TECHNICAL REPORT

Pre-Design Investigation Work Plan

West Lot Site - Utica
Oneida County, New York

September 1998

BBL
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1. Introduction

This document presents a plan for conducting pre-design investigation activities at the West Lot Site (referred to hereafter as "the site") located in Utica, New York. The site is currently listed as a Class 2 site on the New York State Registry of Inactive Hazardous Waste Sites (Site No. 633036). Numerous environmental studies have been conducted in connection with the site to characterize the nature and extent of affected media, evaluate remedial alternatives, and assess the risk to human health and the environment posed by site-derived constituents identified in site soil and ground water. These studies are summarized in Table 1. In March 1998, New York State Department of Environmental Conservation (NYSDEC) released a Record of Decision (ROD) that presented the selected remedial action for the site. The selected remedy generally consists of removing and treating an area of affected soils referred to as the "burn pit" and extracting and treating affected ground water emanating from this area. The selected remedy also contains a provision for evaluating the quality of ground water in the bedrock beneath the site. This work plan identifies the additional data required to design the ground-water extraction system and assess the quality of ground water in the bedrock beneath the site as specified in the ROD, and describes the field work that will be conducted.

2. Design Investigation

A design investigation will be conducted to collect the data required to design a ground-water extraction system and evaluate the quality of ground water in bedrock beneath the site to meet selected ROD-remedy requirements. The necessary data consist of field-derived hydraulic response data and water-quality data that will be collected during steady-state pumping of the kame aquifer beneath the site and will be used to:

- Estimate the limits of the capture zone developed by the pumping well;
- Estimate the specific capacity, maximum sustained yield, and appropriate pumping rate of the pumping well;
- Estimate the transmissivity and storativity for the aquifer; and
- Evaluate the quality of ground water collected by the pumping well and the quality of ground water in the bedrock beneath the site.

The design investigation will consist of the following activities:

- Pumping Well and Monitoring Well Installation;
- Well Development and Specific Capacity Testing;
- Pumping Test Implementation; and
- Pumping Test Data Evaluation.

The field activities will be performed by Blasland, Bouck & Lee, Inc. (BBL), and will be completed in accordance with the existing Sampling and Analysis Plan (SAP; BBL, May 1994), which consists of a Quality Assurance Project Plan (QAPP), Field Sampling Plan (FSP), and Health and Safety Plan (HASP). Those aspects of the design investigation that are not addressed by the existing SAP are covered in the SAP addendum that comprises Appendix A.

2.1 Pumping Well and Monitoring Well Installation

2.1.1 Purposes

The purposes of the well-installation program are to:

- Provide a pumping and head-monitoring system to use during an aquifer pumping test to gather the data required to design the ground-water extraction system; and

- Facilitate collection of ground-water samples from the bedrock beneath the site.

The focus of the pumping and head-monitoring system is the 25 to 35-foot thick sand and gravel (kame) deposit. The water table is at a depth of approximately three to eight feet, within the upper portion of the kame deposit. The kame is bounded at the bottom by an approximately ten-foot thick, dense layer of till. BBL has reviewed available geologic and hydraulic data for the site and determined an appropriate location for the pumping well, and locations where additional monitoring wells will be installed to complete the head-monitoring array based in these data (Figure 1). The location of the pumping well was determined through work performed by BBL as part of the Feasibility Study Report Supplement (BBL, 1998). This work suggested that a single pumping well, located downgradient of the burn pit and along the VOC-plume axis, might be adequate to accomplish the goals of the ground-water extraction system described in the ROD. The locations of the new sand-and-gravel monitoring wells were selected to fill data gaps in the site head-monitoring array.

To evaluate the quality of ground water in the bedrock beneath the site, one monitoring well will be installed in the bedrock, downgradient of the burn pit (Figure 1).

2.1.2 Field Methodology

Pumping-Test Monitoring Wells

Monitoring wells will be installed at key locations near the pumping well to provide hydraulic-response data during the pumping test (Figure 1). The design and installation methods used for the new monitoring wells will be consistent with those used for the existing site monitoring wells located near the downgradient site property line. Monitoring wells will consist of two-inch I.D. polyvinyl chloride (PVC) screens and risers. Screen lengths will be ten feet and screened intervals will generally span from the water table to ten feet below the water table. The screened interval of the borehole annulus will be filled with a appropriately-sized sand pack that extends to two feet above the top of the screen. A two-foot thick bentonite seal will be placed above the sand pack, followed by cement and/or bentonite grout to grade. Each new monitoring well will be completed above ground surface with a lockable protective casing set in concrete. If necessary, monitoring wells may be installed flush with the ground surface with a protective cover.

