EXHIBIT C

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Final Cleanup Action Plan

Bothell Service Center Simon & Son
18107 Bothell Way NE
Bothell, Washington

FSID # 33215922
VCP # NW2946

Issued By:

Washington State Department of Ecology
Toxics Cleanup Program
Northwest Regional Office
3190 160th Avenue SE
Bellevue, Washington 98008

DEPARTMENT OF
ECOLOGY
State of Washington

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1.0 INTRODUCTION

This Cleanup Action Plan (CAP) was prepared by Kane Environmental, Inc., (Kane Environmental) for the Bothell Service Center Simon & Son Site (BSCSS; the Site) in Bothell, Washington. This CAP was prepared for the Washington State Department of Ecology (Ecology) in collaboration with the City of Bothell. A vicinity map and Site location are shown on Figure 1. This CAP has been prepared to meet the requirements of the Model Toxics Control Cleanup Act (MTCA) administered by Ecology under Chapter 173-340 of the Washington Administrative Code (WAC). This CAP describes Ecology’s proposed cleanup action for this site and sets forth the requirements that the cleanup must meet.

The property containing the source of contamination was previously owned by Bothell Service Center Associates (BSCA) and managed by NLO Property Management (BSCA property). The City of Bothell is the current owner of the BSCSS property and the City owns roadways and other parcels adjacent to the BSCSS property which are also part of the Site. The City is in the process of obtaining a Consent Decree to implement this Cleanup Action Plan for the Site with Ecology and the Attorney General's Office.

The BSCSS property address is 18107 Bothell Way NE, Bothell, WA 98011. The King County Assessor's Office lists the parcel number as 237420-0065. The BSCSS property previously included a one-story, masonry, commercial building approximately 8,410 square feet in area, containing five tenant suites. The building on the BSCSS property and associated aboveground features were demolished in August 2016. The BSCSS property currently contains the concrete at-grade floor of the previous demolished building, and the asphalt paving is also still present.

Kane Environmental completed a draft Remedial Investigation and Feasibility Study for the Site dated August 25, 2017. The Remedial Investigation delineated the extent of halogenated volatile organic compound (HVOC) impacts to both soil and groundwater at the site. The primary source of current HVOC contamination on the Site is from releases associated with historical dry cleaning operations on the BSCA property. The Contaminants of Concern (COCs) in soil and groundwater are Tetrachloroethene (PCE), Trichloroethene (TCE), Cis-1,2 Dichloroethene (DCE) and Vinyl Chloride (VC).

Four remedial alternatives were evaluated in the draft Feasibility Study (draft FS) and are summarized below:

Alternative 1 – Limited Source Soil Excavation and Bioremediation. Emulsified oil product (EOS®) is injected into the groundwater in order to remediate the groundwater through reductive dechlorination.

Alternative 2 – Electrical Resistance Heating (ERH) Bioremediation and Recirculation. Electrical resistance heating (ERH) is used to heat the soil and ground water at the source area. The volatilized contaminants are removed by soil vapor extraction. An array of wells will remove contaminated groundwater and treat it with activated carbon, amended with a bioremediation product, Carbstrate© . It is then re-injected into the aquifer to stimulate anaerobic bioremediation of PCE and its breakdown products.

Alternative 3 – Air Sparging and Soil Vapor Extraction (AS/SVE). Air sparging introduces compressed air into the groundwater to enhance volatilization of contaminants in groundwater and soils. Volatilized contaminants are then recovered via vapor extraction of the overlying vadose zone. The vapors are run through a remediation system, and then discharged into the atmosphere following state and local permit requirements.

Alternative 4 – Excavation to Depth of Glacial Till and Monitored Natural Attenuation. Excavation would remove the source of contamination to its full vertical extent (down to 55 feet). Clean, compacted imported fill material will replace the excavated contaminated soil. Following source soil removal activity, monitored natural attenuation (MNA) would be implemented to remediate the groundwater plume.

Preferred Alternative

Alternative 2 – Electrical Resistance Heating (ERH) Bioremediation and Recirculation

Based on the results of the remedial investigation and feasibility study conducted under MTCA and the application of the selection of remedy criteria, the Preferred Alternative chosen is Alternative 2, Electrical Resistance Heating (ERH) Bioremediation and Recirculation, developed in accordance with WAC 173-340-350 through 173-340-390. Alternative 2 will be the primary alternative supplemented with limited and targeted soil excavation and disposal, and soil vapor extraction in the vadose zone. Additionally, contingency-based focused and targeted excavations may be utilized if post-ERH soil confirmation sampling determines that residual HVOC-impacted soils remain in the vadose zone soils in the area of the ERH activity on the BSCA property. Use of engineering controls and institutional controls are included on a contingency basis and may be used after the remedial action has been completed. Potential vapor intrusion, associated with future development, will be mitigated by the installation of vapor barriers and passive venting systems, or other vapor intrusion mitigation methods and documented in an environmental covenant.

1.1 Purpose

This document is the Cleanup Action Plan (CAP) for the Bothell Service Center Simon & Son Site located Bothell, Washington. The general location of the Site is shown in Figures 1 and 2. A CAP is required as part of the site cleanup process under Chapter 173-340 WAC, Model Toxics Control Act (MTCA) Cleanup

Regulations. The purpose of the CAP is to describe the preferred cleanup alternative for the Site determined from the RI/FS. More specifically, this plan:

- Describes the Site;
- Summarizes current site conditions;
- Summarizes the cleanup action alternatives considered in the remedy selection process;
- Describes the selected cleanup action for the Site and the rational for selecting this alternative;
- Identifies site-specific cleanup levels and points of compliance for each hazardous substance and medium of concern for the proposed cleanup action;
- Identifies applicable state and federal laws for the proposed cleanup action;
- Discusses performance and compliance monitoring requirements; and
- Presents the schedule for implementing the CAP.

Ecology has made a preliminary determination that a cleanup conducted in conformance with this CAP will comply with the requirements for selection of a remedy under WAC 173-340-360.

1.2 Regulatory Framework

The Site is listed in Ecology's database as Bothell Service Center (BSC), and also as Simon & Son Fine Drycleaning. The Site is assigned facility number 33215922 for dry cleaning solvent contamination in soil and groundwater. The VCP number for the Site is NW2946 and Cleanup Site ID No. 427. It should be noted that the Site was formerly in the VCP as project number NW0794 from 2001 to 2006.

Ecology lists the Site Discovery/Release Report having been received on August 1, 2001 (Ecology, 2015a). On February 16, 2015, the City of Bothell entered the Site into Ecology's Voluntary Cleanup Program.

Implementation of this cleanup plan will be under a consent decree that settles only for the Bothell Service Center Simon & Son Site HVOC contamination and does not ascribe regulatory compliance and settlement for other contaminated sites located on Lot D such as the Schuck's/Wexler and Bothell Former Hertz sites.

2.0 SITE DESCRIPTION

2.1 Site History

The property containing the source of contamination was previously owned by Bothell Service Center Associates (BSCA) and managed by NLO Property Management (BSCA property). The City of Bothell is the current owner of the BSCSS property and the City owns roadways and other parcels adjacent to the BSCSS property, which are also part of the Site. The City is in the process of obtaining a Consent Decree to implement a Cleanup Action Plan for the Site with Ecology and the Attorney General's Office.

The BSCSS property address is 18107 Bothell Way NE, Bothell, WA 98011. The King County Assessor's Office lists the parcel number as 237420-0065. The BSCSS property previously included a one-story, masonry, commercial building approximately 8,410 square feet in area, containing five tenant suites. The building on the BSCA property and associated aboveground features were demolished in August 2016. The BSCA property currently contains the concrete at-grade floor of the previous building, and the asphalt paving is also still present.

Per MTCA, a “Site” is “any site or area where a hazardous substance…has been deposited, stored, disposed of, or placed, or otherwise come to be located”. Figure 2 shows the approximate extent of the Site as defined by the extent of HVOC, primarily the dry cleaning solvent PCE, at concentrations greater than Washington’s Model Toxics Control Act (MTCA) Method A groundwater and soil cleanup levels. The HVOC plume originating from the former Simon & Son Fine Drycleaning facility on the BSCSS property is known to exist beneath the BSCSS property and extend onto adjacent and downgradient properties, including (from up- to down-gradient):

- 98th Avenue NE, located to the west and southwest of the BSCA property;
- The vacated portion of State Route 522 located immediately south of the BSCA property;
- The adjoining former Al’s Auto Bothell Wexler property to the east, now owned by the City;
- The location of the Bothell Former Hertz Facility (former Hertz property) south of the vacated portion of SR522, now vacant, undeveloped, and also owned by the City.

2.2 Human Health and Environmental Concerns

The RI/FS identified exposure pathways of COCs at the Site. Based on the nature and the extent of contamination, the likely greatest potential risk to human receptors is dermal contact of soil and/or groundwater to construction workers during soil-disturbing activities. The second most likely exposure risk is inhalation of vapors during soil-disturbing activities or by commercial workers.

These risks can be mitigated under a cleanup action that either removes the contaminants to levels that are protective to receptors or that places institutional or engineering controls to prevent exposure, following MTCA requirements.

Based on the nature and extent of contamination, the likely greatest potential risk to ecological receptors include incidental soil ingestion and dermal contact, as well as ingestion and direct contact with groundwater. Based on the exposure pathways analysis, the land use on the Site and the surrounding area make wildlife exposure unlikely.

See Figure 3 for the Conceptual Site Model.

2.3 Cleanup Standards

The COCs in soil and groundwater are Tetrachloroethene (PCE), Trichloroethene (TCE), Cis-1,2 Dichloroethene (DCE) and Vinyl Chloride (VC).

The selected cleanup levels for the identified Constituents of Concern in soil are as follows:

- MTCA Method A Soil Cleanup Levels for Unrestricted Land Uses (WAC 173-340-900, Table 740-1), and MTCA Method B Direct Contact values:
    - PCE 0.05 mg/kg
    - TCE 0.03 mg/kg
    - Cis-1,2 DCE 160 mg/kg (MTCA Method B)
    - VC 175 mg/kg (MTCA Method B)
- MTCA Method A Cleanup Levels for Groundwater (WAC 173-340-900, Table 720-1), and MTCA Method B Noncancer:
    - PCE 5 ug/L
    - TCE 5 ug/L
    - Cis-1,2 DCE 16 ug/L (MTCA Method B)
    - VC 0.2 ug/L

The points of compliance are the locations at which cleanup levels for the Contaminants of Concern (COCs) must be attained to meet the requirements of MTCA and support issuance of a satisfaction of Order or Decree for the Site and subsequent delisting. In accordance with WAC 173-340-740(6), the point of compliance for soil is all soil within the boundaries of the Site. In accordance with WAC 173-

340-720(8), the point of compliance for groundwater is all groundwater within the boundaries of the Site.

A Remediation Level of 1 ppm for PCE in soil will be used in case the MTCA Method A Soil Cleanup Level is not achieved in the ERH remedial action area.

3.0 DESCRIPTION OF SELECTED REMEDY

An array of electrical resistance heating (ERH) wells will be installed in the area of the former dry cleaning operation, and will extend to the west along the east side of 98th Avenue NE, south beyond the former BSC building footprint, and east to approximately half the distance of the former BSC building footprint. The ERH system will operate for approximately six months. Concurrently, injection and extraction wells will be installed in the remaining area of the PCE plume. The injection wells will place a bioremediation product into the subsurface groundwater, and at the same time, remove groundwater from edge of the plume. This will create groundwater recirculation cycle will be controlled by pumps located in an aboveground trailer. The extracted groundwater will be run through activated carbon, and then this clean groundwater will be amended with the bioremediation product, and re-injected into the groundwater. Groundwater performance monitoring will be conducted during both activities (ERH and Bioremediation). There is also an area of PCE contaminated soil in the eastern portion and adjacent to the east perimeter of the former BSC building, that will be removed by soil vapor extraction (SVE). The SVE system will be separate from the ERH and Bioremediation systems and operate for approximately six months. Also, localized, targeted soil excavation of PCE contaminated soil will be conducted in near-surface soil in the eastern area of the former BSC building footprint that was identified during site characterization.

3.1 General Description of the Cleanup Action

Based on the results of the remedial investigation and feasibility study conducted under MTCA (Kane Environmental, 2017) and the application of the selection of remedy criteria, the Preferred Alternative is Alternative 2 (Electrical Resistive Heating/Bioremediation with Groundwater Recirculation), augmented by targeted soil excavation and soil vapor extraction, developed in accordance with WAC 173-340-350 through 173-340-390. Alternative 2 will be implemented as the primary alternative for source control and plume remediation. Figure 4 shows the layout for the ERH thermal remediation, Soil Vapor Extraction, and Groundwater Bioremediation and Recirculation systems.

Remediation of other areas of contamination outside of the electrical resistive heating (ERH) remediation zone will be addressed by groundwater bioremediation and recirculation, targeted soil excavation and disposal, and soil vapor extraction in the vadose zone. Use of additional vadose soil excavation and removal in the source area (ERH treatment zone) engineering controls and institutional controls are included on a contingency basis if the MTCA Method A soil cleanup levels in the vadose zone soils are not met. Furthermore, a vapor barrier and passive venting system, or other vapor intrusion mitigation measures, will be implemented in the areas of the building development as part of the environmental covenant.

3.2 Electrical resistance heating (ERH)

ERH involves heating the soil and groundwater using electrodes installed in wells in the source area, and connected to a source of electricity, resulting in heating of the subsurface soil and groundwater. The subsurface is heated to a range of 80 to 100 degrees Centigrade (°C), which then volatilizes the contaminants into the unsaturated zone where they are removed by soil vapor extraction.

Installation of the ERH system includes drilling boreholes, installing electrodes and temperature monitoring probes, and soil vapor extraction screens in each borehole, and staging and connecting operating equipment (power control unit, transformer, power cables, vapor recovery lines, activated carbon, steam condenser, blower, and cooling tower). One of the six 55-foot deep ERH electrode will be placed at monitoring well location MW-9 where DNAPL was encountered. The boreholes are drilled in a triangular grid pattern (typically 15-foot spacing) that is located to optimize electrical and thermal distribution in the subsurface. The backfill around the electrode/vapor screen consists of a conducting material such as a sand and graphite or sand and steel shot mix. The electrodes are in electrical contact with the soil matrix throughout the target soil zone. The vapor extraction screen would be positioned over the target interval, in the unsaturated zone.

Once the electrode and vapor recovery system is constructed, including connection of all electrical and vapor lines at the surface, then the system would undergo functional testing. After testing is successfully completed, the system would be turned on. Electrical power is supplied continuously to the electrodes to heat up the subsurface. Heating the soil to the target temperature of 80°C to 100°C usually takes about 1 month. After the target temperature is achieved in approximately one month, it would be maintained for a period of 4 to 5 months to complete the thermal treatment. During the entire heating period, the vapor extraction system would be operating. As the soil is heated, contaminant vapor flow in the recovery system would progressively increase as the volatility of the contaminants increases. When the soil temperatures get close to the target, a significant amount of water would start to vaporize, which creates a steam-stripping effect for the volatiles. This steam is subsequently condensed in the steam condenser. Because of the heat and the steam-stripping effect, the removal of volatile contaminants from low-permeability silty soils is much more effective than standard air sparging and soil vapor extraction.

The progress of treatment with ERH is monitored through soil temperature monitoring of the subsurface, periodic collection and analysis of extracted vapors, and soil sampling for treatment confirmation. Thermocouples located at 5-foot intervals spanning the vertical target treatment zone would be used to track the subsurface soil temperature profile as it approaches and attains the target temperature. Air samples collected weekly from the vapor recovery line, after the condenser and before the activated carbon treatment, would be used along with vapor recovery stream flow-rate readings, to track the total amount of volatile contaminants removed from the subsurface as thermal treatment progresses. Performance air samples will provide data to ensure that the activated carbon treatment system is not saturated by elevated recovery. The soil samples, typically collected at 60, 90, and 100 percent of the thermal treatment cycle, would be used to verify the extent of contaminant removal indicated by the air sampling results. The soil compliance sampling is conducted approximately 4 to 6 months after starting the system. The soil compliance monitoring plan will be included in the Engineering Design Report.

3.3 Post-ERH Remediation

Although the ERH treatment is expected to attain MTCA cleanup levels for groundwater and soil under optimal conditions, a remediation level of 1 ppm PCE in soil will be set as a targeted remediation goal for this component of the cleanup. If this is not met at the end of the treatment schedule, a decision can be made to either extend the duration of thermal treatment for a limited time or implement a contingency involving targeted vadose soil excavation in the ERH treatment area. Following this step, residual soil and groundwater contamination in the ERH treatment area will be addressed by engineered and institutional controls using an environmental covenant. Similarly, other areas of the site containing residual contamination not in compliance with cleanup levels despite remediation efforts in the CAP (bioremediation, groundwater treatment and recirculation, SVE) will also have engineered and institutional controls (environmental covenant) in order to be protective.

3.4 Bioremediation and Groundwater Recirculation System Approach

3.4.1 Process Overview

The groundwater recirculation system is an automated, programmable treatment process to extract contaminated groundwater, run the groundwater through activated carbon to remove HVOCs, add a remedial substrate (bioremediation), and reinject the groundwater/substrate mixture back into the aquifer. This recirculation provides a continuous supply of remedial substrate to be utilized by the established microbial community responsible for the Reductive Dechlorination (RD) process. Through operating injection vertical wells in conjunction with vertical extraction wells, artificial groundwater gradients can be produced within a groundwater plume to induce the cycling of biologically-active and remedial substrate-rich treatment water uniformly throughout the contaminated zone. In addition, the substrate injections promote desorption of the majority contaminant mass present on the soil matrix, thereby dissolving this mass into the groundwater and furthering the overall RD remedial process. The microbial community responsible for RD requires dissolved contamination as mass adsorbed to the soil matrix is not readily bioavailable to these microbes. The recirculation loop has the added benefit of providing a degree of hydraulic control to mitigate downgradient migration of the contaminated groundwater plume.

One groundwater recirculation system will be installed and used to operate in the Shallow, Intermediate and Deep portion of the aquifer at the same time. In addition, when the system is initially turned on and the extraction pumps are all extracting, groundwater elevations will be collected to evaluate the degree of communication with key monitoring locations and radius of influence.

As an example, dextrose is a substrate that binds to certain microbial enzymes and, in the presence of oxygen (what the microorganisms need to "breathe"), produces carbon dioxide and water (i.e. mineralization). This process is called aerobic oxidation. Anaerobic biodegradation can occur also, but is significantly different because the microorganisms have to use other compounds, in the absence of oxygen, to "breathe". Microorganisms have a preference for which compounds they want to use for respiration, and these are referred to as terminal electron acceptors (TEAs). The generally accepted order of these TEAs, from most desired to least desired, are as follows:

Oxygen > Nitrate > Manganese (+4) > Iron (+3) > Sulfate > Carbon Dioxide

Since this is a predictable and reliable sequence these parameters can be measured/observed in groundwater to evaluate and characterize the microbial community in impacted saturated zones. Chlorinated solvents can be utilized by microorganisms as a TEA also, but their placement in this sequence varies widely. However, general academic research has shown that PCE and TCE tend to be utilized as a TEA at about the same time as nitrate and iron/manganese, while cis-DCE and VC tend to utilize about the same time as sulfate and carbon dioxide. So, complete dechlorination to ethene requires either sulfate-reducing or methanogenic conditions (i.e. when carbon dioxide is reduced to methane).

When all of the TEAs are utilized for microbial respiration they are 'reduced' because they are taking on electrons (negative charge) that come from the utilization of the primary substrate (i.e. electron donor and energy source). The reduction of these compounds causes the formation of different products. For instance, nitrate is reduced to nitrogen gas, ferric iron is reduced to ferrous iron (soluble form), sulfate is reduced to hydrogen sulfide, and carbon dioxide is reduced to methane. For the chlorinated solvents, a chlorine atom is replaced with a hydrogen atom, causing a change in the molecular structure (i.e. dechlorination). The final byproducts are ethene and/or ethane, which are benign, and are not recalcitrant because they are rapidly mineralized by microbes as a carbon/energy source.

The ultimate goal is to obtain contact between the substrate and the >95% chlorinated solvent mass sorbed to the organic fraction of the soil matrix in order to stimulate ERD where the bulk of the contaminant are sorbed. Without contact there is no reaction. Therefore, delivery of the substrate to the subsurface is paramount, which is why a groundwater recirculation approach was selected. Slug injections fail to achieve effective contact due to the generation of preferential flow pathways, while a long-term recirculation approach minimizes this problem. By inducing hydraulic gradients via injection/extraction, a user can push/pull the amended groundwater to any location desired, even under existing buildings/roads. The most transmissive zones in the saturated zone will be the first to receive the amended groundwater, which will cause microbes to grow in the effective pore space. As they grow in the pore space they foul it with biomass, reducing the effective porosity in that zone, and facilitating fluid transport to the less transmissive zones.

The initial substrate, Carbstrate product, initiates the ERD process and causes the bulk of the pore space to be lightly fouled with biomass. At the end of the system operation substrate addition ceases causing the microbial death rate to increase, and the dead biomass begins to decay. This biomass then becomes a secondary, long-term substrate that sustains ERD for at least 1.5 - 2 years due to the rotting/decaying biomass generated from the substrate (behaves like an electron donor). Academic literature (Yang and McCarty, 2004) supports this concept that decaying biomass yields better ethene/ethane generation rates than primary substrates like lactate or soybean oil.

Chlorinated solvent retardation rates decrease from PCE to VC, so there will be varying rates of contaminant migration towards the extraction wells. Typically, cis-DCE and VC are observed at higher concentrations at the extraction well locations due to their higher solubility values and lower sorption coefficients. Each location is going to have its own unique baseline conditions, and we will be plotting the VOC data over time to evaluate contaminant transport/breakthrough and biotransformation at all locations. The main benefit of anaerobic dechlorination is that it enhances the desorption of the VOCs, making them more soluble and bioavailable.

One potential risk with this method is the possibility for biofouling, which occurs when bacteria, supported by the injected substrate, accumulate and grow around the well screen, inhibiting the productivity and function of the well. However, the proposed recirculation system is designed with precautionary measures and operational procedures in place to prevent biofouling, by adding the substrate using weekly injections, not on an on-going basis.

3.4.2 Substrate

Carbstrate™, a nutrient-amended carbohydrate amendment, is proposed as the electron donor substrate. Its qualities include high water solubility, no particulate matter, low viscosity, and a low retardation factor in order to ensure mobility within the target treatment zone. If the substrate has a low solubility or significant retardation factor, then delivery via induced hydraulic gradients would require multiple pore volumes of recirculation prior to achieving site-wide delivery. In addition to its solubility and low-retardation factor, it is a non-toxic, food-grade product that includes the macro-nutrients that will be necessary for effective microbial growth (i.e. nitrogen and phosphate) as well as a specific suite of trace metals that have been shown to be critical for active anaerobic microbial activity. It is also a dry substrate, which helps prevent fouling of injection points and equipment components.

3.4.3 Substrate Concentrations

The proposed remedial approach is to pulse-inject a nutrient-amended carbohydrate to a re-circulating groundwater system to overcome the terminal electron acceptor (TEA) sinks (i.e. dissolved oxygen, nitrate, sulfate, etc.) and create sulfate-reducing and/or methanogenic conditions throughout the desired saturated zone. Either of these conditions will promote the transfer of electrons to the chlorinated solvents, which will reduce their concentrations and remediate the target area. The Site-wide delivery of the substrate throughout the saturated zone will be optimized via groundwater recirculation facilitated by the automated system.

The desired substrate concentration was calculated using stoichiometric ratios of carbohydrate to TEAs and chlorinated solvents at the Site. Terminal Electron Acceptors are estimated and the mass of substrate is calculated to overcome this estimate (Attachment B). Vendor experience, system capacity, and ongoing data will be used for substrate dosing. The proposed system will *pulse-inject* a higher concentration of nutrient/carbohydrate-amended groundwater throughout the target zone (saturated and smear zones) to achieve a 50-200 mg/L TOC concentration. This concentration of TOC has been shown to be the effective concentration to achieve robust anaerobic dechlorination. The goal is to not only fully dechlorinate the minor mass of chlorinated solvents dissolved in groundwater, but also fully dechlorinate the majority of the chlorinated solvent mass sorbed onto the organic fraction in the soil as it partitions into the groundwater. A copy of the Material Safety Data Sheets (SDS) for Carbstrate™ is located in Attachment C.

3.4.4 Groundwater Recirculation System

This section describes the groundwater recirculation pilot system to be installed and operated at the Site. This full-scale system will include: a remediation equipment enclosure; vertical injection wells; vertical extraction wells; monitoring wells; and conveyance/conduit lines.

The drawdowns observed during the aquifer tests indicate that hydraulic control at the BSCA property is feasible at modest pumping rates. The proposed remedial approach will utilize six extraction wells in the Shallow zone, four extraction wells for the Intermediate zone, and four extraction wells for the Deep zone (Figure 4). Pump test data is provided in Attachment D. The remedial approach uses hydraulic control/capture to primarily distribute the substrate across a large area via displacement and advective flow at very low flow rates (<10 gpm total combined flow). The low system flow rate, and programmed injection timeframes in the system, keep injection wells only receiving flow for a limited time (usually a few minutes) before it ceases injection and allows the well to pressurize and sit idle for 15 to 20 minutes. This pulsed, low flow delivery approach is more a volumetric approach that needs to recirculate at least 3 to 6 pore volumes in order to achieve effective distribution/contact of the substrate across the bulk of the impacted soil matrix (where the bulk of the solvents are sorbed) to achieve remedial goals. For the Shallow aquifer zone (dimensions of 150 feet x 100 feet x 10 feet saturated thickness, 0.15 effective porosity), there are approximately 170,000 gallons of groundwater in one pore volume. A recirculation system operating at 3 to 6 gpm will recirculate one pore volume in 0.65 to 1.3 months. Over the anticipated bioremediation remedial timeframe of an estimated 2 to 3 years, the system will recirculate dozens of pore volumes, obtaining a high degree of contact/distribution, without generating significant hydraulic head to drive the plume offsite. Lower groundwater extraction rates in the Shallow zone will not inhibit the remedial process, and will help remediate that upper solvent mass without pulling it deeper (or causing short-circuiting) into the Intermediate zone. Heated water flushing may not be prevented, but it is not considered a major concern. The concern is substrate distribution across a large area under slow flow conditions in the pore space, and active displacement is the only way obtain mixing/contact with the substrate can be achieved.

