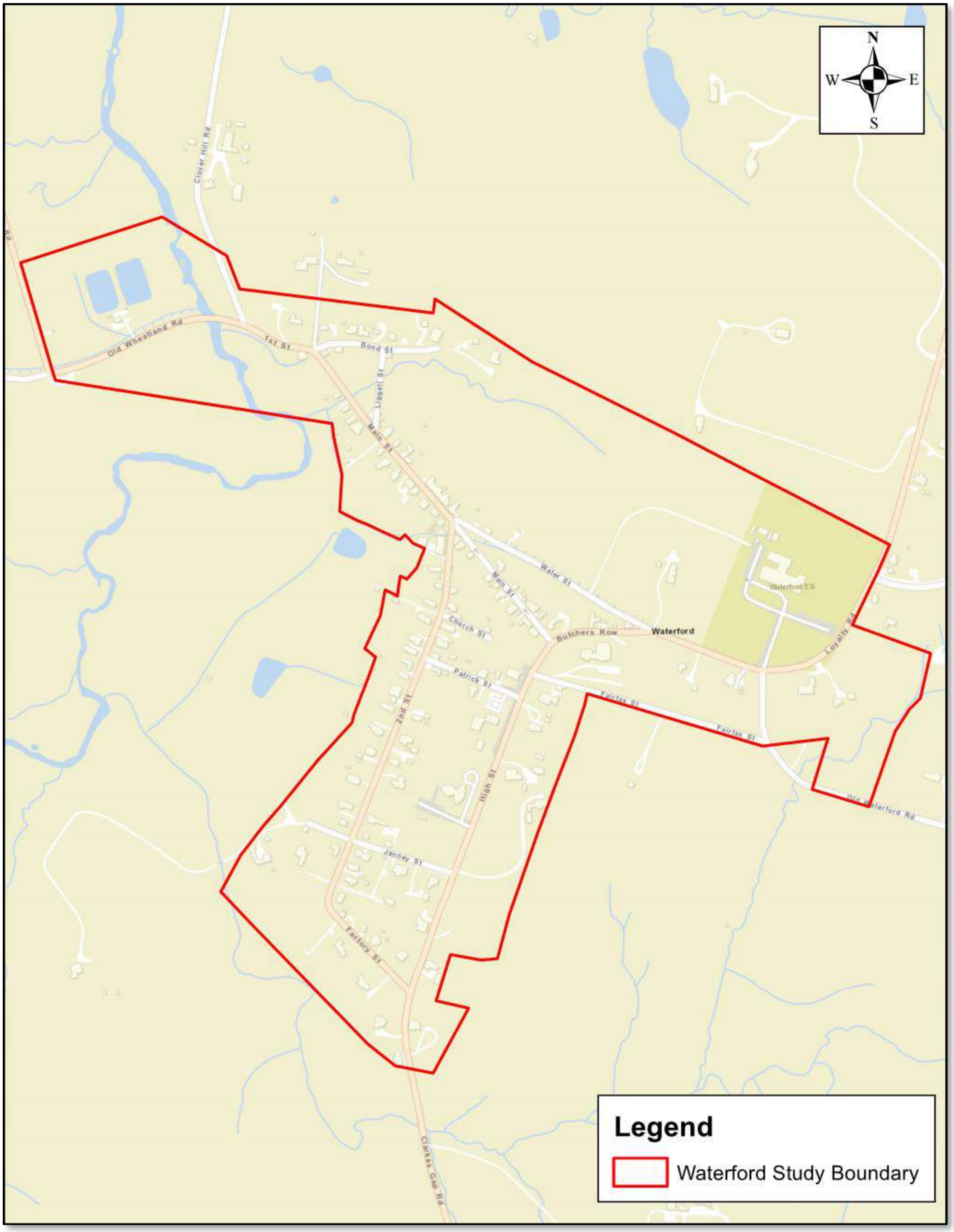


Figure 1 – Waterford Study Boundary

Demand Study

This section describes how the existing and potential future demands were determined for the Waterford community and presents these estimates. Due to the historical nature of this community, current and future water demands for the community have been developed by considering regulatory requirements, current zoning, the Loudoun County Comprehensive Plan and engineering best practices. These methods will be described in detail below.

Regulatory Requirements

Loudoun Water's Engineering Design Manual (EDM) standards and Commonwealth of Virginia statue 12VAC5-590-640 – General Design Considerations, which is administered by the Virginia Department of Health (VDH), were referenced for flow regulations. Note that Commonwealth of Virginia statue 12VAC5-590-690, which outlined demand standards based on usage, has been repealed as of June 23, 2021. The newest regulation for demand calculations is outlined in 12VAC5-590-640. The latest regulation states that "Waterworks design shall be based on sound engineering practice substantiated in the engineer's design and approved by the department. Historical data or typical usage figures of waterworks with similar service area characteristics and appropriate peaking factors shall be used to support the design." For the purpose of these demand projects, churches and auditorium demands have been estimated using 5 gpd per occupant calculation based on engineering practice.

Based on the study boundary shown in **Figure 1**, the existing buildings and structures that require a potable water connection within the Waterford community include 112 residential homes (dwelling units), five (5) businesses (not including businesses within residential parcels/homes, which were assumed to be included under residential calculations), the Waterford Elementary School, three (3) churches, and an auditorium (Old School Auditorium). Vacant parcels and structures that do not require water service (e.g., sheds) were not considered in the existing demand estimates. The Second Street School is not included in either the existing or future demand estimates because there is currently no water use at the site and the operators of this facility indicated that they expect no anticipated future water use. **Table 1** summarizes the community by use.

Table 1 – Waterford Community by Use

Use	# of Existing Buildings
Dwelling Unit (Residential Structure)	112
Commercial and Industrial	5
School	1
Churches	3
Auditorium	1

Using these existing buildings and structures within the Waterford community, the applicable EDM and VDH demand requirements were determined. Loudoun Water's EDM provides standards for residential homes, commercial and industrial buildings.

Demands for residential homes, commercial and industrial buildings, and schools were estimated using EDM standards or sound engineering practices as outlined in the latest VDH waterworks regulations discussed above. The exact population of the Waterford community within the study boundary cannot be determined using available population data sources including, but not limited to, US Census, Commonwealth of Virginia, and Loudoun County population data. As a result, Loudoun Water's EDM standards were used to estimate residential demand, as these standards are based on the number of dwelling units within the community, which have been determined using available data, while the VDH standards require a community population, which is not able to be determined. Since EDM standards state to include 3.5 persons per dwelling unit, and 100 gallons per day (gpd) for each person within the dwelling unit, the exact demand for each dwelling unit was determined to be 350 gpd.

The EDM standards were also used for commercial and industrial buildings and schools, as these standards are more conservative than the VDH standards. The number of employees for each business, as well as the amount of days that the business is occupied, was determined either by contacting the businesses or by online research. The Old School Auditorium has an office space that is regularly-used, and it should be noted that only this office space for the Old School Auditorium is counted within estimates for commercial and industrial buildings. Other demands for events held at the Old School Auditorium are discussed below.

The three (3) churches and the Old School Auditorium have uses that do not fall into any of the EDM or VDH standards. As outlined in the new VDH regulations, demands can be based on sound engineering practice. Without performing fixture counts, a conservative average daily demand was calculated using the most conservative attendance (based on survey/feedback from the community) and assuming a 5 gpd per person demand. The 5 gpd demand was generated using the historic demand calculations of 'theaters', as the usage of these facilities is similar.

The standards used in calculating the estimated demands are summarized in **Table 2**.

Table 2 – Water Demand Estimate Standards

Regulating Agency	Facility	Unit	Demand (gpd)
Loudoun Water EDM	Dwelling Unit (Residential Structure)	Per Dwelling Unit (Residential Structure)	350
	Commercial and Industrial	Per Employee	100
	School	Per Staff and Students	20
Virginia Department of Health (VDH)	Churches	Per Person	5
	Auditorium	Per Person	5

Existing Development Demand Estimates

Research was conducted on residential and commercial properties within the community to determine the number of developed properties within the community. Communications were made with appropriate commercial developments within the community to ensure that the existing development demand estimates were as accurate as possible while adhering to the aforementioned standards. The following list summarizes how the existing average daily demands (ADD) were calculated for each facility:

- Residence: To calculate the residential demand in Waterford, the number of residential structures, or, dwelling units was first determined using a Geographic Information System (GIS) layer provided by Loudoun Water, which displayed all of the buildings in Waterford. The number of dwelling units was counted from this image. Vacant parcels and structures that do not require water service (e.g., sheds, Second Street School, etc.) were not counted and are not considered in the existing demand estimates. **Table 3** shows how the estimated existing residential ADD for Waterford was calculated.

Table 3 – Residential Population Existing Demand Calculations

Facility	Number of Dwelling Units (Residential Structures)	Demand (gpd/dwelling unit)	Estimated ADD (gpd)
Residential	112	350	39,200

- Commercial and Industrial: The number of employees for each business was determined either by contacting the businesses or by online research, as described in the list below. Following these descriptions, a summary of the current commercial and industrial demand calculations is provided as **Table 4**.
    - *Loudoun Mutual Insurance* – Upon discussion with this business, it was conveyed that 30 to 35 full time employees work in the building, that they provide one (1) to two (2) summer internships each year and that they host quarterly meetings with 10 to 15 additional guests. To be conservative in estimating, it is assumed that 52 employees work full time at this building.
    - *Waterford Market* – Online research suggested that one (1) person owns the store, and it was assumed that this person solely runs the store.
    - *The Corner Store* – Based on conversation with a person who has knowledge of the store, generally less than five (5) people total work for the store, with a maximum of one (1) to two (2) people working at the store at a time. To be conservative, it was assumed that five (5) employees work at the store.
    - *United States Postal Service (USPS)* – Online research suggested that approximately four (4) people work at this store.
    - *Wastewater Treatment Plant (WWTP)* – LW conveyed that, on average, one employee works at the WWTP.
    - *Old School Auditorium* – Although this auditorium is used for events that are later included in the estimates for “theaters,” upon discussion with the Waterford Foundation Executive Director, it was conveyed that this space is also used for offices and that approximately four (4) to five (5) people work in this space. It was assumed that five (5) people work at the auditorium to be conservative.

Table 4 – Commercial and Industrial Existing Demand Calculations

Facility	Quantity (Employee)	Demand (gpd/Employee)	Estimated ADD (gpd)
Loudoun Mutual Insurance	52	100	5,200
Waterford Market	1		100
The Corner Store	5		500
USPS	4		400
WWTP	1		100
Old School Auditorium	5		500
Total Estimated Existing ADD (Commercial & Industrial)			6,800

- School: The number of staff at the Waterford Elementary School was determined by counting the number of people listed on the "Staff Email Directory" page of the school's website. The number of students at the Waterford Elementary School was taken from the Loudoun County Public Schools "School Profiles" website, where the number of students enrolled in the elementary school is reported. The estimated existing demand for this facility was calculated using this information and is summarized in **Table 5**.

Table 5 – School Demand Calculations

Facility	Quantity	Unit	Demand (gpd)	Unit	Estimated ADD (gpd)
School	196	Staff and Students	20	Per Staff and Students	3,920

- Churches: The types of services and events held at each church within the Waterford community, as well as the number of people that attend each event, was determined by contacting the churches. Then, the service(s) or event(s) with the highest number of attendees was used to develop the estimates in order to be conservative. These assumptions are described below, and a summary of the church estimates is provided following these descriptions as **Table 6**.

    - *John Wesley Church* – In discussion, the Waterford Foundation Executive Director conveyed that the largest event at the John Wesley Church would be a wedding. It is approximated that a wedding would hold 20 to 40 attendees at the church. Therefore, it is assumed that demand is needed for 40 people, to be conservative.

    - *Waterford Baptist Church* – Through email communications, the recently retired pastor of this church conveyed that the largest events at the Waterford Baptist Church are weddings, funerals and fellowship meals. It is approximated that these events would hold 100 attendees at the church. Therefore, it is assumed that demand is needed for 100 people, to be conservative.

    - *Catoctin Presbyterian Church* – Through email communications, the pastor of this church conveyed that the largest event at the Catoctin Presbyterian Church is the Christmas Eve Service. It is approximated that this service would hold 130 attendees at the church. Therefore, it is assumed that demand is needed for 130 people, to be conservative.

Table 6 – Churches Existing Demand Calculations

Facility	Event	Quantity (Person)	Demand* (gpd/Person)	Estimated ADD (gpd)
John Wesley Church	Weddings/Other	40		200
Waterford Baptist Church	Wedding/Funeral/Fellowship Meal	100	5	500
Catoctin Presbyterian Church	Christmas Eve Service	130		650
Total Estimated Existing ADD (Churches)				1,350

- Old School Auditorium: Upon discussion with the Waterford Foundation Executive Director, it was conveyed that larger events at the Old School Auditorium have approximately 80 to 150 attendees, and that smaller events have approximately 25 to 50 attendees. To be conservative, it was assumed that demand is needed for 150 attendees. Using this information and assumption, the estimated existing demand for this facility was calculated and is summarized in **Table 7**.

Table 7 – Auditorium Existing Demand Calculations

Facility	Event	Quantity (Person)	Demand (gpd/Person)	Estimated ADD (gpd)
Old School Auditorium	Larger Event	150	5	750

Existing Development Demand Estimates Summary

The existing development demand estimates were determined according to the above section and are summarized in **Table 8**.

Table 8 – Existing Demand Estimates

Facility	**Existing Estimated ADD (gpd)**
Residential	39,200
Commercial & Industrial	6,800
School	3,920
Churches	1,350
Auditorium	750
Total Estimated Existing ADD	**52,020**

The existing estimated ADD for water was calculated to be 52,020 gallons per day (gpd). From this, the maximum ADD and peak hour demand were determined using LW standards. According to the EDM, the maximum ADD is found by multiplying the average daily water demand by 2, and the peak hour demand is found by multiplying the maximum ADD by 2. Therefore, the maximum ADD is 104,040 gpd, and the peak hour demand is 208,080 gpd. The peak hour demand in gallons per minute (gpm) is 145 gpm.

However, there are several additional requirements that need to be met when determining the required quantity of water to serve the community. These requirements are as follows:

- Loudoun Water – 1.2 gpm per connection
- Loudoun County – 1.0 gpm per connection
- Virginia Water Works Regulations – 0.5 gpm per connection (*since repealed*)

As previously described, there are 112 dwelling units, one (1) school, five (5) commercial & industrial facilities, three (3) churches and one (1) auditorium in Waterford. Assuming all of these facilities would be connected to water, should a water system be installed at Waterford, there would be 122 connections. Virginia Water Works Regulations were modified in 2021, repealing 12VAC5-590-690 eliminating the connection flow requirement. LW has the most conservative connection requirements, therefore; the total minimum required demand would be as calculated below:

$$122\ connections\ \times 1.2\ gpm/connection\ \sim 146\ gpm$$

Since the LW requirements are more conservative than the existing demand estimates, the existing demand flow for the Waterford community should be 146 gpm.

Potential Future Demand Estimates

The potential future demand estimates were developed by assuming that all 154 parcels in the Waterford study boundary, except for the ten (10) parcels identified as being excluded in **Table 9**, are occupied and require water service. **Table 9** also identifies the reason that the parcels were excluded.

Table 9 – Potential Future Demand Estimate Excluded Parcels

Parcel Excluded	Reason
303160752000	The lot size is smaller than the minimum required lot size for sites served by any type of sewer or water system (public or private) per Revised 1993 Zoning Ordinance.
303162510000	
303164873000	
303174886000	
304461160000	
303263619000	This lot is partially in the study boundary. The size of the portion of the lot that is in the boundary is smaller than the minimum required lot size for sites served by any type of sewer or water system (public or private) per Revised 1993 Zoning Ordinance.
304283694000	
303268922000	This lot is the site of the historic Waterford Old Jail, which is not expected to require connection to water.
303360508000	This lot is the site of the historic Waterford Old Mill, which is not expected to require connection to water.
304462192000	This lot is the site of the historic Waterford Second Street School, which is not expected to require connection to water.

Therefore, a total of 144 parcels (22 additional residential connections) could potentially be occupied and require water service in the future. The future residential population demand calculations are shown in **Table 10**. Estimates for commercial demand, school demand, demands for the three (3) churches and demand for the Old School Auditorium do not change.

Table 10 – Residential Population Future Demand Calculations

Facility	Number of Dwelling Units (Residential Structures)	Demand (gpd/dwelling unit)	Estimated ADD (gpd)
Residential	134	350	46,900

Potential Future Demand Estimates Summary

The potential future demand estimates were determined according to the above section and are summarized in **Table 11**.

Table 11 – Future Demand Estimates

Facility	Estimated Potential Future ADD (gpd)
Residential	46,900
Commercial & Industrial	6,800
School	3,920
Churches	1,350
Auditorium	750
Total Estimated Potential Future ADD	**59,720**

The estimated potential future ADD for water was calculated to be 59,720 gpd. From this, the maximum ADD and peak hour demand were determined using LW standards. According to the EDM, the maximum ADD is found by multiplying the average daily water demand by 2, and the peak hour demand is found by multiplying the maximum ADD by 2. Therefore, the maximum ADD is 119,440 gpd, and the peak hour demand is 238,880 gpd, which is equal to 166 gpm.

As previously described, Loudoun Water requires that a demand of 1.2 gpm be provided per connection. Therefore, the total minimum required demand would be as calculated below:

$$144\ connections\ \times\ 1.2\ gpm/connection\ \sim\ 173\ gpm$$

Since the potential future demand estimates are more conservative than the LW requirements, the recommended demand flow to be used for the Waterford community is 173 gpm.

Conclusion

For existing development demand estimates, demands for residential homes, commercial and industrial buildings, and schools were estimated using EDM and/or VDH standards. The total minimum required demand was also calculated per Loudoun Water requirements, which require that a demand of 1.2 gpm be provided per connection.

The potential future demand estimates were developed by assuming that 144 parcels in the Waterford study boundary, excluding the ten (10) parcels identified in **Table 9**, are occupied and require water service. The total minimum required demand was also calculated per Loudoun Water requirements, which require that a demand of 1.2 gpm be provided per connection.

Based on the analysis described above, a community well system serving the existing development would require a well yield of 146 gpm with a potential future yield requirement of 173 gpm based on potential future buildout. Therefore, the recommended demand flow (for the study area) to be used for sizing of a community water distribution piping and well/treatment systems (as needed) for the Waterford community is 173 gpm.

Appendix C
Well Yield Survey Letter, Map and Results

Waterford – Well Yield Survey

1. Do you encounter problems with the amount of water your well provides?

   If you answered 'Yes' please explain problems encountered below:

   ____

   ____

   ____

2. Do you encounter these quantity problems only at certain times of the year? Yes _____ No _____

   If you answered 'Yes' please place an X over every typical month(s) when quantity problems occur below:

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC

   Please provide additional explanation below, if needed:

   ____

   ____

   ____

3. For the well problems noted in question 2, if they occur on a regular frequency, please indicate the frequency below:

   Indicate the number of hours and times DAILY__________,

   Indicate the number of days WEEKLY__________,

   Or Indicate the number of weeks MONTHLY______?

4. For the well problems noted in question 2, if they occur on an intermittent frequency, please describe below:

   ____

   ____

   ____

5. Have you observed a noticeable decrease in the amount of water provided by your well within the last five years (since 2016)? Yes _____ No _____

   If you answered 'Yes' please explain below:

   ____

   ____

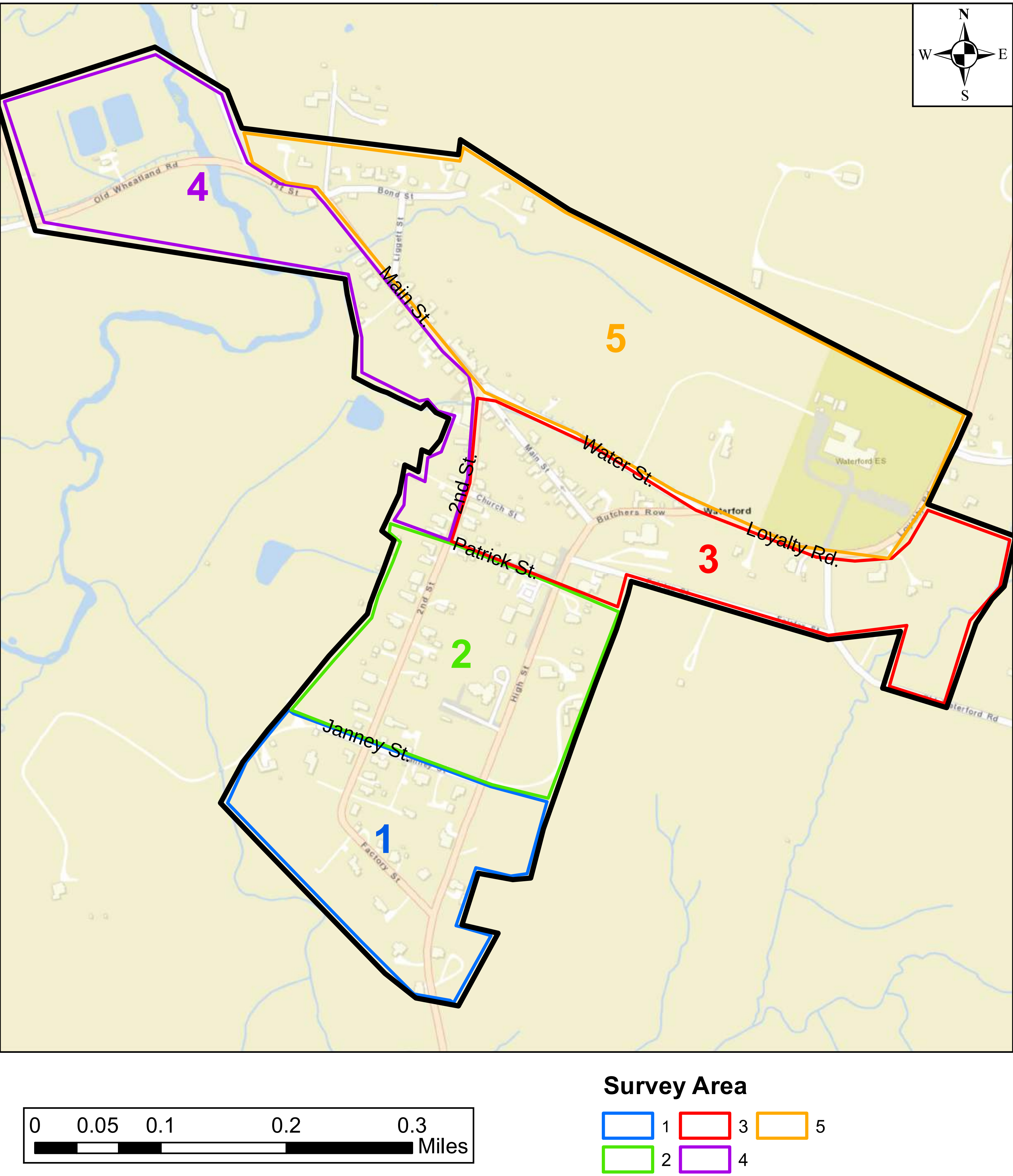
   ____

6. Using the figure provided with this survey, please indicate the geographical area, by zone number, where your well is located. The purpose of this information is to provide general location information for well quality concerns without identifying a specific parcel or well's location:

   Zone ____

7. Please provide any additional information or comments:

Waterford Survey Areas



Zone 1

Question 1		Do you encounter problems with the amount of water that your well provides? If you answered 'Yes' please explain problems encountered below
Yes	No	
1	10	
Comments:		
1	not at all; no problems	
2	—	
3	—	
4	Yes - sometimes typically overnight we run out of water. I haven't found any pattern to it - just usually @ night. It may be more related to our pump flush or something. I haven't noted the pump doing anything different during these times though.	
5	—	
6	—	
7	—	
8	—	
9	—	
10	—	
11	—	

Question 2		Do you encounter these quantity problems only at certain times of the year? Yes___ No___ If you answered 'Yes' please place an X over every typical month(s) when quantity problems occur below: Please provide additional explanation below, if needed
Yes	No	
0	11	
Comments:		
1	—	
2	—	
3	Not aplicable. No problems	
4	—	
5	—	
6	—	
7	—	
8	—	
9	—	
10	—	
11	—	

Zone 1

Question 3				For the well problems noted in question 2, if they occur on a regular frequency, please indicate the frequency below Indicate the number of hours and times DAILY____ WEEKLY____ MONTHLY____
Daily	Weekly	Monthly	N/A	
1	0	1	10	

Comments:

1	—
2	—
3	Not aplicable. No problems
4	Daily: 1-2 hours - typically overnight Monthly: 1-2x per month
5	—
6	—
7	—
8	—
9	—
10	—
11	—

Question 4	For the well problems noted in question 2, if they occur on an intermittent frequency, please describe below:
*qualitative question	

Comments:

1	—
2	—
3	Not aplicable. No problems
4	seems random to me
5	—
6	—
7	—
8	—
9	—
10	—
11	—

Zone 1

Question 5		Have you observed a noticeable decrease in the amount of water provided by your well within the last five years (since 2016)? Yes___ No___ If you answered 'Yes' please explain below
Yes	No	
0	11	

Comments:

1	—
2	—
3	—
4	—
5	—
6	—
7	—
8	—
9	—
10	Move here last year
11	—

Question 6		Using the figure provided with this survey, please indicate the geographical area, by zone number, where your well is located. The purpose of this information is to provide general location information for well quality concerns without identifying a specific parcel or well's location
*zone question		
# of responses in Zone 3:	11	

Comments:

Zone 1

Question 7	Please provide any additional information or comments
*qualitative question	

Comments:

1	I have owned property for 24 years and have not experienced any changes in ample flow of water.
2	No problems with water supply at all
3	We are only 2 people. We used to have children at home so family of 5. We installed 3 water stroage tanks in basement which are fed by the well. So it is a constant reserve. It may disguise our water issues if they exist.
4	—
5	I installed a filter system for the greenstone + sulfur smell. Please do not encumber the entire village with a community water system. Please be focused on the few who may need some creative specific solutions. Please think outside the box for those few.
6	—
7	—
8	My well is 620 feet deep. It was estimated at a gallon a minute when drilled. No reason to think that has changed. It has supported as many as five people for a week with no problems.
9	We have been very fortunate not to have experienced any issues with water availability, and have always affiliated this to lack of density in the southern location within the village.
10	I installed a water quality system last year. Both water softening and for iron. The iron was at 17 mg/L. The water smelled pretty bad prior to installation of tanks, now fine.
11	Water is very hard iron/sulfur requires treatment

Zone 2

Question 1		Do you encounter problems with the amount of water that your well provides? If you answered 'Yes' please explain problems encountered below
Yes	No	
2	13	
Comments:		
1	—	
2	—	
3	—	
4	—	
5	—	
6	—	
7	No problems with flow, but only 2 residents and moderate use	
8	—	
9	—	
10	We have a slow flow	
11	n/a, no well	
12	—	
13	Our well has gone dry in the past but usually recovers in 24 hours. We try to avoid water problems by spacing water usage. We always think we hav a small amount of water.	
14	—	
15	Occasionally it runs out if we use an excessive amount to water grass or for a large company function.	

Question 2		Do you encounter these quantity problems only at certain times of the year? Yes___ No___ If you answered 'Yes' please place an X over every typical month(s) when quantity problems occur below: Please provide additional explanation below, if needed
Yes	No	
0	15	
Comments:		
1	we do not have quantity problems - EVER!	
2	We never have any problems.	
3	—	
4	No water quantity problems during the year!	
5	—	
6	Just moved into house late Dec, so our experience can only be based on time between Dec 27 and present time, March 15, 2021	
7	—	
8	No seasonal problems. Quality excellent	
9	—	
10	We installed a reservoir tank in 2006 that solved the issue.	
11	—	
12	—	
13	We seem to have problems during periods of low to no rain fall.	
14	—	
15	—	

Zone 2

Question 3				For the well problems noted in question 2, if they occur on a regular frequency, please indicate the frequency below Indicate the number of hours and times DAILY____ WEEKLY____ MONTHLY____
Daily	Weekly	Monthly	N/A	
0	0	0	15	

Comments:

1	See answer to question 2!
2	See answer to #2
3	—
4	—
5	—
6	—
7	—
8	—
9	—
10	—
11	—
12	—
13	—
14	—
15	—

Question 4	For the well problems noted in question 2, if they occur on an intermittent frequency, please describe below:
*qualitative question	

Comments:

1	See answer to question 2!
2	See answer to #2
3	—
4	—
5	—
6	—
7	—
8	—
9	—
10	—
11	—
12	—
13	During periods of low to no rain fall
14	—
15	—

Zone 2

Question 5		Have you observed a noticeable decrease in the amount of water provided by your well within the last five years (since 2016)? Yes___ No___ If you answered 'Yes' please explain below
Yes	No	
0	15	
Comments:		
1	—	
2	—	
3	—	
4	—	
5	(uncertain)	
6	—	
7	—	
8	Replaced 30 year old pump 10 years ago. Normal for pumps. Otherwise no	
9	—	
10	—	
11	—	
12	—	
13	Has been consistent during our 20+ years	
14	—	
15	—	

Question 6		Using the figure provided with this survey, please indicate the geographical area, by zone number, where your well is located. The purpose of this information is to provide general location information for well quality concerns without identifying a specific parcel or well's location
*zone question		
# of responses in Zone 3:	15	
Comments:		

Zone 2

Question 7	Please provide any additional information or comments
*qualitative question	

Comments:

1	We have lived here for 26 years and never had a problem, even when we had 2 teenagers living with us. Also, we share our well with our neighboring home which does not have a well.
2	We share a well with our neighbor since this property does not have a well. Never had a problem 26 years.
3	—
4	We've been in our house since January 2009 and have never had a problem with getting enough water.
5	—
6	—
7	House and water system are newer than most in the village (1987). High acid content of the well water required deacidification, but flow has always been adequate.
8	Not at all interested in town-wide water. Seek local solutions for those in true need.
9	—
10	—
11	This property has no well or water supply.
12	I am one person living in a 4 BR 3 bathroom house - Both of my neighbors have experienced periodic water issues but they are no longer family groups. My well doesn't have to recover from multiple showers in the same day, nor do I run my dishwasher or do laundry every day.
13	We hope that public water will be available in Waterford (Village). Living without knowing if you have water to run your house is less than inconvinient. The quality of water is also a concern with having a shallow well.
14	—
15	—

Zone 3

Question 1		Do you encounter problems with the amount of water that your well provides? If you answered 'Yes' please explain problems encountered below	Question 2		Do you encounter these quantity problems only at certain times of the year? Yes___ No___ If you answered 'Yes' please place an X over every typical month(s) when quantity problems occur below: Please provide additional explanation below, if needed
Yes	No		Yes	No	
8	17		1	24	

Comments:		Comments:	
1	No, but see comments in question 7	1	—
2	—	2	—
3	—	3	—
4	We have more water than we need from our well.	4	As stated above, we have no problems.
5	No; however one males lives in the house. He is young and not particular, being a working person often absent from the house.	5	—
6	—	6	—
7	—	7	—
8	—	8	—
9	The well draws 2 gallons a minute if there is a gathering of 10 people over a weekend I have to hire a water truck to supplement the amount of water.	9	—
10	Occasionally the well goes dry but recharges rather quickly	10	—
11	I would note there is only one person in my household - - until you know the level of water used by a household it will be hard to come up with any useful analysis or adequacy. E.G. water may be adequate for 1 or 2 but would be inadequate for a family of say 5 or 6.	11	—
12	Continued use without interruption will result in no water until well recovers. This is tenant occupied and tenant is very careful. High concentration of iron and black grit. This year had to install $2000.00 sand filter to control.	12	—
13	Any prolonged use can result in loss of water. This is a rental property and tenant has been very cooperative in limiting water use. As owner we have installed low flush toilets. Tenant knows NO CAR WASH, No Garden or grass etc.	13	Lack of water all months.
14	If water is used without pause such as in washing machine dish washer etc. well goes "dry". We do not use water for extended time. Plan water use, pause use like washing mach. Do not flush toiled except in "emergency".	14	Lack of water is constant throughout the year.
15	—	15	—

Zone 3

Question 1		Do you encounter problems with the amount of water that your well provides? If you answered 'Yes' please explain problems encountered below	Question 2		Do you encounter these quantity problems only at certain times of the year? Yes___ No___ If you answered 'Yes' please place an X over every typical month(s) when quantity problems occur below: Please provide additional explanation below, if needed
Yes	No		Yes	No	
8	17		1	24	
16		During periods of very dry weather	16		Only periods of dry weather, it doesn't depend on time of year, but it usually happens in a dry summer.
17		Use of the building for the benefit of the community is limited to 59 days per year for uses of 25+ persons due to the well. SPEX-2008-0050	17		—
18		We have struggled with water for 20+ years in Waterford. In 2017, our 2nd well went dry. Our New well only provides a point of water every 45 min, about 6 gallons a day. The new well is > 700' deep. We truck water in on our own truck + tank every 3-5 days from a local municipality.	18		Our problems have been every month for 20+ years.
19		n/a/ no well	19		—
20		n/a	20		—
21		shared. This property gets water from a neighboring parcel and it is limited.	21		—
22		—	22		—
23		The well has a low gallon per minute yield. A holding tank maintains a volume of water to enable normal consumption.	23		A low gallon per minute means you need to careful with water consumption.
24		—	24		—
25		—	25		—

Zone 3

Question 3				For the well problems noted in question 2, if they occur on a regular frequency, please indicate the frequency below
Daily	Weekly	Monthly	N/A	Indicate the number of hours and times DAILY____ WEEKLY____ MONTHLY____
0	0	0	25	

Comments:	
1	—
2	—
3	—
4	—
5	—
6	—
7	—
8	—
9	—
10	—
11	—
12	Not regular
13	Not regular, on constant alert for call from tenant for "NO WATER". If over used it takes about 24 hr. to recover.
14	continued
15	—

Question 4	For the well problems noted in question 2, if they occur on an intermittent frequency, please describe below:
*qualitative question	

Comments:	
1	—
2	—
3	—
4	—
5	—
6	—
7	—
8	—
9	—
10	Unpredictable as to what causes it or when
11	—
12	No water directly tied to use and length of time use. Have to be extremely vigilant not to use water continually such as no washing machine use without pause, no shower near washing time, etc. Water use is constant problem. Takes up to 24 hr. to recover
13	This well drilled approx.. 2005 is 1000' deep concentrations of calcium have destroyed heating element on H.W.A. Also black grit we have installed expensive sand filter as small in line filters are not sufficient this requires yearly or more often cleaning by pro.
14	Because we schedule water use and or do not use water (such as toilet) we control frequency. This requires constant diligence and eliminating use that most people would consider normal. Do you know that a bath only requires 2 inches of water in tub?
15	—

Zone 3

Question 3				For the well problems noted in question 2, if they occur on a regular frequency, please indicate the frequency below Indicate the number of hours and times DAILY____ WEEKLY____ MONTHLY____	Question 4	For the well problems noted in question 2, if they occur on an intermittent frequency, please describe below:
Daily	Weekly	Monthly	N/A		*qualitative question	
0	0	0	25			
16	—				16	Already has been described above; - dry weather, drought will create a water problem.
17	—				17	—
18	—				18	Constant low to no water. The local well companies do not believe we would find water on our 0.4 acre lot if we attempted to drill a 4th or 5th well.
19	—				19	—
20	—				20	—
21	—				21	—
22	—				22	—
23	Steady low gallon per minute				23	—
24	—				24	—
25	—				25	—

Zone 3

Question 5		Have you observed a noticeable decrease in the amount of water provided by your well within the last five years (since 2016)? Yes___ No___ If you answered 'Yes' please explain below
Yes	No	
4	21	

Comments:

1	—
2	—
3	—
4	It has maintained the same flow for more than 10 years.
5	—
6	—
7	—
8	—
9	—
10	—
11	I have only lived in this house for 2 years.
12	Only because tenant has reduced water use and spread out over times.
13	—
14	We had well "Fracked" which increased flow but after 3-4 yr. problems returned. Because of small lot size, old septic field, near sewer line or property line there is no place to drill a new well.
15	—

Question 6		Using the figure provided with this survey, please indicate the geographical area, by zone number, where your well is located. The purpose of this information is to provide general location information for well quality concerns without identifying a specific parcel or well's location
*zone question		
# of responses in Zone 3:	25	

Comments:

Zone 3

Question 5		Have you observed a noticeable decrease in the amount of water provided by your well within the last five years (since 2016)? Yes___ No___ If you answered 'Yes' please explain below	Question 6		Using the figure provided with this survey, please indicate the geographical area, by zone number, where your well is located. The purpose of this information is to provide general location information for well quality concerns without identifying a specific parcel or well's location
Yes	No		*zone question		
4	21		# of responses in Zone 3:	25	

16	A drought occurred from June thru Nov 2016. During that time I experienced increasing difficulty in drawing water from the well. When it finally rained late Nov '16 the problem went away. I was getting ready to have major plumbing repairs done, new pump, lines to the house from the well replaced, etc.	
17	—	
18	We moved from Main Street to our current home on Second St in 2002. It was said in our town the current home has one of the best water quantities in town. From 2002-2008 we (4) noticed water shortages almost every month until the well went dry in 2019. For 3 years + 2 months we have not had a potable water supply at our home.	
19	—	no well currently
20	—	no well currently
21	—	Property is in zone 3, but receives water from a neighboring parcel in zone 5
22	—	
23	—	
24	—	
25	—	

Zone 3

Question 7	Please provide any additional information or comments
*qualitative question	

Comments:

1	We have three wells. Each is over 700 feet deep. Each provides approximately 1 gallon per minute. We had to drill the two additional wells because the original single well did on occasion run out of water. With the three we have not had a water shortage problem. However, given 700 ft deep wells that return only a gallon per minute, we do worry about the possibility of them going dry.
2	—
3	I believe that the water application that led to this survey was seriously flawed. Boundaries were not clearly defined for the entire village.
4	Your "survey areas map" does not show the USGS Waterford Map depicting a perennial stream that originates on the property adjoining the elementary school (on its western boundary) and follows Water Street down to the center of the village an then flows under Second Street. This is why the street has been called Water Street for over 150 years. It likely provides water underground that serves wells.
5	—
6	Purchased early 2018. Answers reflect experience over last 2 years.
7	—
8	—
9	—
10	—
11	There are at least 2 houses in the Village that have remained empty and have effectively been abandoned because they have no water - - unlikely to catch those problems with this survey as there is no one to fill out a survey for those houses. Note - one of the abandoned houses is in my Zone 3 and one in Zone 4.
12	Water quality very poor Filter installed 2021 after previous filters fails. Iron, Grit, smell
13	Water quality very poor iron, calcium, Grit
14	Water Quality below standard we do not test for fear of results.
15	—

Zone 3

Question 7	Please provide any additional information or comments
*qualitative question	
16	—
17	—
18	We have no potable water. We know many neighbors on their old hand dug wells as their current wells have failed. Do you have a want of these? Questions we would like answered What is the range of more parcels moving toward no water situations over the next 5, 10, 20, 50 years? Is this considered a public health crisis? Can short term well yield tests really give a valid prediction? Call Valley Well, Sing[has?], Broy well drillers and ask them to respond to this survey please! One or all have touched these well situations over the last 50 years, perhaps as high as 80% of these wells: -What impact has development had on our wells? -What impact has Airbnb, VRBO + rentals for the area had on our village wells? -40 years ago many vacant /unlively dwellings -Now Airbnb + VRBO has occupancy near all time? -Thank you for your time, energy + expertise helping our community
19	We would like for this property to have a water supply, but the lot is too small to drill a well with sufficient setbacks.
20	This property is not served by a well. We would like to have a water supply, but the lot is small and the ground was contaminated by an underground gasoline tank leak many decades ago.
21	We would like for this property to have a water supply independent of neighboring parcels but the lot is too small to drill a well with proper setbacks from the structure and property lines.
22	Our well has functioned reliably & adequately for more than fifty years. We know there are areas of Waterford where flow is not adequate & hope that this can be addressed. We understand that in the past testing for potential new wells, such as for a possible expansion of the Waterford Elementary School, has compromised existing wells. We are concerned that conversion to a village-wide, collective water system would do the same. We feel that a less risky solution should be sought that would solve the specific problems some Waterford properties now have without jeopardizing the many functioning wells that now exist nor incurring the expense & village-wide disruption a whole-sale change would entail.
23	Our low yield well is not a problem when managed well.
24	—
25	—

Zone 4

Question 1		Do you encounter problems with the amount of water that your well provides? If you answered 'Yes' please explain problems encountered below
Yes	No	
1	14	
Comments:		
1	—	
2	—	
3	—	
4	—	
5	—	
6	Three people (one baby) in house. Low water pressure at times. Water tastes O.K. through a filter.	
7	—	
8	No, but leasee uses property as an office, and therefore water intake is minimal. If leasee were living there I would think there would be a shortage as inflow is about 1-2 gallons a minute.	
9	—	
10	—	
11	—	
12	—	
13	—	
14	—	
15	—	

Question 2		Do you encounter these quantity problems only at certain times of the year? Yes___ No___ If you answered 'Yes' please place an X over every typical month(s) when quantity problems occur below: Please provide additional explanation below, if needed
Yes	No	
0	15	
Comments:		
1	—	
2	—	
3	—	
4	—	
5	—	
6	Couple in home less than a year so hard to make an accurate appraisal - in general, when less precipitation, increased incidences of low water pressure	
7	—	
8	—	
9	—	
10	—	
11	—	
12	—	
13	—	
14	—	
15	—	

Zone 4

Question 3				For the well problems noted in question 2, if they occur on a regular frequency, please indicate the frequency below Indicate the number of hours and times DAILY____ WEEKLY____ MONTHLY____
Daily	Weekly	Monthly	N/A	
0	0	1	14	

Comments:

1	—
2	—
3	—
4	No issues
5	—
6	Perhaps 2 weeks when there is little precipitation
7	—
8	—
9	—
10	—
11	—
12	—
13	—
14	—
15	—

Question 4	For the well problems noted in question 2, if they occur on an intermittent frequency, please describe below:
*qualitative question	

Comments:

1	—
2	—
3	—
4	—
5	—
6	Meaning? [circled intermittent frequency] you probably meant - if they occur frequently (see 3)
7	—
8	—
9	—
10	—
11	—
12	—
13	—
14	—
15	—

Zone 4

Question 5		Have you observed a noticeable decrease in the amount of water provided by your well within the last five years (since 2016)? Yes___ No___ If you answered 'Yes' please explain below
Yes	No	
0	15	

Comments:

1	—
2	—
3	—
4	—
5	—
6	Because previous couple of three, there maybe two years, did not complain of low water pressure, and before that one person in house for several years had no complaints
7	—
8	—
9	—
10	We have only been in the house 2 years, but no noticeable drop
11	—
12	—
13	—
14	—
15	—

Question 6		Using the figure provided with this survey, please indicate the geographical area, by zone number, where your well is located. The purpose of this information is to provide general location information for well quality concerns without identifying a specific parcel or well's location
*zone question		
# of responses in Zone 3:	15	

Comments:

Zone 4

Question 7	Please provide any additional information or comments
*qualitative question	

Comments:

1	—
2	Thank you!
3	—
4	—
5	—
6	—
7	—
8	—
9	Well was deepened 10 years ago, from 540' to 700' and flow went from 2 QT/min to 5.5 gal/min
10	Thank you for your help! While our well is fine, we would appreciate if the village had better fire hydrants and want to make sure all of our neighbors have water too!
11	This building is not heated, so the well is not used at all during winter months.
12	—
13	My well gets 1 1/2 gal per minute. It is 450 ft deep so the column acts as a resevoir and I do not run out of water. I am very concerned about future water production as my neighbors have run out of water. I'm also very unhappy with the water quality. I failed county water quality for coliform bacteria and had a UV water purification system installed. We only drink bottled water and notice skin problems in the warmer months.
14	This well supports a half-bath, sink, and hose bib. The site's water demand is very low.
15	We have plenty of water year round for household needs - can water the lawn & plants in summer for several hours in addition.

Zone 5

Question 1		Do you encounter problems with the amount of water that your well provides? If you answered 'Yes' please explain problems encountered below
Yes	No	
5	10	

Comments:

1	—
2	—
3	—
4	—
5	My well ran dry, as a result I drilled three wells before finding water. That well drains 2 gal/min and has gone dry, several times but has recharged over time.
6	Yes - I can't use upstairs shower. I have to haul 5 gallon bottled water to bathe. It's hard to lift bottles up 3 flights of stairs. It's going on 2 yrs now.
7	—
8	Any prolonged use back to back shower, wash, etc, can result in no water. This is a very small 1 bath house tenant occupied. Tenant is cooperative with water sourcing.
9	Prolonged use results in loss of water. This is tenant occupied. The well is located on #5 but the property is in #4. Water line to building was installed under street. No room on lot to get well site. Silt and very bad iron concentration. Have installed 2000 sand filter.
10	Infrequently, and only during very dry periods. We have changed toilet to low flush and also switched out a top-loading washer for front loading. We are now more efficient with water use. However, if during dry periods we need to use any water in the garden, we have to be mindful to limit often uses, such as laundry, to lower the risk of running out.
11	—
12	—
13	—
14	Amount no. Water quality is the issue. Lots of silt.
15	—

Question 2		Do you encounter these quantity problems only at certain times of the year? Yes___ No___ If you answered 'Yes' please place an X over every typical month(s) when quantity problems occur below: Please provide additional explanation below, if needed
Yes	No	
1	14	

Comments:

1	—
2	—
3	—
4	—
5	—
6	Low water yield occurs all year - was getting really bad starting about 2 years ago
7	—
8	—
9	Lack of water is constant
10	[Circled July and August] See above
11	—
12	—
13	—
14	—
15	—

Zone 5

Question 3				For the well problems noted in question 2, if they occur on a regular frequency, please indicate the frequency below
Daily	Weekly	Monthly	N/A	Indicate the number of hours and times DAILY____ WEEKLY____ MONTHLY____
0	0	0	15	

Comments:	
1	—
2	—
3	—
4	—
5	—
6	They occur all the time. Always a low yield
7	—
8	Not regular
9	Not regular
10	Infrequent, with minimal household use, we do just run out of water, in part due to greater water efficiency
11	—
12	—
13	—
14	—
15	—

Question 4	For the well problems noted in question 2, if they occur on an intermittent frequency, please describe below:
*qualitative question	

Comments:	
1	—
2	—
3	—
4	—
5	—
6	They are pretty steady - early in morning I can do more laundry because well filled up over night
7	—
8	Problems tied to use. Back to back use can result in "no water". Water filter installed - last year had to install larger filter. Sometimes has to be changed every week.
9	This well installed on easement not on owners property with over 1000' private water line under main street in 1985. Constant worry that line will need replacement.
10	See above
11	—
12	—
13	—
14	—
15	—

Zone 5

Question 5		Have you observed a noticeable decrease in the amount of water provided by your well within the last five years (since 2016)? Yes___ No___ If you answered 'Yes' please explain below
Yes	No	
2	13	

Comments:

1	—
2	—
3	—
4	—
5	—
6	When I moved into house in 2014 I could wash full load of laundry - now I can only wash 3 tshirts. I cannot shower on 3rd floor. Water only drips out. I have to buy 5 gallon bottled water and use a battery operated shower head now.
7	—
8	Hard to tell when you are conserving water all the time.
9	—
10	During this same time, we made household adjustments described above in order to be more efficient in our water usage.
11	—
12	—
13	—
14	—
15	—

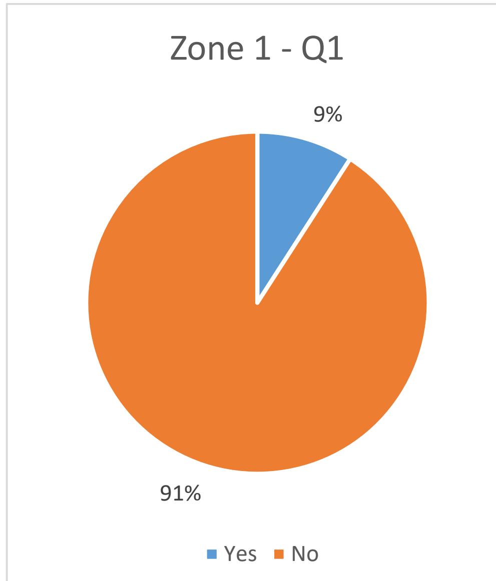
Question 6		Using the figure provided with this survey, please indicate the geographical area, by zone number, where your well is located. The purpose of this information is to provide general location information for well quality concerns without identifying a specific parcel or well's location
*zone question		
# of responses in Zone 3:	15	

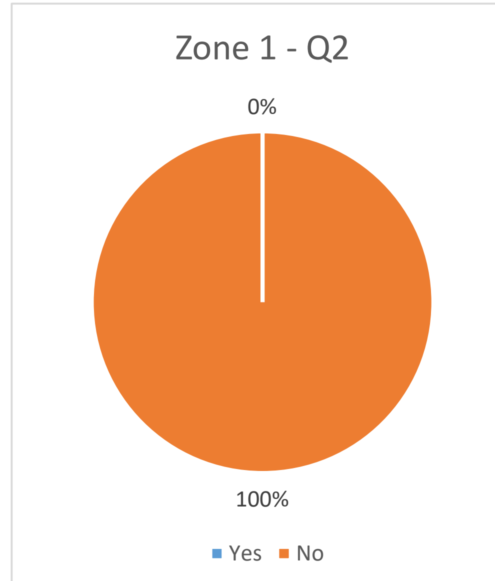
Comments:

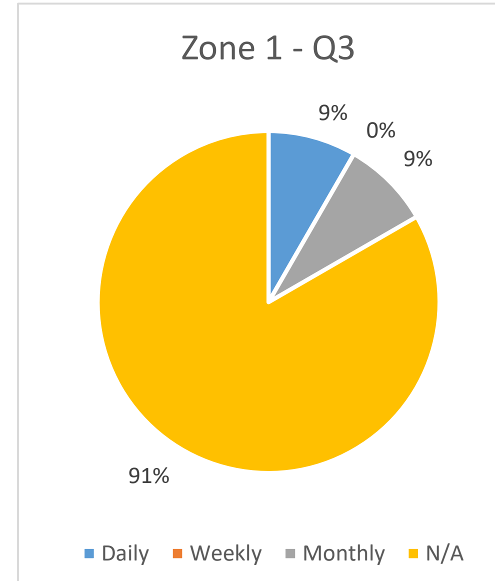
Zone 5

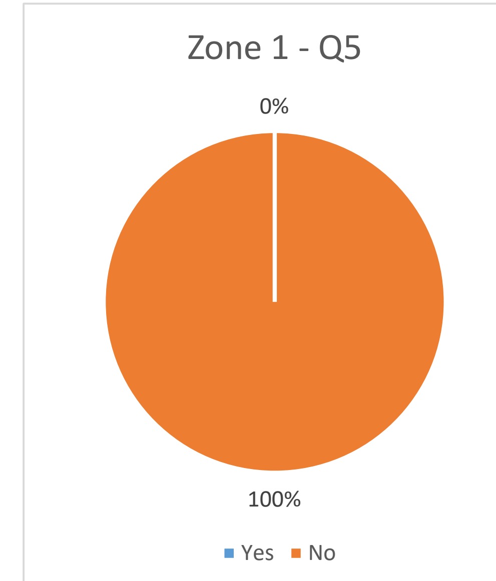
Question 7	Please provide any additional information or comments
*qualitative question	
Comments:	
1	—
2	In support of options that bring fire hydrants/safety
3	In support of options that bring fire hydrants/safety
4	—
5	Water quality must also be reviewed. Thank you
6	We need help with water supply. I have lived overseas in 3rd world countries - and had more water than I have in Waterford. I was stationed in Saudi Arabia - Riyadh. I feel like I'm camping in my house. We need to get in Loudoun Co water as soon as possible. Thank you.
7	We are at the lower end (Mill Side) of Zone 5. We do use bottled water to drink as the nitrate/nitrite levels are a bit high. But the water is potable and there are no odors
8	Water quality very poor filter installed requires frequent changing
9	Well is located in Area 5; Water is piped under street to building located in Area 4. Water quality below standard iron, Grit
10	—
11	—
12	Note: I share a well with the neighbors on Main St. Before I moved to Waterford, the old well ran dry. The prior owners dug a new well (750 feet), and so far I have not encountered problems, however I have only been here 9 months.
13	Concerned about location of a shared well within the historic district. If water lines are dug, will you coordinate w/ utilities to bury power and data cables? Cost to hook up to a shared service is a concern
14	We would sign up for county water supply to avoid quality issues with our well water.
15	We have a deep well and plenty of reserve for plant & lawn watering in the summer

Responses: 11	Zone 1									
	Q1		Q2		Q3				Q5	
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
	1	10	0	11	1	0	1	10	0	11
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	9%	91%	0%	100%	9%	0%	9%	91%	0%	100%

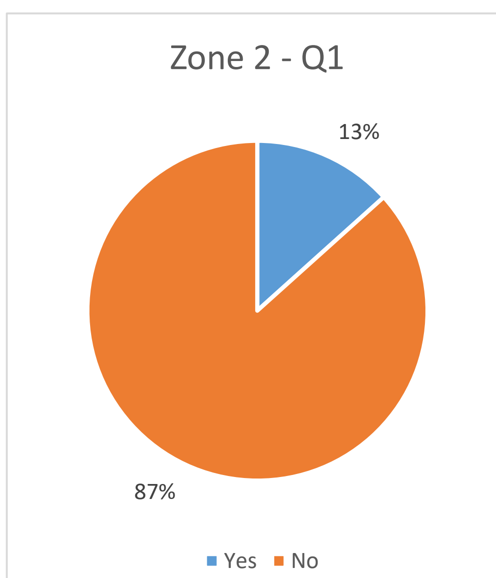


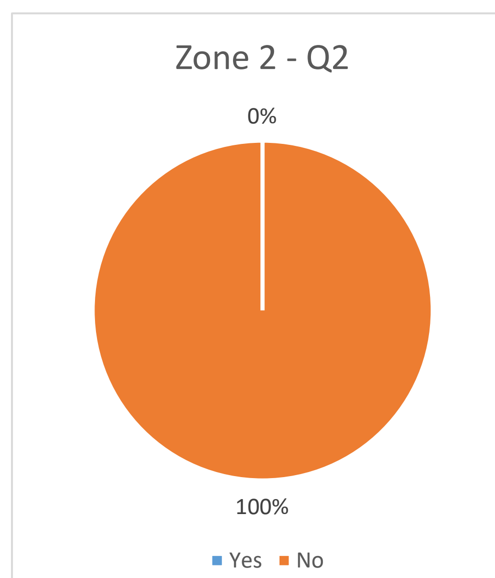


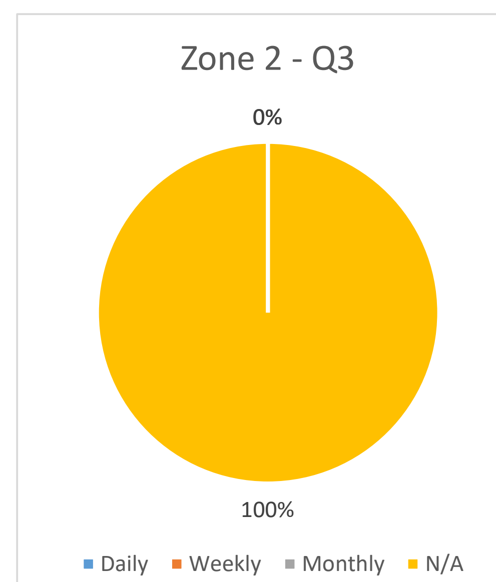


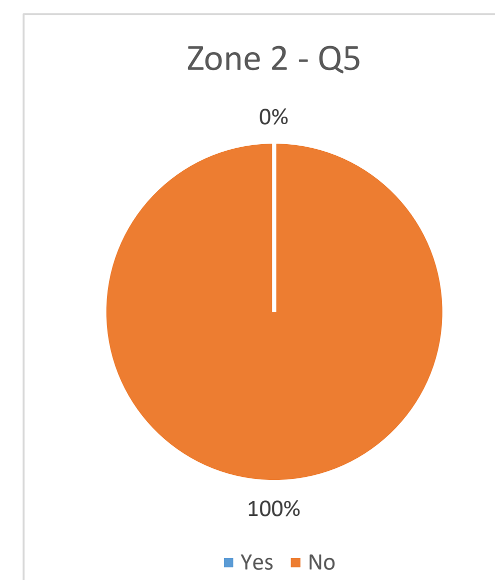


Responses: 15	Zone 2									
	Q1		Q2		Q3				Q5	
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
	2	13	0	15	0	0	0	15	0	15
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	13%	87%	0%	100%	0%	0%	0%	100%	0%	100%





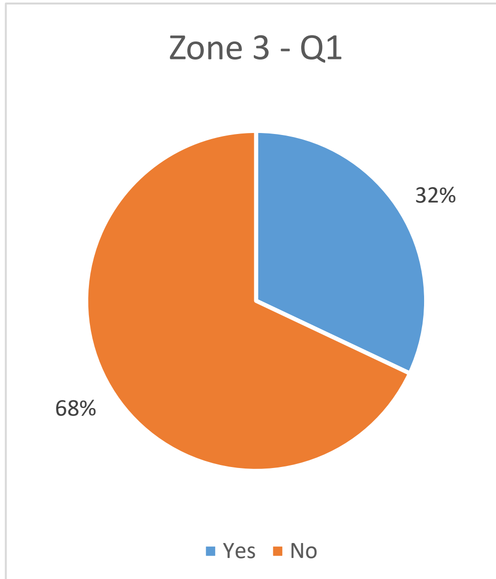


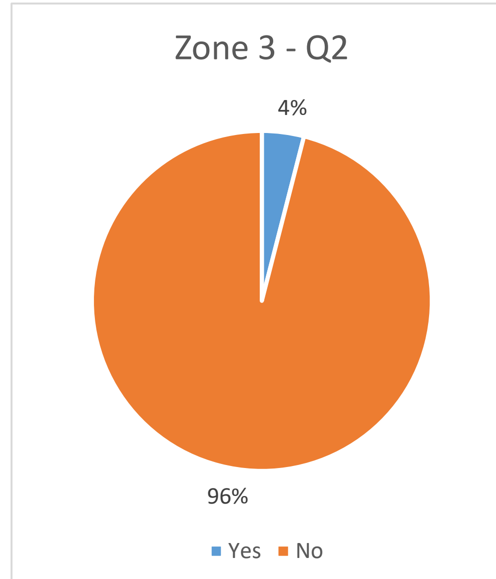


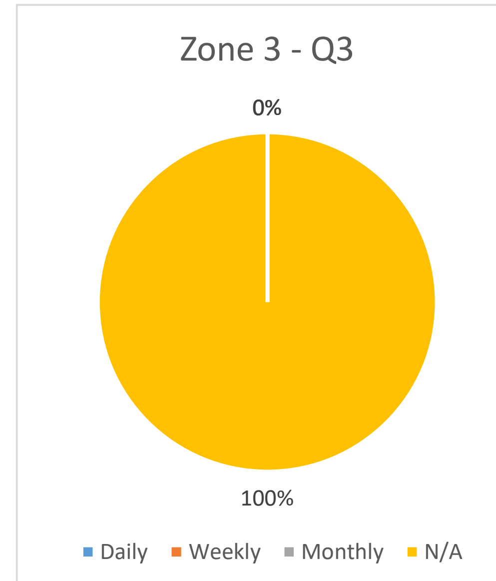
Responses: 25

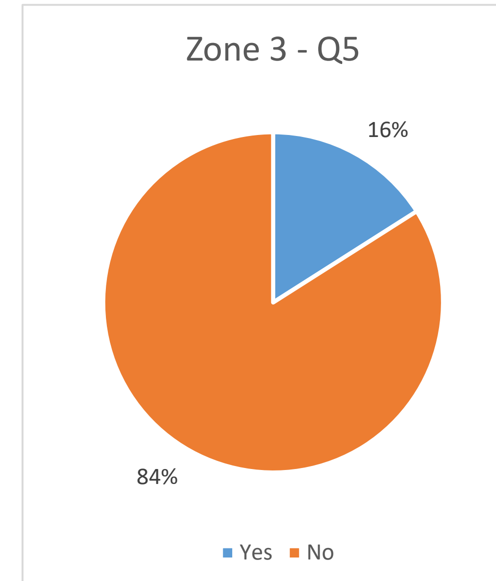
Zone 3									
Q1		Q2		Q3				Q5	
Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
8	17	1	24	0	0	0	25	4	21
Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
32%	68%	4%	96%	0%	0%	0%	100%	16%	84%

%





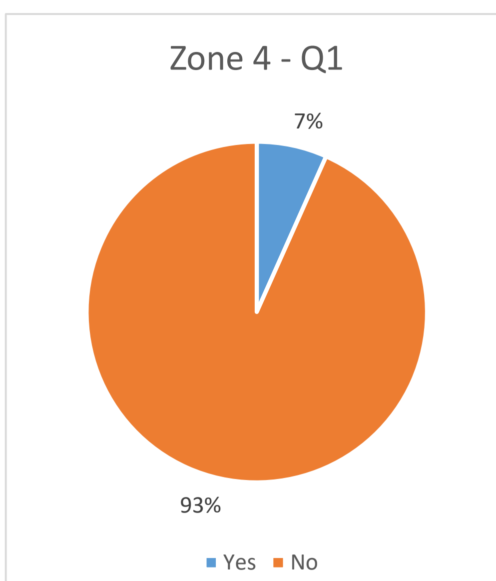


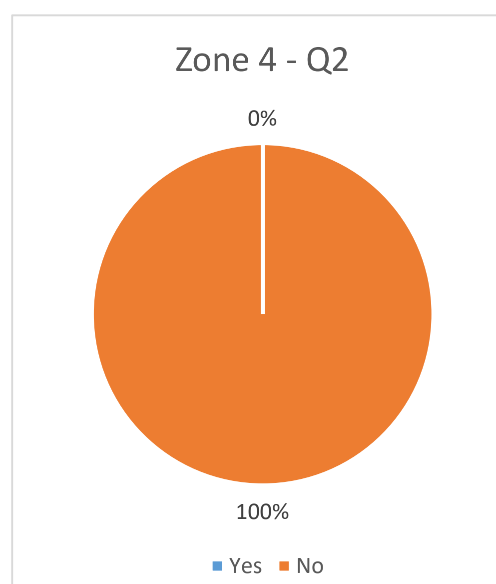


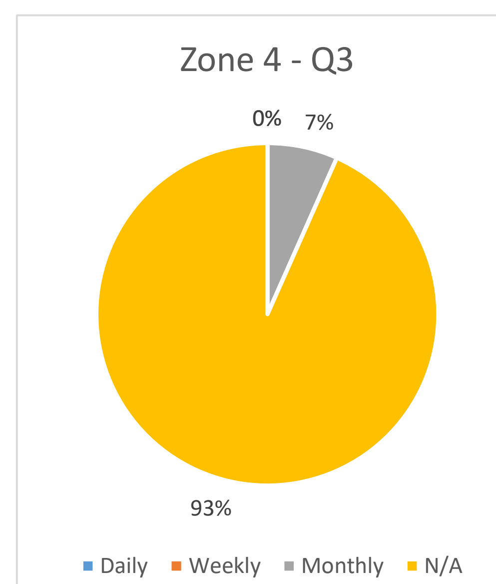
Responses: 15

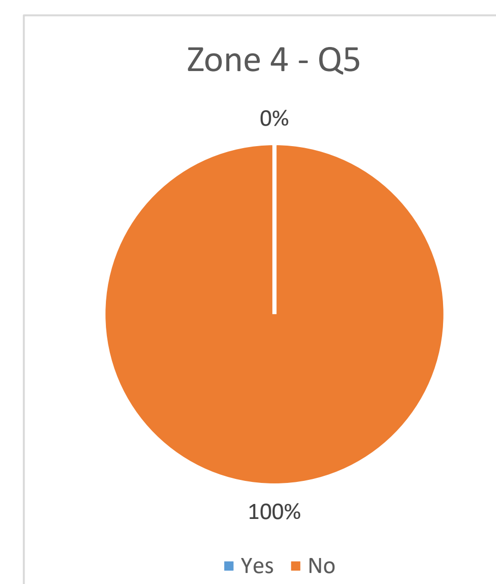
Zone 4									
Q1		Q2		Q3				Q5	
Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
1	14	0	15	0	0	1	14	0	15
Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
7%	93%	0%	100%	0%	0%	7%	93%	0%	100%

%









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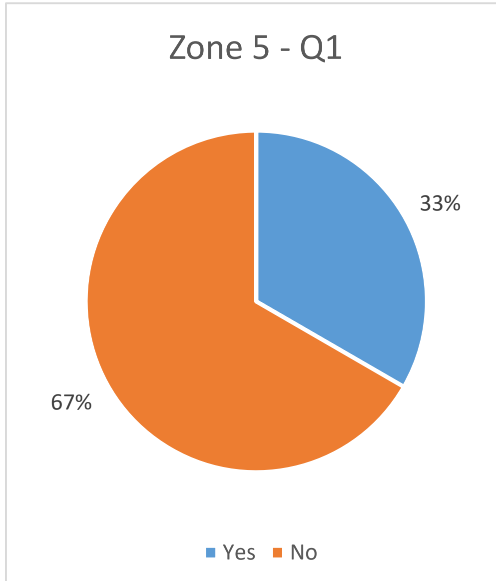
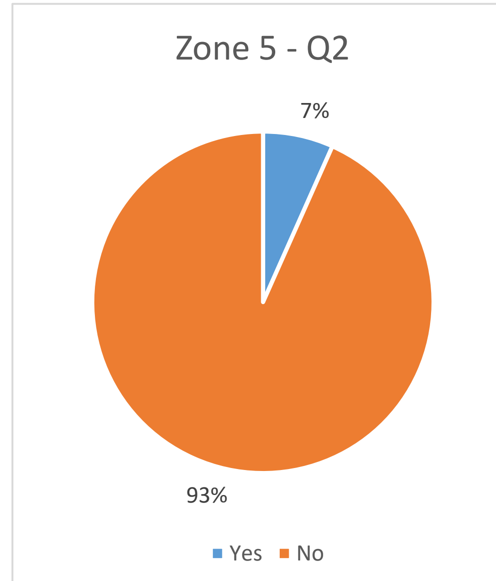
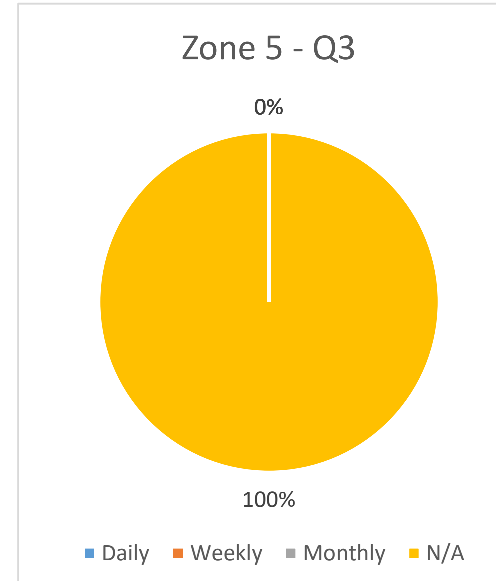
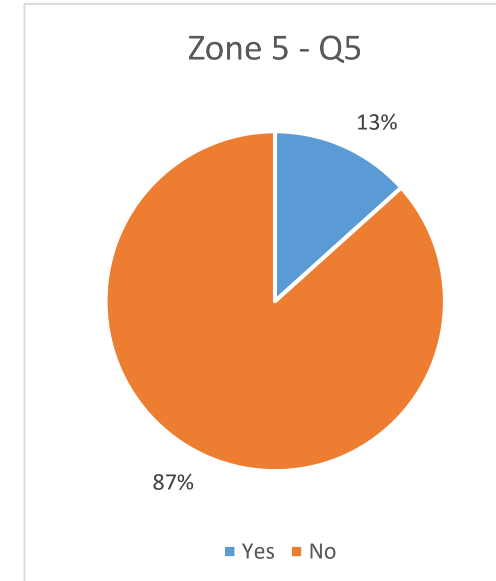
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	33%	67%	7%	93%	0%	0%	0%	100%	13%	87%