Bedrock Monitoring Well

The bedrock monitoring well will be installed and constructed in the same manner, and using the same materials as the pumping-test monitoring wells described above with the following exceptions:

- Larger augers (six-and-one-quarter inch I.D.) will be used to advance the borehole to the top of competent bedrock. The top of competent bedrock will be defined as the depth of auger refusal.

- A five-and-seven-eighths inch diameter roller bit will be used to advance the boring an additional two feet ahead of the augers into competent rock forming a "rock socket".

- A permanent, four-inch I.D. steel casing will be grouted into the rock socket using cement/bentonite grout. The augers will be subsequently removed.

- After the grout has been allowed to set (24 hours minimum), drilling will be continued using a HX/HQ-sized core barrel. Retrieved core will be logged by the BBL hydrogeologist and retained for future reference.

- The borehole will be advanced to a depth of 30 feet below the top of competent bedrock.

- The monitoring well will consist of a 20-foot long screen, set at the bottom of the boring. The sand pack will extend two feet above the screen top, and the bentonite seal will extend from the sand-pack top to at least one foot above the bottom of the permanent steel casing. The annular space above the seal will be filled with cement/bentonite grout.

Pumping Well

For installation of the pumping well, a pilot hole will first be drilled at the proposed well location using 4-1/4" I.D. hollow stem augers. The purpose of the pilot hole is to facilitate collection of formation samples for grain-size-distribution (sieve) analysis. These analyses will be used to select the appropriate slot size for the pumping-well screen. The samples will be collected using 2" O.D. split-spoon sampler at five-foot intervals, beginning at the water table and ending at the base of the aquifer, at the top of the till. Sieve analyses will be performed on each sample recovered according to ASTM D422-63 (re-approved 1990).

Once the pumping-well screen has been sized and delivered to the site, the pilot hole will be reamed to the base of the aquifer using 8-1/4" hollow-stem augers. The pumping well will screen the entire saturated thickness of the kame aquifer (approximately eight to 38 feet below grade). The screen slot size and filter-pack size will be selected based on the results of the sieve analyses described above, according to the method presented in Driscoll (1986). Based on available subsurface data, it is anticipated that the well will be constructed of a six-inch I.D., stainless-steel screen coupled to a Schedule 80 PVC riser; however, a final determination will be made following the pilot hole is advanced. The screen will be enveloped in a filter pack that extends two feet above the screen. A bentonite seal will be emplaced above the filter pack and will extend to a depth of two feet below grade. The remaining annular space will be filled with cement.

Decontamination and Disposition of Investigation-Derived Waste

Drilling tools that come in contact with subsurface soils or ground water will be decontaminated according to the procedures contained in the existing SAP. Similarly, investigation-derived wastes will be handled and disposed in a manner consistent with the existing SAP, except ground-water produced by the pumping well. This water will be contained, and subsequently routed to the existing ground-water treatment system. Settled solids will be disposed in the same manner as drilling cuttings derived from installation of the pumping well.

Surveying

The new pumping well and monitoring wells will be located by survey with respect to the existing site coordinate system. Vertical survey control will also be established for the ground surface and the top of riser at the pumping well and each new monitoring well. Surveying will be performed by a New York State licensed surveyor.

2.1.3 Data Analysis, Usage and Presentation

The pumping well and monitoring well construction details and survey coordinates will be added to the existing hydrogeologic database for the site to facilitate the compilation and depiction of the data obtained during the pumping test described in Section 2.3. The well construction data will be presented in Design Investigation Report described in Section 2.4.

2.2 Pumping Well and Monitoring Well Development/Specific-Capacity Testing

2.2.1 Purpose and Objectives

The new pumping well and monitoring wells will be developed to improve their hydraulic connection to the formation. Following development, specific capacity tests will be performed at each new monitoring well to estimate the hydraulic conductivity of the formation in the vicinity. The objectives of well development will be to remove fine sediment from the well, produce sediment-free discharge water, and increase the yield of the pumping well to the degree practicable. The specific capacity test objectives will be to pump each monitoring well at a relatively constant rate for a period of approximately 1 hour and obtain periodic water-level measurements at the pumped monitoring well to allow hydraulic-conductivity estimation.