All extraction wells will be four-inch diameter wells, which will increase the yield and hydraulic control at the BSCA property during full-scale remediation. The bulk of the contaminant mass resides in the Shallow zone, where the groundwater extraction rates were the lowest (<0.2 to 0.6 gpm) and the drawdown was the highest. As mentioned, MW-06 is screened deeper than the other Shallow wells, which is why it had a higher sustainable yield. MW-25 did not yield a sustainable extraction rate at less than 2 gpm (only operated for 4 minutes, yielding 7 to 8 gallons), but it did recharge 6.5 feet in one minute during the recovery phase, showing groundwater extraction at that location with a programmable submersible pump is feasible. A programmable pump will have a dwell time entry to pulse the extraction wells on and off, which could be set at 1 to 5 minutes for this site. If the wells recharge that quickly, they will yield a moderate extraction rate with a fixed system. The larger diameter extraction wells will likely yield at least 0.5 to 1 gpm sustainable pumping rates, and a large radius of influence (ROI) as it is pumped on over a large timeframe. The placement of the three extraction wells on Figure 4 are approximately on 50 foot centers along the western BSCA property line between MW-9 to MW-39, which will provide a high degree of hydraulic control on this end of the plume. The 50-foot centers were chosen based on the lithology and drawdown information. The Shallow zone test showed an influence of at least a 50-foot ROI using a 2-inch diameter well. Based on this data, the hydraulic control in this area will be very high. The extraction wells at 25 feet away will come into competition with the other well, reducing their yields, but providing a higher degree of hydraulic control. If the extraction wells are moved too close together they will start to dewater each other. Therefore, the three proposed extraction wells and their placement are appropriate. These three wells pumping at the same time will create a larger ROI, that will extend beyond the known VOC impacts in the Shallow zone, based on the total observed ROI during pumping tests. In addition, there are three extraction wells distributed to the east and south of the BSCA property to provide hydraulic control and substrate distribution at the distal end of the plume. Both the Intermediate and Deep zones have four extraction wells that are placed in accordance with the contaminant plumes onsite to provide a high degree of hydraulic control/capture. We expect these extraction wells to yield a much higher pumping rate (4 to 6 gpm), and maintain a high degree of hydraulic control/capture.

Remedial product injection into the vertical injection wells will be feasible due to the sufficient hydraulic conductivity and medium dense nature of the soils. The ability to extract groundwater at sustainable rates, and then re-inject that groundwater containing the amendments is implementable and appropriate for this site.

The placement of the extraction wells surrounding the injection wells is done in a manner that will provide a high degree of plume containment. With these low flow rates and the highly sorbed nature of the chlorinated solvents, chlorinated solvent mass will not migrate beyond the extraction wells. Extraction wells will be monitored for VOC concentrations. In addition, selected monitoring wells downgradient of the extraction wells will be used as performance monitoring wells for off-property plume migration and treatment.

3.4.5 Remediation Equipment Enclosure

The groundwater recirculation system will be operated using aboveground equipment housed in a secure weatherproof enclosure. The remediation equipment enclosure will be situated on the Site. Equipment contained within this enclosure will include: a 200-gallon poly tank to contain the concentrated Substrate injection solution (“solution tank”); an air compressor; a programmable logic controller (PLC) system; and injection and extraction manifolds, with their respective pressure gauges, ball valves, flow meters and sampling ports. In addition, a 1,000-gallon poly tank to hold the extracted groundwater (“holding tank”) and a 150-gallon activated carbon drum will be located immediately outside the enclosure.

The groundwater extraction pumps located in an aboveground trailer, approximately 10 feet long, 8 feet wide, and 8 feet high, will send groundwater from the extraction wells to the pre-treatment holding tank. The pre-treatment holding tank will contain a high/high, high, and low float for logic control. A transfer pump will pump the groundwater from the pre-treatment tank through GAC vessels (in series), and into the post-treatment holding tank (also containing three floats for logic control). The in-situ delivery (ISD) system will pull treated groundwater from the post-treatment holding tank, and amend it automatically using a metering peristaltic pump connected to a small substrate solution/mixing 50-gallon tank located inside the aboveground trailer. The concentrated substrate solution will be metered into the injection header at a specified rate when the system is in the injection mode. The ISD system will inject the groundwater containing the substrate to the desired injection wells, based on set times and rates dictated by the operator. The proposed injection schedule, and the performance and confirmation monitoring plans will be included in the Engineering Design Report. Substrate will be added one time per week to the solution/mixing tank via field technicians during their weekly site visits.

Attachment F provides the general layout of the remediation equipment enclosure and presents the process and instrumentation diagram of this bioremediation system.

3.4.6 Well Installations

The bioremediation system will include the installation of vertical injection wells and vertical extraction wells. These wells will be installed by a Washington state licensed well driller. Prior to conducting the well installations, Underground Service Alert (USA) will be notified as required by Washington law at least 48 hours in advance of the field activities.

3.4.7 Vertical Injection and Extraction Wells

Vertical injection wells will be used for the Intermediate and Deep portion of the aquifer. The wells will be installed in an array that will provide substrate throughout the entire Intermediate and Deep HVOC plume. It is possible that some of the existing groundwater monitoring wells will be used as injection wells, which will be evaluated in the Engineering Design report.

Because the existing monitoring wells on Site are either not the proper diameter, or not screened to the target pilot system depths, or not strategically located in the most optimal location, a series of new Shallow, Intermediate, and Deep extraction wells will be installed for the remedial approach. An estimated six new 4-inch diameter Shallow extraction wells (SEWs) will be installed and screened from 5-20 ft bgs. An estimated six 4-inch diameter Intermediate extraction wells (IEWs) will also be installed and screened from 25-35 ft bgs. An estimated four 4-inch diameter Deep extraction wells (DEWs) will be installed and screened from 40-55 ft bgs. The vertical extraction well locations were selected to correspond for the Shallow portion of the aquifer, and are spaced based on the observed ROIs for each zone during the 2017 pump tests. Figure 4 depicts the preliminary locations of the injection and extraction wells.

The vertical extraction wells will be installed using sonic drilling technology, which advances a non-perforated steel conductor casing, thereby mitigating potential cross-contamination of the aquifer zones. In addition, sonic drilling will limit the exposure of vapors emanating from the open borehole and generated from the soil cuttings. The vertical extraction wells will be constructed in 8-inch diameter borings using 4-inch diameter, Schedule 40 PVC. The screened sections for all zones will be constructed using 0.010-inch machine slotting. Each well will be hung within the center of the borehole, with sand filter pack (#2/12 sand, or equivalent) placed within the annular space as the conductor casing is removed.

The sand filter pack will extend 1 ft. above the screen intervals, followed by 1 foot of hydrated bentonite, and then cement to the ground surface. Each well will be completed in a concrete vault, with camlock fittings installed on the well heads for connecting with the remediation system's conveyance lines.

The down-hole drilling equipment will be decontaminated following each well installation using a high-pressure rinse. The used decontamination rinse water will be stored within 55-gallon steel drums or a poly tank pending offsite disposal.

Development of the extraction wells will proceed no sooner than 48 hours following the well installation activities to allow time for the cement surface seal to set. Each well will be developed using a surge block to remove the fines from the filter pack. Following the surging, groundwater within each well will be pumped out and monitored for pH, turbidity, electrical conductivity (EC) and temperature. The pumping will continue until these parameters stabilize to within a 10 percent fluctuation or until a maximum of 10 well casing volumes are purged.

Following the completion of the development activities, each well head will be retrofitted to support the extraction equipment. For the pilot system, this equipment will include: a 3-inch diameter, stainless steel submersible pump (Grunfos Redi-Flo3, or equivalent); electrical line; and 1-inch diameter discharge hose.

3.4.8 Groundwater Monitoring Wells

Because all of the vertical extraction wells will be used for extraction only, selected extraction wells will be utilized as groundwater compliance monitoring locations in addition to selected existing groundwater wells. These wells will be sampled for MNA parameters and VOCs to assess the performance of the remedial action. Groundwater performance samples will be collected from all key monitoring locations throughout the ERH and bioremediation remedial action. See Section 3.7 for chemical parameters and analytes to assess the bioremediation treatment performance.

3.4.9 Conveyance Lines

Below ground conveyance lines will be installed connecting to the injection and extraction wells. The lines will be installed in trenches approximately 16-inches wide by 2 feet deep. The conveyance lines will merge into a common trench near the treatment system compound that will be approximately 3 feet wide by 2 feet deep. These conveyance lines will be constructed using 1-inch diameter PVC pipe electrical conduit for the extraction well pumps will also be included within the conveyance line trenches. Waste material associated with trenching activity, including concrete and soil, will be assumed to be investigation derived waste (IDW). The handling and disposal of IDW is discussed below.

3.5 IDW

Investigation derived waste (IDW) generated from the installation of the remediation system trenching and drilling activities will include drill cuttings from extraction and injection well installation, soil and concrete excavated from the construction of the directional drilling entry pits and the injection trenches, well development water, and decontamination rinse water. This IDW will be stored in either water-proof roll-off containers or 55-gallon drums that will be labeled, and sampled for waste characterization and profiling, and stored on Site pending receipt of the analytical data. It is assumed that the generated IDW may be disposed as Contained-In designation, and some IDW may potentially require disposal as RCRA hazardous waste.

3.6 Permitting

The installation of the ERH and groundwater Bioremediation/Recirculation system will be properly permitted through the appropriate regulatory agencies. An electrical permit will be obtained by from the City of Bothell to install the 100 amp 120/240v single-phase temporary service required for the operation of this system. In addition, a UIC permit from the Washington State Department of Ecology will be required to re-inject extracted and treated groundwater containing Carbstrate.

3.7 System Performance Criteria and Performance Monitoring

For baseline and system performance monitoring data, groundwater samples will be collected from the key monitoring wells proposed herein. The performance and compliance groundwater monitoring plan will be included in the Engineering Design report. All key monitoring wells will be analyzed for the following:

- VOCs (limited chlorinated solvent suite, EPA 8260B).
- Ammonia-nitrogen (EPA 350.1).
- Sulfate-sulfur (EPA 375.4 MOD).
- Methane/ethene/ethane (low level analysis via Microseeps, Inc.).
- Total organic carbon (TOC, multiple methods).
- Dissolved iron and chloride

In addition, groundwater quality parameters (i.e. Conductivity, ORP and pH) should be taken during sampling events. These parameters will be sampled and analyzed every month the first quarter, followed by quarterly collection. The key groundwater monitoring wells to be sampled will include:

- Shallow Zone: MW-3, MW-21, MW-30, MW-37, HZ-MW-16, HZ-MW-19 and HZ-MW-22
- Intermediate Zone: MW-12, MW-20, MW-36, HZ-MW-23, and HZ-MW-29
- Deep Zone: MW-31, MW-32, MW-35, MW-38, and HZ-MW-25
- 3 Extraction Wells from different aquifer depths

Extraction wells will be sampled in a manner to minimize any aeration of groundwater samples. The extraction pumps can be operated manually using the PLC of the system by the field technicians. Each extraction well conveyance line will have its own flow meter and gate valve to control the extraction flow rate. In addition, each line will have its own sample port and tubing to collect samples from. Once the pump is turned on, the conveyance line will be evacuated/filled and the pump flow rate will be reduced using the gate valve (to about 1-2 gpm). Once the flow rate is reduced, the sample port will be opened to flush the line and check for air bubbles. If no air bubbles are observed, then a sample will be collected. If bubbles are observed, the flow rate will be reduced until no bubbles are observed. All extraction wells will be sampled for baseline conditions prior to system startup.

3.8 Schedule

The construction of the infrastructure and subsequent installation of the groundwater recirculation system will immediately commence following the approval of this Cleanup Action Plan. It is anticipated that the permitting and mobilization activities will require up to one month. The well installation and development activities are expected to require another 4 to 6 weeks, which will be followed by the initial system start-up (2 weeks).

3.9 Targeted Soil Excavation and SVE System

Limited soil excavation will be conducted during the installation of the remediation systems on the BSCSS property. Limited Soil Excavation has been included in the Preferred Alternative to address any potential additional HVOC soil that may be found during system installations. Soils will be sampled and designated for disposal following Ecology requirements. See Figure 4 for locations. These limited vadose zone soil excavation locations are the PCE hot spots discussed in the RI/FS report.

Following thermal (ERH) treatment, confirmation vadose zone soil samples will be collected in the ERH treatment and Bioremediation/Groundwater Recirculation areas to confirm if remediation levels and/or cleanup standards were met in the soil vadose zone source area. This hot soil sampling will be completed following a specific health & safety protocol for hot soil sampling. As a contingency, if soil cleanup standards and/or remediation levels were not attained, targeted vadose zone soil excavation and removal will be carried out to achieve cleanup standards in the ERH treatment area as much as practicable and following a work plan to be approved by Ecology. See also Section 7.0 for additional details on performance and compliance monitoring.

A Soil Vapor Extraction system will be installed in the eastern portion of the BSCA property to remediate vadose zone soils contaminated and impacted by PCE, found in proximity to the former BSC sewer line near the sewer manhole to the east of the former building. The SVE system installation would occur at the same time as the Bioremediation system, and air blowers will be connected to electrical power for the Bioremediation system. Compliance air sampling will be conducted on a monthly basis until concentrations are synoptic, then confirmation soil sampling will be conducted. See Figure 4 for locations of the SVE systems. Detailed engineering specifications will be provided in the Engineering Design Report.

4.0 HEALTH AND SAFETY PLAN

Kane Environmental has prepared a Site-specific Health and Safety Plan (HASP) to be followed when performing field activities at the Site. This HASP, which will be available in the Engineering Design Report, was prepared to comply with the requirements of Title 29 of the Code of Federal Regulations, Part 1910 (20 CFR 1910), collectively referred to as "Hazardous Waste Operations and Emergency Response (HAZWOPER)". The HASP identifies physical, industrial, chemical and biological hazards, establishes hazard monitoring action levels, specifies the required Personal Protective Equipment (PPE), and includes a map showing the route to the nearest hospital with an emergency medical facility. A copy of the HASP will be maintained on the Site, and all visitors to the Site will be provided a health and safety briefing prior to commencing with their activities.

5.0 APPLICABLE, RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

Potential ARARs were identified for each medium of potential concern. The primary ARARs relating to the cleanup action include:

- MTCA, Chapter 70.105D of the Revised Code of Washington (RCW);
- Cleanup Regulations, WAC 173-340;
- Dangerous Waste Regulations, WAC 173-303, and
- State Environmental Policy Act (SEPA) Checklist [RCW 43.21C.030(2)(a) and (2)(b)].

These primary ARARs are anticipated to be the most applicable to the cleanup action because they provide the framework for the cleanup action, including applicable and relevant regulatory guidelines, cleanup standards, waste disposal criteria, references for additional ARARs, and standards for documentation of the cleanup action.

Other applicable ARARs and guidance documents for cleanup of the Site may include:

- Occupational Safety and Health Act, Part 1910 of Title 29 of the Code of Federal Regulations;
- Safety Standards for Construction Work, WAC 296-155;
- Solid Waste Management, Reduction and Recycling, RCW 70.95;
- Construction Stormwater General Permit
- Minimum Functional Standards for Solid Waste Handling, WAC 173-304;
- Criteria for Municipal Solid Waste Landfills, WAC 173-351;
- Minimum Standards for Construction and Maintenance of Wells, WAC 173-160
- Accreditation of Environmental Laboratories, WAC 173-50; and
- Underground Injection Control Program, WAC 173-218.

6.0 RESTORATION TIMEFRAME

The ERH operation is estimated to take 6 months from site mobilization to ERH system demobilization. The bioremediation process will start at approximately the same time as the ERH start, and will be operational for an estimated 2 to 3 years. Performance groundwater monitoring will be conducted during the remedial action activity, and groundwater compliance monitoring will be conducted after completion of the performance groundwater monitoring. The estimated timeframe for the total remedial action is 5 to 6 years, including groundwater performance and compliance monitoring.

7.0 PERFORMANCE AND COMPLIANCE MONITORING

Groundwater performance monitoring will be conducted in selected wells during the ERH system operation, at approximately 4 to 6 months after system startup. Up to two groundwater performance wells will be installed within the ERH treatment zone to monitoring PCE and its breakdown products concentrations during the treatment activity. The wells will be designed to withstand the heated water and have special surface completions for sampling following health and safety requirements.

Soil performance monitoring will only be conducted in the area of the ERH system approximately 4 months after ERH startup and following shutdown of the ERH system, approximately 6 months after ERH startup in vadose zone soils. Vadose zone soil samples will be collected in selected areas in the ERH treatment area to determine if the ERH system has reduced PCE, and its breakdown products, to concentrations below their cleanup levels. The soil sampling will be conducted using hot soil sampling techniques following health and safety requirements. Soil samples will be collected and sent to an Ecology-approved environmental laboratory for analysis of Halogenated VOCs (HVOCs) by EPA Method

8260. Results at the end of thermal treatment will be evaluated according to whether the remediation level and/or cleanup standards are achieved by the thermal remediation. Contingent vadose zone soil excavation and removal will be conducted at the soil source area based on the results, based on a work plan to be approved by Ecology.

Performance groundwater monitoring will be continued during the Bioremediation system operation until PCE, and its breakdown products, concentrations in groundwater are below their applicable cleanup levels.

Groundwater compliance monitoring will start at the time when PCE, and its breakdown products, groundwater concentrations have reached their applicable cleanup levels in the selected performance monitoring wells. Groundwater compliance monitoring will be conducted quarterly for 2 years. A groundwater compliance monitoring contingency will be provided in the Engineering Design Report in case groundwater compliance monitoring is continued after 2 years. The City of Bothell and Ecology will have with long-term access to the extent necessary to operate, maintain and monitoring remedial systems and the cleanup, and compliance groundwater monitoring.

A total of eight (8) groundwater wells will be selected, based on the results of the remedial actions, to provide performance and compliance groundwater monitoring for the Site. A groundwater compliance contingency, which would extend the groundwater biannual compliance monitoring for one year, will be started at the end of the proposed compliance monitoring in June 2022 if COC groundwater cleanup levels have not been reached. After one additional year, if COC groundwater cleanup levels have not been reached, an environmental covenant will include a 5-year compliance sampling event for the duration of the environmental covenant. Groundwater analytical results are needed for the 5-year periodic review. The five year groundwater compliance monitoring is only required if cleanup levels are not achieved and institutional controls through the environmental covenant on groundwater use are needed.

Furthermore, potential vapor intrusion, associated with future development, will be mitigated by the installation of vapor barriers and passive venting, or other vapor intrusion mitigation methods and included in the environmental covenant. The environmental covenant will include annual sampling events of indoor air for three years, to be conducted after the ERH remedial action and during tenant occupancy following sampling protocol provided in Ecology's Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Review Draft Revised February 2016) or the current guidance at the time of sampling to confirm the selected vapor mitigation.

Following completion of the Bioremediation and Groundwater Recirculation remedial action, one round of soil vapor sampling will be conducted and subsurface soil vapor data results will be compared to soil vapor screening levels.

8.0 SCHEDULE FOR REMEDIATION SYSTEMS IMPLEMENTATION

The schedule for the implementation is provided in the Consent Decree.

9.0 INSTITUTIONAL/ENGINEERING CONTROLS

If residual contamination remains on the BSCSS property after cleanup, or any of the other criteria for triggering an institutional control under WAC 173-340-440 are met, institutional controls may be implemented, and included in an environmental covenant. Institutional controls may also be implemented prior to completion of remedial actions at the BSCSS property.

Vapor intrusion risks at the site will be addressed by the active remediation of contaminated soil and groundwater at the site and direct mitigation through engineering controls. Engineering controls, such as vapor barriers and passive venting, or other vapor intrusion mitigation methods, will be implemented for the new development structures and included in the environmental covenant.

10.0 PUBLIC PARTICIPATION

This criterion considers whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, federal and state agencies, or any other organization that may have an interest in or knowledge of the Site. A Public Participation Plan and Fact Sheet has been prepared for review during the public comment period for the consent decree as required under MTCA.

11.0 REFERENCES

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Figures

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CAP
Bothell Service Center Simon & Son
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Figure 1
Vicinity Map

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Figure 2
Site Plan

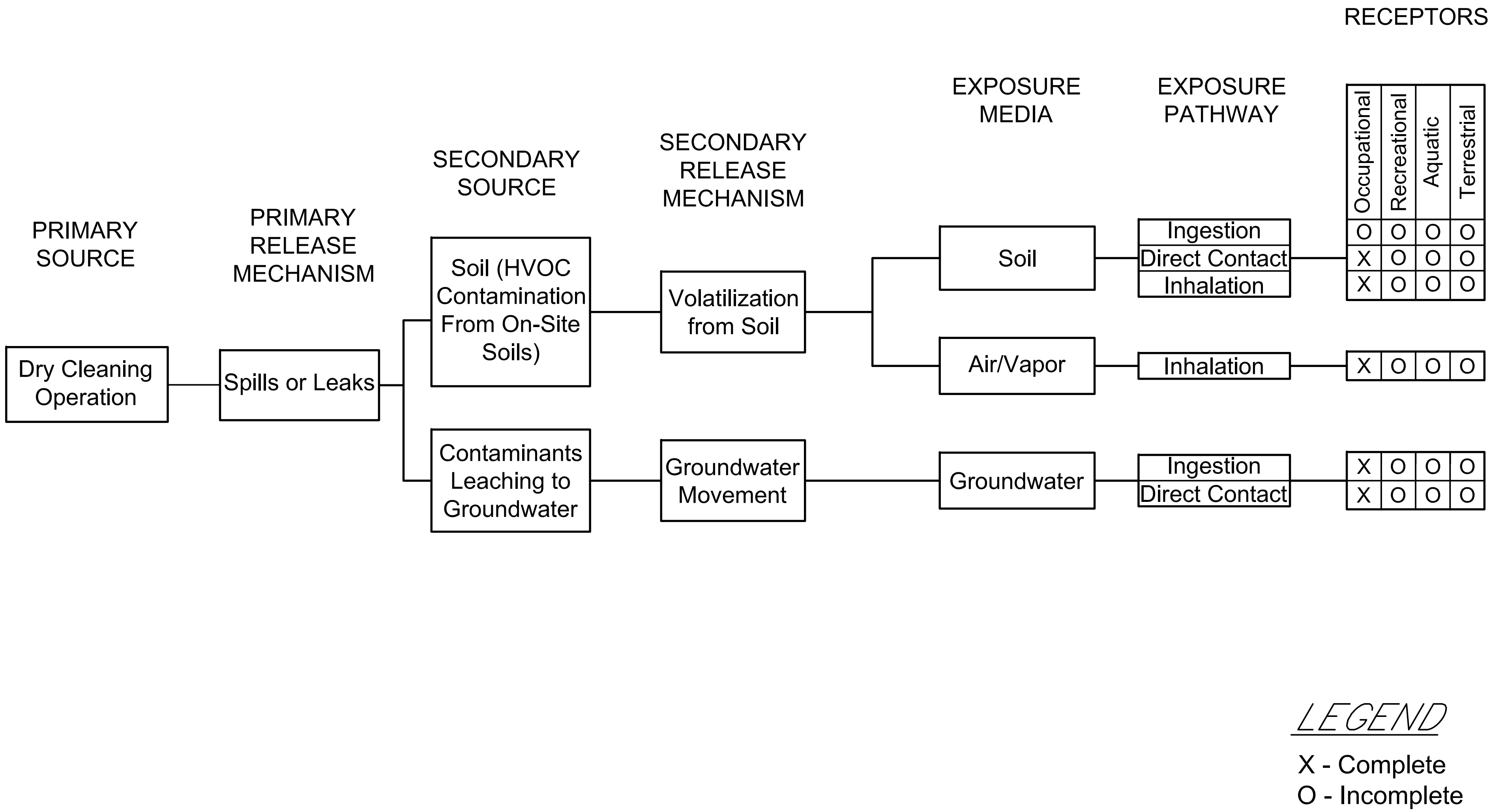

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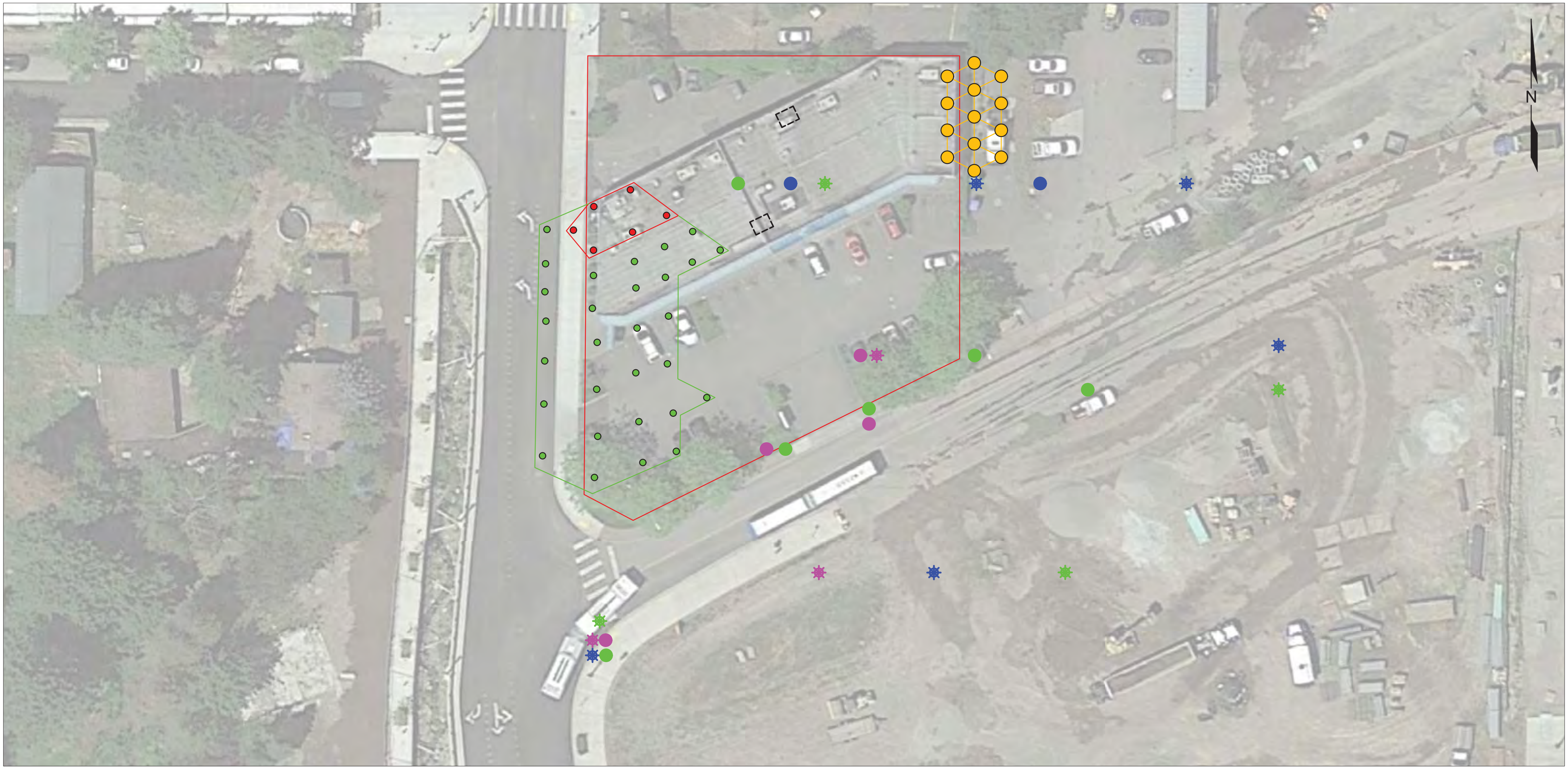
Figure 3
Conceptual Site Model



LEGEND

Red line	BSCA Property Boundary
Green dot	Approximate Location of ERH Probe (5-25 ft bgs)
Red dot	Approximate Location of ERH Probe (5-55 ft bgs)
Dashed line	Approximate Location of Soil Excavation
Yellow circle	Approximate Location of Soil Vapor Extraction (SVE) Well
Blue star	Proposed Extraction Well (Shallow 5-25 ft bgs)
Blue circle	Proposed Injection Well (Shallow 5-25 ft bgs)
Green star	Proposed Extraction Well (Intermediate 25-35 ft bgs)
Green circle	Proposed Injection Well (Intermediate 25-35 ft bgs)
Magenta star	Proposed Extraction Well (Deep 35-55 ft bgs)
Magenta circle	Proposed Injection Well (Deep 35-55 ft bgs)

Aerial Photo Source: Google Earth Pro
Aerial Photo Date: June 27, 2016

0 40 80
Approximate Scale in Feet

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Figure 4
Preferred Remedial Alternative

Attachment A
Previous Studies Summary

Previous Site Assessments and Remedial Activities

This section is adapted from Farallon Consulting's 2011 letter report to Ecology (Farallon, 2011), and HWA Geosciences 2008 environmental assessment reports.

