Task 2 Supplemental Characterization Report

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Prepared by
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Executive Summary

This Phase 2 Task 2 Supplemental Characterization Report presents the results of additional investigations into the groundwater systems underlying the Connecticut Yankee Atomic Power Co. (CYAPCO) Haddam Neck Plant (HNP). These investigations address tasks developed in the Phase 2 Hydrogeologic Investigation Work Plan (Malcolm-Pirnie, 2002) and data needs identified in the Phase 2 Hydrogeologic Characterization Work Plan Task 1 Summary Report (CH2M HILL, 2004).

The Task 2 supplemental characterization provides a basis for refining the hydrogeologic conceptual site model. The conceptual site model describes how groundwater moves beneath the site and how it interacts with surface water, soil and bedrock, and site-related contaminants. The overall site characterization data will also be used to support development of a numerical flow simulation that will be used to describe, and, to the extent reasonable, predict the movement of groundwater beneath the site. The simulations will support remedial action decisions and design of the final status groundwater monitoring system.

Characterization Activities Described in This Report

The following supplemental characterization activities have been performed and are described in this report:

Bedrock Aquifer Characterization

- Packer testing of six bedrock boreholes (BH-118, BH-118A, BH-119, BH-120, BH-121, BH-121A) in 2003
- Geophysical logging of four bedrock boreholes (BH-118A, BH-119, BH-120, BH-121A) in 2003
- Supplemental packer testing of one borehole (BH-121A) in 2004
- Down-hole video logging of four bedrock boreholes (BH-118A, BH-119, BH-120, BH-121A) in 2004
- Hydrophysical logging of four bedrock boreholes (BH-118A, BH-119, BH-120, BH-121A) in 2004

Long-term Water Level Monitoring

- Assessment of hydrographs for 29 monitoring wells for the period from January through August 2004
- Assessment of hydrographs for the Connecticut River for the period from January through August 2004

- Assessment of responses to on-site precipitation, tidal fluctuation and river stage of the Connecticut River, and on-site pumping activities

Repair and Maintenance of Monitoring Wells

- Well repairs
- Abandonment of unneeded and unusable wells

Performance of an Aquifer Pumping Test

- Seventy-two-hour constant rate aquifer test in new well
- Monitored drawdown response in surrounding wells using pressure transducers

Observations and Conclusions

The following observations and interpretations were made as a result of characterization activities:

1. The aquifer in the fractured bedrock underlying the site exhibits the following features:
   - An upward hydraulic pressure differential at depth in the area near the Connecticut River. This is consistent with the function of the river as a discharge boundary for groundwater as well as surface water as described in the preliminary hydrogeologic conceptual site model.
   - Most flow in the fractured rock aquifer occurs within the upper 150 feet of the bedrock formation.
   - Screening analyses for tritium concentration in groundwater within the fractured rock aquifer indicate that tritium is not present deep within the bedrock aquifer.
   - Packer sampling screening analyses for Sr-90 concentrations in groundwater in deep bedrock borehole 121A did not identify Sr-90 within the bedrock aquifer, except for one detection that appears to be a false positive (see Appendix 3, Offsite Laboratory DQA).
   - Water level monitoring in on-site wells indicates that bedrock fractures at depth are hydraulically connected between the inland portions of the industrial area and the bedrock boreholes near the river. This indicates a pathway for migration of site contaminants into and through the bedrock.
2. Long-term water level monitoring at the site reveals the following observations:
   - Three aquifer systems are identified at the site; a surficial unconsolidated formation aquifer, a shallow fractured bedrock aquifer, and a deep fractured bedrock aquifer.
   - Tidal fluctuations in river stage of the Connecticut River are expressed to varying degrees at numerous locations across the site.

- While tidal fluctuations are discernable at many locations, the tidal impacts do not cause major changes (i.e., gradient reversals) in the overall groundwater flow patterns in the aquifer units identified.
- Water elevations in portions of the industrial area inland from the river are more directly responsive to local rainfall than those in areas closer to the river, while water elevations in the near-river areas are more directly responsive to changes in the river stage.
- The effects of operation of the containment building foundation mat dewatering sump (mat sump) on water elevations are observable over a fairly large portion of the central industrial area, and in all three aquifers.

3. The nature of the unconsolidated deposits aquifer in the HNP industrial area has been more fully characterized by the test well installation in the study area. Evaluation of the pumping test in the unconsolidated deposits aquifer and the proposed tests in the bedrock aquifer will generate reliable estimates of hydraulic properties in the respective aquifer systems including:
    - Hydraulic Conductivity
    - Transmissivity
    - Storativity

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Acronyms and Abbreviations

API	American Petroleum Institute
bgs	below ground surface
CEC	cation exchange capacity
CSM	conceptual site model
CYAPCO	Connecticut Yankee Atomic Power Co.
DI	de-ionized
DTW	depth to water
EPA	Environmental Protection Agency
FRes	fluid resistivity
FTemp	fluid temperature
gph	gallons per hour
gpm	gallons per minute
HNP	Haddam Neck Plant
HPL	Hydrophysical logging
HTD	Hard-To-Detect
LSC	liquid scintillation counting
LTP	License Termination Plan
MCL	maximum contaminant level
MDC	Minimum Detection Concentration
MDL	Minimum Detection Limit
MSL	mean sea level
PAB	primary auxiliary building
pCi/L	picocuries per liter
RCB	reactor containment building
SOC	substances of concern
TD	total depth
TEDE	Total Effective Dose Equivalent
TOC	top of casing
TPU	total propagated uncertainty

SECTION 1

1 General Overview

A series of specific recommendations for additional data collection and groundwater monitoring system maintenance activities was defined in the Task 1 Summary Report (CH2M HILL, March 2004) based on the project needs and the quality and quantity of existing information. The recommendations in the Task 1 Summary Report are focused on data collection and actions to support site closure decisions. Section 1 summarizes the purpose of the Task 2 Supplemental Characterization Report, outlines the additional groundwater related data collection and groundwater monitoring system maintenance needs documented in the Task 1 Summary Report, and identifies the status of those data collection tasks.

1.1 Purpose

Task 2 data will be used to refine the conceptual site model (CSM), support construction of a numerical flow simulation model to estimate future groundwater flow pathways and determine post-closure monitoring locations at the plant. The estimated future concentrations will be compared to site closure criteria to evaluate the time required to achieve closure under natural attenuation conditions and to assess the potential need for groundwater remediation.

Task 2 groundwater monitoring system maintenance activities are to assess, remediate, or replace groundwater monitoring wells that have inadequate seals and construction, to abandon unnecessary monitoring wells, and to upgrade the monitoring well system as necessary to support data collection activities required to achieve closure.

1.2 Task 2 Supplemental Activities Identified in the Task 1 Summary Report

Task 2 supplemental activities identified in the Task 1 Summary Report are detailed below. The objectives and status of each activity are discussed, and the path forward detailed.

1.2.1 Documentation of Preferential Pathways Exposed During Demolition Activities

Continued definition of preferential pathways is part of the overall strategy for refining the current understanding of site conditions and updating the CSM at HNP. Demolition of existing buildings and structures is ongoing, currently bedrock is exposed in the tank farm tent excavation, and will soon be uncovered in the excavation between the primary auxiliary building (PAB) and the reactor containment building (RCB). These and other excavations are likely to expose backfill and blast-fractured bedrock areas which may be significant preferential pathways located near contamination sources and/or groundwater plumes. Recording and mapping of visual observations of preferential pathways exposed during demolition work was identified as a task 2 activity. Visual observations of preferential pathways are being recorded and will be mapped to delineate these features and evaluate any possible impact to the aquifer systems.

1.2.2 Identification of Contaminant Migration Pathways

The pathways by which site groundwater contaminants have migrated from the near-surface groundwater and points of release into the deeper bedrock formation aquifer were not clearly defined. In order to understand the contaminant transport mechanisms sufficiently, it is necessary to identify, and to the extent possible, quantify the mechanism(s) of vertical contaminant movement at this site.

The mechanisms that potentially affect vertical contaminant movement at the site include differential hydraulic heads, effectiveness of monitoring well seals, and vertical pathways associated with the operation of the mat sump which pumps from a deep bedrock excavation beneath the RCB.

Both the evaluation of the pressure differential records and the assessment of vertical pathways associated with the operation of the mat sump are discussed in Section 4 with analysis of the pressure transducer monitoring network hydrographs.

Vertical pressure differentials have been mapped with depth in BH-121A, and are discussed in Section 2.3, packer testing static pressure tests. In addition, evidence for vertical bedrock fractures as migration pathways and connectors of subhorizontal fractures in the bedrock is discussed in Section 3, borehole geophysics.

An evaluation of the effectiveness of groundwater monitoring well seals was conducted as part of the groundwater monitoring well maintenance and abandonment program to evaluate the monitoring wells potential as a conduit for vertical migration, and is discussed in Section 5-monitoring well system status.

1.2.3 Geologic Data Collection

Additional geologic observations and measurements at the industrial area was needed to provide further characterization of site conditions to refine the CSM. Confirmation of the nature and apparent extent of the shallow bedrock/interface zone, particularly in the industrial area, was needed to delineate preferential pathways and determine hydraulic connection between the shallow unconsolidated deposits and fractured bedrock aquifer systems. In addition, further characterization of transmissive bedrock intervals and their interconnection in existing deep boreholes was needed to resolve current data gaps concerning groundwater flow paths in deep bedrock. Task 2 activities identified to acquire these data include additional rock cores collected on the flanks of the former rock promontory to evaluate the presence of weathered rock and/or fracture density in this interval, and several options for geophysical surveys. These geophysical technologies mentioned for additional characterization at HNP focused on borehole applications, including hydrophysical logging, downhole camera logging, and colloidal borescope surveys.

Hydrophysical logging was conducted in open bedrock boreholes BH-118A, BH-119, BH-120, and BH-121A to determine transmissive intervals and relative flow rates by recording the fluid electrical conductivity profiles in a borehole filled with DI water under both ambient and stressed conditions. The hydrophysical logging clearly identified flow zones in the bedrock, and provided strong evidence for interconnection of these flow zones. Hydrophysical logging also provided estimates of transmissivity of these zones. A discussion of hydrophysical logging and the analysis of results are in Section 3, borehole geophysics.

Optical camera surveys were conducted in boreholes BH-118A, -119, -120, and -121A to visually inspect the boreholes and identify possible open fractures in the bedrock interval. A discussion of the optical camera survey results is in Section 3, borehole geophysics.

Additional characterization details concerning the unconsolidated deposits at the boundary of the bedrock were obtained from continuous split spoon samples collected during the aquifer test well installation. The preliminary data from the boring and aquifer test are discussed in Section 6, aquifer hydraulic properties characterization.

1.2.4 Aquifer Hydraulic Properties Data Collection

Characterization of the hydraulic properties data gaps is an essential component of the completion of Task 2 work elements. Estimates of hydraulic conductivity for the three primary aquifers are needed to complete groundwater flow modeling. Data to determine the impact of the mat sump and tank farm dewatering well operation on the site aquifer system is also needed to assess possible remedial actions for site closure. Task 2 activities previously identified to collect this information include:

- constant rate aquifer testing and variable rate (step) aquifer testing for calculation of estimated hydraulic conductivity values,
- connection evaluations in other wells during this aquifer testing,
- single well slug testing, and
- confirmation packer testing in borehole 121A.

An unconsolidated deposits aquifer test was conducted in natural deposits found in the southwest section of the industrial area. This test was performed to estimate hydrologic parameters of the hydrostratigraphic unit and to evaluate the possible hydraulic connection between the shallow unconsolidated deposits and the fractured bedrock system. Preliminary analysis of this data is discussed in Section 6, aquifer hydraulic properties characterization.

Supplemental single-well slug tests were not performed due to the uncertainty inherent to the slug test method in transmissive aquifers. The aquifer pumping test was conducted instead of additional slug tests.

Observations showing strong evidence for connections of zones in different wells have been made from hydrographs from various bedrock wells. These connections are interpreted from observations of time synchronous changes in water levels in wells distant from a bedrock well being pumped. Hydrographs are also being evaluated to assess seasonal fluctuations and general trends observed in water levels on site, as well as to assess drawdown, hydraulic conditions, and any impacts from pumping operations of the mat sump and tank farm dewatering wells. This information is discussed in Section 4.

In addition to packer testing conducted in 2003, confirmatory packer testing was conducted in borehole 121A to collect hydraulic data from discrete intervals in the fractured bedrock. Uncertainties in the tritium distribution identified by packer testing conducted in 2003 necessitated additional data be collected. Both packer testing campaigns are discussed in Section 2.

1.2.5 Well Maintenance Activities

Task 2 monitoring well maintenance activities consist of a review of available well records (e.g., boring logs, well construction diagrams, sampling and analyses records) to assess the adequacy of well construction and propose repairs, abandonment, and replacement of wells determined to not meet current well construction standards.

Monitoring well maintenance and abandonment activities are detailed in Section 5, monitoring well system status.

1.2.6 Geochemical Data

Geochemical Task 2 activities previously identified include:

- Analysis of archived soil samples for cation exchange capacity (CEC) and contaminant distribution coefficient (K_d) values. Also collection of new samples from identified source areas if further evaluation determined any need. As remediation plans developed, it has become clear that the contaminated soil represented by the archived soil samples will be excavated and removed from the site and replaced with clean fill. As a result, the additional CEC and K_d testing of that soil became unnecessary. The excavated soil will be replaced with engineered fill from off-site sources. Candidate fill soil has been subjected to testing to determine apparent K_d for target substances of concern.

- Collection and analysis of groundwater samples for major cation (calcium, magnesium, sodium, and potassium) and major anions (bicarbonate, sulfate, and chloride) in summer sampling event for assessment of general water quality conditions. Major ion analysis has been performed during the December 2003 and September 2004 sampling events. These results are discussed in the respective semi-annual groundwater monitoring reports.

- Analysis of groundwater samples for general geochemical indicator parameters such as pH, specific conductance, and TDS to visually compare background geochemical conditions against areas that show evidence of anthropogenic impacts. General indicator parameters have been measured at each quarterly groundwater monitoring event.

SECTION 2

2 Packer Testing

Packer testing has played a large role in characterization of the groundwater flow regime and apparent distribution of SOCs in the fractured bedrock underlying the Connecticut Yankee (CY) HNP. Two packer testing campaigns have been conducted and are discussed in the following sections.

2.1 Overview of Packer Testing at HNP

Packer testing at HNP was designed to identify hydraulically-active zones in the fractured bedrock, and to assess the vertical extent of SOCs so that a bedrock aquifer monitoring system could be designed. Packer testing methodology provides a means to isolate vertically-discrete intervals or zones of bedrock within a borehole, allowing water to be pumped from the isolated zone, and generating a representative sample of groundwater from fractures within the bedrock. The packer testing approach applied at HNP utilized a straddle packer assembly, so called because it uses two inflatable packers to isolate the borehole above and below a zone of interest, thus "straddling" the zone.

Six bedrock boreholes were drilled at HNP between January and August 2003 and tested using a straddle packer assembly. Of these six, four are located between the river and the industrial area (BH-119, BH-120, BH-121, and BH-121A), and two within the industrial area on the southeast end of the turbine building (BH-118, BH-118A) as shown in Figure 2-1. The six boreholes were tested in 2003 using a 23-foot packer isolation interval. After review of the 2003 results, the contaminant distribution (specifically tritium) was determined to be inconsistent with the apparent hydraulic properties of the bedrock (i.e., the sampling and analysis indicated a nearly uniform distribution of tritium throughout the borehole profiles).

Based on this anomalous contaminant distribution and the absence of pressure-sensing instrumentation on the 2003 packer assembly, a decision was made to retest one borehole using a different packer assembly and revised test approach. The subsequent packer testing campaign was conducted during 2004 in borehole 121A using a packer assembly equipped with data-logging pressure transducers above, within, and below the isolated interval. This second campaign confirmed that the anomalous tritium distribution observed in 2003 likely resulted from collection of non-representative groundwater samples. The 2004 sampling results indicated the presence of tritium in discrete zones within the rock, and not uniformly distributed throughout the borehole.

The 2004 packer testing campaign also confirmed the presence of an upward pressure differential in the deep bedrock. The observed pressure differential in the bedrock aquifer unit is consistent with the assumption that the Connecticut River forms a discharge boundary for shallow and deep groundwater beneath HNP in addition to serving and a surface water discharge boundary for the same area.

The scope, objectives, and results of the packer testing activities at HNP are discussed in the following subsections.

2.1.1 Scope of Packer Testing at HNP

Packer testing at HNP was limited to testing conducted over the drilled intervals of six bedrock boreholes. The 2003 packer testing campaign consisted of drilling and straddle packer testing two 4-inch diameter boreholes (BH-118 and BH-121), and four 6-inch diameter boreholes (BH-118A, BH-119, BH-120, and BH-121A). The switch to 6-inch diameter boreholes was to make installation and removal of the straddle packer assembly easier. The 2004 testing campaign was limited to testing of borehole BH-121A.

2.1.2 Objectives

The objectives for the 2003 packer testing campaign were as follows:

1. Identify the elevation of water bearing zones within the rock and to quantify the amount of water they transmit.
2. Assess the vertical distribution of SOCs through collection and laboratory analysis of representative samples.
3. Identify target zones for subsequent monitoring well installation for water quality monitoring.

The objectives of the 2004 packer testing campaign included the 2003 testing objectives, but were expanded to include the following:

1. Quantitatively determine the quality of the packer seal(s) at each interval tested to ensure collection of representative samples from isolated intervals.
2. Profile hydraulic head with respect to depth by measuring pressure head for specific zones or intervals and assessing head potential (i.e., upward, neutral, or downward) and pressure head differential (e.g., vertical gradients between zones).
3. Identify zones of fracture interconnection both vertically and laterally and, to the extent possible quantify the flow through these zones.

The packer testing effort at HNP was not meant to be a final assessment of chemical and hydrologic conditions within the fractured rock aquifer, as packer testing is a screening technology. The information gained from packer testing is being used to support the design of a groundwater monitoring system for the fractured bedrock aquifer.

2.2 2003 Packer Testing Campaign

The first packer study was conducted from January through November of 2003 in boreholes BH-118, -118A, -119, -120, -121, and -121A utilizing both 4-inch and 6-inch boreholes and packer assemblies. While originally designed solely to assess the vertical distribution of SOCs, modifications in the methodology utilizing a 6-inch borehole packer sampling approach allowed the collection of yield and discharge data as well. The results of sampling and analysis for tritium in deep bedrock groundwater from the 2003 campaign were rejected as non-representative due to an inability to confirm the lower packer seal during sampling and being inconsistent with the interpretation of bedrock hydrogeologic conditions and flow zones developed from the borehole geophysical logs conducted in the boreholes. The groundwater yield data in both shallow and deep bedrock as well as the tritium distribution in shallow bedrock were qualified as estimated based on the inability to verify packer seal during sampling. The 2003 packer study is detailed below.

2.2.1 2003 Campaign Methodology

At the start of the 2003 packer testing program, packer testing was conducted concurrently with the drilling of the 4-inch diameter boreholes to be sampled. Eight-inch diameter boreholes were advanced from the ground surface to contact with bedrock and extended approximately 5 feet into bedrock. Four-inch casings for the 4-inch boreholes were then grouted into the bedrock to form a "rock socket." The intent of the rock socket is to attempt to isolate or seal the borehole and the crystalline bedrock that it penetrates from the overlying unconsolidated aquifer system. The boreholes were then advanced by air rotary drilling methodology using a downhole hammer bit, uncased to depth. Initially, the drilling and sampling program followed the approach described in the Phase 2 Hydrogeologic Characterization Work Plan (Malcolm-Pirnie, 2002) of alternating drilling and packer sampling 20-foot sections of bedrock, but was modified as discussed below.

The first borehole drilled and tested, BH-121, was a 4-inch diameter borehole drilled 20 feet into bedrock beyond the end of the casing and rock socket. A 23-foot overall length packer assembly was then inserted into the boring and a groundwater sample was collected by pumping from the isolated interval. The borehole was then advanced another 20 feet and the process of inserting the packer and collecting a groundwater sample repeated. This alternating drilling and packer sampling technique that had been specified in the Phase 2 Work Plan was continued to the borehole's 200 foot total depth.

The second borehole, BH-118, followed the same technique to a depth of approximately 200 feet below ground surface (bgs). At that time, the decision was made to drill to the completion depth of the borehole, and packer sample from the bottom of the borehole, upward. This decision was made to accelerate the testing process by reducing the time required to insert and remove the packer system at each interval, and to reduce damage to the packer assembly due to repeated trips in and out of the borehole. BH-118 was subsequently drilled to a total depth of 400 feet, and packer sampled at 23-foot intervals starting at 395 feet bgs, and continuing upwards.

The 4-inch boreholes, BH-121 and BH-118 were packer sampled with packers designed for a 4-inch hole, and a small submersible pump installed inside the riser pipe, with holes drilled in the bottom of the riser pipe inside the isolated interval (Figure 2-2). When the maximum lift capacity of the pump was exceeded in the second hole tested, BH-118, the submersible pump was replaced with a bladder pump.

All subsequent borings intended for packer testing were drilled in a similar manner to the 4-inch boreholes (i.e., cased through the unconsolidated formation and the casing grouted into a rock socket in the top of the bedrock formation) using a 6-inch diameter down-hole hammer bit. These holes, however, were all drilled continuously to completion depths of approximately 600 feet (Table 2-1), and packer tested from the bottom of the borehole upward. The change to 6-inch diameter boreholes improved the packer installation and removal process.

The 6-inch borehole packer system (Figure 2-3) used packers designed to seal 6-inch boreholes. During sampling of the 4-inch boreholes, the bladder pump system provided insufficient pumping rates, so the 6-inch packer system was constructed with a submersible pump and supplementary airlift to evacuate water from the packed interval. This pumping system was used on boreholes BH-119, -120, -121A, and -118A. Below the maximum lift depth of the pump, the airlift was used to clear the water from the riser pipe. This method allowed maximum removal of water from the packed interval, and minimum dilution of subsequent purge volumes by water in the riser pipe. The water level within the borehole above the upper packer was measured during pumping using an electric water level meter to detect fluctuations in water level that would indicate a leak or bypass of the upper packer.

Extracted water was discharged at the testing site into a steel 700-gallon capacity "B-25" box of dimensions 3.9 feet high by 4 feet wide by 6 feet long. The volume discharged was determined by measuring the water level in the box before and after a pumping event. The elapsed time required to recharge and pump that volume of water was also recorded to determine the apparent yield of the isolated interval in gallons per minute. These volume and yield data were not collected during sampling of the 4-inch boreholes. The sampling effort was intended to collect representative groundwater samples by extracting a minimum of three volumes of water from each isolated interval prior to collecting water samples for radiochemical analysis. After determining yield and purging the required volumes (if possible), samples of the water were collected and analyzed for tritium content by HNP's on-site radiochemistry laboratory. Selected samples were also analyzed for gamma-emitting isotopes by gamma spectroscopy analysis at the on-site laboratory.

Incomplete seals between the inflatable packers and the borehole wall were detected in a few zones in each borehole. Incomplete seals were typically indicated by rapid decreases in water level in the zone above the uppermost packer during pumping from the isolated interval. When an incomplete seal was detected, the packer was moved up or down the borehole and re-inflated and re-tested for seal. This system was not designed to monitor water pressures in the middle or lower packed interval, and could not detect leaks from the lower zone, or slight leaks from the upper zone.

At the completion of packer testing, flexible synthetic borehole liners (Flexible Liner Underground Technology-FLUTe™) were deployed into the 6-inch and 4-inch boreholes to attempt to seal off the borehole sidewalls. The FLUTes™ fully deployed in the shallower 4-inch boreholes, though it took several months for full deployment in BH-118 below 200 feet bgs. The 6-inch FLUTes™ could only be deployed to about 250 feet bgs in the deeper 6-inch boreholes, apparently because the borehole water below that depth would not displace back into the formation. This suggests that the bedrock formation below that level did not yield, or take, water. This information is consistent with the results of borehole geophysical logging conducted during the 2003 packer sampling program and the hydrophysical logging conducted in 2004. The results of geophysical and hydrophysical logging are discussed in Section 3.

2.2.2 2003 Packer Study Hydraulic Response

During the 2003 packer testing, transient pressure effects were observed in monitoring well MW-106D, which had been temporarily equipped with a data-logging pressure transducer to evaluate effects of restarting the mat sump extraction pumps. This activity was coincidental with the drilling and initial packer testing of the two 4-inch boreholes, BH-118 and BH-121. Inspection of the MW-106D hydrograph revealed pressure responses (identified as drawdown and recharge responses) that were temporally related to drilling and packer testing at the bedrock boreholes. The transients could not be correlated to other activities on-site (e.g., mat sump operation)

Figure 2-4 shows the water level hydrograph for MW-106 D during a period coinciding with active packer testing at BH-118. Similar responses were noted in the hydrograph for MW-106 D during packer testing and air rotary drilling in BH-121 (Figures 2-5 and 2-6). Comparison inspection of the hydrographs from other nearby monitoring wells that were also being monitored at the time revealed no discernable pressure transients that could be related to the drilling/testing activities. Monitoring wells MW-102 D, 102 S, 103 S, 105 S, 105 D, 106 S, 107 S, 107 D, 114, 115, and the mat sump were equipped with data logging pressure transducers during that period of activity. These observations suggest that the network of fractures within the crystalline bedrock system is structurally controlled, and displays preferential pathways or conduits along which hydraulic pressure effects can be readily transmitted.

2.2.3 2003 Packer Study Analytical Results and Yield Data

The 2003 packer study tritium analysis results and yield data are presented in Tables 2-2 through 2-7.

Data quality assessment of the 2003 packer testing results indicated that both the sampling and analysis and hydraulic yield measurements were potentially compromised by non-representativeness of the measurement technique. The 6-inch borehole packer assembly used in the 2003 campaign was constructed such that a substantial volume of water remained in the isolated interval below the submersible pump inlet. This resulted in accumulation of an unpumpable heel of water that consisted primarily of mixed groundwater that had been present in the borehole prior to packer inflation. Most of the water in the deeper regime of the open boreholes is expected to have come from the relatively high-yielding zones in the upper portion of the bedrock. The upper zones also contain the highest tritium concentration. Groundwater samples collected from low, or non-yielding zones at depth in the boreholes were potentially impacted by the contaminated water heel in the packer-isolated interval. All 2003 packer samples collected were also potentially affected by undetected water leaking past the straddle packers.

In addition to apparent non-representativeness of the radioanalytical results, the yield measurements at depth may be biased high due to the inability to confirm that the lower packer was sealed. Yields that were significantly higher at some depths in the 2003 packer campaign then corresponding depths measured in the 2004 campaign are interpreted to be potentially affected by water leaking past the packers. The geophysical logging results, including heat-pulse flowmeter logs, indicate decreasing flow rates with increasing depth, and very little flow below 250 feet bgs. A detailed summary of these previous packer testing activities is documented in a CH2M HILL memorandum titled *Data Quality Assessment of Deep Bedrock Packer Testing, 2003 Activities.* February, 2004 (Appendix 1).

2.3 2004 Packer Testing Campaign

Results of sampling and analysis from the 2003 packer study suggested the presence of tritium at depths as deep as 500 feet bgs. Additional observations collected (e.g., borehole geophysical logging) did not support the presence of substantial tritium at great depth below the plant. Deep downward vertical migration of SOCs was not anticipated given the extremely low yields encountered during packer sampling in the deeper fractured bedrock system, the general absence of hydraulically active fractures in the deeper bedrock system, and the anticipated upward vertical hydraulic gradient associated with the Connecticut River functioning as a regional discharge boundary.

Following a critical review of the 2003 test results, the results of tritium analysis of groundwater were rejected as non-representative. An effort was initiated to develop an alternative testing protocol to verify or refute the apparent vertical distribution of tritium in deep bedrock. Because of the measurement uncertainty exhibited by the 2003 test results, it was decided to verify the new test protocol in one borehole.

As the revised packer testing proceeded in BH-121A, additional testing (i.e., hydrophysical logging was implemented in all four 6-inch boreholes. The combined results of packer testing and hydrophysical logging provided a valid basis for designing the bedrock monitoring system. The 2004 packer test campaign is described in the following subsections. The results of hydrophysical logging are discussed in Section 3.0 of this report.

2.3.1 Methodology

Borehole BH-121A was selected for the first application of the revised packer test protocol. This borehole was chosen because the analytical results collected there during the 2003 packer sampling program indicated a relatively uniform distribution of tritium below 144 feet bgs, and the borehole was believed to be sited within a tritium plume that occurs within the unconsolidated deposits and shallow bedrock aquifers. The 2004 packer testing program was designed to collect pressure gradient measurements and discrete zone samples from selected depths in borehole 121A to clarify contaminant migration directions and distribution.

A straddle packer assembly was fabricated that included data-logging pressure transducers installed above, between, and below the two inflatable packers. This configuration provided a basis to evaluate packer seal during pumping and to quantify the vertical component of the groundwater gradient at that elevation in the borehole. Equipment and measurement techniques were designed to minimize the volume of unpumpable water in the isolated interval, and maximize sample representativeness. The pump was placed inside the riser pipe and holes were drilled in the riser pipe just above the lower packer. This allowed the isolated interval to drain more completely, thus minimizing unpumpable water.

The packers were separated by a 5-foot isolation interval. Water was pumped from the interval with a RediFlo™ submersible pump installed inside the riser pipe. A bladder pump was used at depths greater than the lift capability of the submersible pump (e.g., about 200 feet bgs). Schematic of the 2004 packer equipment is shown in Figure 2-7.

The target intervals (Table 2-8) chosen were based on an assessment of analytical and yield results from the previous packer sampling effort, and geophysical logs for BH-121A. Sample zones were based on a combination of the previous packer testing tritium detections and higher yield zones from data collected during the same study. In addition, zones were based on geophysical log indications of open fractures from the acoustic televiewer log, or any other log signature indicative of a possible flow zone. These log signatures include fluid resistivity profile changes, caliper, and flow-meter log changes. The initial suite of selected test intervals also included intervals that were not expected to produce water based on available information.

Packer testing was started at the deepest selected target zone. A yield of 1 gallon per hour (gph) was selected as the lower limit of yield that would be sampled, due to the extreme length of time required to extract adequate sample volume. When this first zone was determined to have apparent yield too low to sample (i.e., <0.04 gallons/hr), it was decided to proceed to the next highest geophysical signature possibly indicative of groundwater flow. When this next zone also was determined to produce negligible water, it was decided to concentrate efforts on zones where the geophysical logs indicated open fractures.

Figure 2-8 is a flow diagram of the packer testing protocol for the 2004 packer study. The methodology used during the 2004 packer testing program in BH-121A is outlined below.

- The FLUTe™ liner was removed from borehole 121A.
- The packer assembly was stopped at three elevations during insertion into the borehole (i.e., 150, 300, and 450 feet bgs). At these elevations, a sample of borehole water was collected for tritium analysis, and the packers were subsequently inflated to measure the static pressure head in the three zones (i.e., above, within, and below the packed interval).
- After lowering the packer assembly to the selected isolation interval, the packer glands were pressurized to seal off the test interval and the zones above, within, and below were allowed to equilibrate before testing. The packer inflation pressure was observed and recorded to ensure that the packers remained sufficiently inflated.
- Real-time measurements of pressure head in each zone (above, below, and within the isolation interval) were recorded using data-logging pressure transducers before, during and after purging and sampling. The pressure head, adjusted for barometric pressure and referenced to ground elevation, represents the potentiometric head at the discrete interval. An on-site transducer dedicated for barometric pressure monitoring was used to conduct barometric corrections. A pressure transducer installed in the river provided continuous tidal fluctuation data for comparison to apparent tidal response seen on the packer test data. Transducer sampling rates varied from 1 second to 1 minute intervals over the course of testing. High density data logging (i.e., sampling rates more than 1 per five seconds) produced cumbersome data files that were not conducive to rapid processing and interpretation
- To test the packer seal, the water was pumped from the isolated packer interval, and the zone was allowed to recover for approximately one hour. The pressure differential between the upper and lower transducers and the transducer within the packed interval was observed before, during, and after initial evacuation of the packed interval to assess the quality of the packer seal. An effective seal was indicated by stable pressures above and below the packed interval before, during, and after test interval pumping. Observed

pressure variations in the units above and/or below the test interval that occurred coincidental with, or shortly after, pumping of the test interval were assumed to indicate inadequate packer seal or flow through vertical fractures that bypass the packer.

- If pressure measurements outside the test interval dropped immediately upon pumping the test interval, this was inferred to indicate that an effective seal was not established with the borehole wall. If pressure measurements dropped shortly after pumping commenced in the test interval and the drawdown curve assumed a different slope than that of the test interval, this was inferred to indicate that water was leaking around the packers through connections in fractures within the formation. In either of these cases, the packer assembly was adjusted to a different depth interval. If a satisfactory seal could not be achieved after two packer relocation attempts (a total of three attempts) the zone was passed and the next higher elevation zone was packer tested.
- When an effective seal was confirmed, the recharge rate was calculated from the recovery of the isolated interval after the pumping. If the interval produced sufficient water in the professional opinion of the hydrogeologist, the sampling process continued as discussed below. If the formation within the isolated interval yielded less than 1 gallon per hour (i.e., approximately 0.017 gpm for the interval), the unit was further assessed by the project hydrogeologist to determine whether it was appropriate to continue testing the interval. Once an interval met the sample collection criteria, the interval was pumped, and a sample of the water collected for analysis for pH, specific conductance, temperature ORP and tritium. This sample was considered to represent borehole water and NOT formation groundwater. At shallow depths (approximately less than 200 feet bgs, a Grundfos RediFlo™ 2 submersible pump was used to purge the sample zone. Below that depth, a bladder pump was used, though a RediFlo™ pump was still used to draw the water down to the maximum possible for the RediFlo™.
- After removal of the first volume of water from the isolated interval (i.e., the borehole water), the apparent inflow into the interval was assessed. If the interval pumped dry in the initial evacuation, the interval was allowed to fill for about one hour or until a pumpable volume of water refilled as determined by the hydrogeologist based on his professional judgement and the apparent properties of the interval. The packed interval may not have refilled completely when pumped in order to minimize the volume of water required to be removed prior to collection of a representative sample. Consideration was made to minimize water volume purged prior to sampling to avoid pulling water from great distances in the fracture network. During the refilling, the pressure was monitored. At the end of the refilling period, the interval was pumped again and the volume of water produced was measured.
- The produced water was sampled for pH, specific conductance, temperature, ORP and tritium. The effects of residual heel water in the interval was assessed after each pumping event for a total of three events. When the effects of residual heel water had been minimized based on the inflow of water into the interval, then a sample was collected and analyzed for pH, specific conductance, temperature, ORP, tritium, gamma spectroscopy, and total beta activity.

- After the interval was sampled, or sufficient time had passed to declare that the interval was non-yielding, the packer system was deflated and raised to the next sequential test interval and the sampling process started again.
- The HNP lab prepared groundwater samples for tritium analysis using distillation sample preparation followed by liquid scintillation counting. The detection limit for tritium was approximately 1000 pCi/L. Field blanks were collected on a 1/20 samples basis. An equipment rinseate blank was collected from the packer system and bladder pump following decontamination prior to installation of the packer system. At the end of the packer testing program, the distance between the inflatable packer glands was increased to 23 feet as indicated by the observed conditions, and the packer sent back down hole to attempt to test passed intervals again.

2.3.2 Review of Static Pressure Tests

Static pressure measurements across the packer assembly indicate the vertical pressure differential at that depth in the borehole. Static and pumping pressure records converted to water elevation graphs are in Appendix 2. Static bottom zone pressure transducer readings were subtracted from static top zone pressure transducer readings to give the vertical component of the hydraulic pressure differential between the top and bottom zone in one packed interval. Static top and bottom zone pressures were individually averaged over the length of record available (generally less than a day) to give the most accurate vertical pressure differential. The resultant pressure differentials were plotted with depth to show the vertical pressure differential profile in BH-121A (Figure 2-9).