2.2.2 Field Methodology

BBL anticipates that development will be performed by gently surging the wells using an appropriate surge block or bailer, and/or purging using either a bailer or pump; however, the pumping-well methodology may be modified if formation samples and observations made during drilling suggest that another development method (e.g., jetting) would be more appropriate. Development at each well will be considered sufficient when the turbidity of the purged water has been reduced to the extent practicable, and a minimum of five well volumes has been removed. Detailed well-development procedures are presented in the existing SAP.

Specific capacity tests will entail pumping each new monitoring well at relatively constant rate and measuring the drawdown inside the tested monitoring well. To optimize the efficiency of data acquisition, specific capacity tests can be performed at the end of monitoring-well development. Each specific capacity test will be performed until the either the drawdown in the tested monitoring well has achieved steady state, the monitoring well has been pumped for up to one hour, or the monitoring well has been pumped dry. Specific capacity tests will be performed in accordance with the procedures specified in Appendix A.

2.2.3 Data Analysis, Usage, and Presentation

The specific capacity test duration, the test pumping rate, the measured drawdown, and the geometry of the well intake section will be used to estimate the hydraulic conductivity of the formation surrounding the monitoring well screens based on the method of Walton (1962). Specific capacity test results are considered more reliable than slug test results for estimating hydraulic conductivity, and may approach the accuracy of pumping tests (Rovey and Cherkauer, 1995). The hydraulic conductivity data deduced from specific capacity test results will be used to refine the current understanding of the hydraulic-conductivity distribution in the area downgradient of the burn pit.

2.3 Pumping Test Implementation

2.3.1 Purpose and Objectives

Following the development and specific-capacity testing activities a step-drawdown (step) test and a comprehensive, constant-rate pumping test will be performed to empirically test the hydraulic effectiveness of the pumping well.

The purpose of the step test will be to determine the optimum discharge rate for the constant-rate pumping test. The step test will have the following data-acquisition objectives:

- Pumping rate needed to carry out the constant-rate pumping test;
- Efficiency and specific capacity of the new pumping well; and
- A preliminary estimate of the hydraulic conductivity of the aquifer.

The purpose of the pumping test will be to provide an empirical demonstration of the hydraulic influence that can be achieved during pumping of the well. The pumping-test objectives will be to pump the new well for a sufficient duration to:

- Measure the transient hydraulic response and the empirical, steady-state pumping rate and hydraulic-head distribution within the formation during pumping;
- Approach steady-state head and flow conditions; and
- Identify the effects of gravity drainage of the unconfined formation.

Detailed pumping-test procedures are presented in the SAP Addendum included in Appendix A.

2.3.2 Field Methodology

The step test will involve pumping the new pumping well at successive increments with increasing pumping rates, and monitoring the drawdown in the pumping well. In addition, to provide an initial assessment of the hydraulic influence produced in the formation during pumping, water-levels will also be monitored at nearby monitoring wells. Based on existing site information, it is anticipated that the step test will consist of four steps, lasting approximately one hour each. The actual number of steps and the pumping rate for each step may be modified based on observations made during installation and development of the pumping well. The step test will be used to establish the initial pumping rate for the constant-rate pumping test. The step-testing procedures are discussed in detail in the SAP Addendum (Appendix A).

Immediately prior to the constant-rate test, an initial, comprehensive round of ground-water elevations will be obtained from essentially all accessible monitoring well near the site, including the newly-installed pumping well and monitoring wells. This data set will establish the initial pre-pumping head distribution which will be used to assess the hydraulic changes induced by pumping.

Pumping will then be started at the new pumping well. The pump will be operated at a relatively constant rate for a sufficient duration to approach or achieve steady-state head and flow conditions (72 hours minimum). The pumping rate will be monitored frequently for the first 24-hours and then at least twice per day for the remainder of the pumping test. Flow-rate measurements will be obtained using an in-line, totalizing flow meter.

Pressure transducers connected to automated data loggers will be installed in six monitoring wells located at various distances and directions from the pumping well (Figure 1) to automatically record the transient hydraulic response during pumping. One of the wells monitored using transducers (MW-3) will be situated at a sufficient distance from the pumping well to serve as a background monitoring location, which will record the overall regional hydraulic changes not caused by pumping. As barometric pressure and precipitation can also influence water levels in wells, these data will also be recorded to assess their potential influence on hydraulic conditions in the aquifer during the pumping test.