***Interim Site Characterization Summary*, Environmental Resources Management (ERM), October 17, 2001.**

ERM conducted subsurface soil and groundwater investigation activities at the Site between December 1999 and July 2001 (ERM, 2001). Hand-auger borings HA-l, HA-2, and HA-3 were advanced in December 1999 to assess soil conditions in the vicinity of the former dry cleaning equipment in the Bothell Service Center building. PCE was detected at concentrations exceeding the current MTCA Method A soil cleanup level of 0.05 milligrams per kilogram (mg/kg) in soil samples collected from depths of 1 to 2 feet below ground surface (bgs) in each of the boring locations, confirming that a release of PCE had occurred at the Site.

In June and July 2000, ERM conducted subsurface investigations that involved collection of soil and groundwater samples from direct-push borings B-4 through B-11 and GP-1 through GP-3. The work in June 2000 entailed chemical analyses of soil samples collected from depths up to 4.2 feet bgs. PCE was detected at concentrations exceeding the MTCA Method A soil cleanup level, with the highest concentration of 392 mg/kg detected in a soil sample collected at a depth of 2.5 feet bgs from boring B-9 in the former dry cleaning equipment area. Work later in the summer of 2000 included chemical analyses of soil samples that confirmed PCE in excess of the MTCA Method A soil cleanup level at depths to 9 feet bgs approximately 20 feet southwest (soil boring GP-3) and 50 feet southeast (boring GP-2) of the former dry cleaning equipment area.

PCE and TCE were detected at concentrations exceeding current MTCA Method A groundwater cleanup levels in reconnaissance groundwater samples collected from borings GP-2 and GP-3. Chloroform and 1,1-dichloroethene (1,1-DCE) were also detected at concentrations exceeding current MTCA Method B groundwater cleanup levels in the reconnaissance sample collected from boring GP-3.

To further delineate the extent of PCE and related degradation compounds at the Site, ERM conducted supplemental investigation activities in 2001 that involved advancing and sampling additional direct-push Geoprobe temporary borings SP-1 through SP-12, and installing groundwater monitoring wells MW-1 through MW-7. The groundwater samples collected included both "shallow" and "deep" reconnaissance groundwater samples (exact depths were not indicated in the information available), with results used to support the selection of monitoring well locations. Findings of the supplemental investigation indicated that PCE concentrations in groundwater increased with depth, and PCE and its degradation compounds exceeded MTCA Method A or Method B cleanup levels. Chloroform also was detected at concentrations exceeding the MTCA Method B groundwater cleanup level.

***Interim Site Remediation Summary*, ERM, March 25, 2002.**

In 2001 and 2002, after a technology feasibility evaluation process, ERM conducted two remedial action events consisting of application of in-situ chemical oxidation at the Site to address concentrations of PCE in soil and groundwater. During the first event in 2001, potassium permanganate solution was applied directly to soil exposed by the removal of a section of the floor in the vicinity of the former dry cleaning equipment in the Bothell Service Center building. Also in 2001, ERM applied potassium permanganate directly into the water-bearing zone at depths ranging from 10 to 20 feet bgs at eleven soil boring locations outside the south side of the building using a direct-push drill rig. Approximately 100 to 250 gallons of a 2.5 percent potassium permanganate solution was injected into each boring, with a total injection volume of 1,800 gallons of solution. Groundwater monitoring indicated that HVOC concentrations were reduced in some areas 17 days after injection; however, concentrations rebounded after approximately four months.

Subsurface Investigation Report, **Farallon Consulting (Farallon), January 27, 2003.**

Farallon conducted a subsurface investigation at the Site in September and October 2002 that included drilling and installation of groundwater monitoring wells MW-8 and MW-9, and one groundwater monitoring event. PCE was detected at concentrations exceeding MTCA Method A cleanup levels in a soil sample collected from boring MW-9, in groundwater samples collected from boring SB-1, and in the borings for groundwater monitoring wells MW-8 and MW-9. PCE degradation compounds TCE and DCE were detected at concentrations exceeding their respective MTCA groundwater cleanup levels in groundwater samples collected from borings for monitoring wells MW-8 and MW-9. PCE was detected at concentrations exceeding the MTCA Method A groundwater cleanup level in samples collected from groundwater monitoring wells MW-1 through MW-9, with the exception of well MW-3, located north of the former dry cleaning equipment area. PCE degradation compounds were also detected at concentrations exceeding MTCA groundwater cleanup levels in samples collected from groundwater monitoring wells MW-1, MW-4, MW-5, and MW-6. The subsurface investigation activities are documented in Farallon's report (Farallon, 2003).

Engineering Design Report**, Farallon, July 9, 2004.**

Farallon performed additional subsurface investigations at the Site in September and October 2003 to address data gaps and provide information for the design of a remediation system. The additional subsurface investigations included advancing soil borings SB-2 through SB-6; advancing boring MW-10 to a total depth of 47.5 feet bgs and completing the boring as a 25-foot-deep groundwater monitoring well; advancing borings VE-l and VE-2 to total depths of 21.5 feet bgs and completing the borings as vapor extraction wells; conducting a soil vapor extraction (SVE) pilot test; and collecting soil and groundwater samples for laboratory analyses. PCE was detected at elevated concentrations in saturated soil samples collected below the groundwater table from borings VE-l (17 feet bgs) and VE-2 (15 feet bgs), and the boring for monitoring well MW-10 (8 and 32 feet bgs). PCE also was detected at concentrations exceeding the MTCA Method A groundwater cleanup level in the groundwater samples collected from borings SB-3, MW-10, VE-l, and VE-2.

***Cleanup Action Progress Report June 2006 through June 2007*, Farallon, March 12, 2008.**

Based on results from the subsurface investigations, the ERM remedial action, and a soil vapor extraction (SVE) pilot test, Farallon implemented an additional remedial action approach incorporating several elements, including a SVE system to remove soil vapors containing concentrations of PCE in the subsurface, injection of a chemical oxidant into groundwater in three monitoring wells at the Site to reduce residual HVOC concentrations in groundwater, and long-term monitoring of the natural attenuation of HVOCs in groundwater.

In September 2004, Farallon installed a SVE system at the Site consisting of a remediation compound on the west end of the Bothell Service Center building housing above-ground piping, a blower, electrical controls, and a vent stack. Trenching and installation of underground piping connecting the vacuum blower to vertical SVE wells VE-l and VE-2 and horizontal SVE well HVE-1 extended approximately 20 feet east into the westernmost tenant space, south of the former dry cleaning machine. The SVE system did not extend into any of the other tenant spaces, and no records of any vapor intrusion investigations were found in any prior reports for the BSCA property.

Farallon conducted tracer dye injection tests at the Site in 2005 to evaluate migration pathways to facilitate planning for in-situ treatment alternatives (Farallon, 2008a). The first dye injection test was conducted in February 2005 and included introducing dye through the toilet in the former dry cleaner suite into the sanitary sewer system (sewer dye test). The results of the sewer dye test indicated that there may be leaks in the sewer line directly beneath the building that are impacting groundwater, indicated by tracer detected at monitoring well MW-2. A second dye injection test was conducted in March 2005 and included injection of dye into monitoring well MW-2 (hydrogeologic tracer test). The results of the hydrogeologic tracer test indicated that the dye traveled a distance of approximately 45 to 65 feet from monitoring well MW-2 to MW-1 and MW-6 in 5 days (i.e., 9 to 13 feet per day).

In May 2005, Farallon conducted additional cleanup activities at the Site using in-situ chemical oxidation via hydrogen peroxide injection into monitoring wells MW-2 and MW-9. Because hydrogen peroxide degrades much more rapidly than the permanganate used by ERM in 2001 and 2002, it was unlikely to affect down-gradient surface water receptors if transported through preferential pathways. The injection included a total of 300 gallons of a solution consisting of 10 percent hydrogen peroxide and 90 percent water. Approximately 200 gallons of the solution was injected into monitoring well MW-2.

Selected monitoring wells at the Site were sampled in August 2005 to evaluate post-chemical oxidation injection concentrations of PCE in groundwater. Concentrations of PCE in groundwater had increased at the monitoring wells where hydrogen peroxide was injected (MW-2 and MW-9), and at monitoring wells MW-1 and MW-6, located downgradient of the injection wells. Injection of hydrogen peroxide likely immediately consumed PCE mass in the well boring and in soil surrounding the injection well for several feet prior to breakdown of the hydrogen peroxide. In addition to consuming PCE mass, the hydrogen peroxide oxidized native organic material in this zone. The increased PCE concentrations are attributable to release of dense non-aqueous-phase liquid (DNAPL) HVOC that previously was sorbed to the native organic material, and increased dissolution of the DNAPL to groundwater.

PCE as DNAPL was initially discovered at the bottom of monitoring well MW-9 in late August 2005. Between June 2006 and June 2007, DNAPL was periodically removed from monitoring well MW-9 using a peristaltic pump and dedicated polyethylene tubing. Approximately 450 milliliters of DNAPL was recovered during September 2005. An additional 40 milliliters of DNAPL was removed in February 2006, approximately 500 milliliters each in September 2006 and May 2007, and approximately 200 milliliters in June 2007, for a total of approximately 1,690 milliliters (approximately 0.5 gallon) of DNAPL removed from monitoring well MW-9.

Farallon conducted additional cleanup action via in-situ chemical oxidation between September 2006 and May 2007 at the Site by installing chemical oxidation cells in selected monitoring wells. The chemical oxidation cells were constructed of 1-inch diameter slotted polyvinyl chloride with two end caps glued in place. Each cell consisted of two portions: a lower portion approximately 6 inches in length and filled with chelated iron; and an upper portion approximately 12 inches in length and filled with sodium persulfate. Chelated iron acts as a catalyst to activate the chemical oxidation process by sodium persulfate. The chemical oxidation cells were suspended in monitoring wells MW-1 and MW-4 through MW-9 using polyethylene cord and fully submerged in groundwater.

***Interim Action Status Report November 2007 through August 2008,* Farallon, November 4, 2008.**

In 2007, Farallon evaluated the progress of the chemical oxidation cells and reconsidered the range of remedial technologies assessed in November 2002. The feasibility assessment concluded that Site conditions appeared to be amenable to enhanced in-situ bioremediation and that a bioremediation approach had potential to be more effective in a shorter restoration time frame than chemical oxidation. Farallon implemented a pilot-scale in-situ enhanced bioremediation approach that entailed the following:

- Installation of six new injection wells in November 2007 for introducing a bioremediation edible oil substrate (EOS), an emulsified vegetable oil product produced by EOS Remediation, LLC into the subsurface at monitoring wells MW-14, MW-15, and MW-18, screened in the Intermediate portion of the water-bearing zone, and monitoring wells MW-13, MW-16, and MW-17, screened in the Deep portion.

- Injection of approximately 1,700 gallons of a 20-percent mixture of substrate and water to enhance biodegradation of PCE in the water-bearing zone at the six injection wells and eight temporary borings in February 2008. Results of the injections are discussed in Farallon's 2011 *Project Status Summary*.

- Bioaugmentation to supplement the existing population of *Dehalococcoides* (DHC) bacteria that are responsible for the reductive dechlorination of PCE and its degradation byproducts in groundwater in July 2008.

- Continued operation of the SVE system at the Site to address residual concentrations of PCE in soil above the water table and to mitigate the potential for vapor intrusion into the existing Site building.

***Limited Phase II Environmental Site Assessment, Highway 522 Right-of-Way*, HWA Geosciences (HWA), April 15, 2008, and *Phase II Environmental Site Assessment, Hertz Rentals Property*, HWA, October 10, 2008**

In 2008, HWA performed soil and groundwater investigations south of the BSCA property and installed monitoring wells in the SR522 right-of-way and former Hertz property. The investigations indicated that HVOC contamination had migrated south of the Site onto those properties (HWA, 2008a, 2008b). HWA performed quarterly groundwater monitoring for one year from wells located in the vacated portion of SR522 and former Hertz property south of the Site, and also in the former Al's Auto / Wexler / Schucks property immediately east of the BSCA property, as part of the RI activities described under the Bothell Landing and Bothell Hertz Agreed Orders. Groundwater samples collected by HWA at these properties have consistently had HVOC concentrations exceeding MTCA groundwater cleanup levels, indicating that the release at the BSCA property has migrated downgradient and off property.

***Phase II Environmental Site Assessment, Schuck's Auto Supply,* Floyd & Snider, September 10, 2010.**

Floyd & Snider conducted a Phase II investigation in August 2010, associated with three former gasoline USTs located on the former Schucks property, immediately adjacent to the east of the BSCA property (Floyd & Snider, 2010). The investigation also sought to analyze for potential HVOC impacts to the former Schucks property, from the BSCA property. Borings were predominantly advanced in the area of the former USTs, approximately 34 feet to the east of the BSCA property. Soil and groundwater samples were collected from the boring locations. One boring location (GP-12, 32.5 feet to the east of the BSCA property) reported soils at 6 feet bgs with gasoline concentrations (5,900 ppm) in exceedance of the MTCA Method A cleanup level (100 ppm). None of the other boring locations reported petroleum concentrations in soil above state cleanup levels. None of the groundwater samples collected reported concentrations of petroleum products in exceedance of state cleanup levels. However, groundwater samples collected from GP-12 reported concentrations of gasoline (940 ppb) just below the state cleanup level (1,000 ppb). The investigation also reported HVOC impacts to both soil and water at concentrations in exceedance of MTCA Method A cleanup levels. It should be noted that soil samples with reported HVOC exceedances were collected at 8 and 9 feet bgs, below the observed depth of groundwater (approximately 4 to 7 feet bgs).

***Project Status Summary,* Farallon, November 18, 2011.**

Farallon released a summary of remedial activities conducted at the BSCA property since the November 2008 report (Farallon, 2011). These activities included a second injection event in 2010 and continued groundwater monitoring. Farallon stated that groundwater monitoring at the site indicated that PCE degradation rates had increased in the vicinity of the injection wells. These effects had been most prominent at MW-2 and MW-6. Farallon did note that the effects of the PCE degradation were not evident in the down gradient wells MW-4, MW-5, MW-7 or near the cross-gradient MW-1. The report recommended a larger scale in-situ bioremediation system at the Site.

Farallon also stated that while the removal rate of PCE via the SVE system had initially been high following the installation of the system in 2004, the system had reached near non-detectable concentrations of PCE by 2011. The report stated that while PCE emissions were low, the system helped to mitigate the potential for vapor intrusion into the existing structure at the BSCA property.

Prior to 2011, the system was extracting approximately 0.5 liters of PCE per year. After 2011, little or no HVOCs were reportedly being detected in the off-gas. The SVE system has therefore removed some PCE mass from the vadose zone within its area of operation. The system is currently not in operation since the building was demolished in August 2016.

Focused Soil and Groundwater Investigation, Horse Creek Project, **Shannon & Wilson, Inc., May 7, 2013.**

In October of 2012, Shannon & Wilson advanced several borings along the proposed alignment of the relocated Horse Creek channel. Three borings (GP-7 through GP-9) were located to the west of 98th Avenue NE, west of the BSCA property, which has since been excavated and contains the relocated Horse Creek channel. Soil and groundwater samples were collected from each location and analyzed for HVOCs. HVOCs were reportedly not detected at concentrations above the laboratory reporting limit in any of the groundwater or soil samples analyzed.

Request for "Contained In" Determination for Soils, Storm and Sanitary Sewer System Construction, 98th Avenue Northeast, **HWA, June 11, 2014.**

In May of 2014, HWA advanced three borings (98-B1 through 98-B3) along 98th Avenue NE, just west of the BSCA property. The borings were sited to assess potential HVOC impacts from the BSCA property and request a "Contained In" determination from Ecology for soils excavated during the installation of new utility lines along 98th Avenue NE. Soil samples were collected at 8 feet bgs and analyzed for HVOCs. The northernmost boring, (98-B1) reported concentrations of PCE below the MTCA Method A cleanup level and the central and southern borings (98-B2 and 98-B3, respectively) both reported concentrations of PCE in exceedance of the MTCA Method A cleanup level.

Results of October Groundwater Sampling, **Dalton, Olmsted, and Fugelvand, Inc. (DOF), November 10, 2014.**

In the spring of 2014, DOF performed groundwater monitoring and data analyses for the Site (DOF, 2014). DOF stated that historic groundwater monitoring data, coupled with the October 2014 monitoring results, provided strong evidence that the EOS injection product was successfully facilitating the degradation of PCE at the Bothell Service Center Site.

In summary and prior to 2016, the results of prior subsurface investigations conducted indicated the following:

- A release of an unknown quantity of PCE occurred at the Site between 1989 and 1999 during operation of Simon & Son Fine Drycleaning, and a residual source of PCE remains beneath the northwest corner of the former structure on the BSCA property,
- The PCE release(s) affected the soil above and below the water table as well as groundwater at the Site,
- PCE as DNAPL has been encountered on the Site at depths of approximately 45 to 50 feet bgs.
- Groundwater is affected to a depth of at least 50 feet where a silty stratum occurs in the source area, and at a depth of 30 to 40 feet down-gradient and across much of the Site, and
- The groundwater plume migrated across the Site via east and east-southeasterly flowing groundwater across city rights-of-way, and as far as the City-owned Al's Auto Bothell Wexler property and the former Hertz property parcel.

Attachment B
Estimated Substrate Mass and System Flow Calculations

Attachment B
Estimated Substrate Mass and System Flow Calculations

ESTIMATED TREATMENT AREA

150	ft
200	ft
50	ft
1500000	ft3
55555.6	CY
0.15	
47222.2	CY
225000	ft^3
6373.9	m^3
6373937.677	L
1683999.4	gal

PCE	TCE	DCE	
2000	1000	2000	
2000.00	1000.00	2000.00	
364	126	59	
0.02			
14560	2520	2360	ug/kg
14.56	2.52	2.36	mg/kg
1.8			
3031.2			
1376146789			
1376.146789			
			Total
566.2744578	123.66742	157.05015	**846.99203 lbs**

TYPE OF SYSTEM

Ext. Rate **6 gpm**

8640 gal/day
60480 gal/week
194.9 days to recirculate one PV
6.5 months to recirc one PV

259200 gal/month

MW (g/mol)		**Est. GW Concentration**		Molar Ratio (mol dextrose/mol EA)
32	Avg. DO	4	mg/L	0.16
62	Avg. Nitrate	5	mg/L	0.21
55.9	Avg. iron	10	mg/L	0.04
54.9	Avg. Mn	10	mg/L	0.08
96	Avg. Sulfate	50	mg/L	0.33
180.2	Dextrose			

GROUNDWATER TEA DEMAND

MASS OF DEXTROSE REQ'D	**Moles**	**g dextose**	**lbs dextrose**
Oxygen	796.7422096	22971.67139	50.59839513
Nitrate	514.027232	19297.439	42.50537225
Iron	1140.239298	8561.296731	18.85748179
Manganese	1161.008684	17434.48041	38.40193923
Sulfate	3319.759207	199406.8697	439.2221799
		Sum	**589.5853683 lbs**

GROUNDWATER VOC DEMAND

10.17257642	PCE
4.813393753	TCE
8.702854339	DCE
23.68882451	**lbs**

TOTAL DEXTROSE DEMAND **1460.27 lbs.**
The McCarty Factor (30% used) **4867.55 lbs.**
ETEC Factor of 5-10 FOLD **24338** **48676 lbs**
1734 mg/L dextrose in 1 PV

Attachment C
MSDS Substrate

3830 S Truman Rd. Bldg. 12
Washougal, WA 98671
(971) 222-3903 Fax
www.etecllc.com

Safety Data Sheet

Revision Date: 05/12/15

Section 1: Product and Company Identification

Product Name:	**CarBstrate ™**
MSDS Number:	Not Assigned
Chemical Name:	Proprietary
Chemical Family:	Substrate Mixture
Recommended Use:	Anaerobic bioremediation product
Restrictions on Use:	No Data
Company:	ETEC, LLC 3830 S Truman Rd. Bldg. 12 Washougal, WA 98671 USA
Telephone:	(971) 222-3616

Emergency Telephone:	(800) 535-5053
Medical Emergencies:	(800) 301-7976
U.S. Coast Guard National Response Center:	(800) 424-8802

Section 2: GHS Hazards Identification

This chemical is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Skin Irritant	Category 2
Eye Irritant	Category 2
Specific Target Organ Toxicity - Single Exposure (Respiratory system)	Category 3

Label Elements:

Signal Word: Warning

Hazard Statements:

Causes skin irritation.
Causes eye irritation.
May cause respiratory irritation.

Precautionary Statements:

Avoid breathing dust/ fume/ gas/ mist/ vapors/ spray.
Wash skin thoroughly after handling.
Use only outdoors or in a well-ventilated area.
Wear protective gloves/ eye protection/ face protection.
IF ON SKIN: Wash with plenty of soap and water.
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
Call a POISON CENTER or doctor/ physician if you feel unwell.
Specific treatment (see supplemental first aid instructions on this label).
If skin irritation occurs: Get medical advice/ attention.
If eye irritation persists: Get medical advice/ attention.
Take off contaminated clothing and wash before reuse.
Store in a well-ventilated place. Keep container tightly closed.
Store locked up.
Dispose of contents/ container to an approved waste disposal plant.

Hazards not otherwise classified (HNOC) or not covered by GHS - none

Section 3: Composition/Information on Ingredients

Ingredients as defined by 29 CFR 1910.1200:

Chemical Ingredients:	CAS Number:	Percent Range:
Trade Secret	-	~20%

The specific chemical identity and/or exact percentage of the composition has been withheld as Trade Secret in accordance with paragraph (i) of §1910.1200.

Section 4: First Aid Measures

Description of first aid measures:

Inhalation: Remove victim to fresh air and keep at rest in a position comfortable for breathing. If not breathing, give artificial respiration. Call a poison center or doctor/physician if you feel unwell.

Skin Contact: Wash with plenty of soap and water. Take off contaminated clothing and wash before reuse. If skin irritation occurs: Get medical advice/attention.

Eye Contact: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If eye irritation persists: Get medical advice/attention.

Ingestion: Never give anything by mouth to an unconscious person. Rinse mouth with water.

Most important symptoms and effects, both acute and delayed: See sections 2 and/or 11.

Indication of any immediate medical attention and special treatment needed: No data available.

Section 5: Fire Fighting Measures

Suitable Extinguishing Media: Use any means suitable for extinguishing surrounding fire.

Unsuitable Extinguishing Media: No known information.

Specific Hazards Arising from the chemical/substance: May decompose upon heating to produce corrosive and/or toxic fumes.

Hazardous Combustion Products: Nitrogen oxides, phosphorous oxides, ammonia.

Protective Equipment and Precautions for Fire-Fighters: As in any fire, wear self-contained breathing apparatus and full protective gear.

Section 6: Accidental Release Measures

Personal precautions, protective equipment and emergency procedures: Ensure adequate ventilation. Use personal protective equipment. Avoid dust formation. Do not breathe dust/fume/gas/mist/vapors/spray.

Environmental Precautions: Do not release to the environment. See section 12 for further environmental data.

Methods for Containment/Cleaning Up: Avoid dust formation. Pick up and transfer to properly labeled containers. Ventilate area and wash spill site after material pickup is complete.

Section 7: Handling and Storage

Precautions for Safe Handling: Avoid breathing dust. Use only outdoors or in a well-ventilated area. Wash thoroughly after handling. Keep out of reach of children. Handle in accordance with good industrial hygiene and safety practice.

Conditions for safe storage, including any incompatibilities:

Storage: Store locked up. Keep in tightly closed container, store in a cool, dry, ventilated place.

Section 8: Exposure Controls/Personal Protection

Exposure Limits: There are no OSHA PEL's, NIOSH REL's, or ACGIH TLV's applicable to this material.

Engineering Controls: Ensure adequate ventilation, especially in confined areas. Ensure that eyewash stations and safety showers are close to the workstation location.

Personal Protective Equipment:

Eye Protection: Wear appropriate eye protection/face protection.

Hand Protection: Wear appropriate protective gloves.

Skin and Body Protection: Wear appropriate protective clothing to prevent skin exposure. Take off contaminated clothing and wash before reuse.

Respiratory Protection: Use only in a well-ventilated area. Avoid breathing dust. Wear appropriate NIOSH approved respirator if exposure limits are exceeded or irritation occurs.

Hygiene Measures: Wash thoroughly after handling. Handle in accordance with good industrial hygiene and safety practice.

Section 9: Physical and Chemical Properties

Appearance/Physical State:	Crystals
Color:	White to Yellow
Odor:	Not Available
Odor Threshold:	Not Available
pH:	Not Applicable
Melting/Freezing Point:	Not Available
Initial Boiling Point:	Not Available
Flash Point:	Not Available
Evaporation Rate:	Not Applicable
Flammability (solid, gas):	Not Available
Lower Explosive Limit:	Not Available
Upper Explosive Limit:	Not Available
Vapor Pressure:	Not Available
Vapor Density:	Not Applicable
Relative Density:	1.00
Solubility:	Completely soluble in water
Partition Coefficient:	Not Available
Autoignition Temperature:	Not Available
Decomposition Temperature:	Not Available

Section 10: Stability and Reactivity

Reactivity: No information available.

Stability: Stable under ordinary conditions of use and storage.

Possibility of hazardous reactions: No information available.

Conditions to Avoid: Extremes in temperature and direct sunlight.

Incompatible Materials: Strong oxidizing agents, strong acids, strong bases, Magnesium.

Hazardous Decomposition Products: Other decomposition products - No data available. In case of fire: see section 5.

Hazardous Polymerization: Will not occur.

Section 11: Toxicological Information

Information on Likely Routes of Exposure:

Inhalation: May cause respiratory irritation if inhaled.
Ingestion: No information available.
Skin Contact: Causes skin irritation.
Eye Contact: Causes eye irritation.

Toxicity Data:

Chemical Name	LD50 ORAL	LD50 DERMAL	LC50 INHALATION
Trade Secret	6500 mg/kg (Rat)	7950 mg/kg (Rabbit)	No data

Symptoms: No information available.