Above 155 feet bgs, the vertical component of the groundwater gradient is downward, i.e., given available flow path, groundwater will flow downward as well as in the direction of the horizontal component of flow. Below 160 feet, the vertical component of the gradient is upward, i.e. given available flow paths, groundwater will flow upward as well as in the direction of the horizontal component of flow. Between 155 and 160 feet bgs the vertical component of the groundwater pressure differential switches direction in this borehole. Groundwater gradients being vectors have magnitude and direction. This direction can be separated into a vertical and horizontal component. This packer testing only measured the vertical component of direction as a pressure differential. Horizontal components would have to be measured between wells, and may be much larger than the vertical components measured. It should also be noted that these measurements collected during the packer testing are pressure differentials, if no flow path exists, there is no actual flow.

2.3.3 Packer Testing Program Pumping Pressure Records

Packer pumping water elevation records are included in Appendix 2. Response of the upper and lower zone pressure transducers to pumping in the isolated interval can be grouped into three categories: 1) no response in the upper and lower zones to pumping, 2) immediate and one to one response in either the upper or lower zones (or both) to pumping, or 3) delayed and subdued response in either the upper or lower or both zones to pumping. If there was no response in either the upper or lower zones to pumping in the middle zone, the seals were assumed to be good and the zone isolated, and pumping was continued to see if there was sufficient recharge to sample that zone. Examples of this type of water elevation record include the water elevation records for 465-470 feet bgs and 317-322 feet bgs shown in Figures 2-10 and 2-11. The water elevation record for 465-470 feet bgs shows pump activation and drawdown in the isolated middle zone with no corresponding drawdown in the top or bottom zone. The recharge rate calculated from the recovery of the middle zone after the pump was shut off is 0.04 gallons per hour (gph), insufficient recharge to sample the zone. The water elevation record for 317-322 feet bgs also shows pump activation and drawdown in the isolated middle zone with no corresponding drawdown in the top or bottom zone. The recharge rate in this interval, as shown by the rapid water level increase with time after pumping is stopped, however, is sufficient to sample. The graph also shows the additional pumping and recharge intervals prior to sampling.

Immediate one to one response in the upper and/or lower zones was assumed to indicate packer bypass leakage due to incomplete seal against the borehole wall. Samples collected from packed zones in direct connection with other zones would not be representative of the isolated interval and were not collected. The graph for packer isolation and pumping in Borehole 121A at 162-167 feet bgs (Figure 2-12) is an example of this type of water level change. Both the upper and lower zones respond in a 1 to 1 fashion with commencement of pumping.

A delayed and subdued response in either the upper or lower or both zones to pumping in the middle zone suggests that there is a small local or more remote circuitous connection between the pumped zone and the zone showing response. Professional judgement generally dictated not sampling these intervals unless the bypass response was negligible and the recharge was sufficient. The graph for packer isolation and pumping at 297.5-302.5 feet bgs (Figure 2-13) is an example of this type of elevation record. This graph shows a delayed and subdued inflection in the bottom water elevation indicative of slow formation leakage. Hydraulic responses in other monitoring wells to natural and anthropogenic stresses including packer testing stresses are discussed in section 4 of this report.

2.3.4 2004 Packer Testing Yields and Analytical Results

Table 2-9 summarizes the 2004 packer sampling results indicating whether a seal could be achieved at each zone, the yield of zones that were effectively isolated, and tritium concentrations for those zones from which a sample believed to be representative was collected and analyzed. The tritium concentrations shown in Table 2-9 are the results of on-site analysis at the HNP laboratory. Table 2-9 also includes the 2003 packer program sample results for comparison. The 2004 packer sample results did not exhibit the consistent detection of tritium in groundwater below 200 feet bgs that was shown by the 2003 packer sampling and analysis.

In addition to CY onsite lab analysis, samples were submitted for off-site analysis by General Engineering Laboratories (GEL) under contract to HNP. Off-site analyses were performed for tritium, boron, gross alpha, gross beta, gamma isotopic activity, and Hard-To-Detect (HTD) plant-related radionuclides. These HTDs include alpha, beta and X-ray emitting, fission and activation product radionuclides. Table 2-10 summarizes the analytical results from the off-site laboratory.

The only sealable zone below 183 feet bgs to produce water during packer sampling was at 317-322 feet bgs. Samples analyzed from that depth were reported to contain 496 pCi/L, though calculations described in the data quality assessment suggest that this is entirely residual concentration from the original water trapped during packer isolation. Above 183 feet bgs the number of fractures and their yields increase significantly, as did zones for which seals could not be achieved using the 5-foot packer assembly. This suggests substantial fracture interconnection in these shallower locations. At the following zones: 340-345, 297.5-302.5, 273-278, 287-310, 260- 283, 173-178, 162-167, 157-162, 147 -152, and 114-119 feet bgs, packer seals could not be achieved, yields for these zones can not be quantified from the packer sampling data. Yields for each zone of the borehole was quantified by the hydrophysical logging discussed in section 3. Detectable concentrations of tritium were also found at 178-183 feet bgs (6,060 pCi/L), 152-157 feet bgs (2,430 pCi/L), and 103-108 feet bgs (1,290 pCi/L). In summary, tritium was detected in the apparently more transmissive fracture zones between 103 and 183 feet bgs. It was detected in the deeper interval sampled at 317-322 feet bgs (496 pCi/L), though the on-site analytical data quality assessment suggests that this is entirely from residual concentration diluted from the original water trapped during packer isolation. Below 188 feet bgs there were few apparent fractures, and those tested generally produced substantially less than 1 gallon per hour. Of the three zones below 188 feet bgs for which a seal could not be achieved, two of those zones even with some leakage produced less than 0.04 gallons per hour.

The observed concentrations of the SOCs in the samples shipped off site for analysis were compared to selected standards. In this instance, they were compared to the maximum contaminant level (MCL) promulgated under the Federal Safe Drinking Water Act regulations by the United States Environmental Protection Agency, and subsequently implemented by the State of Connecticut as the state's drinking water standards. The MCLs do not strictly apply to groundwater at HNP because the plant groundwater is not a source of community drinking water. The MCLs do, however, provide an accepted metric for comparison and evaluation of the apparent degree of groundwater contamination.

The MCL for beta and photon emitters (such as Sr-90 and Cs-137) is a dose-based 4 mrem/year, calculated using an agency-specified target organ dose methodology. The concentration of a single nuclide in water that would result in a dose of 4 mrem/year is often used as the MCL. This concentration is referred to as the C_4 concentration, or the derived dose concentration. If only a single beta/photon emitter is present in drinking water, the derived concentration is the MCL for that nuclide. If, however, multiple beta/photon emitters are present in the sample, the fractional dose contribution of each nuclide is summed to determine the total dose. It may be noted that by applying the NRC Total Effective Dose Equivalent (TEDE) calculation method, the yearly dose corresponding to the MCL concentrations for tritium and Sr-90 would be less than 1 mrem/yr for each nuclide.

2.3.4.1 Boron

Boron is a good indicator element in groundwater at the HNP because it is chemically stable and was added to the water in the reactor vessel to control neutron flux when the plant was in operation. Therefore, the occurrence of elevated concentrations of boron in groundwater may be a general indicator of areas that have been impacted by historic releases.

Five (5) samples were collected as part of the 2004 packer testing all of which had detections greater than the Minimum Detection Limit (MDL) of 0.54 micrograms per liter (µg/L). Groundwater analytical results for the 2004 packer testing off site laboratory analyses are summarized in Table 2-10. Boron was detected in the packer sample collected from 317-322 feet bgs at 338 μg/L. This concentration is above the background concentration expected for boron at the CY site. Boron concentrations detected in samples collected between depths of 152 and 183 feet bgs were also above the expected background.

2.3.4.2 Gross Alpha

The likely source of most gross alpha activity in the vicinity of HNP is dissolution of naturally occurring mineral deposits, including radium -226 and radium-224, which are likely present in the underlying crystalline bedrock. Natural levels of gross alpha activity can range as high as a few hundred pCi/L. Although it is possible that plant-related radionuclides contribute to some of the observed gross alpha activity, it is not probable since alpha isotopic analysis generally results in non-detects with nominal detection sensitivity on the order of 0.3 pCi/L, or less.

Five (5) samples were collected for gross alpha activity analysis as part of the 2004 packer testing resulting in four (4) samples detected greater than the laboratory required Minimum Detection Concentration (MDC) of 3 pCi/L. Two (2) of these results also exceeded the Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 15 pCi/L. The gross alpha result for the sample collected at 317-322 feet bgs was 1.9 pCi/L, below the MDC of 2.35, but above the 2-sigma total propagated uncertainty (TPU) of 1.5 pCi/L. The QC blank gross alpha result was 0.84 pCi/L, also above the 2-sigma TPU but below the MDC. Gross alpha activity is expected at these low levels.

2.3.4.3 Gross Beta

Gross beta activity in the vicinity of HNP may result from either naturally occurring or plant-related sources. Potassium-40 (K-40) is a radionuclide resulting from naturally occurring mineral deposits, which may account for relatively high percentage of gross beta activity in certain wells. Detectable levels of gross beta activity in areas of plant-related contamination may also be associated with beta emitters Sr-90 and Cs-137. The CT Public Drinking Water Quality Standard for gross beta radioactivity is 50 pCi/L (Connecticut Department of Public Health, September 2004), though background levels may range as high as a few hundred pCi/L.

Four (4) out of five (5) samples analyzed from the 2004 packer samples collected from BH-121A detected gross beta activity greater than the laboratory required MDC of 4 pCi/L. These concentrations ranged from 9.25 to 35 pCi/L. Gross beta was not detected in the sample collected from the depth 317-322 feet bgs. None of the analyzed concentrations were above the CT Public Drinking Water Quality Standard MCL of 50 pCi/L.

2.3.4.4 Tritium

The presence of tritium in groundwater at HNP is the result of the nuclear fission reaction that was the heat source for the HNP nuclear power generating station.

Tritium was detected in all five (5) packer samples collected. All these detects were at concentrations greater than the required MDC of 400 pCi/L. All detected H-3 concentrations were below the C_4 activity concentration of 20,000 pCi/L. The highest tritium concentration was observed at the depth 153-176 feet bgs (8,170 pCi/L). Tritium was detected in all equipment blanks at concentrations ranging from 323 to 338 pCi/L, and may be in the plant DI water at that concentration.

2.3.4.5 Carbon-14

The presence of carbon-14 at HNP is the result of neutron capture reactions in water and structural materials like steel and concrete. Carbon-14 is determined by liquid scintillation counting (LSC).

Carbon-14 was detected in the sample collected from 152-157 feet bgs (45.4 pCi/L). This is below the MDC of 60 pCi/L, but above the 2-sigma TPU of 36.2 pCi/L. This concentration is below the C_4 activity concentration of 2,000 pCi/L.

Carbon-14 data are normally distributed and the limiting mean of this concentration is statistically equal to zero. The carbon-14 data appear to be part of the underlying background distribution and may be a false positive (see Appendix 3, Offsite Laboratory DQA). Historically, CYAPCO has experienced false positive trends with analytical results analyzed via LSC. These biases have been observed at concentrations at or near the MDC and based on standard statistical methods including T-testing of the limiting mean concentration.

2.3.4.6 Nickel-63

The presence of Nickel-63 at HNP is the result of neutron capture of stainless steel reactor vessel internals. Nickel-63 is determined by LSC.

Nickel-63 was detected in the sample collected from 153-176 feet bgs (10.2 pCi/L). This is below the MDC of 12.2 pCi/L, but above the 2-sigma TPU of 7.4 pCi/L. This concentration is below the C_4 activity concentration of 50 pCi/L.

Nickel-63 data are normally distributed and the limiting mean of this concentration is statistically equal to zero. The nickel-63 data appear to be part of the underlying background distribution and may be a false positive (see Appendix 3, Offsite Laboratory DQA).

2.3.4.7 Strontium-90

Strontium-90 is a fission product of reactor operations at CY. Strontium-90 is determined by gas proportional counting (GPC). Strontium-90 was detected in the sample collected from 153-176 feet bgs (0.368 pCi/L) and in the QC blank (0.67 pCi/L). The sample from the 153-176 foot interval is below the MDC of 0.518 pCi/L, but above the 2-sigma TPU of 0.312. Strontium-90 data are normally distributed and the limiting mean of this concentration is statistically equal to zero. The strontium-90 data appear to be part of the underlying background distribution and may be a false positive (see Appendix 3, Offsite Laboratory DQA). Four of the six GPC blanks were positive. This concentration is below the C_4 activity concentration of 8 pCi/L.

2.3.4.8 Cesium-137

Cesium-137 is a fission product of reactor operations at CY. Cesium-137 was detected in the sample collected from 153-176 feet bgs (1.67 pCi/L). This result is below the MDC of 2.55 pCi/L, but above the 2-sigma TPU of 1.33 pCi/L. Cesium-137 data are normally distributed and the limiting mean of this concentration is statistically equal to zero. The cesium-137 data appear to be part of the underlying background distribution and may be a false positive (see Appendix 3, Offsite Laboratory DQA). The detected Cesium-137 concentration is below the C_4 activity concentration of 200 pCi/L.

2.3.4.9 Plutonium-241

Plutonium-241 is a result of multiple neutron capture of Uranium-235 and Uranium 238, which fueled the CY reactor. Plutonium-241 is determined by LSC.

Plutonium-241 was detected in the sample collected from 152-157 feet bgs (8.81 pCi/L). This concentration is below the MDC of 12.7 pCi/L, but above the 2-sigma TPU of 7.67 pCi/L. Plutonium-241 was also detected in the sample collected from 317-322 feet bgs (8.92 pCi/L). This concentration is below the MDC of 13.7, but above the 2-sigma TPU of 8.24 pCi/L. Both samples are below the C_4 activity concentration of 300 pCi/L. Plutonium-241 data are normally distributed and the limiting mean of this concentration is statistically equal to zero. The plutonium-241 data appear to be part of the underlying background distribution and may be a false positive (see Appendix 3, Offsite Laboratory DQA).

2.3.5 2004 Packer Testing Data Quality Assessment

The 2004 packer testing DQA is in Appendix 3, and is summarized below.

2.3.5.1 On-Site Analytical and Packer Sampling Data Quality Assessment

The results of tritium analysis of groundwater collected from the fractured bedrock formation during the 2004 packer testing campaign in borehole BH-121A are not comparable to the results of tritium analyses resulting from the 2003 packer testing campaign. The instrumented packer assembly and measurement protocols employed during the 2004 effort produced a set of definable, representative samples. The samples collected during the 2003 testing campaign could not be confirmed to be representative. Based on the 2004 packer sampling results tritium is not present at elevated concentrations in the deep bedrock beneath the HNP.

2.3.5.2 Off-Site Analytical Data Quality Assessment

The off-site analytical DQA is located in Appendix 3. For the most part, the data appear to be of sufficient quality; however the carbon-14, nickle-63, strontium-90, cesium-137, and plutonium-241 analytical results on review may be false positives. The off-site analytical data packages are located in Appendix 4.

2.4 Conclusions

The objectives of packer testing have been mostly satisfied in BH-121A.

- The identification of fractures that will transmit significant quantities of water, and the quantification of that flow was prohibited by the problems with packer seals in the more transmissive zones. This objective was met by the hydrophysical logging.
- A preliminary assessment has been made of the vertical distribution of substances of concern. Tritium was identified in groundwater samples collected above 183 feet bgs ranging from 1290 to 6060 pCi/L. The only sample collected during the packer sampling below that depth was from 317 to 322 feet bgs. The tritium concentration from 317-322 feet bgs was measured at 496 pCi/L, though this concentration is accounted for entirely in the DQA by residual concentration from the original water trapped during packer isolation. The carbon-14, nickel-63, strontium-90, cesium-137, and plutonium-241

detections appear on DQA to be false positives. The boron concentration at that depth was measured at 338 µg/L, above the background expected concentration for boron.

- Target zones for subsequent monitoring well installation for water quality monitoring are being chosen based on a compilation of the packer sampling data, the hydrophysical logging data, and the geophysical logs.
- Packer seals were assessed at each depth to ensure collection of representative samples from isolated intervals.
- The vertical groundwater pressure differential profile has been identified from the static pressure testing. Above between 155 and 160 feet bgs the vertical component of the pressure differential is downward. Below 155 to 160 feet bgs, the vertical component of the pressure differential is upward. The magnitude of these pressure differences have been identified and are detailed in Figure 2-9. The pressure differentials in borehole BH-121A are similar for the most part, suggesting that the fracture zones are vertically connected.
- The zones of greater fracture density and interconnection were roughly identified as the larger zones through which the packer would not seal (Table 2-9, 153-168 feet bgs and 172-179 feet bgs), with smaller zones identified at 272-278 feet bgs and 460-471 feet bgs.

The primary purpose of packer sampling is to gather sufficient information to design a groundwater monitoring system for the fractured bedrock aquifer. The data gathered from the packer testing, in combination with hydrophysical logging, conventional geophysical logging, and interpretations of long term hydrographs is sufficient to design a bedrock groundwater monitoring system.

SECTION 3

3 Borehole Geophysics

3.1 Overview of Borehole Geophysics Applications

The borehole geophysical logging program conducted at the HNP, and the reports generated to summarize findings, address one of the work elements of Task 2 of the Phase 2 Hydrogeologic Work Plan. Task 2 is the additional bedrock characterization, site hydrology and vertical and horizontal plume delineation. The specific work element addressed is: Overburden and bedrock hydrogeologic characterization through drilling, soil sampling, rock coring, downhole logging and geophysics, hydraulic conductivity testing of overburden, and transmissivity and interconnectivity of bedrock. Borehole geophysical logging was the main technical approach used for the bedrock characterization effort, providing data to generate reliable estimates of the physical and hydrochemical properties of bedrock intervals, measure flow conditions, contaminant distribution, and to evaluate fracture interconnection in the study area.

Borehole geophysical logging was conducted in four deep boreholes recently installed at the HNP in order to characterize the fractured metamorphic bedrock at the facility. The geophysical logging program can be defined as two separate applications, conventional borehole geophysical logging and fluid logging. Conventional geophysical logging tools provide data related to physical and chemical properties of the rocks surrounding the borehole. Fluid logging techniques measure properties of the fluid column in a borehole. Hydrophysical™ logging is a specialized technique that measures fluid column properties and derives physical properties of discrete rock intervals and/or specific fractures by using an algorithm in a numerical modeling program used to process and evaluate fluid property data. Used in combination, the data obtained by these tools indicate geologic and hydrologic parameters that can not be measured by other methods.

These bedrock characterization data were collected to refine the conceptual site model concerning definition of bedrock lithology, fracture density and orientation, and groundwater flow to delineate possible subsurface migration pathways. As part of refining the CSM, the results of the geophysical logging effort will be reviewed to see if they reflect the current understanding of the regional and local geologic setting at the facility. The findings and overall conclusions of this geophysical logging effort will be used to develop the bedrock groundwater monitoring system and will be integrated into the numerical groundwater flow modeling that will be performed as part of Task 3.

The overall results of geophysical and hydrophysical logging were consistent in the identification of zones of varying hydraulic productivity, particularly in confirming that the bedrock zones deep in the rock (e.g., below 200 feet bgs) produce little groundwater, even under pumping stress conditions. Discrete depth groundwater samples were collected during hydrophysical logging activities. These samples were analyzed for tritium concentration in the HNP on-site laboratory and were used to screen the bedrock interval for the vertical distribution of tritium, confirm the results of previous packer sampling efforts, and help determine screen intervals for the bedrock groundwater monitoring network. The results of tritium analyses and the apparent depth of hydraulically active and tritium-contaminated zones were comparable between the hydrophysical logging and the 2004 packer testing sample results. The 2003 packer sampling results and the hydrophysical logging effort detected tritium at similar concentrations at some depths in the shallow bedrock. Discrete point samples were collected in some intervals where there was not a sufficient straddle packer seal developed in the borehole, providing representative chemical data where previously none was available.

3.1.1 Scope of Geophysical Logging Activities

The scope of geophysical and hydrophysical logging was limited to the four 6-inch diameter open bedrock boreholes (boreholes BH-118A, 119, 120, and 121A). Logging activities were conducted over the overall drilled depth of each borehole. Geophysical and hydrophysical logging data sets were reduced and interpreted by the vendors conducting the surveys. Geophysical logging was conducted by Geophysical Applications, Incorporated. Hydrophysical logging, optical camera logging, and discrete point sample collection was performed by COLOG, Inc.

3.1.2 Objectives of the Geophysical Logging

The objectives of the borehole geophysical logging program implemented at HNP are:

1. To identify lithologic units and contacts in the subsurface, correlate units across the facility.
2. To measure the strike and dip of the foliated sequence and assess the intercalated nature and general structural setting of the bedrock.
3. To locate water-bearing fractures and measure their strike and dip and their apparent aperture. Correlate structural features across the facility if possible.
4. To identify groundwater flow regimes and vertical and horizontal flow direction in the borehole.
5. To identify zones of fracture interconnection if they exist.
6. To estimate the transmissivity of specific fractures or intervals.
7. To determine the fluid electrical conductivity of specific fractures or intervals to look for variations that would suggest isolated flow systems.
8. To assess or screen the vertical distribution of SOCs in the bedrock interval.
9. To provide qualitative and quantitative data to support evaluation and selection of potential water quality monitoring intervals.

3.1.3 Geophysical Logging History

The borehole geophysical logging activities conducted at the HNP as part of the Phase 2 Hydrogeologic Work Plan implementation were completed in two phases. Initially, a suite of conventional borehole geophysical and fluid logs was run in boreholes BH-118A, BH-119, BH-120, and BH-121A by Geophysical Applications, Incorporated during June 2003.

Conventional logs used to characterize the bedrock consisted of natural gamma, caliper, optical televiewer, and acoustic televiewer. Fluid logging tools used to characterize the fluid column of the boreholes included FRes, FTemp, and heat-pulse flowmeter surveys. The subsequent geophysical data evaluation and interpretation of the bedrock hydrogeologic setting at the facility generated by this phase of work were summarized in a report (Geophysical Applications, Inc., 2003) and used to direct both phases of packer testing discussed in Section 2.1.2.

After reviewing the results of two packer testing campaigns, optical camera log and hydrophysical™ logging runs were conducted in boreholes BH-118A, BH-119, BH-120, and BH-121A during July and August 2004 as an alternative approach to further characterize groundwater flow in the bedrock interval at the HNP study area. Based on the hydrophysical™ logging results, discrete point samples were collected to provide additional information regarding vertical distribution of tritium in the bedrock. The optical camera log runs were recorded on VHS videocassettes. The findings of the hydrophysical™ logging task were summarized in a report (COLOG, 2004).

3.2 Geophysical Logging Methodology

The strategy to collect the appropriate data, guide the geophysical log data evaluation, and subsequently interpret site conditions at HNP are consistent with requirements contained in the Phase 2 Hydrogeologic Work Plan (Malcolm Pirnie, 2002) and the geophysical logging program objectives outlined in Section 3.1.2. Hydrophysical logging™ was selected for supplemental characterization because its innovative approach encompasses essential aspects of the geophysical logging and packer testing activities and provides quantitative identification of water-bearing fractures, determination of borehole flow regimes, and estimates of bedrock physical properties.

Measurement of subsurface fracture properties is the primary objective of borehole geophysics applications used to characterize crystalline bedrock hydrogeologic settings, such as the HNP study area. The geophysical investigation methodology utilized logging tools compatible with accepted industry practices for fractured bedrock characterization, by which multiple techniques are employed to provide confirmation and verification of hydrogeologic conditions. The tools used are the current generation of the Mount Sopris Instruments product line, which are considered "industry standard" technology for bedrock characterization. Descriptions of the equipment, methods of investigation, and results of the various logging runs are provided in detail in the two service company reports (Geophysical Applications, Inc., 2003 and COLOG, 2004). A generalized description of tool operating principles, measurements, and applications as applied at HNP are described below:

- The natural gamma log provides a record of total gamma radiation detected in a borehole; it is essentially a Geiger counter that does not allow the discrimination between natural or man-made radioisotopes. The American Petroleum Institute (API) gamma ray unit is the standard unit for natural gamma logs based on measurements made in the API calibration pit; however, some environmental investigations, such as this one, record natural gamma radiation as counts per second. Determining lithology changes, contacts, and bed or rock unit thickness in boreholes are common applications of natural gamma logs. Other applications may include determining clay content or recording the overall radioactivity of either rocks or groundwater within a certain depth interval (Keys, 1997). The main application of natural gamma logs for this characterization effort was to record changes in the lithology of the foliated metamorphic rock sequence; natural gamma logs generally do not provide definitive information concerning fracture identification or fluid flow.

- **Caliper logs** provide a continuous record of borehole diameter. Three-arm mechanical calipers are typically used for logging water wells and environmental investigation boreholes. These types of caliper logs employ mechanically coupled arms that move a linear potentiometer; so changes in resistance, transmitted to the surface as voltage changes, are proportional to average hole diameter. By recording changes in borehole diameter in inches, caliper logs are useful in locating permeable zones, lithology changes, and fractured intervals (Keys, 1997). Identifying borehole enlargements or washouts to indicate the depths of possible fractures was the main application of caliper logs for this bedrock investigation.

- **Fluid temperature** (FTemp) **logs** record temperature (in these logs, degrees Celsius) versus depth in a borehole. Temperature logs can provide useful information relative to the movement of water in a well or borehole, including locating depth intervals that produce or accept groundwater; therefore, these logs indirectly provide information related to permeability (Keys, 1997). Temperature logs are useful for delineating water-bearing zones and identifying vertical flow in the borehole between zones of differing hydraulic head penetrated by wells. Borehole flow between zones is indicated by temperature gradients that are less than the regional geothermal gradient, which is about 1 degree Fahrenheit per 100 feet of depth. Observing fluid temperature changes to identify zones of possible fluid entry in the boreholes was the main application of the FTemp log for this characterization task.

- **Fluid resistivity** (FRes) or **conductivity logs** are records of the capacity of the borehole fluid that enters the probe to transmit electric current. Fluid resistivity values are measured as ohm-meters. Fluid conductivity, the inverse of fluid resistivity, is generally measured in micromhos per centimeter (Keys, 1997), or microsiemens per centimeter. When used in conjunction with other logs, fluid conductivity or fluid resistivity logs may indirectly provide information related to water movement in a well or borehole. Similar to the FTemp log application, fluid resistivity changes were observed to identify zones of possible fluid entry in the boreholes during this bedrock study.

- **Heat-pulse flowmeter logs** also measure flow within a well or borehole; it is designed to measure low-flow velocities. This tool records the direction and rate of vertical flow in the borehole. Borehole-flow rates can be calculated from downhole-velocity measurements. Flow is recorded as feet, meters, or gallons per minute (gpm). Flow direction and velocity are determined by observing the direction and time of travel of a heated parcel of water. The tool operation includes a wire heat grid, located between two thermistors. The wire heat grid is heated by a 1 msec pulse of electric current that is triggered from the surface. The heated sheet of water moves toward one of the thermistors under the influence of the vertical component of flow in the well. The arrival of the heat pulse is plotted on a chart recorder running on a time drive. Deflections of the recorder trace to the right or left indicate upward or downward flow, respectively

(Keys, 1997). The main application of heat-pulse flowmeter surveys for this task was to measure the magnitude and direction of flow and identify possible fluid entry and exit points in boreholes.

- The **acoustic televiewer** is a logging device that provides a high-resolution full 360° image of an open borehole by recording a magnetically oriented, photographic image of the acoustic reflectivity of the borehole wall. The tool measures the borehole with focused beam of ultrasound, registering both amplitude of the reflected signal and the delay in transit travel time. These are related to the reflectivity of the surrounding rocks and the borehole size (caliper), respectively. The signals are presented as continuous images, normally referenced to magnetic North. The acoustic televiewer provides a record of the location, character, and orientation of any features in the casing or borehole that will alter the reflectivity of the acoustic signal. These include the diameter and shape of the borehole, wall roughness that may be caused by drilling method or lithology, differences in rock hardness, and structural features such as bedding, foliation, fractures, and solution cavities (Keys, 1997). The acoustic televiewer logs and optical televiewer logs were the key method for identifying fractures for this study. Acoustic televiewer logs were evaluated using WellCAD's imaging module to measure fracture dip angles and down-dip azimuths. The dip angles of both the "open" and "less-open" fractures were plotted on a stereoplot using an equal-angle Schmidt projection to determine fracture dip direction. Fractures that are noted on both the acoustic televiewer travel-time and amplitude plots are denoted as "open" features. Fractures denoted only on the amplitude plots are likely to have smaller apertures, therefore judged to be "less open" and not likely to be hydraulically active. These "open" features were the focus of further characterization, specifically packer testing, optical camera logging, hydrophysical™ logging, and downhole discrete point samples.

- The **optical televiewer** is a logging device that creates a continuous oriented 360° image of the borehole wall using an imaging system composed of a downhole camera which views a reflection of the borehole wall in a conic mirror. The tool includes a full orientation device that allows for both accurate borehole deviation data to be obtained along with accurate and precise orientation of the image. The optical image recorded includes lithology changes and structural features such as bedding, foliation, fractures, and solution cavities. The primary application of the optical televiewer logs for this characterization effort was to provide identification and orientation of possible fractures and the foliated bedrock sequence.

- An **optical camera** records a color optical image of the borehole. In addition to being recorded on video-cassette-recorder tape, the optical image can be viewed in real time on a television monitor. Well construction, lithology and fractures, water level, cascading water from above the water level, and changes in borehole water quality (chemical precipitates, suspended particles, and gas) can be viewed directly with the camera. The optical camera was used to verify the location of fractures and provide an indication of the nature of fracture apertures (e.g. either "open," "closed," partially healed, etc.) as part of the bedrock characterization data collection.

- Fluid replacement and fluid-column conductivity logging, or **hydrophysical™ logging**, involves electrical conductivity logging of the fluid column over time after the borehole fluid has been diluted or replaced with de-ionized water. Periodic electrical conductivity logs show formation fluids and possible contamination reentering the borehole as a function of the hydraulic conductivity of the surrounding rocks. Hydrophysical logging is used to determine flow magnitude and direction under both ambient and pumping conditions to identify hydraulically conductive intervals to within one well-bore diameter. The data can be analyzed with a multiparameter, finite difference model to produce hydraulic conductivity measurements that compare well with hydraulic conductivity values calculated from packer tests (Keys, 1997). The hydrophysical™ logs were used to measure the magnitude and direction of flow, identify possible fluid entry and exit points in the boreholes. The hydrophysical logs also provided confirmation or alternative interpretations of flow conditions measured by the heat-pulse flowmeter surveys, and indications of water-bearing fractures by the conventional geophysical logs. Other specific hydrophysical™ logging applications for this characterization effort included assessment of possible fracture interconnection within and between boreholes, providing flow measurements to calculate the hydraulic conductivity of specific fractures or intervals, and targeting discrete point sample locations.

In summary, the application of multiple borehole geophysical logging technologies conducted in a sequential manner provides a powerful and effective technical approach to characterize the bedrock aquifer at the HNP. The combined effect of the integrated conventional borehole geophysical log and fluid log data collected during the 2003 and 2004 efforts supports the resulting interpretation of hydrogeologic conditions by providing confirmation of rock and flow properties.

3.2.1 2003 Geophysical Logging Campaign

Data collected during the first phase of the geophysical logging located potential water-bearing fractures and provided groundwater flow measurements to develop an understanding of the general bedrock hydrogeologic conditions in the test area. This provided a basis for initial selection of discrete packer testing intervals. The FTemp, FRes, and natural gamma logs were recorded on the first logging run providing an indication of possible fluid entry in the borehole. The caliper log was obtained during the second logging run and provided the elevation of possible fractures as indicated by surface discontinuities in the borehole wall. The optical televiewer and the acoustic televiewer logs were obtained during the third and fourth logging runs, respectively, and indicated possible fractures and their orientations. The flow meter surveys were the last data collected in each borehole during the first phase of the borehole geophysical investigation and provided an initial assessment of the groundwater flow in the boreholes. The flowmeter logging test intervals were targeted at specific depths inferred from field plots of the caliper, FTemp, and FRes logs (Geophysical Applications, Inc., 2003). Flowmeter data were recorded at the same elevations under both ambient and pumping (0.5 gpm) conditions. Ambient flowmeter measurements did not identify any measurable flow in any of the boreholes logged. All of the zones indicating flow were detected under pumping or stressed conditions.

3.2.2 2004 Geophysical Logging Campaign

During the second phase of geophysical logging, data were collected using video camera logging and hydrophysical logging™ to confirm the location of water-bearing fractures, refine the understanding of the flow regime in the boreholes, assess fracture interconnection, and generate estimated transmissivity values for specific fractures and intervals. Discrete point samples were then collected to assess the vertical distribution of tritium in the bedrock intervals identified a hydraulically active. The optical camera logging was completed in each borehole before the hydrophysical logging™ commenced to confirm the location and apparent aperture of possible fracture features. Hydrophysical logging™ was conducted to provide an overall assessment of hydrogeologic conditions and refine previous interpretations of groundwater flow in the bedrock aquifer system. The hydrophysical logging™ technique was conducted in three sequential logging steps: (1) background or static ambient logging runs prior to DI emplacement, (2) ambient flow logging runs immediately after DI water was emplaced in the borehole, and (3) stress-flow logging runs conducted after DI water was emplaced during low-rate pumping. The ambient water quality logs are conducted to provide baseline values for undisturbed borehole fluid conditions prior to testing. Multiple logging runs were conducted during each step to provide repeatable profiles of the fluid electrical conductivity and temperature changes in the borehole caused by electrically contrasting water being drawn into the borehole by pumping or native formation pressures. The pumping rate, total volume of water removed, and water level in the borehole are also recorded.

The computer programs FLOWCALC and/or BORE II (COLOG, 2004) and (Daughtery and Tsang, 2000) were utilized to evaluate the inflow quantities of the formation water for each specific inflow location. FLOWCALC is used to estimate the interval-specific flow rates for the production test results based on values of fluid electrical conductivity and depth. The values are determined from the "Pumping" and "Pumping during DI Injection logs." Numerical modeling of the reported data is performed using the code BORE II. These methods reflect the flow quantities for the identified water bearing intervals (COLOG, 2004).

For interval-specific permeability estimations, COLOG utilizes Hvorslev's 1951 (Hvorslev, 1951) porosity equation in conjunction with the hydrophysical™ logging results. Several assumptions are made for estimating the permeability of secondary porosity. First, the type of production test COLOG performs in the field may significantly affect the accuracy of the transmissivity estimation. The permeability equation is relatively sensitive to overall observed drawdown. For a high yield borehole, drawdown will usually stabilize and an accurate observed drawdown can be estimated. However, for a low yield borehole, drawdown usually does not stabilize but instead, water level continues to drop until it reaches the pump inlet and the test is complete. In this case COLOG utilizes the maximum observed drawdown. The uncertainty arises in the fact that overall observed drawdown may not have stabilized and therefore may not represent actual formation capacity. Secondly, in an environment where flow originates primarily from secondary porosity, the conditions for using Hvorslev's equation are not met. This assumption of a fracture network producing water versus a porous media is not how the permeability equation was designed to be used. In the absence of a more appropriate equation, COLOG utilizes Hvorslev's 1951 porosity equation based on its sensitivity to interval-specific flow, which can be measured accurately, drawdown which can be measured accurately in the case of a high yield borehole, and its insensitivity to effective radius. The insensitivity to effective radius is critical when an observation well is not available to measure drawdown at a known distance from the subject borehole (COLOG, 2004).