Periodically throughout the pumping test, the transducer data will be downloaded and evaluated graphically to assess whether the hydraulic effects of the pumping are approaching steady-state conditions. Steady-state conditions will be interpreted semi-quantitatively based on a comparison between the net head change recorded at the background monitoring location versus the remaining monitoring wells situated closer to the pumping well.

After 72 hours of pumping, and it has been determined that the test duration is sufficient, a final, comprehensive ground-water elevation measurement round will be obtained at essentially all accessible monitoring wells near the site. This data-measurement round will comprise the primary body of data that will be used to empirically demonstrate the hydraulic influence of the pumping well. Following the completion of the ground-water elevation measurement round, pumping will be terminated and transient recovery data will be obtained at the locations monitored using transducers. Recovery data will be obtained for a period of 24 hours at all the locations monitored using transducers.

Samples of water extracted from the pumping well during the constant-rate test will be periodically collected and submitted to the analytical laboratory for a variety of analyses. Three untreated ground-water discharge samples will be collected from a sampling port in the discharge line at the beginning, approximate midpoint, and end (just prior to discontinuing pumping) of the test. These samples will be analyzed for the following:

- VOCs detected in site ground water during the Remedial Investigation (bromomethane; cis-1,2 dichloroethene; ethylbenzene; tetrachloroethene; toluene; total xylenes; 1,1,1-trichloroethane; trichloroethene; and vinyl chloride);

- Naturally-occurring dissolved inorganics (calcium, iron, and manganese); and

- Five Day Biological Oxygen Demand (BOD_5), chloride, surfactants (methylene blue activated substances [MBAS]), total dissolved solids (TDS), and total suspended solids (TSS).

VOC data will be considered Level IV data, as defined in the existing QAPP; the remaining analytical data generated will be considered Level III. The analytical methods used to perform the analyses are contained in the following table:

VOCs	Inorganics	BOD_5	Chloride	MBAS	TDS	TSS
NYSDEC ASP* 95-1	SW-846 6010	EPA 405.1	EPA 325.3	EPA 425.1	EPA 160.1	EPA 160.2

*Analytical Services Protocol.

Sample handling and documentation will be performed in general accordance with the procedures specified in the existing SAP. The analytical data detection limits for VOCs are contained in the existing SAP. Detection limits, quality assurance/quality control information, and sample-preservation requirements for the remaining analyses are contained in Appendix A.

2.3.3 Data Analysis, Usage and Presentation

Step-Drawdown Test

Step test analyses may include, but will not necessarily be limited to the methods presented in Walton (1962 and 1985) and Driscoll (1986). The step-drawdown test results will be used to assess the pumping well efficiency and specific capacity, and will provide a basis to identify the appropriate pumping rate for the two-week pumping test. The step-drawdown test results will be presented in the Design Investigation Report (Section 2.4).

Constant-Rate Pumping Test

The two rounds of comprehensive ground-water elevation measurements obtained immediately prior to pumping and immediately prior to the completion of the constant-rate pumping test will be used to develop pre-pumping and during-pumping ground-water elevation contour maps, and during-pumping drawdown maps, for the kame aquifer. The drawdown maps will provide an empirical demonstration of the extent and magnitude of the pumping influence. The contours maps of ground-water elevations measured during pumping will empirically illustrate the approximate ground-water capture zone effected during pumping. These maps will be presented in the Design Investigation Report (Section 2.4).

The analysis of the transient hydraulic response data recorded by the transducers may employ, but will not necessarily be limited to one or more of the following:

- The Hantush partial-penetration method and/or Weeks partial-penetration method (as described by Javandel 1984);
- The Hantush - Jacob (1955) Method for leaky - confined aquifers; and
- The Theis (1935) or Cooper - Jacob (1946) Methods for confined aquifers.

Pumping- and recovery-test analysis software (e.g., Duffield and Rumbaugh, 1989) will be used to supplement and facilitate standard type-curve matching techniques. The transient hydraulic response data recorded in the aquifer using transducers will be used to estimate the aquifer transmissivity, storativity, and hydraulic conductivity near the pumping well. These results will be presented in the Design Investigation Report (Section 2.4).

The analytical results will be used to evaluate long-term treatment requirements for the extracted ground water, including the use of the existing air-stripper to treat water generated during full-scale operation of the ground-water extraction system. The analytical results will also be presented in the Design Investigation Report.