Delayed and Immediate Effects, Chronic Effects from Short and Long Term Exposure:

Sensitization: No information available.
Mutagenic Effects: No information available.
Reproductive Toxicity: No information available.
STOT – Single Exposure: Respiratory system.
STOT – Repeated Exposure: No information available.
Aspiration Hazard: No information available.
Chronic Exposure: No information available.
Aggravation of Pre-existing Conditions: Asthma

Carcinogenicity:

Component	CAS	NTP	IARC	OSHA
Trade Secret	N/A	Not listed	Not listed	Not listed

Additional Information: To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Section 12: Ecological Information

Ecotoxicity:

This product is safe for the environment at the concentrations predicted under normal use conditions.

Persistance and Degradability: No information available.

Bioaccumulative Potential: No information available.

Mobility in Soil: No information available.

Other Adverse Effects: No information available.

Section 13: Disposal Considerations

Dispose of contents/container in accordance with all applicable local, state and federal regulations.

Section 14: Transport Information

For Transportation Emergencies Involving This Material, Call:
ChemTrec 1-800-424-9300 Company Code: E419

DOT (LAND): Not regulated.

Section 15: Regulatory Information

SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 311/312 Hazard Categories:

Acute Health Hazard	Yes
Chronic Health Hazard	No
Fire Hazard	No
Sudden Release of Pressure Hazard	No
Reactive Hazard	No

SARA 313: The Trade Secret component is subject to reporting levels (>1.0%) established by SARA Title III, Section 313:

State Right-to-Know:

Component	Massachusetts	New Jersey	Pennsylvania	Illinois	Rhode Island
Trade Secret	-	X	X	-	-

TSCA: Not Applicable

California Prop. 65 Components: This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

Section 16: Other Information

NFPA Rating:

Health Hazard:	2
Fire:	0
Reactivity Hazard:	1

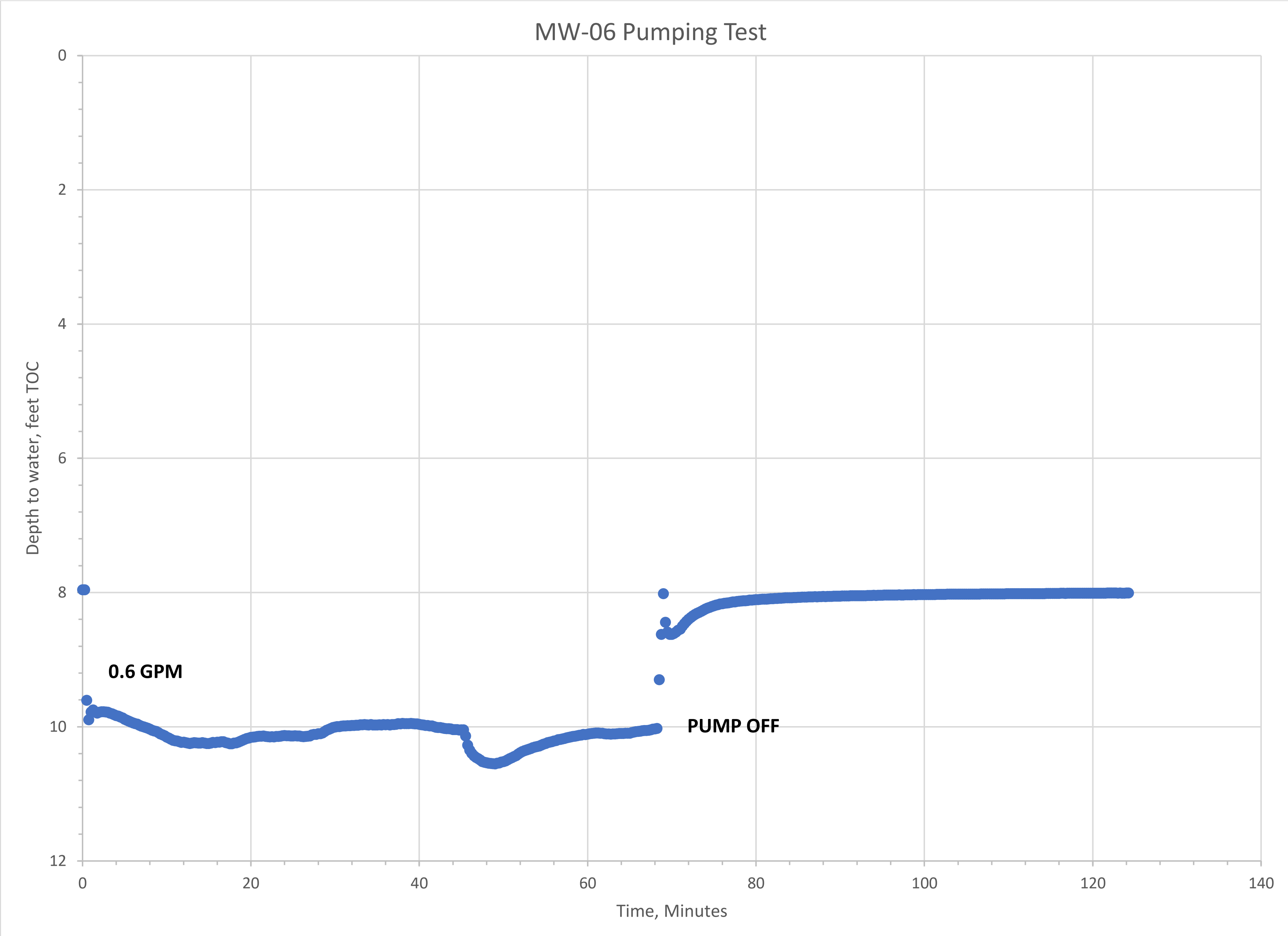
Legend:

ACGIH: American Conference of Governmental & Industrial Hygienists
CAS: Chemical Abstract Service
CFR: Code of Federal Regulations
DOT: Department of Transportation
DSL/NDSL: Domestic Substances List/Non-Domestic Substances List
IARC: International Agency for the Research of Cancer
IATA: International Air Traffic Association
ICAO: International Civil Aviation Organization
IMDG: International Maritime Dangerous Goods

IMO: International Maritime Organizations
NFPA: National Fire Protection Association Health, Flammability & Reactivity; Hazard Scale 0 =minimal/none 4= significant
NTP: National Toxicology Program
OSHA: Occupational Safety & Health Administration
PEL: Permissible Exposure Limits
RCRA: Resource Conservation & Recovery Act
RQ: Reportable Quantity
RTK: Right-To-Know
SARA: Superfund Amendments & Reauthorization Act
STEL: Short Term Exposure Limit
TLV: Threshold Limit Value
TSCA: Toxic Substances Control Act
TWA: Time Weighted Average
TCLP: Toxicity Characteristic Leaching Procedure
VOC: Volatile Organic Compounds

Disclaimer: The information contained in this SDS is presented in good faith and believed to be accurate based on the information provided. The SDS does not purport to be all inclusive, and shall be used only as a guide. While ETEC, LLC believes that the data contained herein comply with 29 CFR 1910.1200, they are not to be taken as a warranty or representation for which ETEC, LLC assumes legal responsibility. ETEC, LLC shall not be held liable or accountable for any loss or damage associated with the use of this material and information. The recommended industrial hygiene and safe use, handling, storage, and disposal procedures are believed to be generally applicable. However, since the use, handling, storage, and disposal are beyond ETEC, LLC control, it is the responsibility of the user both to determine safe conditions for use of this product and to assume liability of loss, damage, or expense arising out of the material's improper use.

Attachment D
Pump Test Results



MW-06 Pumping Test
Depth to water, feet TOC
Time, Minutes
0.6 GPM
PUMP OFF
0
2
4
6
8
10
12
0
20
40
60
80
100
120
140

WELL ID: MW-06-Recovery

Local ID: MW-06
Date: 2/1/2017
Time: 0:00

INPUT

Construction:	
Casing dia. (d_c)	2 Inch
Annulus dia. (d_w)	8 Inch
Screen Length (L)	10 Feet
Depths to:	
water level (DTW)	7.96 Feet
Top of Aquifer	10 Feet
Base of Aquifer	55 Feet
Annular Fill:	
across screen --	Coarse Sand
above screen --	Bentonite
Aquifer Material --	Fine Sand
FLOW RATE	0.6 GPM

COMPUTED

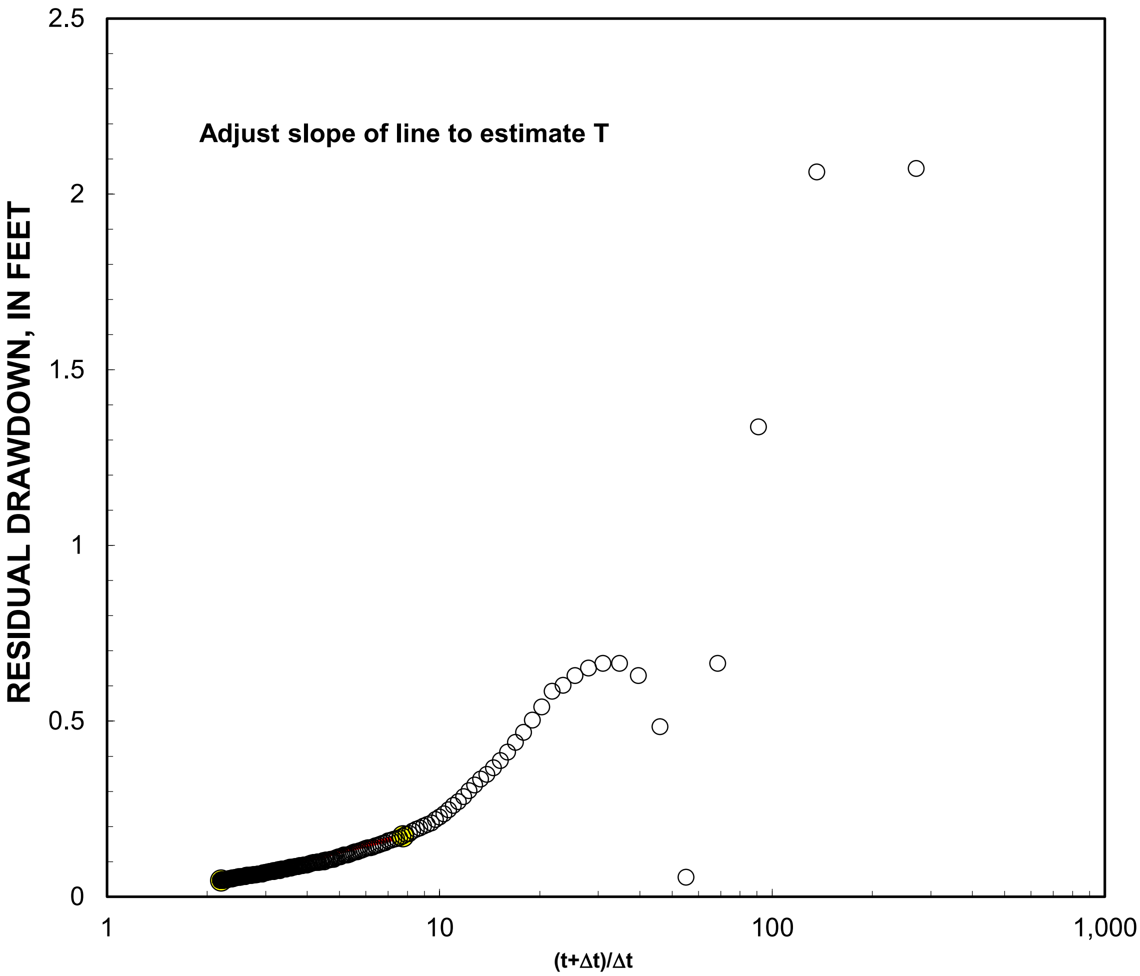
Aquifer thickness = 45 Feet

Slope = 0.230398 Feet/log10

Input is consistent.

K =	2 Feet/Day
T =	92 Feet²/Day

K= 2 is less than likely minimum of 3 for Fine Sand



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

Reduced Data

Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	7.96	51	1/0/00 1:32:15	8.05
2	1/0/00 1:07:45	10.03	52	1/0/00 1:32:45	8.05
3	1/0/00 1:08:15	9.30	53	1/0/00 1:33:15	8.04
4	1/0/00 1:08:45	8.02	54	1/0/00 1:33:45	8.04
5	1/0/00 1:09:15	8.59	55	1/0/00 1:34:15	8.04
6	1/0/00 1:09:45	8.63	56	1/0/00 1:34:45	8.04
7	1/0/00 1:10:15	8.59	57	1/0/00 1:35:15	8.04
8	1/0/00 1:10:45	8.55	58	1/0/00 1:35:45	8.04
9	1/0/00 1:11:15	8.46	59	1/0/00 1:36:15	8.04
10	1/0/00 1:11:45	8.40	60	1/0/00 1:36:45	8.04
11	1/0/00 1:12:15	8.35	61	1/0/00 1:37:15	8.04
12	1/0/00 1:12:45	8.31	62	1/0/00 1:37:45	8.04
13	1/0/00 1:13:15	8.28	63	1/0/00 1:38:15	8.04
14	1/0/00 1:13:45	8.25	64	1/0/00 1:38:45	8.04
15	1/0/00 1:14:15	8.22	65	1/0/00 1:39:15	8.03
16	1/0/00 1:14:45	8.20	66	1/0/00 1:39:45	8.03
17	1/0/00 1:15:15	8.18	67	1/0/00 1:40:15	8.03
18	1/0/00 1:15:45	8.17	68	1/0/00 1:40:45	8.03
19	1/0/00 1:16:15	8.16	69	1/0/00 1:41:15	8.03
20	1/0/00 1:16:45	8.15	70	1/0/00 1:41:45	8.03
21	1/0/00 1:17:15	8.14	71	1/0/00 1:42:15	8.03
22	1/0/00 1:17:45	8.13	72	1/0/00 1:42:45	8.03
23	1/0/00 1:18:15	8.12	73	1/0/00 1:43:15	8.03
24	1/0/00 1:18:45	8.12	74	1/0/00 1:43:45	8.03
25	1/0/00 1:19:15	8.11	75	1/0/00 1:44:15	8.03
26	1/0/00 1:19:45	8.11	76	1/0/00 1:44:45	8.02
27	1/0/00 1:20:15	8.10	77	1/0/00 1:45:15	8.02
28	1/0/00 1:20:45	8.10	78	1/0/00 1:45:45	8.02
29	1/0/00 1:21:15	8.10	79	1/0/00 1:46:15	8.02
30	1/0/00 1:21:45	8.09	80	1/0/00 1:46:45	8.02
31	1/0/00 1:22:15	8.09	81	1/0/00 1:47:15	8.02
32	1/0/00 1:22:45	8.08	82	1/0/00 1:47:45	8.02
33	1/0/00 1:23:15	8.08	83	1/0/00 1:48:15	8.02
34	1/0/00 1:23:45	8.08	84	1/0/00 1:48:45	8.02
35	1/0/00 1:24:15	8.07	85	1/0/00 1:49:15	8.02
36	1/0/00 1:24:45	8.07	86	1/0/00 1:49:45	8.02
37	1/0/00 1:25:15	8.07	87	1/0/00 1:50:15	8.02
38	1/0/00 1:25:45	8.07	88	1/0/00 1:50:45	8.02
39	1/0/00 1:26:15	8.07	89	1/0/00 1:51:15	8.02
40	1/0/00 1:26:45	8.06	90	1/0/00 1:51:45	8.02
41	1/0/00 1:27:15	8.06	91	1/0/00 1:52:15	8.02
42	1/0/00 1:27:45	8.06	92	1/0/00 1:52:45	8.02
43	1/0/00 1:28:15	8.06	93	1/0/00 1:53:15	8.02
44	1/0/00 1:28:45	8.06	94	1/0/00 1:53:45	8.02
45	1/0/00 1:29:15	8.06	95	1/0/00 1:54:15	8.01
46	1/0/00 1:29:45	8.05	96	1/0/00 1:54:45	8.01
47	1/0/00 1:30:15	8.05	97	1/0/00 1:55:15	8.01
48	1/0/00 1:30:45	8.05	98	1/0/00 1:55:45	8.01
49	1/0/00 1:31:15	8.05	99	1/0/00 1:56:15	8.01
50	1/0/00 1:31:45	8.05	100	1/0/00 1:56:45	8.01

Inch	0.083333	Second	1.16E-05		GPM	192.5134
Feet	1	Minute	0.000694		ft3/d	1
Meter	3.28084	Hour	0.041667		ft3/s	86400
cm	0.032808	Day	1		m3/d	35.39525
mm	0.003281				m3/s	3058149
PSI	2.31				liters/s	3058.149
					liters/min	50.96915
Out Units =					cc/s	3.058149
Convert =	1	Feet2/Day				
Convert =	1	Feet/Day				

Casing dia. (dc)	2	Inch	
Annulus dia. (dw)	8	Inch	
Screen Length (L)	10	Feet	
Depths to:			
water level (DTW)	7.96	Feet	
Top of Aquifer	10	Feet	
Base of Aquifer	55	Feet	
Annular Fill:			
across screen --	Coarse Sand		
above screen --	Bentonite		
Aquifer Material --	Fine Sand		
wetted hole	10	Feet	
Aquifer thickness =	45	Feet	
Aquifer thickness =	45	feet	
Aquifer thickness =	45	Feet	1
Aquifer thickness =	45	Feet	**45**

Fraction penetrated = 0.222222

slope points	7.75	0.173
	2.2	0.047

FLOW RATE 0.60 GPM
FLOW RATE 115.508 ft^3/d

Rc = 0.083333 ft
Rw = 0.333333 ft

Slope = 0.230398 Feet $/log_{10}$
Slope = 0.230398 feet/log_{10}

T =	92	ft2/d	
	91.75946	Feet2/Day	1
	92	Feet2/Day	**92**
K =	2.039099	ft/d	
	2.039099	Feet/Day	0.1
K =	2	Feet/Day	**20**

Absolute Shut Down

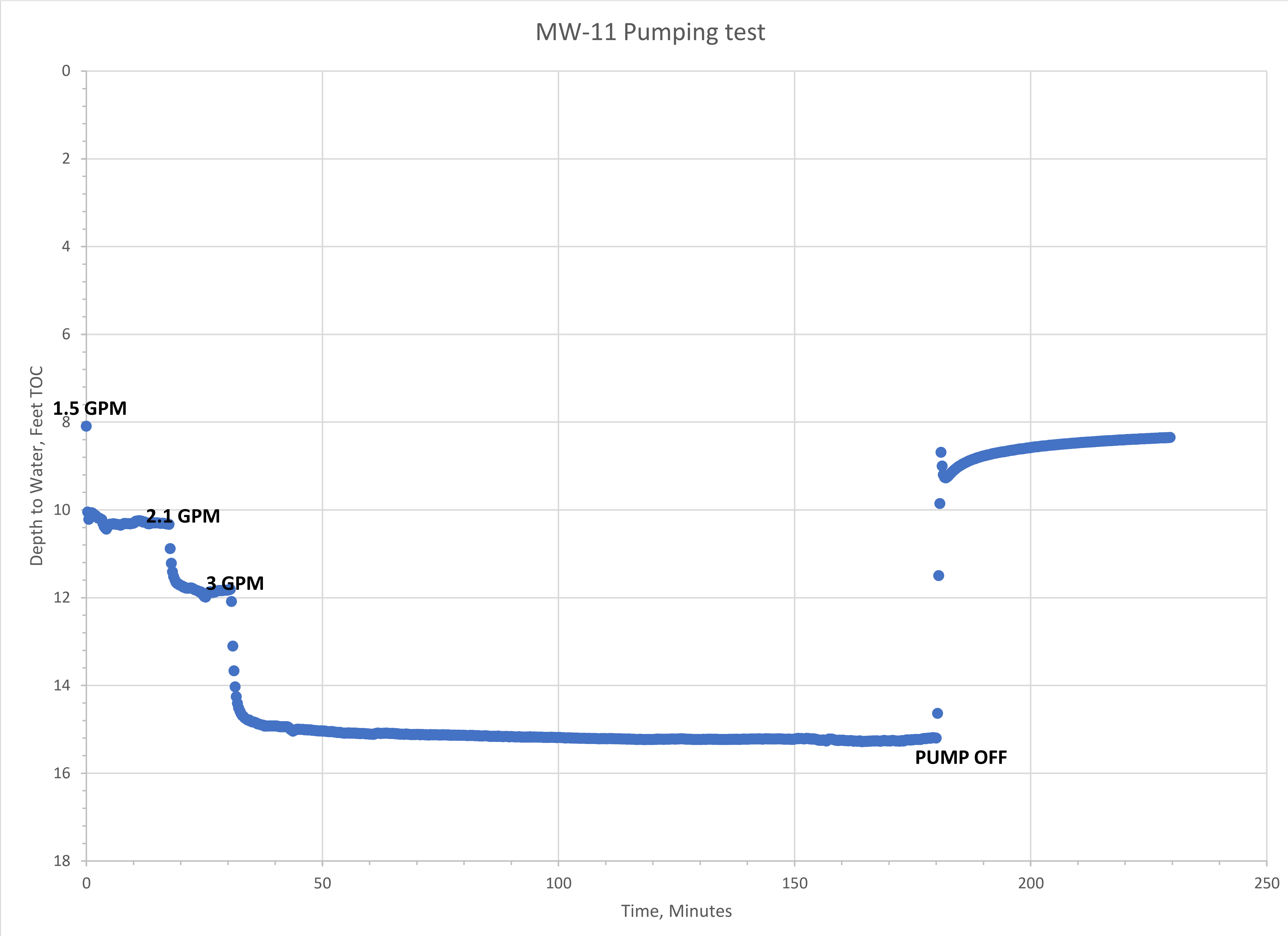
Input is consistent.

Decision		Option			
	0	Water level is below Base of Aquifer			
	0	Casing diameter is greater than the Annulus			
	0	Top of Aquifer is deeperthan Base of Aquifer			
	0	Screen length is less than 1 Feet	1		
	0	Slope will produce a negative K			
	0	K= 2 is less than extreme minimum of 0.05 for Fine Sand	0.05	-2	0.05
	0	K= 2 is greater than extreme maximum of 20 for Fine San	20	1	20
	1	Input is consistent.			
		Error			

WARNING

K= 2 is less than likely minimum of 3 for Fine Sand

Decision		Option			
	0				
	1	K= 2 is less than likely minimum of 3 for Fine Sand	3	0	3
	1	K= 2 is greater than likely maximum of 20 for Fine Sand	20	1	20
	2				



MW-11 Pumping test
Depth to Water, Feet TOC
Time, Minutes
0
2
4
6
8
10
12
14
16
18
0
50
100
150
200
250
1.5 GPM
2.1 GPM
3 GPM
PUMP OFF

WELL ID: MW-11-Recovery

Local ID: MW-11
Date: 1/30/2017
Time: 0:00

INPUT

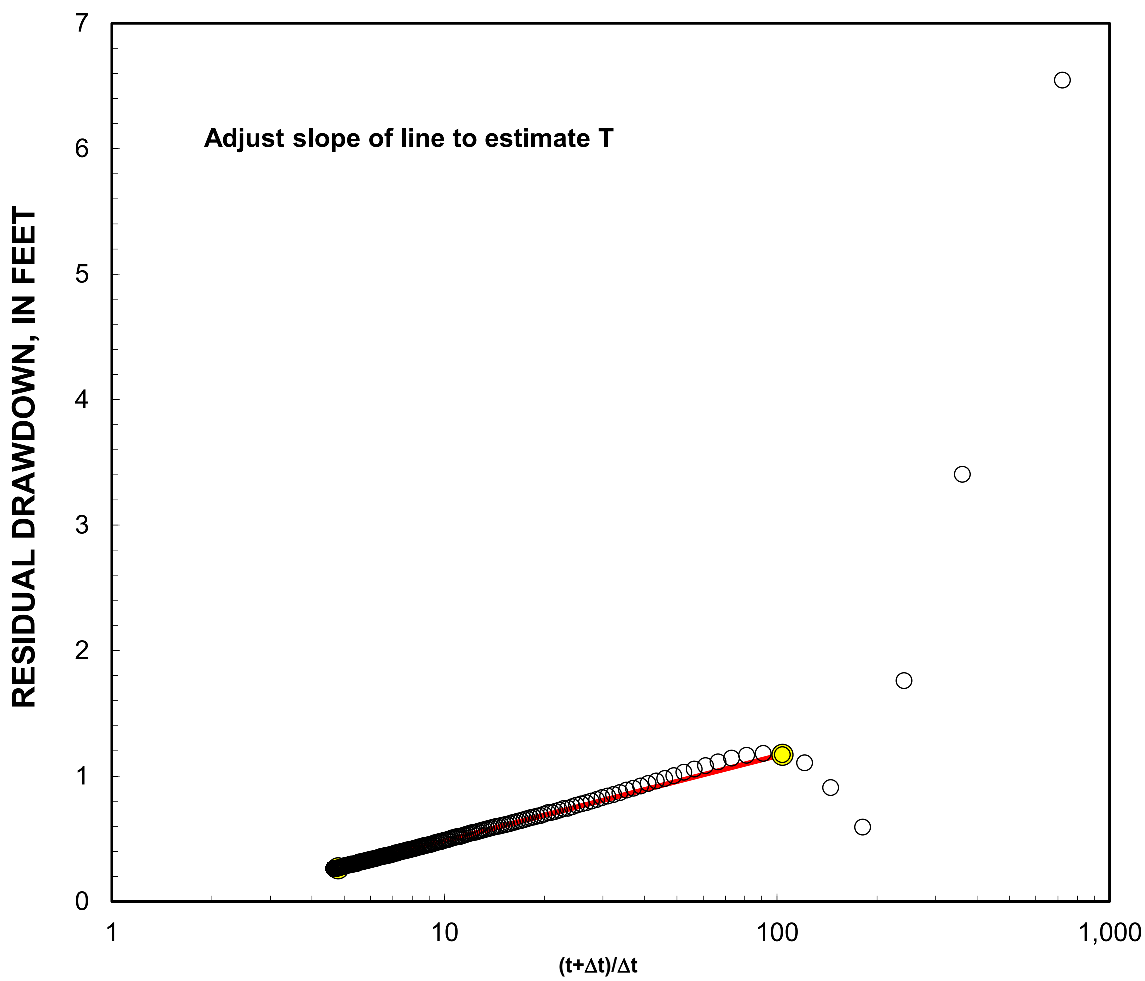
Construction:		
Casing dia. (d_c)	2	Inch
Annulus dia. (d_w)	8	Inch
Screen Length (L)	10	Feet
Depths to:		
water level (DTW)	8.09	Feet
Top of Aquifer	10	Feet
Base of Aquifer	55	Feet
Annular Fill:		
across screen --	Coarse Sand	
above screen --	Bentonite	
Aquifer Material --	Fine Sand	
FLOW RATE	3	GPM

COMPUTED

Aquifer thickness =	45	Feet
Slope =	0.67732	Feet/log10

Input is consistent.