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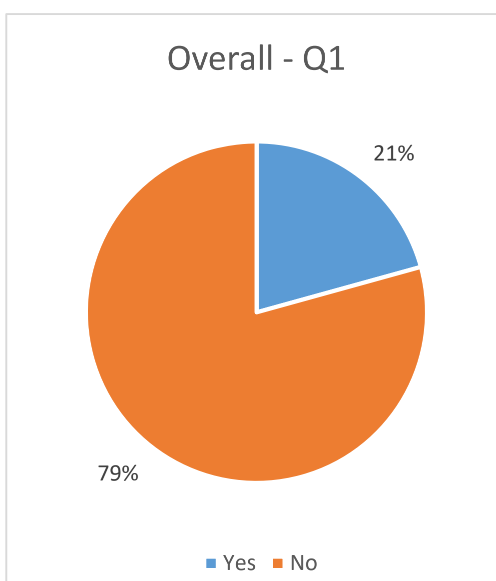
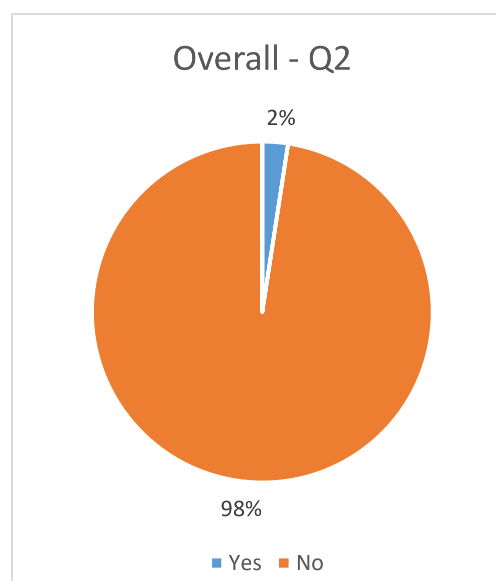
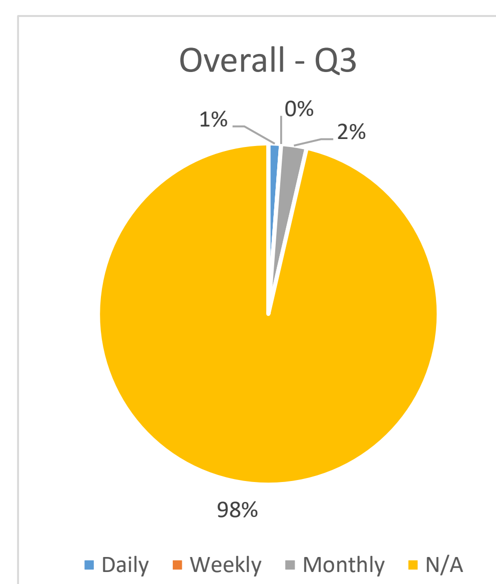
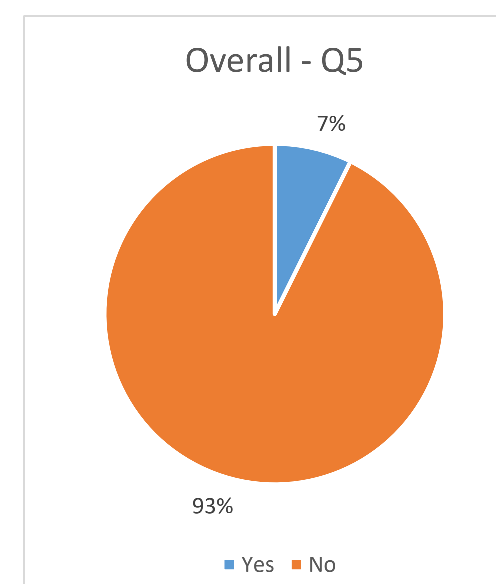
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
	17	65	2	80	1	0	2	80	6	76
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	21%	79%	2%	98%	1%	0%	2%	98%	7%	93%









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	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	9%	91%	0%	100%	9%	0%	9%	91%	0%	100%

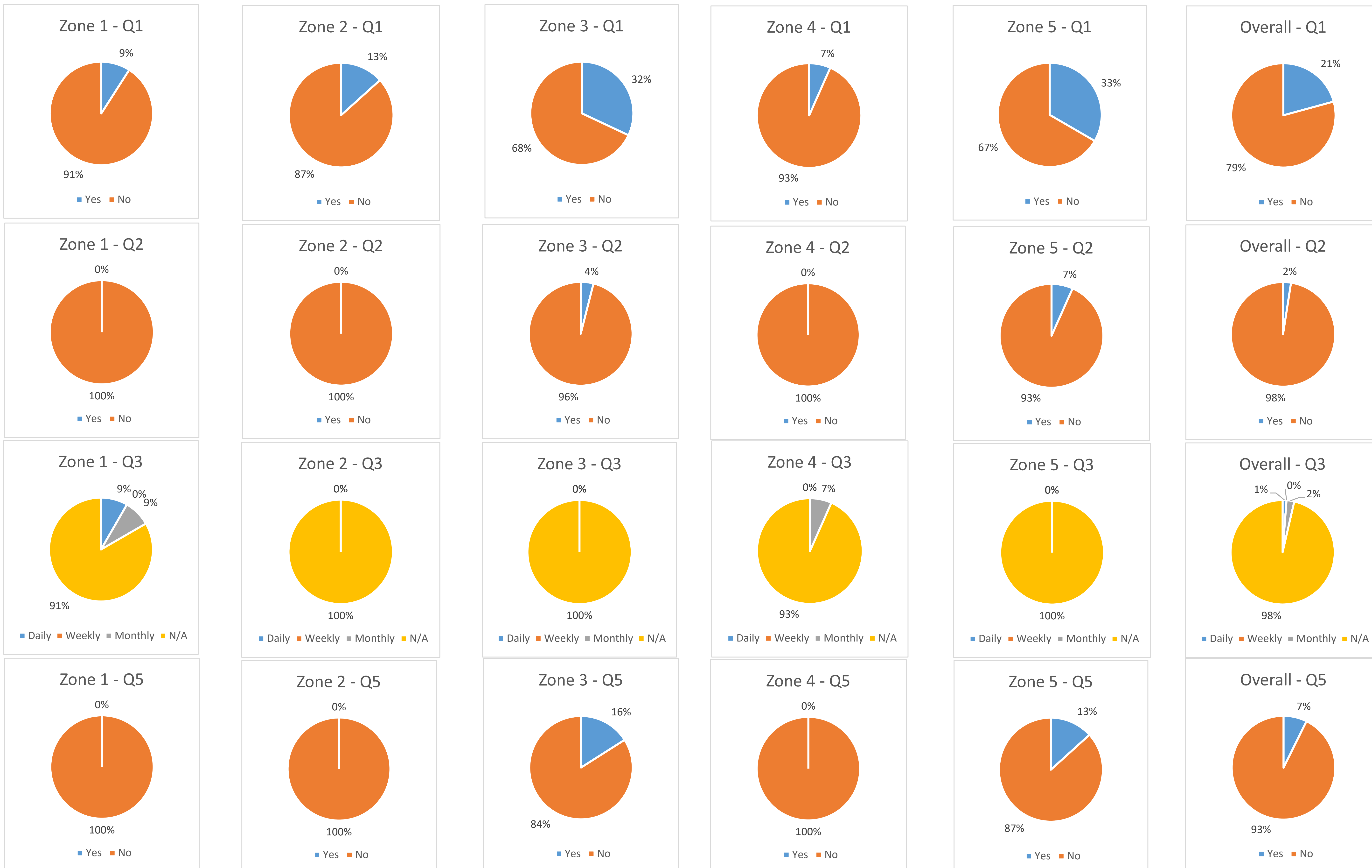
Responses:	Zone 2									
15	Q1		Q2		Q3				Q5	
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
	2	13	0	15	0	0	0	15	0	15
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	13%	87%	0%	100%	0%	0%	0%	100%	0%	100%

Responses:	Zone 3									
25	Q1		Q2		Q3				Q5	
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
	8	17	1	24	0	0	0	25	4	21
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	32%	68%	4%	96%	0%	0%	0%	100%	16%	84%

Responses:	Zone 4									
15	Q1		Q2		Q3				Q5	
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
	1	14	0	15	0	0	1	14	0	15
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	7%	93%	0%	100%	0%	0%	7%	93%	0%	100%

Responses:	Zone 5									
15	Q1		Q2		Q3				Q5	
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
	5	10	1	14	0	0	0	15	2	13
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	33%	67%	7%	93%	0%	0%	0%	100%	13%	87%

Responses:	Overall									
82	Q1		Q2		Q3				Q5	
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
	17	65	2	80	1	0	2	80	6	76
	Yes	No	Yes	No	Daily	Weekly	Monthly	N/A	Yes	No
%	21%	79%	2%	98%	1%	0%	2%	98%	7%	93%


Zone 1 - Q1
9%
91%
Yes No
Zone 2 - Q1
13%
87%
Yes No
Zone 3 - Q1
32%
68%
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Zone 4 - Q1
7%
93%
Yes No
Zone 5 - Q1
33%
67%
Yes No
Overall - Q1
21%
79%
Yes No
Zone 1 - Q2
0%
100%
Yes No
Zone 2 - Q2
0%
100%
Yes No
Zone 3 - Q2
4%
96%
Yes No
Zone 4 - Q2
0%
100%
Yes No
Zone 5 - Q2
7%
93%
Yes No
Overall - Q2
2%
98%
Yes No
Zone 1 - Q3
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0%
9%
91%
Daily Weekly Monthly N/A
Zone 2 - Q3
0%
100%
Daily Weekly Monthly N/A
Zone 3 - Q3
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Daily Weekly Monthly N/A
Zone 4 - Q3
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Daily Weekly Monthly N/A
Zone 5 - Q3
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Overall - Q3
1%
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2%
98%
Daily Weekly Monthly N/A
Zone 1 - Q5
0%
100%
Yes No
Zone 2 - Q5
0%
100%
Yes No
Zone 3 - Q5
16%
84%
Yes No
Zone 4 - Q5
0%
100%
Yes No
Zone 5 - Q5
13%
87%
Yes No
Overall - Q5
7%
93%
Yes No

Appendix D
Groundwater Hydrology Report

Groundwater Resource Evaluation

Waterford, Virginia

March 17, 2022

Groundwater Resource Evaluation
Waterford, Virginia

March 17, 2022

PRESENTED TO

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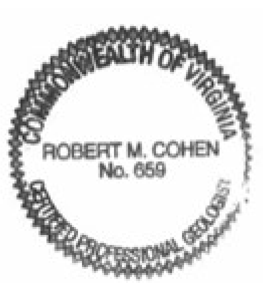
3/17/2022



TETRA TECH

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
bgs	Below ground surface
DTW	Depth to water
GPD	Gallons Per Day
GIS	Geographical Information System
GPM	Gallons Per Minute
LCHD	Loudoun County Health Department
USGS	United States Geological Survey
WES	Waterford Elementary School
WSA	Waterford Service Authority
WWCO	Community well
WWDH	Dry hole well
WWDU	Dug well
WWHP	Heat pump well
WWIN	Individual well
WWNC	Non-community well
WWTS	Test well
WWTP	Wastewater Treatment Plant

1.0 EXECUTIVE SUMMARY

Tetra Tech was contracted by Dewberry to evaluate groundwater conditions in Waterford, Virginia and help assess the feasibility of developing alternative potable water-supply improvements for its residents. Currently, water in the 147-acre Waterford Service Area (WSA) is supplied to approximately 181 residents via 122 connections from approximately 105 individual private water wells. The total groundwater extraction rate in the WSA including pumping for the Waterford Elementary School (WES) is approximately 16,500 gallons per day (GPD).

The Waterford area is underlain by Mesoproterozoic basement rocks of the Blue Ridge anticlinorium including metagranites and metadiorite and by younger Late Proterozoic metadiabase dikes. All rocks in the area were deformed and metamorphosed such that significant groundwater flow in bedrock is restricted to weathered zones and rock fractures at depth. Because well casing is grouted into bedrock to at least 50 feet below ground surface (bgs), well yield is determined substantially by the extent and interconnection of water-bearing fractures that intersect a water well.

Dewberry conducted a survey of WSA landowners in 2021 and found that 17 of 82 homeowners (21%) who responded to the survey encountered problems with the quantity of water provided by their well(s). Factors that contribute to the low yield of many wells in Waterford include: (1) the presence of relatively unfractured, poorly transmissive bedrock; (2) the unusual high density of and small separation between wells constructed on small lots; and (3) reduced recharge to groundwater after home septic drainfields were replaced by sanitary sewer lines and a public wastewater treatment plant in the 1970s.

Three alternatives are being evaluated by Dewberry to improve the water supply in the WSA: (1) a new community public water supply system; (2) one or more private shared well systems to serve less than 15 homes per system; and (3) well deepening or hydrofracking to increase individual well yield. Of these alternatives, development of a public community water-supply system to replace individual wells in the WSA is the most challenging. For a community system, Loudoun Water design criteria requires construction and testing of high yield wells that combined can produce more than 200,000 GPD.

Numerous documents were reviewed to assess groundwater conditions and water well characteristics in the Waterford area. The median bedrock well yield in the WSA is less than 2.0 GPM, which is far below the 8 to 12 GPM range of median yield values reported by Tetra Tech (2019) for bedrock units in the entire Western Hills Watershed of western Loudoun County. The median well depth in Waterford is approximately 550 feet; it significantly exceeds median depths of 300 to 400 feet determined for different bedrock units in the entire Western Hills Watershed (Tetra Tech, 2019).

Interpolated well yield maps suggest that relatively high-yield wells are more likely to be developed in and to the north and east of the WSA. These maps also highlight areas within the WSA that are characterized by poorly transmissive rock and low well yields. However, due to the complex, heterogeneous distribution of water-bearing fractures in the metamorphic rocks of western Loudoun County, dry holes may be drilled in areas with statistically high yields and vice versa.

Water well yields exceeding 70 GPM are required by Loudoun Water to develop a new community public water supply system for Waterford. Of the approximately 190 wells installed in the WSA since the 1950s, none has a reported yield greater than 50 GPM. Extreme high-yield wells are sometimes drilled by chance. Attempts to locate and construct high-yield water wells for either community or shared water supplies would benefit from performing electrical resistivity surface geophysical surveys to select drilling locations on target parcels.

The depth-to-water (DTW) in wells on the west and east sides of the WSA is much shallower (e.g., 15 to 50 feet deep) than in active pumping wells apparently completed in poorly transmissive rock in areas of greater well density (where DTW in wells exceeds 100 feet at 12 locations). Particularly in low-yield wells, DTW is sensitive to both well pumping rates, which vary with time and use, and formation transmissivity. Comparison of DTW values measured in Spring 2006 and in May 2021 shows that groundwater elevations in Waterford area wells rose or changed little between 2006 and 2021 and that, although variable drawdown has occurred since before well pumping began, groundwater mining is not occurring. Hydraulic head distribution maps prepared by Tetra Tech show that groundwater flow through bedrock in the Waterford area is primarily from east to west (towards the South Fork Catoctin Creek) with localized flow and discharge to extraction wells.

Problems with inadequate domestic water yield from bedrock wells can sometimes be remedied by hydrofracturing rock (commonly referred to as hydrofracking), deepening an existing well, drilling a new well, or using other well rehabilitation methods. All these methods are constrained in Waterford by small lot size, difficult access to well sites, well setback requirements, and cost. Some residences rely on more than one well to provide an adequate water supply.

Few contractors perform hydrofracking in Loudoun County. Approximately 67 permits were issued to hydrofrack wells in Loudoun County between 2011 and 2020. Limited documentation indicates that hydrofracking can be used to increase yields of poorly producing water wells in Loudoun County. However, the sustainability of yield increases is not documented and there is no guarantee that hydrofracking will be successful.

Tetra Tech's (2019) report on the Western Hills Watershed presents detailed concentration distribution maps and summary discussions for 20 chemical constituents in groundwater (including metals, other major inorganic constituents, and volatile organic compounds). Results of chemical analyses by National Testing Laboratories on groundwater samples taken in and near Waterford show that area groundwater quality is generally acceptable for a potable water-supply. Iron and manganese, however, would likely require treatment if a new public water supply is developed because these metals are frequently detected in western Loudoun County groundwater above their Secondary Maximum Concentration Levels.

Tetra Tech constructed a two-dimensional, steady-state, groundwater flow model using the MODFLOW 2005 finite-difference program developed by the USGS (Harbaugh et al., 2005) to examine potential replacement of individual domestic wells in the WSA with a community groundwater supply. The model is a simplified representation of the complex, heterogeneous, fractured bedrock aquifer system. Model parameters were input and adjusted to simulate well pumping and match the hydraulic head distribution measured in May 2021 (in the "base case" model). After achieving a reasonable match of observed conditions, the model was used to estimate potential pumping rates that could be sustained at six hypothetical community water-supply wells located at the periphery of the WSA given two different representations of bedrock transmissivity. These simulations suggest that it might be possible to sustain production of 86,000 to 212,000 GPD from six wells located along the periphery of the WSA. Actual sustainable groundwater extraction rates to support a community water-supply system in the Waterford area can only be determined by well drilling and testing. As noted above, electrical resistivity surveys are recommended to increase the probability of constructing high-yield wells on target drilling parcels.

2.0 INTRODUCTION

Tetra Tech was contracted by Dewberry to evaluate groundwater conditions in Waterford, Virginia and help assess the feasibility of developing alternative potable water-supply improvements for its residents. Currently, water in the 147-acre Waterford Service Area (WSA) is supplied to approximately 181 residents based on the 2020 census via 124 connections from as many as 131 individual private water wells that are identified as active in Loudoun County's Wells database.

Figure 1 shows the WSA boundary, parcel property lines, topographic contours, and surface water features in the Waterford area. Much of the WSA is set on a topographic mound, at 400 to 440 feet above mean sea level (MSL), which slopes primarily westward toward the South Fork Catoctin Creek at 340 to 350 feet above MSL.

Figure 2 identifies bedrock units mapped by the U.S. Geological Survey (USGS) in the Waterford area (Southworth et al, 2006 and Loudoun County GIS). Consolidated bedrock is typically encountered below 20 to 40 feet of shallow soil and weathered rock. The WSA is underlain by Mesoproterozoic (greater than 1,000,000 years old) basement rocks of the Blue Ridge anticlinorium[1] including the Marshall biotitic metagranite (Ymb), leucocratic metagranite (Yg), and metanorite / metadiorite (Yn), and by younger Late Proterozoic (approximately 570 million years old) metadiabase dikes (Zmd). The metadiabase dikes intruded the older metagranites and fed the Catoctin Formation basalt flows, which were eroded except along the Catoctin and Blue Ridge Mountains. The subsurface distribution of the metadiabase dikes is ill-defined. All rocks in the Waterford area were deformed and metamorphosed over geologic time such that significant groundwater flow in bedrock is restricted to weathered zones (typically at shallow depth) and rock fractures at depth. Because well casing is grouted into bedrock to at least 50 feet below ground surface (bgs), water well yield is determined substantially by the extent and interconnection of water-bearing fractures that intersect a water well. Conceptual models of groundwater flow conditions affecting water well yield in western Loudoun County are presented in **Figure 3**.

Chapter 1040 of the codified ordinances of Loudoun County specifies 1.0 gallon per minute (GPM) as the minimum acceptable yield for an individual domestic well or from a combination of two wells that each yield at least 0.5 GPM. Water stored in a well (approximately 1.5 gallons per foot for a six-inch diameter well) allows higher rates to be pumped episodically from low-yield wells.

Low-yield wells do not always provide a satisfactory quantity of water to homeowners. Dewberry conducted a survey of WSA landowners in 2021 and found that 17 of 82 homeowners (21%) who responded to the survey[2] encountered problems with the quantity of water provided by their well(s). **Figure 4** shows both results of the Dewberry survey by WSA subarea and reported well yields. Many low-yield wells in Waterford were drilled into

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[1] An anticlinorium is a large anticline on which minor folds are imposed. An anticline is a fold of geologic structure that has an arch-like shape with its oldest beds at its core. An allochthonous fold indicates that the rocks of the anticlinorium were formed elsewhere and were moved to their current location (apparently by compressional forces pushing rocks over a fault surface). The Alleghenian orogeny occurred approximately 325 million to 260 million years ago and was caused by Africa colliding with North America.

[2] The survey was sent owners of 117 residences within the WSA. Thus, 82 respondents represent a 70% response rate.

relatively unfractured, massive crystalline bedrock, particularly in areas with a higher incidence of reported water quantity problems.

Factors that contribute to the low yield of many water wells in Waterford include:

- The presence of relatively unfractured, poorly transmissive bedrock.
- The unusual high density of and small separation between wells constructed on small lots (**Figure 5**) compared to elsewhere in western Loudoun County. Well interference (drawdown from nearby well pumping) can result in dewatering of fractures, decreased formation saturated thickness and transmissivity[3], lowered pump capacity, and lower yield at an affected well.
- Recharge to groundwater in Waterford was reduced beginning in the late 1970s when, to protect groundwater quality, individual home septic drainfields were replaced by sanitary sewer lines and a public wastewater treatment plant (WWTP). The reduced local recharge rate is likely equivalent to a substantial fraction of the total volume of groundwater pumped by WSA residents, which can be estimated as 13,575 gallons per day (gpd) equal to 9.43 GPM (assuming 181 residents each use 75 gpd).

Three main alternatives being evaluated by Dewberry to improve water supply in the WSA are described below:

- Alternative 1 – A new community public water supply system using groundwater extracted from new wells compliant with Loudoun Water and Virginia State Department of Health requirements would be developed to meet existing and future water demands throughout all or a portion of the WSA. Loudoun Water requires new public water-supply wells be set in a 100-foot radial or a square, 200 feet by 200 feet, well lot. The Virginia Department of Health requires a minimum 50-foot setback from potential pollution sources and that public water-supply wells be constructed with thick-wall casing installed to at least 100 feet bgs. Loudoun Water also requires a new groundwater supply system to be able to produce 1.2 GPM per connection for 60 consecutive days. Thus, the current design demand associated with 122 connections is 149 GPM and the future design demand associated with build-out to 144 connections is 173 GPM. Loudoun Water specifies that the water-supply wells must "be independent of one another in hydrogeology", and that systems having more than 50 connections shall provide: (a) three wells each producing at least 0.6 GPM per connection (which is equal to 73.2 GPM per well for 122 connections and 86.4 GPM per well for 144 connections) or (b) four or more wells, the two smallest of which shall combined produce at least 0.6 GPM per connection with the smallest producing at least 0.12 GPM per connection. Ideally, very high-yield wells could be constructed at or near the periphery of the WSA to limit water distribution infrastructure costs and meet well setback requirements. However, as discussed in this report, the potential to achieve this goal (to replace all private wells in the WSA with public water-supply wells) is uncertain.

[3] Transmissivity is the rate at which water passes through a unit width of the aquifer under a unit hydraulic gradient. Hydraulic gradient is the rate of change in hydraulic head per unit of distance of flow in a given direction. Water will flow from higher hydraulic head to lower hydraulic head. Transmissivity is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths.

- Alternative 2 – One or more private shared well systems would be developed to serve less than 15 homes per system. Ideally, the shared wells would meet yield and setback requirements specified for a public water system. Thus, for example, a system serving five homes might be developed using one or more wells that can produce at least 6 GPM. Water treatment might be provided independently at each connected residence as desired by the homeowner. Dewberry is evaluating possible regulatory constraints to implementing this option.
- Alternative 3 – Inadequate domestic groundwater supplies would be improved by addressing individual well problems. This might be accomplished by well hydrofracking, well deepening, well rehabilitation, or drilling a new well.

To assist Dewberry's evaluation of the feasibility of water-supply improvement alternatives in 2021, Tetra Tech:

- Reviewed available data and literature to evaluate groundwater conditions, well yield and depth characteristics, and groundwater extraction potential (see **Section 3**).
- Solicited permission from all landowners in the WSA and owners of several wells outside of the WSA to measure the depth to water in wells on their properties.
- Performed a comprehensive survey to determine depth to water (DTW) and groundwater elevation (hydraulic head) in wells in the Waterford area in May 2021, compared the measured water levels to those measured in Spring 2006 and when wells were drilled to examine potential 'mining' of groundwater, and used the water-level data to estimate groundwater flow directions (see **Section 4**).
- Reviewed available area aquifer test data and monitored hydraulic head changes in select private wells caused by residential pumping stresses to estimate local formation transmissivity during periods extending from one week to months (see **Section 5**),
- Reviewed and evaluated the potential efficacy of hydrofracturing and other options to enhance private domestic well yield (see **Section 6**).
- Compiled, reviewed, and assessed results of groundwater quality analyses performed on samples collected in the Waterford area (see **Section 7**).
- Simulated groundwater flow using a finite-difference mathematical model (based on the USGS MODFLOW code) to examine potential groundwater availability and drawdown impacts associated with new groundwater extraction to support feasibility study alternatives 1 and/or 2 (see **Section 8**).
- Produced data tables and interpretative maps and graphs to present the results of the work described above.

An executive summary for this study is provided in **Section 1** and references are listed in **Section 9**.

3.0 EVALUATION OF WATERFORD AREA WELL YIELD AND DEPTH DATA

3.1 DATA AND LITERATURE REVIEWED

Numerous documents were reviewed to assess groundwater conditions and water well characteristics in the Waterford area. Specific documents identified below are provided in digital format as **Appendix A**.

Tetra Tech downloaded, compiled, and reviewed all scanned Loudoun County Health Department (LCHD) files made available through www.onlinerme.com for all wells inside and some wells outside of the WSA. The LCHD files include well permits, Water Well Completion Reports submitted by well drillers, water quality analysis reports, and other information.

Tetra Tech used Loudoun County Geographic Information System (GIS) data (Excel spreadsheets and shapefiles) related to water wells, bedrock geology, bedrock structures, topography, streams and other water bodies, floodplains, parcels, subdivisions, streets, and other land-use parameters to create interpretative maps and assess relationship between various parameters.

Tetra Tech reviewed hydrogeologic study reports completed for proposed subdivisions near Waterford including Huntley Farm (Friend parcel), Old Wheatland Estates, Brown Division, Waterford Ridge, Waterford Heights (aka Brown Farm), The Crest at Waterford, Stonebrook Farms Hamlet, and Waterford Downs. Locations of most of these properties are shown on **Figure 5**. The hydrogeologic study reports cited above document work performed for County approval to construct individual domestic wells at subdivision sites except for a planned, but never constructed, public water-supply system at Huntley Farm.

Tetra Tech reviewed the *Waterford Elementary School (WES) Groundwater Supply Report* (Tetra Tech, 2006) that it prepared for Loudoun County Public Schools. This report documents results of aquifer testing and a well water level survey conducted in 2006 in Waterford, and other aspects of groundwater use and conditions in Waterford. Groundwater elevations measured in 2006 are compared to those measured in 2021 in **Section 3** herein.

Tetra Tech reviewed *Chapter 5: Assessment of Groundwater Resources in the Western Hills Watershed* of a report (Tetra Tech, 2019) that it prepared for the Loudoun County Department of Building and Development. Waterford is in the northeast portion of this watershed. This report presents detailed information on the watershed's water budget, geology, groundwater, water wells, and groundwater quality.

Tetra Tech reviewed *Evaluating Ground Water Supplies in Fractured Metamorphic Rock of the Blue Ridge Province in Northern Virginia* (Cohen et al, 2007), a technical paper that presents information hydrogeology, water wells, water monitoring, and high-yield well siting in western Loudoun County.

Tetra Tech reviewed USGS geology reports for western Loudoun County including *Geologic Map of the Waterford Quadrangle, Virginia and Maryland, and the Virginia Part of the Point of Rocks Quadrangle* by Burton et al., 1996 and *Geologic Map of Loudoun County, Virginia* by Southworth et al., 2006.

Data and information gleaned from these references are presented below. Additional detailed information regarding Waterford area geology, hydrogeology, wells, and groundwater quality can be accessed from the cited documents compiled in **Appendix A**.

3.2 WATERFORD AREA WELL YIELD AND DEPTH DATA

Select information regarding Waterford area well locations, well depths, well yields, and well water-levels derived from the County Wells database, LCHD well records, and water-level surveys performed by Tetra Tech are summarized in **Table 1**. Several maps were created to illustrate distributions of water well yield, depth, and depth to water and to identify areas with increased probability of constructing new high yield wells for public or shared private water supplies (Alternatives 2 and 3, respectively).

Figure 6 shows locations of 190 active, abandoned, and unused wells in the WSA, including 147 individual wells (WWIN and WWTS types), 25 shallow dug wells (WWDU), 11 ‘dry hole’ wells (WWDH), three non-community water-supply wells (WWNC), three heat pump wells (WWHP), and one community well (WWCO). Three springs are also identified on the north side of Water Street. By comparison, there are approximately 140 property parcels completely contained within the WSA. Most shallow dug plotted on this figure have been either abandoned in accordance with LCHD regulations or are not pumped.

Figure 7 is large map of the WSA area with a large-scale inset plot of the most-congested water well area, which is between and around Water Street to Patrick Street. This map displays reported well locations, identifiers, depths, airlift[4] yields, and depth to water values measured in May 2021.

Figure 8 shows reported water well yield values for wells that are at least 100-feet deep using classified symbols that vary by color and size to highlight spatial differences in well yield. The median bedrock well yield in the WSA is less than 2.0 GPM, which is far less than the 8 to 12 GPM range of median yield values reported by Tetra Tech (2019) for bedrock units in the entire Western Hills Watershed of western Loudoun County. The Western Hills Watershed consists of the drainage basins of the South Fork Catoctin Creek and North Fork Goose Creek and includes Round Hill, Purcellville, and Waterford.

Figure 9 is a graph of the relationship between well depth and reported well yield. As shown for WSA well data, there is a negative (weak) correlation between well yield and well depth because well drilling generally continues to greater depths until a satisfactory yield is achieved at a particular location. The well with the highest reported yield (50 GPM) in the WSA (WWIN-1981-0173) is only 100 feet deep. Hydrogeologic study test well data compiled by Tetra Tech in 2008 and provided in **Table 2** show that, statistically in western Loudoun County, additional water-bearing fractures are encountered, and yield is increased, by drilling deeper, even though the mean yield per depth interval drilled declines from 4.4 GPM between 300 and 400 feet bgs to only 1.0 GPM between 700 and 800 feet. The median well depth in Waterford is approximately 550 feet; it significantly

[4] Airlift yield, as used herein, refers to volume of water per unit of time (e.g., gallons per minute, gpm) that is blown using an air compressor from the bottom of a well after drilling is completed. The flow rate is typically measured using container of known volume and stopwatch by a driller.

exceeds median depths of 300 to 400 feet determined for different bedrock units in the entire Western Hills Watershed (Tetra Tech, 2019).

Two statistical interpolation methods implemented in the ArcMap Spatial Analyst program were used examine spatial differences in well yield in the Waterford area and help identify areas having increased probability for drilling high-yield wells. Raster color maps of interpolated yield based on ordinary kriging (**Figure 10**) and the natural neighbor method (**Figure 11**) both suggest that relatively high-yield wells are more likely to be developed in and to the north and east of the WSA. These maps also highlight areas within the WSA that is characterized by poorly transmissive rock and low well yields. Note, however, that due to the complex, heterogeneous distribution of water-bearing fractures in the metamorphic rocks of western Loudoun County, dry holes may be drilled in areas with statistically high yields and vice versa.

Water well yields exceeding 70 GPM are required by Loudoun Water to develop a new community public water supply system for Waterford (Alternative 1). Of the approximately 190 wells installed in the WSA since the 1950s, none has a reported yield greater than 50 GPM. **Figure 12** shows the locations of high-yield wells reported present throughout Loudoun County classified by yield ranges of 50 to less than 100 GPM, 100 to less than 200 GPM, and greater than 250 GPM, except that wells associated with public water-supply systems such as those serving western Loudoun towns (Middleburg, Round Hill, Purcellville, and Lovettsville) are not plotted for security reasons. The closest well to Waterford in **Figure 12** having a yield of at least 100 GPM is approximately 2.5 miles away.

Extreme high-yield wells are sometimes drilled by chance. However, since about 1994 when AGI introduced its cost-effective, automated electrical resistivity (ER) geophysical equipment, ER surveys have been used successfully to identify drilling sites for community water-supply systems, golf course irrigation wells, and other facilities with high water demand in Loudoun County and throughout the world. Attempts to locate and construct high-yield water wells for either community or shared water supplies (Alternatives 1 and 2) would benefit from (and will require) conduct of electrical resistivity survey work to select drilling locations on target parcels. Depending on landowner agreements, the target parcels for groundwater resource exploration and development may include some of those highlighted in **Figure 13**.

4.0 GROUNDWATER LEVELS AND FLOW DIRECTIONS

With the assistance of the Waterford Citizens Association, in April 2021, emails requesting permission for Tetra Tech to measure the depth to water (DTW) in private wells using a sonic water-level probe were sent to 188 residents and/or landowners in the WSA and several property owners outside of the WSA. In May 2021, with landowners' consent, Tetra Tech measured the DTW in 67 accessible wells that had been drilled into bedrock. No water-level measurements were made in shallow dug wells. Objectives of this survey were to:

- Determine the current (May 2021) DTW and groundwater elevation (hydraulic head) distributions in wells in the Waterford area.
- Compare the May 2021 water levels to those measured in Spring 2006 during Tetra Tech's study of the Waterford Elementary School (WES) groundwater supply and to those measured between 1980 and 2018 when wells were drilled.
- Assess whether groundwater use in Waterford is not sustainable due to groundwater 'mining' whereby ongoing pumping causes continually increasing drawdown due to inadequate recharge.
- Use the water-level data to estimate groundwater flow directions.

Figure 14 displays values of depth to well water below well top of casing measured in May 2021. Top of casing stick-ups typically range from one to two feet above ground but are nearly three feet below ground in two of the wells surveyed. DTW values interpolated using the natural neighbor method are presented using a color map to better display their spatial trends in **Figure 15**. As shown, DTW in wells on the west and east sides of the WSA is much shallower (e.g., 15 to 50 feet deep) than in active pumping wells apparently completed in poorly transmissive rock in areas of greater well density (where DTW in wells exceeds 100 feet at 12 locations). Particularly in low-yield wells, DTW is sensitive to both well pumping rates, which vary with time and use, and formation transmissivity.

DTW values measured when wells were drilled, in Spring 2006, and in May 2021 are compiled in **Table 1** and plotted for comparison on **Figure 16**. **Figure 17** shows the change in DTW values measured in wells between 2006 and 2021 as DTW in 2021 minus DTW in 2006. Thus, positive values indicate an increase in DTW (deeper well water level) and negative values indicate a decrease in depth to water (shallower well water level). The color-coded symbols on this map correspond to well water level rise (lower DTW) and decline (greater DTW). The data show that groundwater elevations measured in Waterford area wells rose or changed little between 2006 and 2021 and that, although variable drawdown has occurred since before well pumping began, groundwater mining is not occurring.

Loudoun County maintained a 400-ft deep groundwater level monitoring well (WWTS-1997-0210) on a parcel adjacent to the WSA south of Fairfax Street between 2005 and 2017. The water level in this well typically rose during winter months and declined during summer and fall months; over approximately 12 years, its depth to water varied between 11 and 33 feet (Tetra Tech, 2019, pages 5-22 to 5-23 in **Appendix A**). The seasonal pattern of hydraulic head fluctuation and absence of any sustained trend of water level change between 2005 and 2017 is consistent with the interpretation that groundwater mining is not occurring in Waterford.

Groundwater flow occurs from higher to lower groundwater elevation (hydraulic head). The water table (the top of the saturated zone in the subsurface) is often a subdued reflection of surface topography because groundwater that mounds up in recharge areas flows and discharges to surface water features, which are located at lower elevations. The direction of groundwater flow is also influenced by the distribution and magnitude of groundwater extraction from wells and other subsurface drainage features. Groundwater at depth in fractured rock is confined and pressurized beneath unfractured massive rock in some areas such that water levels in wells penetrating the fractures rises above the fracture elevations. In the Waterford area, unconfined and confined conditions exist and connections between fractures and water-bearing zones (often referred to as aquifers) are complex.

Hydraulic head distribution maps were prepared by Tetra Tech to illustrate potential groundwater flow patterns in bedrock in the Waterford area based on the Spring 2006 and May 2021 water-level survey data. **Figure 18** presents the hydraulic head contour map for 2006 that was prepared for the WES study. **Figure 19** shows hydraulic heads measured at wells surveyed in May 2021. The hydraulic head data posted in **Figure 19** were interpolated using the natural neighbor method to create the hydraulic head contour map shown in **Figure 20**. Groundwater flow through bedrock in the Waterford area is interpreted to be primarily from east to west (towards the South Fork Catoctin Creek) with localized flow and discharge to extraction wells.

Tetra Tech also monitored groundwater elevations in four wells in and adjacent to Waterford every fifteen minutes using automated Solinst Leveloggers between July 2021 and February 2022. Hydrographs showing the DTW in these wells and in two USGS observation wells are provided in **Figure 50**.

5.0 TRANSMISSIVITY ESTIMATES FROM WELL HYDROGRAPHS AND AQUIFER TESTS

Tetra Tech measured and evaluated hydraulic head changes in 12 domestic wells, including seven pumping wells and four inactive wells in June and July 2021 to help characterize variations in groundwater elevation and bedrock transmissivity in Waterford. Well water levels were recorded automatically as frequently as every minute using pressure transducer dataloggers and sonic water-level probes. Locations of wells monitored during June and July 2021 and during the 2006 Waterford Elementary School (WES) water-supply study are plotted on **Figure 21**.

Figure 21 also shows transmissivity values estimated in and adjacent to Waterford based on analysis of (1) the Waterford Elementary School aquifer test conducted in 2006, (2) Huntley Farm aquifer testing conducted in 1989, (3) WWIN-2018-002 drawdown and recovery data acquired in June 2021 (see **Figure 22**), (4) WWIN-1987-0361 water-level recovery data acquired during days without pumping in July 2021 (**Figure 23**), (5) airlift yields reported by well drillers as explained in **Section 7**, and (6) qualitative assessment of water-level changes caused by episodic domestic well pumping. For the last method (the qualitative assessment), drawdown and recovery responses to pumping observed on well hydrographs were compared to calculated drawdown and recovery trends caused by episodic domestic well pumping from aquifers with six different values of transmissivity (ranging from 0.1 to 100 ft^2/d) using the Papadopulous-Cooper (1967) well hydraulics equation to account for wellbore storage. Domestic well pumping rates were estimated and considered based on observed pumping drawdown periods, home pressure tank size, and other information on domestic water use. The synthetic simulated drawdown/recovery hydrographs for different formation transmissivity values are plotted on **Figure 24**. Hydrographs for each well monitored during this study using water-level dataloggers are provided in **Figures 25 to 31**.

The *Waterford Elementary School Groundwater Supply Report* prepared by Tetra Tech (2006) (in **Appendix A**) for Loudoun County Public Schools documents results of an aquifer test conducted in July 2006 during which the school well (WWNC-1965-0080) was pumped at 12.3 GPM continuously for 48 hours and well water levels were recorded in nine observation wells before, during, and after the pumping period to evaluate formation hydraulic properties and potential drawdown impacts. Locations of wells monitored during the 2006 WES study are plotted on **Figures 21 and 33**. Transmissivity estimates derived from standard analysis of time-drawdown data collected during the 2006 WES aquifer test are posted on **Figure 21**. **Figures 34 to 41** compare water-level changes in the WES well to those in the nine test observation wells. Most observation wells monitored during the 2006 study exhibited no drawdown due to increased pumping at the WES supply well. Transmissivity was characterized qualitatively at domestic wells not affected by WES pumping based on drawdown/recovery cycles induced by domestic well pumping. Extrapolation of WES aquifer test drawdown trends and modeling analysis supports the interpretation that long-term pumping at 12 GPM at the WES well would be sustainable and would not result in drawdown impacts noticeable to nearby well users.

Another controlled 48-hour aquifer test was conducted in 1989 at the proposed Huntley Farm subdivision site located adjacent to the WSA east of High Street and south of Old Waterford Road. Huntley Farm site test wells are plotted on **Figure 21** and aquifer test results provided a transmissivity estimate of 5 ft^2/d. The Virginia Department of Health approved construction of a community water-supply system capable of providing 18 GPM but the developer aborted plans to construct the subdivision. Notably, the Huntley Farm test wells were sited without the benefit of and before cost-effective, automated electrical resistivity survey methods for locating high-yield fracture zones in rock became widely available.

6.0 OPTIONS TO INCREASE INDIVIDUAL DOMESTIC WELL YIELD

Problems with inadequate domestic water yield from bedrock wells can sometimes be remedied by hydrofracturing rock (commonly referred to as hydrofracking), deepening an existing well, drilling a new well, or using other well rehabilitation methods. All these methods are constrained in Waterford by small lot size, difficult access to well sites, well setback requirements, and cost. Some residences rely on more than one well to provide an adequate water supply.

Few contractors perform hydrofracking in Loudoun County. Details regarding hydrofracking procedures and results are not well-documented in LCHD records, company websites, or in other reviewed documents.

According to Scott Miller, President of Northern Virginia Drilling Company, a hydrofracking job in Loudoun County typically takes one day to complete and involves injecting potable water under pressure (as high as 3,500 psi) below a single packer, which is lowered from shallow to greater depths, to open or clean out existing rock fractures and thereby increase well yield. Mr. Miller stated that approximately 3,000 gallons of water are typically injected below ground during the procedure and that a pump test is performed to estimate well yield at least 24 hours after hydrofracking. He indicated, consistent with LCHD records described below, that hydrofracking usually increases well yields by a small amount (less than a few GPM).

Approximately 67 permits were issued by LCHD to hydrofrack wells in Loudoun County between 2011 and 2020. **Table 3** compiles information derived from LCHD files regarding hydrofracking permit applications, wells fracked, and results of fracking. **Figure 42** shows locations of hydrofracked wells and **Figure 43** compares measured well yields before and after fracking. As shown in **Figure 43**, hydrofracking has been used to increase yields of poorly producing water wells in Loudoun County. The sustainability of yield increases, however, is not documented, and there is no guarantee that hydrofracking will be successful.

Edited and augmented excerpts from a fact sheet prepared by the Newfoundland Labrador government are provided below to explain hydrofracking (www.gov.nl.ca/ecc/waterres/cycle/groundwater/well/facts/).

> Hydrofracking is a water well development process that involves injecting water under high pressure through the well into bedrock. This procedure is intended to widen existing fractures in the bedrock and/or extend them further into the formation thereby enlarging the network of water-bearing fractures that transmit water to the well. Hydrofracking can be a cost-effective means of increasing the yield of existing wells with insufficient production rates, or existing older wells with decreased production rates due to incrustation or mineralization of existing bedrock fractures.
>
> After removing all downhole equipment (e.g., pump, pipe, and cable) from the well, one or two inflatable hard rubber packers installed on a pipe are lowered down into the wellbore. The packers are inflated to seal off a section of the well. The packers are set to a minimum of about 20 feet below the bottom of casing and 80 feet below ground surface to prevent a breakout of water under pressure and surface water entering the well. High pressure water is pumped through the packer. The pressure within the sealed off section of the well will rise as the formation resists inflow. At some higher pressure, the pressure will suddenly decline indicating that the formation is accepting water and resistance to flow has decreased. Water

may be pumped into the formation during 5 to 45 minutes at a rate of 25 to 60 GPM. Indications of successful hydrofracturing are a sudden drop in the pressure combined with increased flow into the formation and a strong backflow of cloudy water when pressure is released. If the pressure increases to the maximum working pressure (e.g., 3000 psi) of the equipment with no sudden drop in pressure, then the hydrofracking procedure may have been unsuccessful.

When a single packer is used, the packer is set near the top of the well. Applying pressure in this manner to the wellbore means that the weakest fracture or the fractures of least resistance would be affected. Usually the packer is then moved down the hole to hydrofrack another section of the well. This may be fine for domestic well purposes since the cost for single packer hydrofracking is less than when a double packer system is used. In Loudoun County, hydrofracking contractors typically use single packer systems deployed at multiple depths (**Table 3**). When using a double packer system, the packers are situated 40 to 70 feet apart on a pipe called a drill string. A selected zone in the well can be pressured by inflating both packers and then when done, the packers are deflated and moved elsewhere in the wellbore to pressure another section of the well. This system is more efficient since discrete sections of the wellbore are hydrofracked. Multiple discrete zones can be hydrofracked in this manner. The packers are usually first set near the bottom of the well and moved up the bore to isolate another interval of the well for hydrofracking. Information on specific sections of the well to hydrofrack might be determined from the well driller's log if it indicates depths where water enters the well. A downhole camera can also be used to determine where water-bearing fractures intersect the well.

Hydrofracking poses some risk of impacting an adjacent well if it is within 100 feet and interconnected by bedrock fractures.

The equipment required for hydrofracking should be industry standard equipment capable of supplying high enough pressures to fracture existing rock sequences. Most applications require between 500 and 3000 psi pressure, while occasionally greater pressures are required in tight formations. Although proppants (typically plastic beads or sand) are used extensively by the oil and gas industry during hydrofracking to prop open enlarged cracks/fractures in rock, proppants have not been used in Loudoun County.

Hydrofracking to enhance oil or natural gas production from deep wells is very different than hydrofracking to enhance shallow water well yield. For example, the former typically involves injecting 1.5 to 16 million gallons of water mixed with proppants and chemicals to great depth (more than one mile) at pressures as high as 15,000 psi over three to four days. This process produces a similar volume of wastewater consisting of the injectate mixed with reservoir fluids and contaminants. The produced wastewater is often managed by deep well injection, sometimes resulting in earthquakes. Loudoun County requires that hydrofracking to increase water well yield be performed by a licensed contractor using potable water in accord with permit safeguards.

7.0 GROUNDWATER QUALITY

Tetra Tech's 2019 report on the Western Hills Watershed presents detailed concentration distribution maps and summary discussions for 20 chemical constituents in groundwater (including metals, other major inorganic constituents, and volatile organic compounds). Results of chemical analyses by National Testing Laboratories on groundwater samples taken in and adjacent to the Waterford WSA are listed in **Table 4**. Groundwater quality in the Waterford area is generally acceptable for a potable water-supply. Iron and manganese, however, would likely require treatment if a new public water supply is developed for Waterford because these metals are frequently detected in western Loudoun County groundwater above their Secondary Maximum Concentration Levels.

8.0 MODELING GROUNDWATER FLOW TO ASSESS WATER-SUPPLY DEVELOPMENT

Tetra Tech constructed a two-dimensional, steady-state, mathematical model using the MODFLOW 2005 finite-difference program developed by the USGS (Harbaugh et al., 2005) to examine potential replacement of individual domestic wells in the WSA with a community groundwater supply. The model is a simplified representation of the complex, heterogeneous, fractured bedrock aquifer system. Its finite-difference grid includes 1271 rows, 1040 columns, and one layer comprising 1,321,840 cell blocks with uniform row and column spacings of 20 feet. Model parameters, including bedrock transmissivity, rate of recharge of precipitation, extraction well locations and pumping rates, and surface 'river'[5] and 'drain'[6] boundary conditions were specified to represent existing or possible future conditions at model cell blocks. **Figures 44 to 46** show that the model domain extends from west of Catoctin Creek eastward to the Catoctin Ridge and thousands of feet north and south of Waterford.

Model parameters were input and adjusted to simulate well pumping and the hydraulic head distribution measured in May 2021 (in the "base case" model). After achieving a reasonable match of observed conditions, the model was then used to estimate potential pumping rates that could be sustained at six hypothetical community water-supply wells located at the periphery of the WSA given two different representations of bedrock transmissivity.

Figure 44 shows the locations of river and drain boundary conditions and pumping wells input to the model and simulated hydraulic head contours throughout the model domain. Locations and elevations of the river and drain boundary conditions were derived from Loudoun County GIS layers. Extraction well locations were also derived from County records with some adjustments based on site knowledge. Pumping rates for domestic wells were set to provide 150 GPD per residential parcel. The pumping rate for the WES well is set to 644 GPD. The total pumping rate in the WSA used to represent existing conditions is 16,391 GPD. For comparison, the total pumping rate estimated by Tetra Tech (2006) for the WSA in 2006 based on the combined wastewater treatment plant flow rate from 96 connections was 13,655 GPD.

The distribution of formation transmissivity input to the base case model was estimated by analyzing reported airlift yield and well depth data at 1,351 well locations in the model domain using the Aqtesolv aquifer test analysis program (Hydrosolve, 2007). Results of these transmissivity estimates are listed in **Table 5**. Minimum and maximum transmissivity estimates used for the base case simulations were set to 0.3 and 200 ft^2/d, respectively. Point values of transmissivity were interpolated to all cell blocks using a nearest neighbor

[5] The river boundary condition is a head-dependent boundary condition. In a river cell, water flow into or out of the aquifer is dependent on the head assigned to the river and the conductance term. The head (also referred to as river stage) is compared to the computed head in the aquifer for the cell containing the river. If the aquifer head is higher than the river head, then the river removes water from the aquifer. The amount of water removed is based on the conductance term. The conductance, C, is computed from the following equation: $C = K L W/D$; where K is the hydraulic conductivity of the river bed material, L is the length of the river in the cell, W is the width of the river in the cell, and D is the thickness of the river bed material.

[6] The drain boundary condition is also a head-dependent boundary condition. In a drain cell, the flow of water out of the aquifer is dependent on the head assigned to the stream (drain) and the conductance term. The head (or stage) is compared to the computed head in the aquifer for the cell containing the drain. If the aquifer head is higher than the drain head, then the drain removes water from the aquifer. If the drain head (stage) is higher than the aquifer head, then the drain is considered to be dry and no water is removed or added to the aquifer. The amount of water removed is based on the conductance term as described in footnote 5.

algorithm in the Groundwater Vistas modeling software (Environmental Simulations, Inc., 2017). **Figure 45** shows the transmissivity distribution in the base case simulation.

Recharge rates input to the base case model ranged from 0.2 to 20 inches per year (**Figure 46**) and are proportional to local transmissivity. Recharge is limited in areas of low transmissivity to prevent simulated hydraulic heads from being unrealistically high. The average recharge rate simulated over the entire model domain is 8.71 inches per year. The average recharge rate simulated within the WSA is 4.04 inches per year.

A reasonable match of simulated hydraulic heads in the WSA area (**Figure 47**) to observed hydraulic heads in May 2021 (**Figure 20**) was achieved using the base case model parameters described above. The base case model was then used to calculate simulated steady-state pumping rates at six hypothetical community well locations[7] at the periphery of the WSA assuming no domestic well pumping in the WSA and a drawdown pumping elevation in each community well of 150 feet above MSL. The community wells were modeled using the USGS MNW2 package (Konikow et al., 2009) as 8-inch diameter wells with drawdown/pumping level and associated pumping rates calculated by the Thiem equation, which accounts for the 8-inch well diameter compared to 20-ft by 20-ft cell block size. Simulated hydraulic heads and pumping rates at the six community wells are presented on **Figure 48**. The total steady-state (sustainable) pumping rate for the six wells in this scenario is 86,566 GPD, which is much less than Loudoun Water's design requirement of 249,120 GPD to support 144 connections but approximately five times greater than the estimated existing total groundwater extraction rate in the WSA.

It is important to recognize that modeling groundwater flow in the Waterford area is subject to many simplifying assumptions and substantial uncertainty. For example, bedrock in the model is represented as a confined formation in which transmissivity does not decrease with drawdown. In the real world, formation transmissivity (and potential well productivity) decreases if shallow water-bearing fractures are dewatered due to pumping. For another example of model parameter uncertainty, note that a controlled aquifer test performed at the WES in 2006 (Tetra Tech, 2006) provided estimates of bedrock transmissivity in the WES area of 120 to 400 ft^2/d, which are much higher than the estimate of 27.5 ft^2/d derived from the airlift yield test that was input to the base case model. **Figure 49** shows simulated hydraulic head contours and community well pumping rates for a scenario in which aquifer transmissivity was increased throughout the model domain by a factor of five compared to the base case model. For this scenario, the total steady-state (sustainable) pumping rate for the six wells is 212,389 GPD.

Actual sustainable groundwater extraction rates to support a community water-supply system in the Waterford area can only be determined by well drilling and testing. Electrical resistivity surveys are recommended to increase the probability of constructing high-yield wells on target drilling parcels.

[7] If a community water-supply system is developed for homes in the WSA, it will be desirable to site high-yield wells on large parcels close to residences to be served by the system. The six locations used in the modeling exercise are illustrative and may or may not be feasible depending on several factors including landowner consent.

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TABLES AND FIGURES

Table 1. Waterford Area Water Well Information.

Well ID	Address	Easting (feet)	Northing (feet)	Estimated Ground Elevation (feet>MSL)	Well Riser Stickup (feet)	Hydraulic Head in May 2021 (feet>MSL)	Depth-To-Water in May 2021 (feet<TOC)	Depth-To-Water in Spring 2006 (feet<TOC)	Initial DTW After Drilling (feet)	Initial DTW Drill Date	Difference in DTW from 2006 to 2021 (feet)	Difference in DTW from Initial Date to 2021 (feet)	Reported Well Depth (feet)	Reported Well Yield (GPM)	Comment
Not known	40108 Bond St	11734152	7117947	369.6	1.75	347	25	NM	NA	NA	NA	NA	NA	NA	Not in LC database.
WWIN-2018-0118	40125 Bond St	11734221	7117797	358.8	1.50	347	13	NM	15	6/26/2018	NA	-1.6	640	2.8	
WWIN-1987-0365	40150 Bond St	11734449	7117958	385.0	1.92	306	81	NM	25	9/21/1987	NA	56.0	550	1.0	
WWIN-1988-0525	15525 Butchers Row	11735516	7116567	426.5	1.08	392	36	28	NA	NA	8	NA	445	1.5	Revised horizontal coordinates.
WWIN-1988-0524	15533 Butchers Row	11735420	7116557	429.8	1.00	397	34	28	NA	NA	6	NA	NA	NA	Extended water-level monitoring performed in 2006.
WWIN-1992-0159	40200 Church St	11734926	7116539	403.2	0.83	313	92	152	64	6/15/1992	-61	27.5	440	2.0	Well not pumped for months.
WWIN-1981-0198	40222 Fairfax St	11735329	7116425	439.6	0.42	397	43	38	NA	NA	5	NA	NA	NA	WF School well. Extended water-level monitoring performed in 2006.
WWIN-1973-0176	15550 High St	11735157	7116069	440.3	-0.67	396	44	NM	NA	NA	NA	NA	NA	NA	
WWIN-2000-0182	15565 High St	11735001	7116209	425.0	1.75	385	42	NM	40	12/13/1999	NA	1.8	600	6.0	Revised horizontal coordinates
WWIN-1980-0150	15609 High St	11734778	7115629	420.3	1.67	259	163	177	NA	NA	-14	NA	705	1.0	
WWIN-2010-0061	15655 High St	11734473	7115210	397.6	1.25	271	128	NM	45	7/12/2010	NA	83.2	700	1.0	
WWIN-1970-0104	15676 High St	11734677	7115025	405.8	-2.75	358	45	NM	NA	NA	NA	NA	NA	NA	
Baptist Church	15545 High St	11735006	7116290	421.7	2.33	392	32	NM	NA	NA	NA	NA	NA	NA	Not in LC database.
WWIN-1990-0404	40143 Janney St	11734481	7115311	399.4	0.83	284	117	116	85	1/24/1990	1	31.6	600	4.0	
WWIN-2001-0911	40153 Janney St	11734425	7115382	394.1	1.83	202	194	NM	NA	NA	NA	NA	NA	NA	
WWIN-1998-0116	15443 Loyalty Rd	11736834	7117337	472.8	0.00	442	30	29	40	1/19/1998	1	-9.7	NA	NA	Unused well; no pump. Extended water-level monitoring performed in 2006.
WWIN-1998-0117	15443 Loyalty Rd	11735838	7117483	455.4	0.00	425	30	28	40	1/21/1998	2	-9.7	NA	NA	Revised horizontal coordinates. Extended water-level monitoring performed in 2006.
WWIN-1995-0229	15498 Loyalty Rd	11736696	7116623	462.6	0.00	437	26	25	30	10/25/1995	1	-4.0	NA	NA	Extended water-level monitoring performed in 2006.
WWIN-1988-0529	15510 Loyalty Rd	11736615	7116390	447.4	1.08	429	20	8	NA	NA	12	NA	NA	NA	Extended water-level monitoring performed in 2006.
WWNC-1965-0080	15513 Loyalty Rd	11736513	7117011	467.8	1.08	453	16	26	NA	NA	-10	NA	128	15.0	WES water-supply well. Aquifer test performed in 2006.
WWIN-2001-0737	15514 Loyalty Rd	11735917	7116251	444.6	1.00	416	30	NM	32	2001	NA	-2.5	700	1.5	
WWIN-1998-0115	Loyalty Rd	11736734	7117015	471.9	0.00	445	27	26	40	1/17/1998	1	-13.4	620	5.0	Unused well; no pump. Extended water-level monitoring performed in 2006 and 2021.
WWIN-1981-0168	40105 Main St	11734123	7117747	350.0	1.25	336	16	NM	8	4/2/1981	NA	7.6	240	2.5	
WWIN-1978-0185	40138 Main St	11734477	7117606	392.5	0.50	303	90	NM	NA	NA	NA	NA	300	12.0	
WWIN-1996-0267	40138 Main St	11734441	7117619	386.3	1.25	289	98	237	50	1996	-139	48.4	500	3.0	
WWIN-1981-0169	40145 Main St	11734278	7117271	352.3	0.83	262	92	NM	110	9/23/1981	NA	-18.4	600	1.0	
WWIN-1984-0167	40149 Main St	11734317	7117202	354.1	NR	338	16	NM	NA	NA	NA	NA	200	2.5	

Table 1. Waterford Area Water Well Information.

Well ID	Address	Easting (feet)	Northing (feet)	Estimated Ground Elevation (feet>MSL)	Well Riser Stickup (feet)	Hydraulic Head in May 2021 (feet>MSL)	Depth-To-Water in May 2021 (feet<TOC)	Depth-To-Water in Spring 2006 (feet<TOC)	Initial DTW After Drilling (feet)	Initial DTW Drill Date	Difference in DTW from 2006 to 2021 (feet)	Difference in DTW from Initial Date to 2021 (feet)	Reported Well Depth (feet)	Reported Well Yield (GPM)	Comment
Not known	40152 Main St	11734589	7117492	410.2	1.67	335	77	NM	NA	NA	NA	NA	NA	NA	Unused well; no pump. Extended water-level monitoring performed in
WWIN-1981-0173	40152 Main St	11734599	7117484	411.5	1.50	335	78	NM	18	3/27/1981	NA	59.9	100	50.0	Extended water-level monitoring performed in 2021.
WWIN-1981-0174	40154 Main St	11734626	7117434	411.0	1.50	321	92	90	62	3/26/1981	2	29.5	240	4.0	Revised horizontal coordinates.
WWIN-1982-0124	40176 Main St	11734764	7117230	411.4	1.83	334	79	NM	NA	NA	NA	NA	425	2.0	
WWIN-2011-0053	40194 Main St	11734992	7116797	419.3	1.33	337	83	NM	70	8/19/2011	NA	13.4	605	1.5	
WWIN-1979-0160	40200 Main St	11735046	7116726	428.0	1.58	332	97	89	NA	NA	8	NA	300	3.0	
WWIN-2010-0066	40205 Main St	11734992	7116601	426.7	1.17	259	169	NM	100	7/7/2010	NA	69.1	1000	0.4	
WWIN-2010-0166	40215 Main St	11735002	7116503	408.4	1.08	333	77	NM	100	7/2/2010	NA	-23.4	1100	0.3	Extended water-level monitoring performed in 2021.
WWIN-1986-0338	40215 Main St	11734977	7116519	407.7	0.33	301	107	246	NA	NA	-139	24.8	600	0.1	Extended water-level monitoring performed in 2021.
WWIN-2010-0049	40215 Main St	11734955	7116521	404.5	1.08	290	115	NM	100	7/23/2010	NA	15.2	1000	0.3	
WWIN-2001-0393	40216 Main St	11735263	7116687	414.3	1.92	277	139	106	50	10/1/2001	33	89.2	1000	0.8	Extended water-level monitoring performed in 2006.
WWIN-2012-0017	40221 Main St	11735069	7116476	414.2	1.42	320	95	NM	40	1/30/2012	NA	55.1	700	2.0	
WWIN-1986-0339	40186 Patrick St	11734921	7116313	414.3	1.83	384	32	262	22	11/6/1986	-230	10.4	560	4.0	Revised horizontal coordinates.
WWIN-1111-0018	40189 Patrick St	11734841	7116251	416.2	1.00	403	14	NM	NA	NA	NA	NA	NA	0.0	Well in basement; not used.
WWIN-2001-0530	40189 Patrick St	11734777	7116271	409.6	2.00	307	104	NM	80	10/31/2001	NA	24.3	740	0.5	
WWIN-1986-0343	15479 Second St	11734671	7117028	372.8	1.83	359	16	NM	80	1/31/1986	NA	-64.4	385	0.5	
WWTS-2011-0008	15481 Second St	11734646	7116983	371.3	1.25	319	54	NM	60	2/21/2011	NA	-6.4	540	20.0	
WWIN-1981-0171	15493 Second St	11734637	7116774	374.8	1.58	362	14	12	NA	NA	2	NA	NA	NA	Water is visible.
WWIN-1993-0267	15512 Second St	11734785	7116529	387.7	3.00	179	212	162	12	12/3/1993	50	199.6	600	6.0	
WWIN-1988-0528	15520 Second St	11734897	7116406	404.7	2.17	370	37	227	NA	NA	-190	NA	NA	NA	Not being pumped.
WWIN-2018-0002	15520 Second St	11734923	7116413	404.7	0.92	133	272	NM	400	1/6/2018	NA	-127.6	700	0.5	Owner hauls water; little pumping. Extended water-level monitoring performed in 2021.
WWIN-1991-0191	15523 Second St	11734393	7116556	365.4	1.92	318	50	NM	58	2/11/1992	NA	-8.4	360	5.5	Revised horizontal coordinates.
WWIN-1974-0153	15552 Second St	11734556	7116181	391.8	-2.75	358	31	244	NA	NA	-213	NA	NA	NA	In concrete vault.
WWIN-1983-0115	15555 Second St	11734102	7116299	365.2	1.75	350	17	18	NA	NA	-1	NA	365	4.0	Extended water-level monitoring performed in 2021.
WWIN-1983-0114	15555 Second St	11734377	7116202	376.5	1.42	318	60	NM	NA	NA	NA	NA	545	0.3	

Table 1. Waterford Area Water Well Information.

Well ID	Address	Easting (feet)	Northing (feet)	Estimated Ground Elevation (feet>MSL)	Well Riser Stickup (feet)	Hydraulic Head in May 2021 (feet>MSL)	Depth-To-Water in May 2021 (feet<TOC)	Depth-To-Water in Spring 2006 (feet<TOC)	Initial DTW After Drilling (feet)	Initial DTW Drill Date	Difference in DTW from 2006 to 2021 (feet)	Difference in DTW from Initial Date to 2021 (feet)	Reported Well Depth (feet)	Reported Well Yield (GPM)	Comment
WWIN-1957-0069	15567 Second St	11734374	7116106	379.9	0.58	366	14	25	NA	NA	-11	NA	NA	NA	Water is visible.
WWIN-1987-0361	15575 Second St	11734244	7115978	376.6	1.25	345	32	36	NA	NA	-4	NA	320	2.8	Extended water-level monitoring performed in 2021.
WWIN-1986-0342	15580 Second St	11734453	7115954	388.2	0.33	370	19	NM	15	12/11/1986	NA	3.8	275	0.3	Revised horizontal coordinates. Extended water-level monitoring performed in 2021.
WWIN-1986-0340	15580 Second St	11734539	7115874	398.8	1.25	314	86	76	NA	NA	10	NA	500	0.5	Extended water-level monitoring performed in 2021.
WWIN-1986-0341	15580 Second St	11734548	7115895	399.0	1.00	192	208	249	NA	NA	-41	NA	550	1.5	Extended water-level monitoring performed in 2021.
WWIN-1980-0148	15591 Second St	11734273	7115873	380.0	1.08	315	67	NM	109	9/2/1980	NA	-42.4	325	3.0	
WWIN-1989-0337	15603 Second St	11734043	7115698	373.0	1.75	303	72	NM	60	6/20/1989	NA	11.7	505	10.0	
WWIN-1964-0097	15606 Second St	11734385	7115624	389.8	1.67	350	42	41	NA	NA	1	NA	NA	NA	
WWIN-1992-0236	15619 Second St	11734197	7115567	380.0	0.92	314	67	NM	61	1/14/1992	NA	5.6	400	12.0	
WWIN-1956-0076	15620 Second St	11734302	7115522	384.2	2.00	304	82	107	NA	NA	-25	NA	NA	NA	Owner indicates 620' well depth.
WWIN-2002-0436	15640 Second St	11734313	7115201	388.2	1.25	318	72	NM	17	9/16/2002	NA	54.7	760	1.0	
WWIN-1986-0327	WF parcel	11734986	7117172	430.4	2.00	340	92	NM	NA	NA	NA	NA	NA	NA	Marked "Post Office".
WWIN-1999-0178	WF parcel	11734753	7117272	415.8	1.67	316	101	NM	28	7/21/1999	NA	73.2	740	2.0	
WWIN-1982-0125	40174 Main Street	11734838	7117180	414.3	1.25	332	83	75	NA	NA	8	NA	160	35.0	
WWIN-1991-0155	WF parcel	11735133	7117577	403.0	0.92	343	61	69	69	11/2/1991	-8	-7.7	500	1.0	
WWCO-1986-0325	Fairfax Street	11736180	7114817	395.5	NM	NM	NM	3	8.82	11/1/1988	-3	-8.8	NA	NA	Aquifer test performed in 1989.
WWCO-1989-0329	Fairfax Street	11736630	7114850	400.1	NM	NM	NM	12	17	2/27/1989	-12	-17.0	NA	NA	Aquifer test performed in 1989.
WWCO-1989-0330	Fairfax Street	11737428	7114921	414.0	NM	NM	NM	14	NA	NA	-14	0.0	NA	NA	Aquifer test performed in 1989.
WWIN-1962-0083	15655 High St	11734645	7115209	409.0	NM	NM	NM	25	NA	NA	NA	NA	NA	NA	
WWIN-1973-0307	15570 Second St	11734571	7116026	398.1	NM	NM	NM	425	25	1/1/1973	-425	-25.0	600	0.8	
WWIN-1999-0179	15570 Second St	11734595	7115953	403.2	NM	NM	NM	284	80	1/6/1999	-284	-80.0	680	0.3	
WWIN-1989-0336	Brown St	11738569	7117437	522.8	NM	NM	NM	60	18	NA	-60	-18.0	NA	NA	

Note: NM = Not Measured; NA = Not Available; TOC = Top-of-Casing; DTW = Depth-to-Water; MSL = Mean Sea Level; GPM = gallons per minute.

Table 2. Reported Yield Versus Depth Interval in Western Loudoun County Hydrogeologic Study Test Wells.