2.4 Design Investigation Report

Following completion of the field activities and receipt of analytical results, BBL will prepare a Design Investigation Report that will be presented as an Appendix to the Remedial Design Work Plan. The report will describe the field activities conducted, present all pertinent collected data, and contain a detailed evaluation of the pumping test data. The report will contain:

- Boring logs, well construction diagrams, survey coordinates, and elevation data for the new pumping well and monitoring wells;

- A discussion of specific-capacity, step-drawdown, and constant-rate test results that will include estimates of the specific capacity of the pumping well, the capture zone of the pumping well, and estimates of the transmissivity, hydraulic conductivity, and storativity of the kame aquifer;

- Pre-pumping and during-pumping ground-water elevation contour maps, and during pumping drawdown maps for data collected during the constant-rate pumping test; and

- An evaluation of the ground-water quality data collected.

This design information will be used to develop a basis of design for the ground-water extraction system. The basis of design will be presented in the Remedial Design Work Plan.

3. References

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Table

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Table 1: Summary of Previous Site Investigations
Dunn Geoscience Corporation, Soil Gas Investigations, General Electric Company, French Road Site, City of Utica Area (Albany, New York: April 12, 1990). O'Brien & Gere Engineers, Inc., Site Assessment, General Electric Aerospace, West Lot, French Road Facility, Utica, New York (Syracuse, New York: May 1991). O'Brien & Gere Engineers, Inc., Focused Remedial Investigation, General Electric Aerospace, West Lot Site, General Electric Company, Utica, New York (Syracuse, New York: July 1992). ERM-Northeast, French Road Facility, Hydrogeological Investigation (Syracuse, New York: October 23, 1992). O'Brien & Gere Engineers, Inc., West Lot Site, Additional Investigations (Syracuse, New York: April 16, 1993). O'Brien & Gere Engineers, Inc., Work Plan - Interim Remedial Meausre, West Lot Site, Martin Marietta Coarporation, Utica, New York (Syracuse, New York: September 1993). Blasland, Bouck & Lee, Inc. Remedial Investigation Report - West Lot Site, Utica, New York. August 1995.

Figure

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Appendix A-1

Quality Assurance Project Plan Addendum

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TABLE A-1

ENVIRONMENTAL AND QUALITY CONTROL ANALYSES
WEST LOT SITE PUMPING TEST
UTICA, NEW YORK

Parameters	Analytical Method	Laboratory QA/QC			Field QA/QC		
		MS	MSD	MSB	DUP	Rinse Blank	Trip Blank
Volatile Organic Compounds (VOCs)	NYSDEC ASP 95-1	X	X	X	X	X	X
Dissolved Calcium, Iron, and Manganese	SW-846 6010	--	--	--	--	--	--
Biological Oxygen Demand (BOD)	EPA 405.1	--	--	--	--	--	--
Chloride	EPA 325.3	--	--	--	--	--	--
Surfactants (MBAS)	EPA 425.1	--	--	--	--	--	--
Total Dissolved Solids (TDS)	EPA 160.1	--	--	--	--	--	--
Total Suspended Solids (TSS)	EPA 160.2	--	--	--	--	--	--

<u>Notes:</u>
QA/QC - quality assurance/quality control
MS - matrix spike
MSD - matrix spike duplicate
MSB - matrix spike blank
DUP - field (blind) duplicate
-- - not applicable
Field duplicates and rinsate blanks will be taken at a rate of 1/20; trip blanks at a rate of one per day.

TABLE A-2

SUMMARY OF WATER SAMPLE PRESERVATION, CONTAINER SPECIFICATIONS, AND LABORATORY HOLDING TIMES
WEST LOT SITE PUMPING TEST
UTICA, NEW YORK

Parameter	Method	Sample Container (s) (a)	Chemical Preservative (b)	Holding Time (c)
Volatile Organic Compounds	NYSDEC ASP 95-1	40-ml VOA Vials (2)	1:1 HCL to pH<2	14 days
Dissolved Calcium, Iron, and Manganese*	SW-846 6010	500-ml plastic	1:1 HNO3 to pH <2	6 mos.
BOD	EPA 405.1	1 L plastic or glass	None	48 hours
Chloride	EPA 325.3	250 ml plastic	None	28 days
Surfactants (MBAS)	EPA 425.1	250 ml plastic	None	48 hours
Total Dissolved Solids (TDS)	EPA 160.1	250 ml plastic (d)	None	7 days
Total Suspended Solids (TSS)	EPA 160.2	250 ml plastic (d)	None	7 days

Notes:

* Must be filtered prior to preservation.
(a) Sample containers will be of demonstrated cleanliness.
(b) Samples will be cooled to approximately 4 degrees Celsius.
(c) Starts from verified time of sample receipt.
(d) Only one 250-ml plastic bottle is required to perform both the TDS and TSS analyses.