K =	3.5	Feet/Day
T =	160	Feet²/Day



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

Reduced Data

Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	8.09	51	1/0/00 3:12:15	8.71
2	1/0/00 3:00:00	15.20	52	1/0/00 3:12:30	8.71
3	1/0/00 3:00:15	14.64	53	1/0/00 3:12:45	8.70
4	1/0/00 3:00:30	11.50	54	1/0/00 3:13:00	8.70
5	1/0/00 3:00:45	9.85	55	1/0/00 3:13:15	8.69
6	1/0/00 3:01:00	8.69	56	1/0/00 3:13:30	8.69
7	1/0/00 3:01:15	9.00	57	1/0/00 3:13:45	8.68
8	1/0/00 3:01:30	9.20	58	1/0/00 3:14:00	8.68
9	1/0/00 3:01:45	9.26	59	1/0/00 3:14:15	8.67
10	1/0/00 3:02:00	9.27	60	1/0/00 3:14:30	8.67
11	1/0/00 3:02:15	9.26	61	1/0/00 3:14:45	8.66
12	1/0/00 3:02:30	9.23	62	1/0/00 3:15:00	8.66
13	1/0/00 3:02:45	9.20	63	1/0/00 3:15:15	8.66
14	1/0/00 3:03:00	9.18	64	1/0/00 3:15:30	8.65
15	1/0/00 3:03:15	9.15	65	1/0/00 3:15:45	8.65
16	1/0/00 3:03:30	9.12	66	1/0/00 3:16:00	8.64
17	1/0/00 3:03:45	9.10	67	1/0/00 3:16:15	8.64
18	1/0/00 3:04:00	9.07	68	1/0/00 3:16:30	8.63
19	1/0/00 3:04:15	9.05	69	1/0/00 3:16:45	8.63
20	1/0/00 3:04:30	9.03	70	1/0/00 3:17:00	8.62
21	1/0/00 3:04:45	9.01	71	1/0/00 3:17:15	8.62
22	1/0/00 3:05:00	9.00	72	1/0/00 3:17:30	8.62
23	1/0/00 3:05:15	8.98	73	1/0/00 3:17:45	8.61
24	1/0/00 3:05:30	8.96	74	1/0/00 3:18:00	8.61
25	1/0/00 3:05:45	8.95	75	1/0/00 3:18:15	8.61
26	1/0/00 3:06:00	8.93	76	1/0/00 3:18:30	8.60
27	1/0/00 3:06:15	8.92	77	1/0/00 3:18:45	8.60
28	1/0/00 3:06:30	8.90	78	1/0/00 3:19:00	8.59
29	1/0/00 3:06:45	8.89	79	1/0/00 3:19:15	8.59
30	1/0/00 3:07:00	8.88	80	1/0/00 3:19:30	8.59
31	1/0/00 3:07:15	8.87	81	1/0/00 3:19:45	8.58
32	1/0/00 3:07:30	8.86	82	1/0/00 3:20:00	8.58
33	1/0/00 3:07:45	8.85	83	1/0/00 3:20:15	8.57
34	1/0/00 3:08:00	8.84	84	1/0/00 3:20:30	8.57
35	1/0/00 3:08:15	8.83	85	1/0/00 3:20:45	8.57
36	1/0/00 3:08:30	8.82	86	1/0/00 3:21:00	8.56
37	1/0/00 3:08:45	8.81	87	1/0/00 3:21:15	8.56
38	1/0/00 3:09:00	8.80	88	1/0/00 3:21:30	8.56
39	1/0/00 3:09:15	8.80	89	1/0/00 3:21:45	8.55
40	1/0/00 3:09:30	8.79	90	1/0/00 3:22:00	8.55
41	1/0/00 3:09:45	8.78	91	1/0/00 3:22:15	8.55
42	1/0/00 3:10:00	8.77	92	1/0/00 3:22:30	8.55
43	1/0/00 3:10:15	8.76	93	1/0/00 3:22:45	8.54
44	1/0/00 3:10:30	8.76	94	1/0/00 3:23:00	8.54
45	1/0/00 3:10:45	8.75	95	1/0/00 3:23:15	8.54
46	1/0/00 3:11:00	8.74	96	1/0/00 3:23:30	8.53
47	1/0/00 3:11:15	8.74	97	1/0/00 3:23:45	8.53
48	1/0/00 3:11:30	8.73	98	1/0/00 3:24:00	8.53
49	1/0/00 3:11:45	8.73	99	1/0/00 3:24:15	8.53
50	1/0/00 3:12:00	8.72	100	1/0/00 3:24:30	8.52

Inch	0.083333	Second	1.16E-05		GPM	192.5134
Feet	1	Minute	0.000694		ft3/d	1
Meter	3.28084	Hour	0.041667		ft3/s	86400
cm	0.032808	Day	1		m3/d	35.39525
mm	0.003281				m3/s	3058149
PSI	2.31				liters/s	3058.149
					liters/min	50.96915
Out Units =					cc/s	3.058149
Convert =	1	Feet2/Day				
Convert =	1	Feet/Day				

Casing dia. (dc)	2	Inch	
Annulus dia. (dw)	8	Inch	
Screen Length (L)	10	Feet	
Depths to:			
water level (DTW)	8.09	Feet	
Top of Aquifer	10	Feet	
Base of Aquifer	55	Feet	
Annular Fill:			
across screen --	Coarse Sand		
above screen --	Bentonite		
Aquifer Material --	Fine Sand		
wetted hole	10	Feet	
Aquifer thickness =	45	Feet	
Aquifer thickness =	45	feet	
Aquifer thickness =	45	Feet	1
Aquifer thickness =	45	Feet	**45**

Fraction penetrated = 0.222222

slope points	4.789474	0.267
	103.8571	1.172

FLOW RATE	3.00	GPM
FLOW RATE	577.5401	ft^3/d
Rc =	0.083333	ft
Rw =	0.333333	ft

Slope = 0.67732 Feet $/log_{10}$

Slope = 0.67732 feet/log_{10}

T =	156	ft2/d	
	156.0653	Feet2/Day	10
	160	Feet2/Day	**16**
K =	3.468117	ft/d	
	3.468117	Feet/Day	0.1
K =	3.5	Feet/Day	**35**

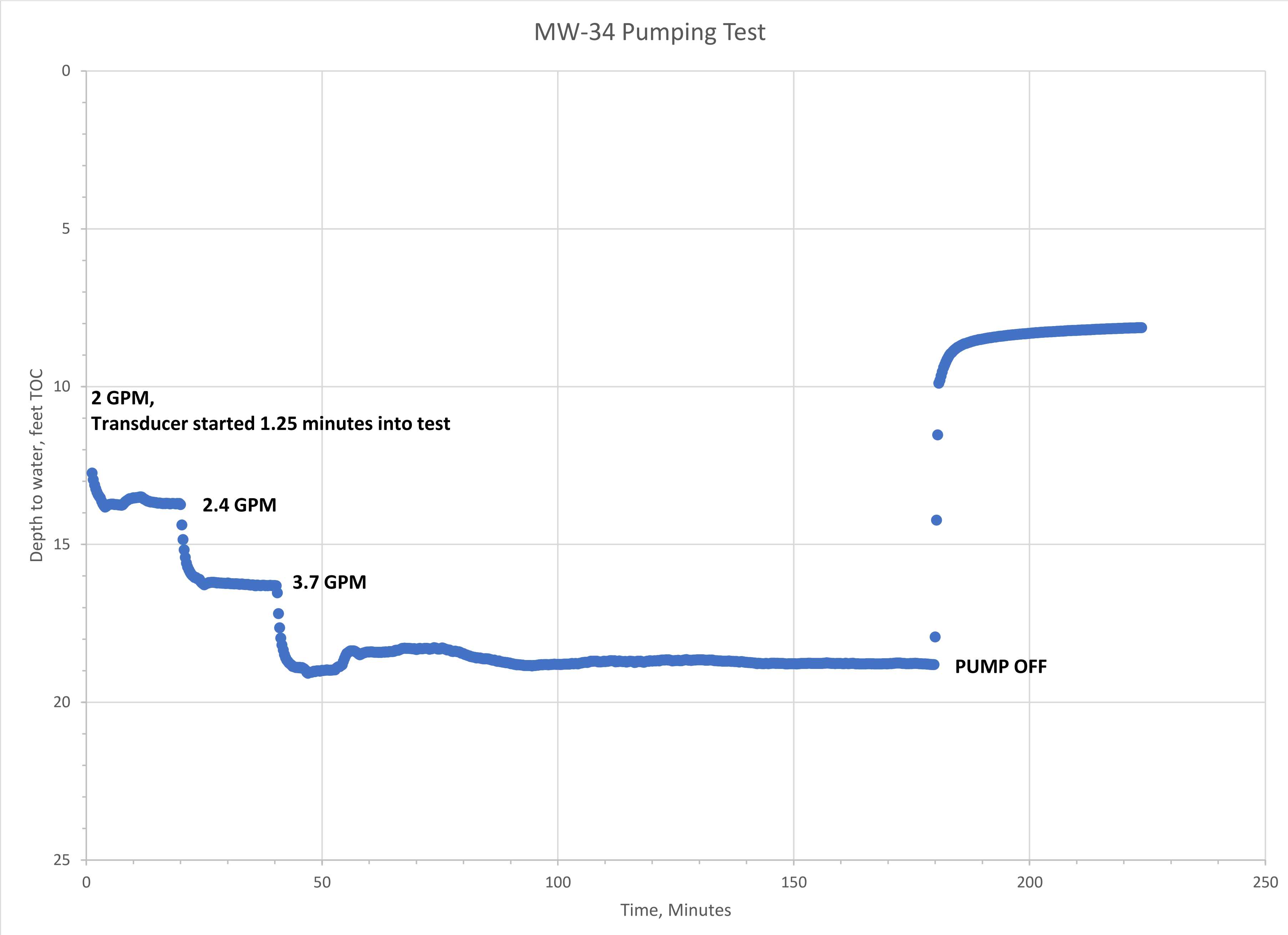
Absolute Shut Down

Input is consistent.

Decision	Option			
0	Water level is below Base of Aquifer			
0	Casing diameter is greater than the Annulus			
0	Top of Aquifer is deeperthan Base of Aquifer			
0	Screen length is less than 1 Feet	1		
0	Slope will produce a negative K			
0	K = 3.5 is less than extreme minimum of 0.05 for Fine Sand	0.05	-2	0.05
0	K = 3.5 is greater than extreme maximum of 20 for Fine Sa	20	1	20
1	Input is consistent.			
	Error			

WARNING

Decision	Option			
0				
0	K = 3.5 is less than likely minimum of 3 for Fine Sand	3	0	3
0	K = 3.5 is greater than likely maximum of 20 for Fine Sand	20	1	20
1				


MW-34 Pumping Test
0
5
10
15
20
25
Depth to water, feet TOC
2 GPM,
Transducer started 1.25 minutes into test
2.4 GPM
3.7 GPM
PUMP OFF
0
50
100
150
200
250
Time, Minutes

WELL ID: MW-34-Recovery

Local ID: MW-34
Date: 2/2/2017
Time: 0:00

INPUT

Construction:	
Casing dia. (d_c)	2 Inch
Annulus dia. (d_w)	8 Inch
Screen Length (L)	10 Feet
Depths to:	
water level (DTW)	8.05 Feet
Top of Aquifer	10 Feet
Base of Aquifer	55 Feet
Annular Fill:	
across screen --	Coarse Sand
above screen --	Bentonite
Aquifer Material --	Fine Sand
FLOW RATE	3.7 GPM

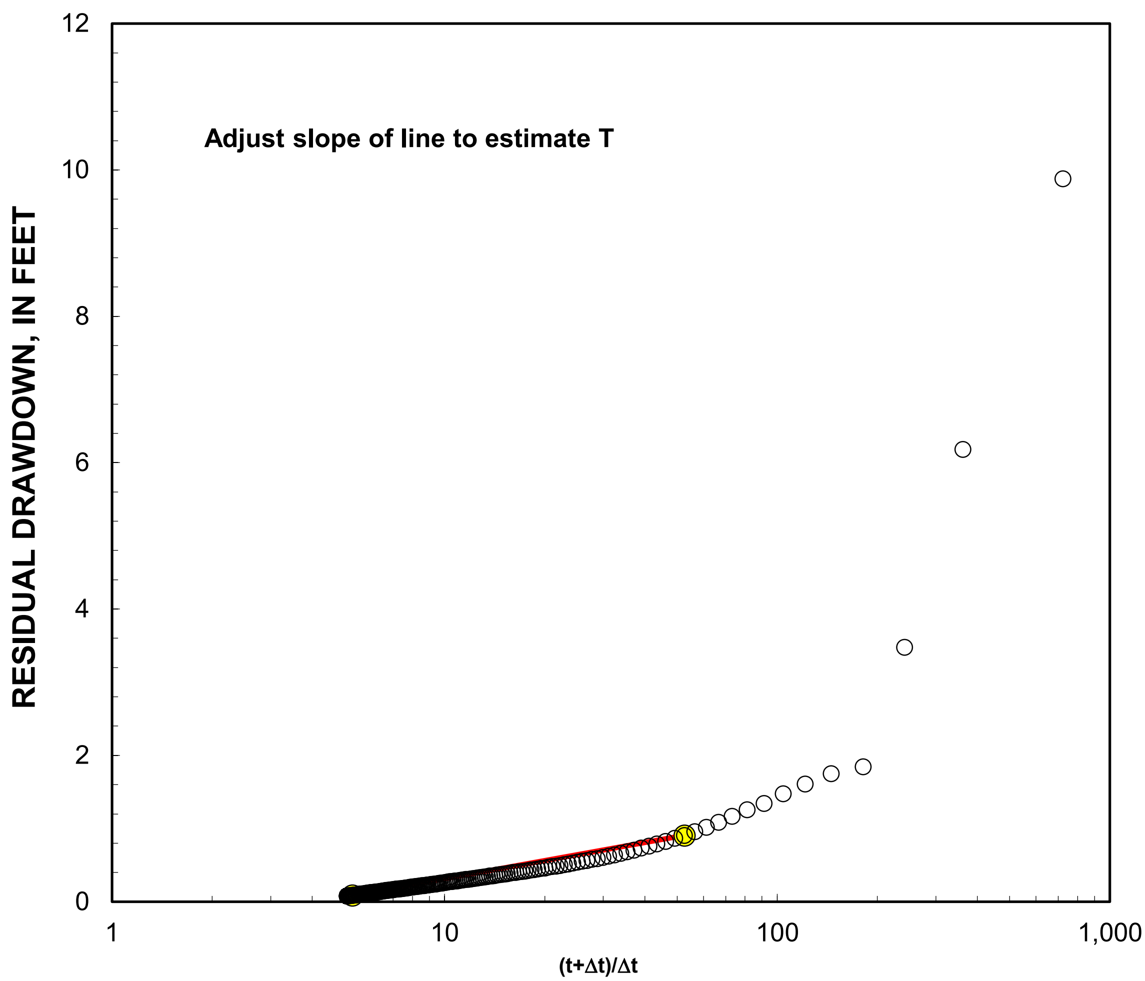
COMPUTED

Aquifer thickness = 45 Feet

Slope = 0.821019 Feet/log10

Input is consistent.

K =	3.5 Feet/Day
T =	160 Feet²/Day



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

Reduced Data

Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	8.05	51	1/0/00 3:12:45	8.44
2	1/0/00 3:00:30	18.81	52	1/0/00 3:13:00	8.44
3	1/0/00 3:00:45	17.93	53	1/0/00 3:13:15	8.43
4	1/0/00 3:01:00	14.23	54	1/0/00 3:13:30	8.43
5	1/0/00 3:01:15	11.53	55	1/0/00 3:13:45	8.42
6	1/0/00 3:01:30	9.90	56	1/0/00 3:14:00	8.42
7	1/0/00 3:01:45	9.80	57	1/0/00 3:14:15	8.41
8	1/0/00 3:02:00	9.66	58	1/0/00 3:14:30	8.40
9	1/0/00 3:02:15	9.53	59	1/0/00 3:14:45	8.40
10	1/0/00 3:02:30	9.39	60	1/0/00 3:15:00	8.40
11	1/0/00 3:02:45	9.31	61	1/0/00 3:15:15	8.39
12	1/0/00 3:03:00	9.22	62	1/0/00 3:15:30	8.39
13	1/0/00 3:03:15	9.14	63	1/0/00 3:15:45	8.38
14	1/0/00 3:03:30	9.07	64	1/0/00 3:16:00	8.38
15	1/0/00 3:03:45	9.01	65	1/0/00 3:16:15	8.37
16	1/0/00 3:04:00	8.96	66	1/0/00 3:16:30	8.37
17	1/0/00 3:04:15	8.92	67	1/0/00 3:16:45	8.37
18	1/0/00 3:04:30	8.88	68	1/0/00 3:17:00	8.36
19	1/0/00 3:04:45	8.84	69	1/0/00 3:17:15	8.36
20	1/0/00 3:05:00	8.81	70	1/0/00 3:17:30	8.36
21	1/0/00 3:05:15	8.78	71	1/0/00 3:17:45	8.35
22	1/0/00 3:05:30	8.76	72	1/0/00 3:18:00	8.35
23	1/0/00 3:05:45	8.74	73	1/0/00 3:18:15	8.34
24	1/0/00 3:06:00	8.71	74	1/0/00 3:18:30	8.34
25	1/0/00 3:06:15	8.69	75	1/0/00 3:18:45	8.34
26	1/0/00 3:06:30	8.67	76	1/0/00 3:19:00	8.33
27	1/0/00 3:06:45	8.66	77	1/0/00 3:19:15	8.33
28	1/0/00 3:07:00	8.64	78	1/0/00 3:19:30	8.33
29	1/0/00 3:07:15	8.63	79	1/0/00 3:19:45	8.33
30	1/0/00 3:07:30	8.62	80	1/0/00 3:20:00	8.32
31	1/0/00 3:07:45	8.60	81	1/0/00 3:20:15	8.32
32	1/0/00 3:08:00	8.59	82	1/0/00 3:20:30	8.32
33	1/0/00 3:08:15	8.58	83	1/0/00 3:20:45	8.31
34	1/0/00 3:08:30	8.57	84	1/0/00 3:21:00	8.31
35	1/0/00 3:08:45	8.56	85	1/0/00 3:21:15	8.30
36	1/0/00 3:09:00	8.55	86	1/0/00 3:21:30	8.30
37	1/0/00 3:09:15	8.54	87	1/0/00 3:21:45	8.30
38	1/0/00 3:09:30	8.53	88	1/0/00 3:22:00	8.29
39	1/0/00 3:09:45	8.52	89	1/0/00 3:22:15	8.29
40	1/0/00 3:10:00	8.51	90	1/0/00 3:22:30	8.29
41	1/0/00 3:10:15	8.51	91	1/0/00 3:22:45	8.29
42	1/0/00 3:10:30	8.50	92	1/0/00 3:23:00	8.29
43	1/0/00 3:10:45	8.49	93	1/0/00 3:23:15	8.28
44	1/0/00 3:11:00	8.48	94	1/0/00 3:23:30	8.28
45	1/0/00 3:11:15	8.48	95	1/0/00 3:23:45	8.28
46	1/0/00 3:11:30	8.47	96	1/0/00 3:24:00	8.27
47	1/0/00 3:11:45	8.46	97	1/0/00 3:24:15	8.27
48	1/0/00 3:12:00	8.46	98	1/0/00 3:24:30	8.27
49	1/0/00 3:12:15	8.45	99	1/0/00 3:24:45	8.27
50	1/0/00 3:12:30	8.45	100	1/0/00 3:25:00	8.26

Inch	0.083333	Second	1.15741E-05	GPM	192.5134
Feet	1	Minute	0.000694444	ft3/d	1
Meter	3.28084	Hour	0.041666667	ft3/s	86400
cm	0.032808	Day	1	m3/d	35.39525
mm	0.003281			m3/s	3058149
PSI	2.31			liters/s	3058.149
				liters/min	50.96915
Out Units =				cc/s	3.058149
Convert =	1	Feet2/Day			
Convert =	1	Feet/Day			

Casing dia. (dc)	2	Inch
Annulus dia. (dw)	8	Inch
Screen Length (L)	10	Feet
Depths to:		
water level (DTW)	8.05	Feet
Top of Aquifer	10	Feet
Base of Aquifer	55	Feet
Annular Fill:		
across screen --	Coarse Sand	
above screen --	Bentonite	
Aquifer Material --	Fine Sand	

wetted hole	10	Feet	
Aquifer thickness =	45	Feet	
Aquifer thickness =	45	feet	
Aquifer thickness =	45	Feet	1
Aquifer thickness =	45	Feet	**45**

Fraction penetrated = 0.222222

slope points	52.57143	0.907
	5.272189	0.087

FLOW RATE	3.70	GPM
FLOW RATE	712.2995	ft^3/d
Rc =	0.083333	ft
Rw =	0.333333	ft

Slope =	0.821019	Feet	$/log_{10}$
Slope =	0.821019	feet/log_{10}	
T =	159	ft2/d	
	158.7915	Feet2/Day	10
	160	Feet2/Day	**16**
K =	3.528701	ft/d	
	3.528701	Feet/Day	0.1
K =	3.5	Feet/Day	**35**

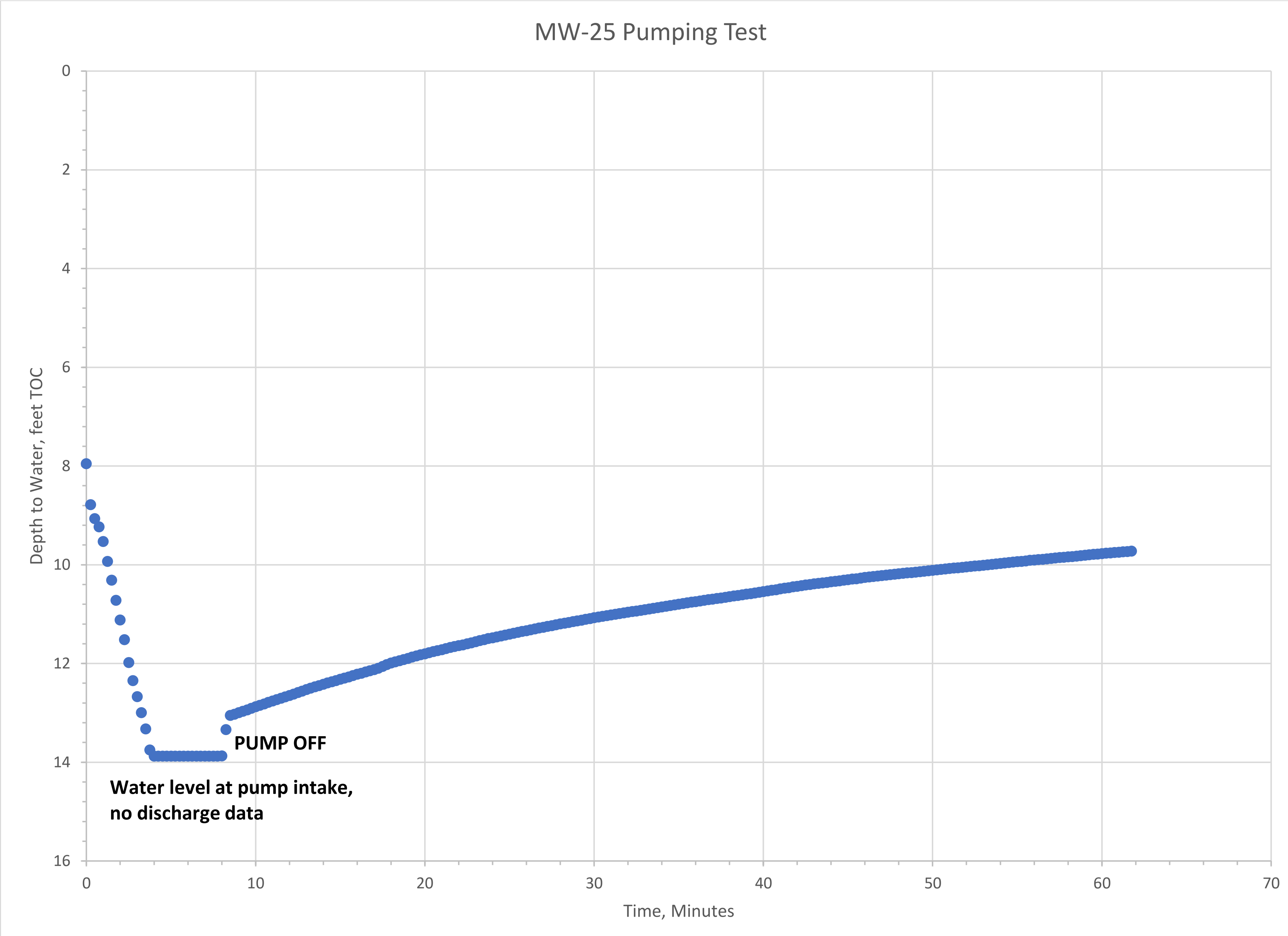
Absolute Shut Down

Input is consistent.

Decision		Option			
	0	Water level is below Base of Aquifer			
	0	Casing diameter is greater than the Annulus			
	0	Top of Aquifer is deeper than Base of Aquifer			
	0	Screen length is less than 1 Feet	1		
	0	Slope will produce a negative K			
	0	K= 3.5 is less than extreme minimum of 0.05 for Fine Sand	0.05	-2	0.05
	0	K= 3.5 is greater than extreme maximum of 20 for Fine Sand	20	1	20
	1	Input is consistent.			
		Error			

WARNING

Decision		Option			
	0				
	0	K= 3.5 is less than likely minimum of 3 for Fine Sand	3	0	3
	0	K= 3.5 is greater than likely maximum of 20 for Fine Sand	20	1	20
	1				


MW-25 Pumping Test
Depth to Water, feet TOC
Time, Minutes
PUMP OFF
Water level at pump intake,
no discharge data
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70

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The Monthly Newsletter of GroundwaterSoftware.com

Vol. 8 No. 2

BOUWER AND RICE SLUG-TEST METHOD & SINGLE WELL SOLUTIONS

Back to Newsletters

Bouwer and Rice Slug-Test Method

Bouwer and Rice (1976) developed a method of determining the hydraulic conductivity of an unconfined aquifer. This method can be used for both fully and partially penetrating wells. While originally developed for unconfined aquifers, it has been found that it can also be used in confined aquifers, provided the top of the well screen is some distance below the bottom of the upper confining layer.