Interval Drilled (feet bgs)	Total Feet Drilled	Total Yield (GPM)	Mean Yield (GPM) per Interval
100 to <200	182,950	5,537	3.03
200 to <300	160,032	6,932	4.33
300 to <400	107,997	4,789	4.43
400 to <500	73,663	2,532	3.44
500 to <600	45,050	872	1.93
600 to <700	24,660	559	2.27
700 to <800	12,059	123	1.02

Table 3. Water Well Hydrofracking Locations and Results in Loudoun County from 2011 to 2020.

Hydrofrack Permit #	Loudoun County Well ID	Easting	Northing	Subdivision and Lot	Parcel Identification Number	Street Address	Drilling Completion Date	Driller	Well Depth (feet)	Reported Airlift Yield Upon Completion of Drilling (GPM)	Reported Yield from Pump Test Prior to Hydrofrack (GPM)	Fracker	Date: Hydrofrack (HF) Post-Hydrofrack Pump Test (HFPT) Hydrofrack Permit (HFP)	Reported Pump Test Well Yield After Hydrofrack (GPM)	Hydrofrack Single Packer Install Depths (feet)	Comment
T00239190001	WWIN-2020-0138	-77.594729840	39.222503321	Waterford Downs Ph 3B Lot 67	261256356000	14219 Amys Meadow Ct, Lees.	2/3/2020	Phillips	1000	0		Phillips	HF: 1/19/2021 HFPT: 1/21/2021	1.00	300', 400', 700'	
T90343880001	WWDH-2020-0141	-77.593062599	39.222586522	Waterford Downs Ph 3B Lot 67	261256356000	14219 Amys Meadow Ct, Lees.	2/3/2020	Phillips	625	0		Phillips	HF: 3/2020	0.00		Abandoned on 1/26/2021.
T00252260001	WWIN-2001-0597	-77.591919054	39.225788762	Waterford Downs Lot 51	261359676000	14080 Amys Meadow Ct, Lees.	2/17/2001	Shaff's	800	1.5	0.84	Phillips	HF: 5/12/2020 HFPT: 5/13/2020	1.00	150', 300', 400'	
T00265910001	WWIN-2006-0068	-77.550962856	39.224464700	Claydin Acres Lot 10	178358564000	41887 Woodcrest Ln, Lees.	1/23/2006		1000	0.06		NVD	HFPT: ~3/21/2006	1.00		
T00354240001	WWIN-2020-0069	-77.666430020	39.270265739	Never to Fork Farm	406476722000	12441 Elvan Rd, Lovett.	8/26/2020	Phillips	700	0.5		Phillips	HF: 9/22/2020 HFPT: 10/9/2020	1.33	100', 200', 300'	
T00360520001	WWIN-2020-0074	-77.593060026	39.227086482	Waterford Downs Lot 52	261460005000	14072 Amys Meadow Ct, Lees.	7/17/2020	Phillips	625	0.25				NA		Hydrofrack permit issued on 9/17/2020. HF results not available.
T00399660001	WWIN-2001-0610	-77.591789495	39.229147801	Waterford Downs Lot 54	262461077000	14000 Amys Meadow Ct, Lees.	2/10/2001	Shaff's	500	6		Phillips		NA		Hydrofrack permit issued. HF results not available.
T10102270001	WWIN-1997-0136	-77.620768199	39.292193579	Quarter Branch Lot 10	332400425000	39918 Canterfield Ct, Lovett.	10/23/1997		700	0.5		Phillips	HF: 1/10/2011 HFPT: ~3/28/2011	5.00	150', 250', 350'	
T10234020001	WWIN-2011-0096	-77.570507898	39.165673689	Raspberry Falls Sec F Lot 206C	226269561000	41384 Fox Creek Ln, Lees.	8/31/2011	Valley	1000	<1		NVD	HFPT: 11/13/2011	1.00		
T10343670001	WWIN-1987-0483	-77.702721507	39.057055195		460252828000	20323 Cockerill Rd, Purc.	9/23/1986		590	1.5				NA		Hydrofrac permit issued after well ran dry circa May 2021. HF results (if performed) not available.
T1034430001	WWIN-2015-0116	-77.585384279	39.219757991	Waterford Downs Ph 1 Lot 19	261178748000	Sydney Meadow Ct	8/24/2015	Valley	800	1.5				NA		"Well hydro-fracture permit for the existing low yield/dry hole at Waterford Manor lot 19." HF Permit issued 6/15/2021. Results not available.
T20311230001	WWIR-2012-0041	-77.640613857	39.064505252	Decosta Division Lot 2	353455718000	19857 Hogback Mountain Rd, Lees.	3/8/2012	NVD	600	0		NVD	HFPT: 4/13/2012	3.00		
T20381690001	WWDH-1989-0379	-77.658126059	39.073959027		388454844000	38880 Leighfield Ln, Lees.	1/30/1989		1005	0		Harley	HF: 8/21/2012	5.00		
T20409700001	WWIN-2012-0134	-77.712275525	39.255758960	AT&T Co., Sec 7 Lot 59	477387669000	12355 White Rock Rd, Purc.	8/16/2012	NVD	800	1		NVD	HFPT: 2/25/2013	4.00		
T30132950003	WWIN-2003-0239	-77.561391383	39.246064278	McClure residence	219385354000	13409 Taylorstown Rd, Lees.	3/6/2019		800	<0.25		NVD		NA		HF permit issued 3/7/2019 but results not available.
T30282610001	WWIN-2013-0038	-77.636187972	39.102846190	Rovang Family Lot 1	443464181000	37724 Rovang Ln, Lovett.	1/29/2013	Valley	505	0		Phillips	HFPT: ~3/10/2013	7.00		
T3035517001	WWIN-2013-0104	-77.755088480	39.102390174	Black Oak Ridge Ph 1 Lot 22	558283244000	18608 Humphrey Ln, Purc.	5/17/2013	Ritter	900	0.25		NVD	HFPT: 6/28/2013	2.09		
T3035520001	WWIN-2013-0081	-77.755807290	39.101287609	Black Oak Ridge Ph 1 Lot 26	558280595000	18602 Montague Pl, Purc.	5/17/2013		900	0		NVD	HFPT: 6/5/2013	1.00		
T30405660001	WWIN-2006-0463	-77.661803886	39.284792432	Dutchmans Creek Lot 4	404103426000	11947 George Farm Dr, Lovett.	4/24/2006 7/2013		500' 1005'	0		Phillips	HF 8/2/2006 HF 9/24/2013	2006: 1 2013: 2	2006: 100', 200', 300' 2013: 100', 250', 350'	
T30420320001	WWIN-2013-0159	-77.611012644	39.251230041	Waterford View Sec 4 Lot 10	297166194000	13160 Waterford View Ct, Lovett.	9/23/2013		800	0		Easterday	HF: 9/23/2013 HFPT: 9/30/2013	7.50		
T30445290001	WWDH-2013-0210	-77.635525391	39.166224535	Walls Family Lot 1E	343260339000	39533 Hamilton Pines Ln, Waterford	10/30/2013		600	0.75		Phillips	HFPT: 12/17/2013	4.00	105', 150', 200'	
T30464060001	WWTS-2006-0634	-77.676611156	39.138357919	Harmony Vista Lot 22	417154167000	17315 Westham Estates Ct, Hamilton	6/14/2006	Phillips	1000	0.5	0.48	S&M or Phillips	HFPT: 8/3/2006	5.00		
T40281870001	WWIN-2003-0476	-77.614372171	39.251118697	Waterford View Sec 4 Lot 4	297157884000	13189 Waterford View Ct, Lovett.	10/24/2003		800	2		NVD	HFPT: 4/9/2014	3.12		Possible HF in 12/2003 by Harley: 3.5 GPM yield.
T40281890001	WWIN-2006-1036	-77.614019216	39.247812965	Waterford View Sec 4 Lot 15	298455099000	13324 Waterford View Ct, Lovett.	1/26/2006	Shaff's	650	1		NVD	HFPT: 4/25/2014	3.96		
T40325510001	WWIN-2004-0431	-77.658594294	39.284351807	Dutchmans Creek Lot 53	368151936000	38787 Dutchmans Knoll Dr, Lovett.	9/21/2004		500	6		Phillips	HF: 5/16/2014	1.50	150', 250', 325'	

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Hydrofrack Permit #	Loudoun County Well ID	Easting	Northing	Subdivision and Lot	Parcel Identification Number	Street Address	Drilling Completion Date	Driller	Well Depth (feet)	Reported Airlift Yield Upon Completion of Drilling (GPM)	Reported Yield from Pump Test Prior to Hydrofrack (GPM)	Fracker	Date: Hydrofrack (HF) Post-Hydrofrack Pump Test (HFPT) Hydrofrack Permit (HFP)	Reported Pump Test Well Yield After Hydrofrack (GPM)	Hydrofrack Single Packer Install Depths (feet)	Comment
T40372380001	WWIN-2014-0120	-77.644539532	38.975010325	Stovepipe Academy	397402653000	23241 Meetinghouse Ln, Aldie	7/1/2014	NVD	720	0		NVD	HFPT: 8/4/2014	3.60		
T40399970001	WWIN-2001-0700	-77.657225372	39.287930337	Dutchmans Creek Lot D-2	368254560000	38864 Irish Corner Rd, Lovett.	1/29/2001		320	6		Phillips	HF: 9/29/2014	10.00	100', 200', 275'	
T40413400001	WWIN-2014-0140	-77.606940858	39.069007383	Wulf Crest Farm Lot 11	314284355000	40336 Rubin Ln, Lees.	9/25/2014	S&M	1160	0.75		S&M	HFPT: 10/16/2014	4.00		
T40454510001	WWIN-2005-0585	-77.615575932	39.273760043	Moffett Family Lot 4	295155671000	12370 Moon Lake Ln, Lovett.	10/28/2005		660	1.5	0.90	NVD	HFPT: 1/8/2015	3.20		
T50353860001	WWIN-2005-0054	-77.694365595	39.164235328	UL2 Family Lot 2	367291749000	39227 Redgate Farm Ln, Lovett.	4/18/2015		650	0		Phillips	HF: 5/8/2015	2.50	150', 200', 300'	
T50383540003	WWIN-2015-0104	-77.620339523	39.243706575	Mountain Valley Lot 4	336201849000	13460 Milltown Rd, Lovett.	7/1/2015	Phillips	550	0		Phillips	HF: 7/17/2015	NA	150', 200', 250'	HF permit issued 7/16/2015 but results not available.
T50413580003	WWIN-1993-0004	-77.551096708	39.215590635	Mount Pleasant Lot 10	179459143000	14475 Woodstart Ct, Purc.	3/23/1993		500	0		Harrell (?)	HFPT: ~4/22/1993	3.30		HF permit issued 10/7/2015 but results not available.
T50465510001	WWIN-2015-0134	-77.608399903	39.150562818	Rawls Div. Lot 1	307477118000	40213 Doe Run Ln, Paeonian Springs	8/26/2015	Valley	1200	1		NVD	HFPT: ~11/18/2015	8.10		
T60265860001	WWIN-1999-0324	-77.688833434	39.123021267	Browns Farm Sec 5 Lot 15	454290844000	37989 Sayre Ct, Purc.	10/21/1999		600	1		NVD		NA		HF permit issued 3/7/2016 but results not available.
T60273700001	WWCO-2002-0414	0.000000000	0.000000000	Town of Hillsboro	517302708000	36906 Charles Town Pike, Purc.	7/8/2002		700	7.5				NA		HF permit issued 3/22/2016 but results not available.
T60277830001	WWIN-2016-0035	-77.612846352	39.237562504	Millcreek Meadows Lot 2	299460895000	40192 Featherbed Ln, Lovett.	3/14/2016	Phillips	900	0.25		Phillips	HF: 3/29/2016	2.00	175', 300', 650'	
T60282190001	WWIN-2016-0024	-77.765424498	39.102499609	Black Oak Ridge Ph 3 Lot 17	558255152000	18238 Wild Raspberry Dr, Purc.	3/15/2016	S&M	1200	0.5		S&M	HFPT: 3/25/2016	1.54		HF Permit issued on 3/24/2016.
T60297180001	WWIN-2005-0776	0.000000000	0.000000000	Waterford Downs Ph 2 Lot 43	261270266000	14219 Courtney Meadow Pl, Lees.	10/24/2005		1000	1		Phillips	HF: 4/21/2016	6.00	150', 300', 500'	
T60352490001	WWIN-2016-0081	-77.568501892	39.164056375	Raspberry Falls Sec F Lot 205D	226262711000	16333 Rogues Hollow Ln, Lees.	6/4/2021	S&M	1000	0		S&M	HFPT: 8/4/2016	0.65		
T60361810001	WWIN-2016-0065	-77.596661773	39.165231176	Lot 2	305199215000	40588 Hurley Ln, Paeonian Springs	7/6/2016	NVD	800	0.5		Phillips	HF: 8/2/2016	2.00	100', 200', 300'	
T60409530001	WWIN-2016-0150	-77.624379957	39.125618202		347394847000	17738 Canby Rd, Lees.	10/11/2016	NVD	800	0.5		NVD	HFP: 10/18/2016	1.20		
T60419810001	WWIN-2016-0201	-77.588756315	39.223970105	Waterford Downs Ph 2 Lot 39	261371914000	40810 Erins View Ct, Lees.	10/30/2016	Phillips	600	0.5		Phillips	HF: 11/18/2016	10.00	150', 300', 400'	
T70249290001	WWIN-2017-0020	-77.708758669	39.108533701	Oak Knoll Farms	491495097000	18379 Telegraph Springs Rd, Purc.	1/6/2017	NVD	700	1		NVD	HFPT: 2/10/2017	5.50		
T70284260001	WWNC-2017-0039	-77.563182009	38.988701199	Fleetwood Farm / Green Works	242195067000	23075 Evergreen Mills Rd, Lees.	1/27/2017	Ritter	720	1.7		NVD	HFP: 3/27/2017	2.60		
T70357120001	WWIN-2004-0433	-77.659196988	39.285080431	Dutchmans Creek Lot 58	404109254000	38775 Dutchmans Knoll Dr, Lovett.	9/24/2004: 10/30/2017:	Phillips	500 1000	8 2		Phillips	HF: 8/23/2017. Deepened 500' to 1000': 10/30/2017. PT: 11/29/2017.	3.00	150', 300'	Deepened to 1000 feet on 10/30/2017. LCHD permit comments: "This permit is for deepening of the existing low yield well T40129790002. This well was hydrofractured, without success. Deepening the well may create more storage or hit another water bearing zone."
T70397370001	WWIN-2016-0095	-77.561962772	39.015111868	Evergreen Village Conservancy Lot 8	240395343000	41644 Reservoir Rd, Lees.	8/10/2016	Allied	400	4		NVD	Deepened from 400' to 1000' circa 8/2017. PT: 9/1/2017	1.08		GW2 forms for well deepening and hydrofracking not available.
T70438310001	WWIN-2017-0179	-77.596323373	39.164488664		306402986000	40562 Hurley Ln, Paeonian Springs		NVD						NA		Hydrofrack permit applied for on 11/2/2017. No copies of perr
T70446070001	WWIN-2017-0177	-77.625306690	39.115515327	Annino Family Lot 14A4	348391554000	18134 Blessed Ln, Lees.	10/2/2017	S&M	1000	0.3		Harley	HFPT: 12/7/2017	2.50		
T70467190001	WWIN-2017-0148	-77.634956941	39.181810447	Old Wheatland Ph 2 Lot 7	342360872000	15701 Vivian Drive, Waterford	12/22/2017	S&M	1060	0.15		S&M	HFPT: 1/23/2018	2.00		

Table 3. Water Well Hydrofracking Locations and Results in Loudoun County from 2011 to 2020.

Hydrofrack Permit #	Loudoun County Well ID	Easting	Northing	Subdivision and Lot	Parcel Identification Number	Street Address	Drilling Completion Date	Driller	Well Depth (feet)	Reported Airlift Yield Upon Completion of Drilling (GPM)	Reported Yield from Pump Test Prior to Hydrofrack (GPM)	Fracker	Date: Hydrofrack (HF) Post-Hydrofrack Pump Test (HFPT) Hydrofrack Permit (HFP)	Reported Pump Test Well Yield After Hydrofrack (GPM)	Hydrofrack Single Packer Install Depths (feet)	Comment
T80223080001	WWIN-2003-0163	-77.663025033	39.301637436		403302157000	38706 Triticum Ln, Lovett.	6/30/2003		605	1		Phillips	HF: 1/16/2018	NA	100', 250'	"This permit is for the 2nd HF of the existing well (WWIN-2003-1613). The first HF was completed in 2004 after the well was originally drilled in 2003. Phillips and Son has been given the option to HF or deepen. Mr. Phillips has stated that his equipment is better now, so they will attempt HF first. If this is not succesful, deepening is to be completed under the same permit. The yield and drawdown test is to be completed at the end of all procedures." Results not available.
T80229700001	WWIN-2017-0161	-77.635736337	39.182518674	Old Wheatland Ph 2 Lot 6	342469998000	15689 Vivian Dr, Waterford	12/29/2017		1080	0		S&M	HFPT: 2/23/2018	4.00		
T80252180001	WWTS-2005-0711	0.000000000	0.000000000	Waterford Downs Ph 2 Lot 40	261367241000	40794 Erins View Ct, Lees.	10/3/2005		800	1.5	1.40	Phillips	HF: 4/12/2018	2.60	150', 250', 375'	
T80252190001	WWIN-2001-0602	-77.590886036	39.223937727	Waterford Downs Ph 2 Lot 41	261366411000	40807 Erins View Ct, Lees.	2/25/2001		800	1		Phillips	HF: 4/13/2018	1.25	150', 250', 375'	
T80295340001	WWTS-2006-0482	-77.769497423	39.112072701	The Bluffs Lot 29	586202287000	35732 Platinum Dr	5/12/2006		700	2		Phillips	HF: 6/1/2018 HFPT: 6/5/2018	1.50	150', 250', 375'	
T80316270001	WWIN-2018-0092	-77.592128775	39.219958694	Waterford Downs Ph 2 Lot 71	261367996000	14329 Amys Meadow Ct, Lees.	5/22/2018	Phillips	600	0.25		Phillips	HFPT: 6/19/2018	1.20	150', 250', 375'	
T80328350001	WWIN-2013-0117	-77.657516676	39.198177586	Reserve at Waterford Lot Sec A 310	376154953000	15111 Lynnford Ct, Waterford	7/2/2013	S&M	1400	1.5		NVD	HFPT: ~7/5/2018	4.69		
T80424570001	WWTS-2005-0777	-77.590500173	39.216516761	Waterford Downs Lot 74	262464049000	14411 Amys Meadow Ct, Lees.	10/27/2005	Shaff's	300	4	11/6/2018: <1.0	Phillips	HF: 11/28/2018 HFPT: 11/30/2018	4.00	120'	"The existing well (WWTS-2005-0777) was drilled and grouted in 2005. An unsuccessful yield and drawdown test was conducted on 11/6/2018." The yield was <1.0 gpm. Thus, it was fracked and retested, with prior yield restored.
T90215320003	WWIN-2019-0059	-77.700128337	39.099651623		456157476000	18707 Haps Ln, Purc.	3/18/2019	Chespk	600	1		NVD	HFPT: 5/23/2019	0.14		HF not successful. Subsequently the well was deepened from 500' to 600' , which resulted in a yield of 6 gpm water at ~670'.
T90240900001	WWIN-2019-0161	-77.545203499	39.259712714	Furnace Mountain Blk 6 Lot B	175473065000	12831 James Monroe Hwy, Lees.	4/17/2019	Phillips	625	0.06		Phillips	4/30/2019	6.60	145', 300'	
T90244370001	WWTS-1989-0792	-77.761980325	39.116155418	Upper Lakes Lot 13	557465079000	18144 Presidio Pl, Round Hill	10/13/1989	GSI	420	2		Phillips	HF: 4/26/2019 HFPT: 5/2/2019	3.00	200'@1400psi, 300@1700psi	
T90261190001	WWIN-2019-0171	-77.760819968	39.111431896	Upper Lakes Lot 7	557166769000	18302 Presidio Pl, Round Hill	4/26/2019	Phillips	530	0.5		Phillips	HF: 5/29/2019 HFPT: ~6/4/2019	6.00		
T90261200001	WWTS-2005-0786	-77.586214917	39.222495121	Waterford Downs, Ph2 Lot 27	261275461000	14220 Courtney Meadow Pl, Lees.	9/22/2005	Shaff's	350	8		Phillips	HFP: 5/2/2019 HF: 1/23/2019 HFPT: 1/25/2019	6.00	150', 250', 300'	Reason for HF not apparent in LCHD records.
T90308480001	WWIN-2019-0164	-77.762674561	39.115751383	RH Rural Estates Upper Lakes Lot 14	557365160000	18159 Presidio Pl, Round Hill	6/18/2019	Phillips	505	0.5	6/18/2019: 0.5	Phillips	HF: 8/26/2019 HFPT: 8/29/2019	4.00	150', 250', 350'	
T90387160001	WWTS-2005-0778	-77.595085547	39.223085089	Waterford Downs Lot 66	261355678000	14183 Amys Meadow Ct, Lees.	10/26/2005 11/27/2019	Shaff's	500 1000	1 4.0		Phillips	HFP: 11/5/2019 HFPT: 1/22/2020	4.00	150', 250', 300'	Initial yield of 500' deep well in 2005 was 1.0 gpm. Apparently deepened to 1000' prior to HF.
T90387220001	WWIN-2001-0590	-77.590359766	39.221566481	Waterford Downs Ph 3A Lot 45	261263711000	14270 Amys Meadow Ct, Lees.	2/9/2001	Shaff's	700		11/23/2005: 1.2	Phillips	HF: 2/4/2020 HFPT: 2/13/2020	8.50	150', 300', 400'	Constant drawdown test by Shaff's Well Drilling on 11/23/2005.
T90387270001 / T90343900001	WWIN-2019-0179	-77.593279390	39.224383349	Waterford Downs Lot 49	261360823000	14170 Amys Meadow Ct, Lees.	10/28/2019	Phillips	625	0.5		Phillips	HF: 11/12/2020 HFPT: 11/20/2019	6.00	150', 300'	
T90397790001	WWIN-2019-0179	-77.593279390	39.224383349	Waterford Downs Lot 68	261256731000	14241 Amys Meadow Ct, Lees.	10/19/2019	Phillips	625	1.25		Phillips	HF: 1/29/2020 HFPT: 2/3/2020	1.50	150', 300' 400'	

Table 4. Summary of Results of Chemical Analyses of Waterford Area Groundwater Samples by National Testing Labs.

Well ID and Location	Reported Well Yield and Depth	Sample Date	Iron (mg/L)	Manganese (mg/L)	Nitrate-Nitrogen (mg/L)	Total Dissolved Solids (mg/L)	Chloride (mg/L)	pH	Volatile Organic Compounds, Trihalomethanes, Pesticides, Herbicides, and PCBs (mg/L)
WWIN-2001-0393 40216 Main Street	0.75 gpm 1000 feet	10/4/2001	0.092	0.150	1.5	260	43	7.6	Toluene - 0.021
WWIN-1998-0117 15543 Loyalty Road	20 gpm 300 feet	2/17/1998	0.660	0.280	<0.5	81	<5	7.4	All Non-Detect
WWIN-1998-0115 Behind WES	5 gpm 620 feet	2/13/1998	0.026	0.140	<0.5	52	<5	6.6	All Non-Detect
WWIN-2011-0008 15481 Second Street	20 gpm 540 feet	2/23/2011	2.133	0.063	<0.5	150	42	9.6	Tetrahydrofuran - 0.01
WWIN-2010-0049 40215 Main Street	0.3 gpm 1000 feet	8/4/2010	<0.02	0.422	<0.5	220	41	6.8	All Non-Detect
WWIN-2008-0174 40266 Water Street	2 gpm 740 feet	11/11/2008	1.000	0.021	<0.5	55	<5	9.3	All Non-Detect
WWCO-1986-0326 Huntley Farm	7 gpm 605 feet	2/27/1989	0.430	0.006	3	166	<10	8.1	All Non-Detect
WWCO-1986-0325 Huntley Farm	20 gpm 605 feet	2/27/1989	0.290	<0.004	<1	123	<10	9.2	All Non-Detect
WWCO-1986-0324 Huntley Farm	4 gpm 700 feet	2/27/1989	0.210	0.012	<1	186	<10	8	All Non-Detect
WWCO-1989-0328 Huntley Farm	4.5 gpm 500 feet	2/27/1989	0.057	0.007	<1	178	<10	8.1	All Non-Detect

Notes:
(1) National Testing Lab analytical reports are provided in Appendix A.
(2) Toluene likely eluted from tape used to secure power cable to pump drop pipe.
(3) Tetrahydrofuran is used in PVC cement.

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWDH-1988-0254	11720185	7120659	90	0.00	54	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2001-0463	11732464	7103932	98	0.00	61	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1993-0051	11735663	7116285	100	0.00	63	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2001-0464	11732529	7103994	100	0.00	63	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1993-0144	11724252	7131426	200	0.00	153	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1987-0301	11722541	7110828	200	0.00	153	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1986-0342	11734453	7115954	275	0.30	221	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1977-0170	11732356	7112239	295	0.00	239	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1976-0104	11724022	7131483	300	0.00	243	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1999-0627	11727284	7106303	300	0.00	243	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1986-0323	11735254	7115460	325	0.00	266	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1986-0322	11735476	7115697	330	0.00	270	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1989-0250	11731287	7104055	345	0.00	284	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1993-0049	11735252	7116396	350	0.00	288	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0056	11722217	7106273	370	0.00	306	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0292	11737686	7118939	390	0.00	324	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2018-0207	11740307	7128745	400	0.00	333	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2020-0010	11740032	7129174	400	0.00	333	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2019-0216	11726633	7117185	400	0.00	333	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1988-0294	11721514	7106661	400	0.00	333	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2004-0383	11732740	7127525	400	0.00	333	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0291	11737080	7119253	410	0.00	342	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1991-0130	11734751	7117781	420	0.00	351	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1986-0375	11736897	7103018	445	0.00	374	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1993-0048	11733835	7128542	450	0.00	378	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1985-0204	11731444	7109372	490	0.00	414	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1988-0293	11721189	7106998	500	0.00	423	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1989-0007	11718479	7125979	500	0.00	423	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0082	11734642	7117356	500	0.00	423	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2000-0461	11731140	7106677	500	0.00	423	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIR-1999-0625	11727423	7106430	500	0.25	423	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1998-0413	11736470	7102494	500	0.50	423	1.11E-01	1.86E-01	1.49E-01	3.00E-01
WWIN-1986-0340	11734539	7115874	500	0.50	est. 396	1.20E-01	2.00E-01	1.60E-01	3.00E-01
WWDH-1981-0147	11723480	7103643	505	0.00	428	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1986-0376	11733014	7104436	515	0.00	437	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1996-0113	11734852	7111990	520	0.00	441	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1987-0303	11722290	7110623	525	0.00	446	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0055	11722206	7105931	525	0.00	446	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1987-0172	11718483	7107813	540	0.00	459	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1999-0172	11721841	7113627	540	0.00	459	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1999-0528	11735902	7103529	540	0.00	459	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1983-0114	11734377	7116202	545	0.30	464	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1991-0097	11735007	7117188	560	0.00	477	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWTS-1999-0632	11722315	7112043	560	1.00	477	2.20E-01	3.49E-01	2.85E-01	3.00E-01
WWIN-1985-0031	11718947	7109786	575	0.00	491	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0290	11737103	7119390	590	0.00	504	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2010-0084	11739029	7109473	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2016-0116	11723177	7112769	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2007-0299	11736915	7103164	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1972-0174	11734871	7116741	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1987-0308	11731021	7112083	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWDH-1987-0363	11734973	7116677	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1988-0255	11720562	7120834	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1988-0256	11720464	7121326	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1991-0014	11734880	7117147	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1991-0025	11737972	7117913	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1992-0137	11733993	7111205	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1993-0050	11735640	7116334	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1994-0230	11739763	7120507	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0322	11741190	7114884	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1997-0100	11734023	7132645	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1998-0409	11734349	7124979	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2000-0085	11719977	7133003	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2001-0527	11722867	7110188	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2004-0382	11731962	7127022	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2005-0334	11719600	7129811	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2006-1024	11718726	7106382	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2006-1025	11718577	7106321	600	0.00	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1986-0338	11734977	7116519	600	0.10	est. 450	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2001-0376	11719721	7112725	600	0.12	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2003-0460	11722954	7104946	600	0.12	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2000-0326	11736351	7102380	600	0.25	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIR-2002-0256	11732436	7104848	600	0.25	513	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2016-0201	11741077	7130091	600	0.50	513	8.90E-02	1.50E-01	1.20E-01	3.00E-01
WWIN-2000-0734	11724825	7106199	600	0.50	513	8.90E-02	1.50E-01	1.20E-01	3.00E-01
WWIN-2002-0438	11734413	7117206	600	0.50	513	8.90E-02	1.50E-01	1.20E-01	3.00E-01
WWIN-2002-0492	11728369	7102888	600	0.50	513	8.90E-02	1.50E-01	1.20E-01	3.00E-01
WWTS-2000-0708	11743636	7120995	600	0.50	513	8.90E-02	1.50E-01	1.20E-01	3.00E-01
WWTS-2000-0697	11740781	7121571	600	0.75	513	1.44E-01	2.35E-01	1.90E-01	3.00E-01
WWIN-1973-0307	11734571	7116026	600	0.80	518	1.44E-01	2.31E-01	1.88E-01	3.00E-01
WWIN-2018-0092	11740136	7128620	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWIN-1990-0416	11735703	7103061	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWIN-2000-0105	11723642	7124814	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWIN-2000-0657	11732626	7103898	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWIN-2001-0010	11722234	7114183	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWIN-2003-0079	11733308	7103358	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWIN-2005-0245	11736858	7120644	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWIN-2005-0246	11736808	7120675	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWTS-1990-0194	11740591	7119140	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWTS-2006-0389	11718489	7121616	600	1.00	513	2.04E-01	3.22E-01	2.63E-01	3.00E-01
WWDH-1988-0463	11731072	7111332	605	0.00	518	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1991-0222	11721108	7106806	610	0.00	522	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1999-0651	11722600	7113118	620	0.00	531	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1997-0490	11734313	7115518	620	1.00	531	1.95E-01	3.10E-01	2.53E-01	3.00E-01
WWDH-2020-0141	11739862	7129575	625	0.00	536	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2020-0074	11739846	7131214	625	0.25	536	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2019-0179	11739794	7130229	625	0.50	536	8.50E-02	1.50E-01	1.18E-01	3.00E-01
WWIN-2013-0127	11719710	7127952	630	1.00	540	1.90E-01	3.04E-01	2.47E-01	3.00E-01
WWDH-1992-0083	11733908	7128838	640	0.00	549	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1994-0225	11739587	7121180	640	0.00	549	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0294	11738168	7119435	640	0.00	549	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1995-0295	11736925	7119218	640	0.00	549	5.00E-02	9.00E-02	7.00E-02	3.00E-01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2001-0751	11720507	7103300	640	0.50	549	8.28E-02	1.40E-01	1.11E-01	3.00E-01
WWIN-1999-0641	11729237	7103921	650	0.50	558	8.04E-02	1.36E-01	1.08E-01	3.00E-01
WWIN-2002-0343	11729090	7102367	650	1.00	558	1.82E-01	2.92E-01	2.37E-01	3.00E-01
WWIN-2002-0422	11730936	7120124	650	1.00	558	1.82E-01	2.92E-01	2.37E-01	3.00E-01
WWIN-2004-0282	11722426	7104831	650	1.00	558	1.82E-01	2.92E-01	2.37E-01	3.00E-01
WWDH-1993-0098	11731577	7110181	660	0.00	567	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1998-0129	11732082	7126261	660	1.00	567	1.79E-01	2.86E-01	2.33E-01	3.00E-01
WWIN-1999-0626	11727414	7106365	660	1.00	567	1.79E-01	2.86E-01	2.33E-01	3.00E-01
WWIN-1999-0179	11734595	7115953	680	0.13	585	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1998-0132	11734823	7116576	680	0.13	585	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1996-0110	11735237	7116779	680	0.50	585	7.60E-02	1.28E-01	1.02E-01	3.00E-01
WWIN-1998-0045	11731841	7129364	680	1.00	585	1.72E-01	2.80E-01	2.26E-01	3.00E-01
WWDH-1997-0101	11734079	7133038	700	0.00	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2000-0823	11723916	7125111	700	0.00	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2006-0982	11722188	7124679	700	0.00	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2002-0233	11723926	7110808	700	0.06	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2004-0667	11721235	7105264	700	0.12	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2001-0383	11722527	7110247	700	0.25	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2001-0526	11722683	7110388	700	0.25	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2001-0746	11723009	7109830	700	0.25	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2005-0221	11721441	7105235	700	0.25	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2005-0635	11722001	7105388	700	0.25	603	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1998-0109	11728014	7113471	700	0.50	603	7.30E-02	1.24E-01	9.85E-02	3.00E-01
WWIN-2018-0002	11734923	7116413	700	0.50	540	8.29E-02	1.41E-01	1.12E-01	3.00E-01
WWIN-2019-0093	11735038	7118644	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWIN-2000-0317	11725003	7109217	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWIN-2001-0392	11734691	7121527	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWIN-2001-0644	11719775	7108063	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWIN-2001-0911	11734425	7115383	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWIN-2002-0643	11736939	7121776	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWIN-2006-0240	11718718	7105733	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWIN-2016-0042	11721118	7104844	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWTS-2002-0073	11729399	7114401	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWTS-2006-0358	11719261	7119769	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWTS-2006-0368	11721426	7120045	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWTS-2006-0382	11719914	7119520	700	1.00	603	1.69E-01	2.70E-01	2.20E-01	3.00E-01
WWIN-2010-0061	11734473	7115210	700	1.00	590	1.72E-01	2.75E-01	2.24E-01	3.00E-01
WWDH-1986-0337	11735064	7116576	705	0.00	608	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1980-0150	11734778	7115629	705	1.00	est. 544	1.90E-01	3.00E-01	2.45E-01	3.00E-01
WWIN-1992-0234	11728401	7110220	710	0.00	612	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1999-0706	11720999	7113473	720	0.00	621	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2000-0176	11729977	7110985	720	0.50	621	7.10E-02	1.20E-01	9.55E-02	3.00E-01
WWIN-2018-0015	11728493	7114626	720	1.00	621	1.63E-01	2.60E-01	2.12E-01	3.00E-01
WWIN-1999-0097	11723034	7124613	720	1.00	621	1.63E-01	2.60E-01	2.12E-01	3.00E-01
WWIN-2002-0434	11721083	7113149	720	1.00	621	1.63E-01	2.60E-01	2.12E-01	3.00E-01
WWIN-2001-0530	11734777	7116271	740	0.50	594	7.50E-02	1.28E-01	1.02E-01	3.00E-01
WWIN-1997-0480	11722612	7124498	740	1.00	639	1.56E-01	2.50E-01	2.03E-01	3.00E-01
WWIN-2003-0137	11740213	7112047	750	1.00	648	1.54E-01	2.50E-01	2.02E-01	3.00E-01
WWTS-2002-0428	11737735	7121385	750	1.00	648	1.54E-01	2.50E-01	2.02E-01	3.00E-01
WWTS-2006-0434	11720841	7121004	750	1.00	648	1.54E-01	2.50E-01	2.02E-01	3.00E-01
WWIN-2002-0436	11734313	7115201	760	1.00	669	1.49E-01	2.40E-01	1.95E-01	3.00E-01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWDH-2002-0074	11727922	7114579	800	0.00	693	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-1987-0302	11722278	7110594	800	0.00	693	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2000-0825	11724901	7109161	800	0.00	693	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2002-0099	11722380	7112554	800	0.00	693	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2004-0568	11742369	7120774	800	0.00	693	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2006-0571	11718558	7106396	800	0.00	693	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2007-0276	11743138	7116337	800	0.00	693	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2001-0589	11740235	7130001	800	0.50	693	6.30E-02	1.06E-01	8.45E-02	3.00E-01
WWIN-2000-0325	11739561	7107705	800	0.50	693	6.30E-02	1.06E-01	8.45E-02	3.00E-01
WWIN-2006-0777	11720428	7115771	800	0.75	693	1.02E-01	1.69E-01	1.36E-01	3.00E-01
WWIN-1998-0496	11721939	7125385	800	1.00	693	1.43E-01	2.31E-01	1.87E-01	3.00E-01
WWIN-2016-0065	11739048	7108675	800	1.00	693	1.43E-01	2.31E-01	1.87E-01	3.00E-01
WWIN-2016-0067	11728074	7108110	800	1.00	693	1.43E-01	2.31E-01	1.87E-01	3.00E-01
WWIN-2000-0653	11728978	7111852	800	1.00	693	1.43E-01	2.31E-01	1.87E-01	3.00E-01
WWIN-2000-0802	11734205	7117425	800	1.00	693	1.43E-01	2.31E-01	1.87E-01	3.00E-01
WWIN-2001-0602	11740474	7130073	800	1.00	693	1.43E-01	2.31E-01	1.87E-01	3.00E-01
WWIN-2006-0065	11736664	7121267	800	1.00	693	1.43E-01	2.31E-01	1.87E-01	3.00E-01
WWTS-2006-0832	11730995	7116130	800	1.00	693	1.43E-01	2.31E-01	1.87E-01	3.00E-01
WWIN-2017-0140	11728647	7114540	800	1.30	693	1.86E-01	2.95E-01	2.41E-01	3.00E-01
WWDH-2002-0073	11730698	7102822	820	0.00	711	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2000-0824	11723938	7125210	820	1.00	711	1.39E-01	2.24E-01	1.82E-01	3.00E-01
WWIN-2005-0729	11736409	7121038	840	1.00	729	1.34E-01	2.18E-01	1.76E-01	3.00E-01
WWTS-2006-0363	11720034	7120419	850	1.00	738	1.31E-01	2.14E-01	1.73E-01	3.00E-01
WWIN-2003-0055	11722542	7112016	880	1.00	765	1.27E-01	2.06E-01	1.67E-01	3.00E-01
WWDH-2015-0118	11740729	7129414	900	0.00	783	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2006-0734	11722766	7112090	900	0.12	783	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2013-0040	11719532	7120569	900	0.50	783	5.40E-02	9.40E-02	7.40E-02	3.00E-01
WWIR-2001-0473	11738641	7104307	900	0.50	783	5.40E-02	9.40E-02	7.40E-02	3.00E-01
WWIN-2020-0030	11728780	7103837	900	1.00	783	1.24E-01	2.01E-01	1.63E-01	3.00E-01
WWTS-2005-0769	11740317	7129797	900	1.00	783	1.24E-01	2.01E-01	1.63E-01	3.00E-01
WWDH-2010-0036	11721987	7118641	920	0.00	801	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2003-0106	11721723	7112308	920	1.00	801	1.20E-01	1.98E-01	1.59E-01	3.00E-01
WWIN-2007-0120	11722607	7125330	920	1.00	801	1.20E-01	1.98E-01	1.59E-01	3.00E-01
WWIN-2017-0003	11728927	7114194	940	1.50	819	1.90E-01	3.00E-01	2.45E-01	3.00E-01
WWDH-2015-0095	11741889	7113105	1000	0.00	873	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2002-0076	11728039	7114632	1000	0.00	873	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2021-0019	11729028	7104290	1000	0.00	873	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWDH-2021-0028	11743393	7112203	1000	0.00	873	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2001-0588	11739827	7129917	1000	0.12	873	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2010-0049	11734955	7116521	1000	0.30	873	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2010-0066	11734992	7116601	1000	0.38	873	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-1999-0568	11736798	7102855	1000	0.50	873	4.70E-02	8.30E-02	6.50E-02	3.00E-01
WWIN-2003-0203	11733528	7133093	1000	0.50	873	4.70E-02	8.30E-02	6.50E-02	3.00E-01
WWIN-2001-0393	11735263	7116687	1000	0.75	855	7.80E-02	1.34E-01	1.06E-01	3.00E-01
WWIN-2020-0138	11739390	7129540	1000	1.00	873	1.10E-01	1.79E-01	1.45E-01	3.00E-01
WWIN-2007-0108	11744219	7120625	1000	1.00	873	1.10E-01	1.79E-01	1.45E-01	3.00E-01
WWTS-2002-0427	11737951	7119737	1000	1.00	873	1.10E-01	1.79E-01	1.45E-01	3.00E-01
WWTS-2005-0776	11740747	7129542	1000	1.00	873	1.10E-01	1.79E-01	1.45E-01	3.00E-01
WWTS-2002-0093	11727611	7115789	1000	1.25	873	1.41E-01	2.30E-01	1.86E-01	3.00E-01
WWIN-2017-0032	11724244	7131610	1000	1.50	873	1.75E-01	2.80E-01	2.28E-01	3.00E-01
WWDH-2003-0167	11722556	7111498	1020	0.00	891	5.00E-02	9.00E-02	7.00E-02	3.00E-01

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Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWDH-2013-0107	11721420	7121165	1040	0.00	909	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2003-0166	11722480	7111584	1040	1.00	909	1.10E-01	1.72E-01	1.41E-01	3.00E-01
WWDH-2017-0162	11728384	7115606	1060	0.00	927	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2017-0148	11728133	7114609	1060	0.15	927	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2017-0041	11728889	7114418	1060	2.10	927	2.30E-01	3.60E-01	2.95E-01	3.00E-01
WWIN-2010-0166	11735002	7116502	1100	0.25	963	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2004-0098	11737706	7105822	1100	0.25	963	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWTS-2002-0431	11737507	7121272	1180	0.75	1035	6.30E-02	1.08E-01	8.55E-02	3.00E-01
WWDH-2017-0160	11728282	7114948	1200	0.00	1053	5.00E-02	9.00E-02	7.00E-02	3.00E-01
WWIN-2015-0134	11735771	7103300	1200	1.00	1053	1.10E-01	1.46E-01	1.28E-01	3.00E-01
WWIN-2013-0117	11721683	7120511	1400	1.50	1233	1.20E-01	1.96E-01	1.58E-01	3.00E-01
WWIN-2013-0188	11721099	7122191	1400	2.00	1233	1.65E-01	2.70E-01	2.18E-01	3.00E-01
WWIN-2019-0213	11740078	7129195	525	1.00	446	2.40E-01	3.77E-01	3.09E-01	3.09E-01
WWIN-1981-0169	11734278	7117271	600	1.00	441	2.40E-01	3.77E-01	3.09E-01	3.09E-01
WWIN-2016-0096	11723082	7112591	800	1.50	693	2.70E-01	3.65E-01	3.18E-01	3.18E-01
WWIN-1998-0111	11736477	7119053	800	1.50	693	2.70E-01	3.65E-01	3.18E-01	3.18E-01
WWIN-2001-0597	11740174	7130744	800	1.50	693	2.70E-01	3.65E-01	3.18E-01	3.18E-01
WWIN-2015-0116	11742047	7128566	800	1.50	693	2.70E-01	3.65E-01	3.18E-01	3.18E-01
WWTS-2005-0771	11740607	7130379	800	1.50	693	2.70E-01	3.65E-01	3.18E-01	3.18E-01
WWIN-2019-0177	11739827	7129487	625	1.25	536	2.52E-01	3.92E-01	3.22E-01	3.22E-01
WWIN-1998-0126	11739741	7119391	500	1.00	423	2.55E-01	3.93E-01	3.24E-01	3.24E-01
WWIN-2002-0296	11740772	7125288	500	1.00	423	2.55E-01	3.93E-01	3.24E-01	3.24E-01
WWIN-2003-0136	11724125	7130781	500	1.00	423	2.55E-01	3.93E-01	3.24E-01	3.24E-01
WWIN-2004-0087	11720819	7116213	500	1.00	423	2.55E-01	3.93E-01	3.24E-01	3.24E-01
WWTS-2005-0778	11739287	7129751	500	1.00	423	2.55E-01	3.93E-01	3.24E-01	3.24E-01
WWIN-2000-0660	11735839	7102157	760	1.50	657	2.70E-01	3.84E-01	3.27E-01	3.27E-01
WWIN-2004-0136	11719746	7110796	760	1.50	657	2.70E-01	3.84E-01	3.27E-01	3.27E-01
WWIN-2001-0737	11735917	7116251	700	1.50	601	2.70E-01	4.24E-01	3.47E-01	3.47E-01
WWIN-2003-0313	11732130	7113943	700	1.50	603	2.70E-01	4.24E-01	3.47E-01	3.47E-01
WWIN-2004-0196	11734575	7106957	700	1.50	603	2.70E-01	4.24E-01	3.47E-01	3.47E-01
WWIN-2006-0412	11724451	7108553	700	1.50	603	2.70E-01	4.24E-01	3.47E-01	3.47E-01
WWTS-2001-0821	11724053	7110995	700	1.50	603	2.70E-01	4.24E-01	3.47E-01	3.47E-01
WWTS-2002-0081	11729983	7115469	700	1.50	603	2.70E-01	4.24E-01	3.47E-01	3.47E-01
WWTS-2006-0373	11718332	7121862	700	1.50	603	2.70E-01	4.24E-01	3.47E-01	3.47E-01
WWIN-2005-0193	11738038	7114993	800	1.75	693	2.75E-01	4.30E-01	3.53E-01	3.53E-01
WWIN-1991-0155	11735133	7117577	500	1.00	388	2.81E-01	4.30E-01	3.56E-01	3.56E-01
WWTS-2006-0269	11719381	7119578	680	1.50	585	2.80E-01	4.32E-01	3.56E-01	3.56E-01
WWIN-2003-0103	11732672	7107046	900	2.00	783	2.80E-01	4.32E-01	3.56E-01	3.56E-01
WWTS-2005-0772	11740581	7129794	900	2.00	783	2.80E-01	4.32E-01	3.56E-01	3.56E-01
WWIN-1996-0158	11740092	7118255	620	1.50	531	3.10E-01	4.86E-01	3.98E-01	3.98E-01
WWIN-1998-0127	11740465	7118689	620	1.50	531	3.10E-01	4.86E-01	3.98E-01	3.98E-01
WWIN-2015-0033	11742046	7111282	800	2.10	693	3.22E-01	4.96E-01	4.09E-01	4.09E-01
WWIN-1998-0363	11736349	7118737	800	2.00	693	3.23E-01	4.96E-01	4.10E-01	4.10E-01
WWIN-2001-0008	11722641	7113422	800	2.00	693	3.23E-01	4.96E-01	4.10E-01	4.10E-01
WWIN-2002-0494	11728299	7102972	800	2.00	693	3.23E-01	4.96E-01	4.10E-01	4.10E-01
WWIN-2004-0119	11727899	7104323	800	2.00	693	3.23E-01	4.96E-01	4.10E-01	4.10E-01
WWIN-1996-0018	11734074	7123890	600	1.50	513	3.30E-01	5.06E-01	4.18E-01	4.18E-01
WWIN-1998-0118	11735368	7119293	600	1.50	513	3.30E-01	5.06E-01	4.18E-01	4.18E-01
WWTS-2000-0712	11743100	7119748	600	1.50	513	3.30E-01	5.06E-01	4.18E-01	4.18E-01
WWDH-2006-0849	11734808	7117864	780	2.00	675	3.30E-01	5.10E-01	4.20E-01	4.20E-01
WWIN-1997-0468	11732952	7102539	400	1.00	333	3.40E-01	5.20E-01	4.30E-01	4.30E-01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-1999-0178	11734753	7117272	740	2.00	641	3.50E-01	5.30E-01	4.40E-01	4.40E-01
WWIN-2018-0023	11728338	7115394	740	2.00	639	3.50E-01	5.30E-01	4.40E-01	4.40E-01
WWIN-2008-0174	11735621	7116736	740	2.00	639	3.50E-01	5.30E-01	4.40E-01	4.40E-01
WWIN-2011-0053	11734992	7116797	605	1.50	482	3.50E-01	5.40E-01	4.45E-01	4.45E-01
WWIN-2017-0179	11739146	7108405	700	1.90	603	3.70E-01	5.68E-01	4.69E-01	4.69E-01
WWIN-2020-0033	11719707	7104620	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-1996-0300	11741383	7106549	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-1997-0169	11722752	7124296	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-2000-0320	11722896	7105371	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-2002-0140	11738260	7102953	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-2002-0629	11723163	7110730	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-2004-0353	11730822	7112818	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-2005-0622	11736236	7121272	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-2006-0237	11743091	7120005	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-2014-0046	11724204	7112941	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWTS-1999-0497	11738862	7105140	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWTS-2005-0688	11721431	7124386	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWTS-2005-0702	11720474	7121980	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWTS-2005-0708	11720744	7122468	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWTS-2005-0908	11720341	7122253	700	2.00	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWTS-2006-0267	11719053	7119456	700	2.05	603	3.77E-01	5.80E-01	4.79E-01	4.79E-01
WWIN-2007-0058	11732608	7109828	620	1.75	531	3.80E-01	5.80E-01	4.80E-01	4.80E-01
WWIN-2012-0017	11735069	7116476	700	2.00	594	3.84E-01	5.90E-01	4.87E-01	4.87E-01
WWIN-2001-0045	11720652	7102081	600	1.75	513	3.90E-01	5.90E-01	4.90E-01	4.90E-01
WWTS-1997-0209	11734623	7115285	600	1.75	513	3.90E-01	5.90E-01	4.90E-01	4.90E-01
WWIN-2019-0008	11735995	7109911	500	1.50	423	4.10E-01	6.10E-01	5.10E-01	5.10E-01
WWIR-2015-0083	11719277	7106328	500	1.50	423	4.10E-01	6.10E-01	5.10E-01	5.10E-01
WWIN-2017-0085	11743230	7112563	660	2.10	567	4.07E-01	6.20E-01	5.14E-01	5.14E-01
WWCO-1989-0329	11736630	7114850	500	1.50	423	4.10E-01	6.20E-01	5.15E-01	5.15E-01
WWIN-2018-0118	11734222	7117797	640	2.00	563	4.07E-01	6.27E-01	5.17E-01	5.17E-01
WWIN-2006-0502	11733016	7103277	800	2.50	693	4.16E-01	6.30E-01	5.23E-01	5.23E-01
WWIN-2016-0182	11728945	7113728	1000	3.00	873	3.90E-01	6.60E-01	5.25E-01	5.25E-01
WWIN-2017-0117	11727671	7110131	640	2.00	549	4.20E-01	6.40E-01	5.30E-01	5.30E-01
WWIN-2005-0517	11729839	7109075	640	2.00	549	4.20E-01	6.40E-01	5.30E-01	5.30E-01
WWIN-2014-0051	11733164	7124562	640	2.00	549	4.20E-01	6.40E-01	5.30E-01	5.30E-01
WWTS-1998-0184	11737145	7102845	640	2.00	549	4.20E-01	6.40E-01	5.30E-01	5.30E-01
WWIN-1986-0341	11734548	7115895	550	1.50	est 405	4.30E-01	6.50E-01	5.40E-01	5.40E-01
WWIN-2006-1026	11718777	7106350	920	3.00	801	4.30E-01	6.60E-01	5.45E-01	5.45E-01
WWIN-1998-0507	11728513	7110268	620	2.00	531	4.43E-01	6.65E-01	5.54E-01	5.54E-01
WWIN-1997-0222	11741642	7108112	620	2.00	531	4.43E-01	6.65E-01	5.54E-01	5.54E-01
WWIN-2015-0051	11741346	7113079	620	2.00	531	4.43E-01	6.65E-01	5.54E-01	5.54E-01
WWTS-1988-0251	11722230	7122287	605	2.00	518	4.49E-01	6.90E-01	5.70E-01	5.70E-01
WWIN-2014-0110	11729404	7115502	600	2.20	513	4.58E-01	6.90E-01	5.74E-01	5.74E-01
WWIN-2016-0060	11721143	7104657	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-1996-0005	11729574	7126206	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-1998-0123	11732499	7111421	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-1999-0098	11723989	7125975	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-1999-0102	11733935	7125172	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-2000-0174	11723319	7110243	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-2000-0180	11732861	7111246	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-2000-0676	11717946	7128965	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2001-0612	11742394	7130745	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWTS-2000-0716	11744091	7121185	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWTS-2000-0725	11742100	7120773	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWTS-2002-0094	11728368	7116190	600	2.00	513	4.59E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-1988-0525	11735516	7116567	445	1.50	383	4.60E-01	6.90E-01	5.75E-01	5.75E-01
WWIN-2004-0610	11725160	7131852	575	2.00	491	4.77E-01	7.20E-01	5.99E-01	5.99E-01
WWIN-2001-0596	11740500	7131667	300	1.00	243	4.86E-01	7.20E-01	6.03E-01	6.03E-01
WWIN-2003-0505	11733066	7102514	500	1.75	423	4.86E-01	7.30E-01	6.08E-01	6.08E-01
WWIN-2018-0128	11740529	7128054	500	1.75	423	4.86E-01	7.30E-01	6.08E-01	6.08E-01
WWTS-2001-0816	11723390	7111874	700	2.50	603	4.86E-01	7.30E-01	6.08E-01	6.08E-01
WWIN-1998-0165	11728221	7103538	560	2.00	477	4.96E-01	7.50E-01	6.23E-01	6.23E-01
WWTS-2001-0654	11722504	7106755	560	2.00	477	4.96E-01	7.50E-01	6.23E-01	6.23E-01
WWTS-2001-0656	11722208	7106049	560	2.00	477	4.96E-01	7.50E-01	6.23E-01	6.23E-01
WWIN-1998-0501	11723236	7105612	680	2.50	585	5.06E-01	7.60E-01	6.33E-01	6.33E-01
WWIN-1999-0596	11724374	7125036	420	1.50	351	5.10E-01	7.60E-01	6.35E-01	6.35E-01
WWIN-2001-0660	11736001	7107501	800	3.00	693	5.20E-01	7.70E-01	6.45E-01	6.45E-01
WWIN-2002-0644	11737123	7120247	800	3.00	693	5.20E-01	7.70E-01	6.45E-01	6.45E-01
WWIN-2005-0158	11742972	7123170	800	3.00	693	5.20E-01	7.70E-01	6.45E-01	6.45E-01
WWIN-2006-0745	11743944	7119149	800	3.00	693	5.20E-01	7.70E-01	6.45E-01	6.45E-01
WWIN-2014-0178	11725723	7122679	800	3.00	693	5.20E-01	7.70E-01	6.45E-01	6.45E-01
WWIN-2017-0072	11742983	7112787	720	2.80	621	5.26E-01	7.93E-01	6.60E-01	6.60E-01
WWIN-2001-0733	11736148	7105939	900	3.50	783	5.30E-01	8.00E-01	6.65E-01	6.65E-01
WWIN-2001-0623	11721341	7113297	520	2.00	441	5.36E-01	8.10E-01	6.73E-01	6.73E-01
WWIN-2002-0479	11727653	7102052	650	2.50	558	5.36E-01	8.10E-01	6.73E-01	6.73E-01
WWIN-2005-0066	11735477	7132421	1300	5.00	1143	5.80E-01	7.80E-01	6.80E-01	6.80E-01
WWIN-2015-0068	11729115	7102045	640	2.40	549	5.58E-01	8.10E-01	6.84E-01	6.84E-01
WWIN-1998-0057	11736095	7125468	500	2.00	423	5.69E-01	8.41E-01	7.05E-01	7.05E-01
WWIN-2000-0106	11723939	7125287	500	2.00	423	5.69E-01	8.41E-01	7.05E-01	7.05E-01
WWIN-2000-0109	11724357	7125212	500	2.00	423	5.69E-01	8.41E-01	7.05E-01	7.05E-01
WWIN-2004-0410	11723463	7110146	500	2.00	423	5.69E-01	8.41E-01	7.05E-01	7.05E-01
WWIN-2005-0597	11737002	7121243	500	2.00	423	5.69E-01	8.41E-01	7.05E-01	7.05E-01
WWIN-2013-0013	11720456	7120031	960	4.00	837	5.70E-01	8.60E-01	7.15E-01	7.15E-01
WWIN-2006-0067	11724478	7107696	620	2.50	531	5.60E-01	8.80E-01	7.20E-01	7.20E-01
WWTS-2006-0388	11722086	7121199	620	2.50	531	5.60E-01	8.80E-01	7.20E-01	7.20E-01
WWIN-1997-0212	11732270	7109317	600	2.50	513	5.90E-01	8.80E-01	7.35E-01	7.35E-01
WWIN-2001-0386	11737828	7116367	600	2.50	513	5.90E-01	8.80E-01	7.35E-01	7.35E-01
WWIN-2014-0083	11734524	7108553	600	2.50	513	5.90E-01	8.80E-01	7.35E-01	7.35E-01
WWIN-2016-0168	11719287	7122874	700	3.00	603	6.00E-01	8.90E-01	7.45E-01	7.45E-01
WWIN-2017-0078	11718735	7119373	700	3.00	603	6.00E-01	8.90E-01	7.45E-01	7.45E-01
WWIN-2001-0375	11719642	7112732	700	3.00	603	6.00E-01	8.90E-01	7.45E-01	7.45E-01
WWIN-2001-0615	11740443	7129648	700	3.00	603	6.00E-01	8.90E-01	7.45E-01	7.45E-01
WWIN-2006-0676	11744126	7120582	700	3.00	603	6.00E-01	8.90E-01	7.45E-01	7.45E-01
WWTS-2001-0525	11722765	7110110	700	3.00	603	6.00E-01	8.90E-01	7.45E-01	7.45E-01
WWIR-2003-0262	11738515	7105043	800	3.50	693	6.10E-01	9.10E-01	7.60E-01	7.60E-01
WWIN-2014-0135	11725146	7122686	700	3.20	603	6.20E-01	9.10E-01	7.65E-01	7.65E-01
WWTS-2001-0651	11721806	7106714	580	2.50	495	6.15E-01	9.27E-01	7.71E-01	7.71E-01
WWIN-2005-0519	11736697	7121521	680	3.00	585	6.20E-01	9.30E-01	7.75E-01	7.75E-01
WWTS-1990-0200	11739357	7121275	465	2.00	392	6.27E-01	9.30E-01	7.79E-01	7.79E-01
WWIN-2004-0010	11739973	7118342	660	3.00	567	6.40E-01	9.60E-01	8.00E-01	8.00E-01
WWIN-2021-0026	11720549	7104583	860	4.00	747	6.50E-01	9.66E-01	8.08E-01	8.08E-01
WWIN-1992-0159	11734926	7116539	440	2.00	369	6.60E-01	9.80E-01	8.20E-01	8.20E-01