TABLE A-3

ESTIMATED DETECTION LIMITS

WEST LOT SITE PUMPING TEST
UTICA, NEW YORK

Parameters	Estimated Detection Limit (ug/L)
Dissolved Calcium	21
Dissolved Iron	6
Dissolved Manganese	1
BOD	3000
Chloride	1000
Surfactants (MBAS)	100
Total Dissolved Solids (TDS)	5000
Total Suspended Solids (TSS)	500

Appendix A-2

Specific-Capacity Test Procedures

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APPENDIX A-2

Specific-Capacity Test Procedures

I. Introduction

Specific-capacity testing is a field method used to estimate the transmissivity of a saturated geologic medium surrounding the screened or open interval of a well. A specific-capacity test involves pumping ground water from a well at a constant rate and quantifying the pumping rate and the magnitude of drawdown inside the tested well after a known duration of pumping. Specific-capacity tests are also referred to as single-well pumping tests.

The transmissivity is calculated based on the observed test pumping rates, the drawdown measured immediately before the end of pumping, the pumping duration that preceded the drawdown measurement, the effective radius of the well, and the estimated storativity of the formation. If the thickness of the effective water bearing zone transmitting ground-water to the well intake is assumed to be approximately equal to the length of the intake, the hydraulic conductivity can be estimated by dividing the transmissivity by the length of the intake.

II. Materials

- a pump (preferably submersible) capable of pumping at a controlled rate between a fraction of one gallon per minute and 10 gallons per minute, equipped with discharge line;
- a power source for the pump;
- a calibrated in-line totalizing flow meter or two calibrated buckets;
- a stopwatch; and
- an electronic water-level indicator.

III. Pre-Test Set-Up

Prior to the installation of the pump into the well to be tested, the static water level inside the well is measured to the nearest 0.01 feet relative to a specified datum at the top of the well using the electronic water-level indicator. The water level and the time of the measurement are recorded in the field notebook.

The water level is measured again several minutes after the initial measurement. This measurement and time are recorded. This procedure is repeated until two consecutive measurements are identical, indicating approximately static conditions. The static depth to water is recorded, as is the depth to water corresponding to a drawdown of 3 feet. The drawdown measured inside of the tested well during a specific capacity test should not exceed a few feet because excessive drawdown promotes inefficient flow to the well ("well loss") imparting error to the transmissivity calculation.

The pump is installed in the well to approximately 5 feet below the static water level, or within 1 foot of the bottom of the well if the initial water column in the well is less than 6 feet. After the pump is installed but prior to pumping, the water level in the well is monitored until it has returned to within 0.01 feet of the static water level.

VI. Test Procedures

The specific capacity test is performed as follows:

1. Hold the water level probe in the well just above the static water level. If an in-line totalizing flow meter is used, record the pre-test volume measurement in the field notebook. If no in-line flow meter is available, place the end on the discharge line in one of the two calibrated buckets. Record the total volumetric capacity of each bucket.
2. Simultaneously start the pump and the stopwatch. Record the start time.
3. Immediately begin monitoring the water level in the well. If the drawdown rapidly approaches or passes the maximum suggested drawdown of 3 feet, quickly reduce the pumping rate until the drawdown is approximately 0.5 to 1.0 feet. All pumping rate adjustments should be completed within one or two minutes of pumping, after which no adjustment should be made other than minor adjustments that may be necessary to maintain a steady pumping rate.
4. Continue to pump for at least 20 minutes, recording the water level in the well approximately every 2 minutes throughout the test. If an in-line flow meter is used, record the volume measurement on the totalizer gauge approximately every 2 minutes during the test. If calibrated buckets are used to measure the pumping rate, record the time at which the bucket reaches its known, recorded volumetric capacity. Transfer the discharge line to the other (empty) calibrated bucket and record the time when it becomes full. Repeat this procedure for the duration of the test.

5. The specific capacity test is complete after at least 20 minutes of pumping have elapsed. A longer pumping period is not necessary to estimate transmissivity from the test. However, if practicable, a longer test may provide a slightly more reliable transmissivity estimate. Immediately before the termination of pumping, record final water level measurement plus the time of the measurement.