3.3 Data Evaluation and Interpretation

The local geologic setting at the HNP industrial area is an important consideration concerning geophysical data evaluation and interpretation. Groundwater flow patterns interpreted from the borehole geophysics data should follow flow regimes typical of fractured metamorphic crystalline rock formations, which defines the current conceptual site hydrogeologic model. The rock matrix in most metamorphic rocks has negligible primary porosity. Secondary porosity in the form of fractures, and to a lesser degree breaks along foliation planes and cleavage, constitute the effective porosity and comprise the flow pathways in this geologic setting. Fracture density and aperture tend to decrease with depth, possibly in response to hydrostatic pressure. Fracture aperture, however, may not be a significant factor concerning fracture flow. Assuming there is little contribution to flow from the rock matrix, which is likely at HNP, groundwater flow direction in crystalline rocks is typically along the strike of transmissive fractures. Fractures in the Industrial Area at the HNP are probably the result of joint sets aligned along the dominant regional north-south structural trends displayed by foliation and faulting (sub-vertical fractures) or those resulting from erosion and unloading (sub-horizontal fractures). Intervals where fracture density is high, especially in the upper portion of the bedrock section, may be fracture sets or networks that are hydraulically interconnected. The intersections of sub-horizontal and sub-vertical fractures are likely significant flow pathways and may provide interconnection for fracture sets. Flow paths may vary with upward, downward, or horizontal directions possible in the study area depending on fracture orientation, degree of interconnection, depth, and proximity to the Connecticut River, the discharge boundary for the study area. The results and findings generated from the two phases of borehole geophysical investigation were compared to this current conceptual site hydrogeologic model to confirm or refine the understanding of hydrogeologic conditions at the facility.

Hydraulically active fractures were inferred by correlating the responses of available geophysical logs. As previously mentioned, the geophysical measurements record different rock or fluid properties and may be more sensitive to indirect effects of the fracture. The response of each tool was evaluated and integrated into an overall interpretation of hydrogeologic conditions in each borehole and ultimately for the bedrock interval at the Industrial Area. A composite montage of the conventional geophysical logs and fluid logs is shown for each borehole to correlate the various tool responses recorded versus depth and illustrate the integration of multiple geophysical logging techniques used to initially characterize water-bearing fractures and flow conditions. Hydrophysical™ log profiles measured during ambient, DI water emplacement, and production tests are also included to depict the flow conditions in each borehole which best illustrate the definitive interpretations of hydrogeologic conditions and vertical distribution of SOCs.

A summary of the findings of the geophysical logging program concerning bedrock characterization and how this information relates to the hydrogeologic setting and refines the understanding of the conceptual site model is included at the end of Section 3.

3.3.1 Borehole BH-118A

The evaluation and resulting interpretation of hydrogeologic conditions in BH-118A from data collected by conventional borehole geophysics and fluid logging techniques are discussed in the following sections. The geophysical logging company reports (Geophysical Applications, Inc., 2003; COLOG, 2004) serve as references for the following text. The hydrophysics™ logging results are discussed separately because of the all-encompassing role the technique plays in the Task 2 bedrock characterization approach and overall data evaluation and interpretation process.

3.3.1.1 BH-118A Conventional Borehole Geophysical Logs

The natural gamma log response in BH-118A shows a consistent low radioactivity profile (low count per second [cps]) through out most of the borehole, suggesting little variation in lithology and an absence of feldspar or potassium-rich mineral composition that would show a higher count rate (see Figure 3-1). Bedrock geologic mapping (London, 1989) and conventional cores collected from BH-118 and BH-121 indicate amphibolite/augite gneiss with some albite/quartz gneiss are the dominant lithologies present in the Industrial Area of the HNP. The interval from 18 to 100 feet bgs, particularly from 18 to 30 feet bgs, shows the highest radioactivity response (high cps readings), possibly in response to different lithologies present in the upper bedrock interval, possibly a massive quartz or albite gneiss sequence as shown by the optical televiewer and camera images.

The caliper log and optical camera logs generally show a good correlation identifying washouts and possible open fractures. The caliper log showed the borehole to be largely in gauge with few small washouts or borehole enlargements except for the interval from 28 to 64 feet bgs. The washout at 55 feet bgs is the largest borehole enlargement feature noted by the caliper log. The optical camera log noted open aperture features to approximately 236 feet bgs that correlated with borehole enlargements noted by the caliper log. The most significant features recorded by the optical camera log were in the upper bedrock interval, specifically a washout at 28 feet bgs and large open aperture sub-horizontal fractures noted at approximately 28, 45, 55, 63, 127, 160, 186, 217, and 236 feet bgs. Suspended material, which may be an indication of fluid flow, was noted by the optical camera log in the features identified from 28 to 160 feet bgs.

Televiewer logs noted many structural and lithologic features in BH-118A, providing images of fractures (both open and healed), intercalated foliation, lithologic contacts, and quartz intrusions throughout the entire borehole. The acoustic televiewer log response indicated many "open" fractures throughout the entire borehole to approximately 470 feet bgs. The "open" fractures noted above 250 feet bgs are mostly low-angle (<10 degrees) sub-horizontal features, while with one exception, the "open" fractures below 250 feet bgs in BH-118A are near vertical features. Most of the features located by the acoustic televiewer log correspond with small borehole enlargements or washouts noted by the caliper log. The "open" fractures that show the largest apparent apertures that are continuous throughout most of the circumference of the borehole and correlate with optical camera log features and caliper log washouts are mostly in the shallower bedrock section. Based on the conventional geophysical logs reviewed, possible fractures noted at approximately 28, 45, 55, 63, 127, 185, and 216 feet bgs in BH-118A are the most significant features identified that are likely groundwater flow paths. It is noted that all of these possible fractures are sub-horizontal features with less than 10 degrees of dip with the exception of the one present at 55 feet bgs.

Numerous other "less open" features were noted by the acoustic televiewer throughout the entire borehole. When these features are reviewed with the optical log images, they are interpreted to be most likely foliation (Figure 3-1). Most of the interpreted foliation features display an inclined to near vertical dip, approximately 40 to 85 degrees mainly to the east. This is consistent with regional and local structural trends of bedrock mapped in the vicinity of the HNP (London, 1989).

3.3.1.2 BH-118A Fluid Logs

There are few indications of fluid entry into the borehole in BH-118A by the FTemp, FRes, or heat-pulse flowmeter logs. There was no flow indicated in the borehole by the ambient heat-pulse flowmeter survey. Inflow was only observed during the heat-pulse flowmeter pumping test from 28 to 35 feet bgs that corresponds to a FTemp inflection at 28 feet bgs, where conventional logs indicate a 5-degree east, southeast dipping "open" fracture is present. A hydraulically active zone was noted by a noticeable FRes inflection that corresponds with an "open" fracture with a 5-degree east, southeast dip at 127 feet bgs that was not confirmed by flowmeter observations. There was no indication of flow from the tool response measured from any fluid logs below 126 feet bgs in BH-118A.

3.3.1.3 BH-118A Hydrophysical™ Logs

Continuous hydrophysical™ logging runs were conducted in BH-118A during unstressed or ambient conditions before DI was emplaced, ambient conditions after DI water was emplaced, and under stressed or pumping conditions to obtain repeatable measurements of fluid electrical conductivity in the fluid column and determine flow patterns. Depth intervals, flow rates, hydraulic conductivity and transmissivity estimates assessed by COLOG for the flow zones identified by the hydrophysical™ logging and the discrete point sample tritium analytical results from the CY laboratory are summarized in Table 3-1.

The ambient fluid electrical conductivity and temperature profiles before DI water was emplaced in the borehole indicated an inflection at approximately 63 feet bgs (see Figure 3-2). The logs recorded a gradual increase in both fluid electrical conductivity and temperature with depth to approximately 100 feet bgs, below which a decrease of both measurements was noted.

The DI water emplacement process involves injection of DI water at the bottom of the well-bore while simultaneous extraction pumping is conducted near water surface at the same rate. Water levels and flow rates are monitored and recorded digitally continuously to ensure minimal to no DI water is lost to the formation. This is achieved by maintaining water level at or below the recorded ambient level.

For ambient flow assessment, the fluid column was replaced by DI water and the borehole left in an undisturbed state to allow natural flow to occur. A series of fluid electrical conductivity and temperature logs were run during the ambient flow characterization test conducted after DI water was emplaced in the borehole to identify changes in the in the fluid column associated with ambient horizontal and/or vertical flow. Logs recorded during this portion of the test illustrate changes in several intervals in the upper bedrock section (see Figure 3-3). During ambient flow testing, boring BH-118A exhibited a horizontal flow regime. Five water-bearing zones were identified under ambient conditions exhibiting horizontal flow, with no vertical pressure gradient observed under ambient conditions. The five water-bearing zones at 45.9 to 46.1, 63.9 to 65.0, 113.9 to 114.5, 127.8 to 128.0 and 219.8 to 219.5 feet contributed water to the borehole at estimated flow rates of 0.0008, 0.002, 0.002, 0.003, and 0.001 gpm, respectively as determined by numeric modeling of the field data. Correcting for convergence of flow at the well-bore and factoring the length of the interval, these flow rates equate to a Darcy velocity, or specific discharge of groundwater in the aquifer of 0.61, 0.28, 0.50, 2.27 and 1.51 feet/day, respectively. A summary of hydrophysical™ logging results determined from the ambient flow characterization test in BH-118A is shown in Table 3-1.

After DI water emplacement was complete, low-rate pumping was conducted to stress the formation and draw groundwater into the borehole where it was contrasted by the DI water in the borehole. Continuous FEC profiling over time yielded the depth and rate of influx of groundwater during pumping. The production test in BH-1118A was conducted with a time-averaged pumping rate of 4.81 gpm.

Multiple logs were run during the production test to provide continuous, repeatable flow profiles to best evaluate flow zones. Of these logs, thirteen fluid electrical conductivity traces are presented in Figures 3-4 and 3-5. These logs clearly illustrate specific intervals of dramatic increase in fluid electrical conductivity with respect to time. The depth at which the peak value for a given interval occurs is indicative of a water-bearing interval. The data presented in Figures 3-4 and 3-5 suggest the presence of 13 hydraulically conductive intervals, with the dominant water-bearing interval at 29.8 to 30.2 feet bgs. Fluid electrical conductivity logging under stressed conditions indicates no appreciable flow below 238.6 feet bgs. Numerical modeling of the reported field data was performed using code BOREII (Hale and Tsang, 1988, Tsang et. al. 1990, Daughtery and Tsang, 2000). This modeling was performed to estimate the rate of inflow and FEC for each identified hydraulically conductive interval during pumping.

In summary, the thirteen interval-specific estimated transmissivities in BH-118A ranged from 0.076 to 145 square feet per day with the interval of 29.8 to 30.2 feet bgs registering the highest transmissivity. The thirteen interval-specific transmissivity estimates differ significantly with respect to each other, however, for the intervals producing the appreciable amounts of flow during testing (the major flow zones at 45.9-68.4 feet bgs) the interval-specific transmissivity estimates do not differ significantly.

Interval specific fluid electrical conductivity values did not vary significantly for most depths. The uppermost flow zone at 29.8 to 30.2 feet bgs displayed the highest value, 857 microseimens per cm (microS/cm), greatly differing values measured in the deeper flow zones. The dominant water-bearing zones (45.9-68.4, 73.9-74.0, and 101.8-128.0 feet bgs) showed ranges of similar fluid electrical conductivity values within their respective depth intervals.

Downhole sampling was conducted in well-bore BH-118A during development pumping at a time-averaged rate of 4.89 gpm after production testing was completed. Eight downhole samples and one wellhead sample were procured from well-bore BH-118A. The samples procured from intervals 45.9-46.1, 63.9-65, and 68.3-68.4 feet bgs contained the highest levels of tritium concentration, with HNP laboratory results of 6,250, 7,230, and 4,460 pCi/L, respectively. The interval specific pore water tritium concentrations calculated for the 45.9-46.1, 63.9-65, and 68.3-68.4 feet bgs intervals exhibited higher values than the HNP lab results with 13,911, 9,818, and 13, 046 pCi/L, respectively. Laboratory analytical results and interval specific pore water tritium concentrations exhibited similar slightly elevated tritium levels for intervals 73.9-74.0, 113.9-114.5, and 127.8-128.0 feet bgs, which correspond to the lowest detected flow zone. The interval specific pore water tritium concentration for flow interval 101.8-101.9 feet bgs was calculated to be non-detect.

The tritium concentrations and interval specific flow data determined by the 2004 hydrophysical™ logging and 2003 packer testing efforts yielded some similar results, particularly in the shallower portion of the bedrock. Since the 2003 packer testing was performed using a 23-foot straddle packer assembly, comparing these results with the hydrophysical™ logging method is not a direct correlation, but the similar results suggest confirmation of hydrogeologic conditions in the borehole. Both methods exhibited similar tritium concentrations (1330 pCi/L by the 2003 packer testing and 1,850 pCi/L by the HNP lab results) and noted the most prolific flow zone in depth ranges that include the 29.8-30.2 feet bgs interval. The tritium concentration of 14,200 pC/L detected from the 43-66 feet bgs interval by the 2003 packer testing is very similar to the 13,911 pCi/L tritium pore water concentration calculated using COLOG's methodology at the 45.9-46.1 feet bgs depth interval. The 2003 packer test results do not match well with the hydrophysical™ logging results below 68.3 feet bgs other than confirming no flow zones below 200 feet bgs. At these other depth intervals, the hydrophysical logging results are considered a more accurate characterization of chemical distribution and flow zones.

Fracture inter-connectiveness in the immediate vicinity of a well-bore can be inferred by the similarity, or lack there of, of parameters such as interval-specific transmissivity estimates and interval-specific fluid electrical conductivity, along with the presence of pressure differentials within the borehole. Typically, fractured bedrock hydrogeologic settings tend to exhibit heterogeneity with respect to both the transmissivities and hydrochemistry of different intervals and specific fractures. The data acquired in BH-118A indicated similar interval-specific transmissivity (1.83 to 145 square ft per day from 29.8-128 feet bgs) and similar fluid electrical conductivity estimates (166 to 857 microS/cm from 29.8-128 feet bgs) among the dominant water-bearing fractures. The similar values of transmissivity and electrical conductivity suggests an inter-connected network of fractures occurs within the shallower portions of the bedrock section where the highest tritium activity concentrations were detected (45.9-68.4 feet bgs). No vertical gradient is observed in the well-bore suggesting that the inter-connected nature of the dominant water-bearing intervals negates any pressure differentials. The data further suggests the fractures intersecting the well bore may be inter-connected in the immediate vicinity of the well-bore.

3.3.2 Borehole BH-119

The evaluation and resulting interpretation of hydrogeologic conditions in BH-119 from data collected by conventional borehole geophysics and fluid logging techniques are discussed in the following sections. The geophysical logging company reports (Geophysical Applications, Inc., 2003; COLOG, 2004) serve as references for the following text. The hydrophysics™ logging results are discussed separately because of the all-encompassing role the technique plays in the Task 2 bedrock characterization approach and overall data evaluation and interpretation process.

3.3.2.1 BH-119 Conventional Geophysical Logs

No natural gamma log was run in BH-119, but the optical camera logs and televiewer logs provide a good illustration of the foliated bedrock sequence in the borehole. Images collected by conventional geophysical logs reveal the banded nature of the bedrock with distinct contacts of amphibolite and augite gneiss likely shown as the dark mafic rock alternating with lighter quartz intrusions and massive quartz\albite gneiss intervals. These lithologies interpreted to be present at the borehole are consistent with published local geologic mapping (London, 1989). The caliper log depicts the borehole to be largely in gauge with very few small washouts or borehole enlargements, the most significant at approximately 87 and 159 feet bgs (see Figure 3-6). The optical camera logs indicated more significant open aperture fractures than the caliper log with features shown at approximately 73, 87, 147, 159, 251, 294, 424, 453, and 592 feet bgs.

There were "open" fractures noted throughout the entire depth of the borehole at 47, 73, 87, 131, 140, 147, 159, 233, 293, 370, 421, 440, 450, 545, 560, 588, and 603 feet bgs. Based on an integrated evaluation of the conventional log data, the features noted at 73, 87, 147, and 159 feet bgs are the most likely water-bearing fractures in the borehole. All of these features are interpreted to be sub-horizontal fractures with dip measured at approximately 5 degrees with variable directions to the northwest, northeast, and northeast. It should be noted that calculated down-dip compass azimuths of nearly horizontal planar features, such as the features previously mentioned, have greater uncertainties than the azimuths of steeply dipping features.

The "less open" fracture features noted in BH-119 show varying degrees of structural dip. A review of optical televiewer and optical camera logs suggests these features are related to foliation. The lower angle dip features noted are usually associated with intervals that have quartz intrusions that deform the foliation and are probably not related to the regional structural dip. High angle dip measurements are more likely representative of the regional geologic setting in the vicinity of BH-119.

3.3.2.2 BH-119 Fluid Logs

Evaluation and interpretation of fluid logs run in BH-119 suggest that hydraulically active fractures may be present in the upper 100 feet of the bedrock interval by the heat-pulse flowmeter-pumping test results, while FRes and FTemp measurements indicate possible flow at greater depths. There was no flow indicated in the borehole by the ambient heat-pulse flowmeter survey. Several inflow zones were noted in the upper 100 feet of bedrock during the heat-pulse flowmeter-pumping test, suggesting the presence of hydraulically active fractures in this interval. Inflow was indicated in several zones in BH-119 by the fluid log response and flowmeter survey measurements between the base of surface casing (46 feet bgs) and 165 feet bgs. Inflow noted between the base of surface casing (46 feet bgs) and 75 feet bgs during the heat-pulse flowmeter pumping test corresponds to the location of an "open" fractures at 47 feet and 73 feet bgs, which display 12 degree dip to the south-southeast and east-southeast, respectively. An inflow zone was noted by flowmeter and a FTemp inflection between 75 to 100 feet bgs that corresponds to two closely-spaced "open" fractures that display 5 degree east-northeast dip at approximately 87 feet bgs. The most inflow during the heat-pulse flowmeter pumping test in MW-119 was noted in the 135 to 165 feet bgs interval that corresponds to FRes and FTemp inflections at 157 feet bgs and to several "open" sub-horizontal fractures noted at 140, 147, and 159 feet bgs. There were FRes inflections at 212 feet bgs and from 271 to 282 feet bgs that suggest a hydraulically active zone. However, these features were not confirmed by flowmeter response and do not correlate with any observed "open" fractures. There was no flow measured by the fluid logs below 282 feet bgs.

3.3.2.3 BH-119 Hydrophysical™ Logs

Multiple logs collected during the ambient, ambient flow characterization, and production flow characterization tests conducted in BH-119 as part of hydrophysical™ logging were used to identify and evaluate chemical and physical properties of water-bearing fractures. Depth intervals, flow rates, hydraulic conductivity and transmissivity estimates assessed by COLOG for the flow zones identified by the hydrophysical™ logging and the discrete point sample tritium analytical results from the CY laboratory are summarized in Table 3-2.

The ambient fluid electrical conductivity and temperature profiles provide data to assess the ambient fluid conditions in BH-119. The ambient fluid electrical conductivity and temperature logs collected indicate inflections at approximately 47 feet bgs as shown in Figure 3-7. The ambient temperature log recorded a gradual increase in temperature with depth to approximately 88 feet bgs, below this depth the log indicates a gradual decrease in temperature to approximately 300 feet bgs. Below this depth the log indicates a gradual increase in temperature with depth. The ambient fluid electrical conductivity log is relatively featureless below the inflection at approximately 47 feet bgs.

DI water emplacement was performed and borehole conditions were allowed to equilibrate before ambient flow testing following standard procedures. During ambient testing, borehole BH-119A exhibited a horizontal flow regime. Five water-bearing zones were identified under ambient conditions exhibiting horizontal flow (see Figure 3-8). No vertical pressure gradient was observed under ambient conditions. The five water-bearing zones at 47.3 to 47.4, 85.2 to 88.8, 160.0 to 160.3, 241.2 to 241.4 and 262.2 to 263.8 feet bgs contributed water to the borehole at estimated flow rates of 0.003, 0.001, 0.001, 0.0002, and 0.0002 gpm, respectively. Correcting for convergence of flow at the well-bore and factoring the length of the interval, these flow rates equate to a Darcy velocity, or specific discharge of groundwater in the aquifer of 4.54, 0.04, 0.50, 0.02 and 0.02 feet/day, respectively.

Low-rate pumping of well-bore fluids after DI water emplacement was conducted at one pumping rate (1.40 gpm) to establish the inflow locations and evaluate the interval-specific inflow rates. Low-rate pumping at a given rate after DI water emplacement is conducted when the subject well-bore cannot sustain more than approximately 2-3 gpm yield. After DI water emplacement was complete, low-rate pumping was conducted to stress the formation and draw groundwater into the well-bore where it was contrasted by the DI water in the well-bore. Continuous fluid electrical conductivity profiling over time yields the depth and rate of influx of groundwater during pumping.

Eight of the fluid electrical conductivity traces are presented in Figure 3-9, showing a clear illustration of specific intervals with a dramatic increase in fluid electrical conductivity with respect to time. The depth at which the peak value for a given interval occurs is indicative of a water-bearing interval. The data presented in Figure 3-9 suggest the presence of eighteen hydraulically conductive intervals, with the dominant water-bearing interval at 85.2 to

88.8 feet bgs. Numerical modeling of the reported field data was performed using code BOREII (COLOG, 2004, Daughtery and Tsang, 2000). This modeling was performed to estimate the rate of inflow and fluid electrical conductivity for each identified hydraulically conductive interval during the pumping. The results of the modeling and analysis are presented in Table 3-2. In summary, the interval of 85.2- 88.8 feet bgs feet dominated inflow producing 0.438 gpm, or 32.4 percent of the total inflow during production testing. The combined flow from intervals 85.2-88.8, 147.8-148.9, and 160.0-160.3 feet bgs dominated flow during the production test, accounting for 78 percent of the flow in the borehole.

The eighteen interval-specific estimated transmissivities in BH-119 ranged from 0.003 to 3.86 square feet per day with the interval of 85.2 to 88.8 feet bgs registering the highest transmissivity. The interval-specific transmissivity estimates among dominant water producing intervals (47.3-160.3 feet bgs) do not differ greatly with respect to each other. However, the interval from 85.2 to 88.8 feet bgs is relatively more transmissive than the other intervals.

Discrete point sampling was conducted in borehole BH-119 during development pumping at a time-averaged rate of 1.41 gpm after production testing was completed. Eight downhole samples and one wellhead sample were collected from borehole BH-119. Samples collected from 47.3-47.4, 74.4-74.5, and 85.2-88.8 feet bgs intervals contained the highest levels of contaminant concentration, all in the upper bedrock interval. The lowest major flow zone was noted at 160-160.3 feet bgs by the fluid electrical conductivity profile with a interval pore water tritium concentration of 1,604 pCi/L calculated by COLOG's methodology, most likely noting the probable base of tritium presence in the bedrock. Samples collected from poorly-developed flow zones at 253.0-254.5 and 456.4-456.7 feet bgs detected tritium at 1,170 pCi/L and 1,570 pCi/L, respectively by the HNP laboratory. Interval specific pore water tritium concentrations calculated using COLOG's methodology were significantly higher at 6,744 and 10,821 pCi/L, respectively, but were determined to not be representative because the flow zones were not developed and the borehole water could not be determined to be mixed at these intervals. This situation is discussed in greater detail in the COLOG hydrophysical logging results report and the CH2M HILL data quality assessment (DQA) of the hydrophysical™ logging discrete point sample results included in Appendix 5.

The 2004 hydrophysical™ logging results showed some similarity with the 2003 packer testing results in the shallower portion of the bedrock, but had very little correlation with packer test results collected in the deeper portion of the bedrock. The 2003 packer testing results generally indicated significantly higher tritium concentrations in intervals where tritium was detected by the discrete point samples and detected tritium at higher concentrations where the hydrophysical™ logs did not detect any flow zones. Hydrophysical™ logging results calculated interval specific pore water concentrations of 9,148, 18,346, and 10,107 pCi/L at intervals 47.3-47.4, 74.4-74.5, and 85.2 feet bgs, respectively compared to 14,300, 35,300, and 32,700 pCi/L detected in packer test intervals 42-65, 63-86, and 84-107 feet bgs, respectively. Results from the calculated pore water tritium concentration at 147.8-148.9 feet bgs were similar to 4,140 pCi/L detected at 143-166 feet bgs 2003 packer test interval. Below this depth range, there was very little correlation between the two different sampling methods. Comparison of the two sampling technologies and strategies are difficult to compare to a great extent, but the hydrophysical logging results are accepted as being more representative of hydrogeologic conditions in BH-119. The 2003 packer test DQA provided in Appendix 1 discusses the evaluation of the packer test results in detail.

The data acquired in BH-119 exhibited similar interval-specific transmissivity (1.87 to 3.86 square feet per day) and similar fluid electrical conductivity estimates (151 to 201 microS/cm) among the dominant water-bearing fractures (47.3-160.3 feet bgs) suggests that an inter-connected network of fractures within the shallower portions of the bedrock section where the highest tritium activity concentrations were detected. No vertical gradient is observed in the borehole suggesting that the inter-connected nature of the dominant water-bearing intervals negates any pressure differentials. The data further suggests the fractures intersecting the well bore may be inter-connected in the immediate vicinity of the well bore.

3.3.3 BH-120

The evaluation and resulting interpretation of hydrogeologic conditions in BH-120 from data collected by conventional borehole geophysics and fluid logging techniques are discussed in the following sections. The geophysical logging company reports (Geophysical Applications, Inc., 2003; COLOG, 2004) serve as references for the following text. The hydrophysics™ logging results are discussed separately because of the all-encompassing role the technique plays in the Task 2 bedrock characterization approach and overall data evaluation and interpretation process.

3.3.3.1 BH-120 Conventional Geophysical Logs

The nature of the intercalated foliated bedrock sequence in BH-120 is well illustrated by the natural gamma log profile and the images recorded by the optical camera and optical televiewer logs. The natural gamma log response indicates low cps or a low radioactivity profile throughout most of the borehole, suggesting little variation in lithology and an absence of feldspar or potassium-rich mineral composition that would show a higher count rate, such as amphibolite (see Figure 3-10). The intervals of relatively high cps or radioactivity profiles such as from 40-75 feet bgs, 200-230 feet bgs, and 400-455 feet bgs correspond to massive quartzite sections or apparent banded structures of rock suggesting different mineralogy, possibly quartz/albite gneiss intercalated with amphibolite or augite gneiss, as recorded by the optical camera and optical televiewer logs. These interpretations of the subsurface geologic setting from the conventional geologic logs run in BH-120 are consistent with local bedrock geologic mapping (London, 1989).

The caliper log shows the borehole to be largely in gauge with few small washouts or borehole enlargements. The irregular caliper log intervals correspond to the interval where most of the "open" fractures were identified from 40 to 160 feet bgs, or sections where there apparent quartz\albite banding or intrusions are suggested by optical camera or televiewer images from 200 to 240 feet bgs and 400 to 455 feet bgs. The most significant caliper log washouts were indicated at approximately 49, 93, 105, 129, 142, 152, 158, and 227 feet bgs. The optical camera log identified apparent open aperture fracture features at 49, 93, 136, 141, 142, 235, and 323 feet bgs, showing correlation with the caliper log in only a few depth intervals in the shallow portion of the borehole.

The majority of the "open" fractures located by the acoustic televiewer log are shallower than 160 feet bgs. Depths where likely "open" fractures were present include 49, 93, 102, 105, 129, 142, 152, 158 feet bgs, and 227 feet bgs. Several "open " fractures were also indicated by the acoustic log response from 445 to 505 feet bgs, but were not confirmed by caliper log response or optical images. An evaluation of the conventional geophysical logs suggests potential water-bearing fractures at 49, 93, 105, 142, 152, 158, and 227 feet bgs. Except for the feature noted at 158 feet bgs, all of the probable water-bearing fractures identified show dips less than 12 degrees.

The acoustic televiewer identified mostly "less open" fracture features in BH-120, especially below 160 feet bgs. Interpretations of the optical televiewer and camera log images suggest these features are bedrock foliation. Most of the interpreted foliation features display near vertical dip approximately 60 to 80 degrees mainly to the east, consistent with attitude of regional and local bedrock structural trends (London, 1989).

3.3.3.2 BH-120 Fluid Logs

Fluid logging results in BH-120 indicate four possible flow zones in the shallow bedrock interval. There was no flow indicated by the ambient heat-pulse flowmeter survey in BH-120. The shallowest potential flow zone identified was indicated by a FRes inflection at approximately 50 feet bgs that correlates with a 12 degree southwest dipping "open " fracture. However, this feature was not confirmed by the flowmeter pumping test. Inflow was measured by the heat-pulse flowmeter pumping test between 65 and 95 feet bgs that correlates with potential water-bearing fractures identified at 93 feet bgs. Minor inflow detected by the flowmeter tool may have occurred between 95 and 125 feet bgs interval that corresponds to a FRes slope change and a sub-horizontal east dipping "open" fracture at 105 feet bgs. Flowmeter inflow was noted between 125 and 155 feet bgs that aligns with several FTemp and FRes inflections and slope changes within that depth range and near horizontal southeast and southwest dipping "open" fractures located at 152 and 158 feet bgs. There was no flow indicated by any fluid logging technique below 160 feet bgs in BH-120.

3.3.3.3 BH-120 Hydrophysical Logs

Multiple logs collected during the ambient, ambient flow characterization, and production flow characterization tests conducted in BH-120 as part of hydrophysical™ logging were used to identify and evaluate chemical and physical properties of water-bearing fractures. Depth intervals, flow rates, hydraulic conductivity and transmissivity estimates assessed by COLOG for the flow zones identified by the hydrophysical™ logging and the discrete point sample tritium analytical results from the CY laboratory are summarized in Table 3-3.

Ambient fluid electrical conductivity and temperature profiles collected during the initial phase of hydrophysical™ logging provided data to assess the ambient fluid conditions in BH-120. The ambient fluid electrical conductivity logs collected indicate inflections at approximately 142 feet bgs while the remainder of the log was relatively featureless as shown in Figure 3-11. The ambient temperature log recorded a gradual decrease in temperature with depth to approximately 313 feet bgs, below this depth the log indicates a gradual increase in temperature to approximately the TD of the well-bore.

DI water emplacement was performed in the standard manner and borehole conditions were allowed to equilibrate before ambient flow testing following standard procedures. Formation water migration caused by horizontal flow within the fluid column is indicated by the increase in fluid electrical conductivity over time in Figure 3-12 for the intervals at 105.6-106.0 feet, 153.2-153.3 feet and 211.0-211.3 feet bgs. Numeric modeling of the reported field data for these intervals suggests horizontal flow is occurring at rates of 0.004, 0.008 and 0.002 gpm, respectively. These flow rates are based on the rate of increase of mass at these intervals. Correcting for convergence of flow at the well-bore and factoring the length of the interval, these flow rates equate to a Darcy velocity, or specific discharge of groundwater in of 1.51, 12.1 and 1.01 feet/day, respectively.

Low-rate pumping of well-bore fluids after DI water emplacement was conducted at one pumping rate to establish the inflow locations and evaluate the interval-specific inflow rates. Low-rate pumping at a given rate after DI water emplacement is conducted when the subject well-bore cannot sustain more than approximately 2-3 gpm yield. After DI water emplacement was complete, low-rate pumping was conducted to stress the formation and draw groundwater into the well-bore where it was contrasted by the DI water in the well-bore. Continuous fluid electrical conductivity profiling over time yields the depth and rate of influx of groundwater during pumping. These procedures were implemented at a time-averaged pumping rate of 1.85 gpm.

Twelve of the multiple logging runs conducted during the production test in BH-120 are shown in Figures 3-13 and 3-14. These logs clearly illustrate specific intervals of dramatic increase in fluid electrical conductivity with respect to time. The depth at which the peak value for a given interval occurs is indicative of a water-bearing interval. The data presented in Figures 3-13 and 3-14 suggest the presence of 11 hydraulically conductive intervals all above 243 feet bgs, with the dominant water-bearing interval at 105.6 to 106.0 feet bgs. Numerical modeling of the reported field data was performed using code BOREII (COLOG, 2004, Daughtery and Tsang, 2000). This modeling was performed to estimate the rate of inflow and fluid electrical conductivity for each identified hydraulically conductive interval during the pumping. The results of the modeling and analysis are presented in Table 3-3. In summary, the interval of 105.6 to 106.0 feet bgs dominated inflow producing 0.778 gpm, or 41 percent of the total inflow during production testing. The combined inflow of intervals 92.8 to 93.6 feet (0.554 gpm) and 105.6 to 106.0 feet bgs combined to account for 71.2 percent of the total inflow during the stressed test.

The eleven interval-specific estimated transmissivities in BH-120 ranged from 0.043 to 8.93 square feet per day with the interval of 105.6 to 106.0 feet bgs registering the highest transmissivity (see Figures 3-13, 3-14). The interval-specific transmissivity estimates of the two dominant water producing intervals (92.8-93.6 feet bgs and 105.6-106.0 ft bgs), do not differ significantly with respect to each other. However, the transmissivities of these two intervals are significantly greater than those calculated for the other intervals.

Discrete point samples were collected downhole in borehole BH-120 during development pumping at a time-averaged rate of 1.80 gpm after production testing was completed. Seven downhole samples and one wellhead sample were procured from well-bore BH-120. The sample procured from 83.5-83.6 feet bgs detected the highest levels of contaminant concentration. The HNP laboratory results (1,390 and 1,360 pCi/L) and the interval specific pore water tritium concentrations calculated by COLOG'S methodology (1,458 and 1,459 pCi/L) detected similar concentrations at the 92.8-93.6 and 105.6-106.0 feet bgs intervals, respectively. Tritium was not detected at any deeper flow zones noted by the hydrophysical™ logs. The 2003 packer test results and the 2004 hydrophysical™ logging results in BH-120 both noted the higher tritium concentrations in the upper bedrock section above 86 feet bgs, but showed little correlation in results below that depth. The 2003 packer test results detected tritium at low concentrations from low-yield zones at depth in BH-120. Differences in the sampling methodologies employed make for a difficult comparison of results at depth, but the hydrophysical™ logging results have been determined to be more representative of hydrogeologic conditions. The 2003 packer test results are discussed in greater detail in the 2003 packer test DQA found in Appendix 1.

The data acquired in BH-120 exhibited similar interval-specific transmissivity (6.0 and 8.39 square feet per day) and relatively similar fluid electrical conductivity estimates (414 and 223 microS/cm) among the two dominant water-bearing fractures suggests that an inter-connected network of fractures occurs within the shallower of the bedrock section portions from 83.5-93.6 feet bgs where the highest tritium activity concentrations were detected. No vertical gradient is observed in the well-bore suggesting that the inter-connected nature of the dominant water-bearing intervals negates any pressure differentials. The data suggest the fractures intersecting the well-bore may be inter-connected in the immediate vicinity of the well-bore.

3.3.4 BH-121A

The evaluation and resulting interpretation of hydrogeologic conditions in BH-121A from data collected by conventional borehole geophysics and fluid logging techniques are discussed in the following sections. The geophysical logging company reports (Geophysical Applications, Inc., 2003; COLOG, 2004) serve as references for the following text. The hydrophysics™ logging results are discussed separately because of the all-encompassing role the technique plays in the Task 2 bedrock characterization approach and overall data evaluation and interpretation process.

3.3.4.1 BH-121A Conventional Geophysical Logs

The conventional geophysical logs provide data to evaluate and interpret the compositional banding and intercalated nature of the bedrock section in the borehole BH-121A (see Figure 3-15). The gamma log shows a low radioactivity profile, which is likely amphibolite and/or augite gneiss for much of the bedrock encountered in the borehole with the high radioactivity intervals corresponding to probable quartz intrusions and massive quartz/albite gneiss sections intercalated in the foliated sequence. This interpretation is supported by the optical televiewer and camera images recorded and is consistent with the knowledge of the geologic setting at the facility (London, 1989).