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Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWTS-1999-0254	11734953	7102571	600	2.75	513	6.60E-01	9.83E-01	8.22E-01	8.22E-01
WWTS-2001-0657	11722016	7105836	640	3.00	549	6.60E-01	9.90E-01	8.25E-01	8.25E-01
WWTS-2005-0685	11720406	7123195	635	3.00	545	6.70E-01	1.00E+00	8.35E-01	8.35E-01
WWIN-2001-0474	11738177	7104419	825	4.00	716	6.90E-01	1.00E+00	8.45E-01	8.45E-01
WWIN-2013-0189	11724063	7112589	620	3.00	531	6.90E-01	1.03E+00	8.60E-01	8.60E-01
WWTS-2002-0082	11728507	7114884	620	3.00	531	6.90E-01	1.03E+00	8.60E-01	8.60E-01
WWIN-2004-0099	11737726	7105626	1000	5.00	873	7.10E-01	1.05E+00	8.80E-01	8.80E-01
WWIN-2004-0261	11737691	7106477	1000	5.00	873	7.10E-01	1.05E+00	8.80E-01	8.80E-01
WWIN-2013-0121	11721081	7121952	1000	5.00	873	7.10E-01	1.05E+00	8.80E-01	8.80E-01
WWTS-2006-0265	11719330	7120093	700	3.50	603	7.19E-01	1.06E+00	8.90E-01	8.90E-01
WWIN-2020-0028	11719624	7104258	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWIN-1996-0161	11738893	7109217	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWIN-2004-0381	11720682	7119943	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWIN-2006-0428	11720054	7110096	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWIN-2010-0151	11727822	7108588	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWIN-2013-0089	11733221	7114851	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWIN-2014-0141	11735599	7107378	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWTS-2000-0314	11728610	7102588	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWTS-2001-0811	11723536	7112742	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWTS-2001-0818	11723090	7111699	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWTS-2006-0255	11718254	7118169	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWTS-2006-0372	11718650	7122866	600	3.00	513	7.25E-01	1.07E+00	8.98E-01	8.98E-01
WWIN-2000-0102	11719606	7126351	500	2.50	423	7.34E-01	1.08E+00	9.07E-01	9.07E-01
WWIN-2004-0294	11723159	7111519	500	2.60	423	7.34E-01	1.08E+00	9.07E-01	9.07E-01
WWTS-1997-0210	11735557	7116083	400	2.00	333	7.48E-01	1.10E+00	9.24E-01	9.24E-01
WWTS-1988-0245	11720306	7121095	405	2.00	338	7.48E-01	1.10E+00	9.24E-01	9.24E-01
WWIN-1982-0124	11734764	7117230	425	2.00	est.330	7.48E-01	1.10E+00	9.24E-01	9.24E-01
WWIR-2004-0385	11732317	7127971	940	5.00	819	7.60E-01	1.11E+00	9.35E-01	9.35E-01
WWIN-2002-0098	11726432	7117720	580	3.00	495	7.60E-01	1.12E+00	9.40E-01	9.40E-01
WWIN-2002-0497	11735898	7103677	580	3.00	495	7.60E-01	1.12E+00	9.40E-01	9.40E-01
WWIN-2003-0001	11722389	7112679	1020	5.50	891	7.60E-01	1.14E+00	9.50E-01	9.50E-01
WWIN-2001-0047	11719692	7103635	520	2.75	441	7.78E-01	1.15E+00	9.64E-01	9.64E-01
WWIN-2013-0065	11718876	7120203	900	5.00	783	8.00E-01	1.19E+00	9.95E-01	9.95E-01
WWIN-2001-0562	11724004	7115696	500	2.75	423	8.25E-01	1.19E+00	1.01E+00	1.01E+00
WWTS-1999-0498	11737984	7105520	540	3.00	459	8.20E-01	1.20E+00	1.01E+00	1.01E+00
WWIN-2013-0108	11721298	7121192	880	5.00	765	8.20E-01	1.22E+00	1.02E+00	1.02E+00
WWTS-2001-0416	11718313	7106426	880	5.00	765	8.20E-01	1.22E+00	1.02E+00	1.02E+00
WWIN-1995-0172	11740254	7119693	620	3.50	531	8.30E-01	1.22E+00	1.03E+00	1.03E+00
WWIN-2017-0087	11719114	7115666	700	4.00	603	8.40E-01	1.22E+00	1.03E+00	1.03E+00
WWTS-2006-0033	11721932	7124800	700	4.00	603	8.40E-01	1.22E+00	1.03E+00	1.03E+00
WWCO-1986-0324	11736630	7114850	700	4.00	603	8.30E-01	1.23E+00	1.03E+00	1.03E+00
WWIN-2013-0006	11719968	7120915	860	5.00	747	8.40E-01	1.25E+00	1.05E+00	1.05E+00
WWIN-2020-0102	11739700	7130525	525	3.00	446	8.50E-01	1.25E+00	1.05E+00	1.05E+00
WWIN-2006-0822	11734508	7117853	920	1.00	801	1.20E-01	1.98E+00	1.05E+00	1.05E+00
WWTS-2001-0649	11721366	7106151	520	3.00	441	8.60E-01	1.27E+00	1.07E+00	1.07E+00
WWIN-2001-0563	11737395	7116429	600	3.50	513	8.60E-01	1.27E+00	1.07E+00	1.07E+00
WWTS-1998-0185	11737091	7102592	680	4.00	585	8.60E-01	1.27E+00	1.07E+00	1.07E+00
WWIN-2013-0218	11720300	7120095	840	5.00	729	8.60E-01	1.28E+00	1.07E+00	1.07E+00
WWIN-2001-0470	11736925	7102072	1000	6.00	873	8.70E-01	1.28E+00	1.08E+00	1.08E+00
WWIN-2002-0235	11722197	7113151	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWIN-1997-0216	11741411	7118784	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-1998-0410	11735963	7118934	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWIN-1999-0176	11739644	7117443	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWIN-2000-0104	11723976	7124539	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWIN-2002-0038	11722629	7113016	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWIN-2002-0234	11722486	7112376	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWTS-2000-0694	11741267	7121367	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWTS-2002-0430	11736702	7121367	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWTS-2006-0385	11720616	7121809	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWTS-2006-0623	11727902	7115494	500	3.00	423	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWIN-2013-0021	11720582	7120110	900	5.50	783	8.90E-01	1.32E+00	1.11E+00	1.11E+00
WWIN-2019-0221	11737347	7112704	800	5.00	693	9.20E-01	1.36E+00	1.14E+00	1.14E+00
WWIN-2021-0009	11719200	7117911	800	5.00	693	9.20E-01	1.36E+00	1.14E+00	1.14E+00
WWIN-2000-0344	11736072	7102081	800	5.00	693	9.20E-01	1.36E+00	1.14E+00	1.14E+00
WWIN-2004-0104	11718797	7111968	800	5.00	693	9.20E-01	1.36E+00	1.14E+00	1.14E+00
WWIN-2004-0271	11741545	7121608	800	5.00	693	9.20E-01	1.36E+00	1.14E+00	1.14E+00
WWIN-2006-0078	11718098	7106531	800	5.00	693	9.20E-01	1.36E+00	1.14E+00	1.14E+00
WWIN-2006-0474	11734621	7107067	800	5.00	693	9.20E-01	1.36E+00	1.14E+00	1.14E+00
WWIN-2002-0232	11729036	7112009	480	3.00	405	9.50E-01	1.38E+00	1.17E+00	1.17E+00
WWIN-1996-0267	11734441	7117619	500	3.00	405	9.50E-01	1.38E+00	1.17E+00	1.17E+00
WWIN-2013-0095	11719961	7120136	780	5.00	675	9.50E-01	1.39E+00	1.17E+00	1.17E+00
WWIN-2019-0119	11739662	7128889	625	4.00	536	9.60E-01	1.40E+00	1.18E+00	1.18E+00
WWIN-2020-0104	11739188	7130509	625	4.00	536	9.60E-01	1.40E+00	1.18E+00	1.18E+00
WWIN-2003-0488	11730391	7119890	775	5.00	671	9.50E-01	1.41E+00	1.18E+00	1.18E+00
WWIN-2003-0490	11718632	7130534	400	2.50	333	9.65E-01	1.42E+00	1.19E+00	1.19E+00
WWIN-2001-0943	11722984	7105910	760	5.00	657	9.80E-01	1.44E+00	1.21E+00	1.21E+00
WWTS-2005-0687	11719750	7125570	460	3.00	387	9.90E-01	1.45E+00	1.22E+00	1.22E+00
WWIN-2001-0384	11724132	7110599	600	4.00	513	1.00E+00	1.48E+00	1.24E+00	1.24E+00
WWTS-2005-0692	11720971	7123011	600	4.00	513	1.00E+00	1.48E+00	1.24E+00	1.24E+00
WWIN-2002-0596	11720310	7113781	600	4.25	513	1.00E+00	1.48E+00	1.24E+00	1.24E+00
WWIN-1997-0167	11723803	7125031	570	4.00	486	1.06E+00	1.55E+00	1.31E+00	1.31E+00
WWIN-1997-0168	11724325	7125292	570	4.00	486	1.06E+00	1.55E+00	1.31E+00	1.31E+00
WWIN-1986-0339	11734921	7116313	560	4.00	484	1.06E+00	1.57E+00	1.32E+00	1.32E+00
WWIR-2020-0025	11736928	7103509	560	4.00	477	1.08E+00	1.57E+00	1.33E+00	1.33E+00
WWIN-1998-0112	11736361	7119199	700	5.00	603	1.07E+00	1.58E+00	1.33E+00	1.33E+00
WWIN-2002-0207	11731948	7103524	700	5.00	603	1.07E+00	1.58E+00	1.33E+00	1.33E+00
WWIN-2004-0632	11741319	7120878	700	5.00	603	1.07E+00	1.58E+00	1.33E+00	1.33E+00
WWIN-2006-0169	11721630	7105132	700	5.00	603	1.07E+00	1.58E+00	1.33E+00	1.33E+00
WWIN-2013-0049	11720126	7121307	700	5.00	603	1.07E+00	1.58E+00	1.33E+00	1.33E+00
WWIN-2014-0117	11730244	7114878	700	5.00	603	1.07E+00	1.58E+00	1.33E+00	1.33E+00
WWTS-2005-0609	11722212	7123866	700	5.00	603	1.07E+00	1.58E+00	1.33E+00	1.33E+00
WWTS-2013-0101	11741842	7113133	700	5.00	603	1.07E+00	1.58E+00	1.33E+00	1.33E+00
WWIN-2016-0128	11723161	7112078	700	5.20	603	1.08E+00	1.57E+00	1.33E+00	1.33E+00
WWIN-2016-0118	11723078	7113070	680	5.20	585	1.10E+00	1.61E+00	1.36E+00	1.36E+00
WWTS-2006-0333	11722333	7121035	680	5.00	585	1.10E+00	1.62E+00	1.36E+00	1.36E+00
WWIN-2013-0002	11719452	7121110	680	5.00	585	1.10E+00	1.62E+00	1.36E+00	1.36E+00
WWIN-2001-0469	11737662	7102841	420	3.00	351	1.11E+00	1.62E+00	1.37E+00	1.37E+00
WWIN-2011-0137	11718325	7107060	420	3.00	351	1.11E+00	1.62E+00	1.37E+00	1.37E+00
WWTS-1989-0022	11718100	7124416	410	3.00	342	1.13E+00	1.64E+00	1.39E+00	1.39E+00
WWIN-2001-0048	11719381	7103813	480	3.50	405	1.13E+00	1.64E+00	1.39E+00	1.39E+00
WWIN-2003-0099	11734523	7107564	800	6.00	693	1.13E+00	1.67E+00	1.40E+00	1.40E+00
WWIN-2017-0001	11728448	7114009	660	5.00	567	1.15E+00	1.68E+00	1.42E+00	1.42E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWTS-2002-0084	11729752	7115678	460	3.50	387	1.19E+00	1.72E+00	1.46E+00	1.46E+00
WWTS-2002-0087	11728812	7115047	460	3.50	387	1.19E+00	1.72E+00	1.46E+00	1.46E+00
WWTS-2005-0697	11721394	7123870	400	3.00	333	1.19E+00	1.73E+00	1.46E+00	1.46E+00
WWIN-2021-0029	11743350	7112314	640	5.00	549	1.20E+00	1.74E+00	1.47E+00	1.47E+00
WWIN-1997-0249	11734457	7105963	640	5.00	549	1.20E+00	1.74E+00	1.47E+00	1.47E+00
WWIN-2013-0187	11721645	7121052	640	5.00	549	1.20E+00	1.74E+00	1.47E+00	1.47E+00
WWTS-2006-0264	11719531	7119975	640	5.00	549	1.20E+00	1.74E+00	1.47E+00	1.47E+00
WWIN-2018-0208	11740633	7128972	500	4.00	423	1.24E+00	1.80E+00	1.52E+00	1.52E+00
WWIN-2019-0208	11726294	7117998	500	4.00	423	1.24E+00	1.80E+00	1.52E+00	1.52E+00
WWIN-2000-0337	11738098	7102076	500	4.00	423	1.24E+00	1.80E+00	1.52E+00	1.52E+00
WWTS-2000-0699	11741334	7122406	500	4.00	423	1.24E+00	1.80E+00	1.52E+00	1.52E+00
WWIN-2001-0062	11735688	7106383	620	5.00	531	1.25E+00	1.80E+00	1.53E+00	1.53E+00
WWIN-2013-0008	11719635	7120351	620	5.00	531	1.25E+00	1.80E+00	1.53E+00	1.53E+00
WWIN-2013-0151	11725106	7112654	620	5.00	531	1.25E+00	1.80E+00	1.53E+00	1.53E+00
WWIN-2008-0039	11719949	7128752	850	7.00	738	1.25E+00	1.80E+00	1.53E+00	1.53E+00
WWTS-1999-0496	11738635	7104658	560	4.50	477	1.29E+00	1.80E+00	1.55E+00	1.55E+00
WWIN-1998-0115	11736734	7117015	620	5.00	522	1.27E+00	1.83E+00	1.55E+00	1.55E+00
WWIN-2001-0036	11720625	7102868	380	3.00	315	1.27E+00	1.84E+00	1.56E+00	1.56E+00
WWTS-1997-0415	11724851	7124655	380	3.00	315	1.27E+00	1.84E+00	1.56E+00	1.56E+00
WWIN-2016-0191	11729209	7114902	600	5.00	513	1.29E+00	1.87E+00	1.58E+00	1.58E+00
WWIN-2019-0194	11725648	7124446	600	5.00	513	1.29E+00	1.87E+00	1.58E+00	1.58E+00
WWIN-1996-0160	11737571	7112350	600	5.00	513	1.29E+00	1.87E+00	1.58E+00	1.58E+00
WWIN-2000-0816	11731101	7130697	600	5.00	513	1.29E+00	1.87E+00	1.58E+00	1.58E+00
WWIN-2002-0483	11727721	7102887	600	5.00	513	1.29E+00	1.87E+00	1.58E+00	1.58E+00
WWIN-2014-0154	11724851	7112507	600	5.00	513	1.29E+00	1.87E+00	1.58E+00	1.58E+00
WWTS-2006-0345	11718832	7122811	600	5.00	513	1.29E+00	1.87E+00	1.58E+00	1.58E+00
WWIN-1999-0170	11721740	7113557	480	4.00	405	1.30E+00	1.88E+00	1.59E+00	1.59E+00
WWTS-1997-0399	11724058	7125650	420	3.50	351	1.31E+00	1.91E+00	1.61E+00	1.61E+00
WWTS-2000-0304	11719709	7103008	425	3.50	356	1.31E+00	1.91E+00	1.61E+00	1.61E+00
WWTS-2000-0306	11719162	7103429	425	3.50	356	1.31E+00	1.91E+00	1.61E+00	1.61E+00
WWIN-2006-0511	11742451	7120020	700	6.00	603	1.32E+00	1.91E+00	1.62E+00	1.62E+00
WWTS-1988-0284	11727961	7114037	305	2.50	248	1.34E+00	1.91E+00	1.63E+00	1.63E+00
WWIN-1987-0361	11734244	7115978	320	2.80	est. 270	1.34E+00	1.95E+00	1.65E+00	1.65E+00
WWIN-2006-0724	11744131	7120098	800	7.00	693	1.35E+00	1.96E+00	1.66E+00	1.66E+00
WWIN-2016-0195	11722042	7121159	680	6.00	585	1.36E+00	1.97E+00	1.67E+00	1.67E+00
WWIN-1999-0255	11734805	7102319	680	6.00	585	1.36E+00	1.97E+00	1.67E+00	1.67E+00
WWDH-1997-0170	11723114	7124351	560	5.00	477	1.40E+00	2.01E+00	1.71E+00	1.71E+00
WWIN-2020-0015	11743244	7111543	520	5.10	441	1.22E+00	2.20E+00	1.71E+00	1.71E+00
WWIN-1999-0234	11727367	7106327	550	5.00	468	1.43E+00	2.06E+00	1.75E+00	1.75E+00
WWCO-1989-0328	11735791	7114720	500	4.50	423	1.44E+00	2.07E+00	1.76E+00	1.76E+00
WWIN-2013-0146	11744233	7121245	700	6.50	603	1.45E+00	2.07E+00	1.76E+00	1.76E+00
WWIN-1999-0177	11735909	7113810	540	5.00	459	1.46E+00	2.11E+00	1.79E+00	1.79E+00
WWIN-2010-0035	11721756	7118487	540	5.00	459	1.46E+00	2.11E+00	1.79E+00	1.79E+00
WWIN-2012-0123	11719863	7120753	540	5.00	459	1.46E+00	2.11E+00	1.79E+00	1.79E+00
WWTS-1988-0246	11719955	7121284	540	5.00	459	1.46E+00	2.11E+00	1.79E+00	1.79E+00
WWIN-2014-0077	11730107	7115695	640	6.00	549	1.47E+00	2.10E+00	1.79E+00	1.79E+00
WWIN-2013-0232	11721677	7120265	800	7.50	693	1.47E+00	2.10E+00	1.79E+00	1.79E+00
WWIN-2000-0315	11724774	7106174	700	5.50	603	1.48E+00	2.11E+00	1.80E+00	1.80E+00
WWIN-2004-0218	11741398	7115976	700	5.50	603	1.48E+00	2.11E+00	1.80E+00	1.80E+00
WWIN-2017-0150	11723539	7112274	580	5.50	495	1.51E+00	2.16E+00	1.84E+00	1.84E+00
WWIN-1998-0033	11718139	7126018	525	5.00	446	1.52E+00	2.16E+00	1.84E+00	1.84E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2005-0507	11727831	7108760	525	5.00	446	1.52E+00	2.16E+00	1.84E+00	1.84E+00
WWIN-2001-0618	11735998	7106429	425	4.00	356	1.51E+00	2.19E+00	1.85E+00	1.85E+00
WWTS-2002-0077	11729193	7113926	425	4.00	356	1.51E+00	2.19E+00	1.85E+00	1.85E+00
WWIN-1998-0120	11735049	7123209	520	5.00	441	1.50E+00	2.21E+00	1.86E+00	1.86E+00
WWIN-2000-0177	11721526	7113880	520	5.00	441	1.50E+00	2.21E+00	1.86E+00	1.86E+00
WWIN-2003-0283	11719867	7111899	520	5.00	441	1.50E+00	2.21E+00	1.86E+00	1.86E+00
WWIN-2013-0165	11732028	7118280	520	5.00	441	1.50E+00	2.21E+00	1.86E+00	1.86E+00
WWIN-2016-0115	11723344	7112747	720	7.00	621	1.51E+00	2.20E+00	1.86E+00	1.86E+00
WWIN-2015-0005	11730819	7114471	620	6.00	531	1.53E+00	2.19E+00	1.86E+00	1.86E+00
WWIN-1993-0267	11734785	7116529	600	6.00	529	1.52E+00	2.20E+00	1.86E+00	1.86E+00
WWTS-2006-0622	11728494	7116431	420	4.00	351	1.54E+00	2.19E+00	1.87E+00	1.87E+00
WWIN-2013-0094	11721830	7122048	560	5.50	477	1.57E+00	2.24E+00	1.91E+00	1.91E+00
WWIN-2013-0115	11722053	7120032	560	5.50	477	1.57E+00	2.24E+00	1.91E+00	1.91E+00
WWIN-2002-0476	11730322	7106378	700	7.00	603	1.58E+00	2.27E+00	1.93E+00	1.93E+00
WWIN-2004-0111	11718935	7104897	700	7.00	603	1.58E+00	2.27E+00	1.93E+00	1.93E+00
WWIN-2004-0114	11718331	7105134	700	7.00	603	1.58E+00	2.27E+00	1.93E+00	1.93E+00
WWIN-2006-0763	11743556	7120442	700	7.00	603	1.58E+00	2.27E+00	1.93E+00	1.93E+00
WWIN-2006-0768	11743755	7119241	700	7.00	603	1.58E+00	2.27E+00	1.93E+00	1.93E+00
WWTS-2005-0606	11719976	7122769	700	7.00	603	1.58E+00	2.27E+00	1.93E+00	1.93E+00
WWIN-2006-0715	11743939	7118885	800	8.00	693	1.60E+00	2.25E+00	1.93E+00	1.93E+00
WWIN-1995-0097	11740913	7119183	600	6.00	513	1.65E+00	2.23E+00	1.94E+00	1.94E+00
WWIN-1995-0255	11740268	7120031	600	6.00	513	1.65E+00	2.23E+00	1.94E+00	1.94E+00
WWIN-1999-0154	11720327	7112712	600	6.00	513	1.65E+00	2.23E+00	1.94E+00	1.94E+00
WWIN-2001-0601	11739523	7130864	600	6.00	513	1.65E+00	2.23E+00	1.94E+00	1.94E+00
WWIN-2001-0747	11722852	7109967	600	6.00	513	1.65E+00	2.23E+00	1.94E+00	1.94E+00
WWIN-2001-0912	11732104	7126321	600	6.00	513	1.65E+00	2.23E+00	1.94E+00	1.94E+00
WWIN-2002-0196	11718509	7117959	600	6.00	513	1.65E+00	2.23E+00	1.94E+00	1.94E+00
WWIN-2006-0819	11744341	7119659	600	6.00	513	1.65E+00	2.23E+00	1.94E+00	1.94E+00
WWIN-2018-0216	11740244	7128338	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-2019-0199	11719018	7123037	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-1996-0264	11724250	7124051	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-1997-0215	11735634	7120129	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-2001-0475	11738386	7104630	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-2001-0913	11720963	7113539	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-2005-0313	11736689	7120731	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-2005-0336	11724398	7127620	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-2005-0707	11743432	7103808	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-2006-0549	11731879	7102083	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIR-2007-0104	11737571	7102818	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWTS-2000-0721	11743754	7120270	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWTS-2001-0414	11718972	7104836	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWTS-2006-0227	11719523	7122408	500	5.00	423	1.61E+00	2.32E+00	1.97E+00	1.97E+00
WWIN-2000-0182	11735001	7116209	600	6.00	504	1.60E+00	2.34E+00	1.97E+00	1.97E+00
WWTS-1989-0012	11718053	7126468	390	4.00	324	1.66E+00	2.42E+00	2.04E+00	2.04E+00
WWIN-1999-0493	11738946	7103012	660	7.00	567	1.68E+00	2.41E+00	2.05E+00	2.05E+00
WWIN-2006-0537	11731712	7114201	580	6.00	495	1.66E+00	2.45E+00	2.06E+00	2.06E+00
WWIN-2013-0005	11720536	7121199	480	5.00	405	1.70E+00	2.43E+00	2.07E+00	2.07E+00
WWIN-2015-0037	11741677	7112811	560	6.20	477	1.71E+00	2.45E+00	2.08E+00	2.08E+00
WWIN-2000-0737	11737389	7102492	650	7.00	558	1.73E+00	2.44E+00	2.09E+00	2.09E+00
WWIN-2015-0022	11742048	7111337	560	6.00	477	1.74E+00	2.45E+00	2.10E+00	2.10E+00
WWIN-2015-0024	11741757	7112543	720	8.00	621	1.76E+00	2.50E+00	2.13E+00	2.13E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2013-0020	11719313	7119470	900	10.00	783	1.75E+00	2.51E+00	2.13E+00	2.13E+00
WWIN-1998-0460	11731339	7106140	460	5.00	387	1.77E+00	2.50E+00	2.14E+00	2.14E+00
WWIN-2006-0781	11720593	7115546	460	5.00	387	1.77E+00	2.50E+00	2.14E+00	2.14E+00
WWTS-1988-0247	11719812	7121408	460	5.00	387	1.77E+00	2.50E+00	2.14E+00	2.14E+00
WWTS-1998-0186	11736981	7102163	460	5.00	387	1.77E+00	2.50E+00	2.14E+00	2.14E+00
WWIN-2004-0272	11723395	7109363	550	6.00	468	1.75E+00	2.52E+00	2.14E+00	2.14E+00
WWTS-2005-0775	11741009	7128818	550	6.00	468	1.75E+00	2.52E+00	2.14E+00	2.14E+00
WWIN-2002-0238	11739845	7117970	540	6.00	459	1.78E+00	2.57E+00	2.18E+00	2.18E+00
WWIN-2012-0006	11719842	7129117	540	6.00	459	1.78E+00	2.57E+00	2.18E+00	2.18E+00
WWIN-2001-0666	11732133	7102274	500	5.50	423	1.81E+00	2.57E+00	2.19E+00	2.19E+00
WWTS-2002-0071	11729287	7115534	200	2.00	153	1.80E+00	2.60E+00	2.20E+00	2.20E+00
WWIN-2017-0054	11736614	7112193	700	8.00	603	1.80E+00	2.60E+00	2.20E+00	2.20E+00
WWIN-2020-0134	11739728	7131298	625	7.00	536	1.81E+00	2.60E+00	2.21E+00	2.21E+00
WWIN-1979-0160	11735046	7116726	300	3.00	225	1.84E+00	2.62E+00	2.23E+00	2.23E+00
WWIN-1986-0327	11734986	7117172	420	4.00	297	1.84E+00	2.62E+00	2.23E+00	2.23E+00
WWIR-2004-0384	11731206	7126905	1200	14.00	1053	1.83E+00	2.63E+00	2.23E+00	2.23E+00
WWIN-2005-0623	11724365	7126155	440	5.00	369	1.88E+00	2.68E+00	2.28E+00	2.28E+00
WWTS-2006-0834	11730107	7116098	440	5.00	369	1.88E+00	2.68E+00	2.28E+00	2.28E+00
WWIN-1997-0450	11734237	7122013	520	6.00	441	1.87E+00	2.69E+00	2.28E+00	2.28E+00
WWIN-2000-0081	11720213	7132579	525	6.00	446	1.87E+00	2.69E+00	2.28E+00	2.28E+00
WWIN-2021-0042	11720881	7109292	600	7.00	513	1.90E+00	2.70E+00	2.30E+00	2.30E+00
WWIN-2001-0606	11740448	7130752	600	7.00	513	1.90E+00	2.70E+00	2.30E+00	2.30E+00
WWIN-2003-0411	11733904	7106880	600	7.00	513	1.90E+00	2.70E+00	2.30E+00	2.30E+00
WWCO-1986-0326	11737094	7114904	605	7.00	518	1.93E+00	2.68E+00	2.31E+00	2.31E+00
WWIN-2001-0945	11722468	7113636	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWIN-2016-0117	11723611	7112645	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWIN-1998-0037	11717945	7125222	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWIN-2001-0009	11722551	7114112	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWIN-2001-0610	11740199	7131968	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWIN-2003-0484	11742170	7123506	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWTS-2000-0313	11728440	7102830	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWTS-2000-0698	11741916	7121915	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWTS-2005-0604	11720260	7122355	500	6.00	423	1.95E+00	2.81E+00	2.38E+00	2.38E+00
WWIN-2017-0013	11728656	7113719	420	5.00	351	2.00E+00	2.81E+00	2.41E+00	2.41E+00
WWIN-2018-0184	11732990	7102890	420	5.00	351	2.00E+00	2.81E+00	2.41E+00	2.41E+00
WWIN-1998-0036	11718281	7124881	420	5.00	351	2.00E+00	2.81E+00	2.41E+00	2.41E+00
WWIN-1999-0175	11739754	7118802	420	5.00	351	2.00E+00	2.81E+00	2.41E+00	2.41E+00
WWIN-2000-0318	11731319	7106994	420	5.00	351	2.00E+00	2.81E+00	2.41E+00	2.41E+00
WWTS-2002-0085	11726067	7116810	420	5.00	351	2.00E+00	2.81E+00	2.41E+00	2.41E+00
WWTS-2006-0335	11721723	7119837	420	5.00	351	2.00E+00	2.81E+00	2.41E+00	2.41E+00
WWIN-2001-0595	11740726	7131563	300	3.50	243	1.99E+00	2.83E+00	2.41E+00	2.41E+00
WWIN-1983-0115	11734102	7116299	365	4.00	312	1.77E+00	3.10E+00	2.44E+00	2.44E+00
WWIN-1984-0167	11734317	7117202	200	2.50	171	2.03E+00	2.88E+00	2.46E+00	2.46E+00
WWIN-1998-0059	11734261	7126034	560	7.00	477	2.04E+00	2.90E+00	2.47E+00	2.47E+00
WWIN-1998-0467	11734239	7125814	560	7.00	477	2.04E+00	2.90E+00	2.47E+00	2.47E+00
WWIN-2015-0078	11734675	7106280	560	7.00	477	2.04E+00	2.90E+00	2.47E+00	2.47E+00
WWTS-1990-0195	11741697	7119496	345	4.00	284	1.95E+00	3.00E+00	2.48E+00	2.48E+00
WWTS-2005-0610	11721721	7124618	600	7.50	513	2.04E+00	2.92E+00	2.48E+00	2.48E+00
WWIN-2013-0014	11719160	7119624	800	11.00	693	2.26E+00	2.75E+00	2.51E+00	2.51E+00
WWIN-2013-0014	11721338	7121388	800	11.00	693	2.26E+00	2.75E+00	2.51E+00	2.51E+00
WWIN-2006-0714	11743624	7119094	700	9.00	603	2.10E+00	2.97E+00	2.54E+00	2.54E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2006-0716	11729196	7111354	700	9.00	603	2.10E+00	2.97E+00	2.54E+00	2.54E+00
WWIN-2015-0028	11742061	7113148	400	5.20	333	2.11E+00	3.01E+00	2.56E+00	2.56E+00
WWIN-2021-0025	11720889	7104512	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWIN-1996-0162	11740376	7114956	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWIN-1999-0080	11720102	7132171	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWIN-1999-0171	11721182	7114338	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWIN-1999-0587	11729869	7127776	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWIN-2005-0045	11737072	7117319	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWIN-2012-0114	11719409	7129300	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWIN-2012-0121	11719503	7129211	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWTS-2005-0631	11728011	7105212	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWTS-2005-0691	11719664	7125282	400	5.00	333	2.11E+00	3.02E+00	2.57E+00	2.57E+00
WWTS-2001-0653	11722323	7106861	540	7.00	459	2.14E+00	3.02E+00	2.58E+00	2.58E+00
WWTS-2005-0785	11742093	7128705	500	6.50	423	2.14E+00	3.06E+00	2.60E+00	2.60E+00
WWIN-1999-0099	11724687	7125915	460	6.00	387	2.17E+00	3.09E+00	2.63E+00	2.63E+00
WWIN-1999-0101	11734183	7125678	460	6.00	387	2.17E+00	3.09E+00	2.63E+00	2.63E+00
WWIN-1999-0174	11737235	7116189	460	6.00	387	2.17E+00	3.09E+00	2.63E+00	2.63E+00
WWIN-2002-0237	11739221	7118076	800	10.00	693	2.40E+00	2.86E+00	2.63E+00	2.63E+00
WWIN-2013-0042	11718162	7119866	760	11.00	657	2.40E+00	2.90E+00	2.65E+00	2.65E+00
WWIN-1997-0166	11720062	7128973	385	5.00	320	2.20E+00	3.10E+00	2.65E+00	2.65E+00
WWIN-2002-0499	11743898	7105432	600	8.00	513	2.20E+00	3.10E+00	2.65E+00	2.65E+00
WWIN-1980-0148	11734273	7115873	325	3.00	194	2.19E+00	3.12E+00	2.66E+00	2.66E+00
WWIN-2019-0169	11726994	7117835	420	5.50	351	2.19E+00	3.13E+00	2.66E+00	2.66E+00
WWIN-2005-0228	11737792	7120958	420	5.50	351	2.19E+00	3.13E+00	2.66E+00	2.66E+00
WWIN-1997-0218	11740668	7120227	450	6.00	378	2.20E+00	3.16E+00	2.68E+00	2.68E+00
WWTS-2000-0710	11742696	7123064	450	6.00	378	2.20E+00	3.16E+00	2.68E+00	2.68E+00
WWIN-1996-0270	11741288	7109151	520	7.00	441	2.24E+00	3.15E+00	2.70E+00	2.70E+00
WWIN-2002-0239	11739781	7117898	520	7.00	441	2.24E+00	3.15E+00	2.70E+00	2.70E+00
WWIN-2013-0012	11718470	7119486	860	12.00	747	2.23E+00	3.20E+00	2.72E+00	2.72E+00
WWIN-1999-0492	11737479	7102056	440	6.00	369	2.30E+00	3.23E+00	2.77E+00	2.77E+00
WWIN-2001-0058	11736199	7105653	440	6.00	369	2.30E+00	3.23E+00	2.77E+00	2.77E+00
WWIN-2013-0167	11725101	7112395	440	6.00	369	2.30E+00	3.23E+00	2.77E+00	2.77E+00
WWTS-2006-0359	11718751	7119575	560	7.30	477	2.20E+00	3.35E+00	2.78E+00	2.78E+00
WWIN-2016-0064	11735054	7106560	500	7.00	423	2.34E+00	3.30E+00	2.82E+00	2.82E+00
WWIN-2018-0178	11723828	7111892	500	7.00	423	2.34E+00	3.30E+00	2.82E+00	2.82E+00
WWTS-2001-0900	11722443	7110418	500	7.00	423	2.34E+00	3.30E+00	2.82E+00	2.82E+00
WWTS-2005-0694	11721535	7122631	500	7.00	423	2.34E+00	3.30E+00	2.82E+00	2.82E+00
WWTS-2005-0696	11722345	7123042	500	7.00	423	2.34E+00	3.30E+00	2.82E+00	2.82E+00
WWTS-2013-0202	11741497	7112553	500	7.00	423	2.34E+00	3.30E+00	2.82E+00	2.82E+00
WWTS-2005-0777	11740610	7127371	300	4.00	243	2.33E+00	3.32E+00	2.83E+00	2.83E+00
WWIN-1996-0260	11718289	7114285	700	10.00	603	2.40E+00	3.30E+00	2.85E+00	2.85E+00
WWIN-2001-0063	11736414	7104820	700	10.00	603	2.40E+00	3.30E+00	2.85E+00	2.85E+00
WWTS-2006-0362	11720964	7120306	350	5.00	288	2.40E+00	3.49E+00	2.95E+00	2.95E+00
WWIN-2015-0128	11741135	7128029	480	7.00	405	2.45E+00	3.50E+00	2.98E+00	2.98E+00
WWIN-1998-0087	11719111	7110074	420	6.00	351	2.50E+00	3.46E+00	2.98E+00	2.98E+00
WWIN-1999-0100	11724502	7124979	420	6.00	351	2.50E+00	3.46E+00	2.98E+00	2.98E+00
WWIN-2000-0175	11724166	7112170	420	6.00	351	2.50E+00	3.46E+00	2.98E+00	2.98E+00
WWIN-2001-0037	11719143	7102863	420	6.00	351	2.50E+00	3.46E+00	2.98E+00	2.98E+00
WWTS-1999-0577	11735129	7102017	420	6.00	351	2.50E+00	3.46E+00	2.98E+00	2.98E+00
WWTS-2001-0655	11722309	7106428	420	6.00	351	2.50E+00	3.46E+00	2.98E+00	2.98E+00
WWTS-2006-0383	11719924	7119845	420	6.00	351	2.50E+00	3.46E+00	2.98E+00	2.98E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2004-0269	11722179	7113235	540	8.00	459	2.48E+00	3.50E+00	2.99E+00	2.99E+00
WWIN-2016-0129	11723437	7112786	540	8.00	459	2.48E+00	3.50E+00	2.99E+00	2.99E+00
WWIN-2013-0133	11721419	7106971	600	9.00	513	2.50E+00	3.56E+00	3.03E+00	3.03E+00
WWIN-2012-0124	11719293	7121037	460	7.00	387	2.56E+00	3.61E+00	3.09E+00	3.09E+00
WWIN-2021-0079	11720302	7104970	400	6.00	333	2.60E+00	3.63E+00	3.12E+00	3.12E+00
WWIN-2001-0071	11734869	7103027	400	6.00	333	2.60E+00	3.63E+00	3.12E+00	3.12E+00
WWIN-2006-0459	11728123	7127101	400	6.00	333	2.60E+00	3.63E+00	3.12E+00	3.12E+00
WWIN-2006-0572	11722764	7112169	400	6.00	333	2.60E+00	3.63E+00	3.12E+00	3.12E+00
WWTS-2000-0688	11743138	7124286	400	6.00	333	2.60E+00	3.63E+00	3.12E+00	3.12E+00
WWIN-2021-0002	11718526	7117751	640	10.00	549	2.60E+00	3.70E+00	3.15E+00	3.15E+00
WWIN-1996-0266	11740475	7120235	640	10.00	549	2.60E+00	3.70E+00	3.15E+00	3.15E+00
WWIN-1979-0303	11719754	7117773	300	4.50	243	2.62E+00	3.72E+00	3.17E+00	3.17E+00
WWIN-2017-0100	11740968	7130964	500	8.00	423	2.70E+00	3.80E+00	3.25E+00	3.25E+00
WWIN-2000-0108	11724479	7125578	500	8.00	423	2.70E+00	3.80E+00	3.25E+00	3.25E+00
WWIN-2002-0477	11728436	7102018	500	8.00	423	2.70E+00	3.80E+00	3.25E+00	3.25E+00
WWIN-2003-0261	11730666	7105890	500	8.00	423	2.70E+00	3.80E+00	3.25E+00	3.25E+00
WWIN-2006-0759	11718232	7106263	500	8.00	423	2.70E+00	3.80E+00	3.25E+00	3.25E+00
WWTS-2005-0605	11719823	7122701	500	8.00	423	2.70E+00	3.80E+00	3.25E+00	3.25E+00
WWIN-2004-0569	11742051	7120400	620	10.00	531	2.70E+00	3.80E+00	3.25E+00	3.25E+00
WWIN-2001-0391	11739536	7117870	440	7.00	369	2.70E+00	3.83E+00	3.27E+00	3.27E+00
WWIN-2017-0033	11729439	7115103	500	8.10	423	2.70E+00	3.83E+00	3.27E+00	3.27E+00
WWIN-2000-0642	11718775	7129352	380	6.00	315	2.76E+00	3.89E+00	3.33E+00	3.33E+00
WWTS-1999-0499	11736577	7105894	380	6.00	315	2.76E+00	3.89E+00	3.33E+00	3.33E+00
WWTS-1988-0241	11718596	7119725	520	8.50	441	2.75E+00	3.90E+00	3.33E+00	3.33E+00
WWTS-2002-0657	11736199	7121104	725	12.00	626	2.80E+00	3.90E+00	3.35E+00	3.35E+00
WWIN-1998-0053	11734598	7125028	320	5.00	261	2.78E+00	3.93E+00	3.36E+00	3.36E+00
WWIN-2005-0356	11737392	7121267	320	5.00	261	2.78E+00	3.93E+00	3.36E+00	3.36E+00
WWTS-2006-0624	11727736	7115984	320	5.00	261	2.78E+00	3.93E+00	3.36E+00	3.36E+00
WWIN-2002-0236	11735407	7123404	600	10.00	513	2.80E+00	4.00E+00	3.40E+00	3.40E+00
WWTS-2006-0829	11730634	7116072	600	10.00	513	2.80E+00	4.00E+00	3.40E+00	3.40E+00
WWIN-2013-0076	11720262	7121751	400	6.50	333	2.84E+00	4.00E+00	3.42E+00	3.42E+00
WWIN-1996-0303	11733952	7105719	340	5.50	279	2.83E+00	4.03E+00	3.43E+00	3.43E+00
WWIN-2001-0043	11719896	7102023	420	7.00	351	2.88E+00	4.07E+00	3.48E+00	3.48E+00
WWTS-2006-0334	11721973	7119472	420	7.00	351	2.88E+00	4.07E+00	3.48E+00	3.48E+00
WWIN-2005-0711	11743745	7120411	700	12.00	603	2.90E+00	4.08E+00	3.49E+00	3.49E+00
WWTS-2006-0830	11730564	7116500	580	10.00	495	2.90E+00	4.10E+00	3.50E+00	3.50E+00
WWIN-1991-0191	11734393	7116556	360	5.50	272	2.95E+00	4.20E+00	3.58E+00	3.58E+00
WWIN-2013-0032	11718223	7119696	840	15.00	729	3.00E+00	4.20E+00	3.60E+00	3.60E+00
WWIN-1996-0262	11718956	7110426	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWIN-2000-0111	11734200	7126933	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWIN-2000-0338	11738445	7103428	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWIN-2000-0817	11731243	7102486	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWIN-2003-0053	11722793	7111381	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWTS-2005-0522	11728643	7104807	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWTS-2005-0629	11728413	7105319	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWTS-2005-0630	11727972	7104685	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWTS-2005-0767	11740979	7127493	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWTS-2006-0344	11719263	7122896	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWTS-2006-0347	11719176	7122682	300	5.00	243	3.00E+00	4.22E+00	3.61E+00	3.61E+00
WWTS-2006-0371	11722597	7121435	560	10.00	477	3.05E+00	4.30E+00	3.68E+00	3.68E+00
WWIN-2019-0118	11742931	7112111	400	7.00	333	3.10E+00	4.30E+00	3.70E+00	3.70E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWTS-2000-0727	11743861	7121095	400	7.00	333	3.10E+00	4.30E+00	3.70E+00	3.70E+00
WWIN-1999-0173	11727269	7113660	500	9.00	423	3.10E+00	4.30E+00	3.70E+00	3.70E+00
WWIN-1998-0058	11736094	7124871	340	6.00	279	3.10E+00	4.36E+00	3.73E+00	3.73E+00
WWIN-2016-0159	11737250	7108330	440	8.00	369	3.20E+00	4.40E+00	3.80E+00	3.80E+00
WWIN-1997-0248	11733969	7104189	440	8.00	369	3.20E+00	4.40E+00	3.80E+00	3.80E+00
WWIN-2001-0476	11737099	7105857	440	8.00	369	3.20E+00	4.40E+00	3.80E+00	3.80E+00
WWIN-2018-0083	11740382	7128394	250	5.00	198	2.37E+00	5.24E+00	3.81E+00	3.81E+00
WWIN-2013-0190	11724496	7112976	460	8.50	387	3.20E+00	4.50E+00	3.85E+00	3.85E+00
WWIN-1996-0261	11718851	7113837	640	12.00	549	3.20E+00	4.50E+00	3.85E+00	3.85E+00
WWIN-2001-0839	11723397	7109838	640	12.00	549	3.20E+00	4.50E+00	3.85E+00	3.85E+00
WWTS-1990-0197	11741162	7119712	305	5.50	248	3.25E+00	4.53E+00	3.89E+00	3.89E+00
WWTS-1997-0443	11724346	7126529	280	5.00	225	3.25E+00	4.54E+00	3.90E+00	3.90E+00
WWIN-2003-0489	11722871	7109070	525	10.00	446	3.30E+00	4.60E+00	3.95E+00	3.95E+00
WWTS-2006-0435	11718707	7120747	525	10.00	446	3.30E+00	4.60E+00	3.95E+00	3.95E+00
WWIN-2020-0116	11739588	7130757	625	12.00	536	3.36E+00	4.59E+00	3.98E+00	3.98E+00
WWIN-1991-0055	11734133	7124986	240	5.00	189	2.47E+00	5.50E+00	3.99E+00	3.99E+00
WWTS-2000-0707	11742535	7120762	300	5.50	243	3.31E+00	4.67E+00	3.99E+00	3.99E+00
WWIN-2000-0319	11720570	7105086	420	8.00	351	3.35E+00	4.70E+00	4.03E+00	4.03E+00
WWIN-2005-0518	11737137	7121225	320	6.00	261	3.40E+00	4.78E+00	4.09E+00	4.09E+00
WWIN-2006-0064	11736524	7121850	320	6.00	261	3.40E+00	4.78E+00	4.09E+00	4.09E+00
WWIN-1999-0090	11723951	7125414	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWIN-2003-0194	11742627	7116425	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWIN-2004-0092	11720178	7115526	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWIN-2005-0787	11743061	7122852	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWIN-2005-0789	11743629	7122258	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWIN-2006-0519	11742508	7119802	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWTS-2005-0607	11719954	7122994	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWTS-2005-0608	11721216	7122345	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWTS-2005-0683	11719854	7123195	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWTS-2005-0699	11719492	7123422	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWTS-2006-0346	11718503	7121294	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWTS-2006-0386	11718590	7120419	500	10.00	423	3.50E+00	4.80E+00	4.15E+00	4.15E+00
WWTS-1989-0011	11719021	7126002	270	5.00	216	3.44E+00	4.88E+00	4.16E+00	4.16E+00
WWIN-2001-0908	11721923	7114321	400	8.00	333	3.50E+00	5.00E+00	4.25E+00	4.25E+00
WWIN-2015-0127	11741181	7128264	720	15.00	621	3.60E+00	4.90E+00	4.25E+00	4.25E+00
WWIN-2002-0484	11728043	7103189	350	7.00	288	3.55E+00	5.02E+00	4.29E+00	4.29E+00
WWIN-1991-0183	11730242	7125465	440	9.00	369	3.60E+00	5.00E+00	4.30E+00	4.30E+00
WWIN-2018-0123	11723632	7107084	260	5.00	207	3.50E+00	5.12E+00	4.31E+00	4.31E+00
WWTS-2002-0096	11728230	7115839	260	5.00	207	3.50E+00	5.12E+00	4.31E+00	4.31E+00
WWIN-2001-0593	11740982	7128288	300	6.00	243	3.70E+00	5.10E+00	4.40E+00	4.40E+00
WWTS-2000-0307	11720228	7103340	300	6.00	243	3.70E+00	5.10E+00	4.40E+00	4.40E+00
WWIN-2001-0598	11741362	7132425	300	6.00	243	3.70E+00	5.10E+00	4.40E+00	4.40E+00
WWIN-2001-0600	11739611	7132050	300	6.00	243	3.70E+00	5.10E+00	4.40E+00	4.40E+00
WWIN-2001-0608	11739943	7132339	300	6.00	243	3.70E+00	5.10E+00	4.40E+00	4.40E+00
WWIN-2001-0752	11720287	7103060	300	6.00	243	3.70E+00	5.10E+00	4.40E+00	4.40E+00
WWTS-2000-0687	11719938	7103459	300	6.00	243	3.70E+00	5.10E+00	4.40E+00	4.40E+00
WWTS-2013-0162	11741343	7112703	300	6.00	243	3.70E+00	5.10E+00	4.40E+00	4.40E+00
WWIN-1981-0174	11734626	7117434	240	4.00	160	3.72E+00	5.10E+00	4.41E+00	4.41E+00
WWIN-1997-0171	11723419	7124408	320	6.50	261	3.72E+00	5.17E+00	4.45E+00	4.45E+00
WWTS-2005-0703	11721891	7123030	475	10.00	401	3.70E+00	5.20E+00	4.45E+00	4.45E+00
WWIN-2001-0471	11736331	7102103	700	15.00	603	3.70E+00	5.20E+00	4.45E+00	4.45E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2006-0708	11743628	7119581	700	15.00	603	3.70E+00	5.20E+00	4.45E+00	4.45E+00
WWTS-2001-0418	11718181	7105484	340	7.00	279	3.72E+00	5.25E+00	4.49E+00	4.49E+00
WWIN-2013-0112	11721567	7121861	600	13.00	513	3.80E+00	5.27E+00	4.54E+00	4.54E+00
WWIN-2004-0172	11734772	7108068	420	9.00	351	3.80E+00	5.30E+00	4.55E+00	4.55E+00
WWIN-2015-0029	11742462	7112093	680	15.00	585	3.80E+00	5.30E+00	4.55E+00	4.55E+00
WWTS-2006-0364	11721235	7121524	420	9.50	351	3.80E+00	5.40E+00	4.60E+00	4.60E+00
WWIN-2013-0001	11719284	7121189	460	10.00	387	3.80E+00	5.40E+00	4.60E+00	4.60E+00
WWIN-2015-0113	11741840	7127813	720	17.00	621	3.50E+00	5.70E+00	4.60E+00	4.60E+00
WWTS-2005-0779	11739436	7131968	300	6.50	243	3.95E+00	5.58E+00	4.77E+00	4.77E+00
WWIN-2014-0209	11723983	7112317	340	7.30	279	4.00E+00	5.60E+00	4.80E+00	4.80E+00
WWIN-2019-0217	11729106	7127197	440	10.00	369	4.05E+00	5.60E+00	4.83E+00	4.83E+00
WWIN-1998-0131	11736138	7119256	440	10.00	369	4.05E+00	5.60E+00	4.83E+00	4.83E+00
WWIN-2017-0141	11728331	7115347	400	8.70	333	4.07E+00	5.60E+00	4.84E+00	4.84E+00
WWIN-2002-0037	11721547	7112606	320	7.00	261	4.07E+00	5.65E+00	4.86E+00	4.86E+00
WWIN-2004-0060	11738618	7105275	400	9.00	333	4.07E+00	5.66E+00	4.87E+00	4.87E+00
WWIN-2007-0105	11737413	7102756	358	8.00	295	4.07E+00	5.70E+00	4.89E+00	4.89E+00
WWIN-2017-0181	11740383	7106693	640	15.00	549	4.10E+00	5.70E+00	4.90E+00	4.90E+00
WWIN-2007-0287	11743228	7116175	350	8.00	288	4.10E+00	5.80E+00	4.95E+00	4.95E+00
WWTS-2005-0774	11741885	7130372	350	8.00	288	4.10E+00	5.80E+00	4.95E+00	4.95E+00
WWTS-2005-0786	11741802	7129561	350	8.00	288	4.10E+00	5.80E+00	4.95E+00	4.95E+00
WWTS-1989-0023	11718792	7125229	270	6.00	216	4.20E+00	5.75E+00	4.98E+00	4.98E+00
WWIN-1989-0337	11734043	7115698	505	11.70	428	4.10E+00	5.90E+00	5.00E+00	5.00E+00
WWTS-1988-0282	11725900	7114905	305	7.00	248	4.30E+00	5.90E+00	5.10E+00	5.10E+00
WWIN-2015-0102	11729287	7115515	620	15.00	531	4.30E+00	5.90E+00	5.10E+00	5.10E+00
WWIN-2005-0198	11719130	7130610	340	8.00	279	4.30E+00	6.00E+00	5.15E+00	5.15E+00
WWIN-1996-0213	11720630	7126762	380	9.00	315	4.30E+00	6.00E+00	5.15E+00	5.15E+00
WWIN-1999-0578	11737833	7102932	420	10.00	351	4.30E+00	6.00E+00	5.15E+00	5.15E+00
WWIN-2001-0044	11720152	7102226	420	10.00	351	4.30E+00	6.00E+00	5.15E+00	5.15E+00
WWIN-2001-0472	11735013	7102972	420	10.00	351	4.30E+00	6.00E+00	5.15E+00	5.15E+00
WWIN-2003-0013	11730828	7102795	420	10.00	351	4.30E+00	6.00E+00	5.15E+00	5.15E+00
WWTS-2006-0268	11718202	7120592	420	10.00	351	4.30E+00	6.00E+00	5.15E+00	5.15E+00
WWTS-2005-0681	11721456	7123576	500	12.00	423	4.30E+00	6.04E+00	5.17E+00	5.17E+00
WWIN-1986-0226	11737220	7128743	300	7.00	243	4.40E+00	6.00E+00	5.20E+00	5.20E+00
WWIN-2001-0385	11721724	7113421	300	7.00	243	4.40E+00	6.00E+00	5.20E+00	5.20E+00
WWTS-2001-0819	11723401	7112010	300	7.00	243	4.40E+00	6.00E+00	5.20E+00	5.20E+00
WWTS-2005-0768	11740826	7128597	300	7.00	243	4.40E+00	6.00E+00	5.20E+00	5.20E+00
WWIN-2003-0098	11732164	7108188	800	20.00	693	4.40E+00	6.00E+00	5.20E+00	5.20E+00
WWIN-2007-0009	11743526	7120938	600	15.00	513	4.40E+00	6.20E+00	5.30E+00	5.30E+00
WWTS-2006-0260	11717957	7118329	600	15.00	513	4.40E+00	6.20E+00	5.30E+00	5.30E+00
WWIN-1997-0094	11741689	7119397	400	10.00	333	4.50E+00	6.30E+00	5.40E+00	5.40E+00
WWIN-2000-0080	11718693	7131867	400	10.00	333	4.50E+00	6.30E+00	5.40E+00	5.40E+00
WWIN-2001-0389	11737516	7115370	400	10.00	333	4.50E+00	6.30E+00	5.40E+00	5.40E+00
WWIN-2005-0077	11723945	7108145	400	10.00	333	4.50E+00	6.30E+00	5.40E+00	5.40E+00
WWIN-2006-0301	11744259	7121391	400	10.00	333	4.50E+00	6.30E+00	5.40E+00	5.40E+00
WWIN-2006-0818	11744214	7118684	400	10.00	333	4.50E+00	6.30E+00	5.40E+00	5.40E+00
WWIN-2009-0073	11729407	7125568	400	10.00	333	4.50E+00	6.30E+00	5.40E+00	5.40E+00
WWTS-2006-0331	11722891	7120301	480	12.00	405	4.50E+00	6.30E+00	5.40E+00	5.40E+00
WWIN-2004-0603	11740955	7121615	580	15.00	495	4.60E+00	6.40E+00	5.50E+00	5.50E+00
WWIN-2001-0039	11719322	7103386	280	7.00	225	4.70E+00	6.48E+00	5.59E+00	5.59E+00
WWTS-2001-0648	11721470	7105666	280	7.00	225	4.70E+00	6.48E+00	5.59E+00	5.59E+00
WWTS-2006-0370	11722727	7120988	320	8.00	261	4.70E+00	6.50E+00	5.60E+00	5.60E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-1999-0494	11738267	7102293	320	8.00	261	4.70E+00	6.50E+00	5.60E+00	5.60E+00
WWTS-2006-0628	11729390	7116387	320	8.00	261	4.70E+00	6.50E+00	5.60E+00	5.60E+00
WWIN-1998-0175	11734896	7104130	380	10.00	315	4.80E+00	6.70E+00	5.75E+00	5.75E+00
WWIN-2001-0603	11739334	7131604	550	15.00	468	4.90E+00	6.80E+00	5.85E+00	5.85E+00
WWIN-2021-0076	11720235	7104895	340	9.00	279	4.90E+00	6.87E+00	5.89E+00	5.89E+00
WWIN-2001-0390	11739194	7115706	440	12.00	369	5.00E+00	6.90E+00	5.95E+00	5.95E+00
WWIN-2001-0478	11736068	7106322	440	12.00	369	5.00E+00	6.90E+00	5.95E+00	5.95E+00
WWTS-1997-0398	11724683	7126345	270	7.00	216	5.00E+00	6.98E+00	5.99E+00	5.99E+00
WWIN-1997-0409	11719221	7108362	300	8.00	243	5.00E+00	7.00E+00	6.00E+00	6.00E+00
WWIN-1999-0075	11718601	7132957	300	8.00	243	5.00E+00	7.00E+00	6.00E+00	6.00E+00
WWIN-2001-0014	11740247	7116036	300	8.00	243	5.00E+00	7.00E+00	6.00E+00	6.00E+00
WWIN-2003-0002	11719895	7102206	300	8.00	243	5.00E+00	7.00E+00	6.00E+00	6.00E+00
WWTS-2002-0429	11736539	7122134	300	8.00	243	5.00E+00	7.00E+00	6.00E+00	6.00E+00
WWTS-2006-0361	11720796	7120603	300	8.00	243	5.00E+00	7.00E+00	6.00E+00	6.00E+00
WWTS-2013-0173	11742939	7112333	700	19.00	603	5.10E+00	6.90E+00	6.00E+00	6.00E+00
WWCO-1986-0325	11736180	7114817	605	20.00	518	5.10E+00	7.00E+00	6.05E+00	6.05E+00
WWIN-2000-0117	11743065	7127744	500	14.00	423	5.10E+00	7.10E+00	6.10E+00	6.10E+00
WWIN-2013-0113	11721952	7121588	600	17.00	513	5.10E+00	7.10E+00	6.10E+00	6.10E+00
WWIN-2019-0092	11726219	7132786	700	20.00	603	5.10E+00	7.10E+00	6.10E+00	6.10E+00
WWIN-2006-0320	11718693	7116761	700	20.00	603	5.10E+00	7.10E+00	6.10E+00	6.10E+00
WWIN-2006-0453	11736954	7121827	860	25.00	747	5.10E+00	7.10E+00	6.10E+00	6.10E+00
WWTS-2000-0311	11727879	7102141	425	12.00	356	5.20E+00	7.20E+00	6.20E+00	6.20E+00
WWIR-2008-0181	11723492	7110404	525	15.00	446	5.20E+00	7.20E+00	6.20E+00	6.20E+00
WWIN-2005-0186	11722690	7113071	520	15.00	441	5.30E+00	7.20E+00	6.25E+00	6.25E+00
WWIN-1999-0094	11724308	7124563	320	9.00	261	5.30E+00	7.30E+00	6.30E+00	6.30E+00
WWIN-2006-0778	11720738	7115941	320	9.00	261	5.30E+00	7.30E+00	6.30E+00	6.30E+00
WWIN-1995-0289	11722912	7125312	420	12.00	351	5.30E+00	7.30E+00	6.30E+00	6.30E+00
WWIN-2001-0038	11719220	7103139	420	12.00	351	5.30E+00	7.30E+00	6.30E+00	6.30E+00
WWIN-2001-0750	11718101	7130266	420	12.00	351	5.30E+00	7.30E+00	6.30E+00	6.30E+00
WWTS-2001-0417	11718450	7105811	420	12.00	351	5.30E+00	7.30E+00	6.30E+00	6.30E+00
WWIN-2015-0032	11742420	7111312	480	14.00	405	5.30E+00	7.40E+00	6.35E+00	6.35E+00
WWIN-2015-0114	11741690	7129268	580	17.00	495	5.30E+00	7.40E+00	6.35E+00	6.35E+00
WWIN-1998-0174	11733428	7103511	350	10.00	288	5.40E+00	7.40E+00	6.40E+00	6.40E+00
WWIN-1997-0404	11743043	7103773	500	15.00	423	5.50E+00	7.60E+00	6.55E+00	6.55E+00
WWIN-2003-0464	11741673	7122871	500	15.00	423	5.50E+00	7.60E+00	6.55E+00	6.55E+00
WWIN-2004-0110	11718649	7103944	500	15.00	423	5.50E+00	7.60E+00	6.55E+00	6.55E+00
WWIN-2004-0128	11742961	7124619	500	15.00	423	5.50E+00	7.60E+00	6.55E+00	6.55E+00
WWIN-2004-0439	11742848	7121388	500	15.00	423	5.50E+00	7.60E+00	6.55E+00	6.55E+00
WWIN-2005-0710	11743230	7121077	500	15.00	423	5.50E+00	7.60E+00	6.55E+00	6.55E+00
WWIN-1981-0168	11734123	7117747	240	7.60	209	5.60E+00	7.60E+00	6.60E+00	6.60E+00
WWIN-2000-0114	11737159	7126012	340	10.00	279	5.50E+00	7.70E+00	6.60E+00	6.60E+00
WWIN-2012-0028	11725093	7111374	340	10.00	279	5.50E+00	7.70E+00	6.60E+00	6.60E+00
WWTS-2006-0836	11729498	7116867	340	10.00	279	5.50E+00	7.70E+00	6.60E+00	6.60E+00
WWIN-2020-0002	11727280	7116807	400	12.00	333	5.60E+00	7.60E+00	6.60E+00	6.60E+00
WWIN-1998-0032	11718835	7126092	400	12.00	333	5.60E+00	7.60E+00	6.60E+00	6.60E+00
WWIN-2005-0788	11743453	7122510	400	12.00	333	5.60E+00	7.60E+00	6.60E+00	6.60E+00
WWIN-2015-0053	11724733	7112745	400	12.00	333	5.60E+00	7.60E+00	6.60E+00	6.60E+00
WWTS-1990-0198	11740790	7120277	305	9.00	248	5.60E+00	7.75E+00	6.68E+00	6.68E+00
WWIN-2002-0420	11718520	7113255	300	9.00	243	5.70E+00	7.86E+00	6.78E+00	6.78E+00
WWIN-2005-0159	11728914	7102467	300	9.00	243	5.70E+00	7.86E+00	6.78E+00	6.78E+00
WWTS-2001-0814	11724101	7112874	300	9.00	243	5.70E+00	7.86E+00	6.78E+00	6.78E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2004-0042	11742132	7116024	480	15.00	405	5.80E+00	7.90E+00	6.85E+00	6.85E+00
WWIN-2005-0201	11744291	7121928	480	15.00	405	5.80E+00	7.90E+00	6.85E+00	6.85E+00
WWIN-2002-0437	11738830	7111890	500	16.00	423	5.80E+00	8.10E+00	6.95E+00	6.95E+00
WWIN-2013-0234	11742764	7112384	620	19.00	531	5.90E+00	8.10E+00	7.00E+00	7.00E+00
WWIN-1998-0489	11741511	7107331	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWIN-2004-0089	11717931	7113143	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWIN-2004-0550	11721316	7104026	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWTS-2005-0690	11719639	7124846	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWTS-2006-0258	11718847	7121144	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWTS-2006-0337	11717928	7123080	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWTS-2006-0357	11719376	7120243	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWTS-2006-0365	11720939	7121308	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWTS-2006-0369	11721743	7121439	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWTS-2006-0384	11719870	7120360	320	10.00	261	5.98E+00	8.20E+00	7.09E+00	7.09E+00
WWTS-2001-0424	11718329	7104668	260	8.00	207	6.00E+00	8.20E+00	7.10E+00	7.10E+00
WWTS-2002-0089	11727119	7116866	260	8.00	207	6.00E+00	8.20E+00	7.10E+00	7.10E+00
WWIN-1999-0241	11742131	7103693	380	12.00	315	5.90E+00	8.30E+00	7.10E+00	7.10E+00
WWTS-2005-0701	11719829	7123981	550	18.00	468	6.00E+00	8.30E+00	7.15E+00	7.15E+00
WWIN-1992-0236	11734197	7115567	400	12.00	305	6.00E+00	8.40E+00	7.20E+00	7.20E+00
WWTS-2005-0784	11742201	7129450	600	19.25	513	6.10E+00	8.30E+00	7.20E+00	7.20E+00
WWIN-2001-0012	11740503	7116675	600	20.00	513	6.10E+00	8.40E+00	7.25E+00	7.25E+00
WWIN-1998-0176	11734940	7104819	280	9.00	225	6.30E+00	8.60E+00	7.45E+00	7.45E+00
WWIN-1995-0207	11735001	7120443	305	10.00	248	6.25E+00	8.70E+00	7.48E+00	7.48E+00
WWIN-2018-0226	11729588	7125134	360	12.00	297	6.40E+00	8.60E+00	7.50E+00	7.50E+00
WWIN-1998-0139	11743030	7108320	360	12.00	297	6.40E+00	8.60E+00	7.50E+00	7.50E+00
WWIN-2007-0061	11720253	7111200	360	12.00	297	6.40E+00	8.60E+00	7.50E+00	7.50E+00
WWTS-1999-0569	11739506	7103784	360	12.00	297	6.40E+00	8.60E+00	7.50E+00	7.50E+00
WWIN-1998-0137	11743655	7109626	440	15.00	369	6.40E+00	8.80E+00	7.60E+00	7.60E+00
WWIN-2004-0440	11742624	7122021	440	15.00	369	6.40E+00	8.80E+00	7.60E+00	7.60E+00
WWTS-1988-0283	11726005	7115575	220	7.00	171	6.38E+00	8.87E+00	7.63E+00	7.63E+00
WWIN-1996-0265	11733853	7124349	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-1989-0209	11725473	7129575	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-1998-0039	11718441	7125697	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2000-0327	11735082	7103377	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2001-0260	11720325	7131660	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2001-0599	11742683	7132047	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2001-0605	11741178	7131240	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2001-0625	11743180	7124286	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2002-0257	11732227	7104928	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2004-0592	11724875	7131823	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2006-0135	11718882	7106221	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWTS-2000-0703	11740975	7122821	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWTS-2000-0728	11741422	7123531	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWTS-2001-0419	11718566	7103597	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWTS-2002-0433	11736504	7120855	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWTS-2006-0085	11720081	7121925	300	10.00	243	6.40E+00	8.90E+00	7.65E+00	7.65E+00
WWIN-2001-0624	11743840	7124019	350	12.00	288	6.50E+00	8.90E+00	7.70E+00	7.70E+00
WWTS-1997-0397	11724381	7126023	325	11.00	266	6.53E+00	8.90E+00	7.72E+00	7.72E+00
WWIN-1999-0093	11724698	7126242	320	11.00	261	6.64E+00	9.10E+00	7.87E+00	7.87E+00
WWIN-2005-0381	11727637	7105818	400	14.00	333	6.70E+00	9.10E+00	7.90E+00	7.90E+00
WWIN-2003-0302	11726829	7129510	500	18.00	423	6.70E+00	9.10E+00	7.90E+00	7.90E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2017-0034	11729568	7114992	340	12.00	279	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-1996-0299	11738760	7107091	340	12.00	279	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-1997-0220	11742081	7107937	340	12.00	279	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-1999-0092	11724382	7126334	340	12.00	279	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2001-0011	11740364	7117211	340	12.00	279	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2003-0292	11720132	7112188	340	12.00	279	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2013-0191	11724711	7112960	340	12.00	279	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-1999-0708	11721188	7113552	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-1999-0710	11742208	7118539	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2016-0124	11721697	7104652	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2019-0053	11734474	7106078	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2001-0060	11736350	7106630	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2001-0840	11722566	7109503	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2006-0877	11738434	7115126	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWIN-2008-0091	11724927	7130220	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWTS-2006-0270	11718547	7122277	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWTS-2006-0356	11718885	7120300	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWTS-2006-0360	11718392	7119323	420	15.00	351	6.80E+00	9.30E+00	8.05E+00	8.05E+00
WWTS-2011-0008	11734646	7116983	540	20.00	459	6.90E+00	9.50E+00	8.20E+00	8.20E+00
WWIN-2015-0001	11725907	7122807	540	20.00	459	6.90E+00	9.50E+00	8.20E+00	8.20E+00
WWIN-2018-0228	11729507	7125820	360	12.50	297	6.90E+00	9.67E+00	8.29E+00	8.29E+00
WWIN-1980-0383	11741746	7118843	205	7.00	158	7.30E+00	9.70E+00	8.50E+00	8.50E+00
WWIN-2010-0144	11734580	7117044	520	20.00	441	7.20E+00	9.80E+00	8.50E+00	8.50E+00
WWIN-2015-0025	11741978	7112288	520	20.00	441	7.20E+00	9.80E+00	8.50E+00	8.50E+00
WWIN-1996-0008	11722924	7125487	400	15.00	333	7.20E+00	9.90E+00	8.55E+00	8.55E+00
WWIN-2002-0386	11730646	7127258	400	15.00	333	7.20E+00	9.90E+00	8.55E+00	8.55E+00
WWIN-2004-0318	11742378	7115765	400	15.00	333	7.20E+00	9.90E+00	8.55E+00	8.55E+00
WWIN-2013-0064	11724311	7111443	400	15.00	333	7.20E+00	9.90E+00	8.55E+00	8.55E+00
WWIN-2013-0111	11721929	7121795	400	15.00	333	7.20E+00	9.90E+00	8.55E+00	8.55E+00
WWIN-2005-0745	11717976	7110392	640	25.00	549	7.20E+00	9.90E+00	8.55E+00	8.55E+00
WWTS-2005-0770	11741957	7127828	200	7.00	153	7.30E+00	1.00E+01	8.65E+00	8.65E+00
WWIN-1996-0271	11741407	7108974	320	12.00	261	7.40E+00	9.90E+00	8.65E+00	8.65E+00
WWIN-2001-0396	11744017	7107200	320	12.00	261	7.40E+00	9.90E+00	8.65E+00	8.65E+00
WWTS-2013-0120	11742492	7111875	320	12.00	261	7.40E+00	9.90E+00	8.65E+00	8.65E+00
WWIN-2000-0183	11741637	7111675	500	20.00	423	7.50E+00	1.00E+01	8.75E+00	8.75E+00
WWIN-2003-0171	11737266	7105657	500	20.00	423	7.50E+00	1.00E+01	8.75E+00	8.75E+00
WWIN-2003-0440	11741920	7123856	500	20.00	423	7.50E+00	1.00E+01	8.75E+00	8.75E+00
WWIN-2004-0348	11718378	7103862	500	20.00	423	7.50E+00	1.00E+01	8.75E+00	8.75E+00
WWIN-2004-0443	11742700	7122174	500	20.00	423	7.50E+00	1.00E+01	8.75E+00	8.75E+00
WWIN-2004-0630	11722751	7106068	500	20.00	423	7.50E+00	1.00E+01	8.75E+00	8.75E+00
WWTS-2006-0831	11730883	7116369	620	25.00	531	7.50E+00	1.00E+01	8.75E+00	8.75E+00
WWIN-2017-0139	11728461	7115392	380	15.00	315	7.60E+00	1.00E+01	8.80E+00	8.80E+00
WWIN-2021-0046	11737192	7111158	495	20.00	419	7.70E+00	1.00E+01	8.85E+00	8.85E+00
WWIN-1998-0125	11739461	7119666	240	9.00	189	7.50E+00	1.04E+01	8.95E+00	8.95E+00
WWIN-2021-0077	11720364	7104726	400	16.00	333	7.80E+00	1.05E+01	9.15E+00	9.15E+00
WWIN-2013-0003	11738068	7103131	400	16.00	333	7.80E+00	1.05E+01	9.15E+00	9.15E+00
WWIN-2006-0413	11737009	7121670	260	10.00	207	7.70E+00	1.10E+01	9.35E+00	9.35E+00
WWTS-2001-0652	11721874	7107011	260	10.00	207	7.70E+00	1.10E+01	9.35E+00	9.35E+00
WWTS-2006-0366	11721327	7121213	260	10.00	207	7.70E+00	1.10E+01	9.35E+00	9.35E+00
WWIN-1978-0185	11734477	7117606	300	12.00	243	7.80E+00	1.10E+01	9.40E+00	9.40E+00
WWIN-2019-0235	11739720	7130084	300	12.00	243	7.80E+00	1.10E+01	9.40E+00	9.40E+00