9. Calculate and record the total volume of ground water removed from the well during the test, and the total duration of the test. Divide the total volume (in gallons) by the total pumping duration (in minutes) to calculate and record the average test pumping rate (in gallons per minute).

V. Specific Capacity Test Data Reduction

Data from a specific capacity test are reduced to a transmissivity estimate for water-bearing formation surrounding the intake of the tested well by entering them into a specific capacity test data reduction spreadsheet program (QSTRANS) developed at Blasland & Bouck Engineers, P.C. QSTRANS iteratively solves for the value of transmissivity in the equation (Walton 1962):

$$Q/s = T / [264 \log(Tt/2693r_w^2S) - 65.5],$$

where Q/s is the specific capacity of the well in gallons per minute per foot, Q is the average test pumping rate in gallons per minute, s is the drawdown measured inside of the tested well after a known duration of pumping (t), T is the transmissivity of the water-bearing zone surrounding the intake of the tested well, S is the estimated storativity of the aquifer, r_w is the effective radius of the well, and t is the time in minutes between the start of pumping and the time when the drawdown was measured. If the well screen is surrounded by a sand pack that may be assumed to be substantially more permeable than the formation, the effective radius of the well is taken to be that of the borehole.

The value of S may be estimated without introducing serious error into the results. For confined aquifers, S should be estimated as 0.0001. For unconfined aquifers, the short-term storativity may be comparable to that of a confined aquifer. Only after a protracted pumping duration (several hours or more) does the storativity begin to approximately the aquifer specific yield of approximately 0.2 to 0.3 (Nwankwor et al., 1984). In the calculation of transmissivity from a specific capacity test of less than one hour duration, therefore, an estimated storativity value of 0.01 should be entered into QSTRANS.

To obtain an estimate of the hydraulic conductivity of the water-bearing zone that transmits ground-water to the well, the calculated transmissivity value may be divided by the estimated thickness of the water-bearing zone. In a stratified formation in which the horizontal hydraulic conductivity may be expected to greatly exceed the vertical hydraulic conductivity, the thickness of the water-bearing zone may be estimated as the length of the well intake to obtain an estimate of the hydraulic conductivity immediately surrounding the well intake.

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Appendix A-3

Step-Test and Constant-Rate Test Procedures

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APPENDIX A-3

Step-Test and Constant-Rate Test Procedures

I. Introduction

A pumping test entails removing ground water from a pumping well and measuring the change in fluid levels in the pumping well and, if possible, in one or more other (observation) wells proximal to the pumping well. Pumping rate and fluid-level data gathered during a test are used to characterize the aquifer parameters to evaluate the potential for contaminant transport and help design a remedial measure, if applicable.

A step-drawdown test of limited duration is implemented to identify a suitable pumping rate for the drawdown portion of the actual pumping test.

II. Materials

The following materials and equipment will be available, as needed, for use during completion of the pumping test:

- Submersible pump equipped with check valve and discharge line;
- In-line totalizing flow meter or calibrated bucket;
- Generator (if electric power source is not available);
- Supply of fuel for generator;
- Several water level probes (number depending on site);
- Oil-water interface probe(s) for separated-phase hydrocarbon (SPH) sites;
- Data logger and pressure transducers;
- Barometer (if nearby weather-station data are unavailable);
- Aquifer test data sheets;
- Field notebook;
- Flashlights;
- Stopwatches;
- Engineer's scale rulers;
- Suitable protective clothing and gear (as specified in the Health & Safety Plan);
- Extension cords;
- Equipment cleaning supplies; and

- Clean 55 gallon steel drums, other suitable containers, or ground-water treatment system (if needed).

III. Step-Drawdown Testing

Step-drawdown testing will be conducted to determine the pumping rate required to stress the aquifer without causing the pumping well to go dry. The step-drawdown test is implemented by pumping the well at several successively higher pumping rates, each for the same duration, and recording the increased depth to water (drawdown) inside the pumping well. From the step-drawdown test, general aquifer properties can be estimated and used to identify an appropriate pumping rate for the subsequent pumping test.