The caliper log recorded in BH-121A shows the borehole to be in gauge with some small borehole enlargements or washouts present from the base of surface casing at 97.5 to 175 feet bgs. This interval corresponds to where most of the "open" fractures identified by the acoustic televiewer are present. Caliper washouts were noted at 115, 159, 165, and 175 feet bgs. Small borehole enlargements were indicated from 268 to 335 feet bgs that correspond to interpreted 'open" fractures noted at that interval. The optical camera images indicated possible fractures with some apparent open aperture at 116, 160, 161, 165, 176, 179, 304, 317, 319, and 543 feet bgs showing a general correlation with the caliper log profile. The optical camera also recorded some "vug"-like features or larger holes in the borehole at 277 and 278 feet bgs.

The acoustic televiewer located few "open" fractures in BH-121A, with a high density of features detected in two depth intervals from 148 to 185 feet bgs and 268 to 275 feet bgs. No "open" fractures were detected below 342 feet bgs. Possible fractures were identified at 115, 148, 156, 159, 161, 164, 165, 175, 185, 205, 268, 269, 274, 275, 300, 318, 320, and 342 feet bgs. Reviewing the conventional geophysical logs suite suggests possible water-bearing fractures are present at approximately 159, 165, 175, 268, 269, 274, 275, 318, 320, and 342 feet bgs. Differing from the overall attitude of potential water-bearing fractures in the other boreholes, the dip angles exhibited by the potentially hydraulically active fractures in BH-121A range from sub-horizontal to sub-vertical, possibly intersecting each other at some depth intervals, particularly between 140 and 185 feet bgs. If these near horizontal and near vertical features do intersect, interconnection of fracture sets in the bedrock is possible.

The vast majority of fracture features identified by the acoustic televiewer in BH-121A were "less open" fracture features. Interpretations of the optical televiewer and camera log images suggest these features are bedrock foliation exhibiting near vertical dip approximately 50 to 80 degrees mainly to the southeast, consistent with regional and local bedrock structural trends (London, 1989).

3.3.4.2 BH-121A Fluid Logs

Five potential hydraulically active zones were identified by fluid logging techniques conducted in BH-121A. There was no flow measured in BH-121A during the ambient heat-pulse flowmeter survey. Inflow was indicated by the heat-pulse flowmeter pumping test observations from base of surface casing (97.5 feet bgs) to 170 feet bgs in the borehole. There was inflow observed from 97.5 to 120 feet bgs during the heat-pulse flowmeter pumping test that corresponded to FRes inflections at 106 feet and 118 feet bgs and an "open" fracture that dips 25 degrees to the southwest. There was inflow indicated by flowmeter measurements also during the pumping test between 120-150 feet bgs that corresponded to FRes inflections at 122, 132, and 147 feet bgs. No "open" fractures are indicated within this interval by the acoustic televiewer log. Most inflow observed by the flowmeter pumping test in BH-121A occurred between 150-160 feet bgs that corresponds to several easterly dipping, near horizontal "open" fractures and borehole enlargement recorded by the caliper log at the base of this interval. Some inflow was observed by the flowmeter during pumping between 160-170 feet bgs that corresponds to several near horizontal and one near vertical "open" fractures dipping to the southeast that align with the largest borehole enlargement measured in the borehole. Several step-like FRes inflections between 274 and 320 feet bgs suggest a hydraulically active zone that was not confirmed by the flowmeter pumping test survey. There are very few "open "fractures identified and no flow observed by flowmeter below 170 feet bgs in BH-121A.

3.3.4.3 BH-121A Hydrophysical™ Logs

Multiple logs collected during the ambient, ambient flow characterization, and production flow characterization tests conducted in BH-121a as part of hydrophysical™ logging were used to identify and evaluate chemical and physical properties of water-bearing fractures. Depth intervals, flow rates, hydraulic conductivity and transmissivity estimates assessed by COLOG for the flow zones identified by the hydrophysical™ logging and the discrete point sample tritium analytical results from the CY laboratory are summarized in Table 3-4.

Ambient fluid electrical conductivity and temperature logs provide data to assess the ambient fluid conditions in BH-121A. The ambient FEC profile indicates notable inflections at approximately 98, 126, 160, 277, 217 and 455 feet bgs (see Figure 3-16). A general increase in fluid electrical conductivity with depth was indicated by the ambient baseline fluid conditions. The ambient temperature log recorded notable inflections at approximately 98, 277, and 405 feet bgs. The temperature log indicates a general decrease in temperature with depth to approximately 277 feet bgs. Below this depth the temperature log indicates a general increase in temperature with depth, with the exception of the infection at approximately 405 feet bgs.

DI water emplacement was performed in the standard manner and borehole conditions were allowed to equilibrate before ambient flow testing following standard procedures.

Five of the logs collected as part of the ambient flow testing are presented in Figure 3-17. These logs illustrate changes at several intervals throughout the upper portion of the borehole. These changes in the FEC profiles with respect to time are associated with ambient horizontal flow occurring within these intervals. Horizontal flow within the fluid column is indicated by the increase in fluid entry conductivity over time for the intervals at 165.9 to 166.8 feet, 278.0 to 278.8 feet and 460.7 to 465.1 feet bgs (see Figure 3-17). Numeric modeling of the reported field data for these intervals suggests that horizontal flow is occurring at rates of 0.012, 0.0008 and 0.0004 gpm, respectively. These flow rates are based on the rate of increase of mass at these intervals. Correcting for convergence of flow at the well-bore and factoring the length of the interval, these flow rates equate to a Darcy velocity, or specific discharge of groundwater in the aquifer 2.02, 0.15 and 0.01 feet/day, respectively.

Low-rate pumping of well-bore fluids after DI water emplacement was conducted at one pumping rate to establish the inflow locations and evaluate the interval-specific inflow rates. Water levels and flow rates are monitored and continuously recorded digitally to ensure minimal to no DI water is lost to the formation. This was achieved by maintaining water level at or below the recorded ambient level. After DI water emplacement was complete, low-rate pumping was conducted to stress the formation and draw groundwater into the well-bore where it is contrasted by the DI water in the well-bore. Continuous fluid electrical conductivity profiling over time yields the depth and rate of influx of groundwater during pumping. These procedures were conducted at a time-averaged pumping rate of 6.69 gpm.

During the period of testing, multiple fluid electrical conductivity profiles were recorded. Of these logs eight fluid electrical conductivity traces are presented in Figure 3-18. These logs clearly illustrate specific intervals of dramatic increase in fluid electrical conductivity with respect to time. The depth at which the peak value for a given interval occurs is indicative of a water-bearing interval. The data presented in Figure 3-18 suggest the presence of thirteen hydraulically conductive intervals, with the dominant water-bearing interval at 165.9 to 166.8 feet bgs. Numerical modeling of the reported field data was performed using code BOREII (COLOG, 2004, Daughtery and Tsang, 2000). This modeling was performed to estimate the rate of inflow and fluid electrical conductivity for each identified hydraulically active interval during the pumping. The results of the modeling and analysis are presented in Table 3-4. In summary, the interval of 165.9-166.8 feet bgs dominated inflow producing 6.26 gpm, or 93.6 percent of the total inflow during production testing.

The thirteen interval-specific estimated transmissivities in BH-121A ranged from 0.004 to 30.7 square feet per day with the interval of 165.9 to 166.8 feet bgs registering the highest transmissivity. The thirteen interval-specific transmissivity estimates show a variation of values at different depth ranges. The transmissivities derived for the depths within intervals from 160.4-166.8, 177.6-328.5, and 446.8-515.2 feet bgs do not differ significantly with respect to each other. The highest transmissivity value estimated was for the dominant water producing zone at 165.9-166.8 feet bgs.

Discrete point samples were collected at depth in borehole 121A during development pumping at a time-averaged rate of 6.75 gpm after production testing was completed. Eight at-depth samples were collected. In summary, samples collected from depth intervals 165.9 – 166.8 and 177.6-177.7 feet bgs detected tritium at elevated pore water tritium concentrations of 7,322 and 8,645 pCi/L, respectively. All other samples analyzed were non-detect as shown in Table 3-4.

The 2003 and 2004 packer test results showed a good correlation with hydrophysical logging results in the upper bedrock section where the dominant water-bearing zones are present in BH-121A. The 2004 packer test results and the 2004 hydrophysical logging results are very similar throughout the borehole in relation to both tritium distribution and flow zones detected, but the 2003 packer testing effort detected tritium at several intervals at depth where the other sampling efforts did not. The calculated pore water tritium concentrations of 7,322 and 8,645 pCi/L from intervals 165.9-166.8 and 177.6-177.7 feet bgs, respectively generally correlate with the 2003 packer test results of 8,890 pCi/L detected from 147-170 feet bgs and 8,630 pCi/L detected from 168-191 feet bgs. The 2004 packer testing results from the 153-176 feet bgs interval (8,170 pCi/L) and the 178-183 feet bgs interval (6,630 pCi/L) are very similar to the interval specific pore water tritium concentrations detected at the same depth range noted above. Below 183 feet bgs, the 2004 packer test results were either non-detect or could not verify packer seal, consistent with hydrophysical logging results. The tritium detections at depth intervals 273-296 (2,610 pCi/L), 294-317 (6,080 pCi/L), 336-359 (8,700 pCi/L), and 441-464 feet bgs (7, 400 pCi/L) in BH-121A by the 2003 packer testing have been determined to be not representative of tritium distribution in the bedrock. In summary, the hydrophysical logging results are considered representative of hydrogeologic conditions in BH-121A. The 2003 packer test results are discussed in detail in the DQA found in Appendix 1.

The data acquired in BH-121A exhibited similar interval-specific transmissivity and similar fluid electrical conductivity estimates suggesting an inter-connected network of fractures in the immediate vicinity of the well-bore from 160.4-177.7 feet bgs. Other flow zones detected at depth may be inter-connected based on similar fluid electrical conductivity values, but do not exhibit tritium distribution within these intervals. No vertical gradient is observed in the well-bore. The data suggest the fractures intersecting the well-bore may be inter-connected in the immediate vicinity of the well-bore where flow zones exist.

3.4 Hydrophysical Sampling Data Quality Assessment

CH2M HILL performed a data quality assessment (DQA) of the analytical results generated by the HNP onsite laboratory and the interval specific pore water tritium concentrations calculated by COLOG from the discrete point samples collected during hydrophysical™

logging at the CYAPCo HNP. The purpose of collecting and analyzing discrete point samples at the industrial area of the HNP was to provide screening of the bedrock interval for the vertical distribution of tritium, confirm the analytical results and overall characterization of the boreholes obtained from previous packer testing, and determine potential screen intervals for water quality monitoring.

The data set generated from the borehole sampling was evaluated against criteria for measurement precision, accuracy, representativeness, completeness, and comparability to determine data validity and usability. Observations concerning the results of the DQA are summarized below:

- Valid, representative data was collected by the discrete point sampling characterization effort.
- The discrete point sample analytical results and calculated pore water tritium concentrations met the hydrophysical/geophysical logging program objectives. The discrete point sample results provided necessary information to further characterize the bedrock beneath the industrial area of the HNP, refine the hydrogeologic conceptual site model, assist with the design of the bedrock groundwater monitoring network, and calibrate the upcoming numerical groundwater modeling for the facility.
- Discrete point samples collected and analyzed from zones that did not fully develop under the hydrophysical™ testing conditions should not be considered representative for assessment of the presence, absence, or relative concentration of tritium. In this scenario, the laboratory analytical results are likely more representative of groundwater from these depths than the interval specific pore water tritium concentrations calculated by COLOG's methodology.
- Laboratory analytical results of discrete point samples collected from low flow zones directly above high flow zones may not yield analytical results representative of those intervals. Because of the mixing of borehole water at the sample collection depth may not be complete and was difficult to determine, the interval specific pore water concentrations calculated using COLOG's methodology are likely more representative of groundwater from these depths than the laboratory analytical results:

The following data deficiencies were noted by the DQA:

- No field duplicate samples were collected to measure precision.
- The onsite laboratory did not use blank and/or matrix spike information to assess accuracy (e.g., blanks, spikes, and standards) of the analytical results.

The data collected as part of this characterization effort met the hydrophysical/geophysical logging program objectives of screening the bedrock for SOCs. This data provides necessary information to refine the hydrogeologic conceptual site model, assist with the design of the bedrock groundwater monitoring network, and support calibration of the numerical groundwater modeling that will be developed for the facility. The hydrophysical sampling DQA is presented in Appendix 5.

3.5 Borehole Geophysics Program Conclusions and Observations Related to Bedrock Characterization at the HNP

The borehole geophysics program conducted at HNP successfully applied multiple geophysical and fluid logging techniques to characterize groundwater flow, estimate aquifer properties, and assess the vertical distribution of SOCs at the Industrial Area. The methodology employed for the fractured bedrock characterization task proved to be an effective means to provide quantification of selected hydrogeologic conditions and indications of contaminant distribution within the bedrock aquifer at the facility. The integration of the conventional borehole geophysical logs and the specialized applications of the fluid logs provided sufficient qualitative and quantitative data to evaluate and interpret properties of the bedrock aquifer system.

The data collected as part of this characterization effort met the geophysical logging program objectives and provided necessary information to refine the hydrogeologic CSM, assist with the design of the bedrock groundwater monitoring network, and provide data to support calibration of the numerical groundwater modeling that will be developed for the facility.

The following observations can be made concerning bedrock hydrogeologic conditions from the borehole geophysical logging program data evaluation and interpretation:

- The geologic setting of the industrial area at HNP conforms to the regional and local bedrock structural mapping. The optical camera and televiewer images show a foliated sequence with apparently a predominantly amphibolite/augite gneiss section intercalated with quartz/albite gneiss and some quartz intrusions. The acoustic televiewer data shows the strike of the foliation is essentially north-south and the measured dip angles are mostly 45 to 85 degrees to the east.
- Because of the steeply dipping foliated rock units, correlation of the units across the facility is not practical. The subsurface bedrock section encountered in the deep boreholes at the industrial area is, however, likely part of the same formation, based on the interpretation of the consistent gamma log response and the optical camera and optical televiewer log image data.
- The multiple logs conducted, located the hydraulically active or water-bearing fractures in the boreholes. The acoustic televiewer logs confirmed the fracture density and orientation of the water-bearing fractures.
- Fracture density and fracture aperture largely decrease with depth in the study area. Most identified fractures, and especially the water-bearing features, are located in the upper 200 feet of the bedrock section. "Open" aperture fractures identified by the acoustic televiewer in the upper 200 feet of the bedrock section, the most hydraulically active depth range in the study area, were roughly one every 20 or 30 feet in BH-119, BH-120, BH-121A except for several depth intervals several "open" features were identified. The "open" fracture density in BH-118A is roughly one every 10 feet in the upper 250 feet of the bedrock section with two every 10 feet between 50 to 70 feet bgs.

- The majority of the "open" aperture fractures identified by the acoustic televiewer were near horizontal features. The attitude of these features are hard to determine by the acoustic televiewer, particularly if the dip angles are measured to be 5 degrees or less. However, their overall strike direction measured is roughly north-south and the dip direction usually exhibits an eastern direction.

- The near vertical "open" aperture fractures typically strike in a roughly north–south direction and exhibit steep dips (45 to 85 degrees) consistent with the regional structural trends (London, 1989).

- The vast majority of the "less" open fractures identified by the acoustic televiewer logs are interpreted to be foliation features and generally strike in roughly north-south direction and dip steeply in a generally eastern direction, mirroring the regional and local structural trends (London, 1989).

- The flow regime in each borehole was evaluated by multiple fluid logging techniques. Fluid entry was measured by all of the fluid logs applied during the characterization. Flow direction and magnitude were measured by the heat-pulse flowmeter and hydrophysical™ logging techniques. Each tool provided useful data and helped confirm hydraulically active intervals, but hydrophysical™ logging provided the most definitive qualitative and quantitative data to locate water-bearing fractures, determine borehole flow regimes, and estimating physical properties of the bedrock aquifer.

- Water-bearing intervals identified by hydrophysical™ logging do not necessarily correlate with the depths of "open" aperture or hydraulically active features identified by the conventional geophysical logs and other fluid logs. However, water-bearing fractures located by conventional geophysical logs generally correlate with water-bearing intervals identified by hydrophysical™ logs. These features usually display relatively larger apparent apertures by the acoustic and optical televiewer response.

- Ambient horizontal flow was identified in each of the four boreholes by hydrophysical™ logging. Ambient flow rates identified ranged from 0.0002 to 0.012 gpm (Tables 3-1 through 3-4).

- Under pumping conditions, a similar flow pattern consisting of horizontal flow from the dominant water-bearing fracture features originating in the upper bedrock section was recorded, no deeper than 167 feet bgs in BH-118A, BH-119, and BH-120. In all four boreholes, little or no flow was determined below 243 feet bgs. These features correlate with near horizontal fractures identified by the acoustic and optical televiewer logs at those depth intervals. There was little or no water-bearing capacity measured in the deeper portions of the bedrock under hydrophysical™ logging or heat-pulse flowmeter pumping tests.

- Interval specific transmissivity estimates of the dominant flow features in the upper bedrock section calculated from hydrophysical™ logging data ranged from 0.488 to 30.7 square feet per day (Tables 3-1 through 3-4).

- The hydraulic conductivity values derived by COLOG for specific intervals in the bedrock (Tables 3-1 through 3-4) are relatively high for a crystalline bedrock aquifer. The values are based on localized flow from discrete intervals, which is typical for this geologic setting. Based on the low ambient flow rates and generally low interval specific transmissivities measured by the hydrophysical™ logs confirmed by the low flow rates measured by the heat-pulse flowmeter surveys, the fractured bedrock interval at the HNP is interpreted to be a relatively low-flow regime with flow dominated by fractures with negligible contribution from the rock matrix.

- Discrete point samples located by hydrophysical™ logging determined that most of the elevated tritium activity concentrations are in the upper 200 feet of the bedrock section, corresponding to major flow zones. The highest tritium activity concentrations in BH-118A, BH- 119, and BH-120 were detected between 45.9 to 88.8 feet bgs. Two detections of tritium in deeper samples in BH-119 are likely false positive measurements. The deeper zones in which tritium was detected, however, will be included in the bedrock monitoring system to define the actual conditions.

- Similar interval specific transmissivity data and fluid electrical conductivity estimates were noted among the dominant water-bearing fractures identified by hydrophysical™ logging, suggesting an inter-connected fracture network comprising the dominant near horizontal water-bearing fractures in all four boreholes. Since only horizontal flow was detected in these fractures by hydrophysical™ logging, this situation is also a possible indication of inter-connection resulting from little to no pressure differential in the upper bedrock section above approximately 165 feet bgs.

- For the dominant near-horizontal water-bearing fractures to be inter-connected, they would likely have to be intersected by and be hydraulically connected with near-vertical fractures. Based on the conventional geophysical logs, the near vertical-fractures identified have the same approximate orientation as the bedrock foliation trends, essentially a north-south strike and easterly dip. The near-horizontal features display nearly the same strike direction as the near vertical features, only with shallower dip. Therefore, the dominant groundwater flow direction in the bedrock aquifer system at the industrial area of HNP is along the strike of both the dominant near-horizontal and near-vertical water-bearing fractures. Based on the orientations of the water-bearing fractures identified by borehole geophysical data, groundwater flow direction along fracture strike flow paths should be towards the south in the direction of the Connecticut River, the likely discharge point for the bedrock flow paths at the facility. The overall groundwater flow direction that is inferred from recent groundwater elevation maps developed for the shallow bedrock at the facility (see figures in Section 4.4) is consistent with this understanding. This concept is an important consideration for refining the hydrogeologic conceptual site model and calibrating numerical groundwater flow models.

- The orientations of the near-horizontal fractures in the subsurface are difficult to define by borehole geophysics because of technology limitations; therefore, the actual groundwater flow direction from these features can not be well defined at this time. When selected monitoring intervals are installed in boreholes 118A, 119, 120, and 121A, groundwater elevations will be measured that will enable interpretation of groundwater flow direction in the shallow, near-horizontal fractured bedrock intervals beneath the industrial area of the HNP.

SECTION 4

4 Long-Term Water Level Analysis

4.1 Overview

Appendix 6 presents water level hydrographs for 28 HNP monitoring wells, one surface water station (Connecticut River), and the mat sump. Water levels at all of these stations were monitored using dedicated data-logging pressure transducers on a continuous basis during an approximate 7-month period between January and August 2004. The locations of these pressure transducers are shown on Figure 4.1.

This time period was divided into three-quarters; January through March, April through June, and July through August. The hydrographs demonstrate that a variety of hydraulic processes are responsible for the observed daily and seasonal water level changes that occur site-wide at HNP. Tables 4-1 through 4-3 provide a detailed summary of the various events on site that had a potential to affect water levels in the 30 locations that were monitored. Table 4-4 shows which locations indicated transient pressure responses to the various man-made and natural events onsite. The long-term water level analysis is used to meet the following data needs:

- Identify aquifer responses to various onsite activities including; recharge responses due to precipitation, mat sump and dewatering well pumping, tidal changes, general river stage variations in the Connecticut River, packer testing, well installations, well development, sampling events, and hydrophysical logging.
- Determine the apparent groundwater flow direction across the site within the three identified hydrostratigraphic units.
- Provide information for aquifer tests.
- Calculate the vertical pressure differences between the identified hydrostratigraphic units across the site.

In addition, data loggers recorded water temperature, which was subsequently compared to water levels at the same frequency. These comparisons are included in Appendix 6.

4.2 Methodology

The transducer system was installed in the last week of January 2004. The data loggers were suspended at the lowest expected water level to be encountered in the well. Initially, the data loggers were attached to the well's cap. The system was subsequently modified to minimize transducer movement during well access. The initial and final transducer suspension configuration is shown in Figure 4-2.

The data loggers were initially set up to record measurements on one-minute intervals. The loggers were subsequently re-programmed to record measurements on five-minute intervals in May 2004 to optimize the memory capacity of the data loggers. The transducers are downloaded on a quarterly basis and as-needed between the routine downloads.

Transducer measurements are converted from pressure (in psig)to a final groundwater elevation value. The transducer reading is a combination of the water column pressure and the atmospheric pressure above the transducer. A barometric pressure transducer is used to correct the transducer pressure for barometric fluctuations. The following calculations were performed to determine the groundwater elevation at each of the transducer locations:

Barometric Pressure correction to achieve the corrected PSI value:

> Corrected PSI =Total PSI (initial transducer reading) - Atmospheric PSI (barometric pressure transducer)

Corrected PSI is then converted to a water column height:

> Height of water column above transducer (feet) = Corrected PSI * 2.3067 feet/PSI

A hand-measured depth to water measurement (DTW) is added to the height of the water column to determine the transducer depth:

> Transducer Depth (feet bgs) = Length of water column (feet) +DTW

The transducer depth, calculated from the DTW collected at the time of download, is then subtracted from the length of the water column, to achieve a DTW at every 5-minute interval:

> DTW at every 5-minute interval (feet bgs) = Transducer Depth (feet) - Length of water column (feet)

The DTW subtracted from the surveyed top of casing elevation (TOC) results in the groundwater elevation:

> Groundwater Elevation (feet AMSL) = TOC - DTW

The transducer data and data reduction calculations are maintained in Microsoft Excel™ spreadsheets. The resulting reduced data sets were subsequently plotted as hydrographs displaying the change in water level elevation (normalized to Mean Sea Level) over time. The hydrographs were inspected for hydraulic responses that appear to be temporarily related to known on-site transient events. A data quality assessment of hydrograph data is included in Appendix 8.

4.3 Hydrographs

Detailed hydrographs for each transducer location are included in Appendix 6. The hydrographs are presented by quarter and hydrostratigraphic unit (e.g. first quarter, shallow bedrock wells). Four or more hydrographs are presented for each location; one graph of the observed groundwater elevation, one hydrograph of the groundwater elevation versus temperature, one hydrograph of the groundwater elevation versus total daily rainfall and one or more hydrographs of the observed groundwater elevation with annotations correlating recorded pressure transients to specific known events.

Groundwater levels at the HNP rise and fall on a daily or seasonal basis in response to recharge events (i.e., precipitation/snowmelt) and other hydraulic effects such as tides, groundwater extraction and borehole testing activities. During periods of minimal recharge that can occur during a prolonged mid-winter freeze or mid-summer drought, groundwater levels in an aquifer will typically decline because of the natural, ongoing base-flow contributions to local or regional discharge zones such as streams, rivers, or lakes. The natural decline (or antecedent trend) in groundwater levels during periods with little or no recharge is expected to vary on a site-wide basis, due to differences in aquifer characteristics and hydraulic properties.

4.3.1 Recharge Responses Due to Precipitation

During the three quarters of monitoring, numerous precipitation events occurred, as well as a snowmelt event in the first quarter, producing many measurable hydraulic responses at all of the monitoring wells and the river.

In the first quarter, potential snowmelt responses were observed during the last weeks of February. Deep and shallow bedrock monitoring wells, which were on a downward trend in groundwater elevation, began to level off. These events potentially correlated to episodes of snowmelt that provided measurable recharge to the local groundwater system. Data obtained from the CY control room indicate that there was no local rainfall between February 8 and March 4. For some bedrock and peninsula area wells located in close proximity to the river and discharge canal, these same recharge events are less abrupt, and are represented by little or no change in the overall groundwater elevation in the first quarter.

Daily rainfall events over 0.4 inches are indicated as increases in water elevation in the hydrographs. These responses are typically temporarily related to the recorded precipitation events and display distinctive recharge curve characteristics. For some bedrock and peninsula area wells located in close proximity to the river and discharge canal, these same recharge events are less abrupt, and are represented by broad responses that are superimposed on the existing pattern of diurnal tidal fluctuations (e.g., MW-108S, MW-109S/D, MW-508S/D, TW-1, MW-124, MW-122S/D, and MW-107S/D). Wells showing a more limited or subdued hydraulic response to these recharge events (e.g., MW-110D, MW-105S, -106S, -106D, and -504) may be completed in zones that are less hydraulically active and/or less affected by direct surface recharge. In wells located close to the river or discharge canal, the fluctuations in water level temporarily associated with precipitation events appear more closely related to the associated changes in river stage of the Connecticut River. These subdued hydraulic responses in wells in the central industrial area (e.g., MW-105S, MW-106S) could also be due to de-watering activities. As groundwater elevations increase, the de-watering well's pump cycles turn off and on less frequently.

4.3.2 Response to Tidal Fluctuations

Diurnal tidal fluctuations affect surface water levels in the Connecticut River and discharge canal which, in turn, have an influence on local HNP groundwater elevations. The hydrograph of the Connecticut River was used as the basis for comparison of groundwater hydrographs to identify apparent tidal responses.

Inspection of the hydrographs indicates that several of the monitoring wells that are in close proximity to the river display distinct rhythmic temporal variations. These temporal variations, when superimposed on the river hydrograph, mimic the tidal fluctuations of the river. Tidal fluctuations observed in some of the hydrographs were more apparent as the groundwater elevation decreased (e.g. MW-109S and MW-504S).

Table 4-4 provides a list of the wells that responded to tidal changes, as well as other activities onsite.

4.3.3 Response to On-Site Pumping Activities

During the three-quarters monitored by the transducer network various onsite pumping activities (e.g. mat sump pumping, and de-watering well activation) took place at the HNP and affected groundwater elevation. The documented events are summarized into three activity tables,(Tables 4-1 through 4-3).

The most dominant onsite activity affecting groundwater elevation is the operation of the reactor containment foundation mat sump (mat sump). The mat sump was installed during plant construction to depress groundwater beneath the containment building and reduce potential buoyant forces on the structure. Pumps in the mat sump are equipped with automatic level controls and cycle regularly, keeping the water level in the sump between -23 and -17 feet below mean sea level (MSL), with an average water elevation of about -20 feet MSL. The operation of the sump creates a localized, but constant, deep depression in the groundwater surface. The mat sump appears to penetrate the unconsolidated aquifer, the shallow bedrock aquifer, and the upper portion of the deep bedrock aquifer. Hydraulic response to the mat sump operation are observed locally in wells completed in all three units. When the mat sump is shut off for an extended period of time there is a noticeable rise in water elevations in the central industrial area surrounding the sump. The water elevation immediately rises in wells in close proximity to the mat sump. This can be seen in the wells 103S/D, 106S/D, and MW-114 during the 2nd and 3rd quarter. Other wells show a gradual increase in water elevations when the mat sump shut off for an extended period of time. Table 4-4 provides a list of the wells that responded to mat sump off/on periods. Figures 4-3, 4-4, and 4-5 show wells that respond to mat sump activities in the unconsolidated aquifer, and shallow and deep bedrock aquifers. Other wells, such as MW-122D, affected by stage changes in the canal or river may be affected by the mat sump, but due to simultaneous rainfall events during mat sump operational interruptions, these responses may be masked.

Three de-watering wells were installed at HNP, at the end of the 1st quarter to support decommissioning activities. Groundwater elevations in wells close to the de-watering wells were affected. The initial development of these wells (DW-1, DW-2, and DW-3) can be observed as draw down and recharge curves in both the shallow and deep bedrock well hydrographs (MW-103S, MW-106S/D, MW-101D). Activation of the de-watering wells in the 2nd quarter influenced groundwater elevations in monitoring wells MW-105D and MW105S. Overall, since the activation of the de-watering wells, there has been a downward trend in the groundwater elevations of MW-103S, MW-106S/D, MW-101D and MW-105S/D. Although this could be a natural trend in groundwater elevations, these wells display an upward trend in groundwater elevation when the de-watering wells are shut off for an extended time frame (Appendix 6, 3rd Quarter Comments). The actual seasonal variation in groundwater elevation in this area has not been previously recorded in detail, so some uncertainty exists regarding the magnitude of the net effect of dewatering activities in the industrial area.

Pumping during packer and hydrophysical™ testing also affected monitoring well groundwater elevations. A direct correlation between the MW-121A packer testing and periods of draw-down in monitoring wells MW-101D,MW-105D, and MW-103D can be seen. On June 7, 2004, pumping was conducted in a zone in MW-121A between 152 and 157 feet bgs. At the same time a draw down was observed in wells 105D, 101D, 103D (Figure 4-6). Other events are shown on the graphs, but seem to only correlate to packer deflation, not pumping. The effects of packer testing were likely expressed at a great distance because of the relative magnitude of hydraulic stress placed on the formation during testing. A typical test stress applied during packer testing was up to 200 feet of drawdown on the tested interval.

Hydrophysical™ testing of deep bedrock boreholes, had a direct effect on the deep bedrock monitoring wells. Groundwater elevation dropped an average of 1.5 feet in the wells adjacent to the deep bedrock holes during the pumping portion of the testing in boreholes BH-118A, BH-119, BH-120 and BH-121A (Figure 4-7). Groundwater elevations in MW-110D, MW-107D, and MW-122D were affected by borehole testing at BH-121A. MW-109D was affected by borehole testing at both BH-120 and at BH-119A. MW-106D was the only well which showed response to testing at BH-118A. These observations of hydraulic response to pumping in the bedrock boreholes demonstrate the anisotropic and heterogeneous characteristics expected of the fractured bedrock unit underlying the plant.

4.3.4 Response to River Stage Fluctuations

The Connecticut River exhibits fluctuations in river stage due to seasonal runoff, impacts of local and upstream precipitation events as well as the tidal fluctuation discussed in Section 4.3.2. Since the drainage area of the Connecticut River is so large and rainfall sufficiently variable, there is not always a good apparent correlation between observed river stage and local rainfall as recorded at HNP. Starting in early March 2004, the Connecticut River exhibited fluctuations that were apparently related to the start of the freshet. Groundwater elevations in monitoring wells in close proximity to the river and the discharge canal respond to these river stage fluctuations. There is a good correlation between the wells that are tidally influenced and the wells that show effects of river stage fluctuations. Between February 8th and March 11th there was an increase in groundwater elevation in these wells, which correlated to the general rise in the river level. During this period of time, however, there were no recorded rainfall recharge events to explain the rise in groundwater elevations. These elevation rises are apparently the result of snowmelt and resulting drainage into the Connecticut River.

4.4 Groundwater Elevation Contour Maps

Groundwater elevation contour maps (contour maps), presented in Figures 4-8 through 4-31, were created for the first three quarters in 2004. The following eight maps for each quarter were generated:

- Unconsolidated unit at high tide
- Unconsolidated unit at low tide
- Shallow bedrock at high tide
- Shallow bedrock at low tide

- Deep bedrock at high tide
- Deep bedrock at low tide
- Unconsolidated unit and shallow bedrock combination at high tide
- Unconsolidated unit and shallow bedrock at low tide.

The dates chosen for the contour maps preceded the groundwater-sampling event for that quarter to ensure that water level observations were not affected by drawdown in the wells related to sample collection. To evaluate potential impacts of tidal fluctuations on groundwater flow, contour maps for both high and low tides were completed for each of the hydrostratigraphic units and are discussed in the following subsections. Monitoring well TW-1 was used in choosing the high and low tide times because of its proximity and direct correlation to the tidal changes that occur in the Connecticut River. The times of the largest tidal changes in TW-1 were used. The corresponding groundwater elevation at that time, for each of the wells, was used to create each of the contour maps. Table 4-5 provides a list of wells and the hydrostratigraphic unit in which each well is screened.

4.4.1 Unconsolidated Unit Groundwater Elevation Contour Maps

The groundwater elevations measured in the unconsolidated hydrostratigraphic unit are representative of the water table surface in the plant property. Groundwater contours mapped in the unconsolidated unit are largely inferred, and generally consistent with the surface topography and modified by areas where structures of other impermeable barriers intersect the groundwater flow in the formation. Based on the inferred contours, groundwater flow in the unconsolidated unit is generally south to southwest, towards the Connecticut River (Figures 4-8, 4-9, 4-16, 4-17, 4-24, and 4-25). The groundwater contours are mapped to depict discharge to the Connecticut River, consistent with the hydrogeologic CSM.

Although tidal changes do not appear to significantly alter the groundwater flow direction in the unconsolidated unit, monitoring wells adjacent to the river (e.g., MW-109S and MW-110S) have water level elevations one to two tenths of a foot lower at low tide. Monitoring wells in the northern (i.e., inland) portion of the industrial area (e.g., MW-100S and MW-101S) are less impacted by tidal fluctuations, as measured groundwater elevations are typically on the order of one or two hundredths of a foot lower at low tide. The overall effects of the Connecticut River tidal change (approximately 0.5 to 0.75 foot) on groundwater flow in the unconsolidated unit is to create a slight decrease in the groundwater gradient adjacent to the river during high tide.

Groundwater flow in the unconsolidated hydrostratigraphic unit is impacted by the presence of subsurface barriers to flow. In the central portion of the industrial area several deep concrete structures are present from the ground surface to the top of bedrock. These structures include the reactor containment building (RCB), the discharge tunnel and the primary auxiliary building (PAB). The 10-foot and 5-foot groundwater contours are mapped much farther to the south in the western portion of the industrial area relative to the eastern portion of the site where the deep concrete structures are located. The displacement of the contours is a function of the presence of the subsurface concrete structures that impede groundwater flow in the unconsolidated unit in the area of the RCB, discharge tunnel, and PAB.

Another important feature in the industrial area is the presence of the mat sump. The sump is located adjacent to the southeast side of the RCB, and is installed approximately 40 feet bgs into the bedrock. The sump cycles regularly, keeping the water level in the sump between -23 and -17 feet below MSL. The presence of the sump creates a small, but deep depression in the groundwater surface, and with the RCB acts to inhibit flow in the unconsolidated unit.

4.4.2 Shallow Bedrock Unit Groundwater Elevation Contour Maps

Assessment of groundwater elevations in wells completed in the shallow bedrock aquifer unit is based on the simplifying assumption that the unit is highly fractured and exhibits the basic characteristics of an unconsolidated porous medium. The inferred groundwater contours are representative of the water table surface of groundwater within the shallow bedrock as measured in monitoring wells screened within the shallow bedrock. Similar to flow in the unconsolidated unit, groundwater flow in the shallow bedrock is generally to the south and southeast towards the Connecticut River.