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-1998-0046	11730345	7128585	300	12.00	243	7.80E+00	1.10E+01	9.40E+00	9.40E+00
WWTS-2000-0705	11742197	7122846	300	12.00	243	7.80E+00	1.10E+01	9.40E+00	9.40E+00
WWIN-2004-0441	11743054	7120610	480	20.00	405	7.90E+00	1.10E+01	9.45E+00	9.45E+00
WWIN-2004-0466	11742750	7121172	480	20.00	405	7.90E+00	1.10E+01	9.45E+00	9.45E+00
WWIN-2014-0078	11729248	7116031	480	20.00	405	7.90E+00	1.10E+01	9.45E+00	9.45E+00
WWTS-2005-0765	11740378	7130986	200	7.50	153	8.00E+00	1.10E+01	9.50E+00	9.50E+00
WWIN-1998-0086	11718042	7113403	360	15.00	297	8.10E+00	1.10E+01	9.55E+00	9.55E+00
WWIN-1998-0113	11736000	7118808	360	15.00	297	8.10E+00	1.10E+01	9.55E+00	9.55E+00
WWIN-2003-0077	11730039	7118189	360	15.00	297	8.10E+00	1.10E+01	9.55E+00	9.55E+00
WWTS-1999-0501	11739015	7104923	360	15.00	297	8.10E+00	1.10E+01	9.55E+00	9.55E+00
WWIN-2001-0387	11739167	7117261	340	13.50	279	8.10E+00	1.11E+01	9.60E+00	9.60E+00
WWIN-1998-0116	11736834	7117337	460	20.00	387	8.30E+00	1.10E+01	9.65E+00	9.65E+00
WWIN-2004-0147	11742078	7121652	460	20.00	387	8.30E+00	1.10E+01	9.65E+00	9.65E+00
WWIN-2004-0638	11726094	7113695	460	20.00	387	8.30E+00	1.10E+01	9.65E+00	9.65E+00
WWIN-2007-0028	11744283	7127754	460	20.00	387	8.30E+00	1.10E+01	9.65E+00	9.65E+00
WWIN-2017-0102	11742949	7116134	350	15.00	288	8.40E+00	1.10E+01	9.70E+00	9.70E+00
WWIN-2002-0306	11739206	7104857	350	15.00	288	8.40E+00	1.10E+01	9.70E+00	9.70E+00
WWIN-2004-0542	11743195	7105497	350	15.00	288	8.40E+00	1.10E+01	9.70E+00	9.70E+00
WWIN-2001-0329	11727833	7126915	560	25.00	477	8.40E+00	1.10E+01	9.70E+00	9.70E+00
WWTS-1988-0240	11718346	7120237	205	9.00	158	6.98E+00	1.27E+01	9.84E+00	9.84E+00
WWTS-1988-0248	11722260	7119929	285	12.00	230	8.40E+00	1.15E+01	9.95E+00	9.95E+00
WWTS-1988-0281	11725552	7115570	200	8.00	153	8.60E+00	1.16E+01	1.01E+01	1.01E+01
WWTS-2000-0715	11743957	7122506	300	13.00	243	8.60E+00	1.18E+01	1.02E+01	1.02E+01
WWTS-2002-0083	11729447	7114806	245	10.00	194	8.43E+00	1.20E+01	1.02E+01	1.02E+01
WWIN-2001-0041	11719840	7102703	280	12.00	225	8.60E+00	1.20E+01	1.03E+01	1.03E+01
WWTS-2001-0650	11721590	7106291	280	12.00	225	8.60E+00	1.20E+01	1.03E+01	1.03E+01
WWIN-2000-0328	11735008	7103670	550	25.00	468	8.60E+00	1.20E+01	1.03E+01	1.03E+01
WWIN-1997-0484	11737988	7107207	340	15.00	279	8.80E+00	1.20E+01	1.04E+01	1.04E+01
WWIN-2017-0074	11723690	7128506	340	15.00	279	8.80E+00	1.20E+01	1.04E+01	1.04E+01
WWIN-2018-0017	11728141	7115778	340	15.00	279	8.80E+00	1.20E+01	1.04E+01	1.04E+01
WWIN-2004-0036	11718937	7112504	340	15.00	279	8.80E+00	1.20E+01	1.04E+01	1.04E+01
WWIN-2005-0022	11738389	7102841	340	15.00	279	8.80E+00	1.20E+01	1.04E+01	1.04E+01
WWIN-2014-0057	11725122	7113244	340	15.00	279	8.80E+00	1.20E+01	1.04E+01	1.04E+01
WWIN-2014-0213	11724997	7122191	340	15.00	279	8.80E+00	1.20E+01	1.04E+01	1.04E+01
WWIN-2004-0035	11718319	7112609	400	18.00	333	8.80E+00	1.20E+01	1.04E+01	1.04E+01
WWTS-2006-0416	11722328	7120819	660	30.00	567	9.00E+00	1.20E+01	1.05E+01	1.05E+01
WWIN-2002-0040	11742933	7104302	525	25.00	446	9.20E+00	1.20E+01	1.06E+01	1.06E+01
WWIN-1998-0177	11734937	7104274	260	12.00	207	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWIN-2004-0200	11725497	7104503	300	14.00	243	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWIN-2017-0106	11721198	7105125	320	15.00	261	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWIN-2001-0394	11741641	7115728	320	15.00	261	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWIN-2004-0124	11721956	7104966	320	15.00	261	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWIN-2012-0147	11719849	7127689	320	15.00	261	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWTS-1999-0665	11736228	7106289	320	15.00	261	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWTS-2000-0305	11719472	7102272	320	15.00	261	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWTS-2006-0332	11721465	7122145	320	15.00	261	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWIN-2001-0059	11737289	7106579	420	20.00	351	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWTS-1999-0637	11721544	7114060	420	20.00	351	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWTS-2006-0330	11718784	7122226	420	20.00	351	9.30E+00	1.30E+01	1.12E+01	1.12E+01
WWIN-1997-0211	11732046	7111912	220	10.00	171	9.51E+00	1.30E+01	1.13E+01	1.13E+01
WWIN-1991-0349	11720623	7107286	310	15.00	252	9.80E+00	1.30E+01	1.14E+01	1.14E+01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2019-0003	11727790	7117120	400	20.00	333	9.90E+00	1.30E+01	1.15E+01	1.15E+01
WWIN-1998-0362	11736306	7118662	400	20.00	333	9.90E+00	1.30E+01	1.15E+01	1.15E+01
WWIN-2005-0722	11742574	7122737	400	20.00	333	9.90E+00	1.30E+01	1.15E+01	1.15E+01
WWIN-2012-0002	11731677	7102407	400	20.00	333	9.90E+00	1.30E+01	1.15E+01	1.15E+01
WWIN-2014-0210	11721886	7117897	240	11.60	189	1.00E+01	1.30E+01	1.15E+01	1.15E+01
WWIN-2004-0458	11742054	7121042	500	25.00	423	1.00E+01	1.30E+01	1.15E+01	1.15E+01
WWIN-2004-0570	11742594	7121627	500	25.00	423	1.00E+01	1.30E+01	1.15E+01	1.15E+01
WWTS-2005-0698	11721413	7124785	500	25.00	423	1.00E+01	1.30E+01	1.15E+01	1.15E+01
WWTS-2005-0700	11718964	7123392	500	25.00	423	1.00E+01	1.30E+01	1.15E+01	1.15E+01
WWIN-2019-0102	11735270	7119039	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-2020-0004	11726776	7118078	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-1999-0082	11718604	7124998	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-1999-0091	11724171	7125973	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-1999-0095	11730085	7126253	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-2001-0590	11740631	7129211	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-2001-0591	11741948	7130659	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-2001-0607	11741011	7130459	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-2004-0066	11726426	7132224	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-2006-0512	11724017	7108360	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-2010-0017	11735164	7105900	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-2014-0155	11724943	7112173	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWTS-2000-0706	11741836	7123127	300	15.00	243	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWTS-2001-0056	11733733	7102226	380	20.00	315	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWTS-2006-0838	11729782	7117228	380	20.00	315	1.00E+01	1.40E+01	1.20E+01	1.20E+01
WWIN-1998-0128	11732275	7127340	225	11.00	176	1.02E+01	1.40E+01	1.21E+01	1.21E+01
WWIN-1998-0128	11732275	7127343	225	11.00	176	1.02E+01	1.40E+01	1.21E+01	1.21E+01
WWIN-2020-0034	11720215	7104916	240	12.00	189	1.04E+01	1.40E+01	1.22E+01	1.22E+01
WWIN-1999-0242	11742361	7103250	240	12.00	189	1.04E+01	1.40E+01	1.22E+01	1.22E+01
WWIN-2001-0739	11732528	7102969	240	12.00	189	1.04E+01	1.40E+01	1.22E+01	1.22E+01
WWIN-2012-0093	11725981	7109397	340	18.00	279	1.10E+01	1.40E+01	1.25E+01	1.25E+01
WWIN-2015-0110	11724574	7111648	340	18.00	279	1.10E+01	1.40E+01	1.25E+01	1.25E+01
WWTS-2005-0689	11719234	7125036	460	25.00	387	1.10E+01	1.40E+01	1.25E+01	1.25E+01
WWIN-2009-0042	11723313	7132465	200	10.00	153	1.09E+01	1.50E+01	1.30E+01	1.30E+01
WWTS-2006-0263	11719589	7119485	260	13.50	207	1.11E+01	1.49E+01	1.30E+01	1.30E+01
WWIN-1997-0213	11732085	7121235	280	15.00	225	1.10E+01	1.50E+01	1.30E+01	1.30E+01
WWIN-2001-0647	11726018	7106477	280	15.00	225	1.10E+01	1.50E+01	1.30E+01	1.30E+01
WWIN-2015-0023	11742127	7111793	280	15.00	225	1.10E+01	1.50E+01	1.30E+01	1.30E+01
WWTS-2002-0091	11727162	7118177	280	15.00	225	1.10E+01	1.50E+01	1.30E+01	1.30E+01
WWIN-1998-0108	11724683	7122559	360	20.00	297	1.10E+01	1.50E+01	1.30E+01	1.30E+01
WWIN-2001-0013	11740655	7116384	360	20.00	297	1.10E+01	1.50E+01	1.30E+01	1.30E+01
WWIN-1996-0159	11741074	7111001	440	25.00	369	1.10E+01	1.50E+01	1.30E+01	1.30E+01
WWIN-2015-0004	11730495	7115375	440	25.00	369	1.10E+01	1.50E+01	1.30E+01	1.30E+01
WWIN-2001-0015	11739925	7116164	320	18.00	261	1.20E+01	1.50E+01	1.35E+01	1.35E+01
WWIN-1998-0124	11737398	7115814	220	12.00	171	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2002-0133	11724921	7102493	220	12.00	171	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWTS-2005-0909	11719932	7125736	220	12.00	171	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-1996-0302	11733363	7105899	260	15.00	207	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-1998-0170	11742682	7103085	260	15.00	207	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-1999-0235	11724027	7108920	260	15.00	207	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWTS-2002-0092	11727537	7117859	260	15.00	207	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWTS-2006-0839	11729262	7117049	260	15.00	207	1.20E+01	1.60E+01	1.40E+01	1.40E+01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2001-0040	11719467	7103120	340	20.00	279	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2001-0734	11736211	7106392	340	20.00	279	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2015-0109	11725050	7111595	340	20.00	279	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2007-0079	11731650	7118360	420	25.00	351	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2003-0260	11741802	7122330	500	30.00	423	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2004-0442	11743145	7122025	500	30.00	423	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2006-0236	11743277	7120425	500	30.00	423	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWTS-2005-0782	11742701	7130627	500	30.00	423	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2003-0282	11741181	7122270	660	40.00	567	1.20E+01	1.60E+01	1.40E+01	1.40E+01
WWIN-2004-0323	11729966	7126434	300	18.00	243	1.20E+01	1.70E+01	1.45E+01	1.45E+01
WWTS-2001-0422	11718397	7104360	300	18.00	243	1.20E+01	1.70E+01	1.45E+01	1.45E+01
WWIN-2000-0690	11743728	7124370	300	18.50	243	1.20E+01	1.70E+01	1.45E+01	1.45E+01
WWIN-2013-0201	11741695	7112565	480	30.00	405	1.20E+01	1.70E+01	1.45E+01	1.45E+01
WWTS-2000-0308	11720106	7102718	250	15.00	198	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWIN-2017-0171	11720938	7104799	320	20.00	261	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWIN-2001-0046	11720573	7102370	320	20.00	261	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWIN-2004-0349	11724128	7127683	320	20.00	261	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWTS-2001-0055	11733628	7102701	320	20.00	261	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWTS-2006-0257	11718181	7120946	320	20.00	261	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWTS-2006-0835	11729392	7116717	320	20.00	261	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWIN-2020-0114	11739629	7130208	325	20.00	266	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWIN-2004-0138	11740865	7121102	400	25.00	333	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWIN-2005-0222	11744050	7122371	400	25.00	333	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWTS-2013-0172	11742549	7112809	400	25.00	333	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWTS-2002-0090	11726058	7117909	460	30.00	387	1.30E+01	1.70E+01	1.50E+01	1.50E+01
WWIN-1996-0400	11728937	7129318	200	12.00	153	1.30E+01	1.80E+01	1.55E+01	1.55E+01
WWIN-1998-0030	11718491	7130566	200	12.00	153	1.30E+01	1.80E+01	1.55E+01	1.55E+01
WWIN-2002-0482	11727914	7102534	200	12.00	153	1.30E+01	1.80E+01	1.55E+01	1.55E+01
WWTS-1988-0286	11727548	7114964	200	12.00	153	1.30E+01	1.80E+01	1.55E+01	1.55E+01
WWTS-1990-0192	11739257	7121090	285	18.00	230	1.30E+01	1.80E+01	1.55E+01	1.55E+01
WWIN-2004-0139	11742362	7122124	380	25.00	315	1.30E+01	1.80E+01	1.55E+01	1.55E+01
WWTS-2006-0229	11718877	7121866	300	20.00	243	1.40E+01	1.80E+01	1.60E+01	1.60E+01
WWIN-2013-0135	11742093	7107967	305	20.00	248	1.40E+01	1.80E+01	1.60E+01	1.60E+01
WWIN-2004-0148	11741909	7121411	440	30.00	369	1.40E+01	1.80E+01	1.60E+01	1.60E+01
WWIN-2015-0034	11742757	7110860	440	30.00	369	1.40E+01	1.80E+01	1.60E+01	1.60E+01
WWIN-2015-0038	11742278	7113184	440	30.00	369	1.40E+01	1.80E+01	1.60E+01	1.60E+01
WWIN-2011-0089	11726477	7103719	580	40.00	495	1.40E+01	1.80E+01	1.60E+01	1.60E+01
WWIN-2004-0496	11717956	7129840	240	16.00	189	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-1998-0117	11735943	7117413	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-1997-0217	11738896	7112822	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-1999-0169	11719915	7117366	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2000-0934	11720800	7113859	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2001-0938	11740174	7115819	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2002-0630	11723617	7110695	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2004-0065	11725776	7131828	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2004-0503	11718110	7104988	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2005-0335	11719491	7129809	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2007-0275	11743033	7116525	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWTS-2000-0696	11741641	7121867	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWTS-2005-0628	11727772	7104738	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWTS-2005-0693	11720854	7124226	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWTS-2005-0773	11742188	7131013	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-1998-0117	11735838	7117483	300	20.00	243	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-1996-0269	11741303	7110466	360	26.00	297	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2001-0061	11736677	7106374	420	30.00	351	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-2001-0477	11736619	7106288	420	30.00	351	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWTS-2002-0088	11727270	7116455	420	30.00	351	1.40E+01	1.90E+01	1.65E+01	1.65E+01
WWIN-1996-0003	11719026	7130005	360	25.00	297	1.40E+01	2.00E+01	1.70E+01	1.70E+01
WWTS-2006-0837	11729782	7116640	360	25.00	297	1.40E+01	2.00E+01	1.70E+01	1.70E+01
WWIN-2002-0188	11731066	7103136	220	15.00	171	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2005-0355	11737185	7121305	220	15.00	171	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2006-0780	11720851	7115549	220	15.00	171	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2018-0082	11740443	7127765	225	15.00	176	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2003-0183	11722415	7111317	225	15.00	176	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2001-0574	11739691	7115975	240	17.00	189	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2001-0564	11739534	7104579	280	20.00	225	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2005-0372	11723903	7111340	340	25.00	279	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2005-0706	11743488	7120280	340	25.00	279	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWTS-2006-0833	11730423	7115651	340	25.00	279	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWIN-2010-0146	11723851	7109685	540	40.00	459	1.50E+01	2.00E+01	1.75E+01	1.75E+01
WWTS-2000-0689	11743323	7124271	275	20.00	221	1.50E+01	2.10E+01	1.80E+01	1.80E+01
WWIN-1998-0140	11741855	7107650	400	30.00	333	1.50E+01	2.10E+01	1.80E+01	1.80E+01
WWIN-2004-0189	11726353	7131649	400	30.00	333	1.50E+01	2.10E+01	1.80E+01	1.80E+01
WWIN-2016-0068	11742071	7124204	420	31.00	351	1.50E+01	2.10E+01	1.80E+01	1.80E+01
WWTS-2006-0367	11721297	7120708	420	33.00	351	1.60E+01	2.10E+01	1.85E+01	1.85E+01
WWIN-2017-0112	11718182	7129949	220	16.00	171	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-1996-0009	11723203	7126190	245	18.00	194	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-1996-0401	11730202	7130269	320	25.00	261	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-1998-0130	11738131	7111045	320	25.00	261	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-2004-0591	11729130	7117721	320	25.00	261	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-2019-0180	11726167	7117281	380	30.00	315	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-2001-0042	11719477	7102611	380	30.00	315	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWTS-2000-0312	11727786	7102673	381	30.00	316	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-2019-0206	11726673	7117071	440	36.00	369	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-2004-0113	11718509	7104982	500	40.00	423	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-2006-0707	11744131	7119622	500	40.00	423	1.60E+01	2.20E+01	1.90E+01	1.90E+01
WWIN-2019-0004	11727988	7116967	260	20.00	207	1.70E+01	2.20E+01	1.95E+01	1.95E+01
WWIN-1998-0455	11741589	7106366	260	20.00	207	1.70E+01	2.20E+01	1.95E+01	1.95E+01
WWIN-2001-0388	11738782	7116024	260	20.00	207	1.70E+01	2.20E+01	1.95E+01	1.95E+01
WWTS-1999-0681	11735739	7105945	260	20.00	207	1.70E+01	2.20E+01	1.95E+01	1.95E+01
WWTS-2002-0097	11728190	7116821	260	20.00	207	1.70E+01	2.20E+01	1.95E+01	1.95E+01
WWIN-1998-0136	11742893	7109617	360	30.00	297	1.60E+01	2.30E+01	1.95E+01	1.95E+01
WWIN-2001-0620	11735913	7105899	360	30.00	297	1.60E+01	2.30E+01	1.95E+01	1.95E+01
WWIN-2020-0085	11731954	7102681	200	15.00	153	1.70E+01	2.30E+01	2.00E+01	2.00E+01
WWIN-1998-0135	11742706	7108945	200	15.00	153	1.70E+01	2.30E+01	2.00E+01	2.00E+01
WWIN-2001-0611	11741918	7130931	200	15.00	153	1.70E+01	2.30E+01	2.00E+01	2.00E+01
WWTS-2006-0631	11728667	7116414	220	17.00	171	1.70E+01	2.30E+01	2.00E+01	2.00E+01
WWTS-2000-0713	11743104	7123138	250	20.00	198	1.70E+01	2.30E+01	2.00E+01	2.00E+01
WWTS-2005-0515	11729093	7104855	250	20.00	198	1.70E+01	2.30E+01	2.00E+01	2.00E+01
WWIN-2019-0125	11718029	7116928	480	40.00	405	1.70E+01	2.30E+01	2.00E+01	2.00E+01
WWIN-1996-0216	11730885	7130093	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWIN-1999-0239	11742777	7102731	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-1999-0240	11740125	7109012	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWIN-2000-0107	11724937	7125955	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWIN-2002-0500	11738219	7103845	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWIN-2002-0631	11723680	7111123	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWIN-2004-0064	11725432	7132273	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWIN-2005-0724	11744256	7123069	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWTS-2001-0813	11724860	7111142	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWTS-2005-0682	11721278	7123490	300	25.00	243	1.70E+01	2.40E+01	2.05E+01	2.05E+01
WWIN-2000-0179	11726860	7115106	240	20.00	189	1.80E+01	2.40E+01	2.10E+01	2.10E+01
WWIN-2006-0600	11718937	7111542	240	20.00	189	1.80E+01	2.40E+01	2.10E+01	2.10E+01
WWTS-1999-0636	11722217	7112737	240	20.00	189	1.80E+01	2.40E+01	2.10E+01	2.10E+01
WWTS-1990-0196	11741867	7120000	345	30.00	284	1.80E+01	2.40E+01	2.10E+01	2.10E+01
WWIN-2000-0110	11724461	7124863	400	35.00	333	1.80E+01	2.40E+01	2.10E+01	2.10E+01
WWTS-2000-0711	11742757	7120148	450	40.00	378	1.80E+01	2.40E+01	2.10E+01	2.10E+01
WWIN-2001-0395	11742233	7110106	560	50.00	477	1.80E+01	2.40E+01	2.10E+01	2.10E+01
WWIN-2015-0119	11741173	7129445	600	53.00	513	1.80E+01	2.40E+01	2.10E+01	2.10E+01
WWIN-2005-0005	11739448	7103947	340	30.00	279	1.80E+01	2.50E+01	2.15E+01	2.15E+01
WWIN-2005-0155	11730217	7109518	340	30.00	279	1.80E+01	2.50E+01	2.15E+01	2.15E+01
WWIN-2014-0052	11728253	7125872	340	30.00	279	1.80E+01	2.50E+01	2.15E+01	2.15E+01
WWIN-2015-0091	11741946	7112742	340	30.00	279	1.80E+01	2.50E+01	2.15E+01	2.15E+01
WWIN-1996-0007	11723298	7125916	285	25.00	230	1.90E+01	2.50E+01	2.20E+01	2.20E+01
WWTS-2006-0387	11721774	7120635	280	25.00	225	1.90E+01	2.60E+01	2.25E+01	2.25E+01
WWTS-1999-0639	11722404	7112266	180	15.00	135	2.00E+01	2.60E+01	2.30E+01	2.30E+01
WWIN-2004-0338	11734030	7106752	220	20.00	171	2.00E+01	2.70E+01	2.35E+01	2.35E+01
WWIN-2004-0190	11741673	7121114	320	30.00	261	2.00E+01	2.70E+01	2.35E+01	2.35E+01
WWTS-1988-0285	11727473	7114302	320	30.00	261	2.00E+01	2.70E+01	2.35E+01	2.35E+01
WWTS-1999-0500	11735767	7106338	260	24.50	207	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-2018-0078	11728640	7115705	260	25.00	207	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-2021-0078	11720194	7105277	260	26.00	207	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-2019-0136	11718064	7129799	300	29.50	243	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-1986-0725	11718914	7106559	305	30.00	248	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-2000-0972	11743670	7116059	360	35.00	297	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-1998-0449	11723946	7128116	500	50.00	423	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-2004-0112	11719250	7104678	500	50.00	423	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-2002-0295	11743061	7104046	590	60.00	504	2.10E+01	2.80E+01	2.45E+01	2.45E+01
WWIN-2019-0002	11727503	7117408	300	30.00	243	2.20E+01	2.80E+01	2.50E+01	2.50E+01
WWIN-2021-0038	11720335	7104483	300	30.00	243	2.20E+01	2.80E+01	2.50E+01	2.50E+01
WWIN-1998-0138	11743532	7108641	300	30.00	243	2.20E+01	2.80E+01	2.50E+01	2.50E+01
WWIN-2001-0661	11738252	7105290	300	30.00	243	2.20E+01	2.80E+01	2.50E+01	2.50E+01
WWIN-2004-0590	11729265	7118320	300	30.00	243	2.20E+01	2.80E+01	2.50E+01	2.50E+01
WWIN-1998-0041	11718449	7124713	250	25.00	198	2.20E+01	2.90E+01	2.55E+01	2.55E+01
WWTS-2001-0820	11724747	7110860	250	25.00	198	2.20E+01	2.90E+01	2.55E+01	2.55E+01
WWTS-2005-0783	11742506	7130238	250	25.00	198	2.20E+01	2.90E+01	2.55E+01	2.55E+01
WWTS-2006-0034	11721668	7122934	250	25.00	198	2.20E+01	2.90E+01	2.55E+01	2.55E+01
WWTS-2000-0704	11742344	7122711	475	50.00	401	2.20E+01	2.90E+01	2.55E+01	2.55E+01
WWIN-2004-0227	11739334	7104147	560	60.00	477	2.20E+01	2.90E+01	2.55E+01	2.55E+01
WWTS-1999-0490	11721817	7113111	160	15.00	117	2.30E+01	3.00E+01	2.65E+01	2.65E+01
WWIN-1998-0054	11735332	7132229	500	53.00	423	2.30E+01	3.00E+01	2.65E+01	2.65E+01
WWIN-1998-0121	11734916	7122866	200	20.00	153	2.30E+01	3.10E+01	2.70E+01	2.70E+01
WWIN-2002-0425	11720662	7113873	200	20.00	153	2.30E+01	3.10E+01	2.70E+01	2.70E+01
WWIN-2005-0203	11735090	7102580	200	20.00	153	2.30E+01	3.10E+01	2.70E+01	2.70E+01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWTS-2000-0692	11744049	7123464	200	20.00	153	2.30E+01	3.10E+01	2.70E+01	2.70E+01
WWTS-2000-0695	11741574	7120824	200	20.00	153	2.30E+01	3.10E+01	2.70E+01	2.70E+01
WWTS-2001-0817	11723169	7112303	200	20.00	153	2.30E+01	3.10E+01	2.70E+01	2.70E+01
WWIN-2006-0279	11718705	7105509	240	25.00	189	2.30E+01	3.10E+01	2.70E+01	2.70E+01
WWTS-2002-0079	11728135	7117338	245	25.00	194	2.30E+01	3.10E+01	2.70E+01	2.70E+01
WWTS-2013-0099	11741324	7112127	300	32.00	243	2.30E+01	3.10E+01	2.70E+01	2.70E+01
WWNC-1965-0080	11736513	7117011	150	15.00	112	2.40E+01	3.10E+01	2.75E+01	2.75E+01
WWIN-2017-0109	11741429	7129999	480	55.50	405	2.40E+01	3.10E+01	2.75E+01	2.75E+01
WWIN-1999-0096	11726367	7128152	320	35.00	261	2.40E+01	3.20E+01	2.80E+01	2.80E+01
WWIN-2019-0181	11726588	7118107	360	40.00	297	2.40E+01	3.20E+01	2.80E+01	2.80E+01
WWIN-1999-0576	11738135	7102251	510	60.00	432	2.50E+01	3.20E+01	2.85E+01	2.85E+01
WWIN-1998-0122	11735141	7121892	225	25.00	176	2.50E+01	3.40E+01	2.95E+01	2.95E+01
WWTS-2000-0722	11743349	7121691	225	25.00	176	2.50E+01	3.40E+01	2.95E+01	2.95E+01
WWIN-1997-0452	11729722	7104217	300	35.00	243	2.60E+01	3.30E+01	2.95E+01	2.95E+01
WWIN-2000-0173	11728583	7123814	300	35.00	243	2.60E+01	3.30E+01	2.95E+01	2.95E+01
WWTS-2005-0766	11741150	7130368	300	35.00	243	2.60E+01	3.30E+01	2.95E+01	2.95E+01
WWTS-2013-0171	11742884	7111284	300	40.00	243	2.90E+01	3.00E+01	2.95E+01	2.95E+01
WWIN-2012-0145	11719426	7128252	340	40.00	279	2.60E+01	3.30E+01	2.95E+01	2.95E+01
WWIN-2017-0110	11741504	7130203	500	60.50	423	2.50E+01	3.40E+01	2.95E+01	2.95E+01
WWIN-2017-0186	11736754	7110381	260	30.00	207	2.60E+01	3.40E+01	3.00E+01	3.00E+01
WWIN-2000-0178	11721629	7114156	260	30.00	207	2.60E+01	3.40E+01	3.00E+01	3.00E+01
WWIN-2018-0029	11741451	7130598	375	45.00	311	2.60E+01	3.40E+01	3.00E+01	3.00E+01
WWIN-2005-0532	11722770	7132934	180	20.00	135	2.60E+01	3.50E+01	3.05E+01	3.05E+01
WWIN-2006-0063	11736468	7121338	180	20.00	135	2.60E+01	3.50E+01	3.05E+01	3.05E+01
WWIN-2002-0251	11730541	7103251	220	25.00	171	2.60E+01	3.50E+01	3.05E+01	3.05E+01
WWIN-2006-0779	11721156	7115811	220	25.00	171	2.60E+01	3.50E+01	3.05E+01	3.05E+01
WWTS-2006-0630	11727513	7116057	220	25.00	171	2.60E+01	3.50E+01	3.05E+01	3.05E+01
WWIN-1997-0418	11723667	7126676	140	14.50	99	2.70E+01	3.50E+01	3.10E+01	3.10E+01
WWIN-2003-0243	11723152	7132909	400	50.00	333	2.70E+01	3.50E+01	3.10E+01	3.10E+01
WWIN-2000-0736	11738496	7102622	250	30.00	198	2.70E+01	3.60E+01	3.15E+01	3.15E+01
WWTS-2000-0691	11743661	7123680	250	30.00	198	2.70E+01	3.60E+01	3.15E+01	3.15E+01
WWTS-2005-0686	11721566	7122907	250	30.00	198	2.70E+01	3.60E+01	3.15E+01	3.15E+01
WWIN-1998-0497	11723273	7106224	175	20.00	131	2.70E+01	3.70E+01	3.20E+01	3.20E+01
WWIN-1998-0031	11718120	7130324	240	28.00	189	2.80E+01	3.70E+01	3.25E+01	3.25E+01
WWTS-2002-0078	11725967	7118833	245	30.00	194	2.80E+01	3.70E+01	3.25E+01	3.25E+01
WWTS-2002-0086	11729068	7115799	245	30.00	194	2.80E+01	3.70E+01	3.25E+01	3.25E+01
WWTS-2006-0629	11728915	7116458	240	30.00	189	2.80E+01	3.80E+01	3.30E+01	3.30E+01
WWIN-1997-0164	11718185	7125849	200	25.00	153	2.90E+01	3.90E+01	3.40E+01	3.40E+01
WWIN-1997-0214	11731862	7122677	200	25.00	153	2.90E+01	3.90E+01	3.40E+01	3.40E+01
WWIN-2001-0051	11731877	7103805	200	25.00	153	2.90E+01	3.90E+01	3.40E+01	3.40E+01
WWIN-2003-0157	11737634	7124200	200	25.00	153	2.90E+01	3.90E+01	3.40E+01	3.40E+01
WWIN-2004-0506	11729471	7118600	200	25.00	153	2.90E+01	3.90E+01	3.40E+01	3.40E+01
WWTS-2002-0432	11738736	7120527	200	25.00	153	2.90E+01	3.90E+01	3.40E+01	3.40E+01
WWIN-2000-0079	11718236	7131750	300	40.00	243	2.90E+01	3.90E+01	3.40E+01	3.40E+01
WWIN-2013-0057	11730280	7104543	300	40.00	243	2.90E+01	3.90E+01	3.40E+01	3.40E+01
WWIN-2004-0018	11727259	7103072	425	60.00	356	3.10E+01	4.00E+01	3.55E+01	3.55E+01
WWIN-1997-0069	11718920	7125894	220	30.00	171	3.20E+01	4.20E+01	3.70E+01	3.70E+01
WWIN-1999-0642	11728996	7103913	220	30.00	171	3.20E+01	4.20E+01	3.70E+01	3.70E+01
WWIN-2001-0324	11720768	7132767	220	30.00	171	3.20E+01	4.20E+01	3.70E+01	3.70E+01
WWTS-2000-0702	11742579	7122523	250	35.00	198	3.20E+01	4.20E+01	3.70E+01	3.70E+01
WWTS-2005-0780	11740303	7131263	250	35.00	198	3.20E+01	4.20E+01	3.70E+01	3.70E+01

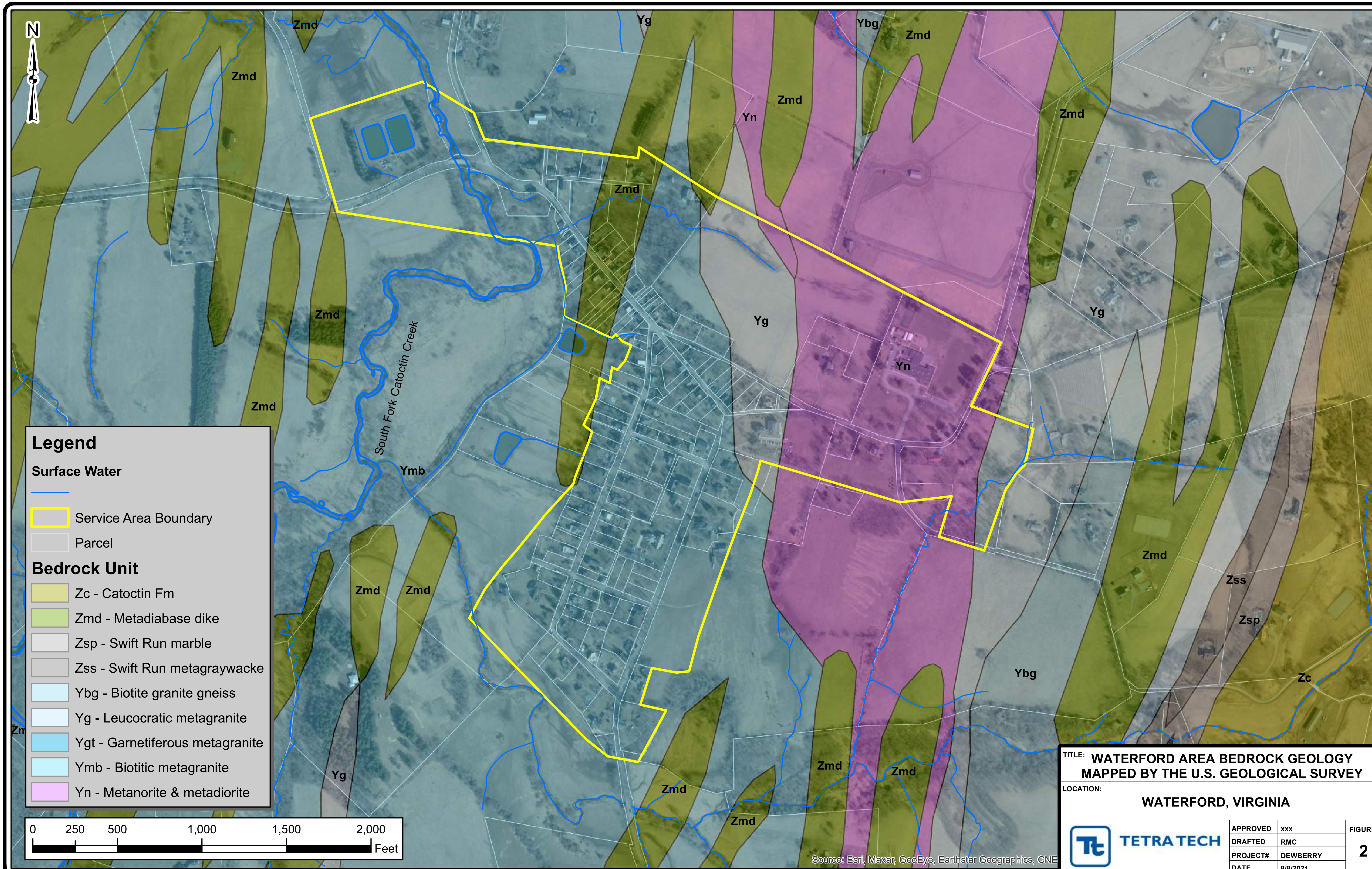
Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

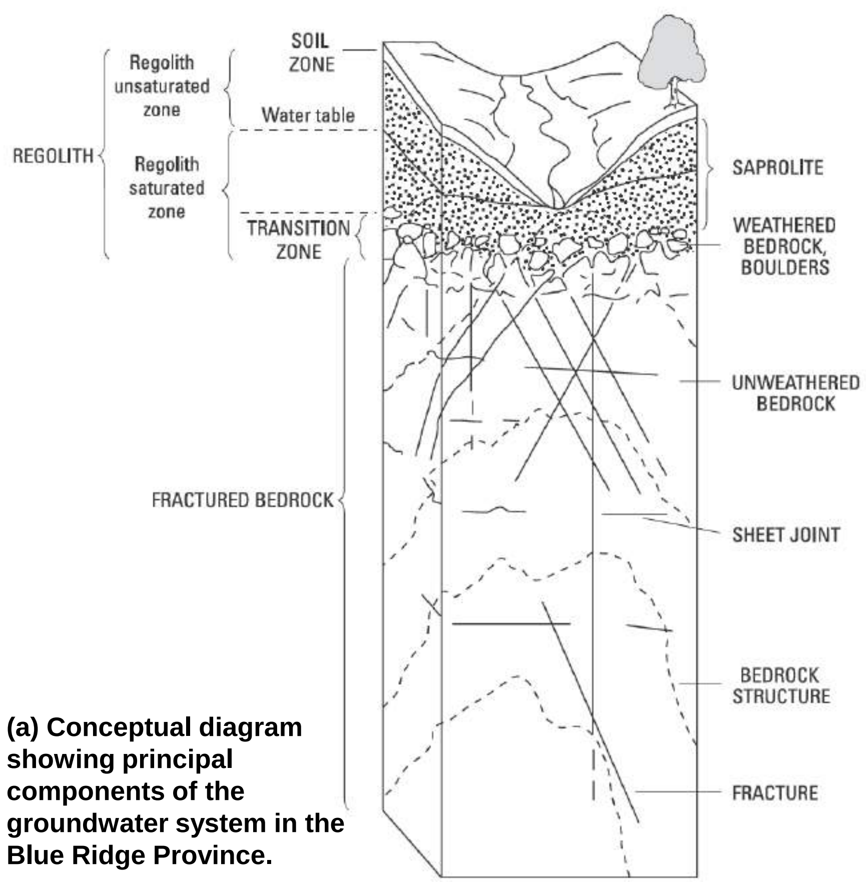
Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWTS-2002-0080	11726831	7116888	280	40.00	225	3.20E+01	4.30E+01	3.75E+01	3.75E+01
WWIN-2001-0462	11732079	7103799	200	40.00	153	1.00E+00	7.50E+01	3.80E+01	3.80E+01
WWIN-2021-0024	11725634	7106750	300	45.00	243	3.30E+01	4.40E+01	3.85E+01	3.85E+01
WWIN-2000-0181	11739108	7117651	300	45.00	243	3.30E+01	4.40E+01	3.85E+01	3.85E+01
WWNC-2018-0059	11725624	7103797	490	70.00	414	3.30E+01	4.40E+01	3.85E+01	3.85E+01
WWIN-2001-0594	11741216	7127604	150	20.00	108	3.40E+01	4.40E+01	3.90E+01	3.90E+01
WWIN-2005-0596	11737162	7121398	180	25.00	135	3.40E+01	4.40E+01	3.90E+01	3.90E+01
WWIN-2000-0339	11737374	7102809	325	50.00	266	3.50E+01	4.60E+01	4.05E+01	4.05E+01
WWIN-2003-0290	11723364	7119516	325	50.00	266	3.50E+01	4.60E+01	4.05E+01	4.05E+01
WWTS-2002-0095	11728531	7115750	260	40.00	207	3.50E+01	4.70E+01	4.10E+01	4.10E+01
WWIN-1999-0541	11718117	7131883	260	40.00	207	3.50E+01	4.70E+01	4.10E+01	4.10E+01
WWTS-1990-0193	11739627	7119887	205	30.00	158	3.60E+01	4.70E+01	4.15E+01	4.15E+01
WWIN-1997-0163	11718049	7125862	200	30.00	153	3.60E+01	4.80E+01	4.20E+01	4.20E+01
WWIN-2002-0485	11729123	7102785	200	30.00	153	3.60E+01	4.80E+01	4.20E+01	4.20E+01
WWIN-2013-0004	11725324	7111508	200	30.00	153	3.60E+01	4.80E+01	4.20E+01	4.20E+01
WWTS-2000-0701	11741142	7123448	200	30.00	153	3.60E+01	4.80E+01	4.20E+01	4.20E+01
WWTS-2000-0709	11744340	7122246	200	30.00	153	3.60E+01	4.80E+01	4.20E+01	4.20E+01
WWTS-2001-0812	11724384	7111758	250	40.00	198	3.70E+01	4.90E+01	4.30E+01	4.30E+01
WWIN-2015-0064	11733364	7102649	140	20.00	99	3.70E+01	5.00E+01	4.35E+01	4.35E+01
WWIN-2003-0296	11741030	7123383	300	50.00	243	3.80E+01	4.90E+01	4.35E+01	4.35E+01
WWIN-2004-0109	11718586	7104196	300	50.00	243	3.80E+01	4.90E+01	4.35E+01	4.35E+01
WWIN-1999-0251	11738848	7103534	560	100.00	477	3.90E+01	5.00E+01	4.45E+01	4.45E+01
WWIN-2001-0374	11720387	7113212	160	25.00	117	4.00E+01	5.20E+01	4.60E+01	4.60E+01
WWIN-2001-0604	11741610	7130945	280	50.00	225	4.20E+01	5.30E+01	4.75E+01	4.75E+01
WWTS-2006-0627	11728228	7117185	280	50.00	225	4.20E+01	5.30E+01	4.75E+01	4.75E+01
WWIN-2001-0592	11741380	7129048	400	75.00	333	4.20E+01	5.40E+01	4.80E+01	4.80E+01
WWTS-1999-0530	11736840	7106537	440	85.00	369	4.20E+01	5.50E+01	4.85E+01	4.85E+01
WWTS-2000-0714	11743591	7122804	200	35.00	153	4.30E+01	5.50E+01	4.90E+01	4.90E+01
WWTS-2006-0228	11719226	7121993	275	50.00	221	4.20E+01	5.60E+01	4.90E+01	4.90E+01
WWIN-1998-0028	11719188	7132295	225	40.00	176	4.30E+01	5.60E+01	4.95E+01	4.95E+01
WWTS-2006-0625	11727414	7116236	220	40.00	171	4.30E+01	5.70E+01	5.00E+01	5.00E+01
WWTS-1988-0253	11721744	7122423	305	60.00	248	4.50E+01	5.90E+01	5.20E+01	5.20E+01
WWTS-1989-0009	11718713	7126594	165	30.00	122	4.50E+01	6.10E+01	5.30E+01	5.30E+01
WWIN-2002-0036	11720009	7124125	140	25.00	99	4.70E+01	6.00E+01	5.35E+01	5.35E+01
WWIN-2019-0014	11727699	7117406	300	61.00	243	4.70E+01	6.10E+01	5.40E+01	5.40E+01
WWIN-2020-0029	11719200	7104106	240	50.00	189	4.90E+01	6.70E+01	5.80E+01	5.80E+01
WWIN-2014-0058	11725298	7113090	240	50.00	189	4.90E+01	6.70E+01	5.80E+01	5.80E+01
WWIN-2013-0168	11725232	7112130	340	75.00	279	5.10E+01	6.60E+01	5.85E+01	5.85E+01
WWIN-1982-0125	11734838	7117180	160	35.00	est 126	5.30E+01	6.80E+01	6.05E+01	6.05E+01
WWIN-2019-0207	11726727	7117978	360	85.00	297	5.40E+01	7.00E+01	6.20E+01	6.20E+01
WWIN-2009-0066	11732706	7102976	145	30.00	104	5.30E+01	7.20E+01	6.25E+01	6.25E+01
WWIN-1997-0247	11734445	7104453	200	40.00	153	5.10E+01	7.50E+01	6.30E+01	6.30E+01
WWIN-2004-0265	11727601	7106174	200	40.00	153	5.10E+01	7.50E+01	6.30E+01	6.30E+01
WWTS-2000-0726	11744236	7121749	200	40.00	153	5.10E+01	7.50E+01	6.30E+01	6.30E+01
WWTS-2006-0626	11727647	7116398	220	50.00	171	5.60E+01	7.20E+01	6.40E+01	6.40E+01
WWIN-2011-0073	11726435	7126587	200	43.00	153	5.50E+01	7.50E+01	6.50E+01	6.50E+01
WWNC-2013-0230	11724967	7104341	405	100.00	338	5.70E+01	7.30E+01	6.50E+01	6.50E+01
WWIN-1998-0408	11723218	7108742	200	45.00	153	5.70E+01	7.50E+01	6.60E+01	6.60E+01
WWIN-2001-0944	11724716	7111081	250	60.00	198	5.80E+01	7.50E+01	6.65E+01	6.65E+01
WWTS-1990-0199	11740030	7120731	250	60.00	198	5.80E+01	7.50E+01	6.65E+01	6.65E+01
WWIN-2014-0179	11729589	7115772	300	75.00	243	5.80E+01	7.70E+01	6.75E+01	6.75E+01

Table 5. Transmissivity Values Derived from Airlift Yield Data and Input to the Base Case Model.

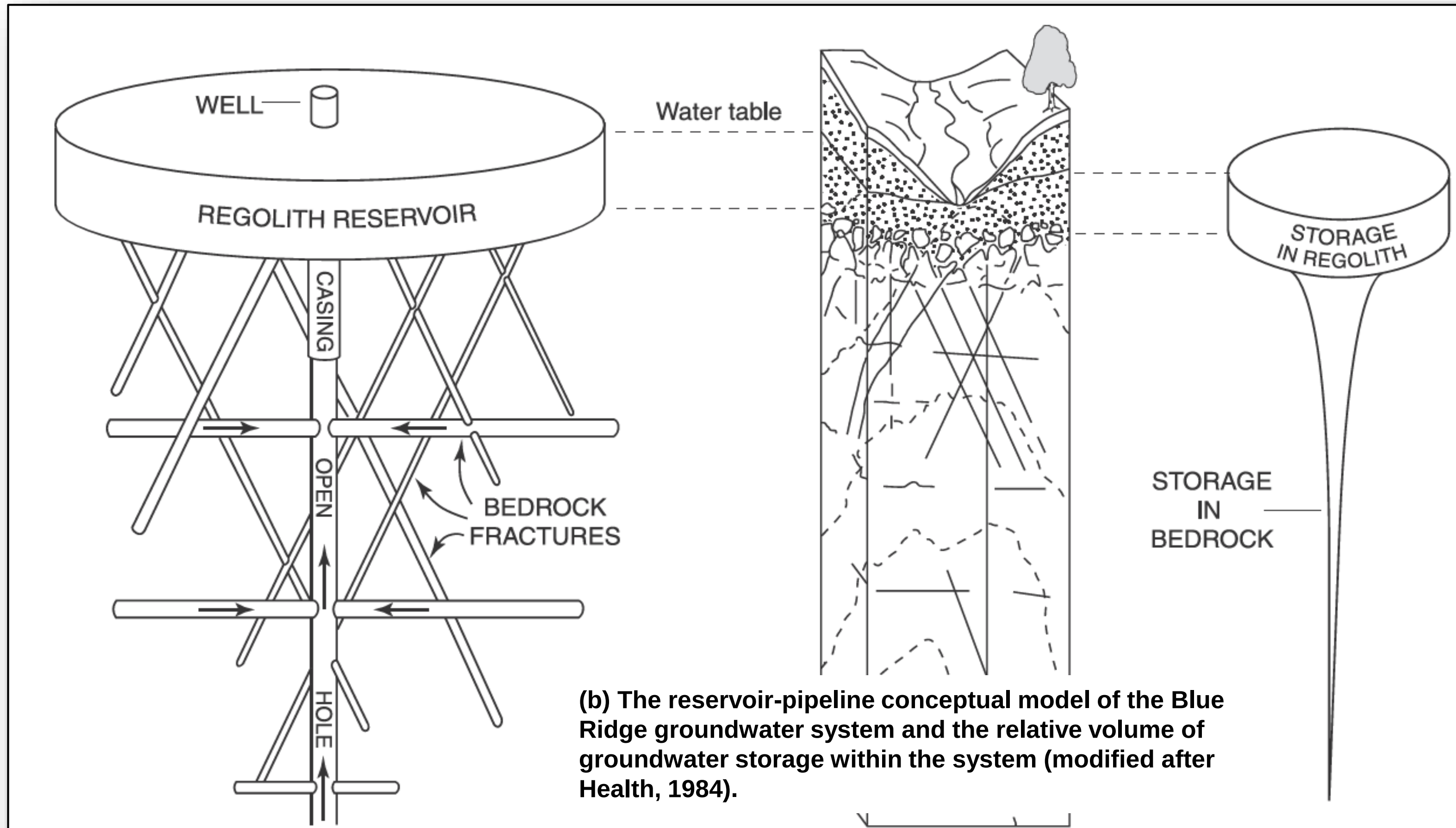
Well ID	Easting (feet)	Northing (feet)	Well Depth (feet)	Reported Airlift Yield (gpm)	Estimated Airlift Test Drawdown (feet)	Transmissivity Estimate based on Storage Coefficient of 0.001 and 90% Drawdown (ft^2/d)	Transmissivity Estimate based on Storage Coefficient of 0.00003 and 90% Drawdown (ft^2/d)	Average of Transmissivity Estimates (ft^2/d)	Transmissivity Input to Base Case Model (ft^2/d)
WWIN-2019-0170	11728251	7116785	200	50.00	153	6.30E+01	8.20E+01	7.25E+01	7.25E+01
WWIN-2020-0003	11726034	7117728	280	75.00	225	6.30E+01	8.30E+01	7.30E+01	7.30E+01
WWTS-1988-0250	11722644	7119917	350	100.00	288	6.60E+01	8.80E+01	7.70E+01	7.70E+01
WWTS-1988-0249	11722347	7119905	285	83.00	230	7.00E+01	9.10E+01	8.05E+01	8.05E+01
WWIN-2005-0790	11744349	7123337	180	50.00	135	7.20E+01	9.40E+01	8.30E+01	8.30E+01
WWIN-2020-0005	11725975	7117160	343	103.00	282	8.60E+01	8.90E+01	8.75E+01	8.75E+01
WWIN-2007-0015	11727879	7103909	608	205.00	520	7.60E+01	9.90E+01	8.75E+01	8.75E+01
WWIN-2001-0609	11742218	7131855	200	60.00	153	7.80E+01	1.00E+02	8.90E+01	8.90E+01
WWIN-2016-0197	11722054	7120975	300	100.00	243	7.90E+01	1.03E+02	9.10E+01	9.10E+01
WWIN-2002-0481	11727416	7102358	285	100.00	230	8.50E+01	1.10E+02	9.75E+01	9.75E+01
WWTS-2005-0516	11728850	7104979	150	50.00	108	8.90E+01	1.16E+02	1.03E+02	1.03E+02
WWIN-2003-0403	11723685	7110395	285	110.00	230	9.60E+01	1.22E+02	1.09E+02	1.09E+02
WWIN-2005-0247	11737922	7120862	260	100.00	207	9.40E+01	1.25E+02	1.10E+02	1.10E+02
WWIN-2020-0001	11727322	7116711	200	75.00	153	9.80E+01	1.27E+02	1.13E+02	1.13E+02
WWIN-2000-0316	11729373	7102319	250	100.00	198	1.01E+02	1.30E+02	1.16E+02	1.16E+02
WWIN-2002-0570	11723667	7110887	250	100.00	198	1.01E+02	1.30E+02	1.16E+02	1.16E+02
WWIN-2005-0792	11743845	7103323	155	60.00	113	1.08E+02	1.36E+02	1.22E+02	1.22E+02
WWIN-2006-0012	11719439	7130920	170	80.00	126	1.27E+02	1.66E+02	1.47E+02	1.47E+02
WWIN-2006-1021	11719230	7131533	170	80.00	126	1.27E+02	1.66E+02	1.47E+02	1.47E+02
WWIN-1981-0173	11734599	7117484	18	50.00	74	1.42E+02	1.84E+02	1.63E+02	1.63E+02
WWIN-2005-0634	11718303	7110667	700	432.00	603	1.45E+02	1.90E+02	1.68E+02	1.68E+02
WWIN-1999-0077	11719046	7132477	100	60.00	63	1.92E+02	2.47E+02	2.20E+02	2.00E+02
WWIN-2021-0012	11725875	7107213	120	100.00	81	2.58E+02	3.33E+02	2.96E+02	2.00E+02
WWIN-1996-0301	11733992	7105859	120	100.00	81	2.58E+02	3.33E+02	2.96E+02	2.00E+02
WWIN-1996-0298	11724773	7102650	150	100.00	108	1.91E+02	2.37E+02	2.14E+02	2.00E+02

N
Legend
Service Area Boundary
Surface Water
20' Topo Contour Interval
Major Floodplain
Parcel
0 250 500 1,000 1,500 2,000
Feet
OLD WHEATLAND RD
MILLTOWN RD
CLOVER HILL RD
FIRST ST
BOND ST
MAIN ST
WATER ST
BUTCHERS ROW
CHURCH ST
PATRICK ST
FAIRFAX ST
SECOND ST
JANNEY ST
HIGH ST
FACTORY ST
CLARKES GAP RD
OLD WATERFORD RD
LOYALTY RD
BROWNS LN
South Fork Catoctin Creek
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNE
TITLE:
WATERFORD AREA TOPOGRAPHY
LOCATION:
WATERFORD, VIRGINIA
TETRA TECH
APPROVED xxx
DRAFTED RMC
PROJECT# DEWBERRY
DATE 8/8/2021
FIGURE
1


N
Zmd
Yg
Ybg
Yn
Ymb
Yg
Zss
Zsp
Zc
South Fork Catoctin Creek
Legend
Surface Water
Service Area Boundary
Parcel
Bedrock Unit
Zc - Catoctin Fm
Zmd - Metadiabase dike
Zsp - Swift Run marble
Zss - Swift Run metagraywacke
Ybg - Biotite granite gneiss
Yg - Leucocratic metagranite
Ygt - Garnetiferous metagranite
Ymb - Biotitic metagranite
Yn - Metanorite & metadiorite
0 250 500 1,000 1,500 2,000
Feet
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNE
TITLE: WATERFORD AREA BEDROCK GEOLOGY MAPPED BY THE U.S. GEOLOGICAL SURVEY
LOCATION: WATERFORD, VIRGINIA
TETRA TECH
APPROVED xxx
DRAFTED RMC
PROJECT# DEWBERRY
DATE 8/8/2021
FIGURE 2

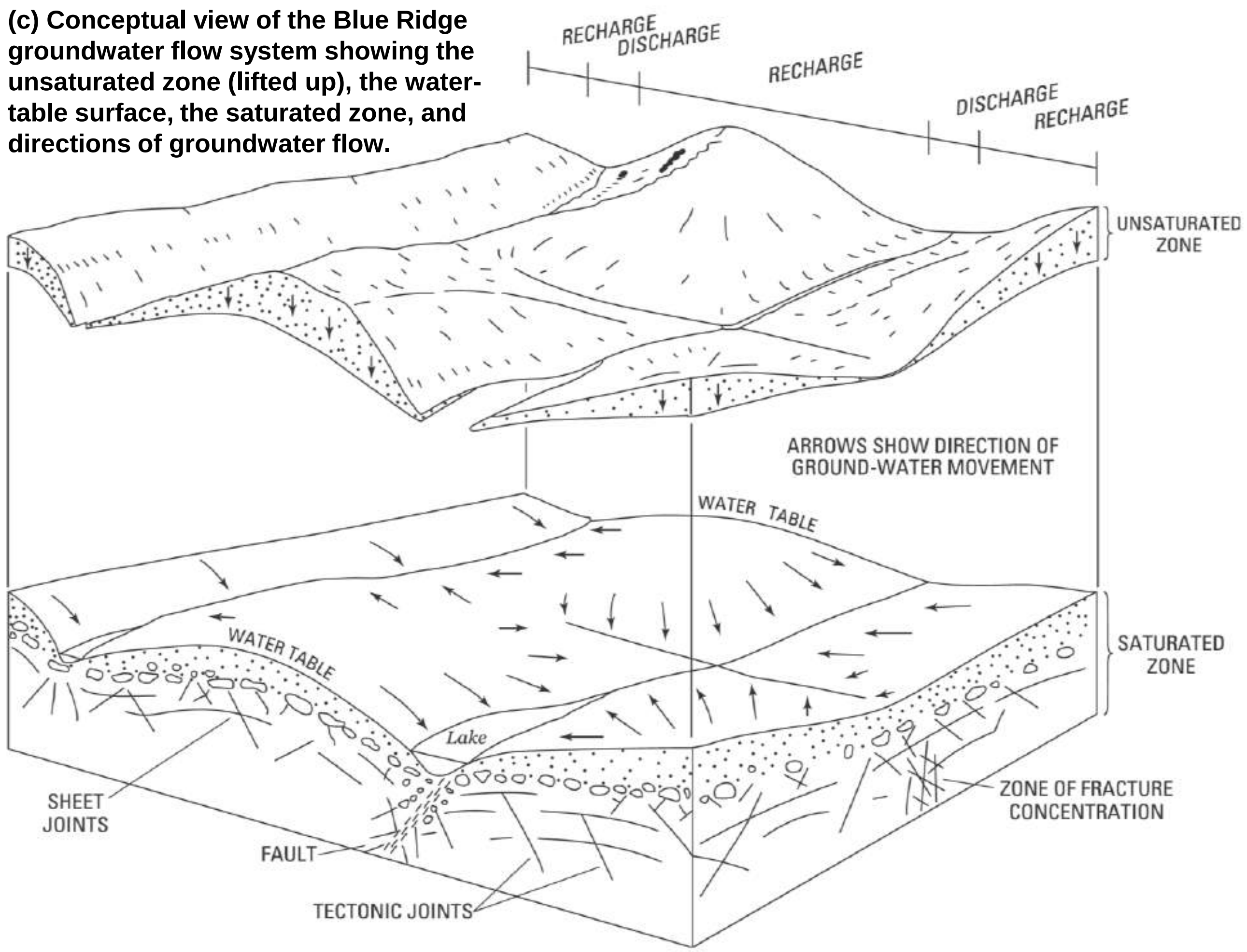


(a) Conceptual diagram showing principal components of the groundwater system in the Blue Ridge Province.



(b) The reservoir-pipeline conceptual model of the Blue Ridge groundwater system and the relative volume of groundwater storage within the system (modified after Health, 1984).

(c) Conceptual view of the Blue Ridge groundwater flow system showing the unsaturated zone (lifted up), the water-table surface, the saturated zone, and directions of groundwater flow.



(d) The transition zone between saprolite and rock sometimes enhances lateral flow, limits downward vertical flow, and functions as a primary transmitter of contaminated groundwater to a stream.

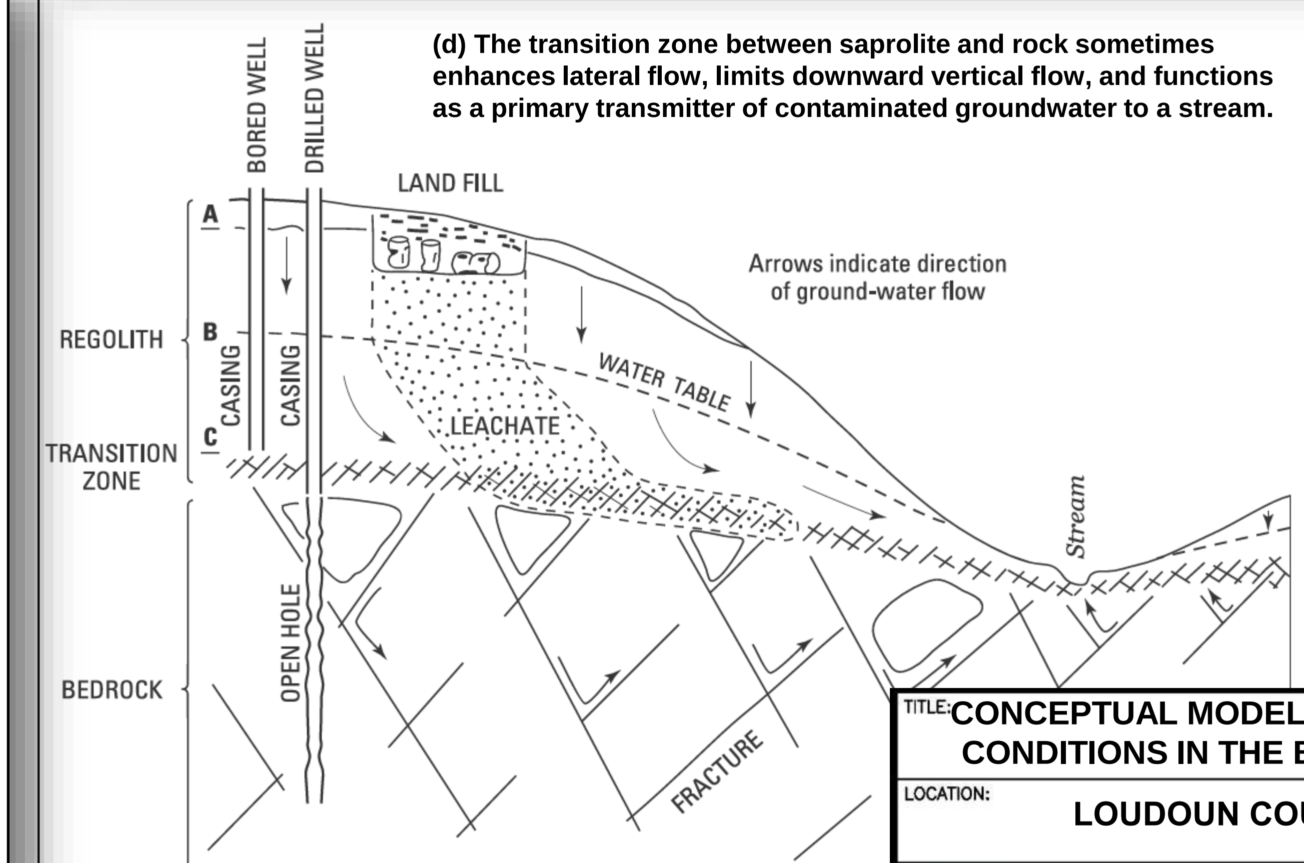


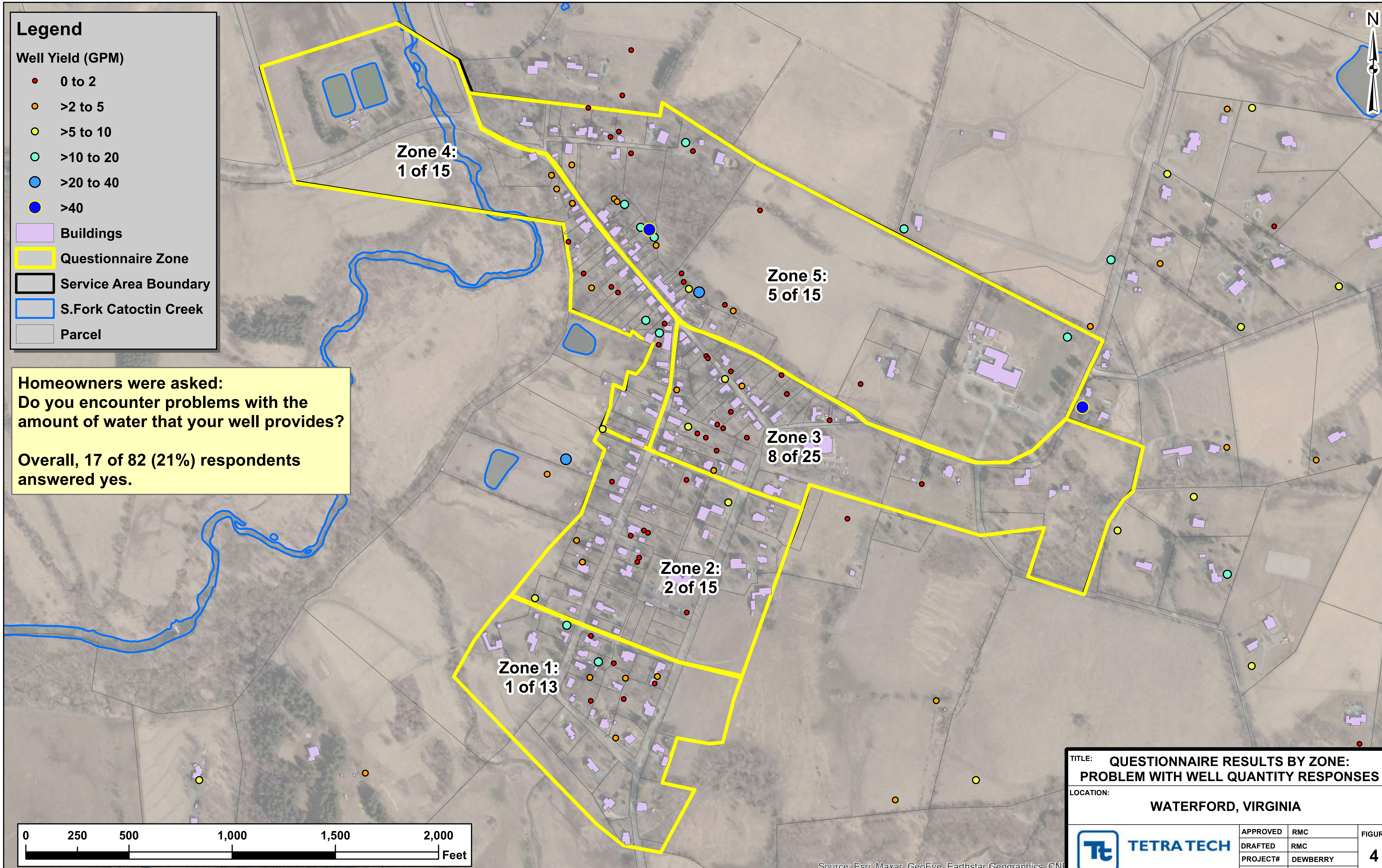
Image sources:
- **(a) Harned and Daniel, 1992.**
- **(b) Heath, 1984.**
- **(c) Daniel, 1990.**
- **(d) Harned and Daniel, 1992.**

TITLE: **CONCEPTUAL MODELS OF HYDROGEOLOGIC CONDITIONS IN THE BLUE RIDGE PROVINCE**

LOCATION: **LOUDOUN COUNTY, VIRGINIA**

TETRA TECH

		FIGURE
APPROVED		3
DRAFTED	RMC	
PROJECT#	DEWBERRY	
DATE	8/8/2021	

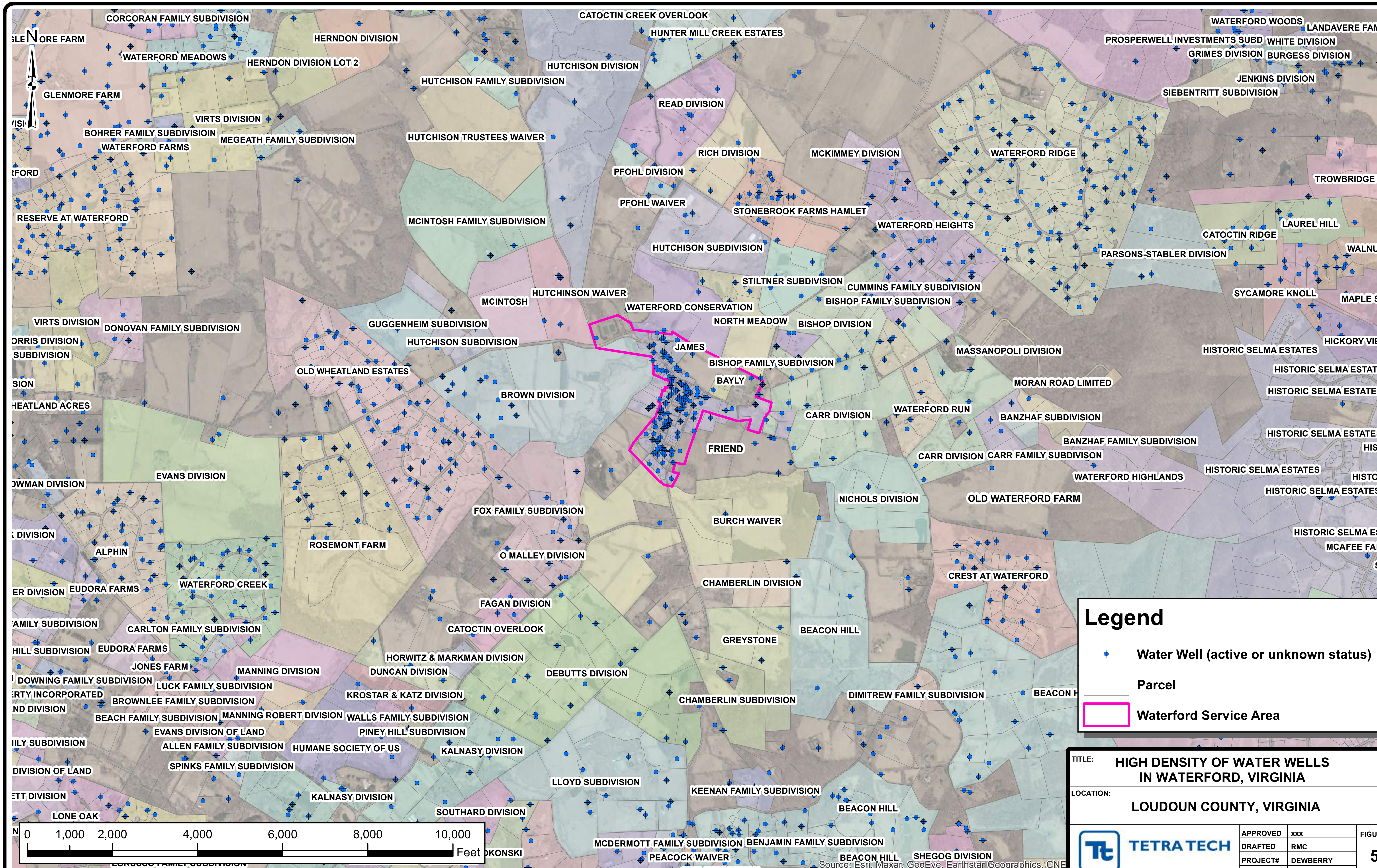


TITLE: QUESTIONNAIRE RESULTS BY ZONE: PROBLEM WITH WELL QUANTITY RESPONSES

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	4
PROJECT#	DEWBERRY	
DATE	8/8/2021	

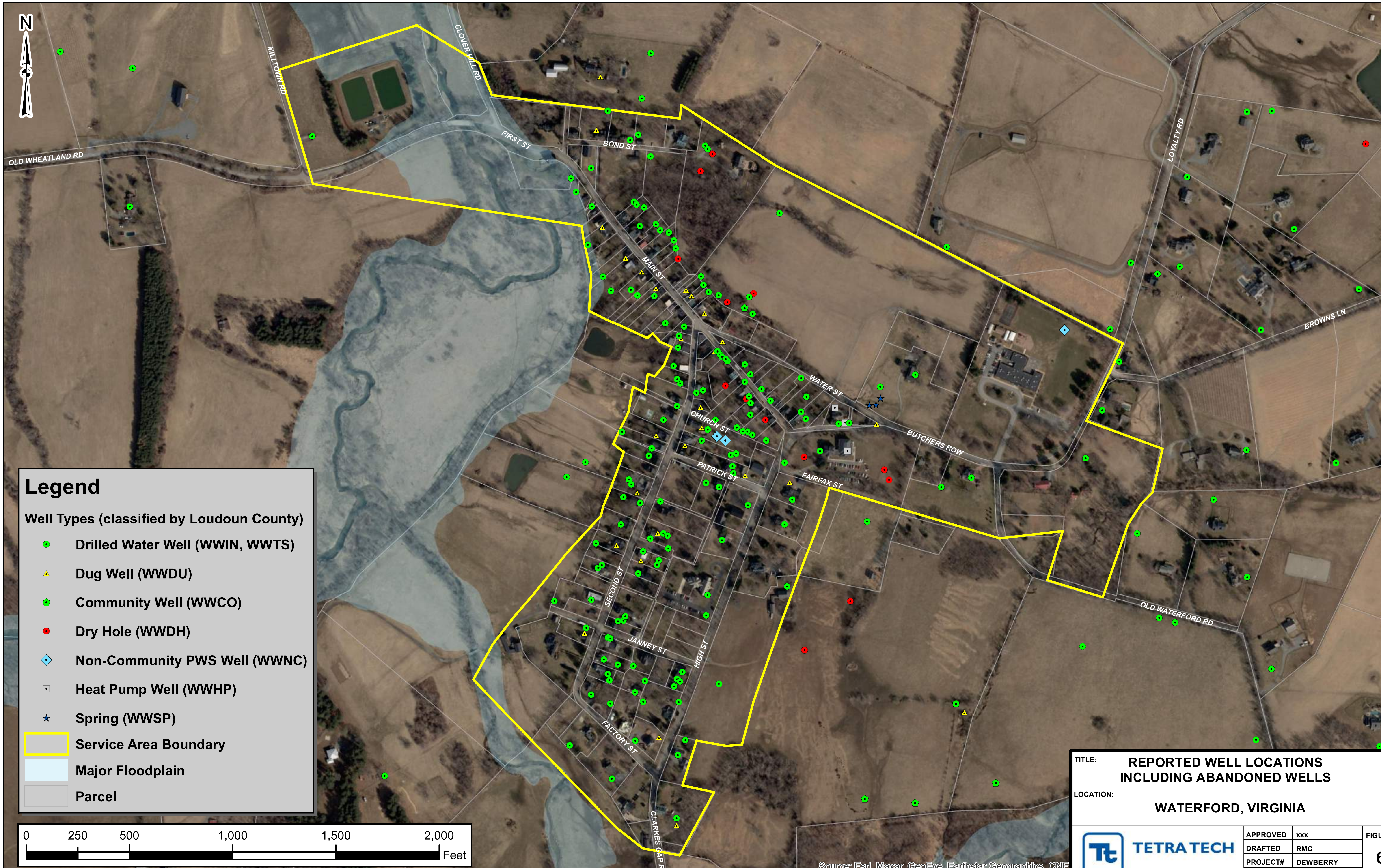


TITLE: HIGH DENSITY OF WATER WELLS IN WATERFORD, VIRGINIA

LOCATION: LOUDOUN COUNTY, VIRGINIA

TETRA TECH

APPROVED	xxx	FIGURE
DRAFTED	RMC	5
PROJECT#	DEWBERRY	
DATE	8/8/2021	



TITLE: REPORTED WELL LOCATIONS INCLUDING ABANDONED WELLS

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	xxx	FIGURE
DRAFTED	RMC	6
PROJECT#	DEWBERRY	
DATE	8/8/2021	

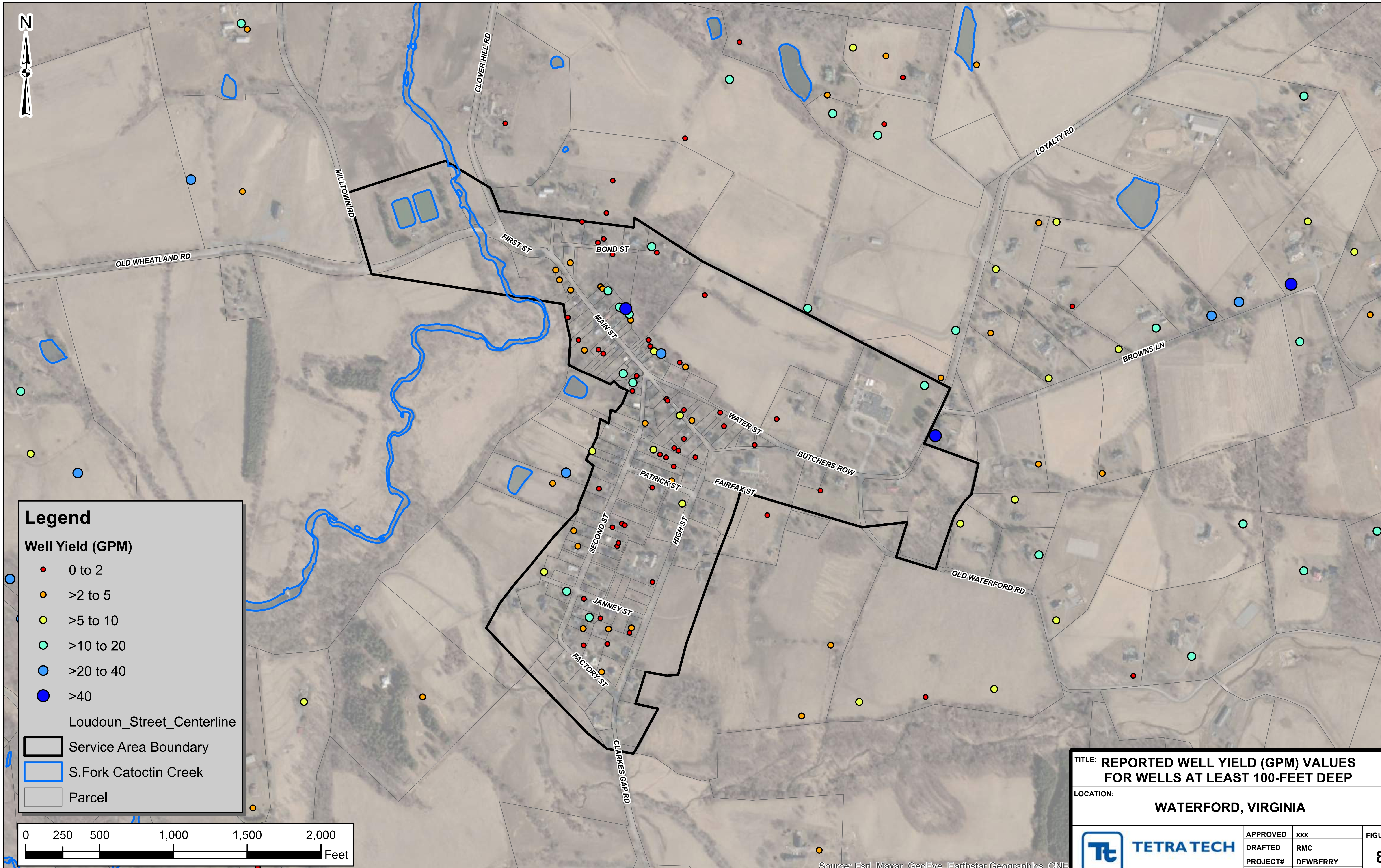
Notes:
1. Posted data includes Well ID over Well Depth (feet) / Well Yield (GPM) / Depth-to-Water in May 2021.
2. Well depth and yield data are derived from County well records including Water Well Completion Reports submitted by drillers.
3. Depth-to-Water values are the depth below the top-of-casing TOC) measured by Tetra Tech in May 2021.
4. Tetra Tech used sonic water level probes to measure the depth-to-water (DTW) in drilled wells. DTW values indicated by the sonic probe of less than 16 feet may actually be shallower due to insensitivity of sonic probe to very shallow water levels.
5. DTW is sensitive to well pumping rates, which vary with time and user, and formation transmissivity.
6. NR indicates Not Reported.
7. NM indicates Not Measured.