The equations used to determine the hydraulic conductivity with the Bouwer and Rice method are as follows:

$$K = \frac{r_c^2 \ln(Re/r_w)}{2L_e}\frac{1}{t}\ln\left(\frac{h_0}{h}\right)$$

where :

K is hydraulic conductivity (L/T)

r_c is the radius of the well casing (L)

r_w is the radius of the well (including gravel envelope) (L)

R_e is the radial distance over which head is dissipated (L)

L_e is the length of the screen (L)

t is the time since $h=h_0$ (T)

h_0 is the drawdown at time t=0 (L)

h is the drawdown at time t=t (L)

Bouwer has presented a method of estimating $\ln(R_e/r_w)$:

For partially penetrating wells:

$$\ln(R_e/r_w) = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{A + B\ln[(b - L_w)/r_w]}{L_e/r_w}\right]^{-1}$$

For fully penetrating wells:

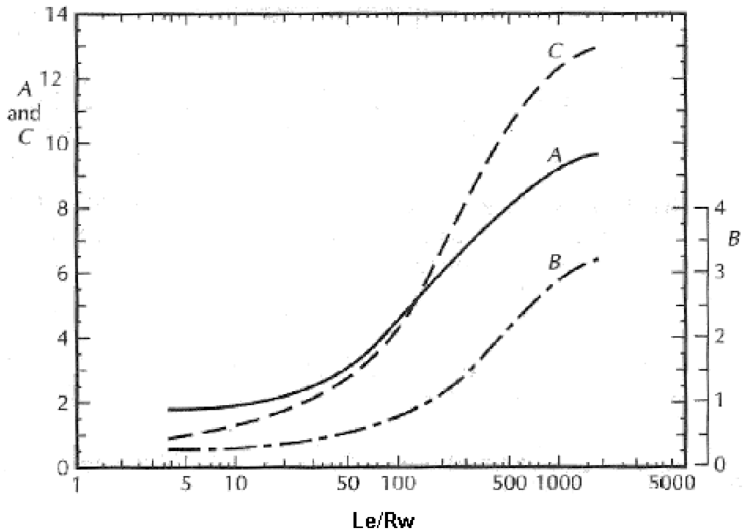
$$\ln(R_e/r_w) = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{L_e/r_w}\right]^{-1}$$

where:

L_w is the length of the well in the aquifer

b is the thickness of the saturated material

A,B,C are dimensionless numbers represented in the following diagram:

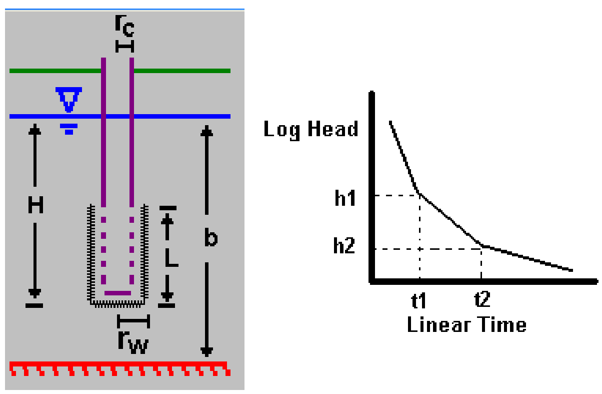


There are many programs available for analyzing slug tests results, including Single Well Solutions

Bouwer and Rice Slug Test

Calculating conductivity using the Bouwer and Rice slug test method

Graphical Display of Inputs



h_1 (head at time $t=t_1$): 11.846

h_2 (head at time $t=t_2$): 10.976

t_1 (time at head h_1): .007986

t_2 (time at head h_2): .016493

How to get this data

Well Type: partially penetrating well ▼

b (Aquifer saturated thickness): 47

H (distance from water table to bottom of pack): 9.55

L (length of the screened interval): 10

r_c (radius of casing): .0833

r_w (radius of well): .333

KEEP UNITS CONSISTENT

Calculate

Results

Conductivity: 0.00659529

References

Batu, V. (1998). Aquifer Hydraulics; A Comprehensive Guide to Hydrogeologic Data Analysis. Published by John Wiley & Sons, Inc. New York, NY.

Fetter, C.W. (1994). Applied Hydrogeology; Third Edition. Published by Prentice-Hall, Inc. , Englewood Cliffs, NJ.

Schwartz, F.W. and Zhang, H. (2003). Fundamentals of Groundwater. Published by John Wiley & Sons, Inc. New York, NY.

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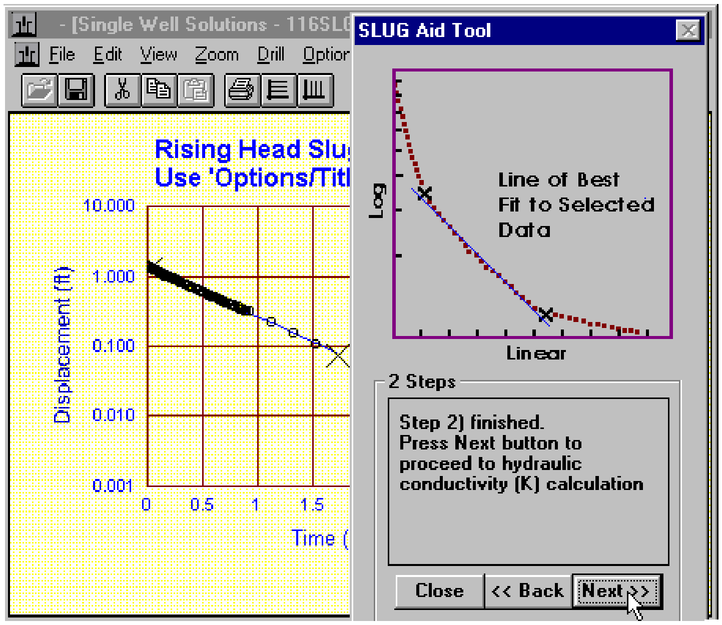
Single Well Solution

Single Well Solutions is a powerful Windows software product that contains a collection of the most popular analytical solutions from "Analysis and Evaluation of Pumping Test Date," by G.P. Kruseman and N.A. deRidder, second edition (1990), for determining aquifer hydraulic conductivity and pumping well efficiency from single well test data



Wide selection of analysis methods

Single Well Solutions is capable of analyzing single well test data with a variety of methods. These methods include:

Slug Tests:

- Bouwer and Rice (1976)
- Cooper et al. (1967)

Constant Discharge

- Hurr and Worthington (1981)
- Hantush (1964)

Variable Discharge

- Bisroy and Summers (1980) (both Intermittent and Uninterrupted Pumping)

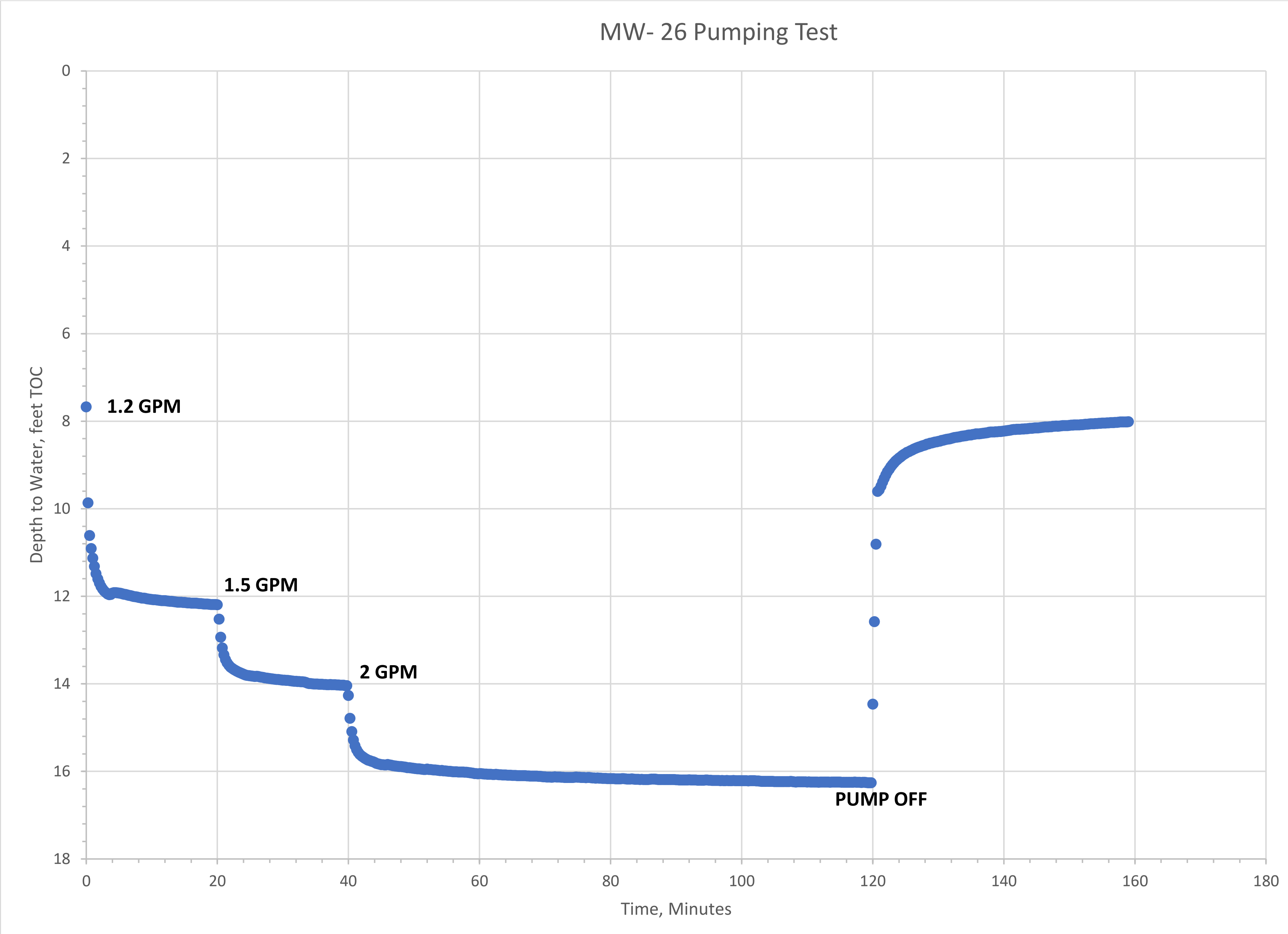
Step Drawdown

- Hantush and Bierschenk (1964)

Constant Discharge Recovery

- Theis (1935)

For more info click here: Single Well Solutions
To demo software click here: Demo


MW- 26 Pumping Test
Depth to Water, feet TOC
Time, Minutes
1.2 GPM
1.5 GPM
2 GPM
PUMP OFF
0
2
4
6
8
10
12
14
16
18
0
20
40
60
80
100
120
140
160
180

WELL ID: MW-26-Recovery

Local ID: MW-25
Date: 2/2/2017
Time: 0:00

INPUT

Construction:	
Casing dia. (d_c)	2 Inch
Annulus dia. (d_w)	8 Inch
Screen Length (L)	10 Feet
Depths to:	
water level (DTW)	7.67 Feet
Top of Aquifer	10 Feet
Base of Aquifer	55 Feet
Annular Fill:	
across screen --	Coarse Sand
above screen --	Bentonite
Aquifer Material --	Fine Sand
FLOW RATE	2 GPM

COMPUTED

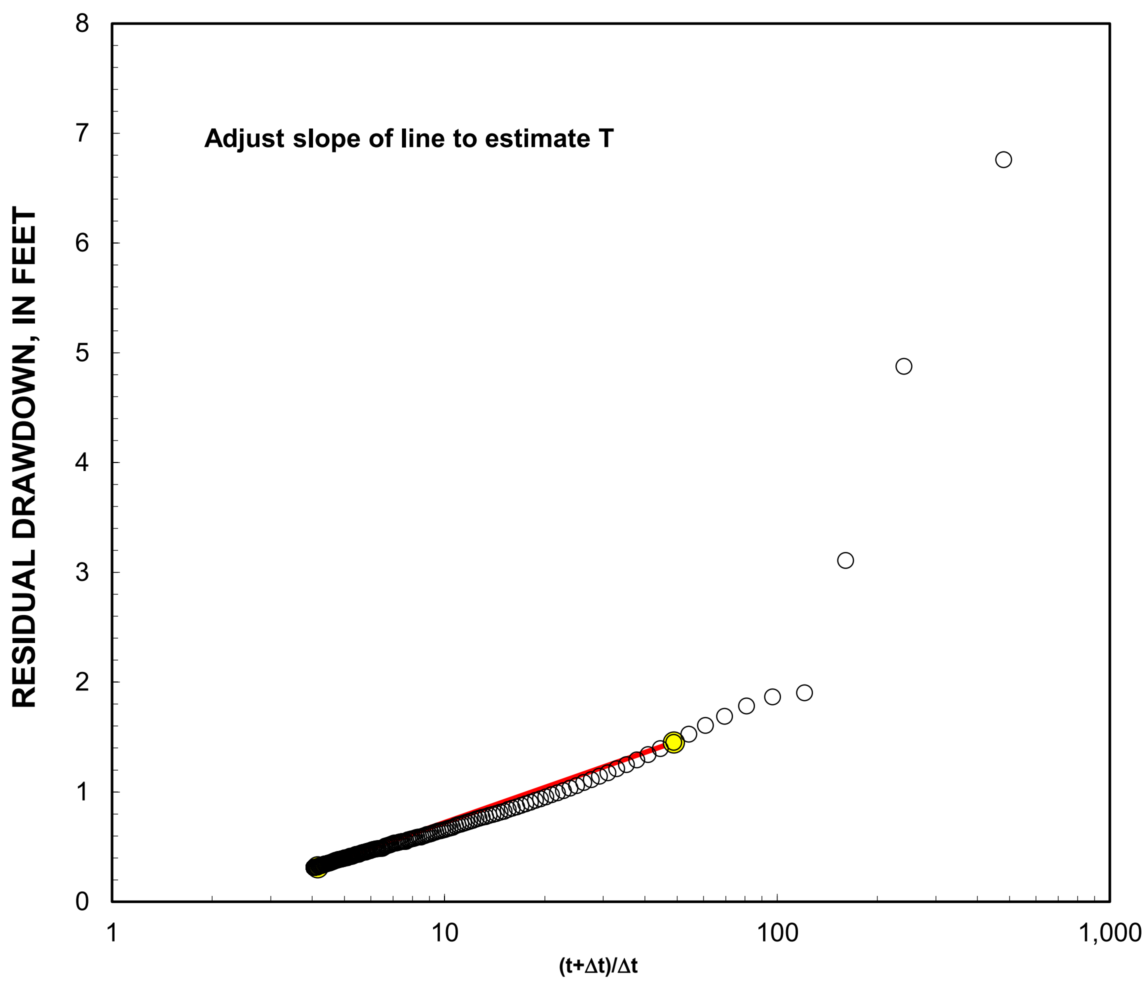
Aquifer thickness = 45 Feet

Slope = 1.060569 Feet/log10

Input is consistent.

K =	1.5 Feet/Day
T =	66 Feet²/Day

K= 1.5 is less than likely minimum of 3 for Fine Sand



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

Reduced Data

Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	7.70	51	1/0/00 2:12:00	8.39
2	1/0/00 1:59:45	16.26	52	1/0/00 2:12:15	8.38
3	1/0/00 2:00:00	14.46	53	1/0/00 2:12:30	8.37
4	1/0/00 2:00:15	12.58	54	1/0/00 2:12:45	8.37
5	1/0/00 2:00:30	10.81	55	1/0/00 2:13:00	8.36
6	1/0/00 2:00:45	9.60	56	1/0/00 2:13:15	8.35
7	1/0/00 2:01:00	9.57	57	1/0/00 2:13:30	8.35
8	1/0/00 2:01:15	9.48	58	1/0/00 2:13:45	8.34
9	1/0/00 2:01:30	9.39	59	1/0/00 2:14:00	8.34
10	1/0/00 2:01:45	9.31	60	1/0/00 2:14:15	8.33
11	1/0/00 2:02:00	9.23	61	1/0/00 2:14:30	8.32
12	1/0/00 2:02:15	9.15	62	1/0/00 2:14:45	8.32
13	1/0/00 2:02:30	9.10	63	1/0/00 2:15:00	8.31
14	1/0/00 2:02:45	9.04	64	1/0/00 2:15:15	8.30
15	1/0/00 2:03:00	8.99	65	1/0/00 2:15:30	8.30
16	1/0/00 2:03:15	8.95	66	1/0/00 2:15:45	8.29
17	1/0/00 2:03:30	8.91	67	1/0/00 2:16:00	8.29
18	1/0/00 2:03:45	8.88	68	1/0/00 2:16:15	8.29
19	1/0/00 2:04:00	8.84	69	1/0/00 2:16:30	8.28
20	1/0/00 2:04:15	8.81	70	1/0/00 2:16:45	8.28
21	1/0/00 2:04:30	8.79	71	1/0/00 2:17:00	8.27
22	1/0/00 2:04:45	8.76	72	1/0/00 2:17:15	8.27
23	1/0/00 2:05:00	8.74	73	1/0/00 2:17:30	8.26
24	1/0/00 2:05:15	8.71	74	1/0/00 2:17:45	8.25
25	1/0/00 2:05:30	8.69	75	1/0/00 2:18:00	8.25
26	1/0/00 2:05:45	8.68	76	1/0/00 2:18:15	8.25
27	1/0/00 2:06:00	8.66	77	1/0/00 2:18:30	8.25
28	1/0/00 2:06:15	8.64	78	1/0/00 2:18:45	8.24
29	1/0/00 2:06:30	8.62	79	1/0/00 2:19:00	8.24
30	1/0/00 2:06:45	8.61	80	1/0/00 2:19:15	8.24
31	1/0/00 2:07:00	8.59	81	1/0/00 2:19:30	8.24
32	1/0/00 2:07:15	8.58	82	1/0/00 2:19:45	8.23
33	1/0/00 2:07:30	8.57	83	1/0/00 2:20:00	8.23
34	1/0/00 2:07:45	8.55	84	1/0/00 2:20:15	8.22
35	1/0/00 2:08:00	8.54	85	1/0/00 2:20:30	8.22
36	1/0/00 2:08:15	8.53	86	1/0/00 2:20:45	8.21
37	1/0/00 2:08:30	8.52	87	1/0/00 2:21:00	8.21
38	1/0/00 2:08:45	8.50	88	1/0/00 2:21:15	8.20
39	1/0/00 2:09:00	8.50	89	1/0/00 2:21:30	8.19
40	1/0/00 2:09:15	8.49	90	1/0/00 2:21:45	8.19
41	1/0/00 2:09:30	8.48	91	1/0/00 2:22:00	8.19
42	1/0/00 2:09:45	8.47	92	1/0/00 2:22:15	8.18
43	1/0/00 2:10:00	8.46	93	1/0/00 2:22:30	8.18
44	1/0/00 2:10:15	8.45	94	1/0/00 2:22:45	8.18
45	1/0/00 2:10:30	8.44	95	1/0/00 2:23:00	8.18
46	1/0/00 2:10:45	8.43	96	1/0/00 2:23:15	8.18
47	1/0/00 2:11:00	8.43	97	1/0/00 2:23:30	8.17
48	1/0/00 2:11:15	8.42	98	1/0/00 2:23:45	8.17
49	1/0/00 2:11:30	8.41	99	1/0/00 2:24:00	8.17
50	1/0/00 2:11:45	8.40	100	1/0/00 2:24:15	8.16

Inch	0.083333	Second	1.15741E-05	GPM	192.5134
Feet	1	Minute	0.000694444	ft3/d	1
Meter	3.28084	Hour	0.041666667	ft3/s	86400
cm	0.032808	Day	1	m3/d	35.39525
mm	0.003281			m3/s	3058149
PSI	2.31			liters/s	3058.149
				liters/min	50.96915
Out Units =				cc/s	3.058149
Convert =	1	Feet2/Day			
Convert =	1	Feet/Day			

Casing dia. (dc)	2	Inch		
Annulus dia. (dw)	8	Inch		
Screen Length (L)	10	Feet		
Depths to:				
water level (DTW)	7.67	Feet		
Top of Aquifer	10	Feet		
Base of Aquifer	55	Feet		
Annular Fill:				
across screen --	Coarse Sand			
above screen --	Bentonite			
Aquifer Material --	Fine Sand			
wetted hole	10	Feet		
Aquifer thickness =	45	Feet		
Aquifer thickness =	45	feet		
Aquifer thickness =	45	Feet		1
Aquifer thickness =	45	Feet		**45**
Fraction penetrated =	0.222222			
slope points	48.9	1.453		
	4.151316	0.317		
FLOW RATE	2.00	GPM		
FLOW RATE	385.0267	ft^3/d		
Rc =	0.083333	ft		
Rw =	0.333333	ft		
Slope =	1.060569	Feet	$/log_{10}$	
Slope =	1.060569	$feet/log_{10}$		
T =	66	ft2/d		
	66.44616	Feet2/Day		1
	66	Feet2/Day		**66**
K =	1.476581	ft/d		
	1.476581	Feet/Day		0.1
K =	1.5	Feet/Day		**15**

Absolute Shut Down

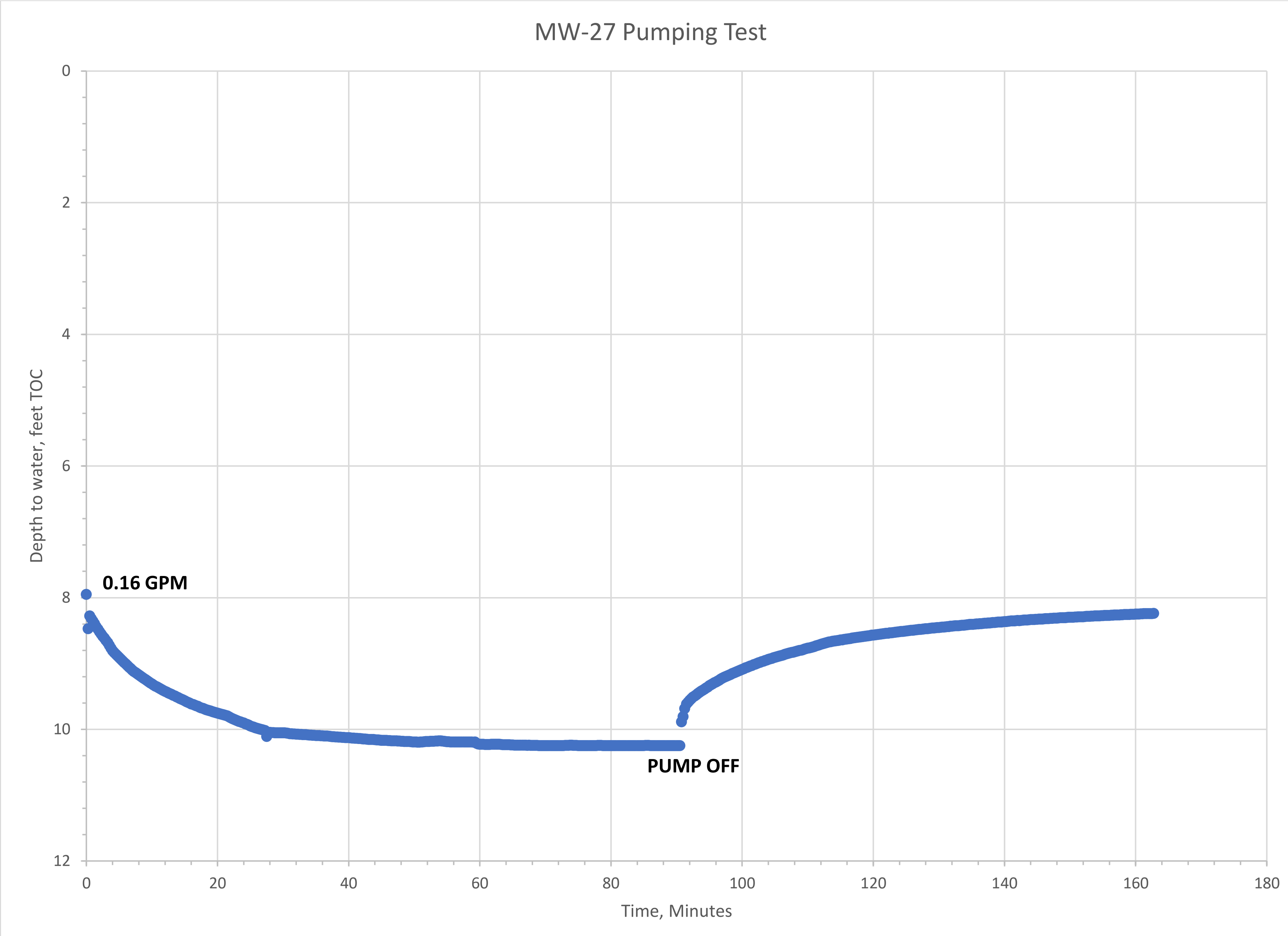
Input is consistent.

Decision		Option			
	0	Water level is below Base of Aquifer			
	0	Casing diameter is greater than the Annulus			
	0	Top of Aquifer is deeper than Base of Aquifer			
	0	Screen length is less than 1 Feet	1		
	0	Slope will produce a negative K			
	0	K= 1.5 is less than extreme minimum of 0.05 for Fine Sand	0.05	-2	0.05
	0	K= 1.5 is greater than extreme maximum of 20 for Fine Sand	20	1	20
	1	Input is consistent.			
		Error			

WARNING

K= 1.5 is less than likely minimum of 3 for Fine Sand

Decision		Option			
	0				
	1	K= 1.5 is less than likely minimum of 3 for Fine Sand	3	0	3
	1	K= 1.5 is greater than likely maximum of 20 for Fine Sand	20	1	20
	2				



MW-27 Pumping Test
Depth to water, feet TOC
0
2
4
6
8
10
12
0.16 GPM
PUMP OFF
0
20
40
60
80
100
120
140
160
180
Time, Minutes

WELL ID: MW-27-Recovery

Local ID: MW-27
Date: 2/1/2017
Time: 0:00

INPUT

Construction:	
Casing dia. (d_c)	2 Inch
Annulus dia. (d_w)	8 Inch
Screen Length (L)	10 Feet
Depths to:	
water level (DTW)	7.95 Feet
Top of Aquifer	10 Feet
Base of Aquifer	55 Feet
Annular Fill:	
across screen --	Coarse Sand
above screen --	Bentonite
Aquifer Material --	Fine Sand
FLOW RATE	0.16 GPM

COMPUTED

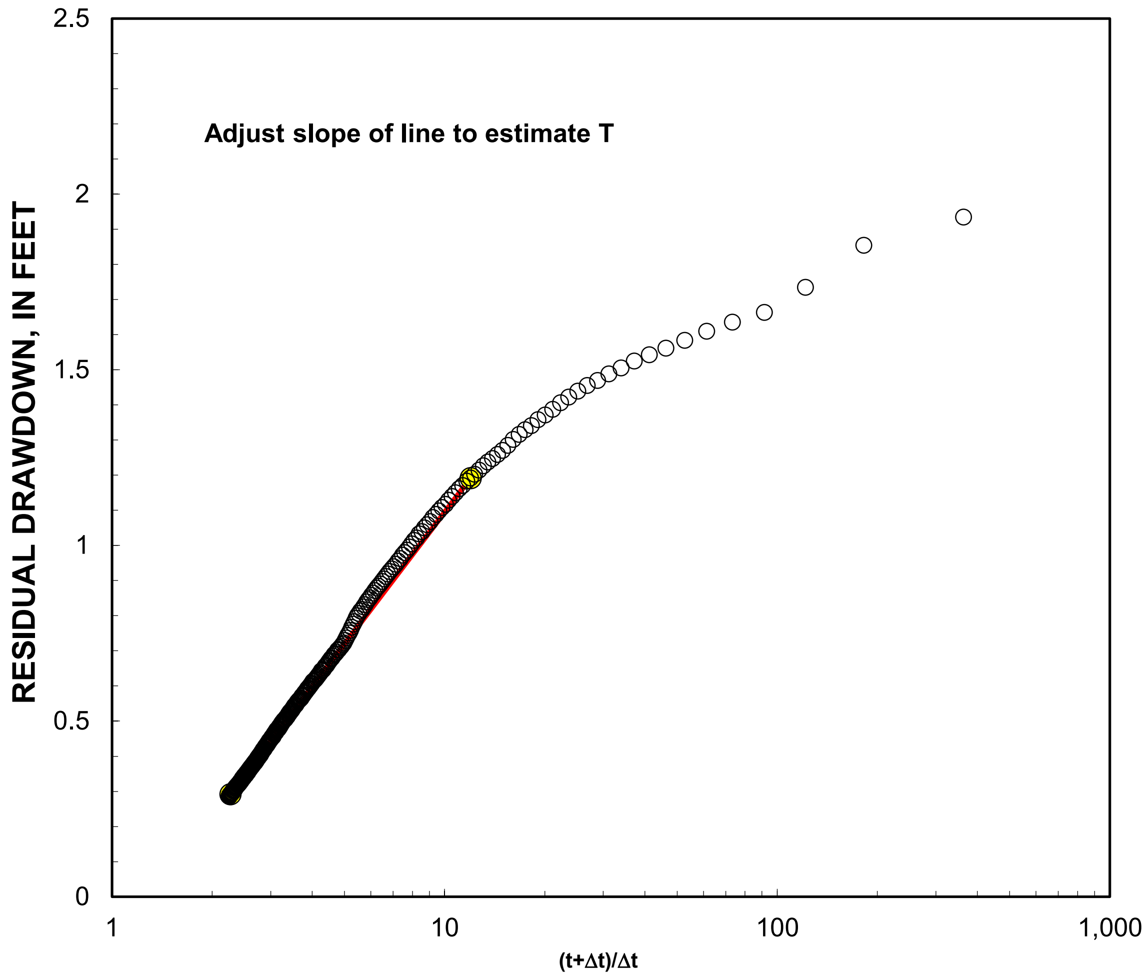
Aquifer thickness = 45 Feet

Slope = 1.246496 Feet/log10

Input is consistent.