Tidal effects in the shallow bedrock of one to two tenths of a foot are observed in monitoring wells adjacent to the river (MW-109D and MW-508D), while only several hundredths of a foot variation occur in monitoring wells in the northern portion of the industrial area (MW-101D and MW-102D). The tidal changes do not substantially impact groundwater flow in the shallow bedrock hydrostratigraphic unit.

Groundwater in the shallow bedrock is interpreted to discharge to the Connecticut River as large upward gradients are observed in monitoring well pairs MW-109D/S and MW-110D/S. These monitoring well pairs are screened in the shallow bedrock and unconsolidated, respectively, adjacent to the river. The strong upward gradients are consistent with both discharge to the river, and a flow direction towards the river.

A cone of depression associated with the mat sump is also present in the shallow bedrock unit. Groundwater levels in monitoring wells adjacent to the mat sump in the shallow bedrock indicate that a large area of influence occurs in the shallow bedrock.

4.4.3 Deep Bedrock Unit Groundwater Elevation Contour Maps

Groundwater flow in the deep bedrock hydrostratigraphic unit is characterized in a limited portion of the HNP, as deep bedrock monitoring wells are only present in the central and northern portions of the industrial area. The deep bedrock monitoring wells in these areas are all influenced by the mat sump, and form a significant cone of depression in that area. As with the shallow bedrock unit, a simplifying assumption of porous media characteristics is applied to the deep bedrock unit to allow plotting of groundwater elevation contours. Based on the observation of anisotropic, directional hydraulic responses to pumping in the bedrock boreholes, the application of porous media characteristics to this aquifer unit introduces substantial uncertainty.

Interpretation of the hydrographs for the deep bedrock monitoring wells indicates that tidal influences are observed in these monitoring wells (Appendix 6). Although deep monitoring wells are not present across the industrial area, the documented tidal influence in the deep bedrock wells indicates that outside the influence of the mat sump groundwater flow in the deep bedrock is towards the Connecticut River.

Pressure head measurements collected during packer testing of borehole 121A indicate that the deep bedrock (i.e., generally below about 180 feet bgs near the river) exhibits upward groundwater pressure. This is consistent with the hydrogeologic conceptual site model which incorporates the working assumption that the Connecticut River is a regional discharge boundary for groundwater as well as surface water.

4.5 Long-Term Water Level Analysis Data Quality Assessment

Data supporting the hydrograph and potentiometric surface analysis are assessed in the Long-Term Water Level Analysis Data Quality Assessment (Appendix 7). Overall, the data quality assessment procedure indicates that the water level data are acceptable for utilizing in the ongoing hydrogeological characterization at the HNP.

SECTION 5

5 Monitoring Well System Status

Section 5 summarizes the status of the monitoring well system; the wells in service, the well repair and maintenance activities, and the monitoring wells that have been abandoned. The monitoring well system at CY is changing to meet the changing needs of the decommissioning process. As the decommissioning work continues, additional wells will be abandoned, and others will be installed in the process of groundwater characterization.

5.1 Wells in Service

There are currently 69 active monitoring wells at CY HNP. An additional 23 were abandoned this year. Table 5-1 summarizes monitoring wells currently in service at CY HNP. Additional bedrock monitoring wells are being designed to monitor the vertical extent of COCs in the bedrock.

5.2 Well Repair and Maintenance Activities

As part of ongoing groundwater monitoring well maintenance activities, all site monitoring wells were inspected to identify those in need of seal repairs or other maintenance issues. A number of repairs and improvements were made to the monitoring well system in 2003 and 2004. Thirty wells with above ground completions were painted high visibility yellow. Twenty eight wells had transducer hanger clips installed, changing the measuring point elevation by distances ranging from +0.01 to -0.18. These changed elevations have been updated in Table 5-1. Six wells were re-developed to improve screen efficiency and to remove fines that had built up in the bottom of the well. Three flush mount wells in areas of heavy equipment traffic had preventative maintenance upgrades to heavy duty road boxes for additional protection. Fourteen flush mount completions had concrete pads replaced. Three above ground completion wells had concrete pads replaced. One well damaged by heavy equipment was repaired by replacing the damaged surface casing and riser. The damaged well was provided additional protection of 3 bollards (steel pipe posts) painted high visibility yellow. Table 5-2 summarizes well repair and maintenance activities.

5.3 Well Abandonment

As part of maintenance of the monitoring well system, a review was completed in June 2004 of all site wells to identify wells that were either unnecessary or unsuitable for site monitoring needs. Those wells identified as unneeded or unsuitable were chosen for abandonment. Wells were abandoned in accordance with State of Connecticut regulations that require monitoring wells be inspected to make sure the screen zone is open. The screen zone is then grouted or otherwise plugged, and the upper 4 feet of well casing must be removed.

Prior to abandonment, site wells chosen for abandonment were measured to confirm they remained open to the total length of the screen. A HDPE hose was then lowered to the bottom of the well, and cement bentonite grout mixed at 5 percent bentonite, 95 percent cement was then pumped from the bottom of the well to the surface. The surface casing was then unscrewed at a depth greater than 4 feet bgs. The three wells that were abandoned in the sand filter beds, MW-111S, MW-1301, and MW-1302, were left with above-ground casings in place. These wells will be removed entirely as part of the demolition and excavation of the sand filters. Table 5-3 summarizes the 23 monitoring wells that were abandoned during 2004 well maintenance activities.

SECTION 6

6 Aquifer Hydraulic Properties Characterization

The hydraulic properties (e.g., hydraulic conductivity, storage capacity, capture zone, etc.) of the water-bearing formations underlying the HNP are an important input to overall assessment of the groundwater conditions at the site. The observed values for these properties are used to calculate estimated groundwater flow rates and to assess the potential for migration of site contaminants. These properties are being assessed at HNP through the following testing protocols:

- Aquifer Pumping Test in the Unconsolidated Formation
- Packer Test Pumping of the Bedrock Formation
- Hydrophysical Logging of the Bedrock Formation
- Assessment of Well Responses to Foundation Dewatering Activities and other onsite pumping events

These activities are discussed in the following subsections.

6.1 Aquifer Pumping Test in Unconsolidated Formation

A constant rate aquifer g test was conducted in a new well specifically designed for the aquifer test. This test has been performed and data collected, however, the analysis of the data and interpretation of results are not yet complete at the time of this writing. The results of the aquifer test will be presented in a subsequent revision of this report. The test well, identified as well AT-1, is located in the industrial area of the plant (Figure 6-1). The unconsolidated aquifer in this area consists of a layer of fluvial deposits overlying less hydraulically conductive glacio-fluvial deposits at depth. The aquifer is covered at the surface by approximately 10 feet of unsaturated fill. Wetted aquifer materials were encountered at approximately 16 feet bgs. The uppermost portions of the aquifer consist of a fluvial red-fine sand unit approximately 25 feet thick. The red, fine sand unit extends to a depth of 41 feet bgs. The red fine sand unit encountered in the soil boring for well AT-1 is consistent in texture and structure to the red sand described at numerous locations across the site. Below 41 feet bgs. the unconsolidated materials becomes a dense, less hydraulically conductive unit of glacio-fluvial and remnant till materials with abundant clay and silts, overlying the weathered rock interface at approximately 48 feet bgs. This dense glacio-fluvial layer of deposits may be the remnant of glacial till and has been variously described in stratigraphic logs across the site. Well AT-1 was constructed with a 25-foot screen that was placed across the red fine sand unit. The stratigraphic log and well construction features are shown in Figure 6-2. Based on evaluation of well logs and hydrogeologic cross sections of the site, the formation conditions at AT-1 should be representative of the majority of the red sand formation across the site.

In addition to well AT-1, one additional monitoring well, OB-25 was installed 29 feet from well AT-1 to provide a proximal location to monitor drawdown response during pumping at AT-1. OB-25 was completed to a total depth 29.5 feet bgs. with a 10 feet screen from 19.5 to 29.5 feet bgs.

The location for well AT-1 and the subsequent aquifer pumping test was selected based on an assessment of site conditions and the relative proximity of the test location to existing wells that could provide monitoring points for the test. Wells AT-1 and OB-25 will also serve as monitoring wells following completion of the aquifer test.

Well AT-1 was drilled and constructed between 07 September 2004 and 09 September 2004. The well was thoroughly developed by surging and pumping prior to beginning the aquifer test. A modified step-drawdown test was performed following well development. The step-drawdown test was intended to meet two specific data needs:

- To measure drawdown and estimated aquifer zone of influence to provide input to post-closure exposure in support of License Termination Plan (LTP) dose modeling (this data need required pumping the aquifer at a rate of approximately 0.5 gallons per minute (gpm) and was met by collecting data during the first step of the step-drawdown test).
- To determine a sustainable pumping rate to use during the constant-rate pumping test.

The drawdown resulting from the step-drawdown test and observed in well AT-1 are shown in Table 6-1 and plotted in Figure 6-3.

The pumping rate selected for the constant-rate test was 29 gpm which corresponded to the maximum output rate of the pump installed in the well. Pumping well AT-1 and the nearest observation wells (OB-25, MW-124, MW-123, MW-109S&D, MW-508S&D, and MW-104) were equipped with data-logging pressure transducers for a minimum of 24 hours prior to the test and for a minimum of 4 days following completion of the test. The constant rate test was started at 1320 hours on 15 September 2004 and continued for 72 hours until 1320 hours on 18 September 2004. Preliminary measurements indicate that drawdown responses were observed at a distance of at least 100 feet from the test well. Although the test did not appear to have reached steady state, or the capacity of the aquifer, preliminary assessment of the observed responses indicates that the test was successful and should be adequate to provide a good measurement of hydraulic conductivity of the aquifer over a fairly large area. The dimensions of the aquifer, the test well, and distances to observation wells are shown in Table 6-2. Plots of drawdown over time for wells AT-1, OB-25, MW-124, MW-123, MW-109S&D, MW-508S&D, and MW-104 are presented in Figures 6-4 through 6-12.

6.2 Assessment of Dewatering Activities

Foundation dewatering at HNP includes the following two activities:

- Operation of the RCB Foundation Mat Dewatering Sump. This sump was part of original plant construction and has been in nearly continuous operation since plant startup.
- Construction and operation of eight dewatering wells located in the vicinity of the PAB and the waste water tank farm. These wells were constructed in 2004 and the first three

were placed in operation on 3, 5, and 6 May 2004 for dewatering wells DW-1, DW-2, and DW-3, respectively. Dewatering wells DW-4, DW-5, and DW-6, and dewatering well points DP-1 and DP-2 have not yet been placed in operation at the time of this writing.

The locations of foundation dewatering wells are shown in Figure 6-13.

The mat sump was constructed to remove groundwater and minimize the potential for buoyant displacement of the reactor containment. The dewatering wells were constructed to depress the groundwater elevation in the vicinity of the PAB and tank farm to facilitate demolition and removal of plant structures. The dewatering wells were not designed or intended to be used for aquifer characterization. The controlled nature of the pumping activities, however, combined with the proximity of the dewatering wells to other wells equipped with data logging pressure transducers allows for at least qualitative assessment of the degree and nature of hydraulic connectivity between wells in the vicinity of the pumping wells. To perform this assessment, selected portions of the hydrographs for wells in the vicinity of the dewatering wells were expanded to provide a higher resolution analysis of the water level effects of pumping the dewatering wells during the first 3 weeks following startup of wells DW-1, -2, and -3. The following wells were identified for assessment:

- MW-101S and -101D
- MW-102S and -102D
- MW-103S and -103D
- MW-104
- MW-105S and -105D
- MW-106S and -106D
- MW-114

Table 6-3 summarizes the assessment of response to dewatering in the above wells. Drawdown in the dewatering wells correlated to response in the unconsolidated formation, and both shallow and deep bedrock. Pumping in these three dewatering wells produced response in deep bedrock monitoring wells MW-101D, MW-103D, MW-105D, MW-106D, and MW-122D, and in shallow bedrock well MW-103S, and MW-106S. Responses were also detected in MW-105S, MW-114S, and MW-122S, screened in the unconsolidated formation. The responses in all three aquifers suggests good hydraulic connection exists locally between the unconsolidated, shallow bedrock, and deep bedrock in the vicinity of those wells.

6.3 Results of Packer Testing

The 2003 packer testing yield data for boreholes BH-119, -120, -121A, and –118A are summarized in tables 2-4 through 2-7. As all yields measured during the 2003 packer sampling campaign were potentially affected by undetected water leaking past the straddle packers, these yield data should be treated as upper limits rather than actual interval specific yields. Yield values below 200 feet bgs are generally below 0.01 gpm.

Table 6-4 summarizes the depths at which straddle packer seals were attempted in the 2004 packer testing campaign of BH-121A, and the apparent yields of those isolated zones for which seals could be achieved. Note that of the forty zones tested in 2004, only fifteen had sufficient seals to confirm or disprove minimum sampling yield requirements. Of the fifteen for which seals could be achieved, eleven had yields below minimum sampling requirements. These yields ranged from 0.16 to less than 0.01 gallons per hour over a 5-foot isolation interval, and 0.25 gallons per hour in the one zone for which a 23-foot seal could be achieved. The depths identified by hydrophysical ™ logging as water producing fracture zones were generally depths at which packer seals could not be achieved. Those intervals for which yields could be measured, therefor, are not representative of the borehole as a whole. They are interpreted to represent the low to no yield zones of BH-121A, and not the water bearing fracture zones. The yield information collected during packer testing is some of the information that will be taken into consideration when constructing the bedrock numerical flow simulation. Hydrophysical™ logging is the main source of hydraulic information for the construction of the hydraulic flow model related to the bedrock aquifer at the site.

Above 155 feet bgs, the vertical component of the groundwater gradient as measured during packer testing is downward. Given the available flow path, groundwater will flow downward as well as in the direction of the horizontal component of flow. Below 160 feet, the vertical component of the gradient is upward. It should be noted that these measurements collected during the packer testing are pressure differentials, if no flow path exists, there is no actual flow.

6.4 Results of Hydrophysical Logging

Hydrophysical logging conducted in boreholes BH-118A, -119, -120, and -121A identified quite clearly the pumping induced flow zones in each of these boreholes. As part of the hydrophysical logging analysis, interval specific flow rates were modeled from the fluid electrical conductivity profiles logged while pumping. The interval specific flow rate is the change in discharge over the selected length of borehole. These interval specific flow rates were used to calculate the hydraulic conductivity values. Interval specific hydraulic conductivities are calculated based on Hvorslev's 1951 porosity equation, a porous-medium equivalent model, and single well drawdown data.

Calculated hydraulic conductivities and transmissivities are presented in Tables 3-1 through 3-4. The transmissivity is calculated by multiplying the hydraulic conductivity of the material in question by the thickness of the aquifer. Aquifer thicknesses were assumed to be the thickness of the fractured interval supplying water.

These hydraulic conductivities and transmissivities calculated will be used in the generation of a numerical flow model of the fractured bedrock. The numerical model will be based on a porous media equivalent.

7 Summary

Information collected during the Task 2 Supplemental Characterization is being used to refine the hydrogeologic CSM, to calibrate a numerical flow simulation model, and to determine post-closure monitoring locations at the plant. Packer testing, and borehole geophysics (especially hydrophysical™ logging) were used to identify and quantify water-bearing transmissive zones within the bedrock formation under the HNP. Groundwater samples were collected in these zones and analyzed for plant related SOCs. This information was used to determine the locations and depths for bedrock groundwater monitoring.

Long-term water level information was collected and used to develop groundwater potentiometric surfaces and flow directions, as well as provide information regarding fracture zone connectivity.

The bedrock characterization and long-term water level monitoring are summarized in the following subsections.

7.1 Summary evaluation of bedrock conditions

The hydrogeologic characteristics of the bedrock underlying HNP were evaluated through application of multiple measurement techniques in open bedrock boreholes. The boreholes are located on the riverward side of the HNP industrial area. The techniques applied (i.e., packer testing, geophysical logging, video logging, and hydrophysical logging ™) each present a different set of observations of the bedrock conditions and in total allow a comprehensive assessment of the bedrock hydrogeology. The summary of bedrock hydrogeologic conditions is described in the following subsections.

7.1.1 Bedrock porosity and fracture systems

The bedrock generally consists of massive crystalline rock with essentially no primary porosity that would allow groundwater flow through the rock. Secondary porosity within the massive rock structure occurs as individual fractures and fracture sets that provide pathways for water into and through the bedrock. Fracture information was derived from optical image and acoustic logs generated by geophysical logging, by visual observation during optical camera logging, and through interpretation of the results of packer testing and hydrophysical™ logging. Individual fractures observed in the HNP borehole studies all exhibited apparent open apertures of less than 0.1 foot.

The highest fracture density observed in boreholes BH-118, -118A, -119, -120, -121, and -121A was identified as near-horizontal fractures sets at depths of less than 250 feet bgs. These horizontal fracture sets are likely intersected by near-vertical fractures at various elevations in that same depth range (i.e., generally less than 250 feet bgs. The frequency and apparent transmissivity of open fractures in the bedrock decreases dramatically with depth.

7.1.2 Bedrock hydrostatic pressure

Observations of hydrostatic pressure within the bedrock formation were collected using an instrumented straddle packer assembly. These measurements indicate that the formation exhibits a downward vertical differential pressure to a depth of about 160 feet bgs and an upward vertical differential pressure over that portion of the bedrock deeper than 160 feet bgs. The actual depth at which the pressure differential reverses from downward to upward likely varies somewhat with seasonal groundwater levels and river stage fluctuations.

The vertical differential pressure observed in boreholes and the horizontal hydraulic gradient observed across the HNP industrial area from the river inland indicate that groundwater underlying the HNP discharges to the Connecticut River. This observation is consistent with the function of the Connecticut River as a regional hydrologic discharge boundary for both surface water and groundwater. The deepest occurrence of bedrock underlying the unconsolidated river bottom in the area adjacent to HNP is located approximately at elevation -170 feet MSL (O'Leary, 1977).

7.1.3 Occurrence of hydraulically-transmissive zones in bedrock

The presence of transmissive zones was evaluated through packer testing, geophysical (heat-pulse flow meter) and hydrophysical™ logging. Multiple transmissive zones were identified in each borehole tested and the apparent degree of transmissivity varies by orders of magnitude between zones. The transmissive zones observed in bedrock boreholes at HNP using these three techniques are summarized in Table 7-1.

These three techniques measure the groundwater flow in different manners and in different orders of scale. Of the three techniques, the hydrophysical™ logging method provides the best vertical resolution of the actual location and apparent thickness of transmissive zones, and the relative capacity of flow zones observed. The results of the three techniques are generally comparable within the ability to identify discrete transmissive zones observed by each method.

7.1.4 Lateral hydraulic connectivity in bedrock

Indication of horizontal/lateral connectivity in the fractured bedrock system was observed during open-borehole pumping for hydrophysical logging in the four 6-inch boreholes, and during interval-specific pumping conducted as part of the packer testing of borehole BH-121A in 2004. Previously, distance drawdown responses had been observed in 2003 during drilling and packer test pumping in some boreholes.

The observations to date indicate hydraulic connection in the bedrock across the industrial area from near the river to the inland extent of the developed area of the site. An example is the observed water level drawdown response in wells MW-105D, MW-103D, and MW-101D during packer test pumping in borehole BH-121A in the interval from 152 to 157 feet bgs. The connectivity appears to be anisotropic in a direction consistent with the strike of near-vertical fractures. A preliminary evaluation of the horizontal hydraulic gradient between those wells indicates the potential for groundwater movement from the observed inland/upgradient locations to the downgradient location near the river.

7.1.5 Occurrence of plant-related SOCs in bedrock

Groundwater samples from the fractured bedrock system were collected and analyzed for plant-related SOCs, with particular focus on tritium as an indicator for the presence of contamination. Tritium was detected with moderate to high confidence at depths to about 185 feet bgs in boreholes BH-118A, -119, -120, and -121A. Tritium detections in intervals deeper than about 200 feet bgs in all boreholes are low confidence values that are likely subject to substantial uncertainty due to potential non-representative sampling. The bedrock zones with measurable tritium in the four 6-inch boreholes are shown in Table 7-2.

Groundwater samples were collected during both packer testing campaigns (i.e., 2003 and 2004) and hydrophysical™ logging activities. The 2004 packer test samples and the hydrophysical discrete-interval samples collected from zones yielding water at more than one gallon per hour are generally considered to exhibit the highest confidence in tritium concentration results. Both techniques are considered to be screening methods for assessing groundwater contamination. Each exhibit uncertainties in the observed SOC concentration in groundwater, particularly in low-yielding bedrock zones where it may not be possible to collect representative groundwater samples using these techniques.

The screening level detection of tritium in groundwater from packer testing and hydrophysical logging sampling and analysis can be separated into two levels of confidence in the analytical results – moderate to high confidence and low confidence. The highest confidence in tritium results are generally associated with higher-yielding zones in the upper portion of the bedrock, where inflow into the borehole was adequate to provide apparently-representative groundwater samples. Samples collected from the low-yielding zones deeper in the bedrock formation are considered lower confidence in both the presence of plant-related contaminants and the observed concentration.

Uncertainty in contaminant measurements collected during packer testing in low-yielding zones results from the inability to either adequately purge the isolated interval or to confirm the absence of packer leak-by during packer testing. The tritium concentration results generated during the 2003 packer testing campaign are largely low-confidence, high-uncertainty results due to the absence of instrumentation in that packer assembly that could have provided measurements confirming the packer seal integrity prior to sampling.

Discrete-interval samples collected from low yielding zones during hydrophysical™ logging may not be representative of formation water due to the extremely small quantity of water entering the borehole and incomplete mixing within the borehole of fluids adjacent to the entrance point. This water may represent water diffusing into the borehole from trapped, small-volume, discontinuous or "dead end" fractures intercepted by the borehole. Using the mass balance equation to derive low yield conditions interval specific pore water concentrations by COLOG's methodology, where the fluid electrical conductivity profile is not well developed, is not the best application of the hydrophysical™ logging technique.

7.2 Bedrock zones selected for monitoring

Evaluating the information collected as part of the packer testing and borehole geophysical logging, discrete intervals of water-bearing zones and potential contaminant migration pathways were identified. Screened intervals for bedrock monitoring wells were selected from these zones based on the following criteria:

1. Monitor identified transmissive zones within the bedrock, with specific attention to those active under ambient flow conditions.
2. Monitor zones contaminated by plant-related SOCs such as tritium to verify maximum concentrations.
3. Monitor zones indicating the limits of the vertical contaminant distribution.
4. Monitor identified transmissive zones within each borehole to determine head differentials.

The available packer testing and geophysical data for each borehole are summarized in Figures 7-1 through 7-4 and selected discrete-depth monitoring zones for boreholes BH-118A, -119, -120, and -121A are identified.

7.2.1 Summary Data Evaluation for BH-118A

Packer testing, hydrophysical™logging, and fracture data for BH-118A are summarized in Figure 7-1. The rationale for selecting each of the proposed monitoring intervals chosen in BH-118A (i.e., 25-35, 45-65, 100-130, 150-165, and 225-240 feet bgs) is summarized in Table 7-3. Of the four 6-inch boreholes, BH-118A exhibits the highest pumping yield. The target screen zone from 25-35 feet bgs was chosen for sampling the most productive flow zone identified by hydrophysical™ logging under pumping conditions (HPL pumping flow zone) in BH-118A at 29.8 to 30.2 feet bgs, producing 79 percent of the total inflow. No tritium was detected in this zone.

The selected zone from 45 to 65 feet bgs was selected to monitor two transmissive zones that exhibited ambient flow during hydrophysical logging (HPL ambient flow) over the intervals from 45.9 - 46.1 feet bgs and 63.9 - 65.0 feet bgs. Tritium was detected in both zones. The fluid electrical conductivity values and transmissivity values are similar, suggesting that these two flow zones are interconnected. The zones 113.9-114.5 feet bgs and 127.8-128.0 feet bgs display HPL ambient flow, and were selected to be screened from 100 to 130 feet bgs. Tritium was detected in both of these zones. The interval 161.7 to 161.8 feet bgs exhibits HPL pumping flow, and was selected to be screened from 150 to 165 feet bgs. The 2003 packer sampling campaign also produced greater than 5 gallons per minute from that depth. No tritium samples have been collected from this interval. The interval 238.5 to 238.6 feet bgs displays the deepest detected HPL pumping flow, and was selected to be screened from 225 to 240 feet bgs. Tritium was not detected at this depth during the 2003 packer testing campaign.

7.2.2 Summary Data Evaluation for BH-119

Packer testing, hydrophysical™ logging, and fracture data for BH-119 are sumarized in Figure 7-2. The rationale for selecting each of the proposed monitoring intervals chosen for

BH-119 is summarized in Table 7-3. Six intervals were selected for screening in BH-119; 45-55, 70-90, 155-165, 250-265, 295-305, and 450-460 feet bgs. The zone 47.3 to 47.4 feet bgs exhibited the largest HPL ambient flow in BH-119, and was selected to be screened from 45 to 55 feet bgs. Tritium was detected at this depth. The zone at 85.2 to 88.8 feet bgs displayed the highest HPL pumping flow, and was chosen for sampling from 70 to 90 feet bgs. It also contained the highest interval specific pore water tritium concentration and interval specific fluid electrical conductivity, significantly different from other zones, suggesting isolated flow. Tritium was detected at this depth. The interval from 160.0 to 160.3 feet bgs exhibited HPL ambient flow and was chosen for screening from 155 to 165 feet bgs. Tritium was detected at this depth. The intervals from 253.0-254.4 and 262.2-263.8 feet bgs displayed HPL ambient flow, and were chosen for screening from 250 to 265 feet bgs. This interval contains the deepest HPL ambient flow zone in BH-119. No tritium was detected at this screen depth. The interval 297.2 to 299.3 feet bgs, exhibited HPL pumping flow, and was selected to be screened from 295 to 305 feet bgs. Tritium was detected in this interval, though the sample is not considered representative (see Appendix 5). The interval 456.4 to 456.7 feet bgs produced HPL pumping flow, and was selected to be screened from 450 to 460 feet bgs. Tritium was detected at this depth, though the sample is not considered representative (see Appendix 5).

7.2.3 Summary Data Evaluation for BH-120

Packer testing, hydrophysical logging and fracture data for BH-120 is summarized by Figure 7-3. The rationales for selecting each of the proposed monitoring intervals chosen in BH-120 are summarized on Table 7-3. Five intervals were selected for screening in BH-120; 75-95, 100-110, 150-160, 205-215, and 235-245 feet bgs. The intervals from 83.5 to 83.6 and 92.8-93.6 feet bgs exhibited HPL pumping flow, and were selected to be screened from 75 to 95 feet bgs. These are the shallowest flow zones identified in this borehole, the most productive, and supplied the highest apparent tritium concentration sampled in BH-120. The interval 105.6 to 106.0 feet bgs displayed HPL ambient flow, and was selected to be screened from 100 to 110 feet bgs. Tritium was detected from this zone. The zone 153.2 to 153.3 feet bgs exhibited HPL ambient flow, and was chosen to be screened from 150 to 160 feet bgs. No tritium was detected from this chosen zone. The interval 211.0 to 211.3 feet bgs displayed HPL ambient flow, and was selected to be screened from 205 to 215 feet bgs. No tritium was detected from this chosen zone. The deepest zones to be water-bearing, identified by both hydrophysical™ logging under pumping conditions (238.1 to 238.2 and 242.3 to 243.2 feet bgs) and packer testing (231-254 feet bgs) were selected to be screened from 235 to 245 feet bgs.

7.2.4 Summary Data Evaluation for BH-121A

Packer testing, hydrophysical™ logging and borehole fracture information from geophysics for borehole BH-121A is summarized in Figure 7-4. The rationale for selecting each of the proposed monitoring intervals chosen in BH-121A is summarized in Table 7-3. Five interval were selected for screening in BH-121A; 100-110, 160-180, 275-285, 305-320, and 460-470 feet bgs. The zone from 100 to 110 feet bgs was chosen to sample the shallowest water-bearing zone identified by packer testing in BH-121A. Tritium was detected from this zone. The zone from 160 to 180 feet bgs was selected to sample the zone 165.9 to 166.8 feet bgs exhibiting HPL ambient flow and the zones 160.4 to 160.5 and 177.6 to 177.7 feet bgs displaying HPL pumping flow. This zone contains the shallowest detected HPL ambient flow zone, and the most transmissive HPL pumping zone in this borehole. Tritium was detected in samples from this zone. Strong upward pressure differentials were identified in this zone during packer testing. The zone from 278 to 278.8 feet bgs exhibits HPL ambient flow, and was selected to be screened from 275 to 285 feet bgs. No tritium was detected from this zone. The zone from 308.4 to 309.0 foot bgs produces HPL pumping flow, and was selected to be screened from 305 to 320 feet bgs. No tritium was detected from this interval. The zone from 460.7 to 465.1 feet bgs displays the deepest HPL ambient flow zone identified in BH-121A, and was chosen to be screened from 460 to 470 feet bgs. No tritium was detected from this interval.

7.3 Conclusions and Interpretation of Long-Term Water Level Information

Groundwater flow in the unconsolidated material and shallow bedrock is to the south and south west toward the Connecticut River, as would be expected near a major discharge boundary. In the vicinity of the mat sump, groundwater in the unconsolidated deposits and shallow bedrock flows toward the mat sump. Current deep bedrock monitoring locations are all clustered around the mat sump and show flow toward the mat sump due to sump pumping. Additional deep bedrock monitoring locations will be installed closer to the Connecticut River in the 6-inch bedrock boreholes (BH-118A, -119, -120, and -121A) to clarify groundwater flow directions in the deep bedrock over a larger area of the site.

Diurnal tidal changes do affect water levels in a number of wells on site, but do not significantly change groundwater flow directions. Groundwater elevations generally declined through the first, second, and third quarters in response to seasonal precipitation fluctuations, but groundwater flow directions remained relatively unchanged.

The long-term hydrographs show fracture connections between a number of wells. Fluctuations in drawdown and recharge curves in water level measurements from deep bedrock wells MW-103S, -106S/D, and -101D appear to be caused by development of dewatering wells DW-1, DW-2, and DW-3, screened in the unconsolidated deposits overlying bedrock. This confirms hydraulic connection, at least in the vicinity of these wells, between the unconsolidated deposits and the shallow and deep bedrock. Pumping during packer and hydrophysical ™ testing also affected monitoring well groundwater elevations. Pumping in BH-121A from the straddle packed interval 152 to 157 feet bgs, appeared to cause drawdown responses in wells MW-105D, 101D, and 103D. The measured response in wells ranging from 550 feet to 830 feet away, with no response in the wells directly adjacent to BH-121A, clearly demonstrates the anisotropic and heterogeneous characteristics expected of the fractured bedrock underlying the plant.

7.4 Recommendations

To further characterize the hydraulic connections and aquifer properties within the bedrock aquifer, it is recommended that a constant rate aquifer pumping test be conducted in the open bedrock borehole BH-118. The following locations are recommended for monitoring pressure changes:

1. All port depths in the multi-port sampling systems to be installed in BH-118A, -119, -120, and -121A.
2. Site-wide shallow and deep bedrock monitoring wells.
3. Unconsolidated deposits monitoring wells located within a few hundred feet of the borehole being pumped.

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TABLE 2-1
Summary of Borehole Dimensions

Borehole ID	Depth to Bedrock (ft)	Total Depth (ft)	Diameter (inches)
118	8	400	4
118A	10	578	6
119	39.5	612	6
120	36	552	6
121	21	200	4
121A	90.5	582	6

TABLE 2-2
Summary of 2003 Packer Sampling in BH-121

Depth interval (ft bgs)	Concentration (pCi/L)
20-50	10,900
50-70	9,630
70-90	11,100
90-110	11,200
110-130	11,050
130-150	4,140
150-170	2,320
170-190	3,990

TABLE 2-3
Summary of 2003 Packer Sampling in BH-118

Depth Interval (ft bgs)	Concentration (pCi/L)	Purge from which Sample was Collected
24-47	6,180	4
45-68	9,940	3
66-89	7,000	4
87-110	7,330	3
108-131	5,800	4
129-152	4,320	3
150-173	<1,090 [1]	3
171-194	2,870	3
192-215	2,160	3
213-236	1,500	3
234-257	2,450	3
255-278	3,220	3
276-299	4,280	1
297-320	3,730	1
318-341	6,060	1
339-364	3,790	3
371-395	4,280	3

[1] Less than MDC-Minimum detectable concentration

TABLE 2-4
Summary of 2003 Packer Sampling in BH-119

Depth Interval (ft bgs)	Concentration (pCi/L)	Yield (gpm)
42-65	14,300	Not collected
63-86	35,300	Not collected
84-107	32,700	Not collected
105-128	13,300	Not collected
126-149	8,120	Not collected
143-166	4,140	Not collected
170-193	<1,030 [1]	0.03
191-214	4,900	0.04
212-235	6,660	0.11
233-256	<987 [1]	0.01
254-277	No sample [2]	<0.01
275-298	1,610	0.07
296-319	5,780	0.03
317-340	3,850	0.01
338-361	No sample [2]	<0.01
359-380	7,940	0.02
387-408	1,940	Not collected
400-420	4,000	0.01
418-441	<1,200 [1]	0.03
439-462	<1,210 [1]	0.23
460-483	<1,060 [1]	0.01

[1] Less than MDC-Minimum detectable concentration

[2] No sample was collected, interval is classified as very low yield

TABLE 2-5
Summary of 2003 Packer Sampling in BH-120

Depth Interval (ft bgs)	Concentration (pCi/L)	Yield (gpm)
42-65	5,080	0.03
63-86	5,160	0.04
84-107	<MDC [1]	11.18
105-161	1,470 [2]	28.65
147-170	<MDC [1]	0.08
168-191	<1,030[1]	<0.01
189-212	<904[1]	0.43
210-233	<939[1]	1.03
231-254	<940[1]	0.03
252-275	1,300	<0.01
275-298	1,420	0.01
296-319	1,480	<0.01
317-340	1,380	<0.01
338-361	1,710	<0.01
359-382	1,840	<0.01
387-403	1,640	<0.01
399-422	1,930	<0.01
420-443	1,830	<0.01
441-464	2,010	<0.01
462-485	1,600	<0.01
483-506	No Sample[3]	<0.01
504-527	1,940	<0.01

[1] MDC- Minimum detectable concentration, recorded as MDC where actual value not recorded on data sheet.

[2] Packer would not seal during sampling. The water elevation above the top packer dropped approximately 10 feet during the fill time.

[3] Insufficient yield to sample.