TITLE: REPORTED WATERFORD AREA WELL DATA
WELL ID, DEPTH (FT), AIRLIFT YIELD (GPM), DTW (FT)

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	xxx	FIGURE 7
DRAFTED	RMC	
PROJECT#	DEWBERRY	
DATE	6//2/2021	



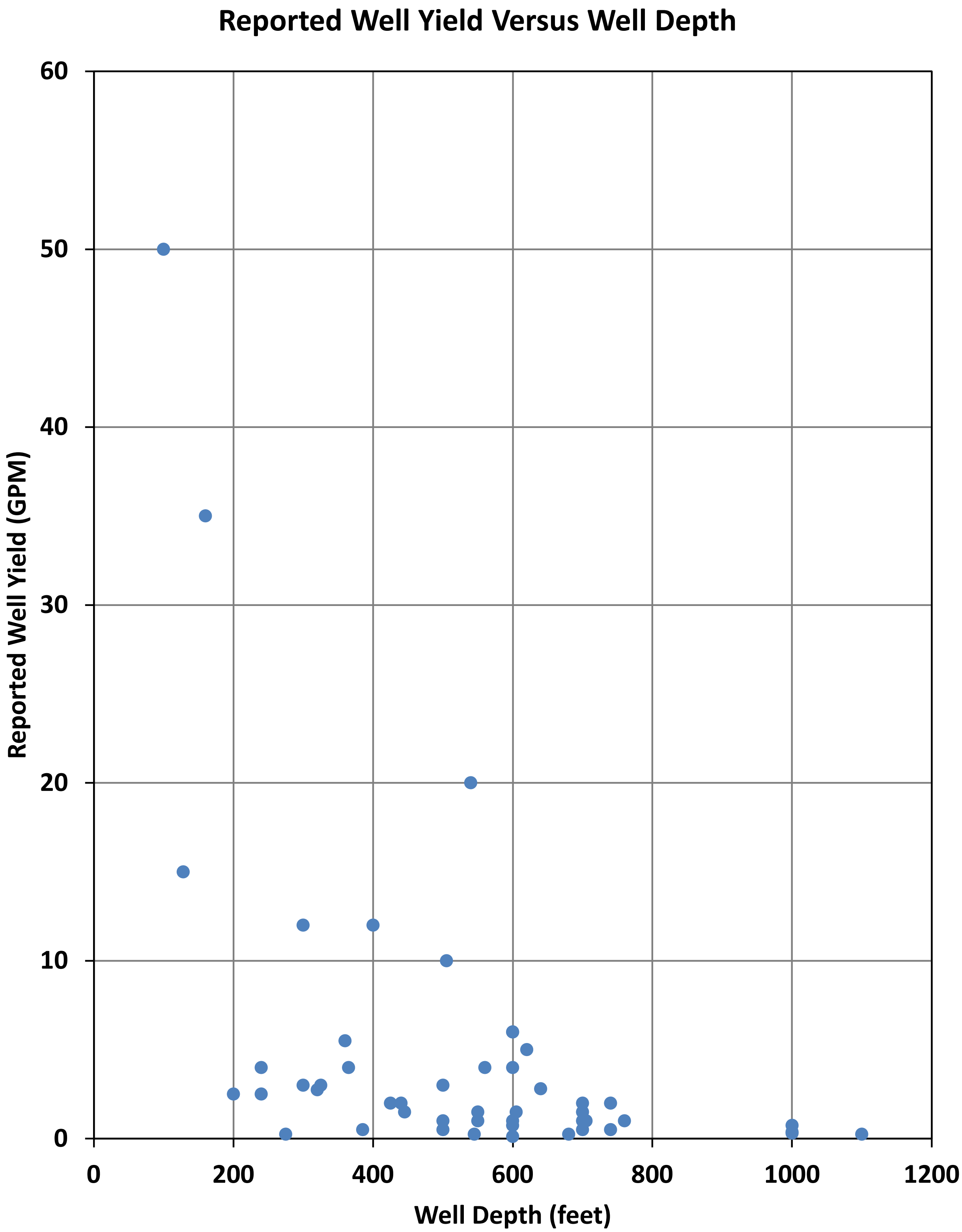
TITLE: REPORTED WELL YIELD (GPM) VALUES FOR WELLS AT LEAST 100-FEET DEEP

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

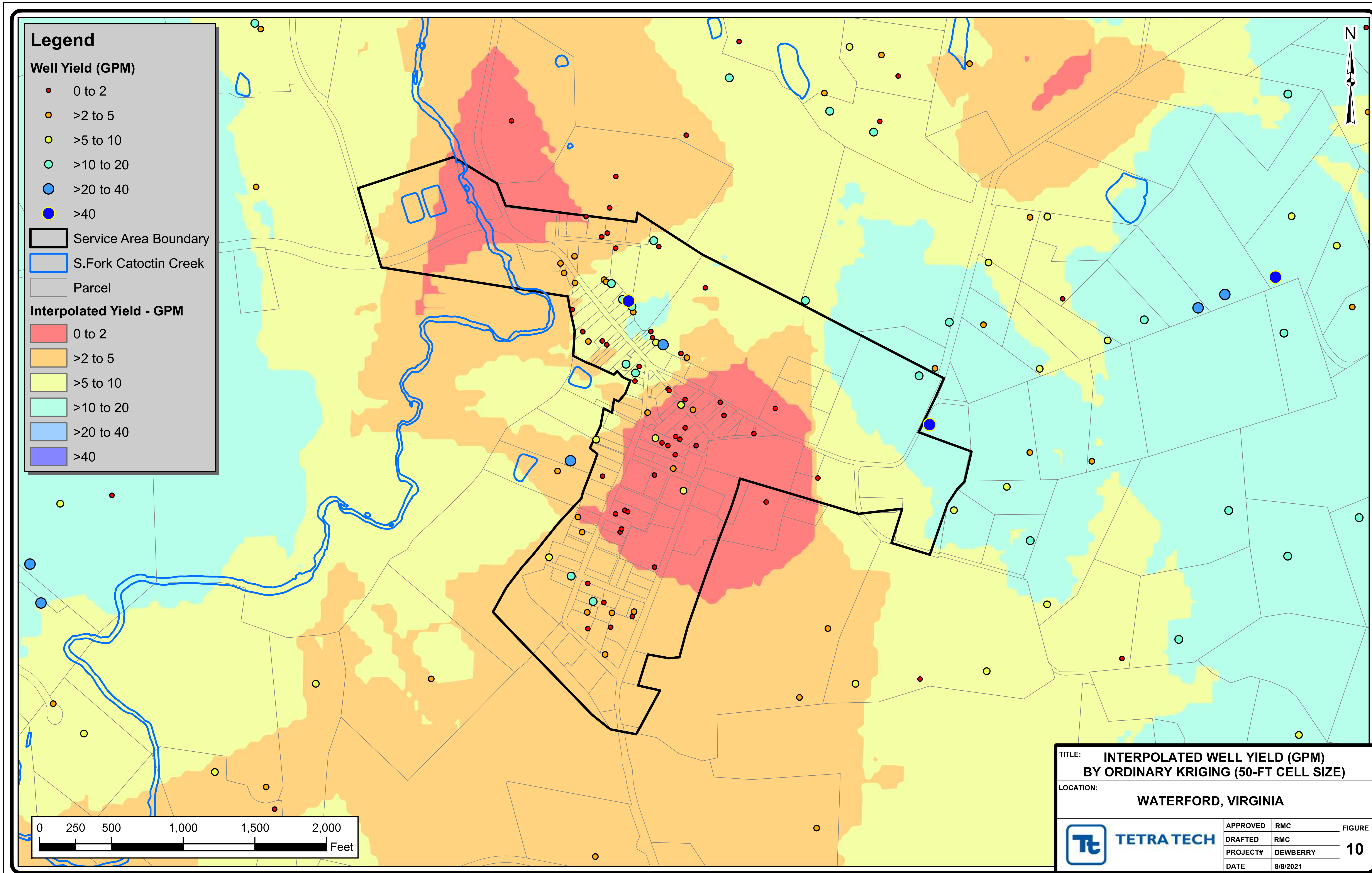
APPROVED	xxx
DRAFTED	RMC
PROJECT#	DEWBERRY
DATE	8/8/2021

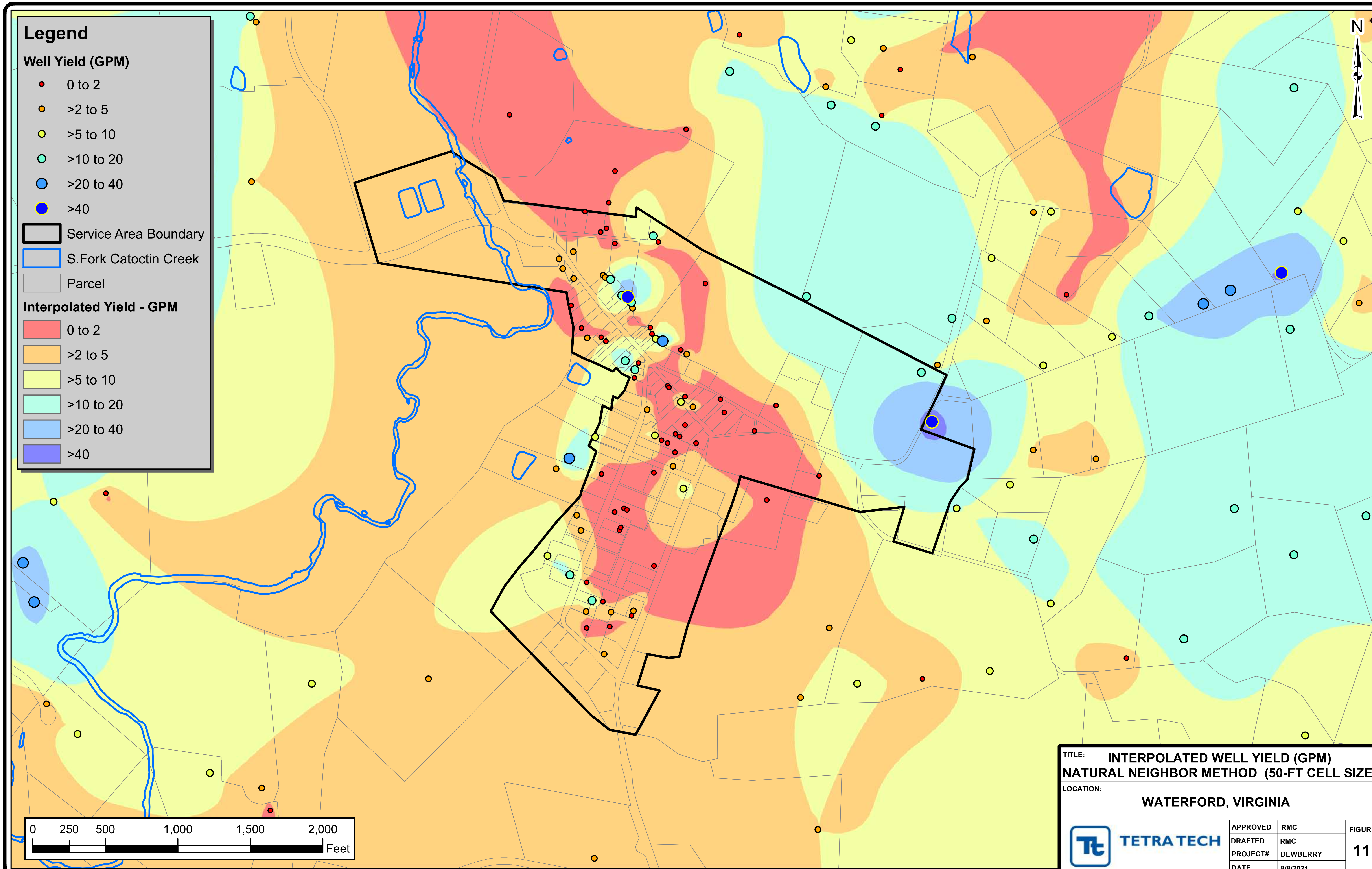
FIGURE 8



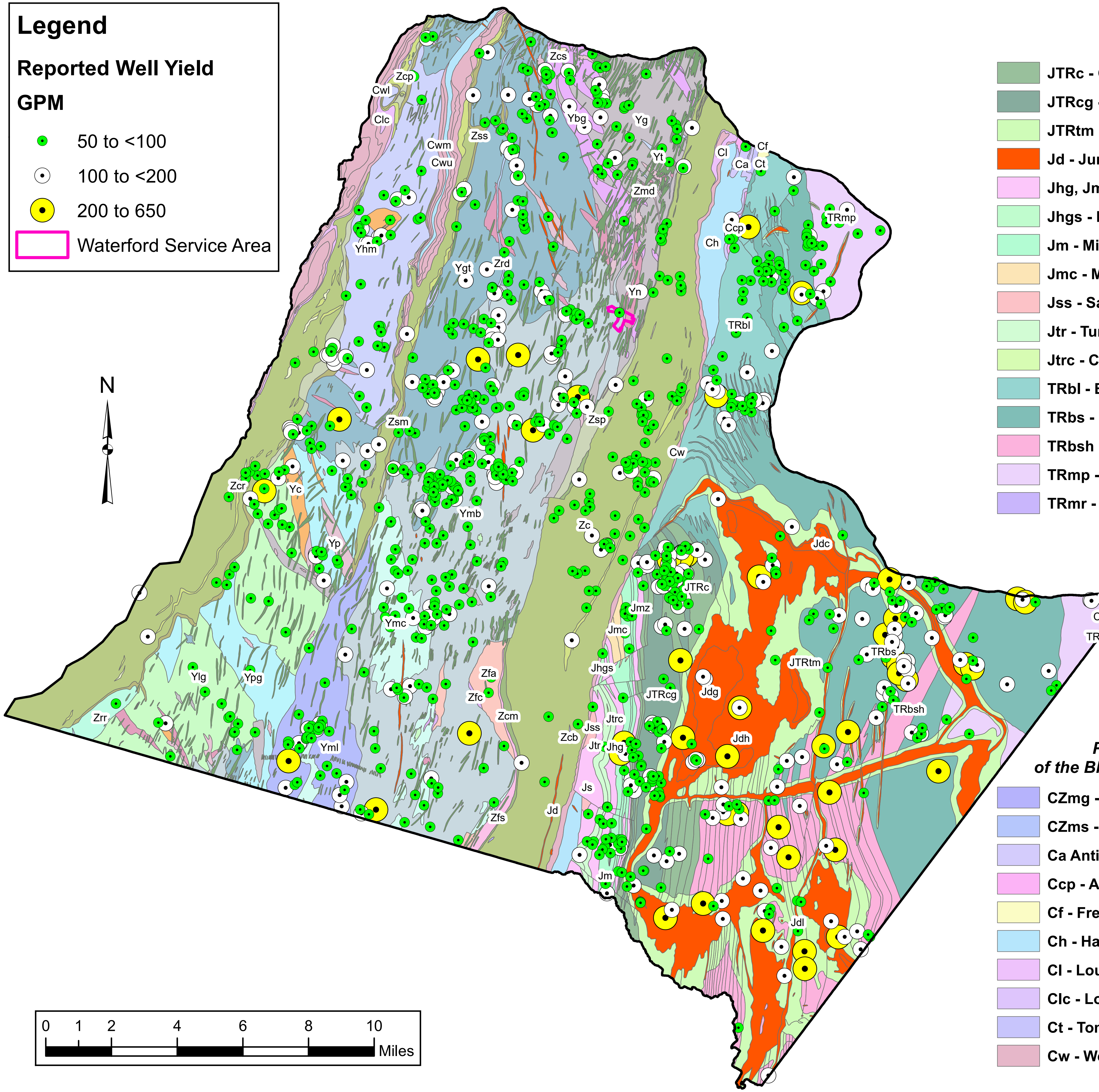
Note: The inverse relationship between yield and depth occurs because drilling is often halted after an adequate yield is obtained. Additional yield in shallow wells may be obtained by drilling deeper.

TITLE:	WELL YIELD (GPM) VERSUS DEPTH REPORTED FOR WELLS IN WATERFORD S.A.			
LOCATION:	WATERFORD, VIRGINIA			
TETRATECH	APPROVED	RMC	FIGURE	
	DRAFTED	RMC	9	
	PROJECT#	DEWBERRY		
	DATE	8/8/2021		


Legend
Well Yield (GPM)
0 to 2
>2 to 5
>5 to 10
>10 to 20
>20 to 40
>40
Service Area Boundary
S.Fork Catoctin Creek
Parcel
Interpolated Yield - GPM
0 to 2
>2 to 5
>5 to 10
>10 to 20
>20 to 40
>40
N
0 250 500 1,000 1,500 2,000
Feet
TITLE:
INTERPOLATED WELL YIELD (GPM)
BY ORDINARY KRIGING (50-FT CELL SIZE)
LOCATION:
WATERFORD, VIRGINIA
TETRA TECH
APPROVED RMC
DRAFTED RMC
PROJECT# DEWBERRY
DATE 8/8/2021
FIGURE
10



N
Legend
Well Yield (GPM)
0 to 2
>2 to 5
>5 to 10
>10 to 20
>20 to 40
>40
Service Area Boundary
S.Fork Catoctin Creek
Parcel
Interpolated Yield - GPM
0 to 2
>2 to 5
>5 to 10
>10 to 20
>20 to 40
>40
0 250 500 1,000 1,500 2,000 Feet
TITLE: INTERPOLATED WELL YIELD (GPM)
NATURAL NEIGHBOR METHOD (50-FT CELL SIZE)
LOCATION: WATERFORD, VIRGINIA
TETRA TECH
APPROVED RMC
DRAFTED RMC
PROJECT# DEWBERRY
DATE 8/8/2021
FIGURE 11



Mesozoic Rocks of the Culpeper Basin

- JTRc - Catharpin Crk clastics
- JTRcg - Catharpin Crk conglomerate sandstone
- JTRtm - Balls Bluff siltstone
- Jd - Jurassic diabase
- Jhg, Jmz, Js - Jurassic basalt
- Jhgs - Hickory Grove sandstone siltstone
- Jm - Midland siltstone sandstone conglomerate
- Jmc - Midland conglomerate arkose
- Jss - Sander siltstone
- Jtr - Turkey Run sandstone
- Jtrc - Catharpin Creek clastics
- TRbl - Balls Bluff limestone conglomerate
- TRbs - Balls Bluff sandstone siltstone
- TRbsh - Balls Bluff shale siltstone
- TRmp - Manassas arkosic sandstone
- TRmr - Manassas sandstone conglomerate

Paleozoic Rocks of the Blue Ridge Anticlinorium

- CZmg - Mather Gorge metagraywacke
- CZms - Mather Gorge schist
- Ca Antietam meta-arkose
- Ccp - Antietam phyllite
- Cf - Frederick limestone
- Ch - Harpers metasiltstone phyllite
- Cl - Loudoun phyllite
- Clc - Loudoun quartz conglomerate
- Ct - Tomstown dolostone
- Cw - Weverton quartzite

Late Proterozoic Rocks of the Blue Ridge Anticlinorium

- Zc - Catoctin metabasalt
- Zcb - Metabasalt breccia
- Zcm - Catoctin marble
- Zcp - Catoctin phyllite
- Zcr Metarhyolite
- Zcs - Metasiltstone, metasandstone
- Zfa- Fauquier metaarkose
- Zfc - Fauquier metaconglomerate
- Zfs - Fauquier metamudstone
- Zmd - Metadiabase
- Zrd - Metarhyolite dike
- Zrr - Feldspar quartz syenite
- Zsm - Swift Run marble
- Zsp - Swift Run phyllite
- Zss - Swift Run schist metasandstone

MesoProterozoic Basement Rocks of the Blue Ridge Anticlinorium

- Ybg - Biotitic granite gniess
- Yc - Charnockite
- Yg - Leucocratic metagranite
- Ygt - Garnetiferous metagranite
- Yhm - Horneblende monz. gneiss
- Ylg - Layered granitic gneiss
- Ymb - Marshall metagranite
- Ymc - Coarse-grained metagranite
- Yml - Pink leucocratic metagranite
- Yn - Metanorite, metadiorite
- Yp - Paragneiss
- Ypg - Porphyroblastic metagranite
- Yt

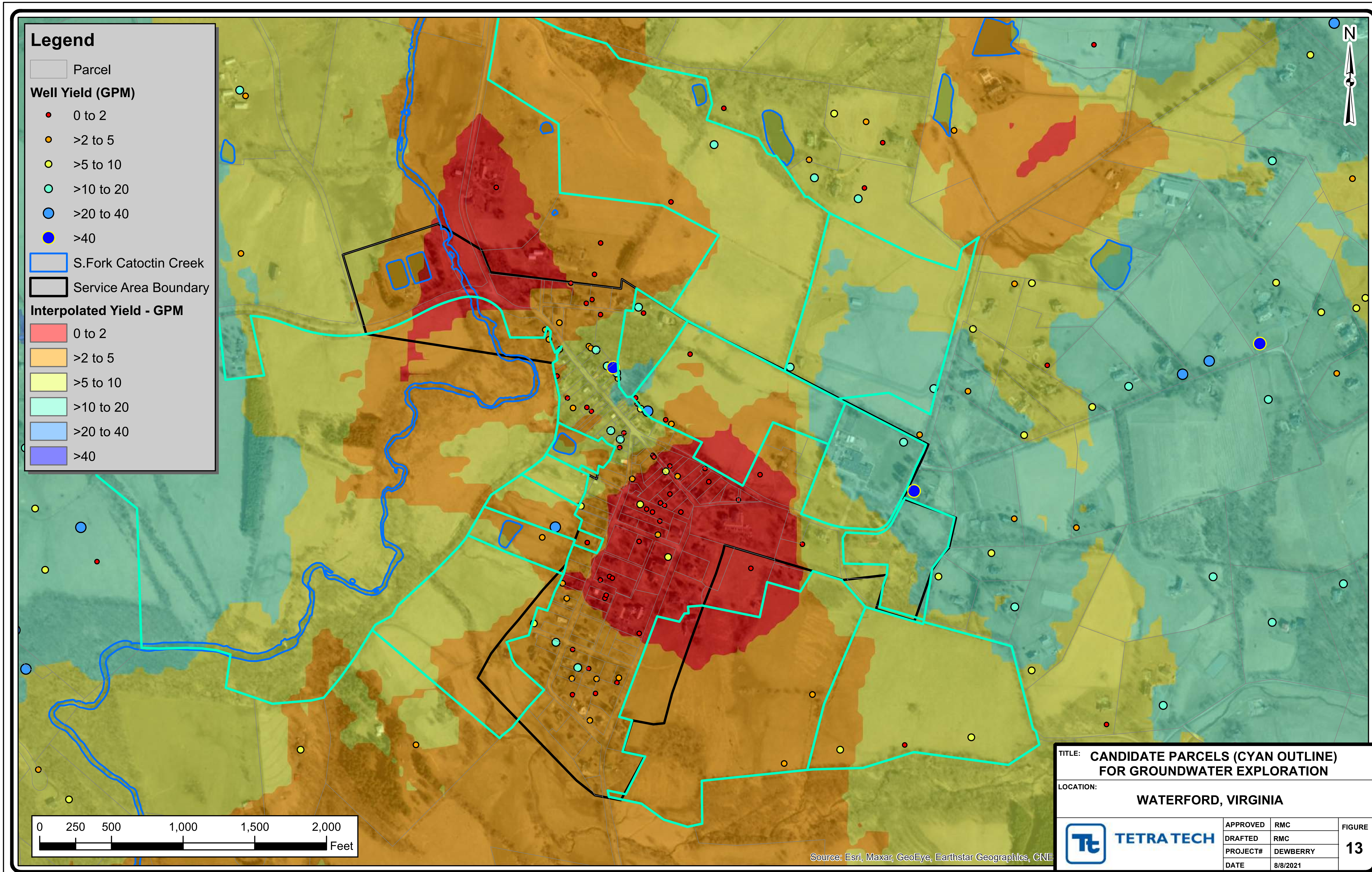
TITLE: HIGH-YIELD WELLS REPORTED BY WELL DRILLERS AND LOUDOUN COUNTY

LOCATION: LOUDOUN COUNTY, VIRGINIA

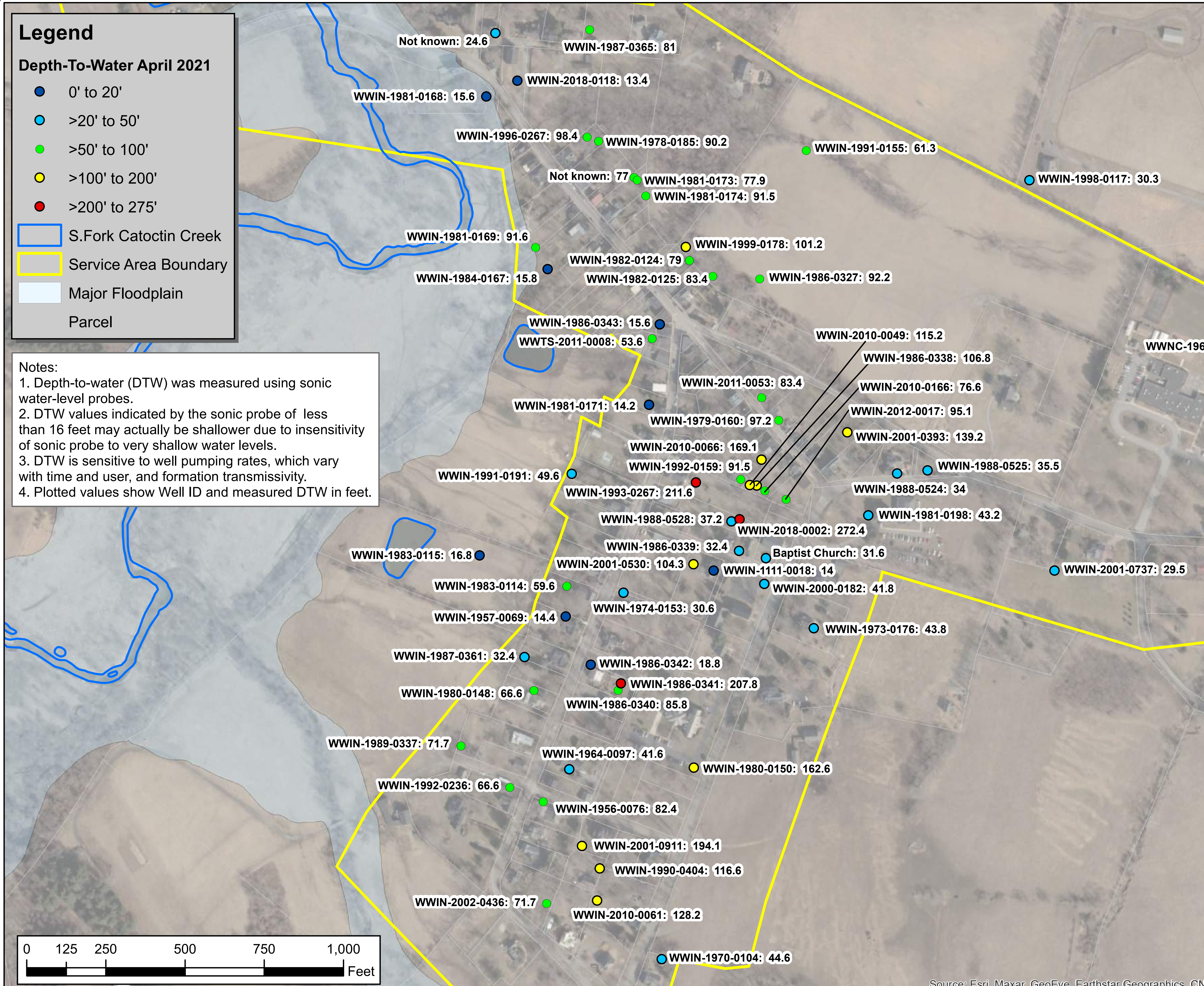
TETRA TECH

APPROVED	xxx
DRAFTED	RMC
PROJECT#	DEWBERRY
DATE	8/8/2021

FIGURE 12



Legend
Parcel
Well Yield (GPM)
0 to 2
>2 to 5
>5 to 10
>10 to 20
>20 to 40
>40
S.Fork Catoctin Creek
Service Area Boundary
Interpolated Yield - GPM
0 to 2
>2 to 5
>5 to 10
>10 to 20
>20 to 40
>40
N
0 250 500 1,000 1,500 2,000 Feet
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNE
TITLE: CANDIDATE PARCELS (CYAN OUTLINE) FOR GROUNDWATER EXPLORATION
LOCATION: WATERFORD, VIRGINIA
TETRA TECH
APPROVED RMC
DRAFTED RMC
PROJECT# DEWBERRY
DATE 8/8/2021
FIGURE 13

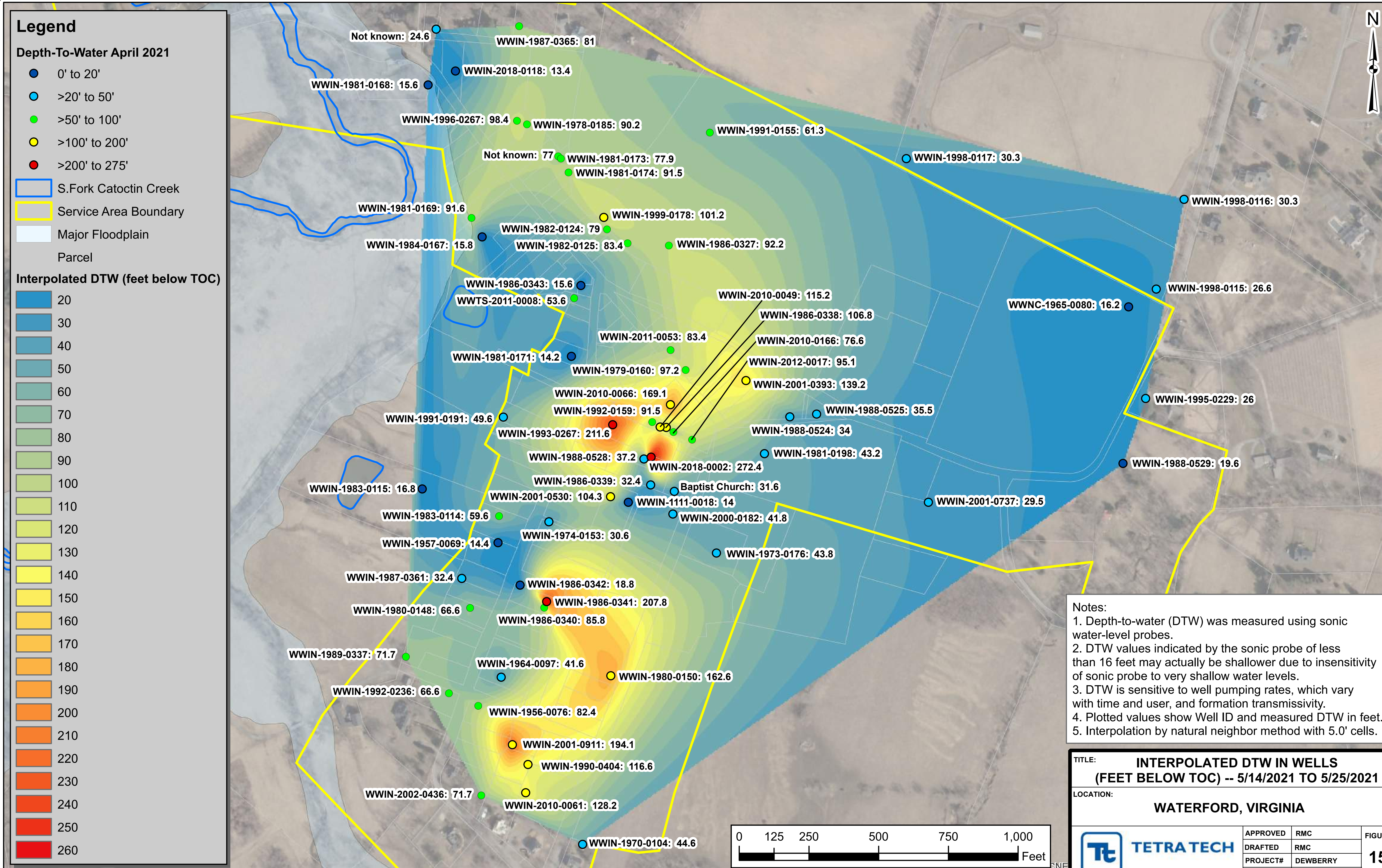


TITLE: DEPTH TO WATER (FEET BELOW TOP OF CASING) IN WELLS -- 5/14/2021 TO 5/25/2021

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	14
PROJECT#	DEWBERRY	
DATE	8/9/2021	



Notes:
1. Depth-to-water (DTW) was measured using sonic water-level probes.
2. DTW values indicated by the sonic probe of less than 16 feet may actually be shallower due to insensitivity of sonic probe to very shallow water levels.
3. DTW is sensitive to well pumping rates, which vary with time and user, and formation transmissivity.
4. Plotted values show Well ID and measured DTW in feet.
5. Interpolation by natural neighbor method with 5.0' cells.

TITLE:
INTERPOLATED DTW IN WELLS (FEET BELOW TOC) -- 5/14/2021 TO 5/25/2021

LOCATION:
WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	15
PROJECT#	DEWBERRY	
DATE	8/9/2021	

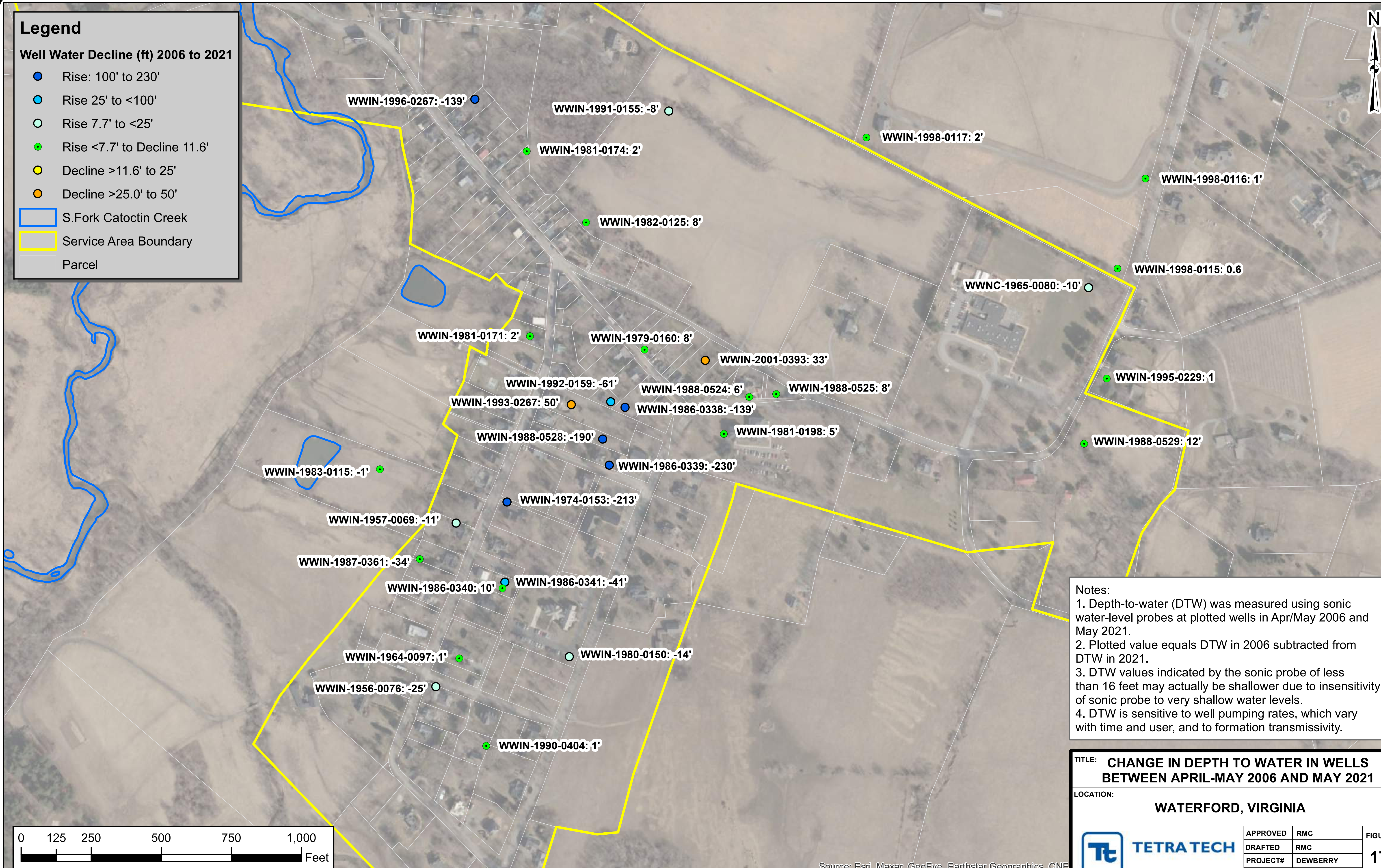
TITLE: WELL DEPTH-TO-WATER DATA
INITIAL DTW / APR-MAY 2006 DTW / MAY 2021 DTW

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	xxx
DRAFTED	RMC
PROJECT#	DEWBERRY
DATE	8/9/2021

FIGURE 16



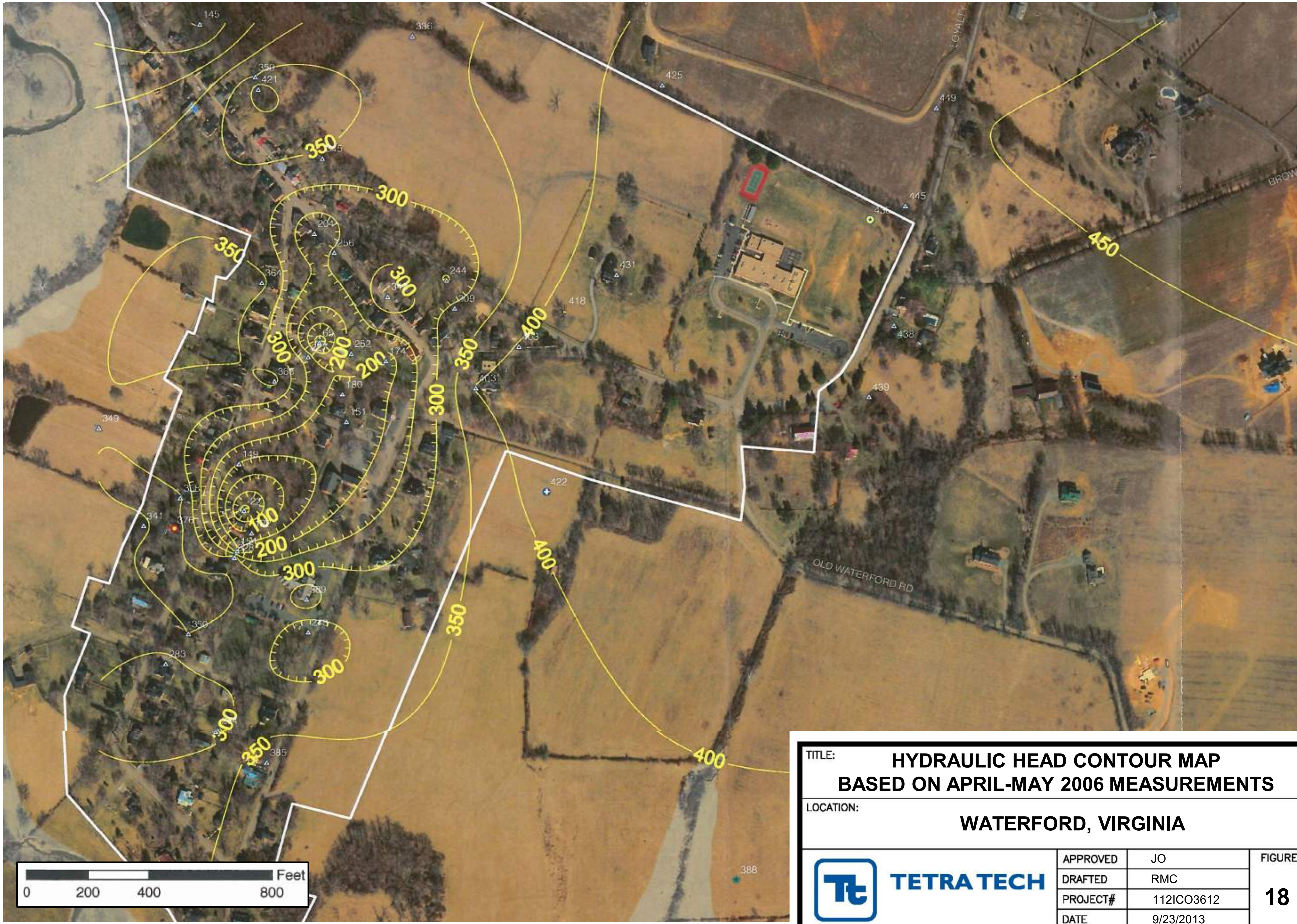
Notes:
1. Depth-to-water (DTW) was measured using sonic water-level probes at plotted wells in Apr/May 2006 and May 2021.
2. Plotted value equals DTW in 2006 subtracted from DTW in 2021.
3. DTW values indicated by the sonic probe of less than 16 feet may actually be shallower due to insensitivity of sonic probe to very shallow water levels.
4. DTW is sensitive to well pumping rates, which vary with time and user, and to formation transmissivity.

TITLE: **CHANGE IN DEPTH TO WATER IN WELLS BETWEEN APRIL-MAY 2006 AND MAY 2021**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	17
PROJECT#	DEWBERRY	
DATE	5/30/2021	

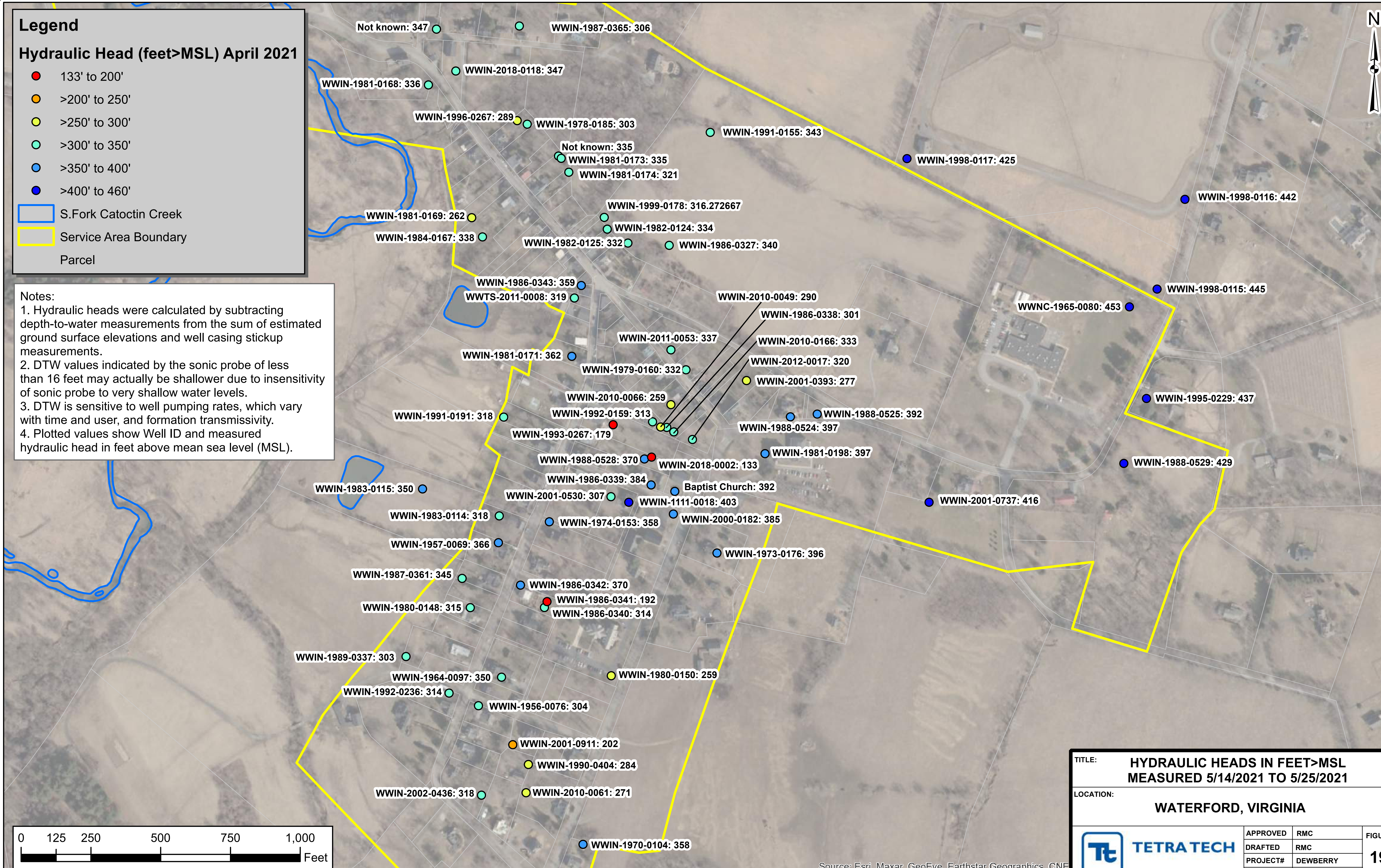


TITLE: **HYDRAULIC HEAD CONTOUR MAP BASED ON APRIL-MAY 2006 MEASUREMENTS**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

APPROVED	JO	FIGURE
DRAFTED	RMC	18
PROJECT#	112ICO3612	
DATE	9/23/2013	

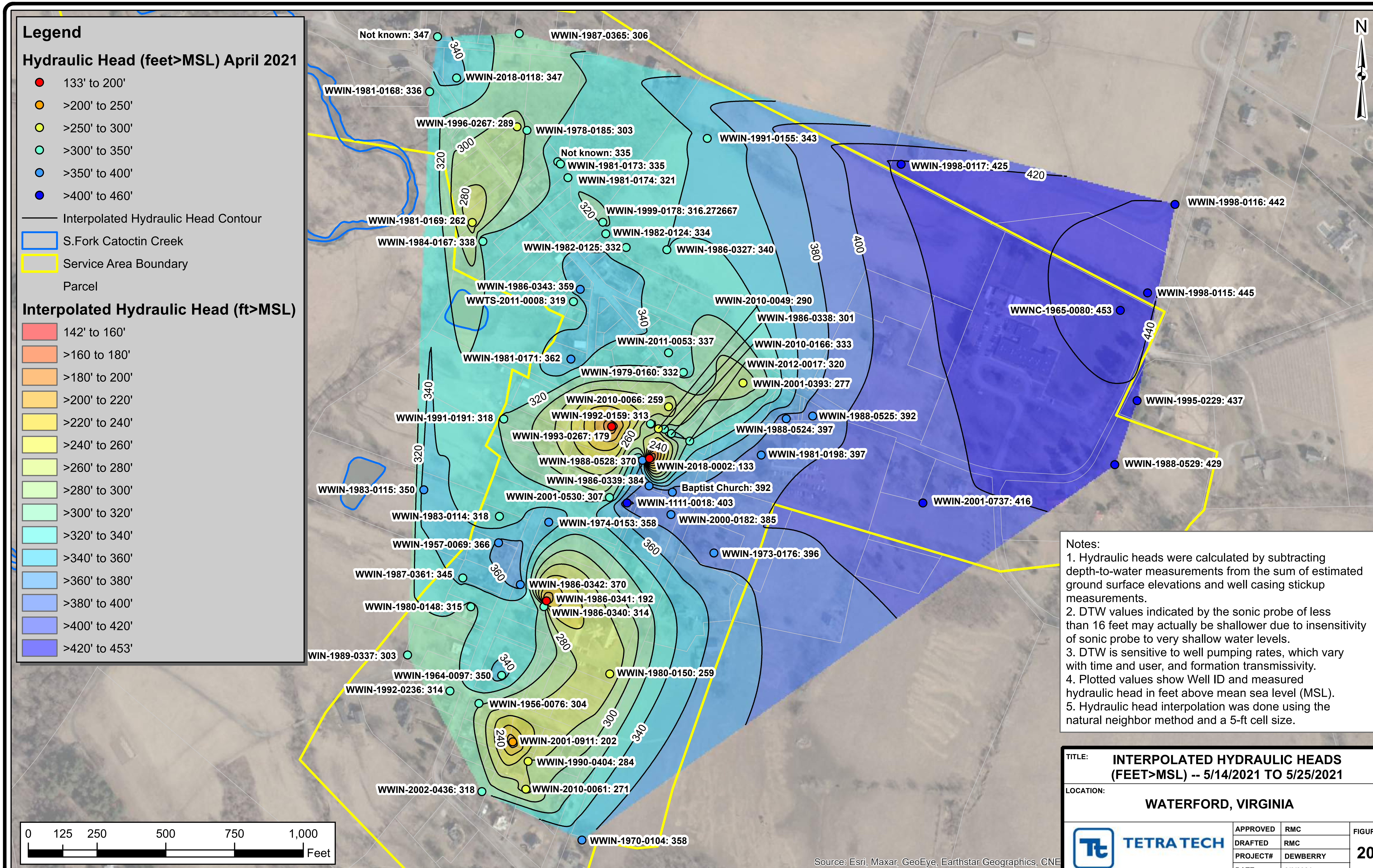


TITLE: HYDRAULIC HEADS IN FEET>MSL MEASURED 5/14/2021 TO 5/25/2021

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE	
DRAFTED	RMC		19
PROJECT#	DEWBERRY		
DATE	8/9/2021		



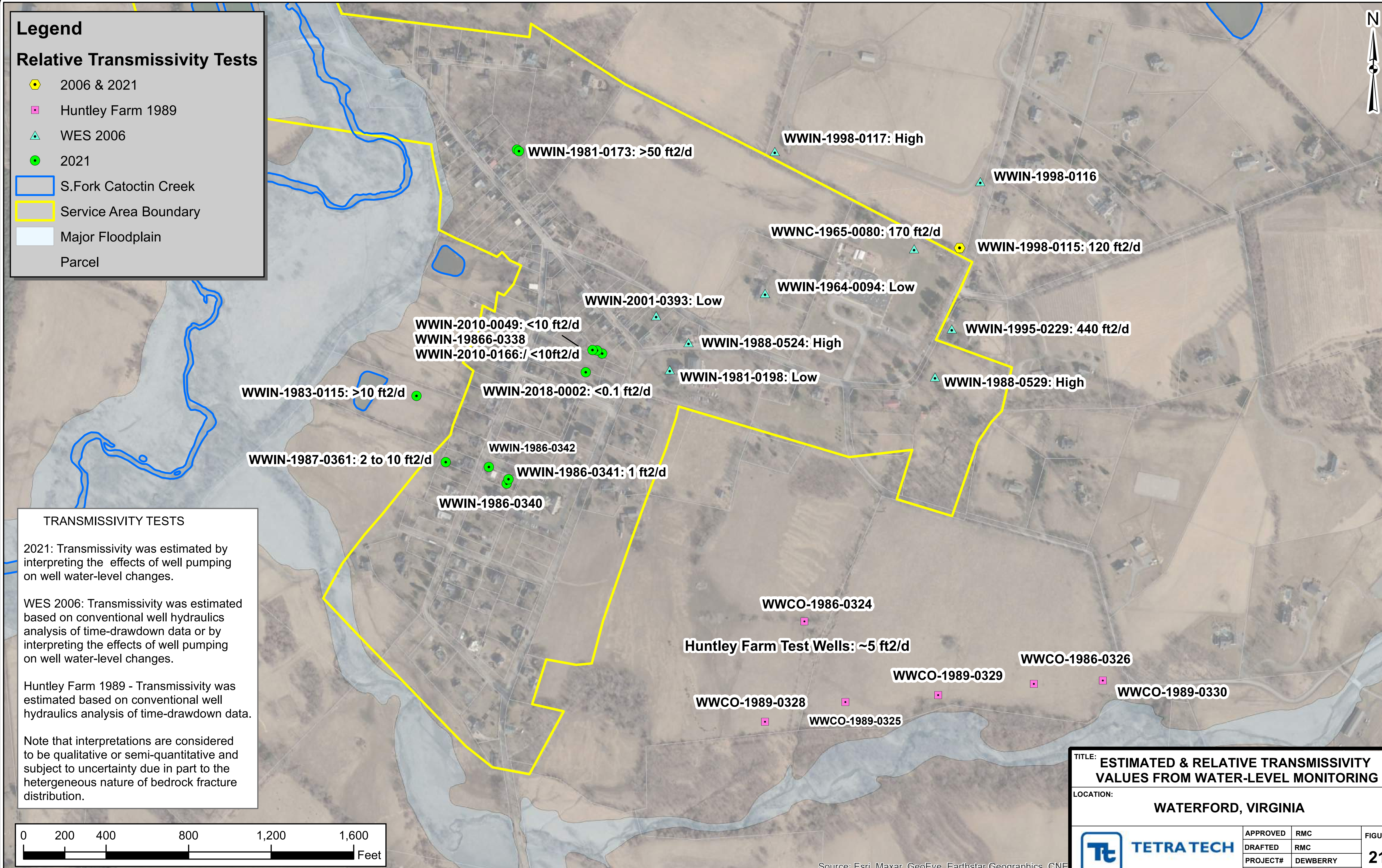
Notes:
1. Hydraulic heads were calculated by subtracting depth-to-water measurements from the sum of estimated ground surface elevations and well casing stickup measurements.
2. DTW values indicated by the sonic probe of less than 16 feet may actually be shallower due to insensitivity of sonic probe to very shallow water levels.
3. DTW is sensitive to well pumping rates, which vary with time and user, and formation transmissivity.
4. Plotted values show Well ID and measured hydraulic head in feet above mean sea level (MSL).
5. Hydraulic head interpolation was done using the natural neighbor method and a 5-ft cell size.

TITLE: INTERPOLATED HYDRAULIC HEADS (FEET>MSL) -- 5/14/2021 TO 5/25/2021

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	20
PROJECT#	DEWBERRY	
DATE	8/9/2021	



TRANSMISSIVITY TESTS

2021: Transmissivity was estimated by interpreting the effects of well pumping on well water-level changes.

WES 2006: Transmissivity was estimated based on conventional well hydraulics analysis of time-drawdown data or by interpreting the effects of well pumping on well water-level changes.

Huntley Farm 1989 - Transmissivity was estimated based on conventional well hydraulics analysis of time-drawdown data.

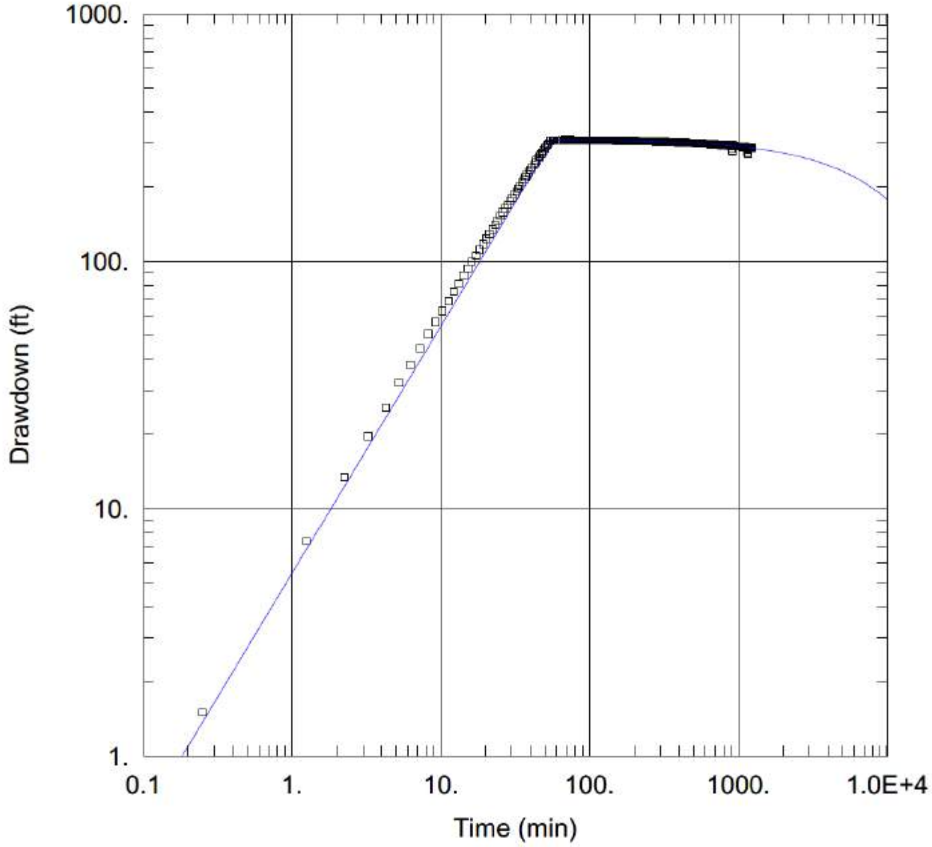
Note that interpretations are considered to be qualitative or semi-quantitative and subject to uncertainty due in part to the hetergeneous nature of bedrock fracture distribution.

TITLE: ESTIMATED & RELATIVE TRANSMISSIVITY VALUES FROM WATER-LEVEL MONITORING

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	21
PROJECT#	DEWBERRY	
DATE	8/9/2021	



WWIN-2018-0002 DRAWDOWN/RECOVERY TEST IN JUNE 2021

Data Set: P:\Loudoun 2005\Dewberry Waterford\Waterford\WWIN-2018-0002 TEST JUNE 2021.aqt
Date: 08/19/21 Time: 17:19:46

PROJECT INFORMATION

Company: Tetra Tech
Client: Dewberry
Project: 117-8878001
Location: Waterford, VA
Test Well: WWIN-2018-0002
Test Date: JUNE 2021

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
WWIN-2018-0002	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ WWIN-2018-0002	0	0

SOLUTION

Aquifer Model: Confined

Solution Method: Papadopulos-Cooper

T = 0.01974 ft^2/day

S = 4.235E-7

r(w) = 0.25 ft

r(c) = 0.25 ft

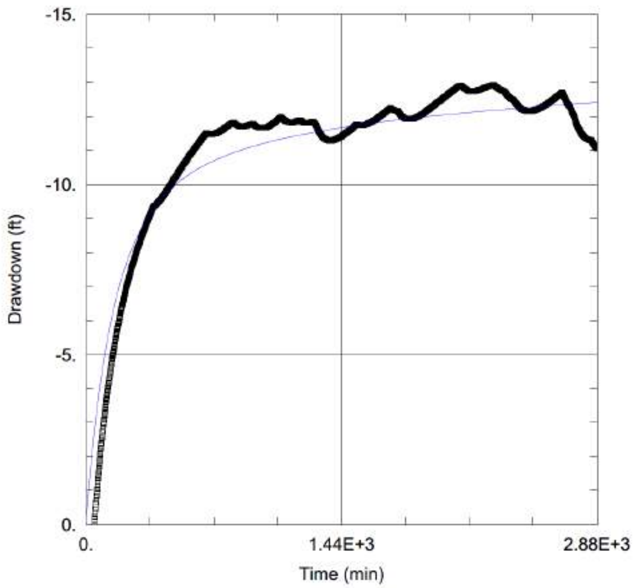
Notes:

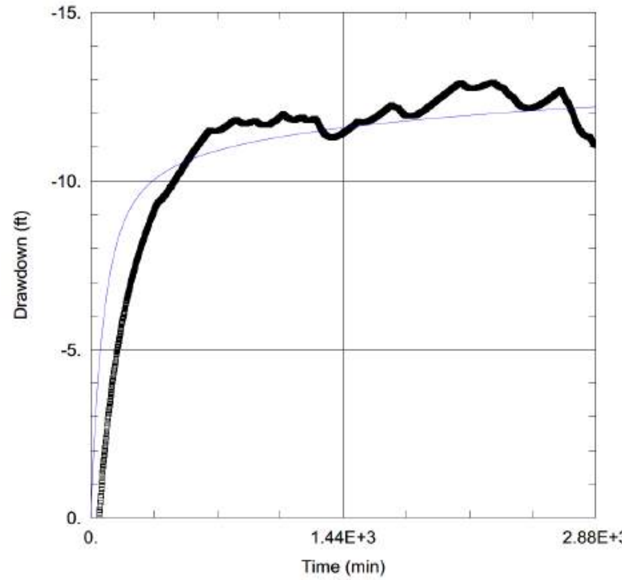
1. Pumping ~8 GPM for 57 minutes on 6/8/2021 caused 312 feet of drawdown.
2. Analysis of time-drawdown data indicate water pumped is derived from wellbore storage with very slow recovery from the formation.