K =	0.1 Feet/Day
T =	4.5 Feet²/Day

K= 0.1 is less than likely minimum of 3 for Fine Sand



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

Reduced Data

Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	7.95	51	1/0/00 1:55:15	8.64
2	1/0/00 1:30:45	9.89	52	1/0/00 1:55:45	8.63
3	1/0/00 1:31:15	9.69	53	1/0/00 1:56:15	8.62
4	1/0/00 1:31:45	9.59	54	1/0/00 1:56:45	8.61
5	1/0/00 1:32:15	9.53	55	1/0/00 1:57:15	8.61
6	1/0/00 1:32:45	9.49	56	1/0/00 1:57:45	8.60
7	1/0/00 1:33:15	9.46	57	1/0/00 1:58:15	8.59
8	1/0/00 1:33:45	9.42	58	1/0/00 1:58:45	8.58
9	1/0/00 1:34:15	9.39	59	1/0/00 1:59:15	8.58
10	1/0/00 1:34:45	9.36	60	1/0/00 1:59:45	8.57
11	1/0/00 1:35:15	9.32	61	1/0/00 2:00:15	8.57
12	1/0/00 1:35:45	9.29	62	1/0/00 2:00:45	8.56
13	1/0/00 1:36:15	9.27	63	1/0/00 2:01:15	8.55
14	1/0/00 1:36:45	9.24	64	1/0/00 2:01:45	8.54
15	1/0/00 1:37:15	9.21	65	1/0/00 2:02:15	8.54
16	1/0/00 1:37:45	9.19	66	1/0/00 2:02:45	8.53
17	1/0/00 1:38:15	9.17	67	1/0/00 2:03:15	8.53
18	1/0/00 1:38:45	9.14	68	1/0/00 2:03:45	8.52
19	1/0/00 1:39:15	9.12	69	1/0/00 2:04:15	8.51
20	1/0/00 1:39:45	9.10	70	1/0/00 2:04:45	8.51
21	1/0/00 1:40:15	9.08	71	1/0/00 2:05:15	8.50
22	1/0/00 1:40:45	9.06	72	1/0/00 2:05:45	8.50
23	1/0/00 1:41:15	9.04	73	1/0/00 2:06:15	8.49
24	1/0/00 1:41:45	9.02	74	1/0/00 2:06:45	8.49
25	1/0/00 1:42:15	9.00	75	1/0/00 2:07:15	8.48
26	1/0/00 1:42:45	8.98	76	1/0/00 2:07:45	8.48
27	1/0/00 1:43:15	8.97	77	1/0/00 2:08:15	8.47
28	1/0/00 1:43:45	8.95	78	1/0/00 2:08:45	8.46
29	1/0/00 1:44:15	8.93	79	1/0/00 2:09:15	8.46
30	1/0/00 1:44:45	8.91	80	1/0/00 2:09:45	8.46
31	1/0/00 1:45:15	8.90	81	1/0/00 2:10:15	8.45
32	1/0/00 1:45:45	8.88	82	1/0/00 2:10:45	8.45
33	1/0/00 1:46:15	8.87	83	1/0/00 2:11:15	8.44
34	1/0/00 1:46:45	8.86	84	1/0/00 2:11:45	8.43
35	1/0/00 1:47:15	8.84	85	1/0/00 2:12:15	8.43
36	1/0/00 1:47:45	8.83	86	1/0/00 2:12:45	8.43
37	1/0/00 1:48:15	8.82	87	1/0/00 2:13:15	8.42
38	1/0/00 1:48:45	8.80	88	1/0/00 2:13:45	8.42
39	1/0/00 1:49:15	8.79	89	1/0/00 2:14:15	8.41
40	1/0/00 1:49:45	8.78	90	1/0/00 2:14:45	8.41
41	1/0/00 1:50:15	8.76	91	1/0/00 2:15:15	8.40
42	1/0/00 1:50:45	8.75	92	1/0/00 2:15:45	8.40
43	1/0/00 1:51:15	8.73	93	1/0/00 2:16:15	8.39
44	1/0/00 1:51:45	8.72	94	1/0/00 2:16:45	8.39
45	1/0/00 1:52:15	8.70	95	1/0/00 2:17:15	8.39
46	1/0/00 1:52:45	8.69	96	1/0/00 2:17:45	8.38
47	1/0/00 1:53:15	8.67	97	1/0/00 2:18:15	8.38
48	1/0/00 1:53:45	8.66	98	1/0/00 2:18:45	8.37
49	1/0/00 1:54:15	8.65	99	1/0/00 2:19:15	8.37
50	1/0/00 1:54:45	8.65	100	1/0/00 2:19:45	8.37

Inch	0.083333	Second	1.16E-05	GPM	192.5134
Feet	1	Minute	0.000694	ft3/d	1
Meter	3.28084	Hour	0.041667	ft3/s	86400
cm	0.032808	Day	1	m3/d	35.39525
mm	0.003281			m3/s	3058149
PSI	2.31			liters/s	3058.149
				liters/min	50.96915
Out Units =				cc/s	3.058149
Convert =	1	Feet2/Day			
Convert =	1	Feet/Day			

Casing dia. (dc)	2	Inch	
Annulus dia. (dw)	8	Inch	
Screen Length (L)	10	Feet	
Depths to:			
water level (DTW)	7.95	Feet	
Top of Aquifer	10	Feet	
Base of Aquifer	55	Feet	
Annular Fill:			
across screen --	Coarse Sand		
above screen --	Bentonite		
Aquifer Material --	Fine Sand		
wetted hole	10	Feet	
Aquifer thickness =	45	Feet	
Aquifer thickness =	45	feet	
Aquifer thickness =	45	Feet	1
Aquifer thickness =	45	Feet	**45**

Fraction penetrated = 0.222222

slope points	11.9697	1.192
	2.270175	0.292

FLOW RATE	0.16	GPM
FLOW RATE	30.80214	ft^3/d
Rc =	0.083333	ft
Rw =	0.333333	ft

Slope =	1.246496	Feet	$/log_{10}$
Slope =	1.246496	feet/log_{10}	
T =	5	ft2/d	
	4.522804	Feet2/Day	0.1
	4.5	Feet2/Day	**45**
K =	0.100507	ft/d	
	0.100507	Feet/Day	0.01
K =	0.1	Feet/Day	**10**

Absolute Shut Down

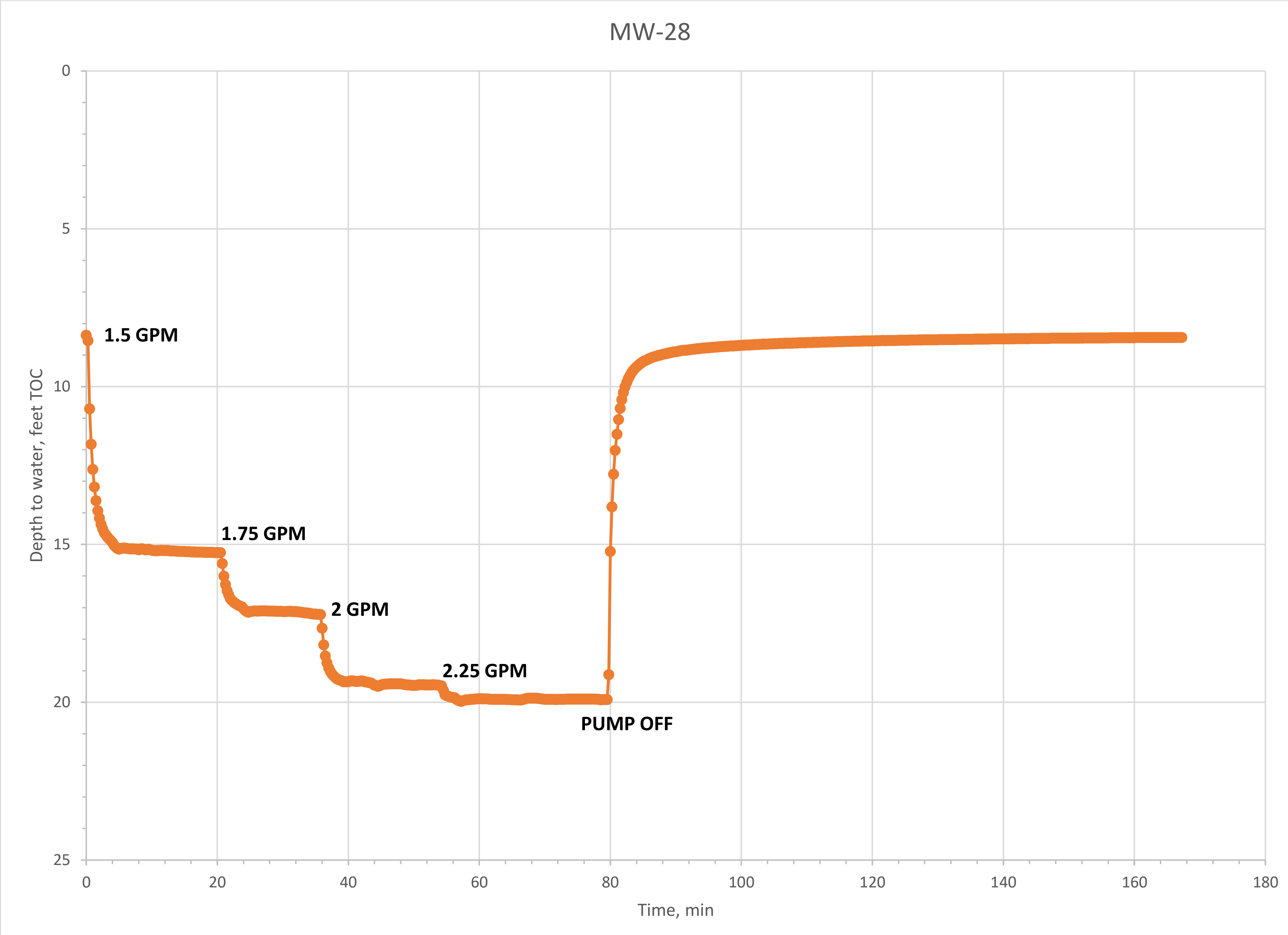
Input is consistent.

Decision	Option			
0	Water level is below Base of Aquifer			
0	Casing diameter is greater than the Annulus			
0	Top of Aquifer is deeperthan Base of Aquifer			
0	Screen length is less than 1 Feet	1		
0	Slope will produce a negative K			
0	K= 0.1 is less than extreme minimum of 0.05 for Fine Sand	0.05	-2	0.05
0	K= 0.1 is greater than extreme maximum of 20 for Fine Sa	20	1	20
1	Input is consistent.			
	Error			

WARNING

K= 0.1 is less than likely minimum of 3 for Fine Sand

Decision	Option			
0				
1	K= 0.1 is less than likely minimum of 3 for Fine Sand	3	0	3
1	K= 0.1 is greater than likely maximum of 20 for Fine Sand	20	1	20
2				


MW-28
Depth to water, feet TOC
Time, min
0
5
10
15
20
25
0
20
40
60
80
100
120
140
160
180
1.5 GPM
1.75 GPM
2 GPM
2.25 GPM
PUMP OFF

WELL ID: MW-28

Local ID: Hypo-1
Date: 4/4/2001
Time: 0:00

INPUT

Construction:	
Casing dia. (d_c)	2 Inch
Annulus dia. (d_w)	8 Inch
Screen Length (L)	10 Feet
Depths to:	
water level (DTW)	8.37 Feet
Top of Aquifer	8 Feet
Base of Aquifer	55 Feet
Annular Fill:	
across screen --	Coarse Sand
above screen --	Bentonite
Aquifer Material --	Fine Sand
FLOW RATE	2.25 GPM

COMPUTED

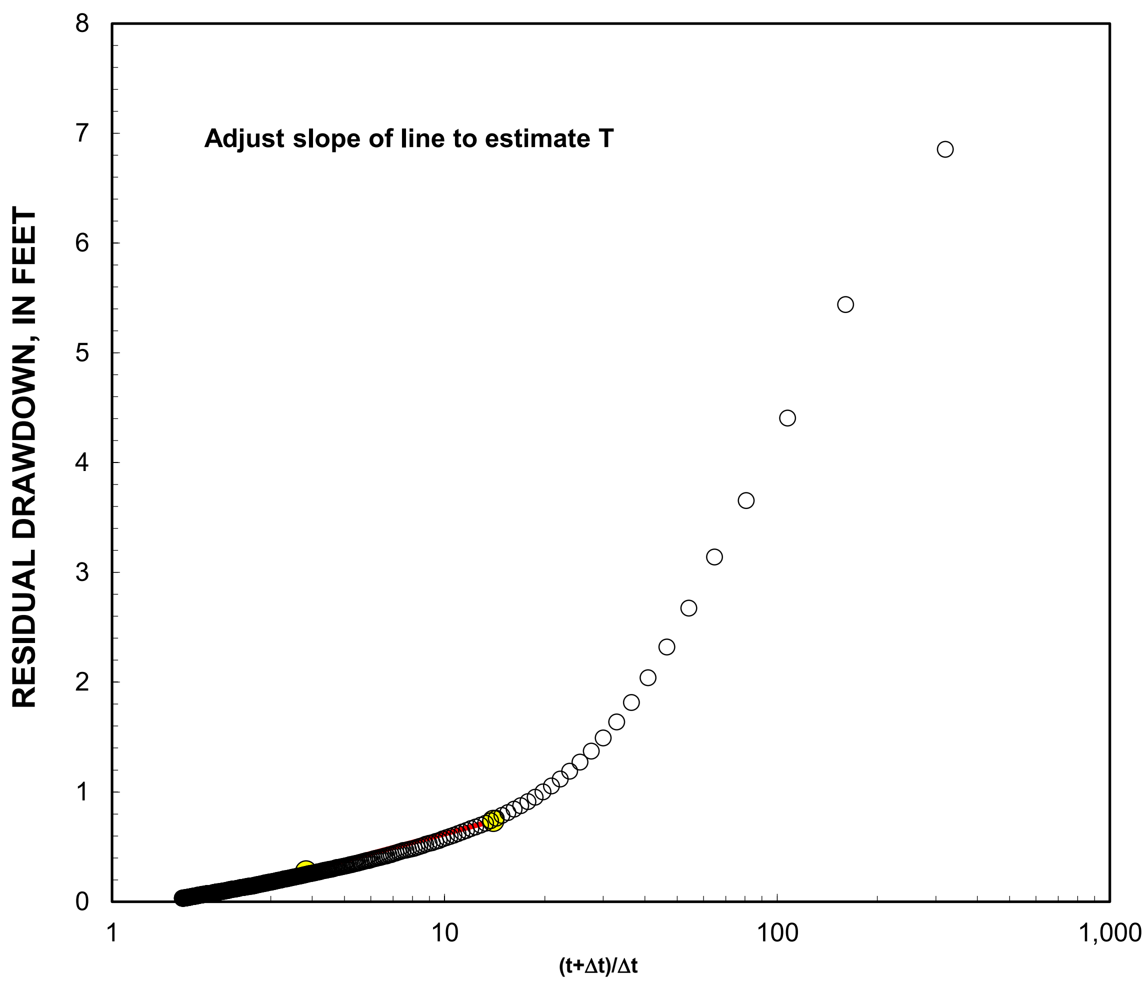
Aquifer thickness = 47 Feet

Slope = 0.813601 Feet/log10

Input is consistent.

K =	2.1 Feet/Day
T =	97 Feet²/Day

K= 2.1 is less than likely minimum of 3 for Fine Sand



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

Reduced Data

Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	0.00	51	1/0/00 2:22:00	0.11
2	1/0/00 1:20:45	3.65	52	1/0/00 2:23:15	0.11
3	1/0/00 1:22:00	1.82	53	1/0/00 2:24:30	0.10
4	1/0/00 1:23:15	1.19	54	1/0/00 2:25:45	0.10
5	1/0/00 1:24:30	0.91	55	1/0/00 2:27:00	0.10
6	1/0/00 1:25:45	0.76	56	1/0/00 2:28:15	0.10
7	1/0/00 1:27:00	0.67	57	1/0/00 2:29:30	0.10
8	1/0/00 1:28:15	0.59	58	1/0/00 2:30:45	0.09
9	1/0/00 1:29:30	0.54	59	1/0/00 2:32:00	0.09
10	1/0/00 1:30:45	0.50	60	1/0/00 2:33:15	0.09
11	1/0/00 1:32:00	0.47	61	1/0/00 2:34:30	0.09
12	1/0/00 1:33:15	0.43	62	1/0/00 2:35:45	0.09
13	1/0/00 1:34:30	0.40	63	1/0/00 2:37:00	0.08
14	1/0/00 1:35:45	0.38	64	1/0/00 2:38:15	0.08
15	1/0/00 1:37:00	0.36	65	1/0/00 2:39:30	0.08
16	1/0/00 1:38:15	0.34	66	1/0/00 2:40:45	0.08
17	1/0/00 1:39:30	0.33	67	1/0/00 2:42:00	0.08
18	1/0/00 1:40:45	0.31	68	1/0/00 2:43:15	0.07
19	1/0/00 1:42:00	0.30	69	1/0/00 2:44:30	0.07
20	1/0/00 1:43:15	0.29	70	1/0/00 2:45:45	0.07
21	1/0/00 1:44:30	0.28	71	1/0/00 2:47:00	0.07
22	1/0/00 1:45:45	0.26	72	1/0/00 2:48:15	0.07
23	1/0/00 1:47:00	0.26	73	1/0/00 2:49:30	0.07
24	1/0/00 1:48:15	0.25	74	1/0/00 2:50:45	0.07
25	1/0/00 1:49:30	0.24	75	1/0/00 2:52:00	0.07
26	1/0/00 1:50:45	0.23	76	1/0/00 2:53:15	0.06
27	1/0/00 1:52:00	0.22	77	1/0/00 2:54:30	0.06
28	1/0/00 1:53:15	0.21	78	1/0/00 2:55:45	0.06
29	1/0/00 1:54:30	0.21	79	1/0/00 2:57:00	0.06
30	1/0/00 1:55:45	0.20	80	1/0/00 2:58:15	0.06
31	1/0/00 1:57:00	0.19	81	1/0/00 2:59:30	0.06
32	1/0/00 1:58:15	0.19	82	1/0/00 3:00:45	0.06
33	1/0/00 1:59:30	0.18	83	1/0/00 3:02:00	0.05
34	1/0/00 2:00:45	0.18	84	1/0/00 3:03:15	0.05
35	1/0/00 2:02:00	0.17	85	1/0/00 3:04:30	0.05
36	1/0/00 2:03:15	0.16	86	1/0/00 3:05:45	0.05
37	1/0/00 2:04:30	0.16	87	1/0/00 3:07:00	0.05
38	1/0/00 2:05:45	0.15	88	1/0/00 3:08:15	0.05
39	1/0/00 2:07:00	0.15	89	1/0/00 3:09:30	0.05
40	1/0/00 2:08:15	0.15	90	1/0/00 3:10:45	0.04
41	1/0/00 2:09:30	0.15	91	1/0/00 3:12:00	0.04
42	1/0/00 2:10:45	0.14	92	1/0/00 3:13:15	0.04
43	1/0/00 2:12:00	0.14	93	1/0/00 3:14:30	0.04
44	1/0/00 2:13:15	0.13	94	1/0/00 3:15:45	0.04
45	1/0/00 2:14:30	0.13	95	1/0/00 3:17:00	0.04
46	1/0/00 2:15:45	0.13	96	1/0/00 3:18:15	0.04
47	1/0/00 2:17:00	0.12	97	1/0/00 3:19:30	0.04
48	1/0/00 2:18:15	0.12	98	1/0/00 3:20:45	0.04
49	1/0/00 2:19:30	0.12	99	1/0/00 3:22:00	0.04
50	1/0/00 2:20:45	0.11	100	#N/A	#N/A

Inch	0.083333	Second	1.16E-05
Feet	1	Minute	0.000694
Meter	3.28084	Hour	0.041667
cm	0.032808	Day	1
mm	0.003281		
PSI	2.31		

GPM	192.5134
ft3/d	1
ft3/s	86400
m3/d	35.39525
m3/s	3058149
liters/s	3058.149
liters/min	50.96915
cc/s	3.058149

Out Units =
Convert = 1 Feet2/Day
Convert = 1 Feet/Day

Casing dia. (dc)	2	Inch	
Annulus dia. (dw)	8	Inch	
Screen Length (L)	10	Feet	
Depths to:			
water level (DTW)	8.37	Feet	
Top of Aquifer	8	Feet	
Base of Aquifer	55	Feet	
Annular Fill:			
across screen --	Coarse Sand		
above screen --	Bentonite		
Aquifer Material --	Fine Sand		
wetted hole	9.63	Feet	
Aquifer thickness =	46.63	Feet	
Aquifer thickness =	46.63	feet	
Aquifer thickness =	46.63	Feet	1
Aquifer thickness =	47	Feet	47

Fraction penetrated = 0.206519

slope points	14	0.738
	3.83	0.28

FLOW RATE	2.25	GPM
FLOW RATE	433.1551	ft^3/d
Rc =	0.083333	ft
Rw =	0.333333	ft

Slope = 0.813601 Feet /log_{10}
Slope = 0.813601 feet/log_{10}

T =	97	ft2/d	
	97.44279	Feet2/Day	1
	97	Feet2/Day	97
K =	2.089702	ft/d	
	2.089702	Feet/Day	0.1
K =	2.1	Feet/Day	21

Absolute Shut Down

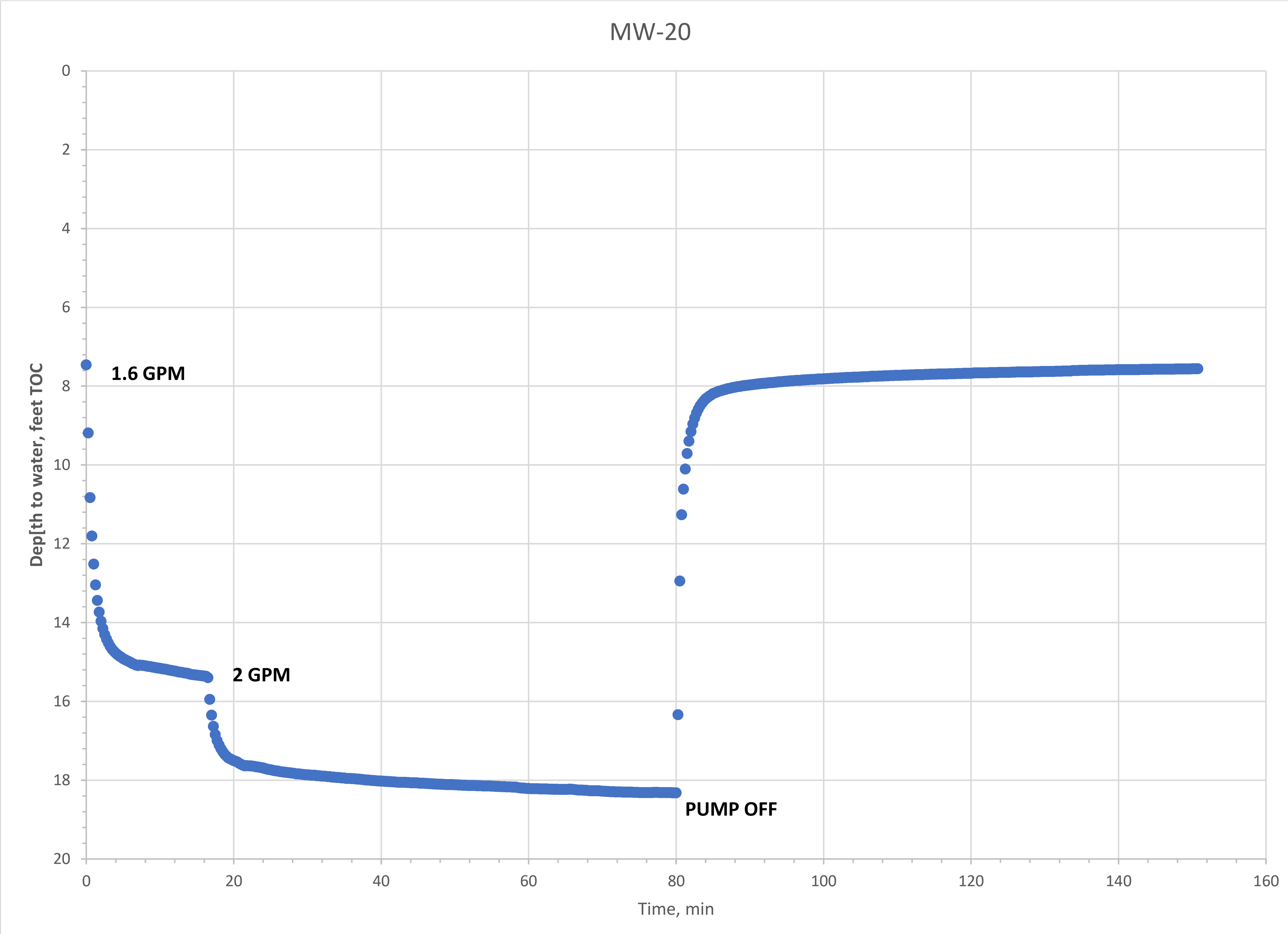
Input is consistent.