TABLE 2-6
Summary of 2003 Packer Sampling in BH-121A

Depth Interval (ft bgs)	Concentration (pCi/L)	Yield (gpm)
84-107	<1,100	0.05
105-128	<1,090	0.01
126-144	No Sample [1]	0.03
147-170	8,890	8.72
168-191	8,630	0.06
189-212	No Sample [1]	<0.01
210-233	No Sample [1]	<0.01
231-254	No Sample [1]	<0.01
252-275	No Sample [1]	0.02
273-296	2,610	0.06
294-317	6,080	0.01
315-338	<1,110	0.01
336-359	8,700	0.05
357-380	No Sample [1]	<0.01
378-401	No Sample [1]	<0.01
399-422	No Sample [1]	<0.01
420-443	No Sample [1]	<0.01
441-464	7,400	<0.01
462-485	No Sample [1]	<0.01
483-506	No Sample [1]	<0.01
504-527	No Sample [1]	<0.01
525-548	No Sample [1]	<0.01
546-569	No Sample [1]	<0.01

[1] No sample was collected, interval is classified as very low yield

TABLE 2-7
Summary of 2003 Packer Sampling in BH-118A

Depth Interval (ft bgs)	Concentration (pCi/L)	Yield (gpm)
3-24	No Sample [1]	<0.01
22-45	1,330	11.24
43-66	14,200	>10
64-87	No Seal	No Seal
85-108	10,000	0.14
106-129	No Seal	No Seal
127-150	No Seal	No Seal
148-171	1,880	>5
154-177	2,520	>10
169-192	No Seal	No Seal
190-213	No Seal	No Seal
211-234	No Seal	No Seal
232-255	No Seal	No Seal
238-261	<1,000	0.01
253-276	No Sample [1]	0.01
274-297	No Sample [1]	<0.01
295-318	No Sample [1]	<0.01
316-339	No Sample [1]	<0.01
337-360	No Sample [1]	<0.01
358-381	No Sample [1]	<0.01
379-402	No Sample [1]	<0.01
400-423	No Sample [1]	<0.01
421-444	No Sample [1]	<0.01
442-465	No Sample [1]	<0.01
463-486	No Sample [1]	<0.01
484-507	No Sample [1]	<0.01
505-528	No Sample [1]	<0.01
526-549	No Sample [1]	<0.01
547-570	No Sample [1]	<0.01

[1] No sample was collected, interval is classified as very low yield

TABLE 2-8
Summary of Selected Test Intervals in Borehole 121A

Retest Interval (ft bgs)	Previous Interval (ft bgs)	Previous Purge Volume (gallons)	Previous ^3H Concentration (pCi/L)	Apparent Yield (gpm)
103 – 108	84 – 107	97	Not detected	0.050
114 – 119	105 – 128	102	Not detected	0.01
145 - 150 147 – 152 152 – 157 157 – 162 162 – 167	147 - 170	207	8,890	8.72
168 - 173 173 – 178 178 – 183 183 – 188 188 – 193	168 – 191	123	8,630	0.06
203 – 208	189 – 212	39	Not sampled	<0.01
266 – 271 271 - 276 273 – 278 278 – 283 283 – 288 288 – 293	273 - 296	134	2,610	0.06
293 – 298 297.5 – 302.5 298 – 303 303 – 308 308 – 313 316 - 321 313 – 318	294 - 317	140	6,080	0.01
335 – 340 340 – 345 345 – 350 350 – 355 353 – 358	336 – 359	128	8,700	0.05
441 – 446 446 – 451 451 - 456 456 – 461 466 – 471	441 - 464	98	7,400	0.01

TABLE 2-9

Summary of Packer Testing Data in Borehole 121A, 2003 and 2004 Campaigns

2004 Packer Test Intervals		Tritium [1]	Apparent Yield	Purge Vol.	2003 Packer Test Intervals	Tritium	Apparent Yield [5]	Purge Vol.
23-ft Interval	5-ft Interval	(pCi/L)	(g/hr)	(gal)	23-ft Interval	(pCi/L)	(g/hr)	(gal)
	103-108	1,290	0.41	31	84-107	<MDA	3	97
	113-118 #2	No seal, not sampled						
	114-119 #1	No seal, not sampled			105-128	<MDA	0.6	102
	115-120 #3	No seal, not sampled						
	145-150	Low yield/NS[2]	0.05					
	147-152	Low yield/NS	0.01					
153-176 #2		8,170[3]	No seal, but sampled					
155-178 #1		No seal, not sampled						
	151.5-156.5 #2	2,430	0.65	45				
	152-157 #1	No seal, not sampled			147-170	8,890	523	207
	156-161 #2	No seal, not sampled						
	157-162 #1	No seal, not sampled						
	158-163 #3	No seal, not sampled						
	162-167 #1	No seal, not sampled						
	162.5-167.5 #3	No seal, not sampled						
	163-168 #2	No seal, not sampled						
	168-173	Low yield/NS	0.03					
	172-177 #2	No seal, not sampled						
	173-178 #1	No seal, not sampled			168-191	8,630	3.6	123
	174-179 #3	No seal, not sampled						
	178-183	6,060	2.5	58				
	183-188	Low yield/NS	<0.02					
	188-193	Low yield/NS	0.02		189-212	Not Sampled	>0.6	39
	203-208	Low yield/NS	0.04					
256-279 #2		No seal, not sampled						
260-283 #1		No seal, not sampled						
	266-271	Low yield/NS	0.156					
	271.5-276.5 #3	No seal, not sampled			273-296	2,610	3.6	134
	272-277 #2	No seal, not sampled						
	273-278 #1	No seal, not sampled						
287-310 #2		No seal, not sampled						
291-314 #3		No seal, not sampled						
292-315 #1		No seal, not sampled						
	297.5-302.5	Bypass, low yield/NS	<0.02		294-317	6,080	0.6	140
	316-320 #1	No seal, not sampled						
	317-322 #2	496[4]	2.4					
324.2-347.2		Low yield/NS	0.25		336-359	8,700	3	128
	340-345	Low yield/NS	<0.01					
	465-470	Low yield/NS	0.04		441-464	7,400	0.6	98
	466-471	No seal, not sampled						

1) Tritium analyses from offsite lab.

2) NS = Not sampled

3) Sample collected in highly fractured, highly permeable zone, even though seal was not achieved. Sample was collected under low flow conditions.

4) Sample identified in data quality assessment as potentially biased by residual heel water.

TABLE 2-10

MW-121A Summary of Offsite Analytical Results Detections Only Compared to CY Onsite Lab Results

Depth (ft bgs) or QC Sample	Boron (µg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	H-3 Offsite (pCi/L)	H-3 Onsite (pCi/L)	C-14 (pCi/L)	Ni-63 (pCi/L)	Sr-90 (pCi/L)	Cs-137 (pCi/L)	Pu-241 (pCi/L)
MW-121A (103'-108')	45.2	11.9	12.4	1290	<1280	< 53.5	< 12.8	< 0.574	< 2.49	< 13.9
MW-121A (152'-157')	214	26.4	21.4	2430	3200	45.4	< 12.8	< 0.49	< 2.36	8.81
MW-121A (153'-176')	189	129	35	8170 [1]	8170 [1]	< 54.2	10.2	0.368	1.67	< 12.8
MW-121A (178'-183')	215	12.9	9.25	6060	6360	< 108	< 9.47	< 0.949	< 2.23	< 28.7
MW-121A (317'-322')	338	1.9	< 3.53	496	<1230	< 107	< 10.5	< 1.06	< 2.54	8.92
QC Blank	15	< 0.94	2.55	< 197	NA	< 8.27	< 8.84	0.67	< 3.09	< 12.5
QC Blank (Bladder Pump)	12.9	< 1.68	< 3.67	325	NA	< 107	< 11	< 1.08	< 5.92	< 14.1
QC Blank (Grundfos Pump)	5.42	< 0.861	< 3.39	329	NA	< 113	< 10.7	< 1.11	< 2.43	< 14.1
QC Blank (Riser Pipe)	2.34	< 0.951	< 2.27	338	NA	< 106	< 10.9	< 1.33	< 2.4	< 28.4

1-Seal not achieved

NA = Not analyzed

TABLE 3-1. SUMMARY OF HYDROPHYSICAL™ LOGGING RESULTS WITH HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY ESTIMATIONS; CH2MHILL; CYAPCO; HADDAM NECK, CT; BOREHOLE BH-118A.

Project and Borehole Name	CYAPCO: BH-118A
AWL Prior to Pumping (ft bgs)	19.31
Diameter of Borehole (ft)	0.51
Observed Drawdown (ft)	4.81
Effective Radius (ft)	100

Source: Modified from the Hydrophysical™ Logging Results (COLOG, 2004)

Interval No.	Top of Interval (ft bgs)	Bottom of Interval (ft bgs)	Thickness of Interval (ft bgs)	Ambient Flow[1] (gpm)	Darcy Velocity in Aquifer[2] (Specific Discharge) (ft/day)	Interval Specific Flow Rate During Pumping (gpm)	Delta Flow[3] (gpm)	Delta Flow (ft^3/min.)	Interval Specific Hydraulic Conductivity[4] (ft/day)	Transmissivity (ft^2/day)	Interval Specific Fluid Electrical Conductivity (microS/cm)	HNP Onsite Lab Result (pCi/L)	Interval Specific Pore water Concentration of Tritium (pCi/L)
1	29.8	30.2	0.4	0.000	NA	3.81	3.810	0.50936	3.63E+02	1.45E+02	857	1850	ND
2	45.9	46.1	0.2	0.001	0.61	0.185	0.184	0.02463	3.51E+01	7.01E+00	398	8550	13911
3	63.9	65.0	1.1	0.002	0.28	0.238	0.236	0.03155	8.17E+00	8.99E+00	382	7330	9818
4	68.3	68.4	0.1	0.000	NA	0.132	0.132	0.01765	5.03E+01	5.03E+00	303	6300	13046
5	73.9	74.0	0.1	0.000	NA	0.211	0.211	0.02821	8.03E+01	8.03E+00	252	4290	5939
6	101.8	101.9	0.1	0.000	NA	0.048	0.048	0.00642	1.83E+01	1.83E+00	185	2790	ND
7	113.9	114.5	0.6	0.002	0.50	0.053	0.051	0.00682	3.24E+00	1.94E+00	183	3390	5466
8	127.8	128.0	0.2	0.003	2.27	0.106	0.103	0.01377	1.96E+01	3.92E+00	166	2550	2550
9	161.7	161.8	0.1	0.000	NA	0.008	0.008	0.00107	3.05E+00	3.05E-01	126	NS	NS
10	187.2	187.3	0.1	0.000	NA	0.005	0.005	0.00067	1.90E+00	1.90E-01	118	NS	NS
11	206.0	206.1	0.1	0.000	NA	0.004	0.004	0.00053	1.52E+00	1.52E-01	113	NS	NS
12	219.8	219.9	0.1	0.001	1.51	0.003	0.002	0.00027	7.62E-01	7.62E-02	111	NS	NS
13	238.5	238.6	0.1	0.000	NA	0.005	0.005	0.00067	1.90E+00	1.90E-01	107	NS	NS

[1] All ambient flow identified for this borehole is horizontal ambient flow.

[2] Darcy velocity is calculated using the observed volumetric flow rate, the cross-sectional area of the flow interval in the borehole and a borehole convergence factor of: (COLOG, 2004). The darcy velocity is only applicable to ambient horizontal flow.

[3] Delta Flow is the difference between interval-specific flow rate (during pumping) and ambient flow rate.

[4] Hydraulic conductivity and transmissivity estimates are based on single well drawdown data, a porus-medium equivilent model and Hvorslev's 1951 porosity equation.

AWL = Ambient Water Level
NA = Not Applicable
ND = No Detect/Below Detection Limit for that Sample
NS = Not Sampled
gpm = gallons per minute
ft = feet
bgs = below ground surface
min = minute
microS/cm = microsiemens per centimeter
pCi/L = picocuries per liter

TABLE 3-2. SUMMARY OF HYDROPHYSICAL™ LOGGING RESULTS WITH HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY ESTIMATIONS; CH2MHILL; CYAPCO; HADDAM NECK, CT; BOREHOLE BH-119.

Project and Borehole Name	CYAPCO: BH-119
AWL Prior to Pumping (ft bgs)	18.28
Diameter of Borehole (ft)	0.51
Observed Drawdown (ft)	20.75
Effective Radius (ft)	100

Source: ***Modified from the Hydrophysical™ Logging Results (COLOG, 2004)***

Interval No.	Top of Interval (ft bgs)	Bottom of Interval (ft bgs)	Thickness of Interval (ft bgs)	Ambient Flow[1] (gpm)	Darcy Velocity in Aquifer[2] (Specific Discharge) (ft/day)	Interval Specific Flow Rate During Pumping (gpm)	Delta Flow[3] (gpm)	Delta Flow (ft^3/min.)	Interval Specific Hydraulic Conductivity[4] (ft/day)	Transmissivity (ft^2/day)	Interval Specific Fluid Electrical Conductivity (microS/cm)	HNP Onsite Lab Result (pCi/L)	Interval Specific Pore water Concentration of Tritium (pCi/L)
1	47.3	47.4	0.1	0.003	4.54	0.158	0.155	0.02072	1.37E+01	1.37E+00	201	7550	9148
2	74.4	74.5	0.1	0.000	NA	0.169	0.169	0.02259	1.49E+01	1.49E+00	185	7340	18346
3	85.2	88.8	3.6	0.001	0.04	0.438	0.437	0.05842	1.07E+00	3.86E+00	183	5540	10107
4	147.8	148.9	1.1	0.000	NA	0.251	0.251	0.03356	2.01E+00	2.22E+00	151	2180	3085
5	160.0	160.3	0.3	0.001	0.50	0.273	0.272	0.03636	8.00E+00	2.40E+00	168	1520	1604
6	178.4	184.0	5.6	0.000	NA	0.008	0.008	0.00107	1.26E-02	7.06E-02	167	NS	NS
7	236.0	236.1	0.1	0.000	NA	0.002	0.002	0.00027	1.77E-01	1.77E-02	166	NS	NS
8	241.2	241.4	0.2	0.000	NA	0.003	0.003	0.00040	1.32E-01	2.65E-02	167	NS	NS
9	253.0	254.5	1.5	0.0002	0.02	0.013	0.013	0.00171	7.53E-02	1.13E-01	167	<1110	<1110
10	262.2	263.8	1.6	0.0002	0.02	0.004	0.004	0.00051	2.10E-02	3.35E-02	168	NS	NS
11	288.1	288.3	0.2	0.000	NA	0.002	0.002	0.00027	8.83E-02	1.77E-02	169	NS	NS
12	297.2	299.3	2.1	0.000	NA	0.015	0.015	0.00201	6.31E-02	1.32E-01	169	1170	6744[5]
13	318.7	321.5	2.8	0.000	NA	0.002	0.002	0.00027	6.31E-03	1.77E-02	169	NS	NS
14	384.2	385.5	1.3	0.000	NA	0.001	0.001	0.00013	6.79E-03	8.83E-03	170	NS	NS
15	426.7	430.9	4.2	0.000	NA	0.003	0.003	0.00040	6.31E-03	2.65E-02	171	NS	NS
16	446.5	452.8	6.3	0.000	NA	0.0003	0.000	0.00004	4.20E-04	2.65E-03	171	NS	NS
17	456.4	456.7	0.3	0.000	NA	0.012	0.012	0.00160	3.53E-01	1.06E-01	172	1570	10801[5]
18	472.0	481.1	9.1	0.000	NA	0.004	0.004	0.00053	3.88E-03	3.53E-02	173	NS	NS

[1] All ambient flow identified for this borehole is horizontal ambient flow.

[2] Darcy velocity is calculated using the observed volumetric flow rate, the cross-sectional area of the flow interval in the borehole and a borehole convergence factor of 2.5 (COLOG, 2004). The darcy velocity is only applicable to ambient horizontal flow.

[3] Delta Flow is the difference between interval-specific flow rate (during pumping) and ambient flow rate.

[4] Hydraulic conductivity and transmissivity estimates are based on single well drawdown data, a porus-medium equivilent model and Hvorslev's 1951 porosity equation.

[5] Interval specific pore water tritium concentrations in low flow zones such as these are not considered representative (see Data Quality Assessment Appendi

AWL = Ambient Water Level
NA = Not Applicable
ND = No Detect/Below Detection Limit for that Sample
NS = Not Sampled
gpm = gallons per minute
ft = feet
bgs = below ground surface
min = minute
microS/cm = microsiemens per centimeter
pCi/L = picocuries per liter.

TABLE 3-3. SUMMARY OF HYDROPHYSICAL™ LOGGING RESULTS WITH HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY ESTIMATIONS; CH2MHILL; CYAPCO; HADDAM NECK, CT; BOREHOLE BH-120.

Project and Borehole Name	CYAPCO: BH-120
AWL Prior to Pumping (ft bgs)	17.96
Diameter of Borehole (ft)	0.51
Observed Drawdown (ft)	16.90
Effective Radius (ft)	100

Source: Modified from the HydroPhysical™ Logging Results (COLOG, 2004)

Interval No.	Top of Interval (ft bgs)	Bottom of Interval (ft bgs)	Thickness of Interval (ft bgs)	Ambient Flow[1] (gpm)	Darcy Velocity in Aquifer[2] (Specific Discharge) (ft/day)	Interval Specific Flow Rate During Pumping (gpm)	Delta Flow[3] (gpm)	Delta Flow (ft^3/min.)	Interval Specific Hydraulic Conductivity[4] (ft/day)	Transmissivity (ft^2/day)	Interval Specific Fluid Electrical Conductivity (microS/cm)	HNP Onsite Lab Result (pCi/L)	Interval Specific Pore water Concentration of Tritium (pCi/L)
1	83.5	83.6	0.1	0.000	NA	0.045	0.045	0.00602	4.88E+00	4.88E-01	421	1730	15413
2	92.8	93.6	0.8	0.000	NA	0.554	0.554	0.07406	7.51E+00	6.00E+00	414	1390	1458
3	105.6	106.0	0.4	0.004	1.51	0.778	0.774	0.10348	2.10E+01	8.39E+00	223	1360	1459
4	130.1	130.4	0.3	0.000	NA	0.079	0.079	0.01056	2.85E+00	8.56E-01	172	<1200	<1200
5	142.4	142.9	0.5	0.000	NA	0.264	0.264	0.03529	5.72E+00	2.86E+00	184	<1200	<1200
6	153.2	153.3	0.1	0.008	12.1	0.026	0.018	0.00241	1.95E+00	1.95E-01	175		
7	171.1	171.2	0.1	0.000	NA	0.008	0.008	0.00107	8.67E-01	8.67E-02	176		
8	211.0	211.3	0.3	0.002	1.01	0.074	0.072	0.00963	2.60E+00	7.80E-01	297	<833	<833
9	228.9	232.8	3.9	0.000	NA	0.016	0.016	0.00214	4.45E-02	1.73E-01	180	<1200	<1200
10	238.1	238.2	0.1	0.000	NA	0.008	0.008	0.00107	8.67E-01	8.67E-02	179	NS	NS
11	242.3	243.2	0.9	0.000	NA	0.004	0.004	0.00053	4.82E-02	4.34E-02	181	NS	NS

[1] All ambient flow identified for this borehole is horizontal ambient flow.

[2] Darcy velocity is calculated using the observed volumetric flow rate, the cross-sectional area of the flow interval in the borehole and a borehole convergence fact 2.5 (COLOG, 2004). The darcy velocity is only applicable to ambient horizontal flow.

[3] Delta Flow is the difference between interval-specific flow rate (during pumping) and ambient flow rate.

[4] Hydraulic conductivity and transmissivity estimates are based on single well drawdown data, a porus-medium equivilent model and Hvorslev's 1951 porosity equation.

AWL = Ambient Water Level
NA = Not Applicable
ND = No Detect/Below Detection Limit for that Sample
NS = Not Sampled
gpm = gallons per minute
ft = feet
bgs = below ground surface
min = minute
microS/cm = microsiemens per centimeter
pCi/L = picocuries per liter

TABLE 3-4. SUMMARY OF HYDROPHYSICAL™ LOGGING RESULTS WITH HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY ESTIMATIONS; CH2MHILL; CYAPCO; HADDAM NECK, CT; BOREHOLE BH-121A.

Project and Borehole Name	CYAPCO: BH-121A
AWL Prior to Pumping (ft bgs)	17.35
Diameter of Borehole (ft)	0.51
Observed Drawdown (ft)	37.33
Effective Radius (ft)	100

Source: Modified from the Hydrophysical™ Logging Results (COLOG, 2004)

Interval No.	Top of Interval (ft bgs)	Bottom of Interval (ft bgs)	Thickness of Interval (ft bgs)	Ambient Flow[1] (gpm)	Darcy Velocity in Aquifer[2] (Specific Discharge) (ft/day)	Interval Specific Flow Rate During Pumping (gpm)	Delta Flow[3] (gpm)	Delta Flow (ft^3/min.)	Interval Specific Hydraulic Conductivity[4] (ft/day)	Transmissivity (ft^2/day)	Interval Specific Fluid Electrical Conductivity (microS/cm)	HNP Onsite Lab Result (pCi/L)	Interval Specific Pore Water Concentration of Tritium (pCi/L)
1	160.4	160.5	0.1	0.000	NA	0.180	0.180	0.02406	8.83E+00	8.83E-01	194	6250	ND
2	165.9	166.8	0.9	0.012	2.02	6.26	6.248	0.83529	3.41E+01	3.07E+01	194	7230	7322
2	177.6	177.7	0.1	0.0000	NA	0.090	0.090	0.01203	4.42E+00	4.42E-01	194	4460	8645
3	278.0	278.8	0.8	0.0008	0.15	0.029	0.028	0.00377	1.73E-01	1.38E-01	203	<1260	<1260
4	308.4	309.0	0.6	0.000	NA	0.032	0.032	0.00428	2.62E-01	1.57E-01	221	<1270	<1270
5	326.1	328.5	2.4	0.000	NA	0.037	0.037	0.00495	7.56E-02	1.82E-01	188	<1250	NS
6	446.8	449.1	2.3	0.000	NA	0.001	0.001	0.00013	2.13E-03	4.91E-03	238	NS	NS
7	454.2	456.4	2.2	0.000	NA	0.001	0.001	0.00013	2.23E-03	4.91E-03	256	NS	NS
8	460.7	465.1	4.4	0.0004	0.01	0.008	0.008	0.00102	8.47E-03	3.73E-02	256	<1270	<1270
9	467.9	469.5	1.6	0.000	NA	0.003	0.003	0.00040	9.20E-03	1.47E-02	257	NS	NS
10	483.1	483.2	0.1	0.000	NA	0.003	0.003	0.00040	1.47E-01	1.47E-02	269	NS	NS
11	491.7	491.8	0.1	0.000	NA	0.002	0.002	0.00027	9.81E-02	9.81E-03	274	NS	NS
12	506.0	506.1	0.1	0.000	NA	0.0009	0.001	0.00012	4.42E-02	4.42E-03	285	NS	NS
13	515.1	515.2	0.1	0.000	NA	0.0008	0.001	0.00011	3.93E-02	3.93E-03	291	NS	NS

[1] All ambient flow identified for this borehole is horizontal ambient flow.

[2] Darcy velocity is calculated using the observed volumetric flow rate, the cross-sectional area of the flow interval in the borehole and a borehole convergence factor of 2.5 (COLOG, 2004). The darcy velocity is only applicable to ambient horizontal flow.

[3] Delta Flow is the difference between interval-specific flow rate (during pumping) and ambient flow rate.

[4] Hydraulic conductivity and transmissivity estimates are based on single well drawdown data, a porus-medium equivilent model and Hvorslev's 1951 porosity equation.

AWL = Ambient Water Level
NA = Not Applicable
ND = No Detect/Below Detection Limit for that Sample
NS = Not Sampled
gpm = gallons per minute
ft = feet
bgs = below ground surface
min = minute
microS/cm = microsiemens per centimeter
pCi/L = picocuries per liter

TABLE 4-1
Activities on Site that have a Potential Affect on Transducer Data, 1st Quarter
CYAPCO

Activity	Date	Time	Nature of Transient Event
Transducer Downloads	2/2/04 to 2/10/04	--	
Transducer Downloads	2/19/04 to 2/24/05	--	
Mat Sump Adjustment	2/5/04	--	drawdown
Mat Sump Shut Off	3/22/04	10:15	recharge
Mat Sump Turned Back On	3/22/04	11:15	drawdown
DW-2 Development	2/23/04	--	drawdown
DW-2 Step drawdown Test	3/29/04	--	drawdown
DW-1 Development	2/24/04	--	drawdown
DW-1 Stepdown Test	3/26/04	--	drawdown
DW-1 Stepdown Test	3/29/04	--	drawdown
DW-3 Development	3/2/04	--	drawdown
DW-3 Development	3/3/04	--	drawdown
DW-3 Development	3/4/04	--	drawdown
DW-3 Stepdown Test	3/24/04	--	drawdown
DW-3 Stepdown Test	3/25/04	--	drawdown
Presure Spike seen on Barotroll	3/11/04	7:30	computational affect seen as a slight spike in graph
Presure Spike seen on Barotroll	3/15/04	10:05	computational affect seen as a slight spike in graph
Presure Spike seen on Barotroll	3/16/04	7:10	computational affect seen as a slight spike in graph
Presure Spike seen on Barotroll	3/17/04	7:45	computational affect seen as a slight spike in graph
Presure Spike seen on Barotroll	3/18/04	7:35	computational affect seen as a slight spike in graph
Presure Spike seen on Barotroll	3/22/04	10:05	computational affect seen as a slight spike in graph
1st Quarter Sampling Event	3/15/04 to 3/18/04	--	localized drawdown
DW Development	3/1/04	--	drawdown
Packer testing (300 ft bgs, head measurements)	3/16/04	--	drawdown at specific depth intervals
Packer testing (450 ft bgs, head measurements)	3/18/04	--	drawdown at specific depth intervals
Packer testing (466-471 ft bgs)	3/22/04	--	drawdown at specific depth intervals
Packer testing (465-470 ft bgs)	3/23/04	--	drawdown at specific depth intervals
Packer testing (465-470 ft bgs)	3/29/04	--	drawdown at specific depth intervals

TABLE 4-2

Activities on Site that have a Potential Affect on Transducer Data, 2nd Quarter

CYAPCO

Activity	Date	Time	Comments	Nature of Transient Event
Transducer Downloads	4/12/04 to 4/15/04	--		
Mat Sump Shut Off	4/18/04	4:05		recharge curve
Mat Sump Turned Back On	4/20/04	6:15		drawdown
DW-1 Turned On	5/3/04	12:00		drawdown
DW-2 Turned On	5/5/04	13:00		drawdown
DW-3 Turned On	5/6/04	17:00		drawdown
DW-1, 2, & 3 Shut Off	5/7/04	12:00		recharge curve
MW121A Packer Testing; Zone 271.5 to 276.5	5/6/04	--		downward spike
MW121A Packer Testing; Zone 266 to 271	5/7/04	--		downward spike
DW-1, 2, & 3 Turned Back On	5/10/04	6:10		drawdown
Transducer Modifications	5/11/04 to 5/13/04	--		downward spike
MW121A Packer Testing; Zone 203 to 208	5/11/04	--		downward spike
MW121A Packer Testing; Zone 188 to 193	5/12/04	--		downward spike
MW121A Packer Testing; Zone 183 to 188	5/13/04	--		downward spike
DW-1 Shut Off	5/17/04	14:00	no power to box	recharge curve
DW-1 Turned On	5/17/04	15:48	plugged back in	plugged back in drawdown
DW-2 Shut Off	5/17/04	16:05		drawdown
DW-2 Turned On	5/17/04	16:20		recharge curve
DW-3 Shut Off	5/18/04	9:40	moved control panel and flow meter to new location	recharge curve
DW-3 Turned On	5/19/04	10:05		drawdown
MW121A Packer Testing; Zone 178 to 183	5/18/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 178 to 183	5/18/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 178 to 183	5/18/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 173 to 183	5/19/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 173 to 183	5/20/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 172 to 177	5/21/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 174 to 179	5/24/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 168 to 173	5/26/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 162 to 167	5/27/04	--		drawdown at specific depth interval
Mat Sump Shut Off	5/27/04	23:30		recharge curve
Mat Sump Turned Back On	5/30/04	8:55		drawdown
MW121A Packer Testing; Zone 163 to 168	6/1/04	--		drawdown at specific depth interval
Transducer Downloads	5/12/04 to 6/02/04	--		drawdown at specific depth interval

TABLE 4-2
Activities on Site that have a Potential Affect on Transducer Data, 2nd Quarter
CYAPCO

Activity	Date	Time	Comments	Nature of Transient Event
MW121A Packer Testing; Zone 157 to 162	6/3/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 156 to 161	6/3/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 158 to 163	6/4/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 152 to 157	6/7/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 151.5 to 156.5	6/8/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 151.5 to 156.5	6/9/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 152 to 157	6/10/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 151.5 to 156.5	6/10/04	--		drawdown at specific depth interval
MW-100D/S Re-development	6/15/04	--		localized drawdown
MW-103S Re-development	6/16/04	--		localized drawdown
MW121A Packer Testing; Zone 147 to 152	6/16/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 145 to 150	6/17/04	--		drawdown at specific depth interval
MW-103D Re-development	6/18/04	--		localized drawdown
MW121A Packer Testing; Zone 114 to 119	6/18/04	--		drawdown at specific depth interval
MW-105S Re-development	6/18/04	--		localized drawdown
MW-105D Re-development	6/21/04	--		localized drawdown
2nd Quarter 2004 Sampling Event	6/22/04 to 7/6/04	--		localized drawdown
MW121A Packer Testing; Zone 113 to 118	6/23/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 113 to 118	6/24/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 115 to 120	6/25/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 103 to 108	6/29/04	--		drawdown at specific depth interval
MW121A Packer Testing; Zone 103 to 108	6/30/04	--		drawdown at specific depth interval

TABLE 4-3
Activities on Site that have a Potential Affect on Transducer Data, 3rd Quarter
CYAPCO

Activity	Date	Estimated Time	Comments	Nature of Transient Event
Flute removal BH-121A	Beginning of July	--	2-3 weeks prior to sampling	
Flute removal BH-120	Beginning of July	--	2-3 weeks prior to sampling	
Flute removal BH-118	Beginning of July	--	2-3 weeks prior to sampling	
Flute removal BH-119A	Beginning of July	--	2-3 weeks prior to sampling	
MW121A Packer Testing; 103 to 108	7/1/04	--		drawdown at specific depth interval
Colog BH-119A Testing	7/22/04	15:02	Dilution of the Fluid column complete	recharge
Colog BH-119A Testing	7/23/04	9:25	Pumping Begins, 1.4 gpm	drawdown
Colog BH-119A Testing	7/23/04	15:21	Pumping Ends 1.4 gpm	
Colog BH-119A Testing	7/26/04	--	Sample Collection	drawdown
Colog BH-121A Testing	7/28/04	17:33	Dilution of the Fluid column complete	recharge
Colog BH-121A Testing	7/29/04	10:47	Pumping Begins, 6.69 gpm	drawdown
Colog BH-121A Testing	7/29/04	15:57	Pumping Ends, 6.69 gpm	
Colog BH-121A Testing	7/30/04	--	Sample collection	drawdown
Colog BH-118 Testing	8/2/04	14:10	Dilution of the Fluid column complete	recharge
Colog BH-118 Testing	8/3/04	8:21	Pumping Begins, 4.81 gpm	drawdown
Colog BH-118 Testing	8/3/04	17:46	Pumping Ends, 4.81 gpm	
Colog BH-118 Testing	8/3/04	17:46	Pumping 30 gpm	drawdown
Colog BH-118 Testing	8/3/04	--	Sample Collection	drawdown
MW121A Packer Testing; 324 to 347	8/4/04	--		drawdown at specific depth interval
Colog BH-120 Testing	8/4/04	14:27	Dilution of the Fluid column complete	recharge
Colog BH-120 Testing	8/5/04	8:26	Pumping Begins, 1.85 gpm	drawdown
Colog BH-120 Testing	8/5/04	16:12	Pumping Ends, 1.85 gpm	drawdown
Colog BH-120 Testing	8/5/04	--	Sample collection	drawdown
DW-1, 2, & 3 Shut Off	8/5/04	PM	to repair the yard drainage system	recharge
DW-1, 2, & 3 Turned Back On	8/6/04	AM		drawdown
Mat Sump Shut Off	8/11/04	5:55		recharge
Mat Sump Turned Back On	8/11/04	11:55		drawdown

TABLE 4-4
Well Responses to Various Onsite Activites
1st, 2nd and 3rd Quarters
CYAPCO

Well ID	Onsite Activities: Rainfall Events – Quarter 1st	2nd	3rd	Comments	Tidal Changes – Quarter 1st	2nd	3rd	Comments	River Fluctuations – Quarter 1st	2nd	3rd	Comments	Mat Sump – Quarter 1st (1)	2nd	3rd	Comments	Dewatering (shut on & off, pump tests, development, etc.) – Quarter 1st	2nd	3rd (2)	Comments	Monitoring Well Development – Quarter 1st	2nd	3rd	Comments	Geophysical Logging (stress/pump tests) – Quarter 1st (3)	2nd (3)	3rd	Comments	MW-121A Packer Tests – Quarter 1st	2nd	3rd	Comments
Mat Sump													-	-	-																	
MW-100S	X	X	X						X																							
MW-101D	X	X	X											X			X	X		1st qtr - response to DW-1, 3										X		Isolated zone 152-157ft bgs Gradient=0.01(6)
MW-101S	X	X	X																													
MW-102D	X	X	X											X																		
MW-102S	X	X	X																													
MW-103D	X	X	X											X	X			X				X										
MW-103S	X	X	X											X	X		X	X		1st qtr - response to DW-1, 3		X								X		Isolated zone 152-157ft bgs Gradient=0.007(6)
MW-104S	X	X	X																X	3rd qtr- DW-4 drilling & pump installation												
MW-105D (4)	X	X												X				X				X								X		Isolated zone 152-157ft bgs. Gradient=0.009(6)
MW-105S (4)	X	X												X				X				X										
MW-106D	X	X	X											X	X			X									X	BH-118A				
MW-106S	X	X	X										X	X	X		X	X		1st qtr - response to DW-1, 2										X		Deflation of packer, not zone specific
MW-107D	X	X	X		X	X	X		X	X	X			X													X	BH-121A				
MW-107S	X	X	X		X	X	X		X	X	X			X																		
MW-108	X	X	X		X	X	X		X	X	X																					
MW-109D	X	X	X		X	X	X		X	X	X		X														X	BH-120, BH-119				
MW-109S	X	X	X		X	X	X	2nd qtr - when GW Elev drops tidal signal more apparent	X	X	X																					
MW-110D	X	X	X		X	X	X		X	X	X																X	BH-121A				
MW-110S	X	X	X		X	X	X		X	X	X																					
MW-113S	X	X	X		X	X	X		X	X	X																					
MW-114S (5)	X	X											X	X				X														
MW-122D	X	X	X		X	X	X		X	X	X			?(7)				X									X	BH-121A				
MW-122S	X	X	X		X	X	X		X	X	X			X				X														
MW-124	X	X	X		X		X		X	X	X																					
MW-504S	X	X	X		X	X	X	Not as apparent above 5 ft MSL	X	X	X																					
MW-508D	X	X	X		X	X	X		X	X	X																					
MW-508S	X	X	X																													
RIVER	X	X	X		X	X	X		-	-	-																					
TW-1	X	X	X		X	X	X		X	X	X																					

Notes:
X = indicates that there was a potential transducer response to the stated activity in that particular well
(1) The Mat Sump was shut off. When it was turned back on, a major rainfall event took place in the 1st Quarter. This simultaneous recharge event made it difficult to deduce whether a well responded to the Mat Sump activity.
(2) DW-1, DW-2, and DW-3 were taken off-line at the same time that a major rainfall event took place in the 3rd Quarter. This made it difficult to deduce whether a well responded to the dewatering well activity.
(3) Geophysical logging of BH-118, BH-119A, BH-120, and BH-121A only took place in the 3rd Quarter.
(4) MW-105D and MW-105S were abandoned in the beginning of the 3rd Quarter.
(5) Water Levels in MW-114S dropped below the transducer at the end of the 2nd Quarter.
(6) Gradient calculated from difference in heads prior to stressing 121A over distance from observed well.
(7) Mat sump interruption corresponded to river stage rise, masking possible minor connection.