TITLE:	ANALYSIS OF WWIN-2018-0002 JUNE 2021 WATER-LEVEL DATA
LOCATION:	WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	22
PROJECT#	117-8878001	
DATE	8/19/2021	





WWIN-1987-0361 PUMP OFF (AVERAGE Q ESTIMATED AT 150 GPD)

Data Set: P:\...\WWIN-1987-0361 RECOVERY TEST 150-GPD.aqt
Date: 08/19/21 Time: 17:33:11

PROJECT INFORMATION

Company: Tetra Tech
Client: Dewberry
Project: 117-8878001
Location: Waterford, VA
Test Well: WWIN-1987-0362
Test Date: 7/12-13/2021

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
WWIN-1987-0361	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ WWIN-1987-0361	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Papadopulos-Cooper
T = 1.792 ft^2/day
S = 0.0001
r(w) = 0.25 ft
r(c) = 0.25 ft

WWIN-1987-0361 PUMP OFF (AVERAGE Q ESTIMATED AT 150 GPD)

Data Set: P:\...\WWIN-1987-0361 RECOVERY TEST 300-GPD.aqt
Date: 08/19/21 Time: 17:37:18

PROJECT INFORMATION

Company: Tetra Tech
Client: Dewberry
Project: 117-8878001
Location: Waterford, VA
Test Well: WWIN-1987-0362
Test Date: 7/12-13/2021

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
WWIN-1987-0361	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ WWIN-1987-0361	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Papadopulos-Cooper
T = 3.866 ft^2/day
S = 0.0001
r(w) = 0.25 ft
r(c) = 0.25 ft

Notes:

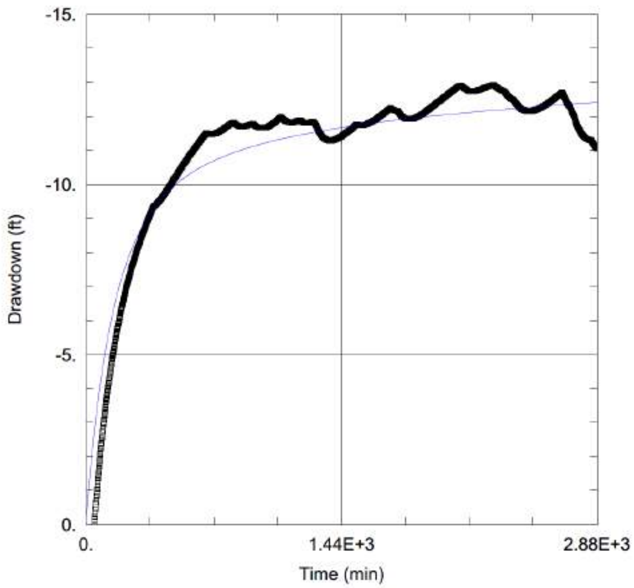
1. Bedrock transmissivity was estimated by analyzing water-level recovery data observed in mid-July 2021 when no pumping occurred and assuming long-term average daily pumping rates of 150 GPD and 300 GPD, and a storage coefficient of 0.0001.
2. As shown above, the estimated transmissivity is approximately 1.8 to 3.9 ft^2/d.

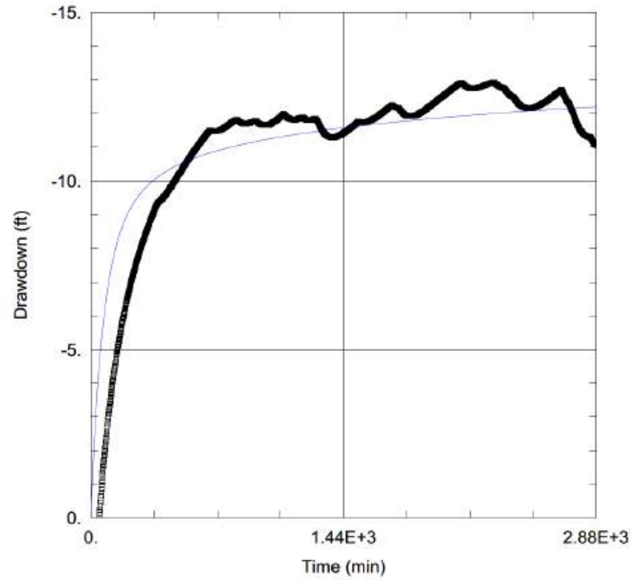
TITLE:
ANALYSIS OF WWIN-1987-0361
JULY 2021 WATER-LEVEL RECOVERY DATA

LOCATION:
WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	**23**
PROJECT#	117-8878001	
DATE	8/19/2021	





WWIN-1987-0361 PUMP OFF (AVERAGE Q ESTIMATED AT 150 GPD)

Data Set: P:\...\WWIN-1987-0361 RECOVERY TEST 150-GPD.aqt
Date: 08/19/21 Time: 17:33:11

PROJECT INFORMATION

Company: Tetra Tech
Client: Dewberry
Project: 117-8878001
Location: Waterford, VA
Test Well: WWIN-1987-0362
Test Date: 7/12-13/2021

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
WWIN-1987-0361	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ WWIN-1987-0361	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Papadopulos-Cooper
T = 1.792 ft^2/day
S = 0.0001
r(w) = 0.25 ft
r(c) = 0.25 ft

WWIN-1987-0361 PUMP OFF (AVERAGE Q ESTIMATED AT 150 GPD)

Data Set: P:\...\WWIN-1987-0361 RECOVERY TEST 300-GPD.aqt
Date: 08/19/21 Time: 17:37:18

PROJECT INFORMATION

Company: Tetra Tech
Client: Dewberry
Project: 117-8878001
Location: Waterford, VA
Test Well: WWIN-1987-0362
Test Date: 7/12-13/2021

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
WWIN-1987-0361	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ WWIN-1987-0361	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Papadopulos-Cooper
T = 3.866 ft^2/day
S = 0.0001
r(w) = 0.25 ft
r(c) = 0.25 ft

Notes:

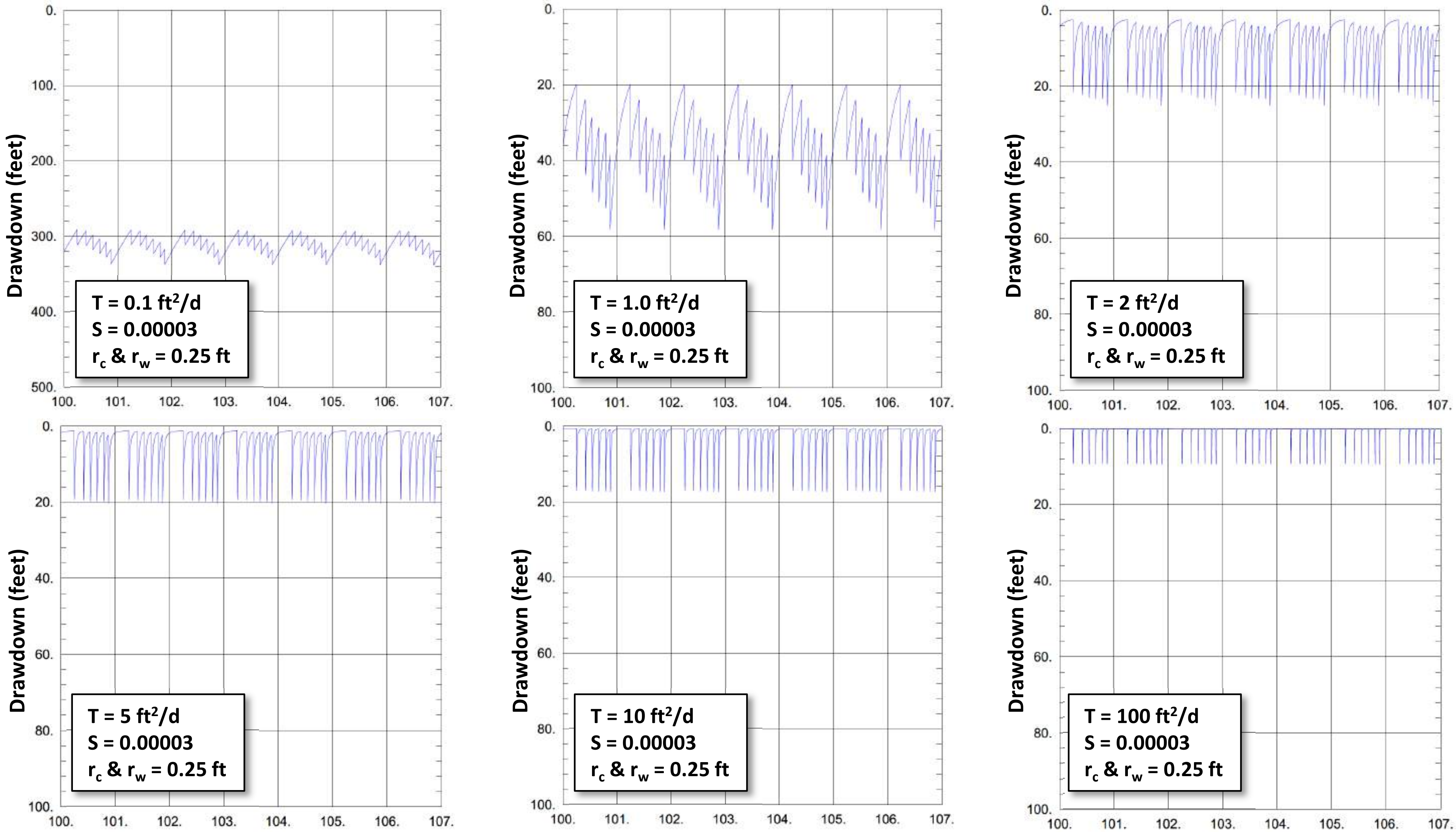
1. Bedrock transmissivity was estimated by analyzing water-level recovery data observed in mid-July 2021 when no pumping occurred and assuming long-term average daily pumping rates of 150 GPD and 300 GPD, and a storage coefficient of 0.0001.
2. As shown above, the estimated transmissivity is approximately 1.8 to 3.9 ft^2/d.

TITLE:
ANALYSIS OF WWIN-1987-0361
JULY 2021 WATER-LEVEL RECOVERY DATA

LOCATION:
WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	**23**
PROJECT#	117-8878001	
DATE	8/19/2021	



Notes:

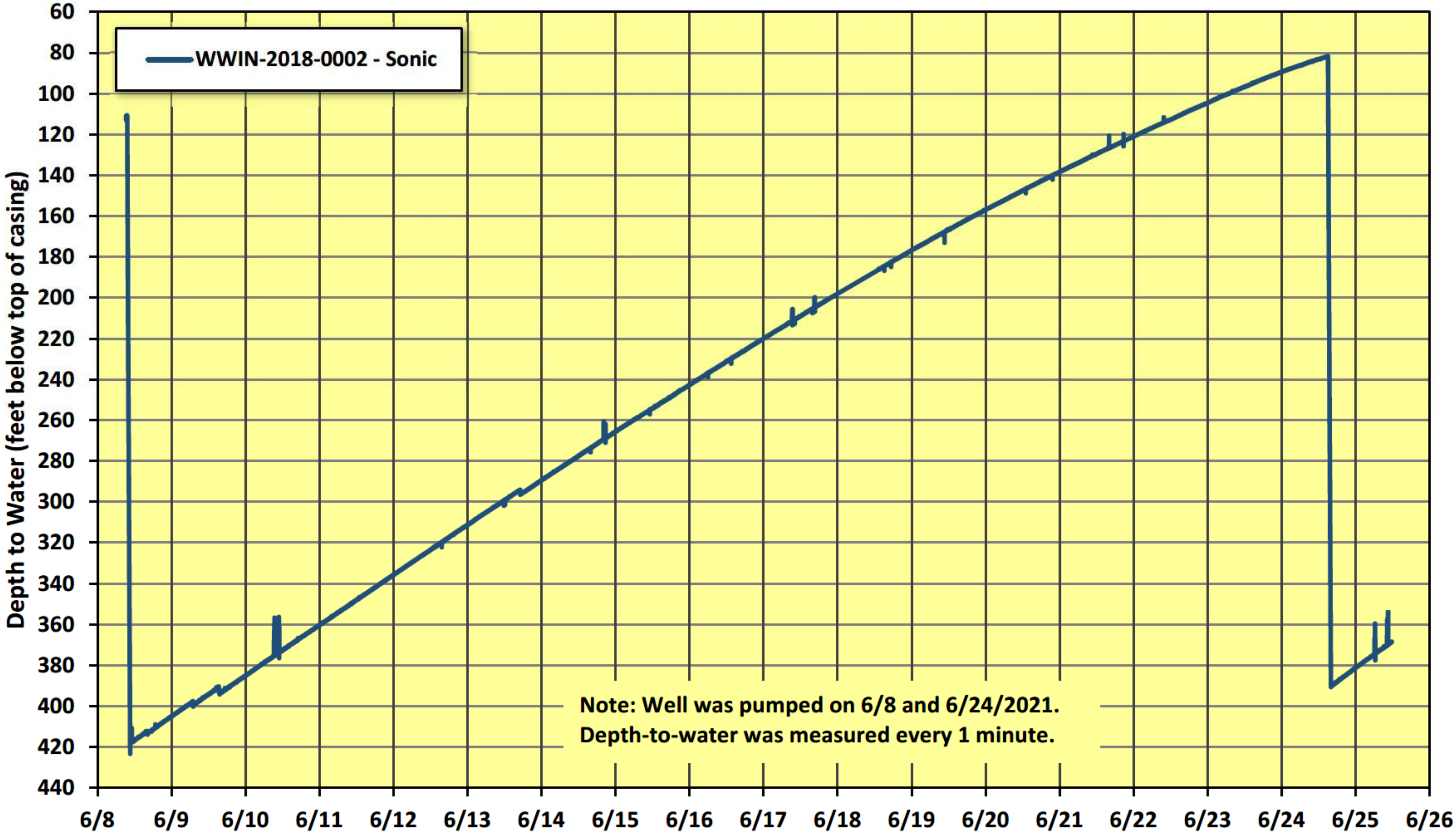
1. Time-drawdown calculations were made using the Papadopulos-Cooper equation implemented in AQTESOLV www.aqtesolv.com.
2. Shown are drawdown/recovery cycles after 100 to 107 days of cyclic pumping of 6 GPM during five 5-minute cycles each day (180 GPD).
3. All calculations were made using a storage coefficient (S) of 0.00003, which is typical of fractured metamorphic rock in Loudoun County and well casing and open hole radii of 0.25 feet. T = transmissivity, a measure of formation's capacity to transmit groundwater.

TITLE: SIMULATED DRAWDOWN DUE TO DOMESTIC WELL PUMPING

LOCATION: WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	24
PROJECT#	117-8878001	
DATE	7/1/2021	



Notes:

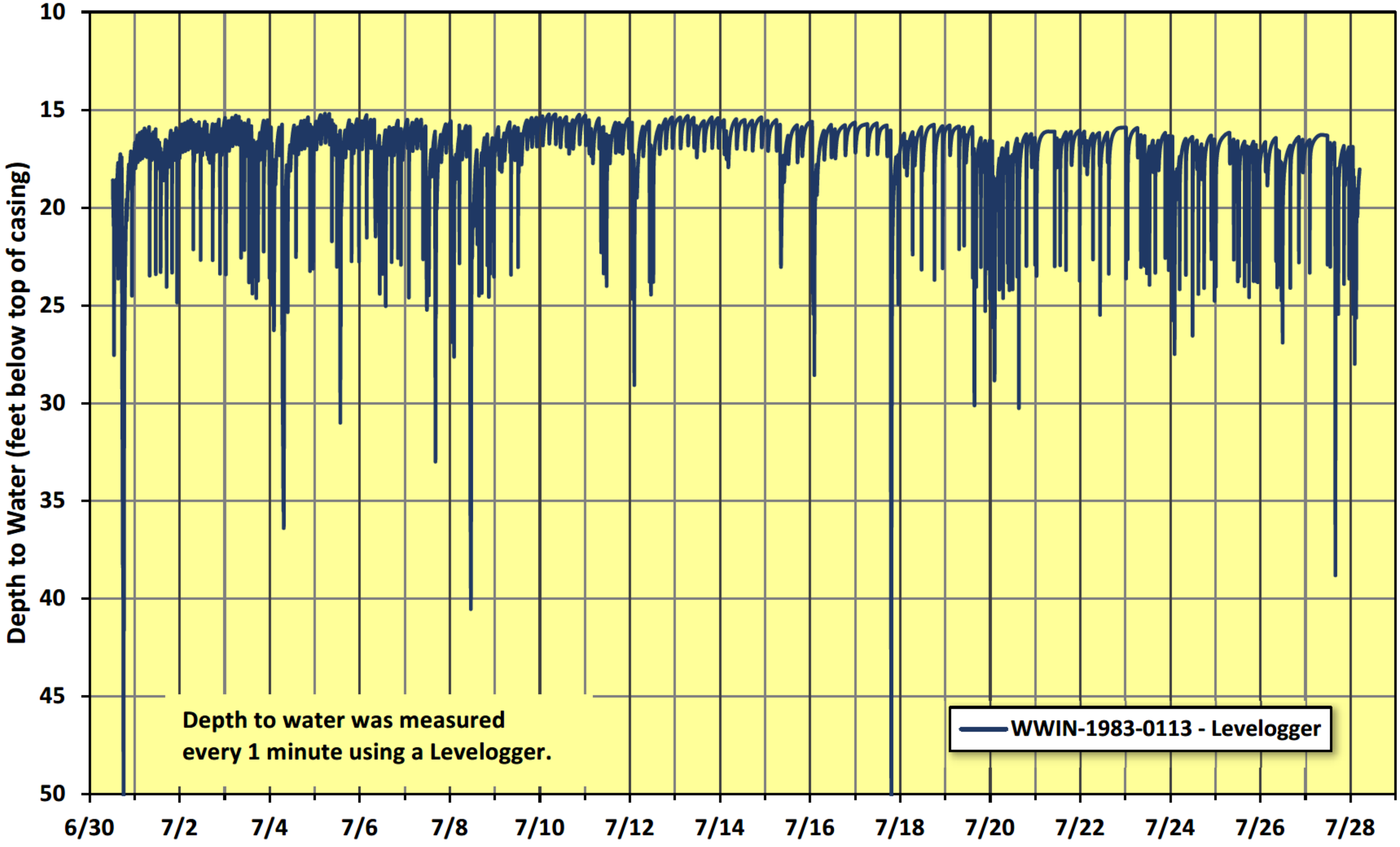
1. WWIN-2018-0002 reportedly had an airlift yield of 0.5 gpm.
2. Depth-to-water was measured every minute using a Sonic probe with datalogger.
3. Pumping ~8 GPM for 57 minutes on 6/8/2021 caused 312 feet of drawdown and pumping ~8 GPM for 55 minutes on 6/24/2021 caused 309 feet of drawdown.
4. Analysis of time-drawdown data indicates that the water pumped is derived from wellbore storage and that the apparent formation transmissivity is ~0.02 ft^2/d.

TITLE: **2021 WELL HYDROGRAPH: WWIN-2018-0002 REPORTED 700' DEEP, 0.5 GPM YIELD**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	25
PROJECT#	117-8878001	
DATE	7/1/2021	



Notes:

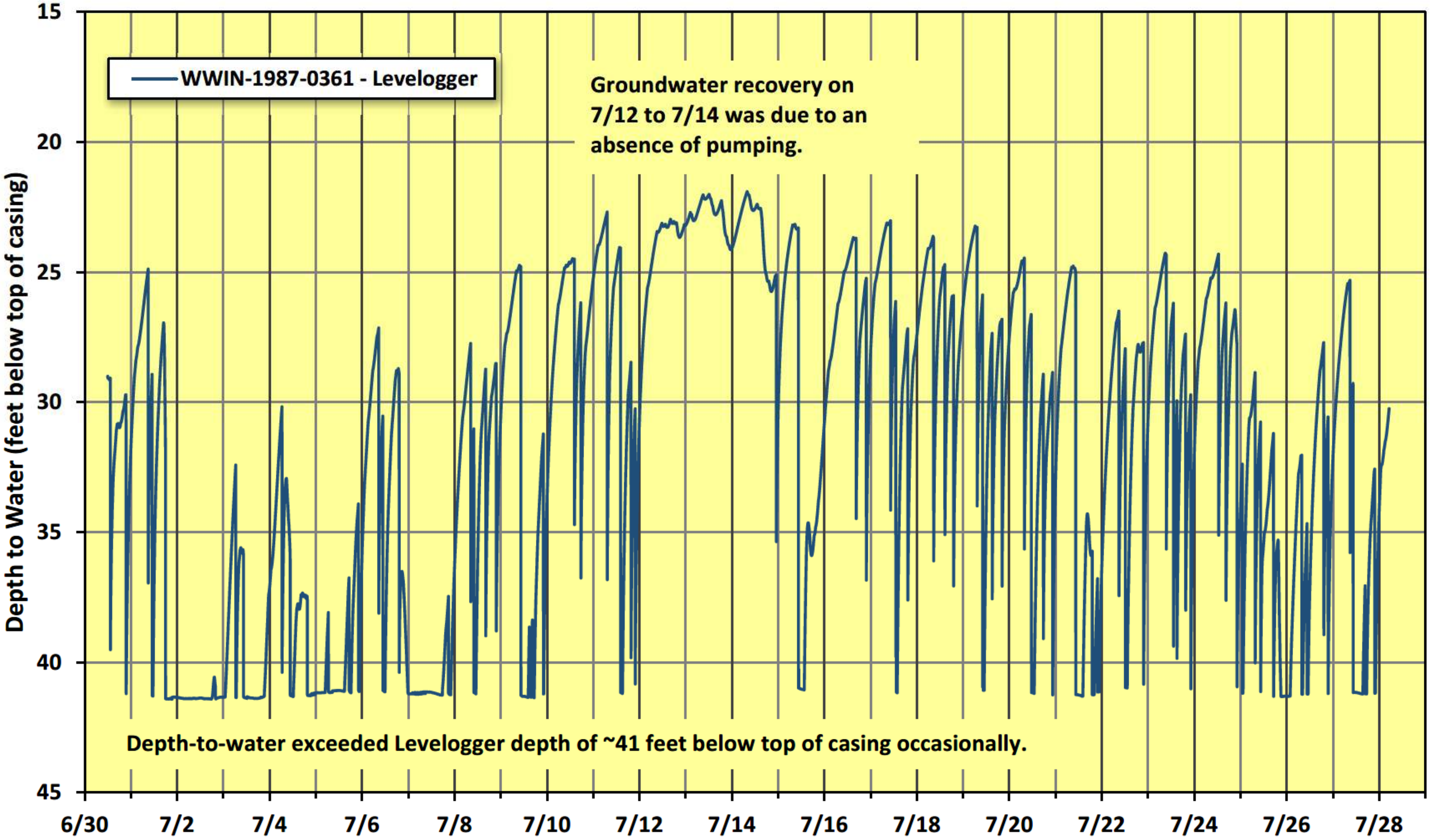
1. Small drawdown/recovery cycles (such as those on 7/10, 7/13, and 7/14) are apparently caused by pumping other wells (no one used water from this well on those days).
2. Analysis of airlift data suggests that the local formation transmissivity is ~1 to 3 ft^2/d. This range is consistent with simulated drawdown shown in Figure 24.

TITLE: **2021 WELL HYDROGRAPH: WWIN-1983-0115 REPORTED 365' DEEP, 4 GPM YIELD**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

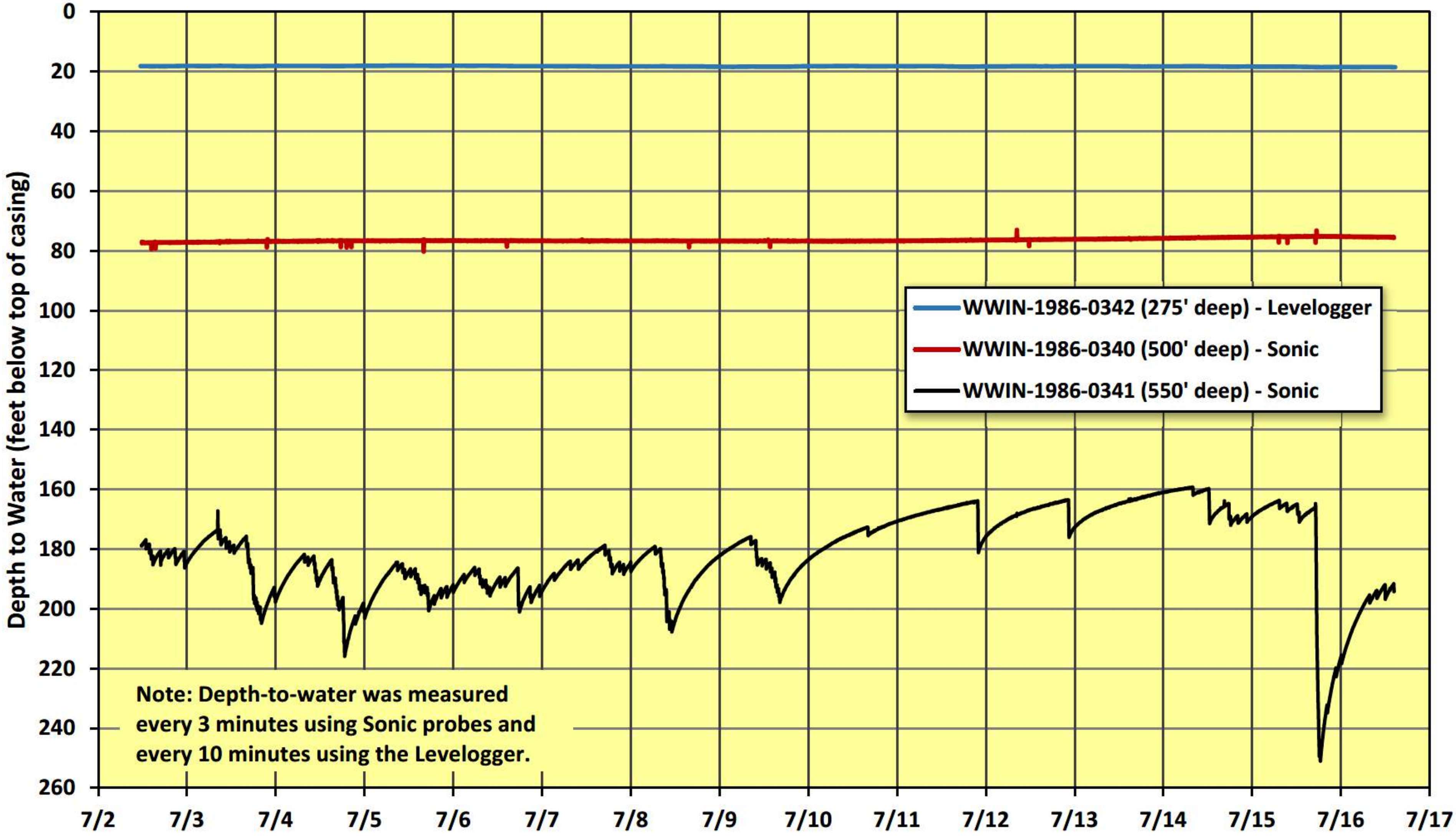
APPROVED	RMC	FIGURE
DRAFTED	RMC	**26**
PROJECT#	117-8878001	
DATE	7/1/2021	



Notes:

1. Depth-to-water was measured every minute using a pressure transducer and datalogger.
2. Analysis of water-level recovery data (Figure 23) suggests that the local formation transmissivity is in the range of 1 to 4 ft^2/d. This range is consistent with the simulated drawdown shown in Figure 24.

TITLE: 2021 WELL HYDROGRAPH: WWIN-1987-0361 REPORTED 320' DEEP, 2.8 GPM YIELD			
LOCATION: WATERFORD, VIRGINIA			
TETRA TECH	APPROVED	RMC	FIGURE
	DRAFTED	RMC	27
	PROJECT#	117-8878001	
	DATE	7/1/2021	



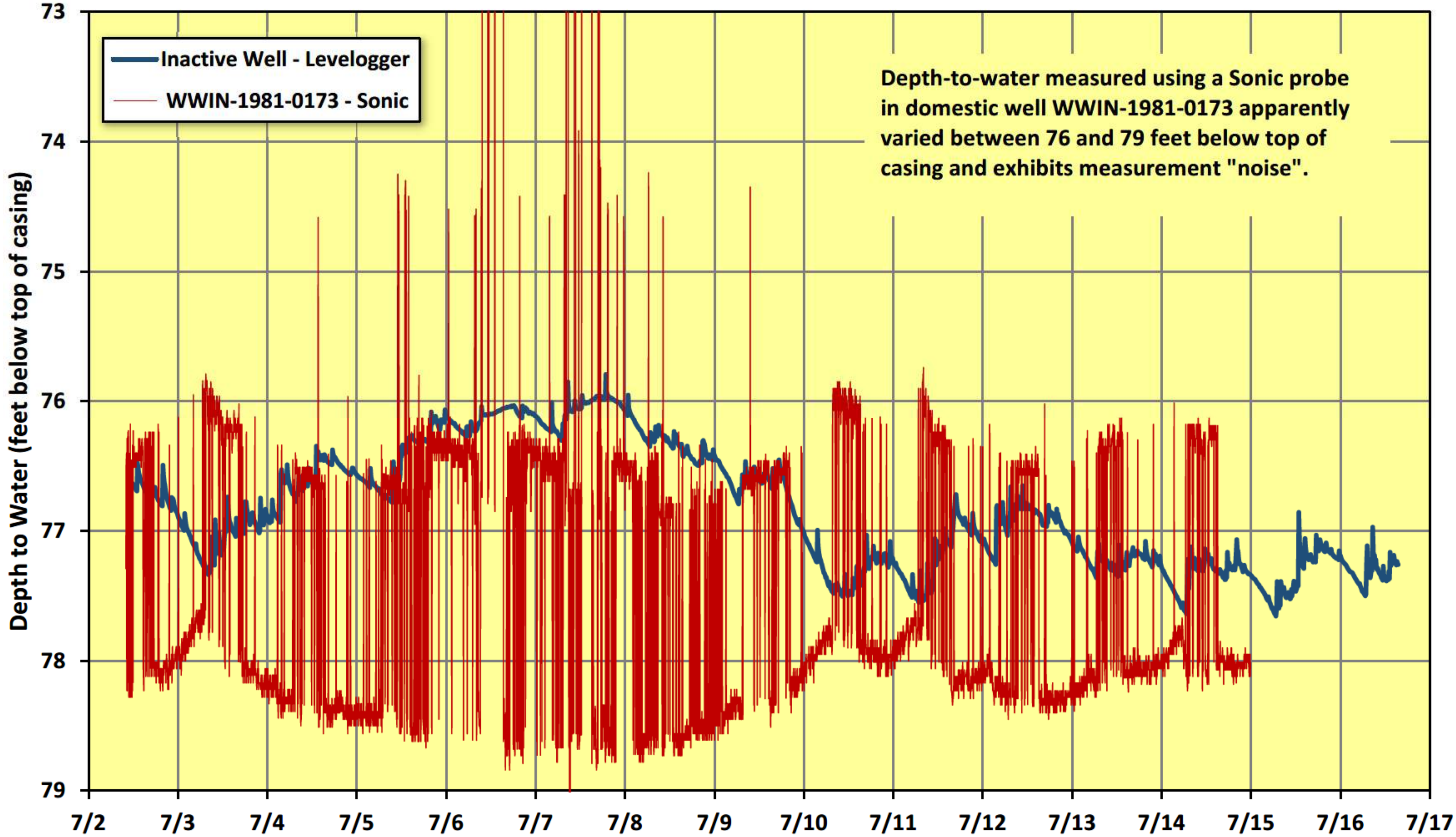
Notes:

1. Drawdown due to pumping WWIN-1986-0341 is not observed at the other wells.
2. Analysis of WWIN-1986-0341 airlift data suggests that the local formation transmissivity is ~0.5 ft^2/d. This range is consistent with simulated drawdown shown in Figure 24.

TITLE:	2021 WELL HYDROGRAPHS: WWIN-2018-0002 WWIN-1986-0340, AND WWIN-1986-0341
LOCATION:	WATERFORD, VIRGINIA

TETRA TECH

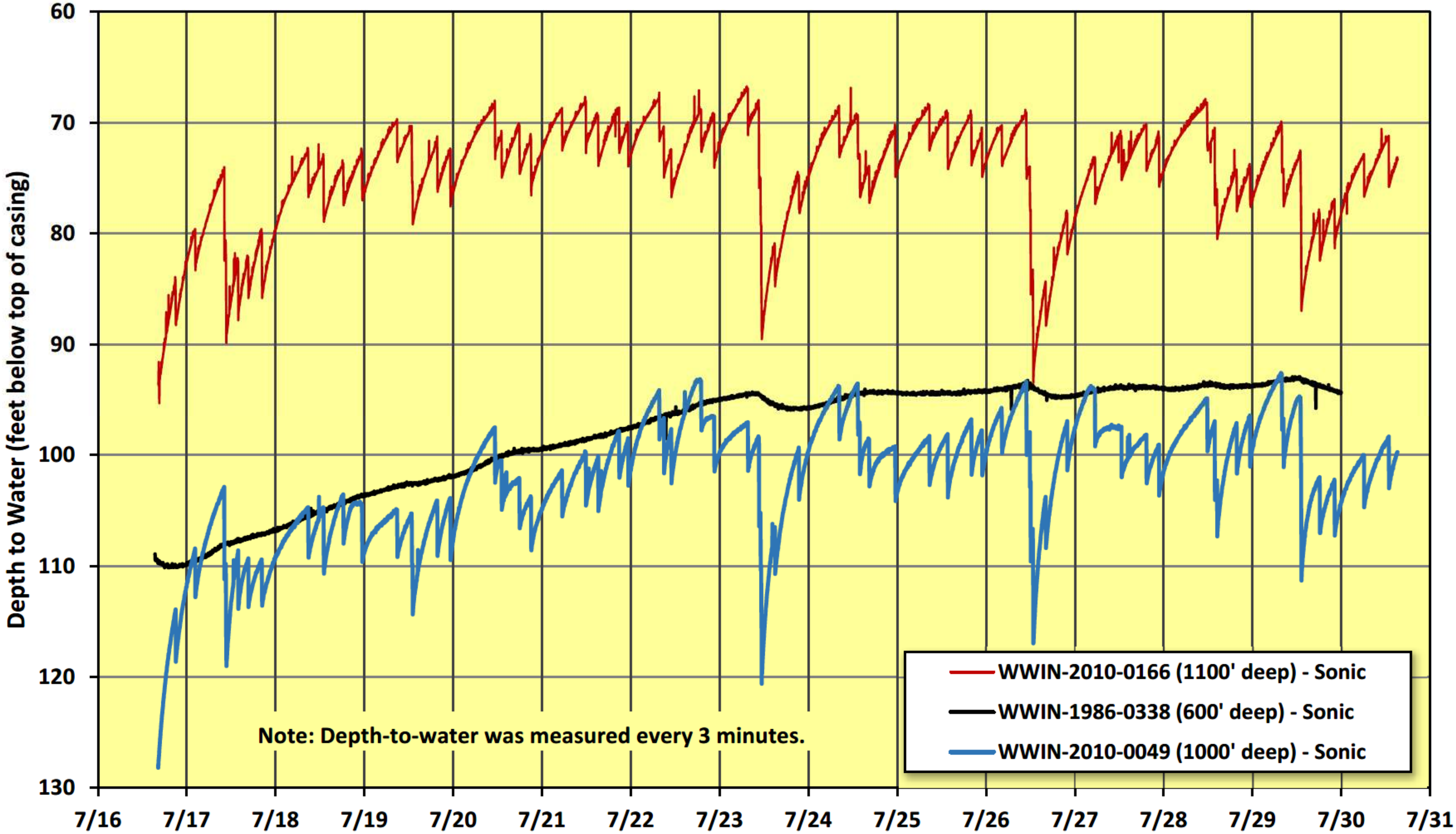
APPROVED	RMC	FIGURE
DRAFTED	RMC	28
PROJECT#	117-8878001	
DATE	7/1/2021	



Notes:

1. WWIN-1981-0173 is located ~26' away from an unused well.
2. Analysis of WWIN-1981-0173 airlift data suggests that the local formation transmissivity is ~160 ft^2/d. This range is consistent with simulated drawdown shown in Figure 24.

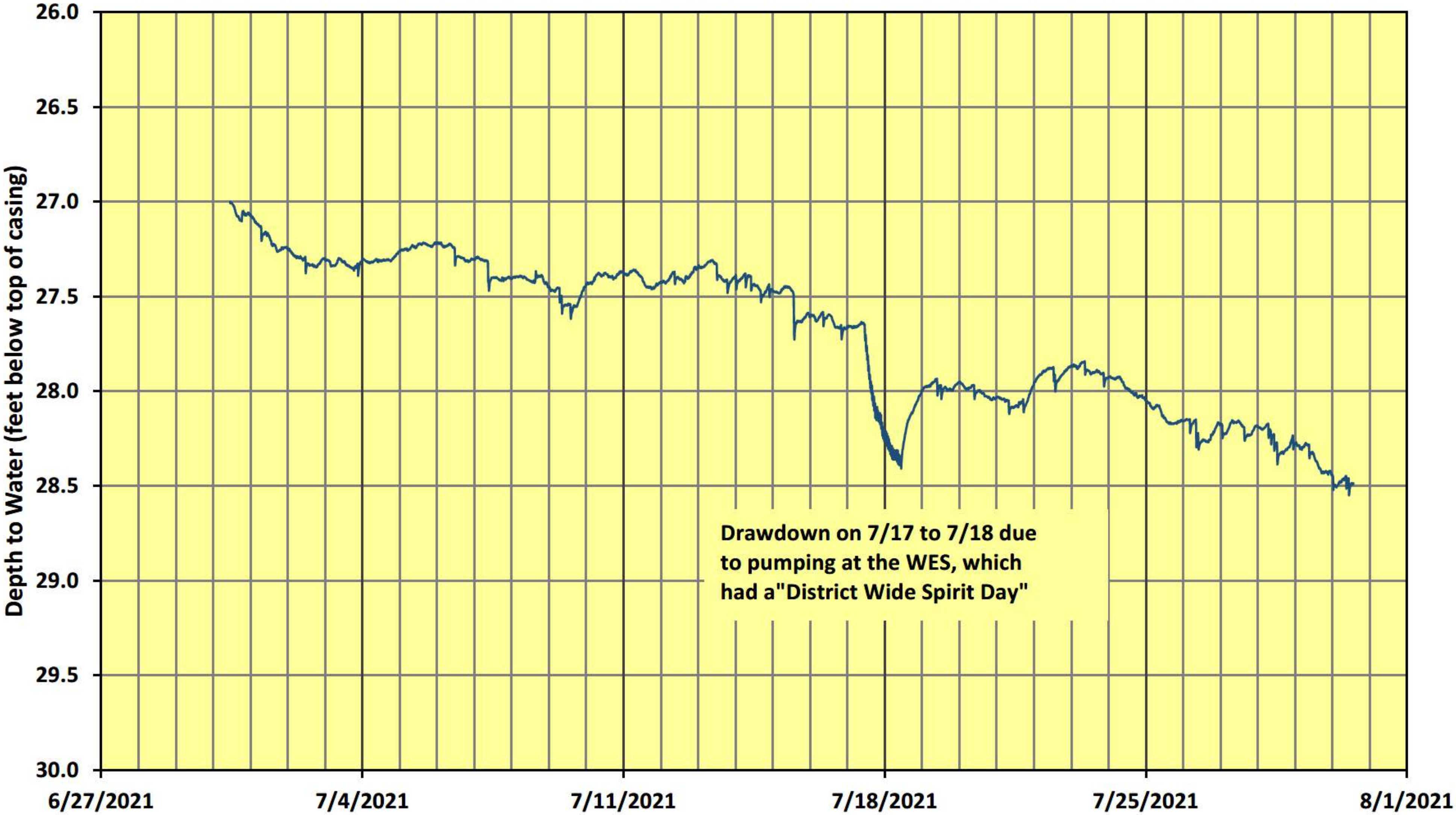
TITLE: 2021 WELL HYDROGRAPHS: WWIN-1981-0173 REPORTED 100' DEEP, 50 GPM YIELD			
LOCATION: WATERFORD, VIRGINIA			
TETRA TECH	APPROVED	RMC	FIGURE
	DRAFTED	RMC	29
	PROJECT#	117-8878001	
	DATE	7/1/2021	



Notes:

1. WWIN-1986-0338 is an inactive well located ~26’ east of WWIN-2010-0166 and 21’ west of WWIN-2010-0049. The two active wells are connected and controlled by the same pressure tank.
2. Analysis of airlift data for these wells time-drawdown data suggests that the local formation transmissivity is approximately 0.1 ft^2/d. This is consistent with simulated drawdown shown in Figure 24.

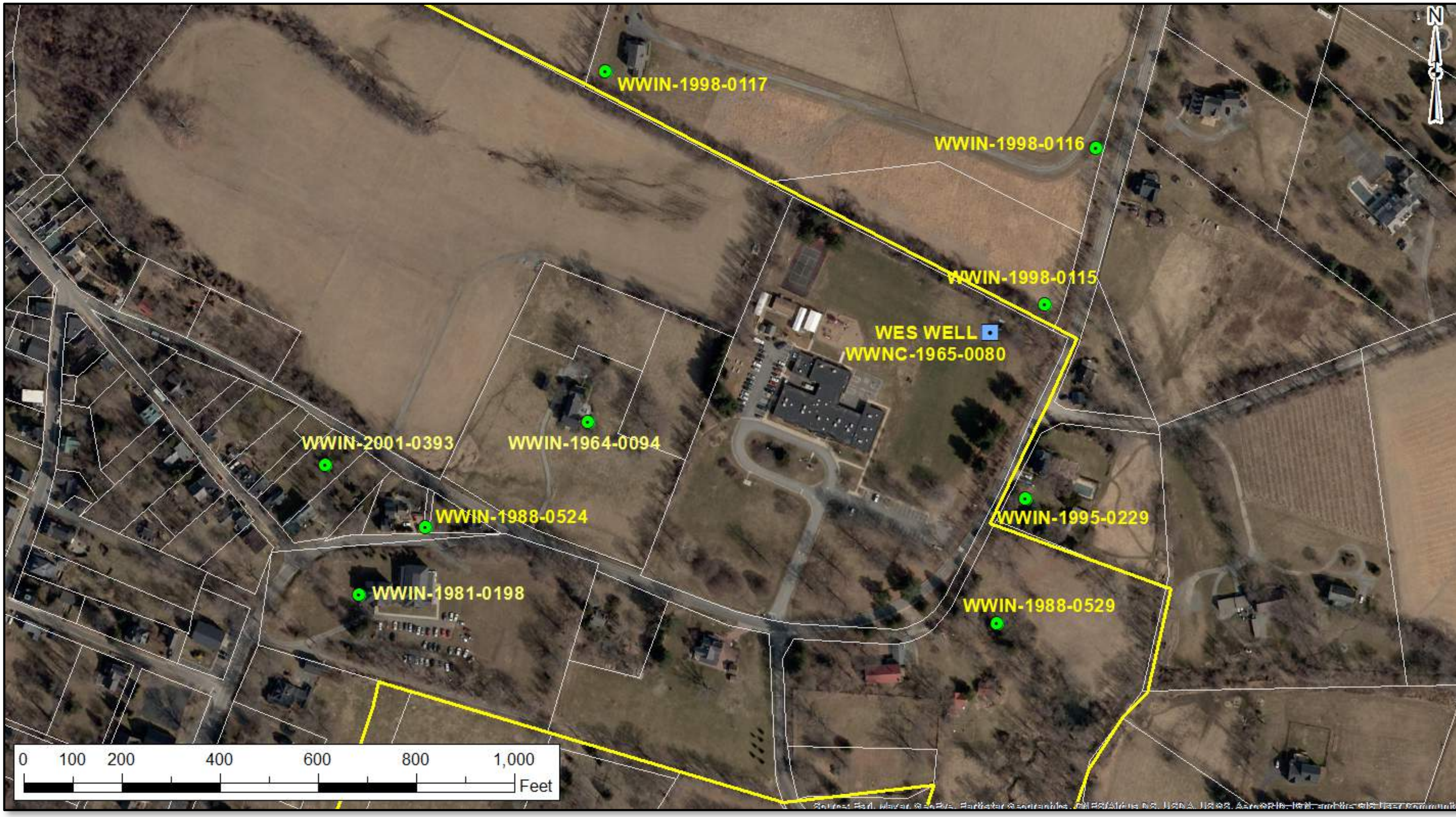
TITLE: 2021 WELL HYDROGRAPHS: WWIN-2010-0166, WWIN-1986-0338, AND WWIN-2010-0049			
LOCATION: WATERFORD, VIRGINIA			
TETRA TECH	APPROVED	RMC	FIGURE
	DRAFTED	RMC	30
	PROJECT#	117-8878001	
	DATE	7/1/2021	



Notes:

1. WWIN-1998-0115 behind the Waterford Elementary School. It has no pump.
2. Depth-to-water was measured every 10 minutes using a pressure transducer/datalogger.
3. Drawdown observed in WWIN-1998-0115 on 7/17 to 7/18/2021 was like that observed during the WES well aquifer test in 2006 (Tetra Tech, 2006).
4. Analysis of time-drawdown data measured in 2006 at WWIN-1998-0115 suggests that the local formation transmissivity is approximately 120 ft^2/d.

TITLE: 2021 WELL HYDROGRAPH: WWIN-1998-0115 REPORTED 620' DEEP, 5 GPM YIELD			
LOCATION: WATERFORD, VIRGINIA			
TETRA TECH	APPROVED	RMC	FIGURE
	DRAFTED	RMC	31
	PROJECT#	117-8878001	
	DATE	7/1/2021	



Notes:

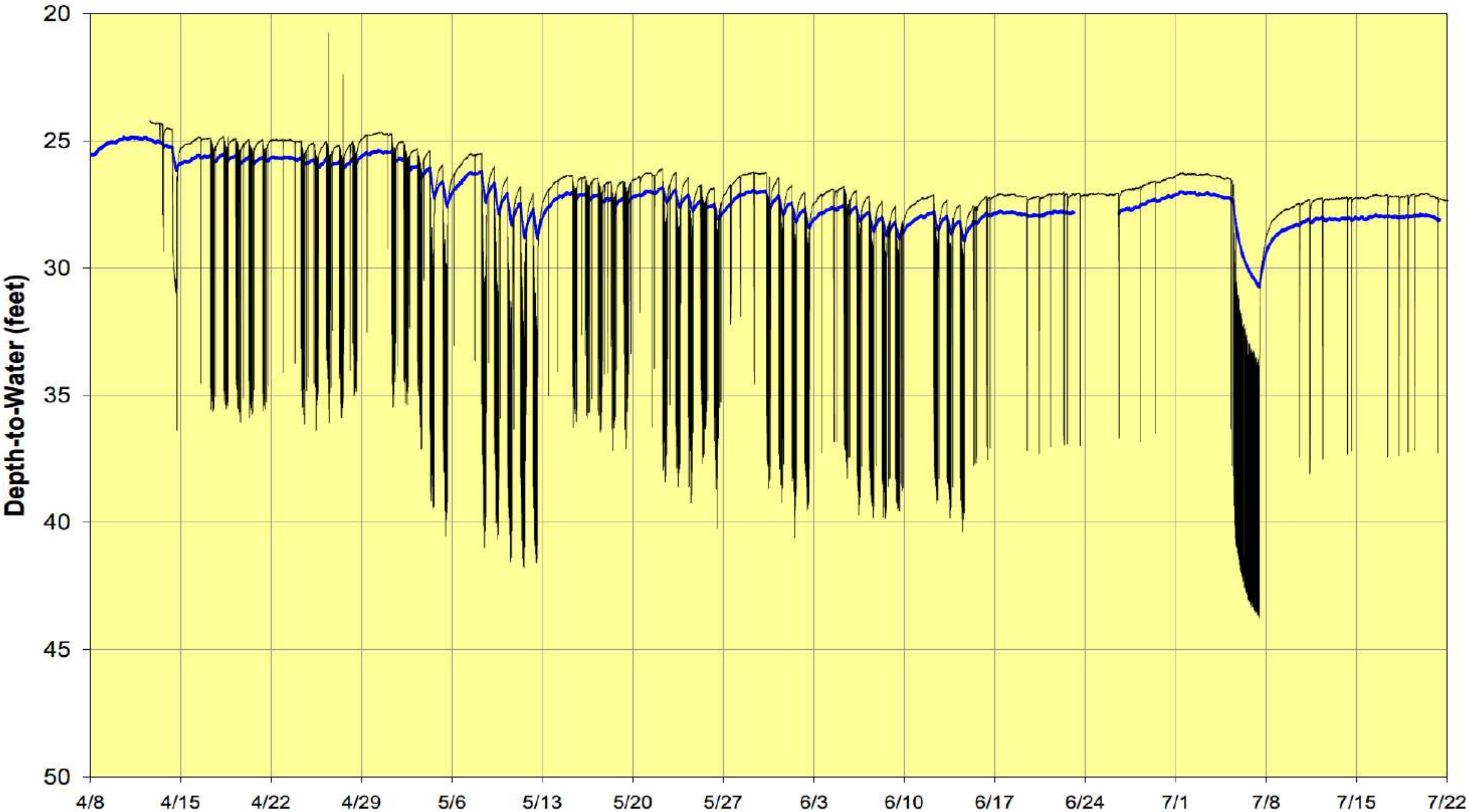
1. Several aquifer tests were performed by pumping the WES supply well (WWNC-1965-0080) between April and July 2006 at steady, controlled rates varying from 4 to 12 GPM.
2. Depth-to-water values were recorded every minute in the nine observation wells and the WES well supply well shown above.
3. Pumping the WES well at 12.2 GPM continuously for 48 hours caused drawdown from 27 feet to 43 feet in July 2006. Typical time-averaged pumping rates for school use are less than 1 GPM.

TITLE: **WATER-LEVEL MONITORING WELLS DURING WES SUPPLY WELL AQUIFER TESTING IN 2006**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	32
PROJECT#	117-8878001	
DATE	7/1/2021	



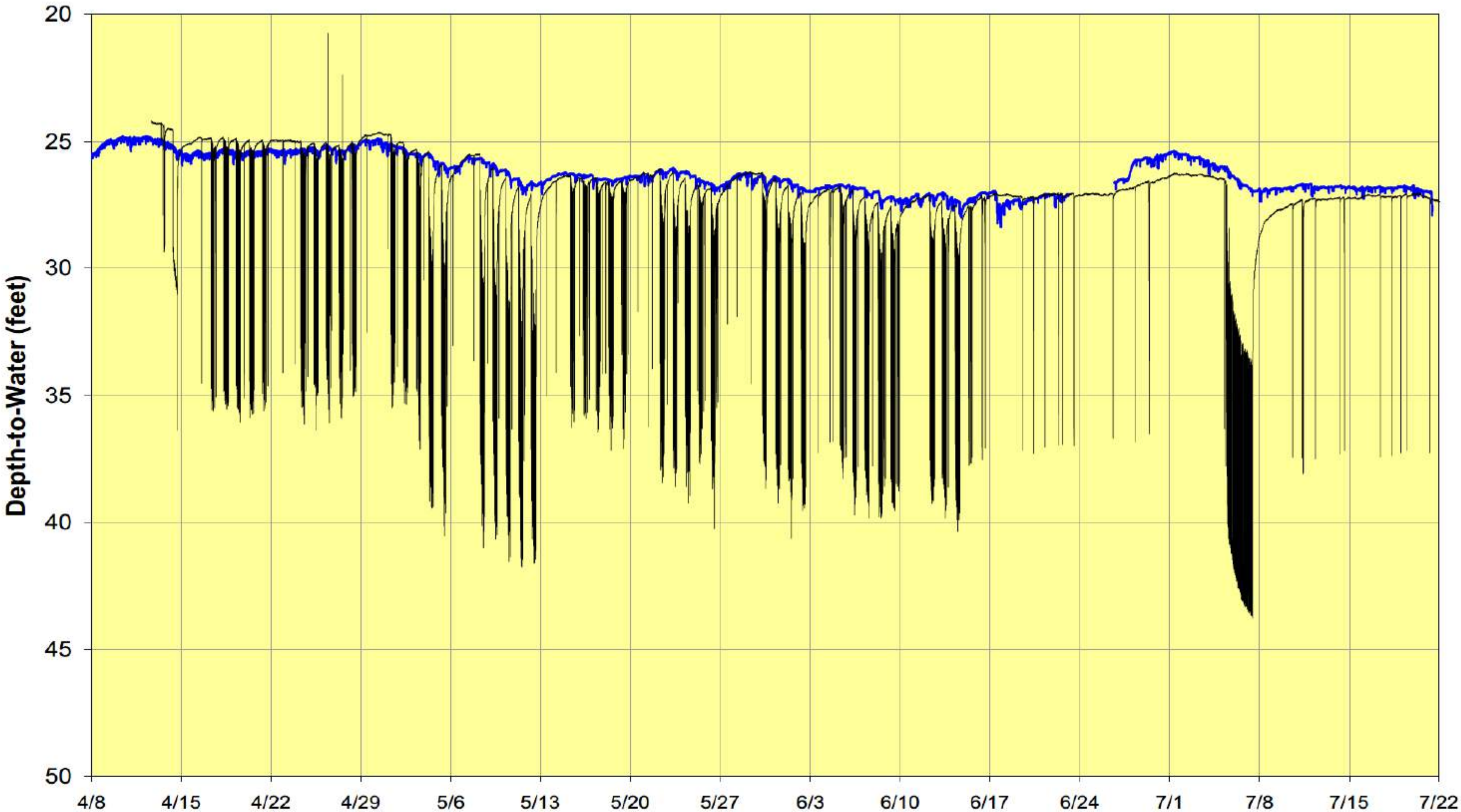
Notes:

1. WWIN-1998-0115 is located ~120 feet northeast of the WES supply well.
2. Less than 5 feet of drawdown, from ~27 to ~30 feet below the top of casing, were caused by pumping at the Waterford Elementary School well during the July 2006 aquifer test.

TITLE:	2006 HYDROGRAPHS: WF UNUSED WELL WWIN-1998-0115 AND WES WELL WWNC-1965-0080
LOCATION:	WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	33
PROJECT#	117-8878001	
DATE	7/1/2021	



Notes:

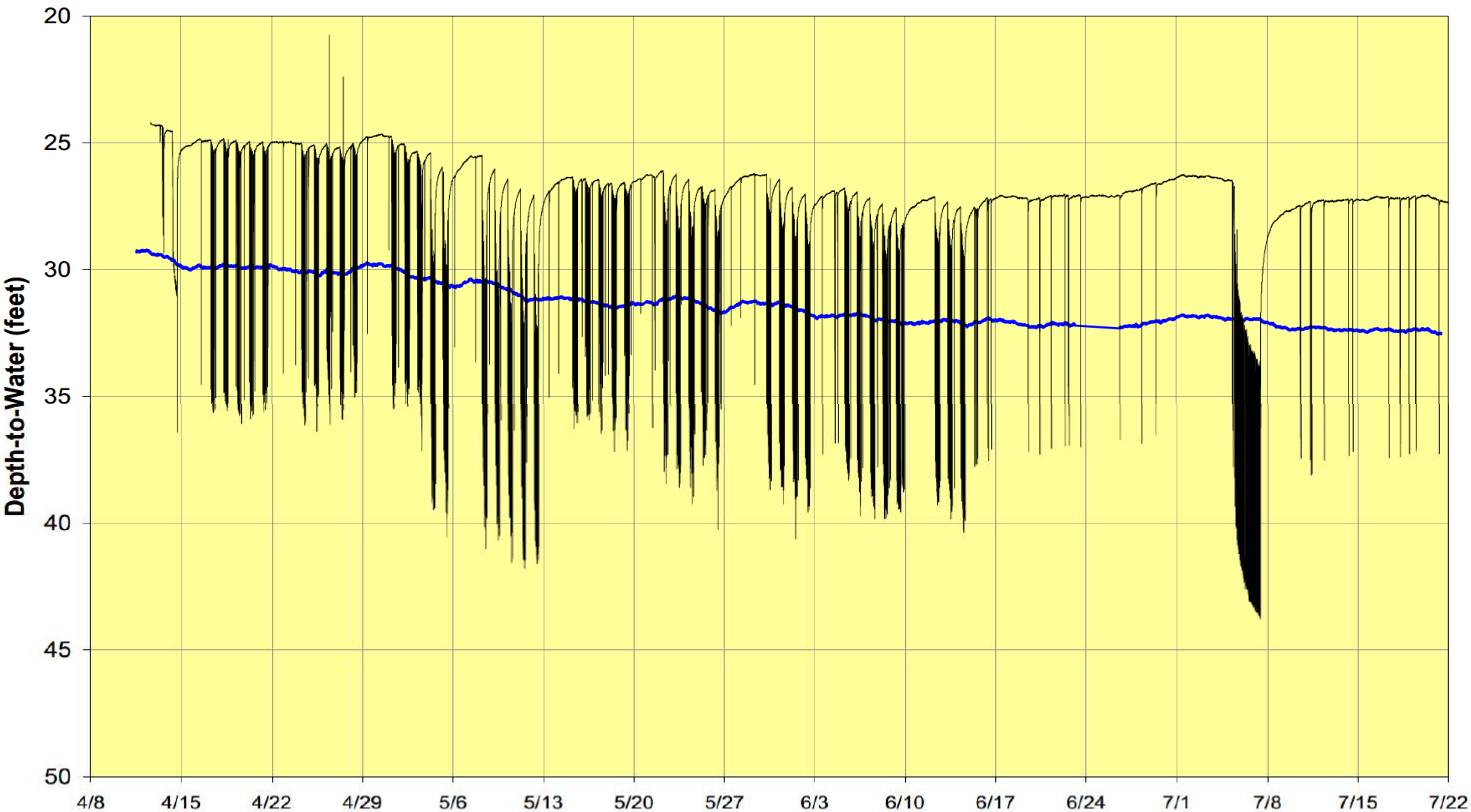
1. WWIN-1995-0229 is located ~350 feet southeast of the WES supply well. Drawdown due to pumping at the Waterford Elementary School well in 2006 was difficult to discern, measuring less than two feet.
2. Consistent with high transmissivity, episodic pumping for domestic use caused less than one foot of drawdown from the static level of ~26 feet below the top of casing.

TITLE: **2006 HYDROGRAPHS: DOMESTIC WELL WWIN-1995-0229 AND WES WELL WWNC-1965-0080**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	34
PROJECT#	117-8878001	
DATE	7/1/2021	



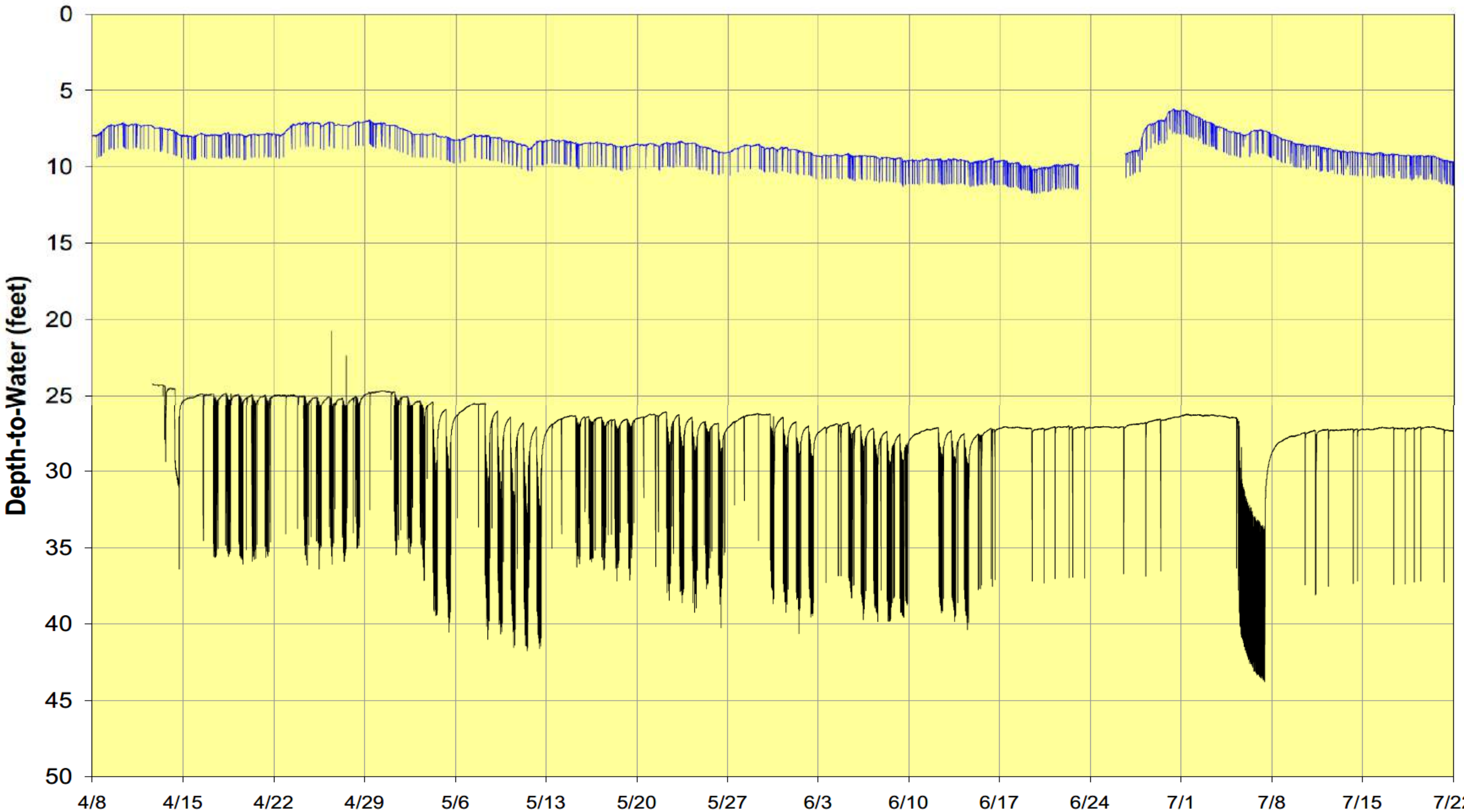
Notes:

1. Unused well WWIN-1998-0116 is located ~425 feet north of the WES supply well. Drawdown due to pumping at the Waterford Elementary School well in 2006 was not apparent.
2. The static depth to water in WWIN-1998-0116 was ~30 to ~32 feet below the top of casing.

TITLE:	2006 HYDROGRAPHS: UNUSED WELL WWIN-1998-0116 AND WES WELL WWNC-1965-0080
LOCATION:	WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	35
PROJECT#	117-8878001	
DATE	7/1/2021	



Notes:

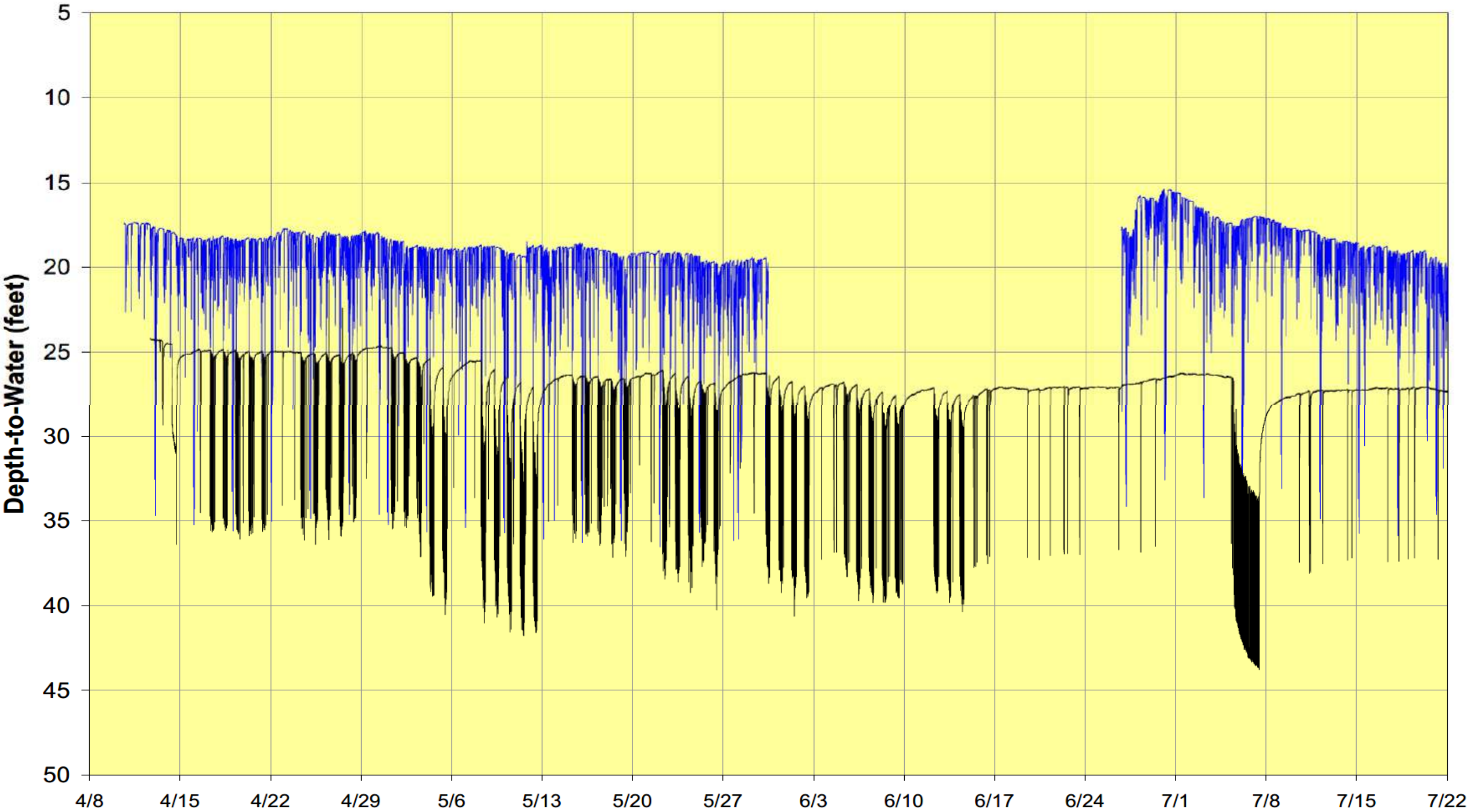
1. WWIN-1988-0529 is located ~600 feet south of the WES supply well. Drawdown due to pumping at the Waterford Elementary School well in 2006 was not apparent.
2. Consistent with relatively high transmissivity, episodic pumping for domestic use typically caused less than 3 feet of drawdown from ~8 to ~10 feet below the top of casing.