IV. Pumping Test Procedures

1. Select an array of observation wells at various distances from the pumping well, including one or more wells distant from the pumping well. These distant wells indicate the "background" fluctuations of the aquifer during the test. Alternately, if only wells proximal to the pumping well are available, water levels data may be obtained several times per day for a few days prior to the pumping test to determined the background trend of water-level changes.
2. Decontaminate all equipment prior to the test according to the protocol contained in the existing Sampling and Analysis Plan (SAP; BBL, May 1994)
3. Measure water levels in all of the wells in the pumping-test monitoring array including the pumping well immediately before beginning the drawdown phase of the test according to the water-level monitoring procedures contained in the existing SAP.
4. Prepare water-level monitoring equipment to be operational when pumping is initiated. The following water-level recording frequency will apply if manual, electronic water-level probes are used:

Time Interval	Approximate Recording Frequency
0 to 10 minutes	every 30 seconds
10 to 20 minutes	every minute
20 to 30 minutes	every two minutes
30 to 100 minutes	every five minutes
100 to 200 minutes	every 10 minutes
200 to 400 minutes	every 30 minutes
400 to 1440 minutes	every hour
1440 to end of test	every eight hours

5. If automatic transducers/data loggers are used to record water levels, data can be recorded more frequently. Transducers should be matched with wells appropriately such that the full range of

potential drawdown can be monitored without placing the transducer at an inappropriate initial depth. The depth of a transducer below the top of fluid in the well should be less than 2.31 times the transducer PSI rating, in feet. Following transducer installation, obtain a transducer reading using the data logger to ensure proper transducer connection and installation depth, plus a manual water level measurement for cross-referencing water-level fluctuations recorded by the transducer during the pumping test. Prepare the datalogger to initiate data acquisition from all transducers at the instant pumping begins.

6. A pumping test typically consists of a pumping, or drawdown, phase and a recovery phase. Initiate the drawdown phase of the pumping test by starting the pump at the pumping test discharge rate (Q) identified based on the step-drawdown testing results. Monitor the discharge rate according to the same schedule listed above for manual water-level measurements. Adjust the pumping rate as needed to maintain as constant a discharge rate as possible. Record all pumping-rate data and adjustments.

7. For each well monitored using a manual water-level indicator, record the following data: clock time, depth to water, and initials of person taking measurement.

8. At each well monitored using transducers, several manual water-level measurements should also be obtained daily to verify proper calibration of the transducers.

9. If barometric-presssure data from a nearby weather station are not available, record barometric pressure from the site barometer every six hours for the duration of the test.

10. Terminate the drawdown phase after sufficient data has been acquired to adequately characterize the aquifer parameters and boundary conditions, typically after 24 hours to one week of pumping.

11. At the instant the pump is shut off, commence the recovery phase data acquisition by recording water level data according to the same measurement frequency used during the drawdown phase. The recovery phase should continue until the water level in the pumping well has recovered approximately 75% of the drawdown incurred during pumping.

12. Decontaminate all equipment at the end of the test according to protocol contained in the existing

SAP.

V. Data Analysis

Several methods of data interpretation may be used to estimate aquifer properties from a pumping test. The assumptions and limitations pertaining to each method of data analysis and the site-specific geology must be carefully considered to select an appropriate method of analysis. Prior to use in parameter calculations, drawdown and recovery data should be corrected for background water-level changes. Background fluctuations data may be obtained from a distant observation well or deduced from a period of water-level monitoring prior to the initiation of the pumping test. Corrections for fluctuations in barometric pressure should be applied to drawdown and recovery data as appropriate.

Water-level data obtained from a test in an unconfined aquifer may be used to estimate the aquifer transmissivity and short-term storativity by the Neuman (1975) method. Alternately, the drawdown data may be modified by the Jacob (1944) correction for plotting and analysis according to the methods listed below for confined aquifers. Long-term storativity, or specific yield, of an unconfined aquifer may be underestimated using the Neuman method or the confined-aquifer methods. The specific yield of an unconfined aquifer is best evaluated, therefore, by calculating the ratio of the total volume of water pumped during the drawdown phase to the total volume of aquifer material dewatered, or the "cone of depression" (Nwankwor et al., 1984).

Data from a pumping test in a confined aquifer may be plotted and analyzed according to the methods of Theis (1935) or Cooper & Jacob (1946) to calculate the transmissivity and storativity of the aquifer. Data from a test in a leaky-confined aquifer may be plotted and analyzed according to the Walton (1962) or Hantush-Jacob (1955) method aquifer analysis may be used to calculated the aquifer transmissivity and storativity as well as the aquitard leakance.

VI. References

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