TABLE 4-5
Groundwater Elevations Used in Creating Contour Maps for the 1st, 2nd, and 3rd Quarters
Task 2 Supplemental Characterization Report, CYAPCO

Well Name	1st. Quarter			2nd. Quarter			3rd. Quarter			Material Well Screened in (U, SB, DB)
	TOC Elevation	2/12/04 at 4:35 High Tide Groundwater Elevation(1)	2/12/04 at 11:35 Low Tide Groundwater Elevation(1)	TOC Elevation(2)	6/12/04 at 21:00 High Tide Groundwater Elevation(1)	6/12/04 at15:10 Low Tide Groundwater Elevation(1)	TOC Elevation	8/22/04 at 17:15 High Tide Groundwater Elevation	8/22/04 at 11:15 Low Tide Groundwater Elevation	
MW-101D	20.86	9.46	9.41	20.82	8.92	9.00	20.82	na	na	DB
MW-102D	20.65	8.33	8.30	20.66	6.02	6.11	20.66	2.46	2.50	DB
MW-103D	21.06	8.05	8.00	21.05	5.19	5.23	21.05	2.07	2.01	DB
MW-105D	20.68	9.15	9.05	20.66	5.25	5.28	20.66	na	na	DB
MW-106D	20.69	7.14	7.03	20.70	4.86	4.80	20.70	2.22	2.10	DB
Mat Sump	21.72	-20.37	-17.67	21.72	-18.21	-21.67	21.72	-19.29	-19.87	DB
MW-122D	20.00	4.78	4.33	19.99	3.81	3.60	19.99	2.18	1.82	DB
MW-101S	20.66	16.22	16.18	20.62	14.67	14.69	20.62	10.70	10.76	SB
MW-102S	20.57	11.54	11.50	20.53	8.34	8.43	20.53	5.13	6.30	SB
MW-103S	20.94	9.48	9.43	20.94	5.11	5.13	20.94	3.21	3.18	SB
MW-106S	20.57	5.88	5.84	20.56	8.36	8.42	20.56	1.94	1.90	SB
MW-107D	20.54	6.36	6.13	20.52	4.86	4.60	20.52	2.24	1.89	SB
MW-109D	20.56	6.44	6.29	20.54	6.14	6.04	20.54	3.34	3.16	SB
MW-110D	22.86	3.18	2.86	22.83	2.94	2.46	22.83	1.31	0.75	SB
Mat Sump	21.72	-20.37	-17.67	21.72	-18.21	-21.67	21.72	-19.29	-19.87	SB
MW-508D	17.79	4.59	4.25	17.78	2.48	2.23	17.78	3.36	3.05	SB
MW-100S	16.47	14.79	14.78	16.45	13.23	13.34	16.45	14.26	14.32	U
MW-104S	20.11	11.28	11.26	20.10	8.96	9.04	20.10	13.29	13.50	U
MW-105S	20.69	7.30	7.26	20.66	5.13	5.17	20.66	na	na	U
MW-107S	20.44	6.11	6.06	20.39	5.22	5.21	20.39	2.82	2.74	U
MW-108	12.30	5.80	4.89	12.15	4.99	3.82	12.15	3.82	2.45	U
MW-109S	20.65	2.97	2.88	20.64	2.62	2.53	20.64	2.50	2.35	U
MW-110S	22.48	1.44	1.40	22.47	1.39	1.35	22.47	1.77	1.69	U
MW-113S	13.60	1.33	1.26	13.56	0.43	0.33	13.56	2.69	2.53	U
MW-114S	20.78	8.43	8.38	20.76	5.37	5.41	20.76	na	na	U
MW-122S	19.84	8.26	8.25	19.84	6.87	6.95	19.84	2.86	2.81	U
MW-124	20.82	3.41	3.39	20.81	2.93	2.95	20.81	2.88	2.87	U
MW-504S	16.67	3.99	3.98	16.66	3.80	3.81	16.66	3.27	3.24	U
MW-508S	17.81	11.52	11.49	17.63	9.45	9.46	17.63	10.37	10.36	U
Mat Sump	21.72	-20.37	-17.67	21.72	-18.21	-21.67	21.72	-19.29	-19.87	U
RIVER	7.90	0.66	-1.28	7.90	2.47	-0.40	7.90	2.75	-0.27	U
TW-1	17.73	2.05	0.19	17.73	3.00	0.31	17.73	3.30	0.42	U

Notes:
1) The date chosen for the contour maps preceded the groundwater monitoring event to ensure that there had not been draw-down in any of the wells.
TW-1 was used in chosing the high and low tide times because of its proximity and direct correlation to the tidal changes that occur in the Connecticut River.
The times of the largest tidal changes in TW-1 were used.
2) TOC Elevations changed after the 1st quarter due to a transducer modification setup.
U = Unconsolidated Hydrostratigraphic Unit
SB = Shallow Bedrock Hydrostratigraphic Unit
DB = Deep Bedrock Hydrostratigraphic Unit
na = data not available

TABLE 5-1
Summary of Monitoring Well Information

Well ID	Northing	Easting	Elevation[1]	Top of Screen[2] (ft bgs)	Bottom of Screen[2] (ft bgs)	Hydrostratigaphic Unit Monitored	Well Status
AST-1	236310.83	668931.59	**21.55**	10	20	Unconsolidated	Abandoned
AST-2	236322.94	668948.16	**19.99**	5	15	Unconsolidated	Abandoned
AST-3	236327.17	668909.46	**21.2**	5	15	Unconsolidated	Abandoned
AST-4	236341.10	668927.83	**20.73**	5	15	Unconsolidated	Abandoned
AT-1	NSD	NSD	NSD	15.5	41.5	Unconsolidated	Active
EOF Supply-1	NSD	NSD	NSD	780	800	Deep Bedrock	Active
EOF Supply-2	NSD	NSD	NSD	1130	1150	Deep Bedrock	Active
MW-AST5	NSD	NSD	NSD	5.5	15.5	Unconsolidated	Active
MW-EOF-1	237503.96	667408.75	24.08	6	16	Unconsolidated	Active
MW-EOF-2	237513.48	667418.44	24.12	7	17	Unconsolidated	Active
MW-1	235304.54	670604.26	12.21	28	38	Unconsolidated	Active
MW-2	235677.79	670527.35	15.99	29	39	Unconsolidated	Active
MW-3	235488.22	670555.25	10.75	12	22	Unconsolidated	Active
MW-4	235638.02	670371.60	15.03	26.5	36.5	Unconsolidated	Active
MW-5	NSD	NSD	NSD	73	93	Unconsolidated	Abandoned
MW-6	NSD	NSD	NSD	58	108	Unconsolidated	Abandoned
MW-7	NSD	NSD	NSD	38	58	Unconsolidated	Abandoned
MW-8	NSD	NSD	NSD	58	88	Unconsolidated	Abandoned
MW-9	NSD	NSD	NSD	66	116	Unconsolidated	Abandoned
MW-10	NSD	NSD	NSD	48	98	Unconsolidated	Abandoned
MW-11	NSD	NSD	NSD	56	66	Unconsolidated	Abandoned
MW-12	NSD	NSD	NSD	57	97	Unconsolidated	Abandoned
MW-13	235130.81	670766.81	20.04	66	96	Unconsolidated	Active
MW-14	NSD	NSD	NSD	66	86	Unconsolidated	Abandoned
MW-15	NSD	NSD	NSD	31	81	Unconsolidated	Abandoned
MW-16D	NSD	NSD	NSD	43	113	Unconsolidated	Abandoned
MW-16S	NSD	NSD	NSD	4.5	24.5	Unconsolidated	Abandoned
MW-17	NSD	NSD	NSD	37	107	Unconsolidated	Abandoned
MW-18	NSD	NSD	NSD	30	60	Unconsolidated	Abandoned
MW-100D	236964.21	668415.29	16.45	21	31	Deep Bedrock	Active
MW-100S	236959.88	668418.62	16.45	3.50	9	Unconsolidated	Active
MW-101D	236845.02	668655.36	20.82	39.80	49.8	Deep Bedrock	Active
MW-101S	236842.33	668653.70	20.62	8.00	18	Shallow Bedrock	Active
MW-102D	236651.79	668905.29	20.66	43.00	53	Deep Bedrock	Active
MW-102S	236655.03	668907.67	20.53	12.80	22.5	Shallow Bedrock	Active
MW-103D	236672.34	668730.02	21.05	45.00	55	Deep Bedrock	Active
MW-103S	236671.52	668726.05	20.94	15.50	24.5	Shallow Bedrock	Active
MW-104S	236673.17	668493.30	20.1	13.00	23	Unconsolidated	Active
MW-105D	236534.06	668645.74	20.66	45.50	55.5	Deep Bedrock	Abandoned
MW-105S	236536.03	668642.86	20.66	14.50	24.5	Unconsolidated	Abandoned
MW-106D	236464.64	668730.32	20.7	45.00	55	Deep Bedrock	Active
MW-106S	236473.85	668738.10	20.56	14.50	24.5	Shallow Bedrock	Active
MW-107D	236374.52	668874.54	20.52	90.00	100	Shallow Bedrock	Active
MW-107S	236371.27	668871.82	20.39	15.00	25	Unconsolidated	Active
MW-108	236243.62	669142.69	12.15	15	25	Unconsolidated	Active
MW-109D	236327.48	668450.18	20.54	45.00	55	Shallow Bedrock	Active
MW-109S	236329.11	668448.13	20.64	15.00	25	Unconsolidated	Active
MW-110D	236083.96	668812.01	22.83	70.00	80	Shallow Bedrock	Active

TABLE 5-1
Summary of Monitoring Well Information

Well ID	Northing	Easting	Elevation[1]	Top of Screen[2] (ft bgs)	Bottom of Screen[2] (ft bgs)	Hydrostratigaphic Unit Monitored	Well Status
MW-110S	236081.77	668815.38	22.47	15.00	25	Unconsolidated	Active
MW-111S	235931.47	668940.43	18.21	15	25	Unconsolidated	Abandoned
MW-112S	235797.44	669204.17	14.51	15	25	Unconsolidated	Active
MW-113S	235773.51	669398.06	13.56	15	25	Unconsolidated	Active
MW-114S	236615.50	668820.92	20.76	7.5	17.5	Unconsolidated	Active
MW-115S	236603.10	668837.00	20.81	7	17	Unconsolidated	Active
MW-117S	235070.57	671286.68	15.95	15	25	Unconsolidated	Active
MW-122D	236490.49	668988.55	19.99	184.70	194.7	Deep Bedrock	Active
MW-122S	236486.50	668988.86	19.84	9	19	Unconsolidated	Active
MW-123	236629.95	668473.66	20.19	23.5	33.47	Shallow Bedrock	Active
MW-124	236478.85	668448.53	20.81	11	21	Unconsolidated	Active
MW-125	236324.23	668797.83	20.31	11	22	Unconsolidated	Active
MW-200	236230.82	673217.72	54.68	8	18	Unconsolidated	Active
MW-201	235811.20	673214.61	58.74	25	35	Unconsolidated	Active
MW-202	236176.51	672987.49	51.64	10	20	Unconsolidated	Active
MW-203	236099.24	672994.67	46.21	8	18	Unconsolidated	Active
MW-204	235928.48	673033.93	41.88	5	15	Unconsolidated	Active
MW-205	235826.44	673093.28	40.57	5	15	Unconsolidated	Active
MW-206	235789.83	673016.63	43.10	5	15	Unconsolidated	Active
MW-207	236021.60	673148.93	46.99	15	25	Unconsolidated	Active
MW-208	235742.54	673120.08	50.21	12	32	Unconsolidated	Active
MW-502	236770.63	668013.02	17.90	20.54	30.22	Unconsolidated	Active
MW-503	236928.27	667916.80	15.31	25.14	34.83	Unconsolidated	Active
MW-504	236881.63	668116.16	16.66	18.97	28.67	Unconsolidated	Active
MW-505	237062.99	668090.60	14.98	16.37	25.07	Deep Bedrock	Active
MW-507D	236799.08	668299.65	18.56	67	77	Deep Bedrock	Active
MW-507S	236795.86	668303.57	18.46	10.88	20.88	Deep Bedrock	Active
MW-508D	236663.18	668190.54	17.78	81.5	91.5	Shallow Bedrock	Active
MW-508S	236666.79	668193.26	17.63	14	24	Unconsolidated	Active
MW-1001	NSD	NSD	NSD	3.5	13.5	Unconsolidated	Active
OB-25	NSD	NSD	NSD	19.5	29.8	Unconsolidated	Active
TPW-1	NSD	NSD	**9.5**	80	100	Unconsolidated	Active
TPW-2	NSD	NSD	**9.5**	80	110	Unconsolidated	Active
TW-1	235020.46	670967.37	17.73	94	112	Unconsolidated	Active
TW-2	235292.04	670515.44	9.67	101	104	Unconsolidated	Active
TW-3	235285.23	670802.16	13.02	49	89	Unconsolidated	Active
TW-4	235087.35	671193.58	10.71	80	120	Unconsolidated	Active
Well-A	NSD	NSD	NSD	37	47	Unconsolidated	Active
Well-B	NSD	NSD	NSD	45	57	Unconsolidated	Active
10-2	NSD	NSD	**10.2**	58	63	Unconsolidated	Active
8-2	NSD	NSD	NSD	40	47	Unconsolidated	Active
9-2	NSD	NSD	NSD	50	57	Unconsolidated	Active

[1]Elevations obtained from Kratzert, Jones and Associates January 2004 survey. Bold text indicates locations not surveyed, determined by Malcolm Pirnie.
[2]Screen depths based on construction logs.
NSD = No survey data is available
ft bgs = Feet below ground surface

TABLE 5-2
Well Repair and Maintenance Activities

Well	Well Repair and/or Maintenance Activity	Painted High Visibility Yellow	New Cement Pad	Transducer Hanger Clip Added
10-2		X		
MW-1		X		
MW-100S	Redeveloped well to remove sediment in bottom of well, and to improve well efficiency.			X
MW-100D	Redeveloped well to remove sediment in bottom of well, and to improve well efficiency.			
MW-101S				X
MW-101D				X
MW-102S	Replaced flush mount surface completion.		X	X
MW-102D	Replaced flush mount surface completion.		X	X
MW-103S	Redeveloped well to remove sediment in bottom of well, and to improve well efficiency.			X
MW-103D	Redeveloped well to remove sediment in bottom of well, and to improve well efficiency.			X
MW-104	Replaced flush mount surface completion with heavy duty road box for heavy traffic area.		X	X
MW-105S	Redeveloped well to remove sediment in bottom of well.			X
MW-105D	Redeveloped well to remove sediment in bottom of well.			X
MW-106S			X	X
MW-106D			X	X
MW-107S			X	X
MW-107D			X	X
MW-108S	Crushed by heavy hauler. Repaired with new riser and coupler, and added three traffic posts.	X	X	X
MW-109S	Replaced flush mount surface completion with heavy duty road box for heavy traffic area.		X	X
MW-109D	Replaced flush mount surface completion with heavy duty road box for heavy traffic area.		X	X
MW-110S	Drilled drain hole in protective casing.	X	X	X
MW-110D	Drilled drain hole in protective casing.	X	X	X
MW-111	Drilled drain hole in protective casing.	X		
MW-112S	Drilled drain hole in protective casing.	X		
MW-113S	New aluminum lid. Drilled drain hole in protective casing.	X		X
MW-114				X
MW-117		X		
MW-122S			X	X
MW-122D			X	X
MW-123			X	
MW-124			X	X
MW-125			X	
MW-13		X		
MW-2		X		
MW-200		X		
MW-201		X		
MW-202		X		
MW-203		X		
MW-204		X		
MW-205		X		
MW-206		X		
MW-207		X		
MW-208		X		
MW-3		X		
MW-4		X		
MW-504				X
MW-508S				X
MW-508D				X
TPW-1		X		
TPW-2		X		
TW-1		X		X
TW-2		X		
TW-3		X		
TW-4		X		
Well-A 8-2		X		
Well-B 9-2		X		

TABLE 5-3
Summary of Monitoring Wells Abandoned at the Connecticut Yankee Site

Well ID	Casing Type	Protective Casing	Location
MW-9	PVC	None	Lower Peninsula
MW-17	PVC	None	Lower Peninsula
MW-16S	PVC	None	Lower Peninsula
MW-16D	PVC	None	Lower Peninsula
MW-15	PVC	None	Lower Peninsula
MW-6	PVC	None	Lower Peninsula
MW-5	PVC	None	Lower Peninsula
MW-18	PVC	None	Lower Peninsula
MW-14	PVC	Steel	Lower Peninsula
MW-11	PVC	None	Lower Peninsula
MW-7	PVC	None	Lower Peninsula
MW-10	PVC	None	Lower Peninsula
MW-8	PVC	None	Lower Peninsula
MW-12	PVC	None	Lower Peninsula
MW-105S	PVC	Roadbox	Industrial area
MW-105D	PVC	Roadbox	Industrial area
AST-1	PVC	Steel	Industrial area
AST-2	PVC	Steel	Industrial area
AST-3	PVC	Steel	Industrial area
AST-4	PVC	Steel	Industrial area
MW-111S	PVC	Steel	Peninsula
MW-1301	PVC	Roadbox	Peninsula
MW-1302	PVC	Roadbox	Peninsula

Table 6-1 Unconsolidated Deposits Aquifer Step Drawdown Test									
Date	Clock Time	Date/Time	AT-1 Depth to Water (ft bgs)	Drawdown (ft)	Step	OB-25 Depth to Water (ft bgs)	Drawdown (ft)	Discharge (GPM)
09/14/2004	1:20 PM	9/14/04 13:20	17.95	0	0	19.09	0	0
09/14/2004	1:25 PM	9/14/04 13:25	17.95	0	0	19.09	0	0
09/14/2004	1:30 PM	9/14/04 13:30	17.95	0	0	19.09	0	0
09/14/2004	1:35 PM	9/14/04 13:35	17.95	0	1	19.09	0	0.5
09/14/2004	1:40 PM	9/14/04 13:40	17.95	0	1	19.09	0	0.5
09/14/2004	1:45 PM	9/14/04 13:45	17.97	0.02	1	19.09	0	0.5
09/14/2004	1:50 PM	9/14/04 13:50	17.97	0.02	1	19.09	0	0.5
09/14/2004	1:55 PM	9/14/04 13:55	17.97	0.02	1	19.09	0	0.5
09/14/2004	2:00 PM	9/14/04 14:00	17.97	0.02	1	19.09	0	0.5
09/14/2004	2:05 PM	9/14/04 14:05	17.97	0.02	1	19.09	0	0.5
09/14/2004	2:10 PM	9/14/04 14:10	17.97	0.02	1	19.09	0	0.5
09/14/2004	2:15 PM	9/14/04 14:15	17.97	0.02	1	19.09	0	0.5
09/14/2004	2:20 PM	9/14/04 14:20	17.97	0.02	1	19.09	0	0.5
09/14/2004	2:25 PM	9/14/04 14:25	17.97	0.02	1	19.085	-0.005	0.5
09/14/2004	2:30 PM	9/14/04 14:30	17.97	0.02	1	19.08	-0.01	0.5
09/14/2004	2:35 PM	9/14/04 14:35	17.97	0.02	1	19.08	-0.01	0.5
09/14/2004	2:40 PM	9/14/04 14:40	17.97	0.02	1	19.08	-0.01	0.5
09/14/2004	2:45 PM	9/14/04 14:45						
09/14/2004	2:50 PM	9/14/04 14:50						
09/14/2004	2:55 PM	9/14/04 14:55						
09/14/2004	3:00 PM	9/14/04 15:00						
09/14/2004	3:05 PM	9/14/04 15:05						
09/14/2004	3:10 PM	9/14/04 15:10						
09/14/2004	3:15 PM	9/14/04 15:15						
09/14/2004	3:20 PM	9/14/04 15:20	17.94	0	2	19.08	0	0
09/14/2004	3:25 PM	9/14/04 15:25	17.94	0	2	19.07	-0.01	0
09/14/2004	3:30 PM	9/14/04 15:30	17.94	0	2	19.07	-0.01	10
09/14/2004	3:35 PM	9/14/04 15:35	18.38	0.44	2	19.1	0.02	10
09/14/2004	3:40 PM	9/14/04 15:40	18.4	0.46	2	19.12	0.04	10
09/14/2004	3:45 PM	9/14/04 15:45	18.42	0.48	2	19.13	0.05	10
09/14/2004	3:50 PM	9/14/04 15:50	18.42	0.48	2	19.14	0.06	10
09/14/2004	3:55 PM	9/14/04 15:55	18.43	0.49	2	19.15	0.07	10
09/14/2004	4:00 PM	9/14/04 16:00	18.44	0.5	2	19.15	0.07	10
09/14/2004	4:05 PM	9/14/04 16:05	18.45	0.51	2	19.16	0.08	10
09/14/2004	4:10 PM	9/14/04 16:10	18.46	0.52	2	19.16	0.08	10
09/14/2004	4:15 PM	9/14/04 16:15	18.47	0.53	2	19.17	0.09	10
09/14/2004	4:20 PM	9/14/04 16:20	18.47	0.53	2	19.18	0.1	10
09/14/2004	4:25 PM	9/14/04 16:25	18.47	0.53	2	19.18	0.1	10
09/14/2004	4:30 PM	9/14/04 16:30	18.47	0.53	2	19.18	0.1	10
09/14/2004	4:35 PM	9/14/04 16:35	18.69	0.75	3	19.2	0.12	15
09/14/2004	4:40 PM	9/14/04 16:40	18.7	0.76	3	19.2	0.12	15
09/14/2004	4:45 PM	9/14/04 16:45	18.72	0.78	3	19.22	0.14	15
09/14/2004	4:50 PM	9/14/04 16:50	18.72	0.78	3	19.22	0.14	15
09/14/2004	4:55 PM	9/14/04 16:55	18.73	0.79	3	19.22	0.14	15
09/14/2004	5:00 PM	9/14/04 17:00	18.74	0.8	3	19.24	0.16	15
09/14/2004	5:05 PM	9/14/04 17:05	18.75	0.81	3	19.25	0.17	15
09/14/2004	5:10 PM	9/14/04 17:10	18.76	0.82	3	19.25	0.17	15
09/14/2004	5:15 PM	9/14/04 17:15	18.76	0.82	3	19.25	0.17	15
09/14/2004	5:20 PM	9/14/04 17:20	18.77	0.83	3	19.26	0.18	15

Table 6-1 Unconsolidated Deposits Aquifer Step Drawdown Test								
Date	Clock Time	Date/Time	AT-1 Depth to Water (ft bgs)	Drawdown (ft)	Step	OB-25 Depth to Water (ft bgs)	Drawdown (ft)	Discharge (GPM)
09/14/2004	5:25 PM	9/14/04 17:25	18.77	0.83	3	19.26	0.18	15
09/14/2004	5:30 PM	9/14/04 17:30	18.78	0.84	3	19.26	0.18	15
09/14/2004	5:35 PM	9/14/04 17:35	19.33	1.39	4	19.3	0.22	29
09/14/2004	5:40 PM	9/14/04 17:40	19.35	1.41	4	19.32	0.24	29
09/14/2004	5:45 PM	9/14/04 17:45	19.38	1.44	4	19.33	0.25	29
09/14/2004	5:50 PM	9/14/04 17:50	19.4	1.46	4	19.34	0.26	29
09/14/2004	5:55 PM	9/14/04 17:55	19.41	1.47	4	19.34	0.26	29
09/14/2004	6:00 PM	9/14/04 18:00	19.43	1.49	4	19.35	0.27	29
09/14/2004	6:05 PM	9/14/04 18:05	19.44	1.5	4	19.36	0.28	29
09/14/2004	6:10 PM	9/14/04 18:10	19.45	1.51	4	19.37	0.29	29
09/14/2004	6:15 PM	9/14/04 18:15	19.46	1.52	4	19.37	0.29	29
09/14/2004	6:20 PM	9/14/04 18:20	19.47	1.53	4	19.38	0.3	29
09/14/2004	6:25 PM	9/14/04 18:25	19.48	1.54	4	19.39	0.31	29
09/14/2004	6:30 PM	9/14/04 18:30	19.49	1.55	4	19.39	0.31	29

Test location: AT-1

Test Type: Unconsolidated Step Drawdown Test

Date Start: 9/14/2004

Measuring equipment: AT-1 (Heron, blue/white); OB-25 (Solinst #122)

TABLE 6-2
Aquifer Test Component Dimensions

Component	Dimension	Distance from Test Well
Duration of Test	72 Hours	NA
Pumping Well (AT-1) Total Depth	-20.5 ft MSL[1]	0 ft.
Test Well Screened Interval	25 ft. (elevation +5.1 MSL to –19.9 MSL)	0 ft.
Test well casing and screen diameter	5-inches	NA
Test well screen configuration	0.020-inch slot vee-wire wrapped	NA
Pump Capacity	Rated 25gpm, 1/2Hp, 110Vac, Actual pumping rate 29 gpm	
Pump placement	Intake at –19 MSL	
Observation Well OB-25 Total Depth and screened interval	-9 ft MSL (elevation +1.3 to –8.7 MSL).	29.1 ft.
Well MW-124 total depth and screened interval	-0.48 MSL (elevation +9.82 to –0.18 ft MSL)	109.1 ft.
Well MW-123 total depth and screened interval	-13.61 MSL (elevation –3.31 to –13.28 ft MSL)	191.6 ft.
Well MW-508S total depth and screened interval	Unknown	227.9 ft [2]
Well MW-109S total depth and screened interval	-4.6 ft MSL (elevation +5.65 to –4.35 ft MSL)	195.7 ft [2]

1) Pumping well and OB-25 elevations approximate, locations not surveyed as of yet.

2) Distance to MW-508S and MW-109S measured in CAD, structures interfered with direct line measurement.

TABLE 6-3

Well Responses to Dewatering Well Activities

1st, 2nd and 3rd Quarters

CYAPCO

	Activity:								
	Rainfall Events				Dewatering (shut on & off, pump tests, development, etc.)				
	Quarter				Quarter				
Well ID	1st	2nd	3rd	Comments	1st	2nd	3rd [1]	Comments
Mat Sump								
MW-100S	X	X	X					
MW-101D	X	X	X		X	X		1st qtr - response to DW-1, 3
MW-101S	X	X	X					
MW-102D	X	X	X					
MW-102S	X	X	X					
MW-103D	X	X	X			X		
MW-103S	X	X	X		X	X		1st qtr - response to DW-1, 3
MW-104S	X	X	X				X	3rd qtr- DW-4 drilling & pump installation
MW-105D [2]	X	X				X		
MW-105S [2]	X	X				X		
MW-106D	X	X	X			X		
MW-106S	X	X	X		X	X		1st qtr - response to DW-1, 2
MW-107D	X	X	X					
MW-107S	X	X	X					
MW-108	X	X	X					
MW-109D	X	X	X					
MW-109S	X	X	X					
MW-110D	X	X	X					
MW-110S	X	X	X					
MW-113S	X	X	X					
MW-114S [3]	X	X				X		
MW-122D	X	X	X			X		
MW-122S	X	X	X			X		
MW-124	X	X	X					
MW-504S	X	X	X					
MW-508D	X	X	X					
MW-508S	X	X	X					
RIVER	X	X	X					
TW-1	X	X	X					

Notes:

X = indicates that there was a potential transducer response to the stated activity in that particular well

(1) DW-1, DW-2, and DW-3 were taken off-line at the same time that a major rainfall event took place in the 3rd Quarter. This made it difficult to deduce whether a well responded to the dewatering well activity.

(2) MW-105D and MW-105S were abandoned in the beginning of the 3rd Quarter.

(3) Water Levels in MW-114S dropped below the transducer at the end of the 2nd Quarter.

TABLE 6-4
Summary of Packer Seal Data in Borehole 121A
2004 Data with 2003 Data for Comparison

2004 Packer Test Intervals		Tritium	Apparent Yield	2003 Packer Test Intervals	Apparent Yield[2]
23-ft Interval	5-ft Interval	(pCi/L)	(g/hr)	23-ft Interval	(g/hr)
	103-108	1,290	0.41	84-107	3
	113-118 #2	No seal, not sampled		105-128	0.6
	114-119 #1	No seal, not sampled			
	115-120 #3	No seal, not sampled			
	145-150	Low yield/ not sampled	0.05	147-170	523
	147-152	Low yield/ not sampled	0.01		
153-176 #2		8,170[1] No seal but sampled			
155-178 #1		No seal, not sampled			
	151.5-156.5 #2	2,430	0.65		
	152-157 #1	No seal, not sampled			
	156-161 #2	No seal, not sampled			
	157-162 #1	No seal, not sampled			
	158-163 #3	No seal, not sampled			
	162-167 #1	No seal, not sampled			
	162.5-167.5 #3	No seal, not sampled			
	163-168 #2	No seal, not sampled		168-191	3.6
	168-173	Low yield/ not sampled	0.03		
	172-177 #2	No seal, not sampled			
	173-178 #1	No seal, not sampled			
	174-179 #3	No seal, not sampled			
	178-183	6,060	2.5		
	183-188	Low yield/ not sampled	<0.02		
	188-193	Low yield/ not sampled	0.02	189-212	>0.6
	203-208	Low yield/ not sampled	0.04		
256-279 #2		No seal, not sampled		273-296	3.6
260-283 #1		No seal, not sampled			
	266-271	Low yield/ not sampled	0.156		
	271.5-276.5 #3	No seal, not sampled			
	272-277 #2	No seal, not sampled			
	273-278 #1	No seal, not sampled			
287-310 #2		No seal, not sampled			
291-314 #3		No seal, not sampled		294-317	0.6
292-315 #1		No seal, not sampled			
	297.5-302.5	Bypass and Low yield/ not sampled	<0.02		
	316-320 #1	No seal, not sampled			
	317-322 #2	496	2.4		
324.2-347.2		Low yield/ not sampled	0.25	336-359	3
	340-345	Low yield/ not sampled	<0.01		
	465-470	Low yield/ not sampled	0.04	441-464	0.6
	466-471	No seal, not sampled			

1) *Sample collected in highly fractured, highly permeable zone, even though seal was not achieved. Sample was* collected under low flow conditions.

2) 2003 packer campaign apparent yields identified in data quality assessment as potentially representative of packer bypass. The 2004 yield data is considered more representative.

Table 7-1. Occurrence of Transmissive Zones in Bedrock Boreholes at HNP.

Geophysical Logging heat pulse flow meter under pumping conditions Transmissive Zones ft bgs, flow (gpm)	Packer Testing* Transmissive Zones (ft bgs)	Hydrophysical Logging Transmissive Zones-ft bgs, flow under pumping conditions (gpm)
Borehole 118 (4-inch borehole)		
No geophysical log performed	No yield information collected	No hydrophysical log performed
Borehole 118A		
25 ft bgs	22-45[1]	29.8-30.2[3] ft bgs(3.81 gpm)
No detected flow below 35 ft.	43-66[1]	45.9-46.1[4] ft bgs (0.185 gpm)
	148-171, 154-177[1]	63.9-65.0[4] ft bgs(0.238 gpm)
		68.3-68.4 ft bgs(0.132 gpm)
		73.9-74.0 ft bgs(0.211 gpm)
		101.8-101.9 ft bgs (0.048 gpm)
		113.9-114.5[4] ft bgs (0.053 gpm)
		127.8-128.0[4] ft bgs (0.106 gpm)
		161.7-161.8 ft bgs (0.008 gpm)
		187.2-187.3 ft bgs (0.005 gpm)
		206.0-206.1 ft bgs (0.004 gpm)
		219.8-219.9[4] ft bgs (0.003 gpm)
		238.5-238.6 ft bgs (0.005 gpm)
Borehole 119		
45 ft bgs (0.1 gpm)	Started collecting yield info at 170 feet bgs.	47.3-47.4[4] ft bgs (0.158 gpm)
75 ft bgs (0.08 gpm)	212-235[1]	74.4-74.5 ft bgs (0.169 gpm)
100 ft bgs (0.06 gpm)	275-298[1]	85.2-88.8[3] ft bgs (0.438 gpm)
135 ft bgs (0.06 gpm)	439-462[1]	147.8-148.9[3] ft bgs (0.251 gpm)
No detected flow below 165 ft bgs.		160.0-160.3[3] ft bgs (0.273 gpm)
		178.4-184.0 ft bgs (0.008 gpm)
		236.0-236.1 ft bgs (0.002 gpm)
		241.2-241.4 ft bgs (0.003 gpm)
		253.0-254.5[4] ft bgs (0.013 gpm)
		262.2-263.8[4] ft bgs (0.004 gpm)
		288.1-288.3 ft bgs (0.002 gpm)
		297.2-299.3 ft bgs (0.015 gpm)
		318.7-321.5 ft bgs (0.002 gpm)
		384.2-385.5 ft bgs (0.001 gpm)
		426.7-430.9 ft bgs (0.003 gpm)
		446.5-452.8 ft bgs (0.0003 gpm)
		456.4-456.7 ft bgs (0.012 gpm)
		472.0-481.1 ft bgs (0.004 gpm)
Borehole 120		
40 ft bgs (0.09 gpm)	84-107, 105-161, 147-170[1]	83.5-83.6 ft bgs (0.045 gpm)
65 ft bgs (0.09 gpm)	189-212[1]	92.8-93.6[3] ft bgs (0.554 gpm)
95 (0.05 gpm)	210-233[1]	105.6-106.0[3,4] ft bgs (0.778 gpm)
125 (0.04 gpm)	231-254[1]	130.1-130.4 ft bgs (0.079 gpm)
No flow detected below 155 ft bgs.		142.4-142.9 ft bgs (0.264 gpm)
		153.2-153.3 ft bgs (0.026 gpm)
		171.1-171.2 ft bgs (0.008 gpm)
		211.0-211.3[4] ft bgs (0.074 gpm)

Geophysical Logging heat pulse flow meter under pumping conditions Transmissive Zones ft bgs, flow (gpm)	Packer Testing* Transmissive Zones (ft bgs)	Hydrophysical Logging Transmissive Zones-ft bgs, flow under pumping conditions (gpm)
Borehole 120 continued		
		228.9-232.8 ft bgs (0.016 gpm)
		238.1-238.2 ft bgs (0.008 gpm)
		242.3-243.2 ft bgs (0.004 gpm)
Borehole 121 (4-inch borehole)		
No geophysical log performed	No yield information collected	No hydrophysical log performed
Borehole 121A		
95 ft bgs (0.26 gpm)	113-120[2]	160.4-160.5 ft bgs (0.180 gpm))
120 ft bgs (0.23 gpm)	147-170[1], 153-168 [2]	165.9-166.8[3, 4] ft bgs (6.26 gpm)
150 ft bgs (0.22 gpm)	172-183[2]	177.6-177.7 ft bgs (0.090 gpm)
160 (0.08 gpm)	256-283[2]	278.0-278.8[4] ft bgs (0.029 gpm)
No flow detected below 170 ft bgs.	271.5-315[2]	308.4-309.0 ft bgs (0.032 gpm)
		326.1-328.5 ft bgs (0.037 gpm)
		446.8-449.1 ft bgs (0.001 gpm)
		454.2-456.4 ft bgs (0.001 gpm)
		460.7-465.1[4] ft bgs (0.008 gpm)
		467.9-469.5 ft bgs (0.003 gpm)
		483.1-483.2 ft bgs (0.003 gpm)
		491.7-491.8 ft bgs (0.002 gpm)
		506.0-506.1 ft bgs (0.0009 gpm)
		515.1-515.2 ft bgs (0.0008 gpm)

1) The lack of pressure sensing instrumentation to confirm packer seals makes yield data from 2003 packer testing campaign potentially non-representative.
2) Transmissive zone assumed where packer would not seal.
3) A dominant flow zone in that particular borehole.
4) Zone displays ambient flow.

Table 7-2. Occurrence of Tritium in Bedrock Boreholes at HNP.