TITLE: **2006 HYDROGRAPHS: DOMESTIC WELL WWIN-1988-0529 AND WES WELL WWNC-1965-0080**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

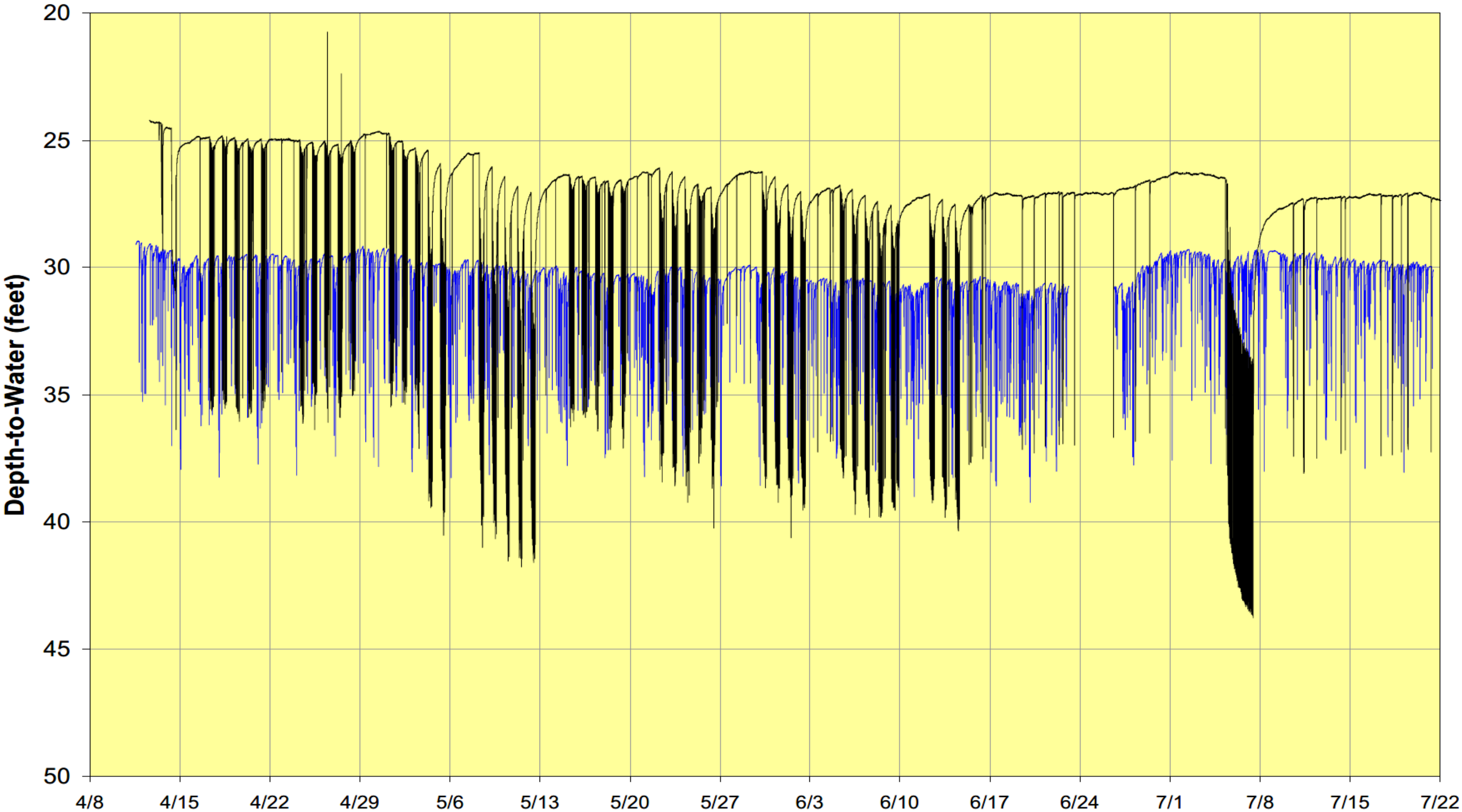
APPROVED	RMC	FIGURE
DRAFTED	RMC	36
PROJECT#	117-8878001	
DATE	7/1/2021	



Notes:

1. WWIN-1964-0094 is located ~850 feet southwest of the WES supply well. Drawdown due to pumping at the Waterford Elementary School well in 2006 was not apparent.
2. Consistent with relatively low transmissivity, episodic pumping for domestic use typically caused 5 to 20 feet of drawdown from ~17 to ~30 feet below the top of casing.

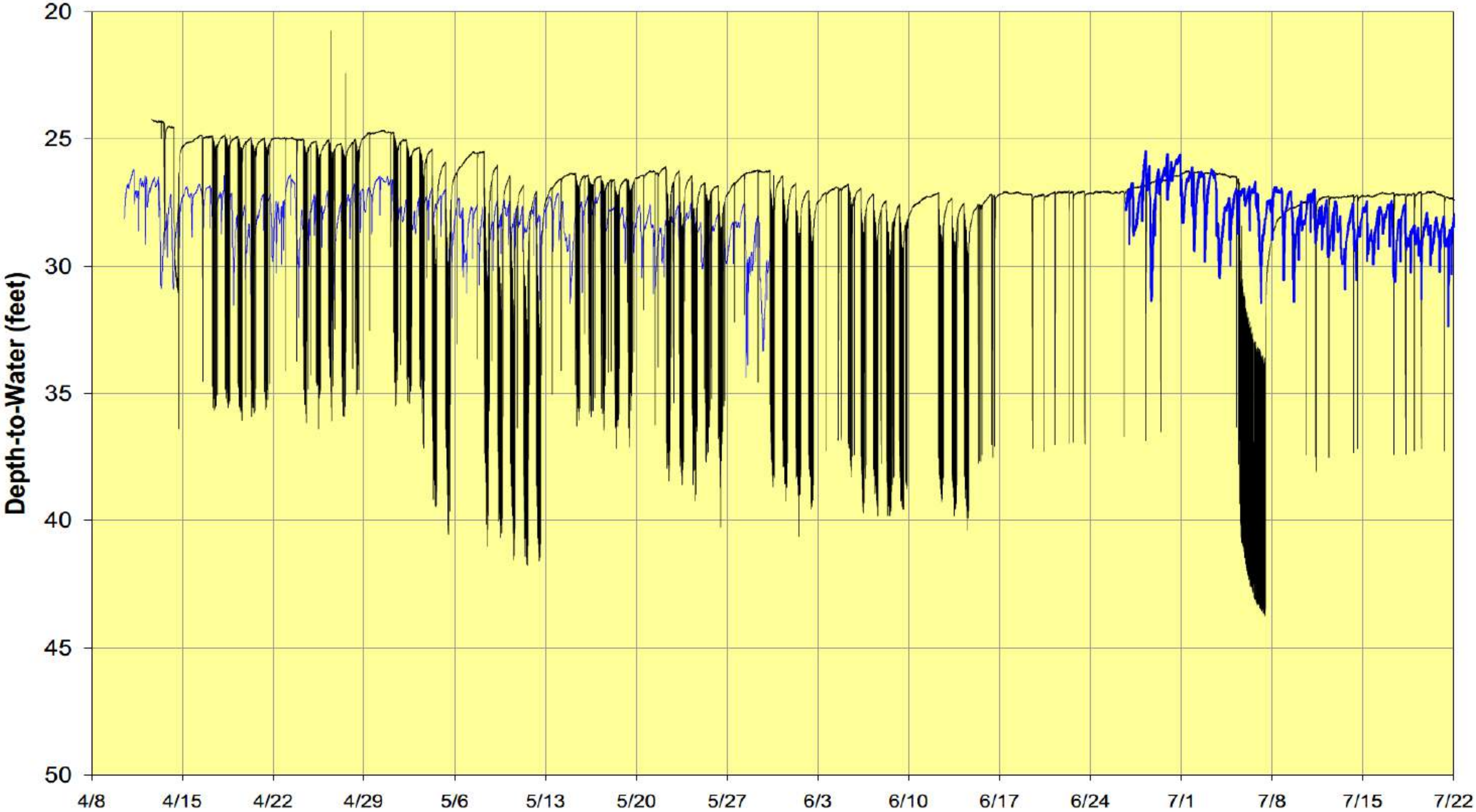
TITLE: 2006 HYDROGRAPHS: DOMESTIC WELL WWIN-1964-0094 AND WES WELL WWNC-1965-0080				
LOCATION: WATERFORD, VIRGINIA				
TETRA TECH	APPROVED	RMC	FIGURE	
	DRAFTED	RMC	37	
	PROJECT#	117-8878001		
	DATE	7/1/2021		



Notes:

1. WWIN-1998-0117 is located ~955 feet northwest of the WES supply well. Drawdown due to pumping at the Waterford Elementary School well in 2006 was not apparent.
2. Consistent with relatively high transmissivity, episodic pumping for domestic use typically caused ~5 feet of drawdown from ~30 to ~35 feet below the top of casing.

TITLE: 2006 HYDROGRAPHS: DOMESTIC WELL WWIN-1998-0117 AND WES WELL WWNC-1965-0080			
LOCATION: WATERFORD, VIRGINIA			
TETRA TECH	APPROVED	RMC	FIGURE
	DRAFTED	RMC	38
	PROJECT#	117-8878001	
	DATE	7/1/2021	



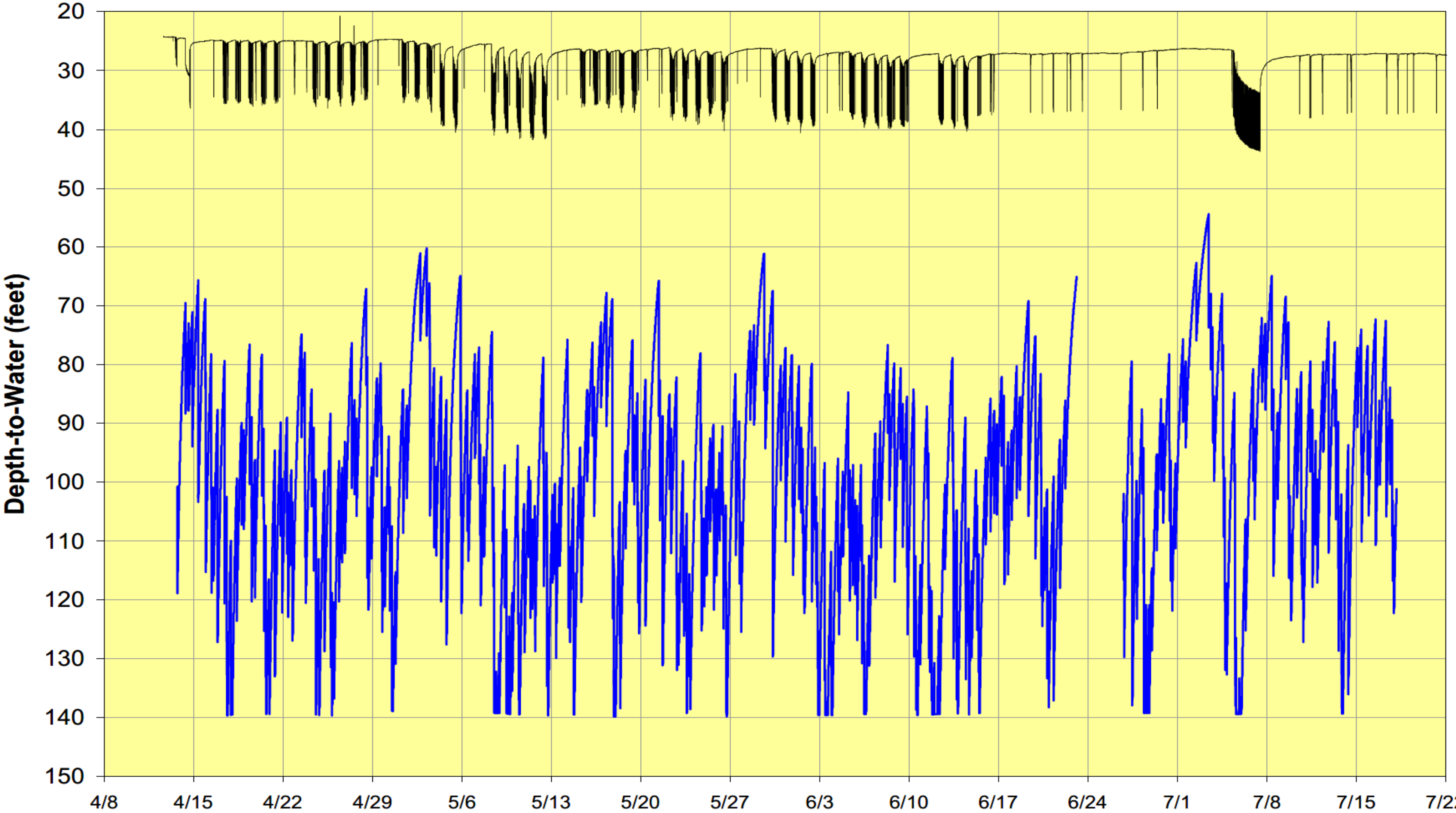
Notes:

1. WWIN-1998-0524 is located ~1230 feet southwest of the WES supply well. Drawdown due to pumping at the Waterford Elementary School well in 2006 was not apparent.
2. Consistent with relatively high transmissivity, episodic pumping for domestic use typically caused ~5 feet of drawdown from ~27 to ~32 feet below the top of casing.

TITLE:	2006 HYDROGRAPHS: DOMESTIC WELL WWIN-1998-0524 AND WES WELL WWNC-1965-0080
LOCATION:	WATERFORD, VIRGINIA

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	39
PROJECT#	117-8878001	
DATE	7/1/2021	

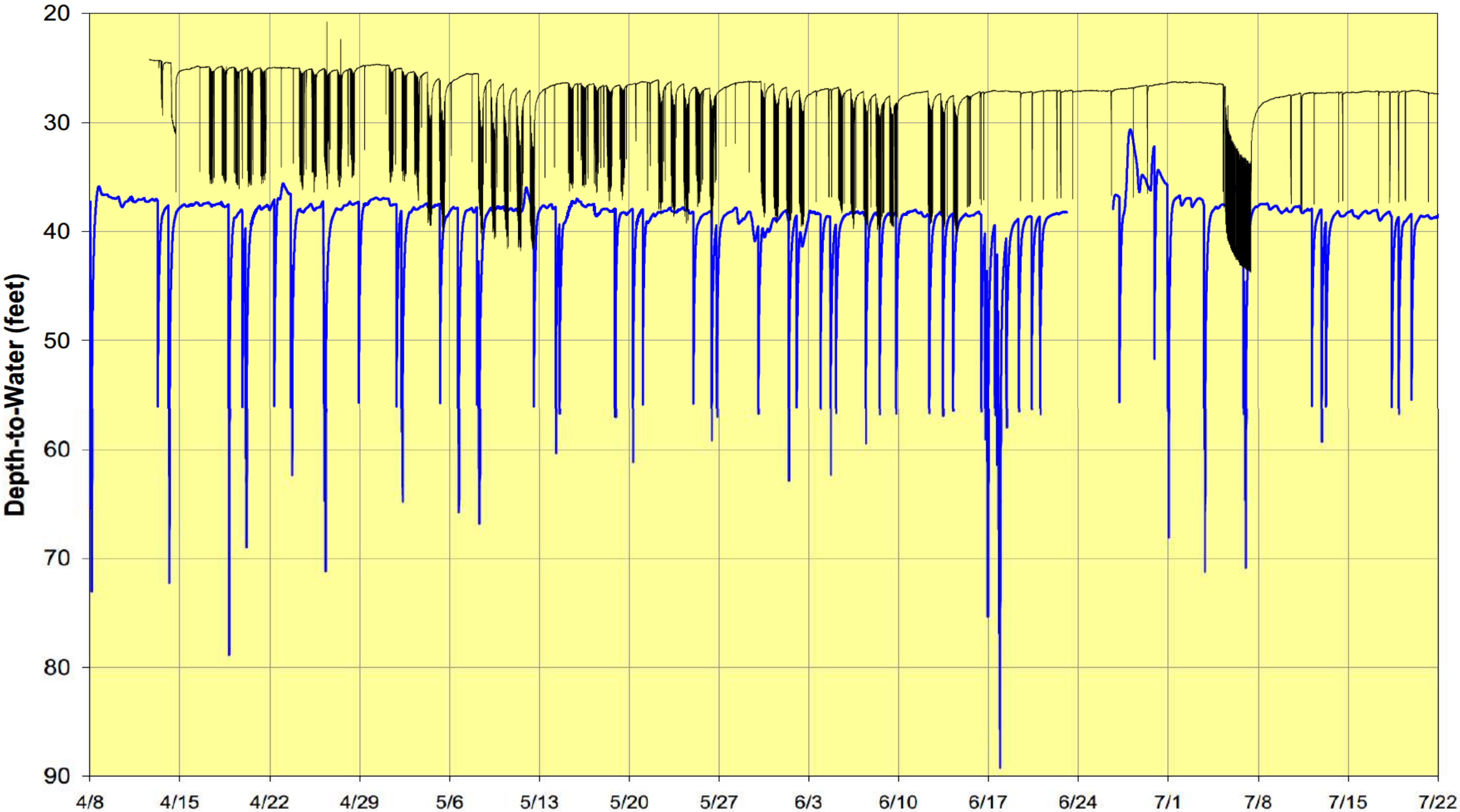


Notes:

1. WWIN-2001-0393 is located ~1395 feet southwest of the WES supply well. Drawdown due to pumping at the Waterford Elementary School well in 2006 was not apparent.
2. Consistent with low formation transmissivity, episodic pumping for domestic use typically caused ~50 feet of drawdown from ~80 to ~130 feet below the top of casing.

TITLE:	2006 HYDROGRAPHS: DOMESTIC WELL WWIN-2001-0393 AND WES WELL WWNC-1965-0080
LOCATION:	WATERFORD, VIRGINIA

TETRA TECH			FIGURE
	APPROVED	RMC	40
	DRAFTED	RMC	
	PROJECT#	117-8878001	
	DATE	7/1/2021	



Notes:

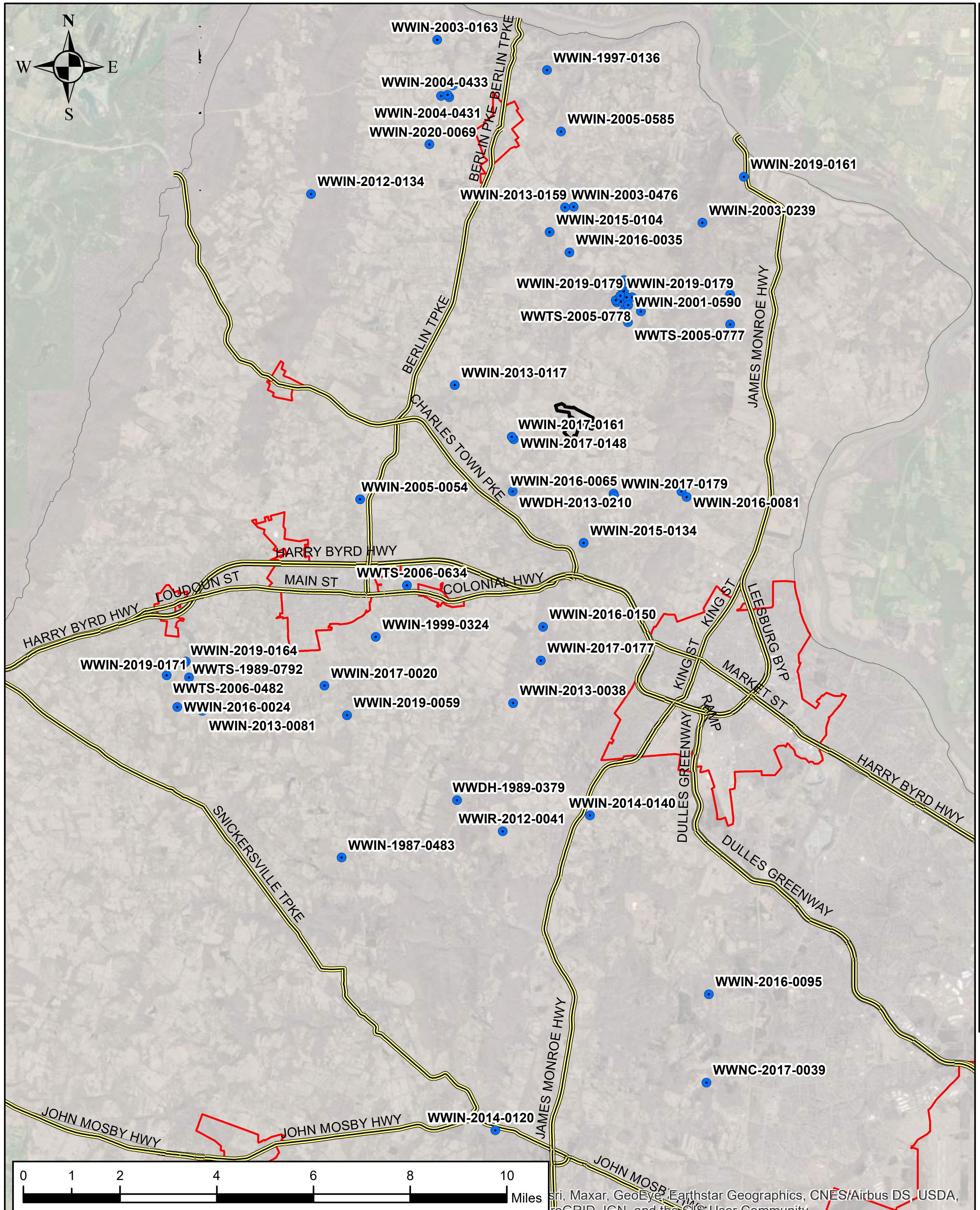
1. WWIN-1981-0198 is located ~1400 feet southwest of the WES supply well. Drawdown due to pumping at the Waterford Elementary School well in 2006 was not apparent.
2. Consistent with relatively low transmissivity, episodic pumping for old school use caused 20 to 40 feet of drawdown from ~38 feet to ~57 to ~80 feet below the top of casing.

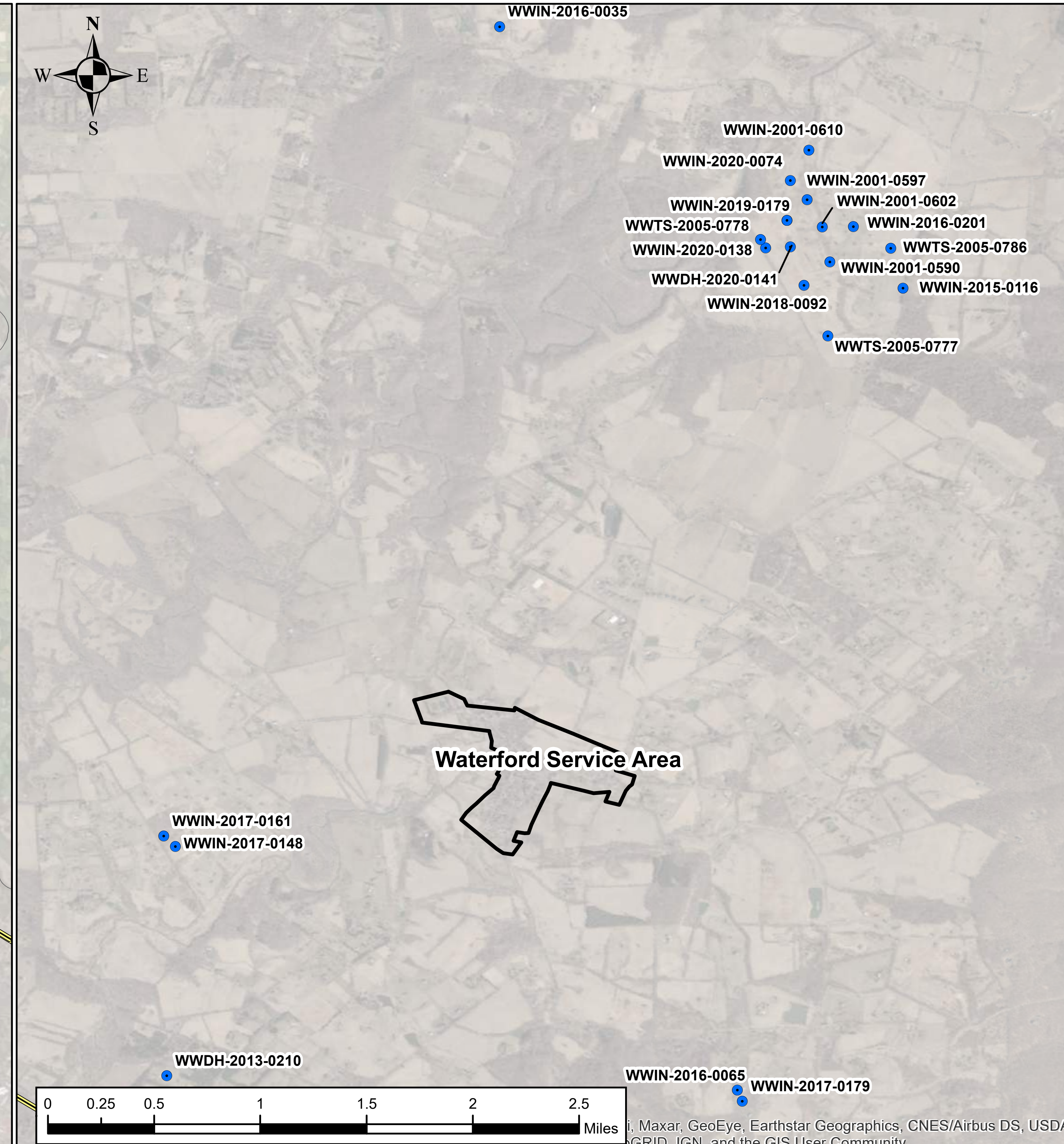
TITLE: **2006 HYDROGRAPHS: WF OLD SCHOOL WELL WWIN-1981-0198 AND WES WELL WWNC-1965-0080**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	41
PROJECT#	117-8878001	
DATE	7/1/2021	

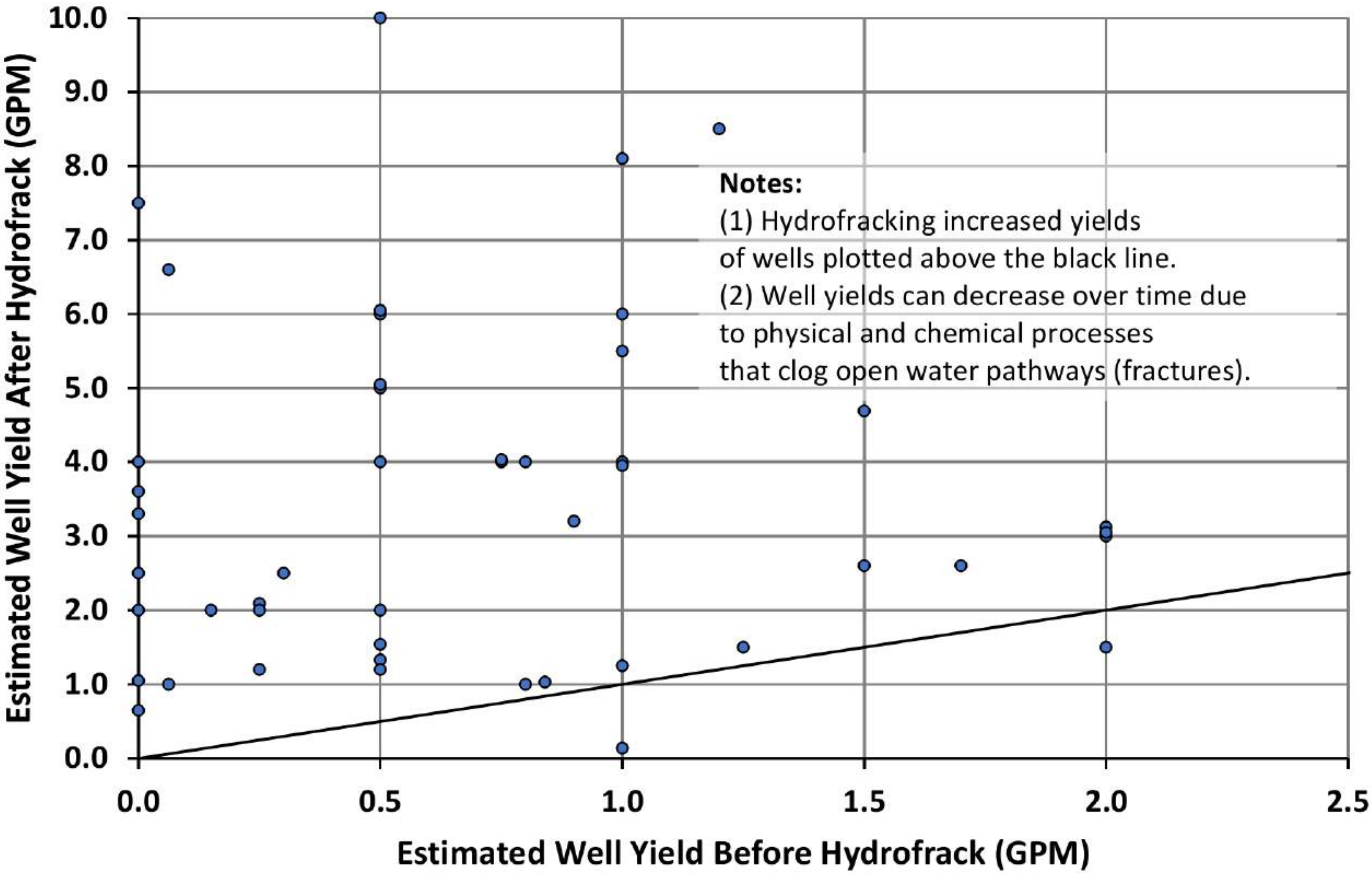




Legend

- Hydrofracked Water Wells 2011 to 2020
- Waterford Service Boundary
- Loudoun County Town Boundaries

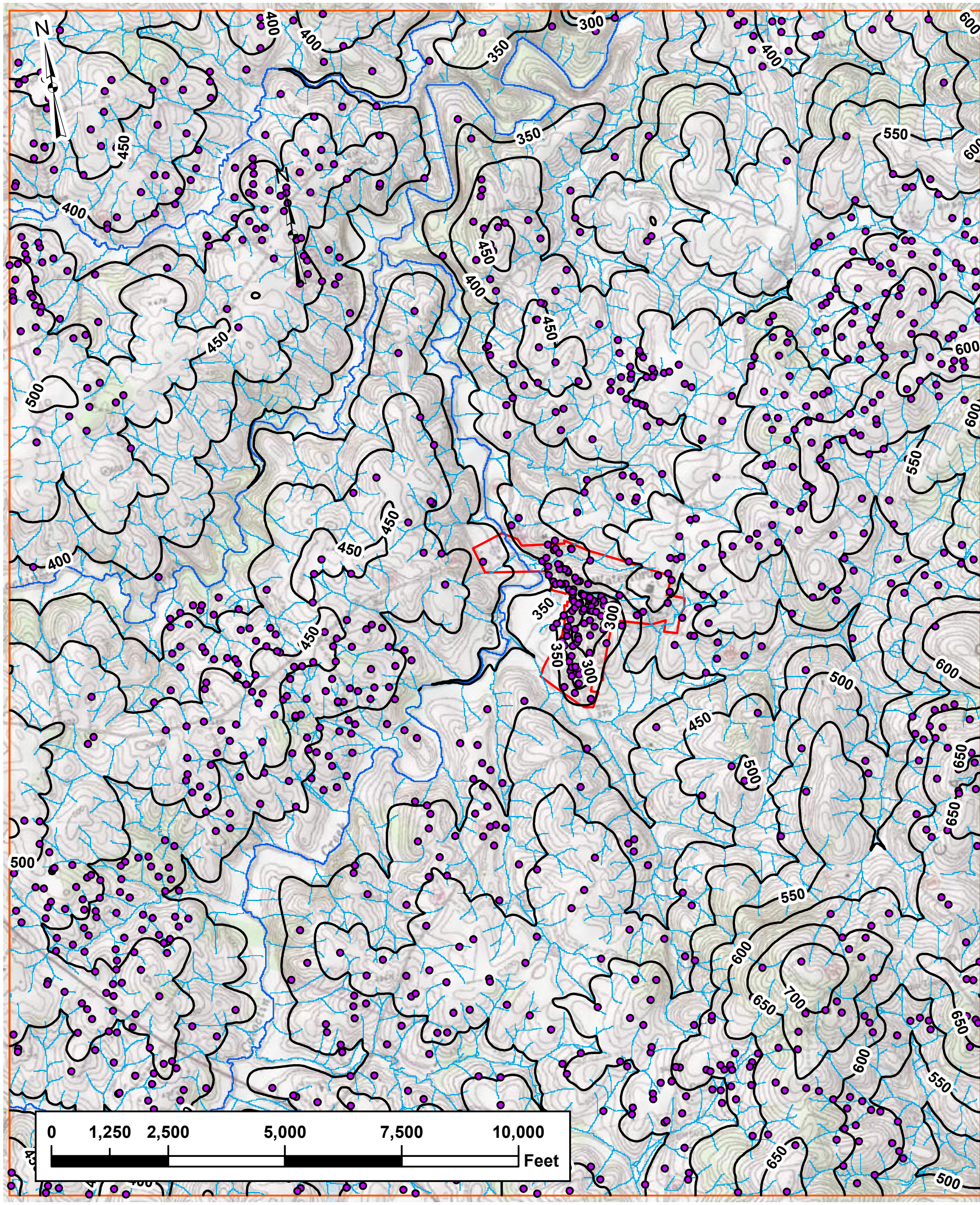
TITLE:	HYDROFRACKED WATER WELLS 2011 TO 2020		
LOCATION:	LOUDOUN COUNTY, VIRGINIA		
TETRA TECH	APPROVED	RMC	FIGURE
	DRAFTED	RMC	42
	PROJECT#	DEWBERRY	
	DATE	7/28/2021	



Notes:

1. Data includes 56 wells most of which were hydrofracked between 2014 and 2020.

TITLE: MEASURED WELL YIELDS BEFORE AND AFTER HYDROFRACKING			
LOCATION: WATERFORD, VIRGINIA			
TETRA TECH	APPROVED	RMC	FIGURE
	DRAFTED	RMC	43
	PROJECT#	117-8878001	
	DATE	7/1/2021	



Legend

- Pumping Wells
- Simulated Hydraulic Heads (ft>MSL)
- Modeled Rivers
- Modeled Drains
- Waterford Service Area
- Model Domain - Grid Outline

Notes:

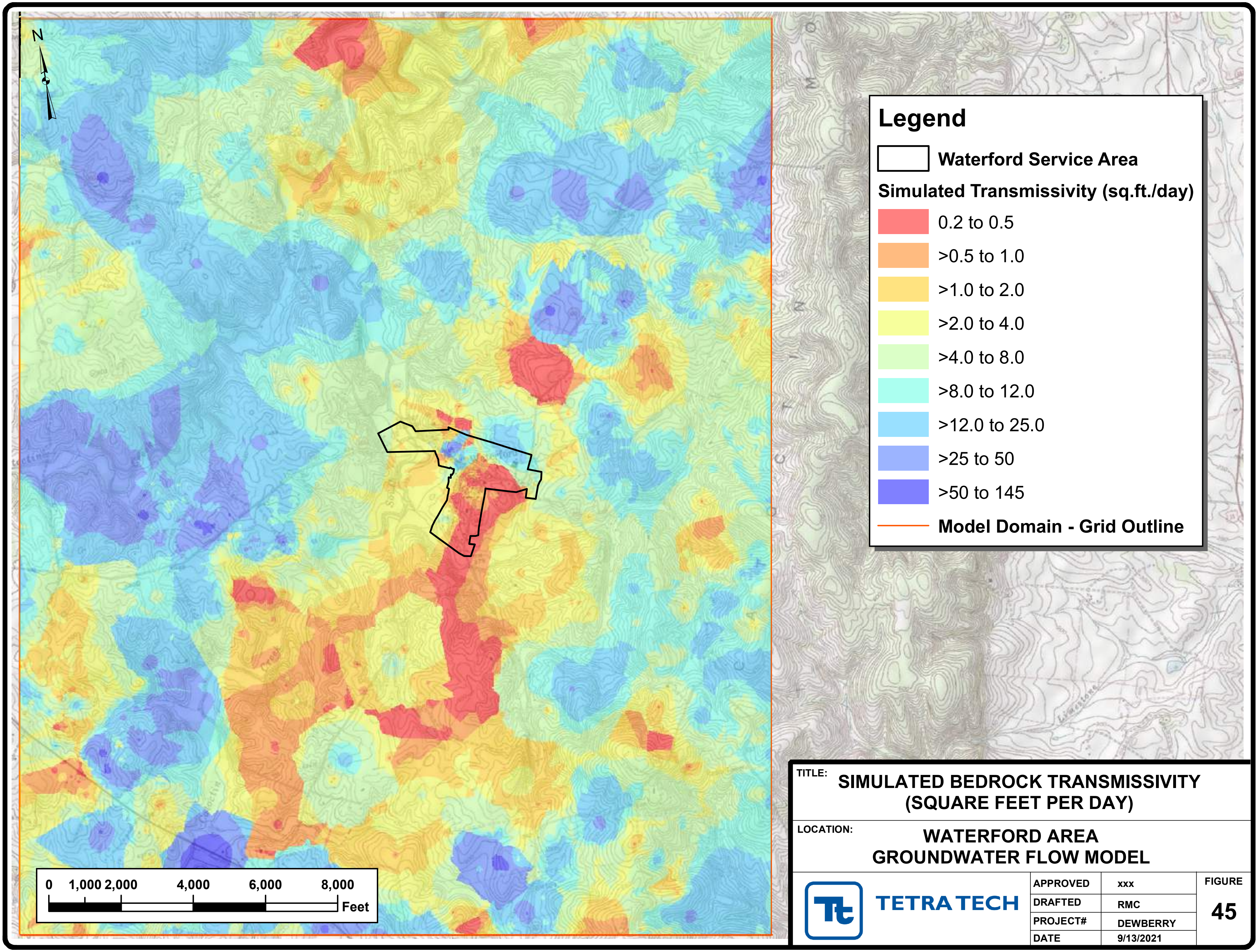
1. The MODFLOW finite-difference grid cell-blocks include 1271 rows and 1040 columns uniformly spaced 20 feet apart.
2. The grid is rotated so that the y-axis is aligned to N10oE.
3. Extraction rates from domestic pumping wells are specified at 150 gallons per day.
4. The Waterford Elementary School supply well pumping rate is specified at 644 gallons per day.
5. The recharge rate is proportional to modeled aquifer tranmissivity and averages 8.71 inches per year over the model domain.

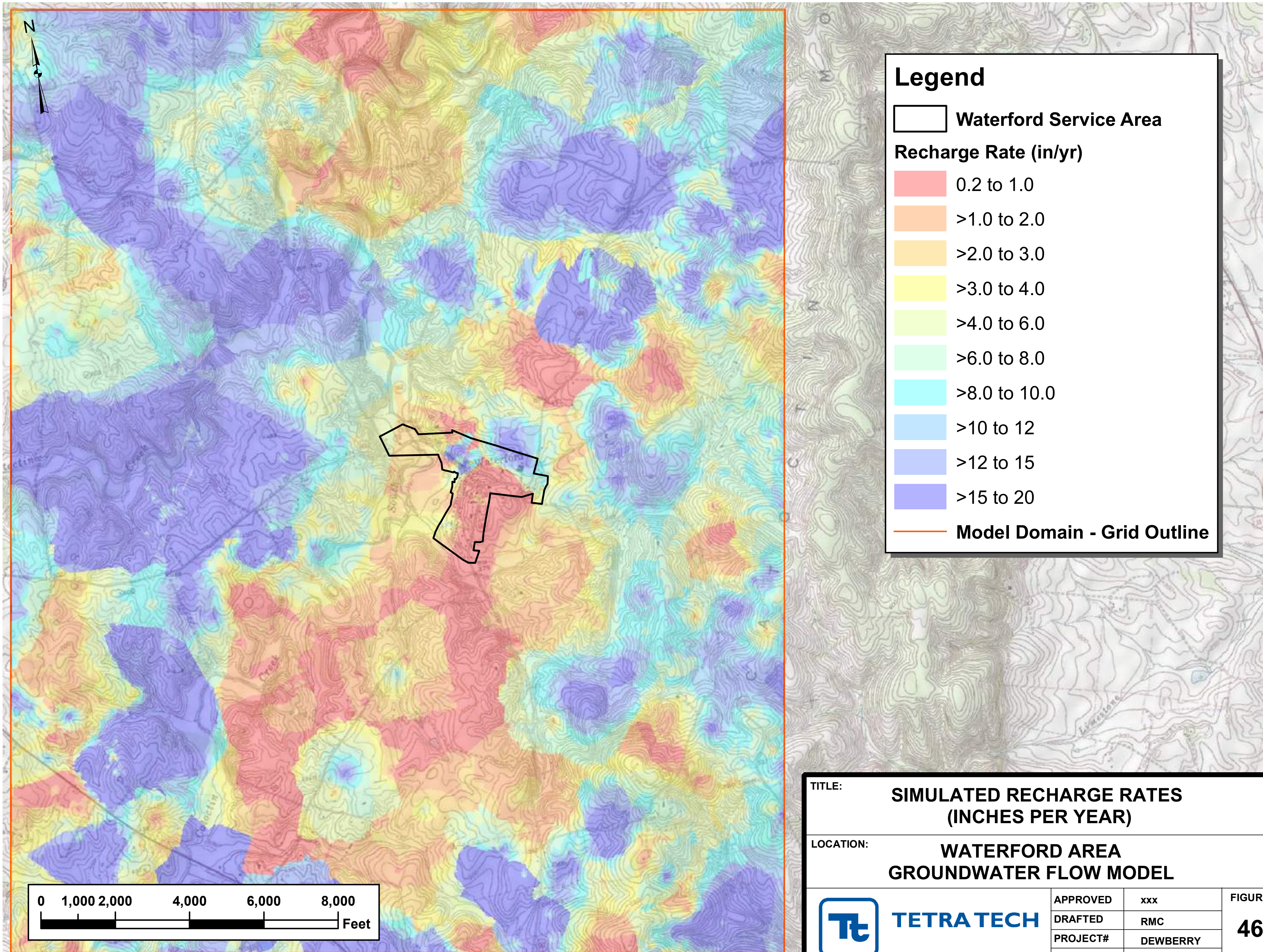
TITLE:
SIMULATED HYDRAULIC HEAD CONTOURS AND BOUNDARY CONDITIONS IN MODEL DOMAIN

LOCATION:
WATERFORD AREA GROUNDWATER FLOW MODEL

TETRA TECH

APPROVED	xxx	FIGURE
DRAFTED	RMC	44
PROJECT#	DEWBERRY	
DATE	9/9/2021	


N
Legend
Waterford Service Area
Simulated Transmissivity (sq.ft./day)
0.2 to 0.5
>0.5 to 1.0
>1.0 to 2.0
>2.0 to 4.0
>4.0 to 8.0
>8.0 to 12.0
>12.0 to 25.0
>25 to 50
>50 to 145
Model Domain - Grid Outline
0 1,000 2,000 4,000 6,000 8,000 Feet
TITLE:
SIMULATED BEDROCK TRANSMISSIVITY
(SQUARE FEET PER DAY)
LOCATION:
WATERFORD AREA
GROUNDWATER FLOW MODEL
TETRA TECH
APPROVED xxx
DRAFTED RMC
PROJECT# DEWBERRY
DATE 9/13/2021
FIGURE
45

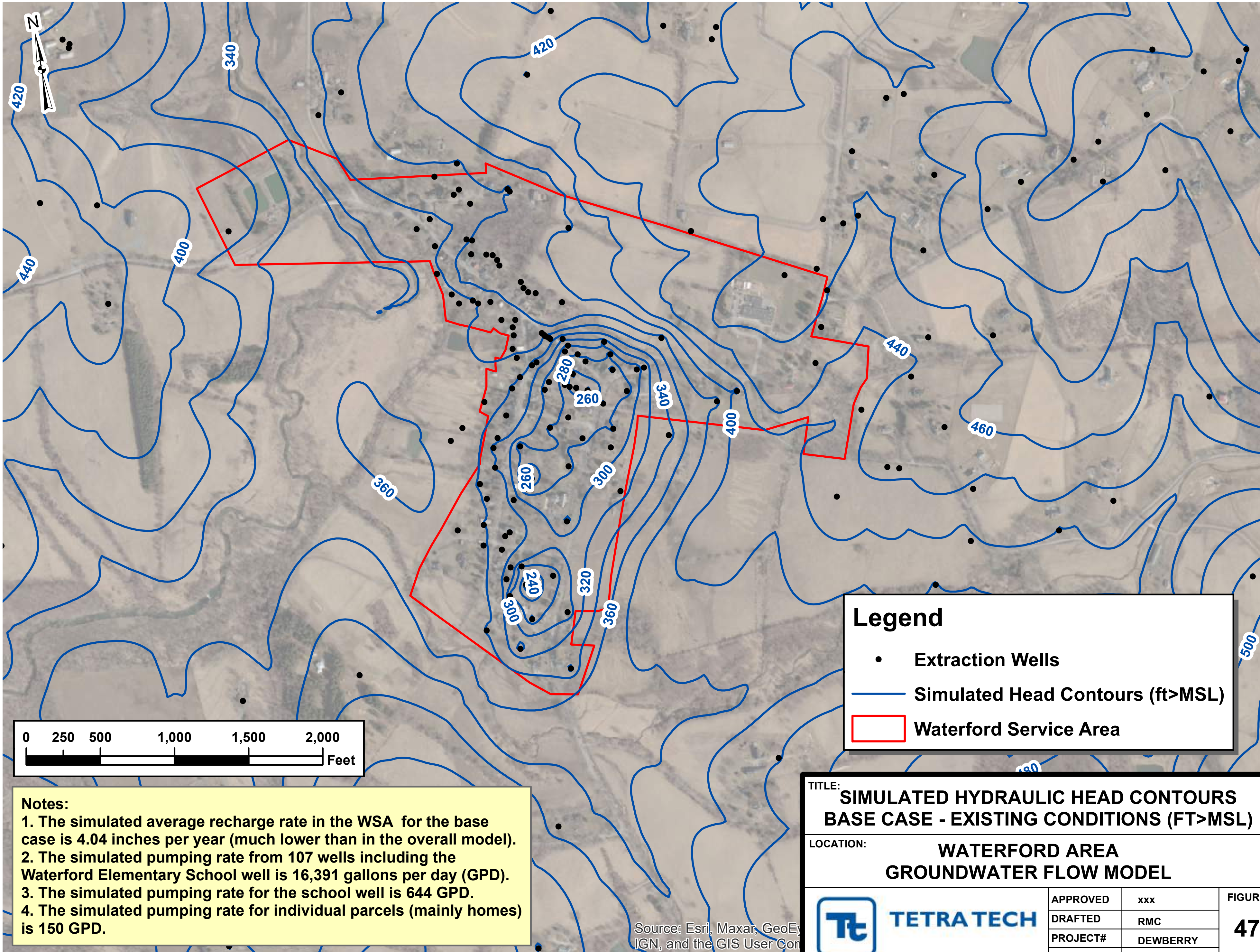


TITLE: SIMULATED RECHARGE RATES (INCHES PER YEAR)

LOCATION: WATERFORD AREA GROUNDWATER FLOW MODEL

TETRA TECH

APPROVED	xxx	FIGURE
DRAFTED	RMC	46
PROJECT#	DEWBERRY	
DATE	9/13/2021	



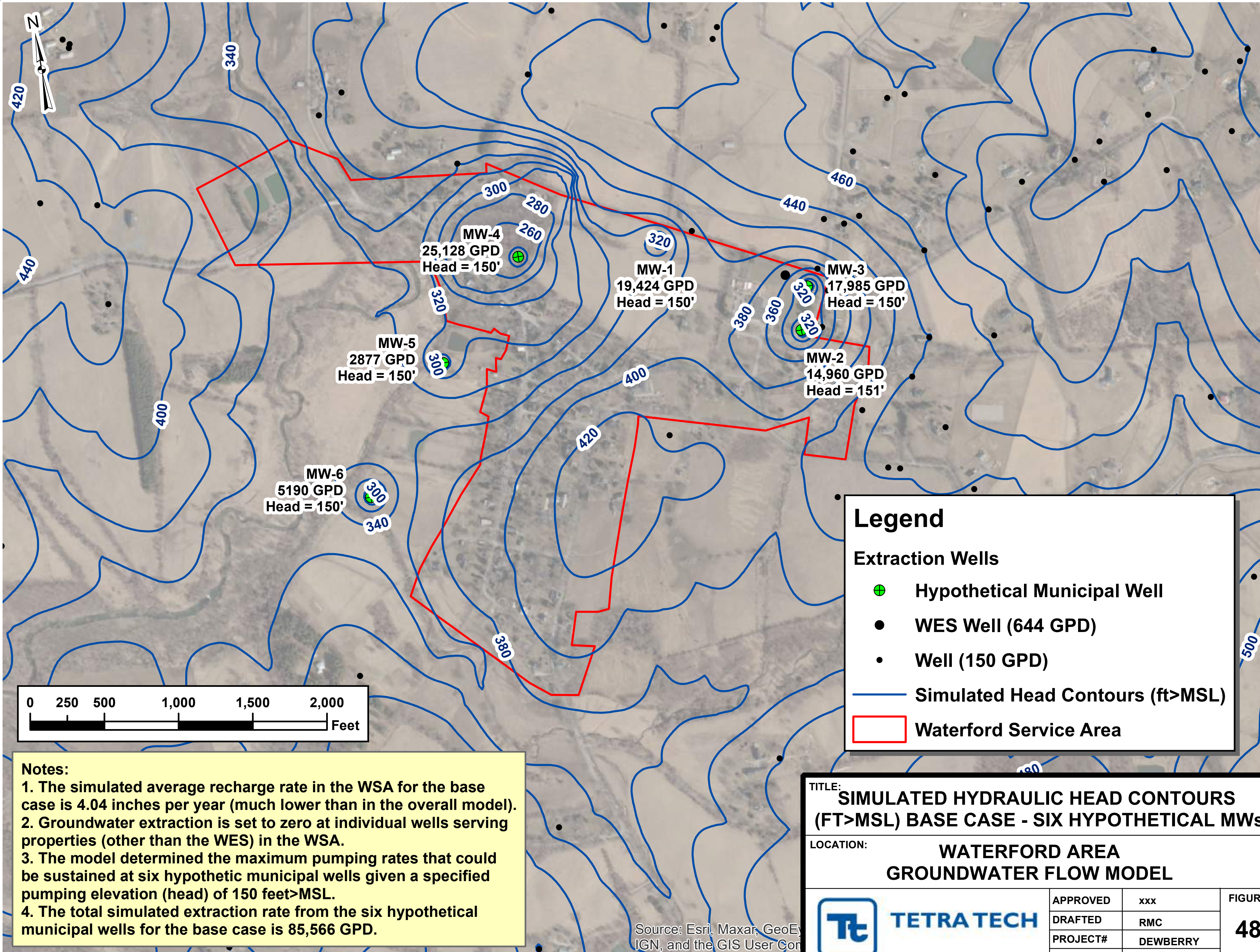
Notes:
1. The simulated average recharge rate in the WSA for the base case is 4.04 inches per year (much lower than in the overall model).
2. The simulated pumping rate from 107 wells including the Waterford Elementary School well is 16,391 gallons per day (GPD).
3. The simulated pumping rate for the school well is 644 GPD.
4. The simulated pumping rate for individual parcels (mainly homes) is 150 GPD.

TITLE:
SIMULATED HYDRAULIC HEAD CONTOURS BASE CASE - EXISTING CONDITIONS (FT>MSL)

LOCATION:
WATERFORD AREA GROUNDWATER FLOW MODEL

TETRA TECH

APPROVED	xxx	FIGURE
DRAFTED	RMC	47
PROJECT#	DEWBERRY	
DATE	9/13/2021	



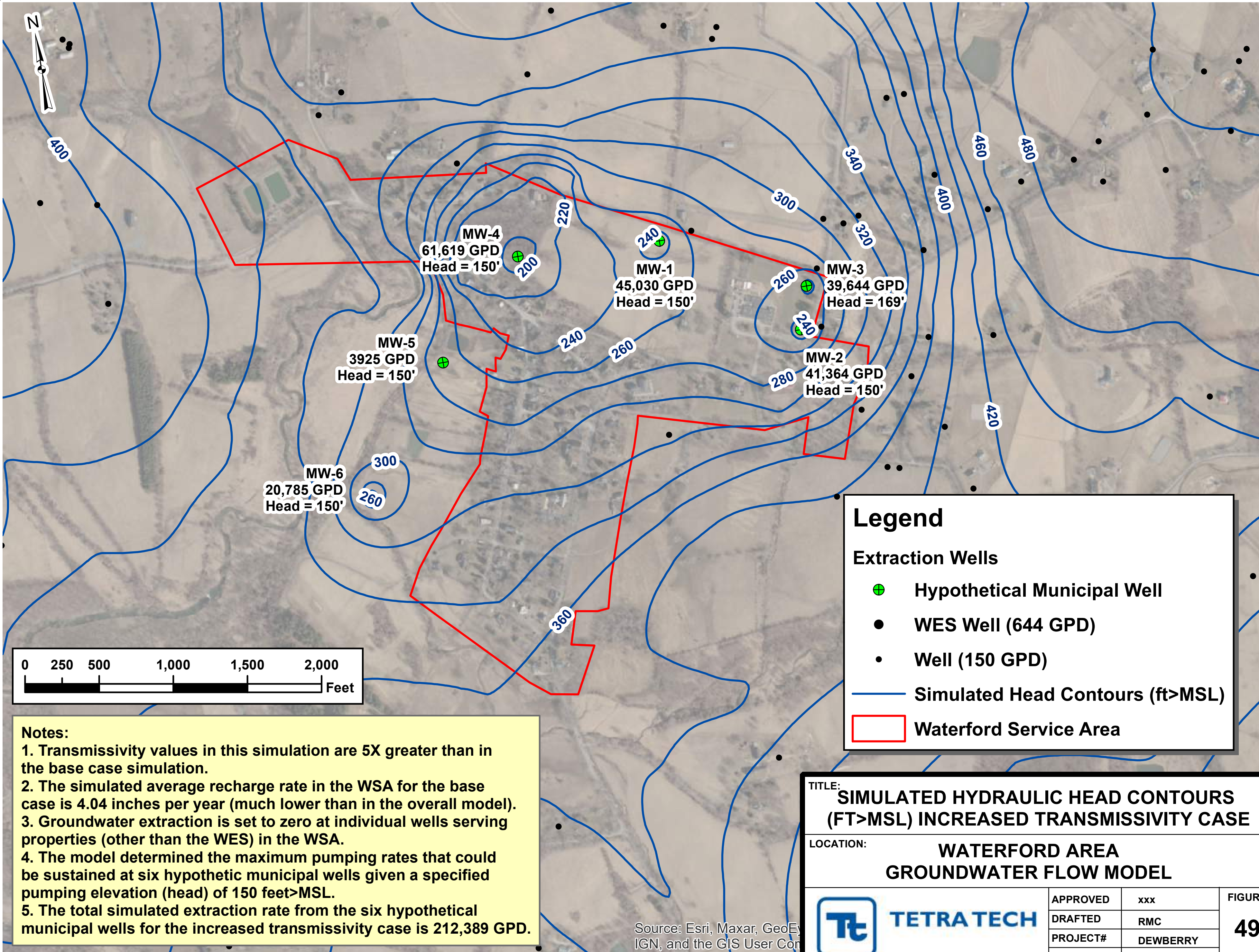
Notes:
1. The simulated average recharge rate in the WSA for the base case is 4.04 inches per year (much lower than in the overall model).
2. Groundwater extraction is set to zero at individual wells serving properties (other than the WES) in the WSA.
3. The model determined the maximum pumping rates that could be sustained at six hypothetic municipal wells given a specified pumping elevation (head) of 150 feet>MSL.
4. The total simulated extraction rate from the six hypothetical municipal wells for the base case is 85,566 GPD.

TITLE: SIMULATED HYDRAULIC HEAD CONTOURS (FT>MSL) BASE CASE - SIX HYPOTHETICAL MWs

LOCATION: WATERFORD AREA GROUNDWATER FLOW MODEL

TETRA TECH

APPROVED	xxx	FIGURE
DRAFTED	RMC	48
PROJECT#	DEWBERRY	
DATE	9/13/2021	



Notes:

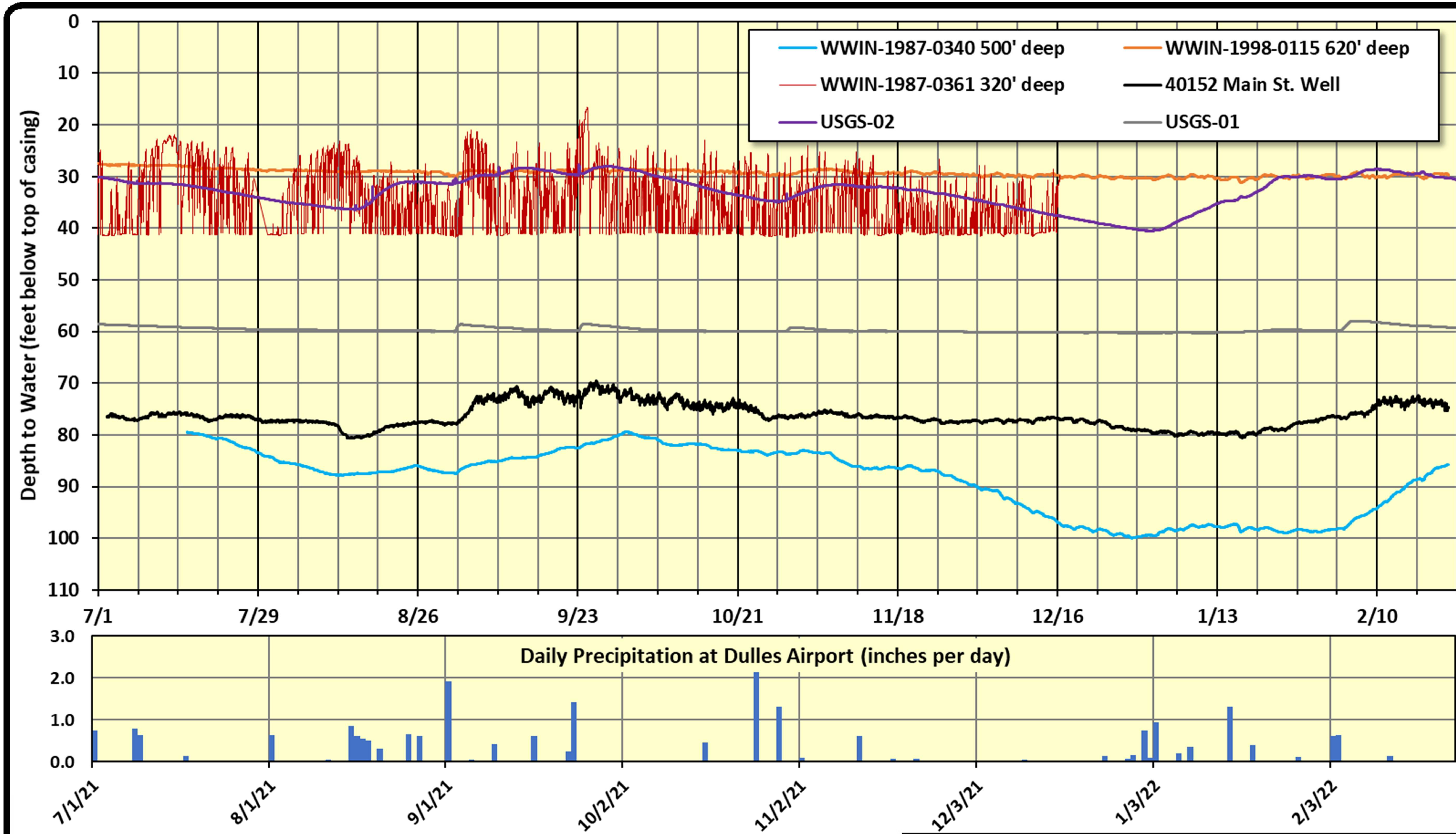
1. Transmissivity values in this simulation are 5X greater than in the base case simulation.
2. The simulated average recharge rate in the WSA for the base case is 4.04 inches per year (much lower than in the overall model).
3. Groundwater extraction is set to zero at individual wells serving properties (other than the WES) in the WSA.
4. The model determined the maximum pumping rates that could be sustained at six hypothetic municipal wells given a specified pumping elevation (head) of 150 feet>MSL.
5. The total simulated extraction rate from the six hypothetical municipal wells for the increased transmissivity case is 212,389 GPD.

TITLE: SIMULATED HYDRAULIC HEAD CONTOURS (FT>MSL) INCREASED TRANSMISSIVITY CASE

LOCATION: WATERFORD AREA GROUNDWATER FLOW MODEL

TETRA TECH

APPROVED	xxx	FIGURE
DRAFTED	RMC	49
PROJECT#	DEWBERRY	
DATE	9/13/2021	



Notes:

1. Solinst Leveloggers were used to record depth-to-water levels in the four Waterford wells between July 2021 and February 2022.
2. Information on the two USGS bedrock monitoring wells located in Loudoun County is available at https://waterdata.usgs.gov/va/nwis/current/?type=gw.

TITLE: **HYDROGRAPHS: FOUR MONITORED WELLS IN WATERFORD AND USGS MONITORING WELLS**

LOCATION: **WATERFORD, VIRGINIA**

TETRA TECH

APPROVED	RMC	FIGURE
DRAFTED	RMC	50
PROJECT#	117-8878001	
DATE	2242022	

APPENDIX A: DIGITAL FILES

1. Loudoun County Health Department files for Waterford area wells
2. Burton, W.C., A.J. Froelich, A.J., J.S. Pomeroy, and K.Y. Lee, 1995. Geology of the Waterford quadrangle, Virginia and Maryland, and the Virginia part of the Point of Rocks quadrangle: U.S. Geological Survey Bulletin 2095, 30 p., 1 pl. in pocket, scale 1:24,000.
3. Cohen, R.M., C.R. Faust, and D.S. Skipp, 2007. Evaluating ground water supplies in fractured metamorphic rock of the Blue Ridge Province in Northern Virginia, in Proceedings of NGWA-USEPA Fractured Rock Conference, Portland, ME.
4. Emery and Garrett, 2002. Detailed Hydrogeologic Study, Development of Individual Wells for the Stonebrook Farm Subdivision, Loudoun County, Virginia, prepared for Spotswood Land Development LLC.
5. Emery and Garrett, 2005. Detailed Hydrogeologic Study, Development of Individual Wells for the Waterford Downs Subdivision, Loudoun County, Virginia, prepared for Spotswood Land Development LLC.
6. Southworth, S., W.C. Burton, J.S. Schindler, and A.J. Froelich, 2006. Geologic map of Loudoun County, Virginia: U.S. Geological Survey Geologic Investigations Series Map I–2553, scale 1:50,000.
7. Tetra Tech (GeoTrans), 1989. Hydrogeologic Study of a Proposed Community Water-Supply System at the Proposed Huntley Farm Subdivision Site, Waterford, Virginia, prepared for Lehigh Properties.
8. Tetra Tech (GeoTrans), 1989. Hydrogeologic Study of the Proposed Wheatland Estates Subdivision Site, Wheatland, Virginia, prepared for Woodbridge Construction Company.
9. Tetra Tech (GeoTrans), 1990. Hydrogeologic Investigation of the Brown Farm Subdivision Site, Waterford, Virginia, prepared for Land Concepts, Inc.
10. Tetra Tech (HSI GeoTrans), 2001. Final Hydrogeologic Study of the Proposed Waterford Ridge Subdivision Site, Loudoun County, Virginia, prepared for Mr. Stavros Roberts.
11. Tetra Tech, 2006. Waterford Elementary School Groundwater Supply Report, Waterford, Virginia, prepared for Loudoun County Public Schools.
12. Tetra Tech, 2014. Final Hydrogeologic Study of The Crest at Waterford Subdivision Site, Loudoun County, Virginia, prepared for Carrington Builders LC.
13. Tetra Tech, 2019. Assessment of Groundwater resources in the Western Hills Watershed, Chapter 5, Western Hills Watershed Management Plan prepared for County of Loudoun.
14. Hydrographs of DTW monitored in four wells in and near Waterford and two USGS observation wells between July 2021 and February 2022.

Appendix E
Water Quality Standards

Primary			
Substance	**MCL (mg/L) LC wells**	**MCL (mg/L) VDH**	**MCL (mg/L) EPA**
Microorganisms			
Total Coliforms (including fecal coliform and E. Coli)			**5.0%**
Turbidity		**1 turbidity unit**	— (TT)
Disinfectants			
Chloramines (as Cl2)			**0.010**
Chlorine (as Cl2)			**1.0**
Chlorine dioxide (as ClO2)			**0.060**
Disinfection Byproducts			
Bromate		0.010	0.010
Chlorite		1.0	1.0
Haloacetic Acids		0.060	0.060
Total Trihalomethanes (TTHMs)		0.080	0.080
Inorganic Chemicals			
Antimony		0.006	0.006
Arsenic	0.05	**0.010**	0.010
Asbestos (fiber > 10 micrometers)		7 MFL	7 MFL
Barium	**1.0**	2.0	2
Beryllium		0.004	0.004
Cadmium	0.010	**0.005**	0.005
Chromium	**0.05**	0.1	0.1
Copper		1.3	1.300
Cyanide (as free cyanide)		0.2	0.2
Fluoride	**1.8**	4.0	4.0
Lead	0.05	**0.015**	0.015
Mercury (inorganic)	0.002	0.002	0.002
Nickel		no limits designated	—
Nitrate (measured as Nitrogen)	10.0	10	10
Nitrite (measured as Nitrogen)		1	1
Total Nitrate and Nitrite (as N)		**10**	
Selenium	**0.01**	0.05	0.05
Silver	**0.05**		—
Thallium		0.002	0.002
Organic Chemicals			
Alachlor		0.002	0.002
Atrazine		0.003	0.003
Benzene	0.005	0.005	0.005
Benzo(a)pryrene (PAHs)		0.0002	0.0002

Carbofuran		0.040	0.04
Carbon tetrachloride	0.005	0.005	0.005
Chlordane		0.002	0.002
Chlorobenzene			**0.1**
2,4-D	0.1	**0.07**	0.07
Dalapon		0.2	0.2
1,2-Dibromo-3-chloropropane (DBCP)		0.0002	0.0002
o-Dichlorobenzene		0.6	0.6
p-Dichlorobenzene	0.075	0.075	0.075
1,2-Dichloroethane	0.005	0.005	0.005
1,1-Dichloroethene		**0.005**	—
1,1-Dichloroethylene	0.007	0.007	0.007
cis-1,2-Dichloroethylene		0.07	0.07
trans-1,2-Dichloroethylene		0.1	0.1
Dichloromethane		0.005	0.005
1,2-Dichloropropane		0.005	0.005
Di(2-ethylhexyl) adipate		0.4	0.4
Di(2-ethylhexyl) phthalate		0.006	0.006
Dinoseb		0.007	0.007
Dioxin (2,3,7,8-TCDD)		0.00000003	0.00000003
Diquat		0.02	0.02
Endothall		0.1	0.1
Endrin	**0.0002**	0.002	0.002
Ethylbenzene		0.7	0.7
Ethylene dibromide		0.00005	0.00005
Glyphosate		0.7	0.7
Heptachlor		0.0004	0.0004
Heptachlor epoxide		0.0002	0.0002
Hexachlorobenzene		0.001	0.001
Hexachlorocyclopentadiene		0.05	0.05
Lindane	0.004	**0.0002**	0.0002
Methoxychlor	0.1	**0.04**	0.04
Monochlorobenzene		**0.1**	
Oxamyl (Vydate)		0.2	0.2
Polychlorinated biphenyls (PCBs)		0.0005	0.0005
Pentachlorophenol			**0.001**
Picloram			**0.5**
Simazine		0.004	0.004
Styrene		0.1	0.1
Tetrachloroethylene		0.005	0.005
Toluene		1	1

Toxaphene	0.005	**0.003**	0.003
2,4,5-TP (Silvex)	**0.01**	0.05	0.05
1,2,4-Trichlorobenzene		0.07	0.07
1,1,1-Trichloroethane	0.20	0.2	0.2
1,1,2-Trichloroethane		0.05	**0.005**
Trichloroethylene	0.005	0.005	0.005
Vinyl chloride	0.002	0.002	0.002
Xylenes (total)		10	10
Radionuclides			
Alpha particles		15 picocuries per Liter	15 picocuries per Liter
Beta particles and photon emitters		4 millirems per year	4 millirems per year
Radium 226 and Radium 228		5 pCi/L	5 pCi/L
Uranium		30 ug/L	30 ug/L
Secondary			
Substance	**MCL (mg/L) LC wells**	**MCL (mg/L) VDH**	**MCL (mg/L) EPA**
Aluminum			**0.05 to 0.2**
Chloride	250.0	250.0	250
Color		15 color units	15 color units
Copper	1.0	1.0	1.0
Corrosivity	non-corrosive	non-corrosive	non-corrosive
Fluoride		2.0	2.0
Foaming Agents	0.5	0.5	0.5
Iron	0.3	0.3	0.3
Manganese	0.05	0.05	0.05
Odor		3 threshold odor numbers	3 TON (threshold odor number)
pH		6.5-8.5	6.5-8.5
Silver			**0.1**
Sulfate	250.0	250.0	250
Total Dissolved Solids (TDS)		500	500
Zinc	5.0	5.0	5