Decision	Option			
0	Water level is below Base of Aquifer			
0	Casing diameter is greater than the Annulus			
0	Top of Aquifer is deeperthan Base of Aquifer			
0	Screen length is less than 1 Feet	1		
0	Slope will produce a negative K			
0	K= 2.1 is less than extreme minimum of 0.05 for Fine Sand	0.05	-2	0.05
0	K= 2.1 is greater than extreme maximum of 20 for Fine Sa	20	1	20
1	Input is consistent.			
	Error			

WARNING

K= 2.1 is less than likely minimum of 3 for Fine Sand

Decision	Option			
0				
1	K= 2.1 is less than likely minimum of 3 for Fine Sand	3	0	3
1	K= 2.1 is greater than likely maximum of 20 for Fine Sand	20	1	20
2				


MW-20
Dep[th to water, feet TOC
Time, min
1.6 GPM
2 GPM
PUMP OFF
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160

WELL ID: MW-20

Local ID: Hypo-1
Date: 4/4/2001
Time: 0:00

INPUT

Construction:	
Casing dia. (d_c)	2 Inch
Annulus dia. (d_w)	8 Inch
Screen Length (L)	5 Feet
Depths to:	
water level (DTW)	7.7 Feet
Top of Aquifer	8 Feet
Base of Aquifer	55 Feet
Annular Fill:	
across screen --	Coarse Sand
above screen --	Bentonite
Aquifer Material --	Silt, Loess
FLOW RATE	0.5 GPM

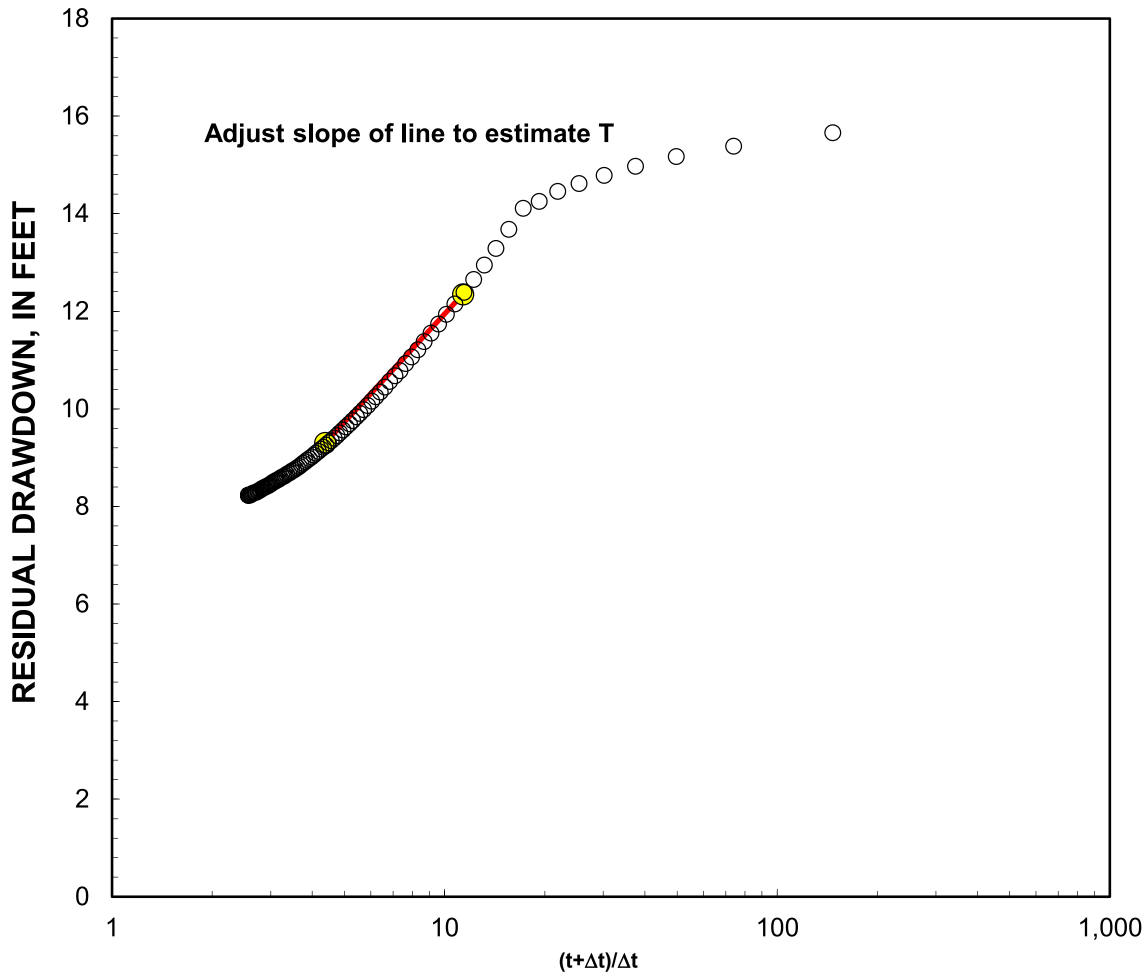
COMPUTED

Aquifer thickness = 47 Feet

Slope = 7.356781 Feet/log10

Input is consistent.

K =	0.051 Feet/Day
T =	2.4 Feet²/Day



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

Reduced Data

Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	0.00	51	1/0/00 0:48:45	9.02
2	1/0/00 0:36:30	15.96	52	1/0/00 0:49:00	8.98
3	1/0/00 0:36:45	15.66	53	1/0/00 0:49:15	8.95
4	1/0/00 0:37:00	15.39	54	1/0/00 0:49:30	8.92
5	1/0/00 0:37:15	15.17	55	1/0/00 0:49:45	8.89
6	1/0/00 0:37:30	14.98	56	1/0/00 0:50:00	8.86
7	1/0/00 0:37:45	14.79	57	1/0/00 0:50:15	8.83
8	1/0/00 0:38:00	14.62	58	1/0/00 0:50:30	8.80
9	1/0/00 0:38:15	14.46	59	1/0/00 0:50:45	8.77
10	1/0/00 0:38:30	14.26	60	1/0/00 0:51:00	8.74
11	1/0/00 0:38:45	14.11	61	1/0/00 0:51:15	8.72
12	1/0/00 0:39:00	13.68	62	1/0/00 0:51:30	8.70
13	1/0/00 0:39:15	13.29	63	1/0/00 0:51:45	8.68
14	1/0/00 0:39:30	12.95	64	1/0/00 0:52:00	8.66
15	1/0/00 0:39:45	12.65	65	1/0/00 0:52:15	8.64
16	1/0/00 0:40:00	12.39	66	1/0/00 0:52:30	8.62
17	1/0/00 0:40:15	12.15	67	1/0/00 0:52:45	8.60
18	1/0/00 0:40:30	11.94	68	1/0/00 0:53:00	8.59
19	1/0/00 0:40:45	11.74	69	1/0/00 0:53:15	8.57
20	1/0/00 0:41:00	11.55	70	1/0/00 0:53:30	8.55
21	1/0/00 0:41:15	11.38	71	1/0/00 0:53:45	8.53
22	1/0/00 0:41:30	11.21	72	1/0/00 0:54:00	8.52
23	1/0/00 0:41:45	11.06	73	1/0/00 0:54:15	8.50
24	1/0/00 0:42:00	10.93	74	1/0/00 0:54:30	8.48
25	1/0/00 0:42:15	10.79	75	1/0/00 0:54:45	8.46
26	1/0/00 0:42:30	10.68	76	1/0/00 0:55:00	8.44
27	1/0/00 0:42:45	10.56	77	1/0/00 0:55:15	8.43
28	1/0/00 0:43:00	10.45	78	1/0/00 0:55:30	8.42
29	1/0/00 0:43:15	10.34	79	1/0/00 0:55:45	8.40
30	1/0/00 0:43:30	10.25	80	1/0/00 0:56:00	8.39
31	1/0/00 0:43:45	10.16	81	1/0/00 0:56:15	8.38
32	1/0/00 0:44:00	10.07	82	1/0/00 0:56:30	8.36
33	1/0/00 0:44:15	9.99	83	1/0/00 0:56:45	8.35
34	1/0/00 0:44:30	9.91	84	1/0/00 0:57:00	8.33
35	1/0/00 0:44:45	9.84	85	1/0/00 0:57:15	8.32
36	1/0/00 0:45:00	9.76	86	1/0/00 0:57:30	8.31
37	1/0/00 0:45:15	9.70	87	1/0/00 0:57:45	8.29
38	1/0/00 0:45:30	9.63	88	1/0/00 0:58:00	8.29
39	1/0/00 0:45:45	9.57	89	1/0/00 0:58:15	8.28
40	1/0/00 0:46:00	9.51	90	1/0/00 0:58:30	8.28
41	1/0/00 0:46:15	9.45	91	1/0/00 0:58:45	8.26
42	1/0/00 0:46:30	9.40	92	1/0/00 0:59:00	8.25
43	1/0/00 0:46:45	9.35	93	1/0/00 0:59:15	8.24
44	1/0/00 0:47:00	9.30	94	1/0/00 0:59:30	8.23
45	1/0/00 0:47:15	9.26			
46	1/0/00 0:47:30	9.21			
47	1/0/00 0:47:45	9.17			
48	1/0/00 0:48:00	9.13			
49	1/0/00 0:48:15	9.09			
50	1/0/00 0:48:30	9.05			

Inch	0.083333	Second	1.16E-05
Feet	1	Minute	0.000694
Meter	3.28084	Hour	0.041667
cm	0.032808	Day	1
mm	0.003281		
PSI	2.31		

GPM	192.5134
ft3/d	1
ft3/s	86400
m3/d	35.39525
m3/s	3058149
liters/s	3058.149
liters/min	50.96915
cc/s	3.058149

Out Units =
Convert = 1 Feet2/Day
Convert = 1 Feet/Day

Casing dia. (dc)	2	Inch	
Annulus dia. (dw)	8	Inch	
Screen Length (L)	5	Feet	
Depths to:			
water level (DTW)	7.7	Feet	
Top of Aquifer	8	Feet	
Base of Aquifer	55	Feet	
Annular Fill:			
across screen --	Coarse Sand		
above screen --	Bentonite		
Aquifer Material --	Silt, Loess		
wetted hole	5	Feet	
Aquifer thickness =	47	Feet	
Aquifer thickness =	47	feet	
Aquifer thickness =	47	Feet	1
Aquifer thickness =	47	Feet	**47**

Fraction penetrated = 0.106383

slope points	11.357	12.353
	4.372	9.303

FLOW RATE 0.50 GPM
FLOW RATE 96.25668 ft^3/d

Rc = 0.083333 ft
Rw = 0.333333 ft

Slope = 7.356781 Feet $/log_{10}$
Slope = 7.356781 feet/log_{10}

T =	2	ft2/d	
	2.394755	Feet2/Day	0.1
	2.4	Feet2/Day	**24**
K =	0.050952	ft/d	
	0.050952	Feet/Day	0.001
K =	0.051	Feet/Day	**51**

Absolute Shut Down

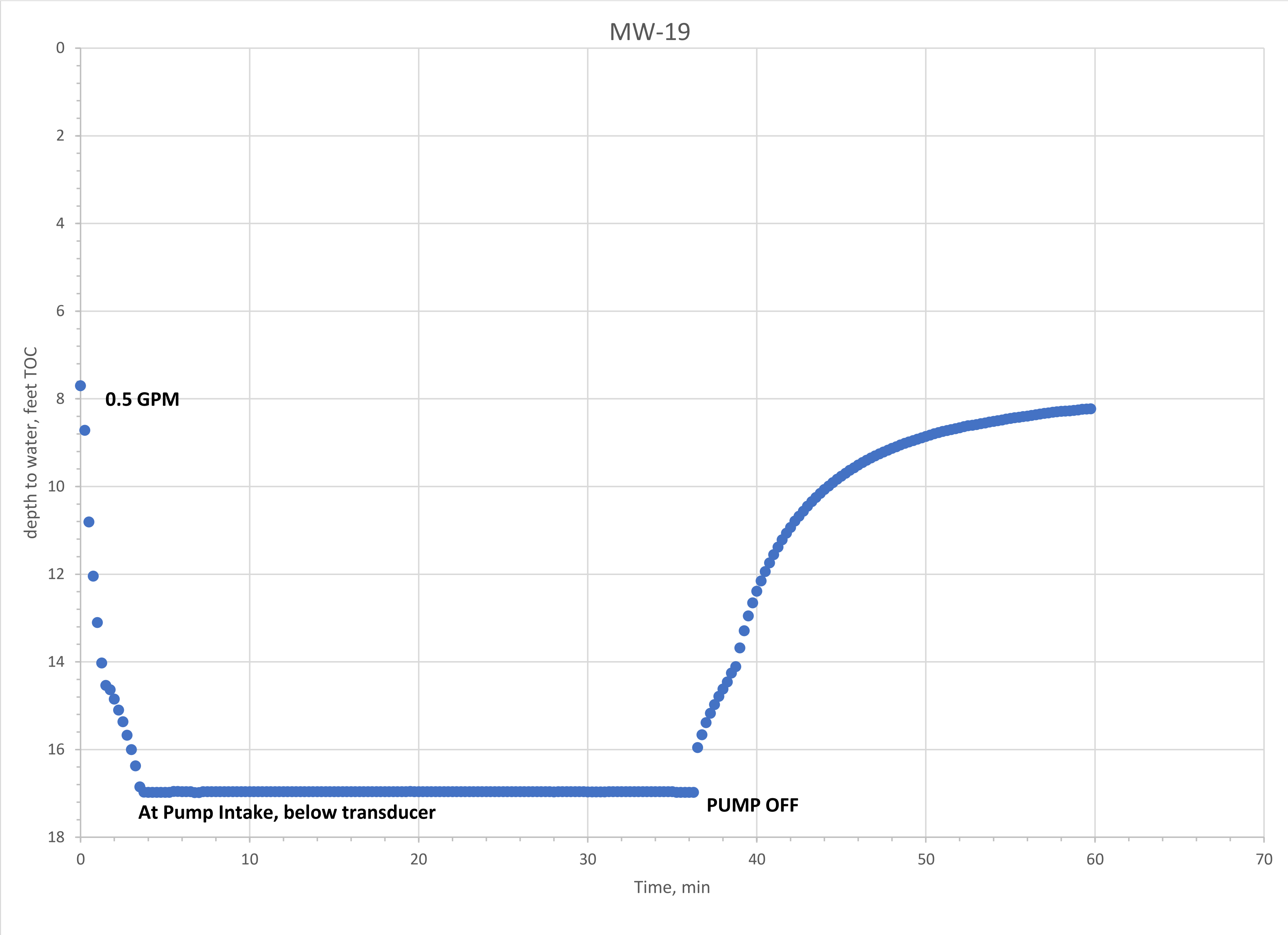
Input is consistent.

Decision	Option			
0	Water level is below Base of Aquifer			
0	Casing diameter is greater than the Annulus			
0	Top of Aquifer is deeperthan Base of Aquifer			
0	Screen length is less than 1 Feet	1		
0	Slope will produce a negative K			
0	K = 0.051 is less than extreme minimum of 0.0003 for Silt , L	0.0003	-4	0.0003
0	K = 0.051 is greater than extreme maximum of 6 for Silt , L	6	0	6
1	Input is consistent.			

Error

WARNING

Decision	Option			
0				
0	K = 0.051 is less than likely minimum of 0.001 for Silt , Loes	0.001	-3	0.001
0	K = 0.051 is greater than likely maximum of 0.1 for Silt , Lo	0.1	-1	0.1
1				


MW-19
depth to water, feet TOC
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
70
Time, min
0.5 GPM
At Pump Intake, below transducer
PUMP OFF

WELL ID: MW-19

Local ID: Hypo-1
Date: 4/4/2001
Time: 0:00

INPUT

Construction:	
Casing dia. (d_c)	2 Inch
Annulus dia. (d_w)	8 Inch
Screen Length (L)	5 Feet
Depths to:	
water level (DTW)	7.7 Feet
Top of Aquifer	8 Feet
Base of Aquifer	55 Feet
Annular Fill:	
across screen --	Coarse Sand
above screen --	Bentonite
Aquifer Material --	Silt, Loess
FLOW RATE	0.5 GPM

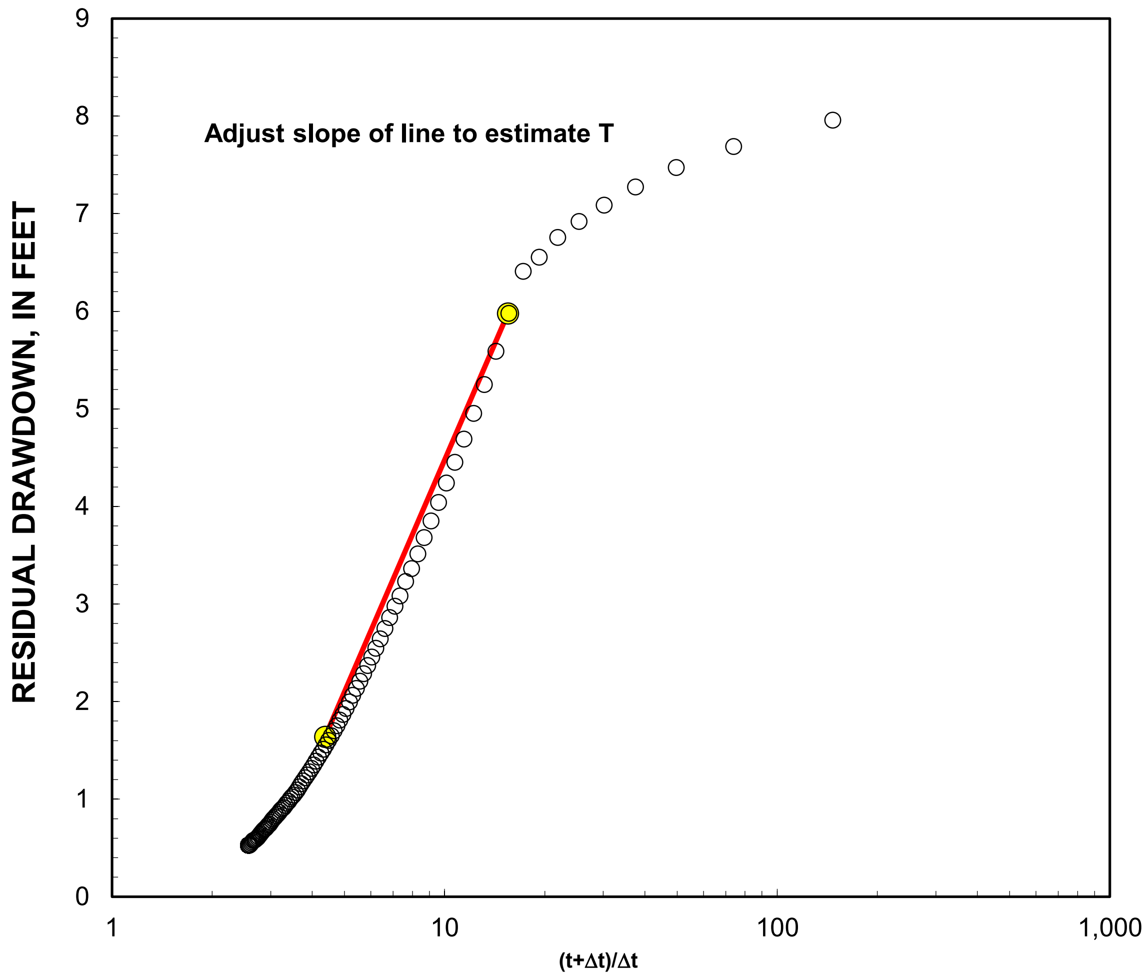
COMPUTED

Aquifer thickness = 47 Feet

Slope = 7.894092 Feet/log10

Input is consistent.

K =	0.047 Feet/Day
T =	2.2 Feet²/Day



REMARKS: Cooper-Jacob recovery analysis of single-well aquifer test

Reduced Data

Entry	Time, Date Hr:Min:Sec	Water Level Feet	Entry	Time, Date Hr:Min:Sec	Water Level Feet
1	1/0/00 0:00:00	7.70	51	1/0/00 0:48:45	9.02
2	1/0/00 0:36:30	15.96	52	1/0/00 0:49:00	8.98
3	1/0/00 0:36:45	15.66	53	1/0/00 0:49:15	8.95
4	1/0/00 0:37:00	15.39	54	1/0/00 0:49:30	8.92
5	1/0/00 0:37:15	15.17	55	1/0/00 0:49:45	8.89
6	1/0/00 0:37:30	14.98	56	1/0/00 0:50:00	8.86
7	1/0/00 0:37:45	14.79	57	1/0/00 0:50:15	8.83
8	1/0/00 0:38:00	14.62	58	1/0/00 0:50:30	8.80
9	1/0/00 0:38:15	14.46	59	1/0/00 0:50:45	8.77
10	1/0/00 0:38:30	14.26	60	1/0/00 0:51:00	8.74
11	1/0/00 0:38:45	14.11	61	1/0/00 0:51:15	8.72
12	1/0/00 0:39:00	13.68	62	1/0/00 0:51:30	8.70
13	1/0/00 0:39:15	13.29	63	1/0/00 0:51:45	8.68
14	1/0/00 0:39:30	12.95	64	1/0/00 0:52:00	8.66
15	1/0/00 0:39:45	12.65	65	1/0/00 0:52:15	8.64
16	1/0/00 0:40:00	12.39	66	1/0/00 0:52:30	8.62
17	1/0/00 0:40:15	12.15	67	1/0/00 0:52:45	8.60
18	1/0/00 0:40:30	11.94	68	1/0/00 0:53:00	8.59
19	1/0/00 0:40:45	11.74	69	1/0/00 0:53:15	8.57
20	1/0/00 0:41:00	11.55	70	1/0/00 0:53:30	8.55
21	1/0/00 0:41:15	11.38	71	1/0/00 0:53:45	8.53
22	1/0/00 0:41:30	11.21	72	1/0/00 0:54:00	8.52
23	1/0/00 0:41:45	11.06	73	1/0/00 0:54:15	8.50
24	1/0/00 0:42:00	10.93	74	1/0/00 0:54:30	8.48
25	1/0/00 0:42:15	10.79	75	1/0/00 0:54:45	8.46
26	1/0/00 0:42:30	10.68	76	1/0/00 0:55:00	8.44
27	1/0/00 0:42:45	10.56	77	1/0/00 0:55:15	8.43
28	1/0/00 0:43:00	10.45	78	1/0/00 0:55:30	8.42
29	1/0/00 0:43:15	10.34	79	1/0/00 0:55:45	8.40
30	1/0/00 0:43:30	10.25	80	1/0/00 0:56:00	8.39
31	1/0/00 0:43:45	10.16	81	1/0/00 0:56:15	8.38
32	1/0/00 0:44:00	10.07	82	1/0/00 0:56:30	8.36
33	1/0/00 0:44:15	9.99	83	1/0/00 0:56:45	8.35
34	1/0/00 0:44:30	9.91	84	1/0/00 0:57:00	8.33
35	1/0/00 0:44:45	9.84	85	1/0/00 0:57:15	8.32
36	1/0/00 0:45:00	9.76	86	1/0/00 0:57:30	8.31
37	1/0/00 0:45:15	9.70	87	1/0/00 0:57:45	8.29
38	1/0/00 0:45:30	9.63	88	1/0/00 0:58:00	8.29
39	1/0/00 0:45:45	9.57	89	1/0/00 0:58:15	8.28
40	1/0/00 0:46:00	9.51	90	1/0/00 0:58:30	8.28
41	1/0/00 0:46:15	9.45	91	1/0/00 0:58:45	8.26
42	1/0/00 0:46:30	9.40	92	1/0/00 0:59:00	8.25
43	1/0/00 0:46:45	9.35	93	1/0/00 0:59:15	8.24
44	1/0/00 0:47:00	9.30	94	1/0/00 0:59:30	8.23
45	1/0/00 0:47:15	9.26			
46	1/0/00 0:47:30	9.21			
47	1/0/00 0:47:45	9.17			
48	1/0/00 0:48:00	9.13			
49	1/0/00 0:48:15	9.09			
50	1/0/00 0:48:30	9.05			

Inch	0.083333	Second	1.16E-05		GPM	192.5134
Feet	1	Minute	0.000694		ft3/d	1
Meter	3.28084	Hour	0.041667		ft3/s	86400
cm	0.032808	Day	1		m3/d	35.39525
mm	0.003281				m3/s	3058149
PSI	2.31				liters/s	3058.149
					liters/min	50.96915
Out Units =					cc/s	3.058149
Convert =	1	Feet2/Day				
Convert =	1	Feet/Day				

Casing dia. (dc)	2	Inch	
Annulus dia. (dw)	8	Inch	
Screen Length (L)	5	Feet	
Depths to:			
water level (DTW)	7.7	Feet	
Top of Aquifer	8	Feet	
Base of Aquifer	55	Feet	
Annular Fill:			
across screen --	Coarse Sand		
above screen --	Bentonite		
Aquifer Material --	Silt, Loess		
wetted hole	5	Feet	
Aquifer thickness =	47	Feet	
Aquifer thickness =	47	feet	
Aquifer thickness =	47	Feet	**1**
Aquifer thickness =	47	Feet	**47**
Fraction penetrated =	0.106383		
slope points	15.5	5.979	
	4.372	1.64	
FLOW RATE	0.50	GPM	
FLOW RATE	96.25668	ft^3/d	
Rc =	0.083333	ft	
Rw =	0.333333	ft	
Slope =	7.894092	Feet $/log_{10}$	
Slope =	7.894092	$feet/log_{10}$	
T =	2	ft2/d	
	2.231756	Feet2/Day	**0.1**
	2.2	Feet2/Day	**22**
K =	0.047484	ft/d	
	0.047484	Feet/Day	**0.001**
K =	0.047	Feet/Day	**47**

Absolute Shut Down

Input is consistent.

Decision	Option			
0	Water level is below Base of Aquifer			
0	Casing diameter is greater than the Annulus			
0	Top of Aquifer is deeperthan Base of Aquifer			
0	Screen length is less than 1 Feet	1		
0	Slope will produce a negative K			
0	K = 0.047 is less than extreme minimum of 0.0003 for Silt , L	0.0003	-4	0.0003
0	K = 0.047 is greater than extreme maximum of 6 for Silt , L	6	0	6
1	Input is consistent.			

Error

WARNING

Decision	Option			
0				
0	K = 0.047 is less than likely minimum of 0.001 for Silt , Loes	0.001	-3	0.001
0	K = 0.047 is greater than likely maximum of 0.1 for Silt , Lo	0.1	-1	0.1
1				