2003 Packer Testing Tritium-bearing[1] zones ft bgs and Concentration (pCi/L)	2004 Packer Testing Tritium-bearing zones (ft bgs) and Concentration in pCi/L	Hydrophysical Logging Tritium-bearing zones (ft bgs) and Concentration in pCi/L
Borehole 118 (4-inch borehole)		
24-47 ft bgs (6,180 pCi/L)	No packer tritium data collected	Not hydrophysically logged
45-68 ft bgs (9,940 pCi/L)		
66-89 ft bgs (7,000 pCi/L)		
87-110 ft bgs (7,330 pCi/L)		
108-131 ft bgs (5,800 pCi/L)		
129-152 ft bgs (4,320 pCi/L)		
171-194 ft bgs (2,870 pCi/L)		
192-215 ft bgs (2,160 pCi/L)		
213-236 ft bgs (1,500 pCi/L)		
234-257 ft bgs (2,450 pCi/L)		
255-278 ft bgs (3,220 pCi/L)		
276-299 ft bgs (4,280 pCi/L)		
297-320 ft bgs (3,730 pCi/L)		
318-341 ft bgs (6,060 pCi/L)		
339-364 ft bgs (3,790 pCi/L)		
371-395 ft bgs (4,280 pCi/L)		
Borehole 118A		
22-45 ft bgs (1,330 pCi/L)	No packer tritium data collected	45.9-46.1 ft bgs (13,911 pCi/L)
43-66 ft bgs (14,200 pCi/L)		63.9-65.0 ft bgs (9,818 pCi/L)
85-108 ft bgs (10,000 pCi/L)		68.3-68.4 ft bgs (13,046 pCi/L)
148-171 ft bgs (1,880 pCi/L)		73.9-74.0 ft bgs (5,939 pCi/L)
154-177 ft bgs (2,520 pCi/L)		113.9-114.5 ft bgs (5,466 pCi/L)
		127.8-128.0 ft bgs (2,550 pCi/L)
Borehole 119		
42-65 ft bgs (14,300 pCi/L)	No packer tritium data collected	47.3-47.4 ft bgs (9,148 pCi/L)
63-86 ft bgs (35,300 pCi/L)		74.4-74.5 ft bgs (18,346 pCi/L)
84-107 ft bgs (32,700 pCi/L)		85.2-88.8 ft bgs (10,107 pCi/L)
105-128 ft bgs (13,300 pCi/L)		147.8-148.9 ft bgs (3,085 pCi/L)
126-149 ft bgs (8,120 pCi/L)		160.0-160.3 ft bgs (1,604 pCi/L)
143-166 ft bgs (4,140 pCi/L)		297.2-299.3 ft bgs (1,170[4] pCi/L)
191-214 ft bgs (4,900 pCi/L)		456.4-456.7 ft bgs (1,570[4] pCi/L)
212-235 ft bgs (6,660 pCi/L)		
275-298 ft bgs (1,610 pCi/L)		
296-319 ft bgs (5,780 pCi/L)		
317-340 ft bgs (3,850 pCi/L)		
359-380 ft bgs (7,940 pCi/L)		
387-408 ft bgs (1,940 pCi/L)		
400-420 ft bgs (4,000 pCi/L)		
Borehole 120		
42-65 ft bgs (5,080 pCi/L)	No packer tritium data collected	83.5-83.6 ft bgs (15,413 pCi/L)
63-86 ft bgs (5,160 pCi/L)		92.8-93.6 ft bgs (1,458 pCi/L)
105-161 ft bgs (1,470 pCi/L)		105.6-106.0 ft bgs (1,459 pCi/L)
252-275 ft bgs (1,300 pCi/L)		

2003 Packer Testing Tritium-bearing[1] zones ft bgs and Concentration (pCi/L)	2004 Packer Testing Tritium-bearing zones (ft bgs) and Concentration in pCi/L	Hydrophysical Logging Tritium-bearing zones (ft bgs) and Concentration in pCi/L
Borehole 120 continued		
275-298 ft bgs (1,420 pCi/L)		
296-319 ft bgs (1,480 pCi/L)		
317-340 ft bgs (1,380 pCi/L)		
338-361 ft bgs (1,710 pCi/L)		
359-382 ft bgs (1,840 pCi/L)		
387-403 ft bgs (1,640 pCi/L)		
399-422 ft bgs (1,930 pCi/L)		
420-443 ft bgs (1,830 pCi/L)		
441-464 ft bgs (2,010 pCi/L)		
462-485 ft bgs (1,600 pCi/L)		
504-527 ft bgs (1,940 pCi/L)		
Borehole 121 (4-inch borehole)		
20-50 ft bgs (10,900 pCi/L)	No packer tritium data collected	Not hydrophysically logged
50-70 ft bgs (9,630 pCi/L)		
70-90 ft bgs (11,100 pCi/L)		
90-110 ft bgs (11,200 pCi/L)		
110-130 ft bgs (11,050 pCi/L)		
130-150 ft bgs (4,140 pCi/L)		
150-170 ft bgs (2,320 pCi/L)		
170-190 ft bgs (3,990 pCi/L)		
Borehole 121A		
147-170 ft bgs (8,890 pCi/L)	103-108 ft bgs (1,290 pCi/L)	165.9-166.8 ft bgs (7,322 pCi/L)
168-191 ft bgs (8,630 pCi/L)	153-176 ft bgs (8,170[2] pCi/L)	177.6-177.7 ft bgs (8,645 pCi/L)
273-296 ft bgs (2,610 pCi/L)	151.5-156.5 ft bgs (2,430 pCi/L)	
294-317 ft bgs (6,080 pCi/L)	178-183 ft bgs (6,060 pCi/L)	
336-359 ft bgs (8,700 pCi/L)	317-322 ft bgs (496[3] pCi/L)	
441-464 ft bgs (7,400 pCi/L)		

1) 2003 packer sampling tritium data evaluated in data quality assessment to be non-representative in low yield zones, and potentially non-representative in higher yield zones.
2) Sample collected under low flow conditions in highly permeable zone where packer seal could not be achieved.
3) Sample identified in data quality assessment as potentially biased by residual heel water.
4) Calculated interval specific pore water tritium concentrations in low flow zones where fluid resistivity profiles are not fully developed, are not considered representative. As such, the value footnoted is the onsite laboratory result.

Table 7-3. Selected Screened Intervals for Bedrock Monitoring Wells.				
Well Identifier	Target Interval (ft bgs)		Screen Length (ft)	Basis/Comment
	Top	Btm		
MW-118A				The borehole exhibits the most productive apparent pumping yields.
MW-118A(30)	25	35	10	Most productive HPL pumping flow zone. No tritium detected.
MW-118A(55)	45	65	20	HPL ambient flow zone. Tritium detected.
MW-118A(115)	100	130	30	Includes 2 zones where ambient flow was detected with HPL. Tritium detected.
MW-118A(157.5)	150	165	15	HPL pumping flow. Packer testing pumping yield estimate: >5gpm. Not sampled for tritium
MW-118A(232.5)	225	240	15	Deepest detected flow during HPL pumping test. No Tritium detected below 240 ft during packer testing.
MW-119				The borehole exhibits the deepest apparent tritium detection (456ft).
MW-119(50)	45	55	10	Most productive detected ambient flow during HPL. Tritium detected.
MW-119(80)	70	90	20	Most productive zone during HPL pumping test. Tritium detected.
MW-119(160)	155	165	10	Deepest zone of detected ambient flow during HPL. Tritium detected.
MW-119(257.5)	250	265	15	HPL ambient and pumping flow zone identified. No tritium detected.
MW-119(300)	295	305	10	HPL pumping flow zone identified. Tritium detected.
MW-119(455)	450	460	10	Deepest zone of significant production identified with packer testing and HPL. Tritium detected.
MW-120				
MW-120(85)	75	95	20	Shallowest detectable flow identified during HPL. Tritium detected.
MW-120(105)	100	110	10	Ambient flow detected during HPL. Tritium detected.
MW-120(155)	150	160	10	Ambient flow detected during HPL. No tritium detected.
MW-120(210)	205	215	10	Ambient flow detected during HPL. No tritium detected.
MW-120(240)	235	245	10	Deepest producing zone identified by packer testing and HPL during the pumping test.
MW-121A				The borehole exhibits the deepest detectable ambient flow with HPL.
MW-121A(105)	100	110	10	Shallowest detectable producing zone identified by packer testing. Tritium detected.
MW-121A(170)	160	180	20	Shallowest detectable ambient flow detected during HPL. Tritium detected. Strong upward head differential identified during Packer testing
MW-121A(280)	275	285	10	Ambient and pumping flow detected during HPL. No tritium detected.
MW-121A(312.5)	305	320	15	HPL pumping flow zone identified. No tritium detected.
MW-121A(465)	460	470	10	Deepest detected ambient flow zone identified during HPL. No tritium detected.

Notes: HPL = Hydrophysical Logging
Ft = Feet
ft bgs = Feet below ground surface
Btm = Bottom
gpm = Gallons per minute

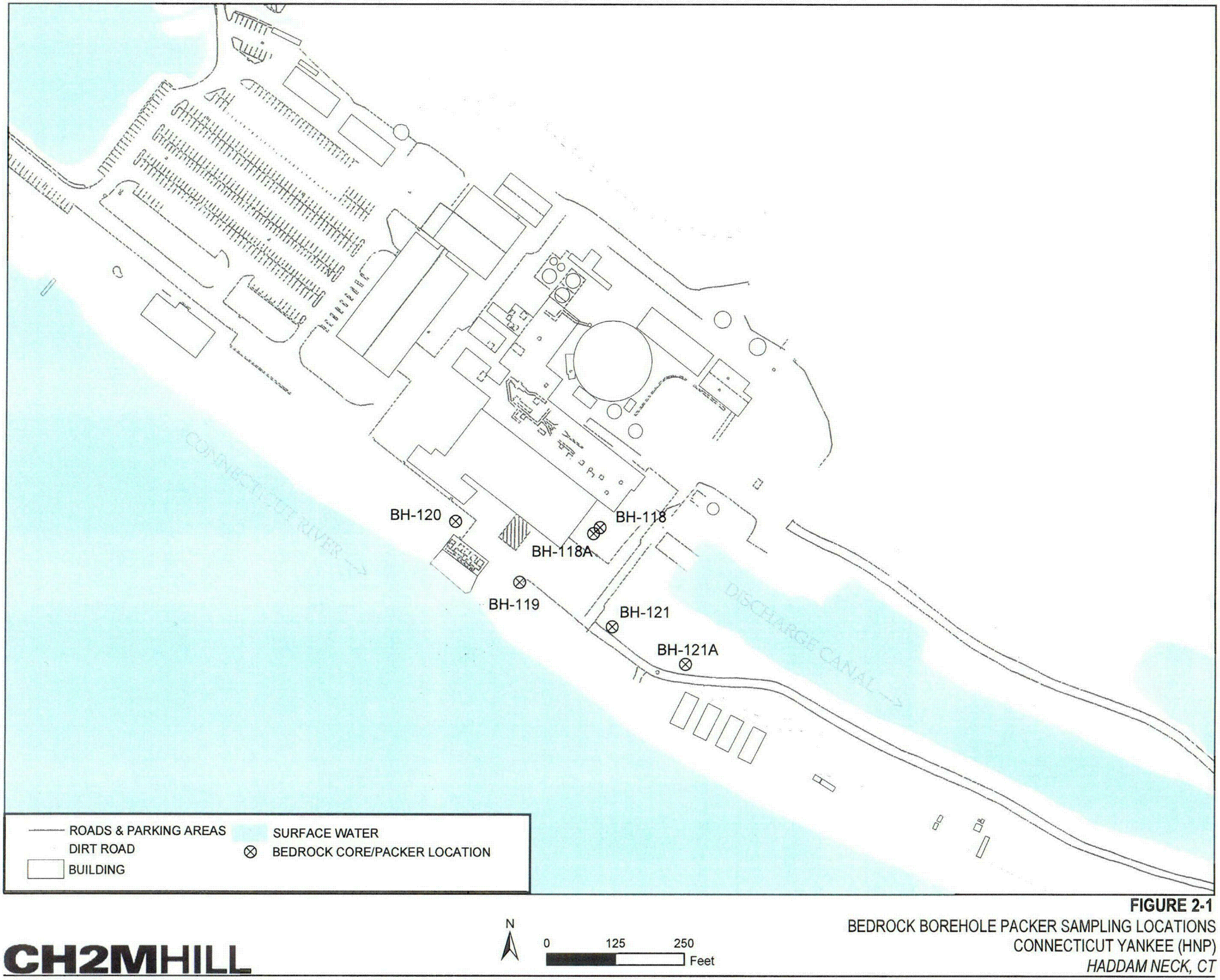
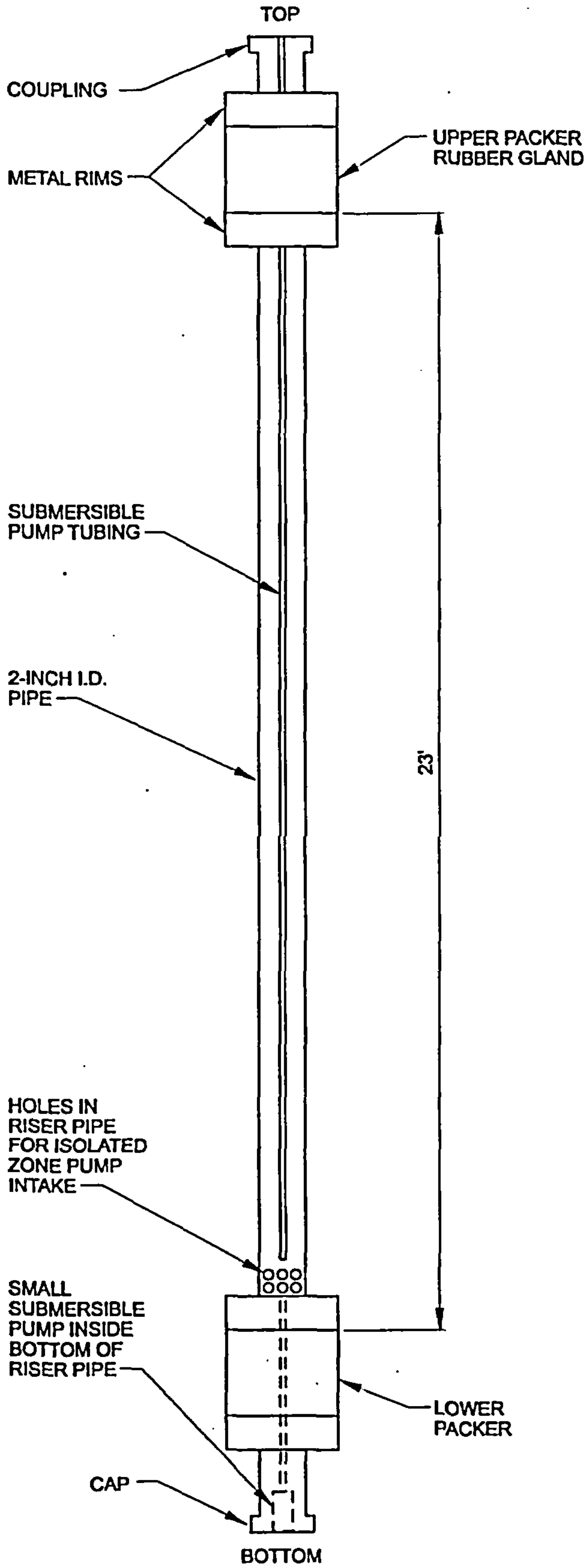


FIGURE 2-1
BEDROCK BOREHOLE PACKER SAMPLING LOCATIONS
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

CH2MHILL

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\BR_CORE_LOCATIONS.mxd JHenderson 9/29/2004

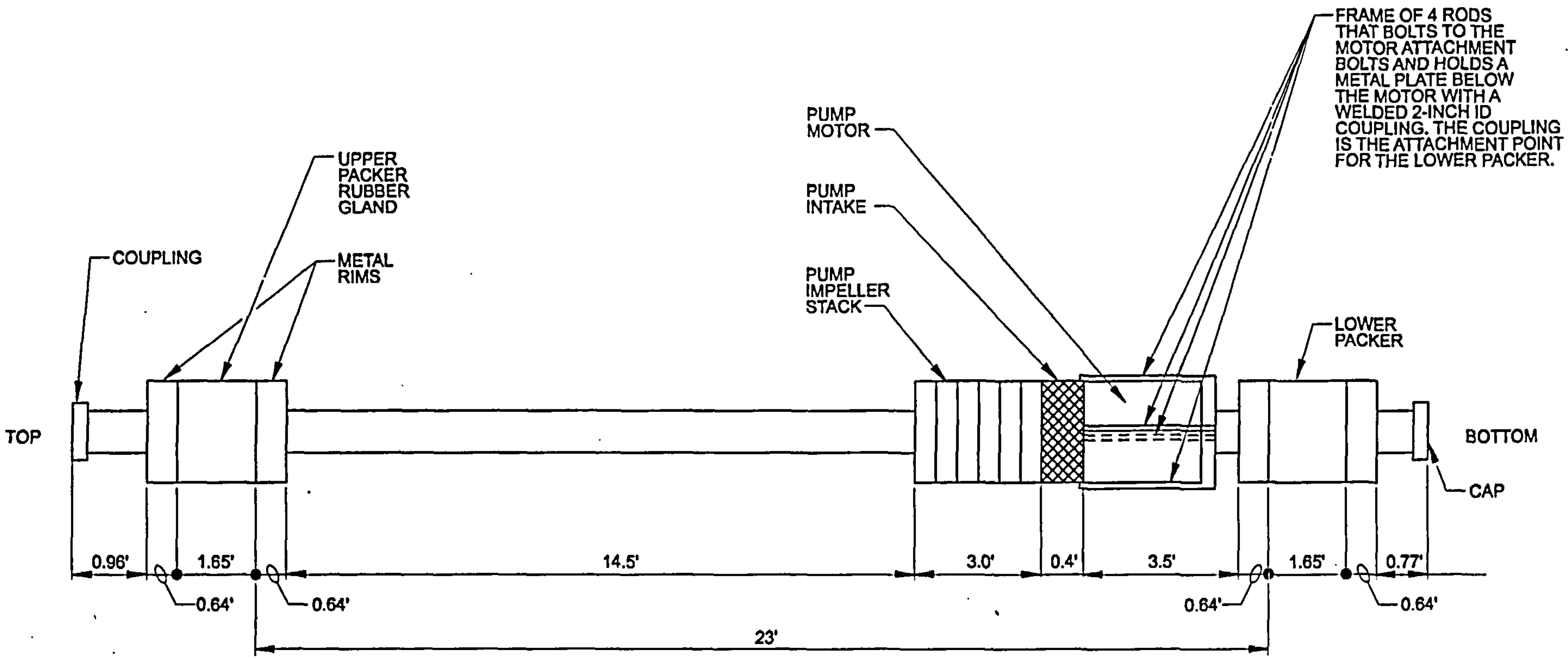
C01



NOT TO SCALE, DISTANCES IN FEET

FIGURE 2-2
ORIGINAL 2003 PACKER SAMPLING DEVICE
FOR 4-INCH BOREHOLES
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

CH2MHILL

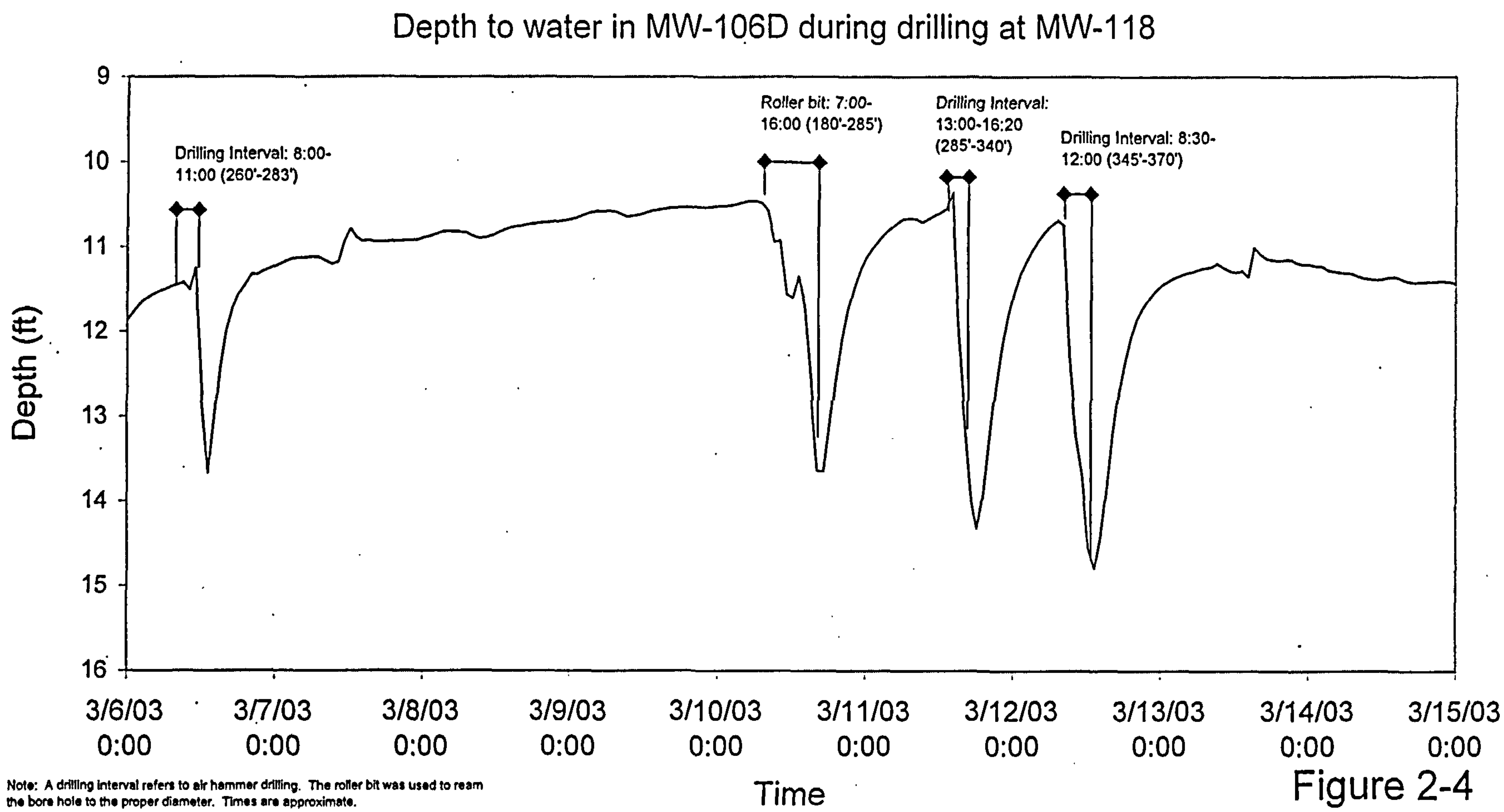


NOT TO SCALE,
DISTANCES IN FEET

FIGURE 2-3
ORIGINAL 2003 PACKER SAMPLING DEVICE
FOR 6-INCH BOREHOLES
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

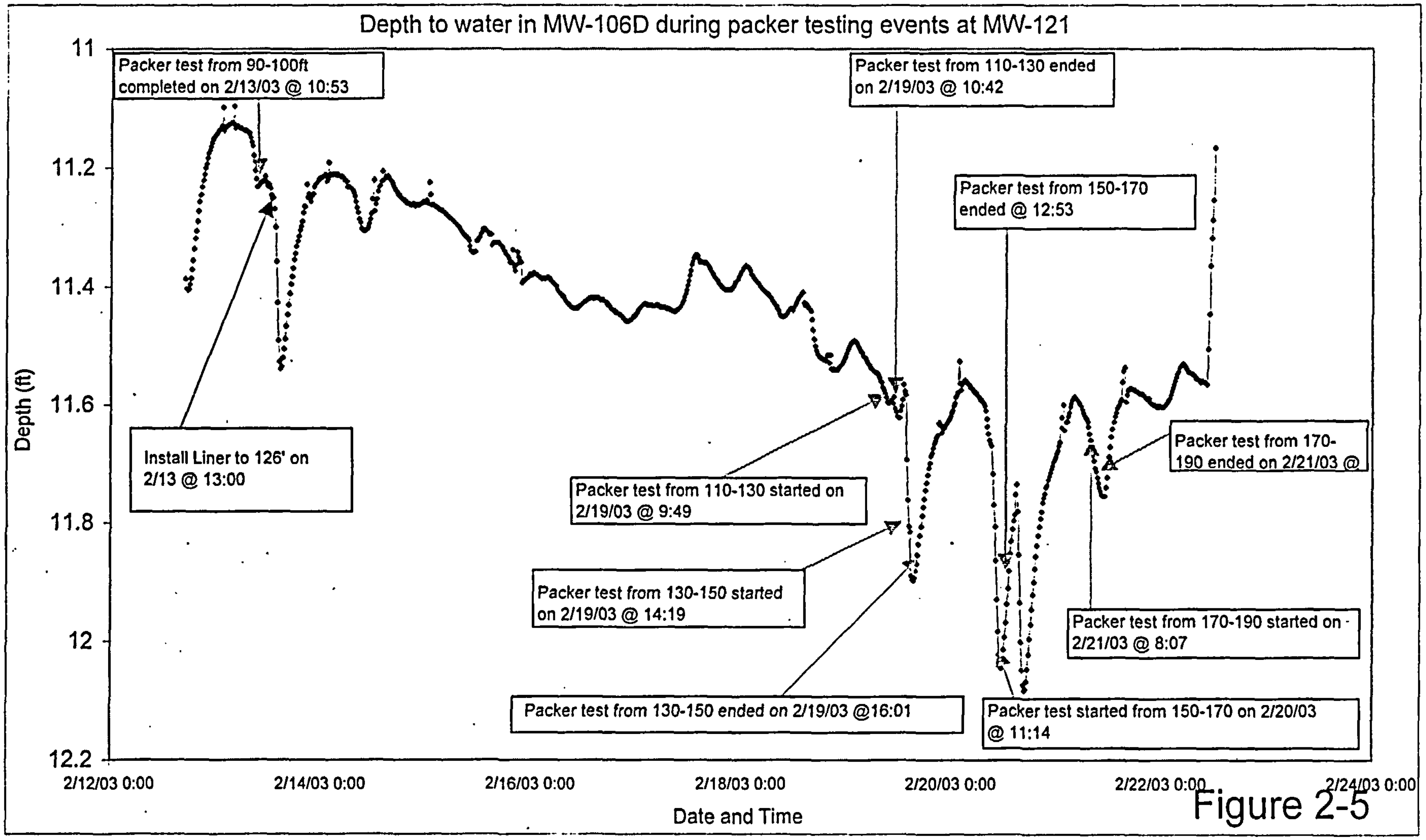
CH2MHILL

//ATLANTA/PROJ/CONNECTICUTYANKEE/283647 05-OCT-2004 fig2-3_283647.dgn



Note: A drilling interval refers to air hammer drilling. The roller bit was used to ream the bore hole to the proper diameter. Times are approximate.

Figure 2-4


Depth to water in MW-106D during packer testing events at MW-121
Packer test from 90-100ft completed on 2/13/03 @ 10:53
Packer test from 110-130 ended on 2/19/03 @ 10:42
Packer test from 150-170 ended @ 12:53
Install Liner to 126' on 2/13 @ 13:00
Packer test from 110-130 started on 2/19/03 @ 9:49
Packer test from 170-190 ended on 2/21/03 @
Packer test from 130-150 started on 2/19/03 @ 14:19
Packer test from 170-190 started on 2/21/03 @ 8:07
Packer test from 130-150 ended on 2/19/03 @16:01
Packer test started from 150-170 on 2/20/03 @ 11:14
Depth (ft)
11
11.2
11.4
11.6
11.8
12
12.2
2/12/03 0:00
2/14/03 0:00
2/16/03 0:00
2/18/03 0:00
2/20/03 0:00
2/22/03 0:00
2/24/03 0:00
Date and Time
Figure 2-5

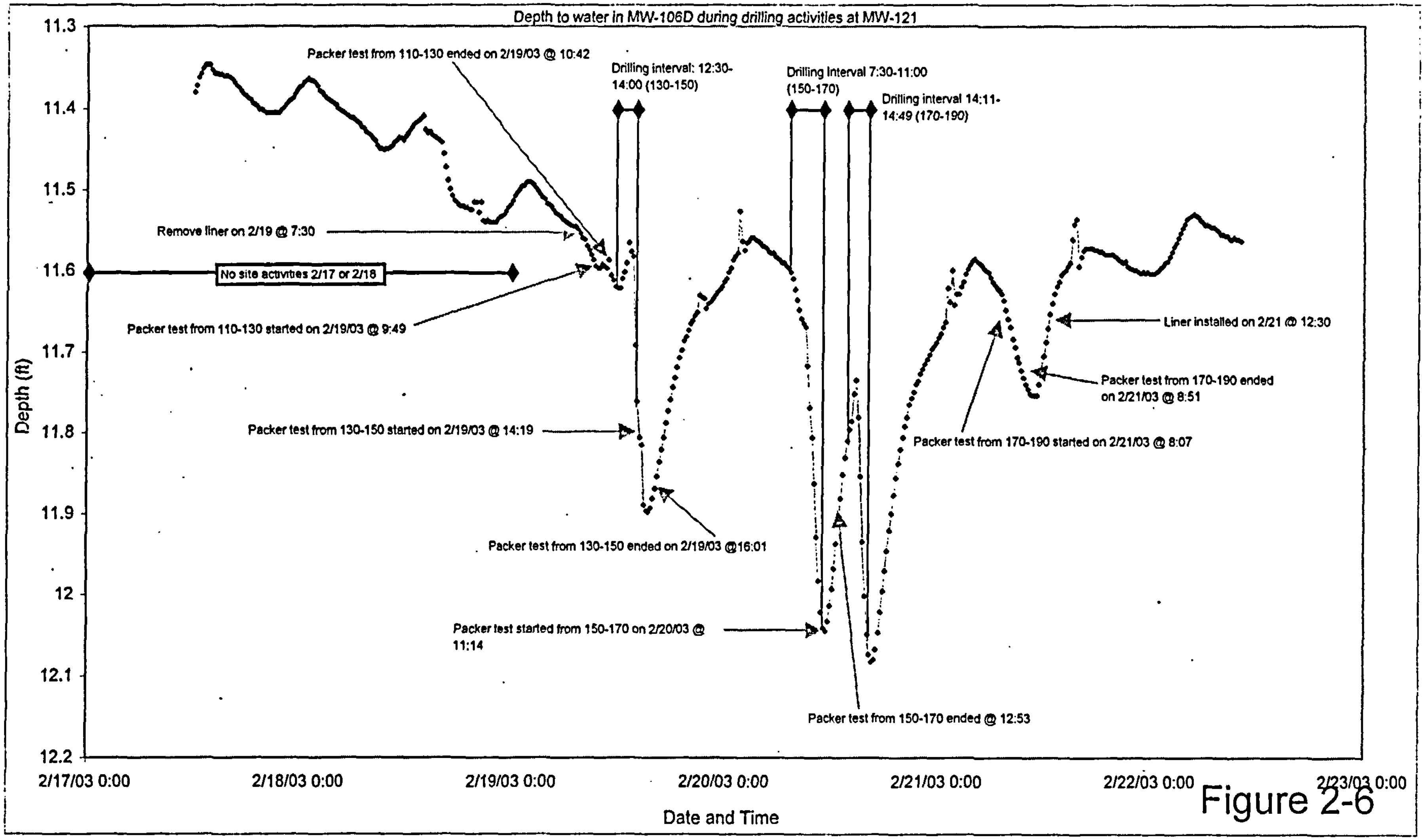
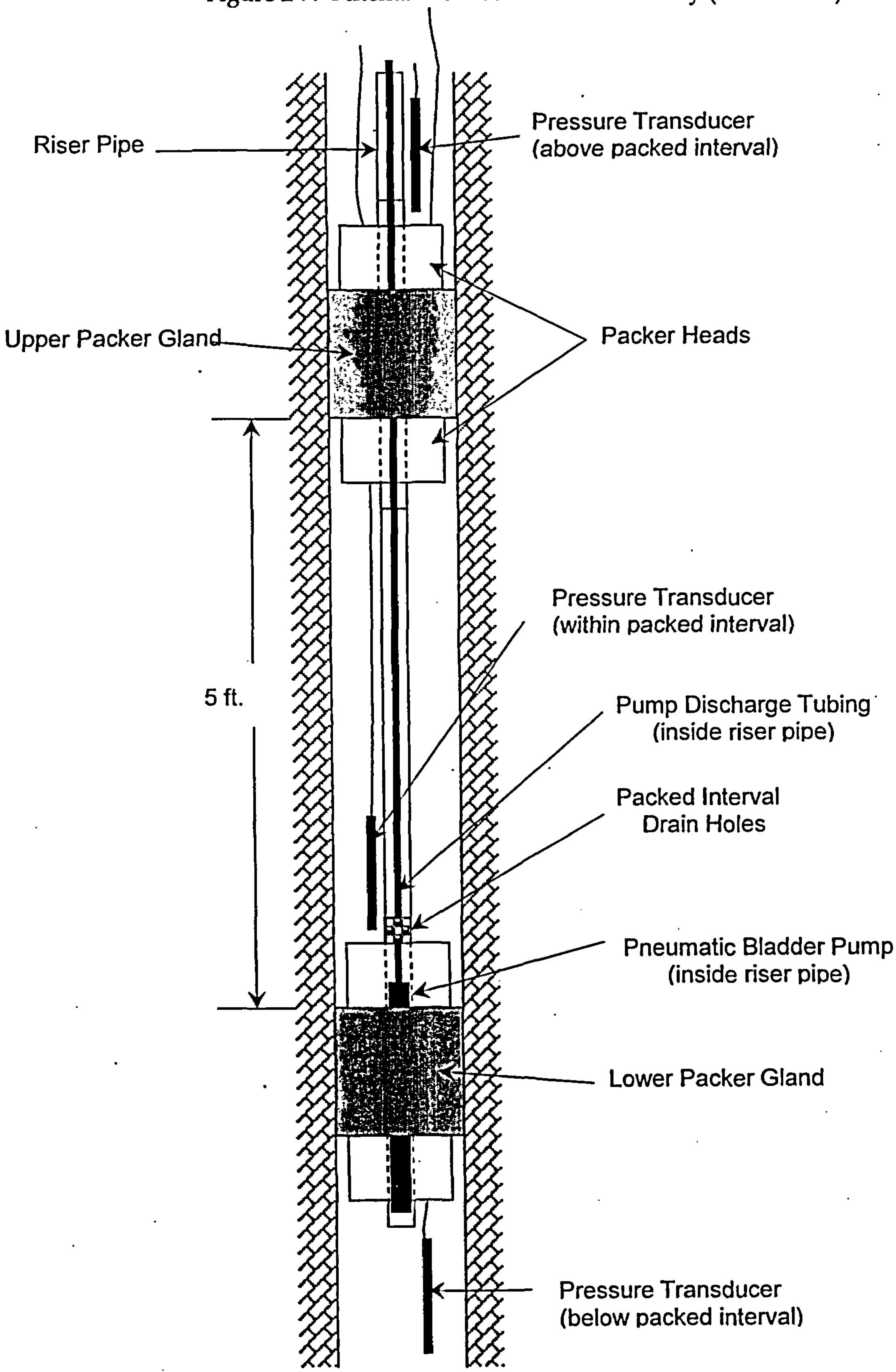

Depth to water in MW-106D during drilling activities at MW-121
Packer test from 110-130 ended on 2/19/03 @ 10:42
Drilling interval: 12:30-14:00 (130-150)
Drilling Interval 7:30-11:00 (150-170)
Drilling interval 14:11-14:49 (170-190)
Remove liner on 2/19 @ 7:30
No site activities 2/17 or 2/18
Packer test from 110-130 started on 2/19/03 @ 9:49
Liner installed on 2/21 @ 12:30
Packer test from 170-190 ended on 2/21/03 @ 8:51
Packer test from 130-150 started on 2/19/03 @ 14:19
Packer test from 170-190 started on 2/21/03 @ 8:07
Packer test from 130-150 ended on 2/19/03 @16:01
Packer test started from 150-170 on 2/20/03 @ 11:14
Packer test from 150-170 ended @ 12:53
Depth (ft)
11.3
11.4
11.5
11.6
11.7
11.8
11.9
12
12.1
12.2
2/17/03 0:00
2/18/03 0:00
2/19/03 0:00
2/20/03 0:00
2/21/03 0:00
2/22/03 0:00
2/23/03 0:00
Date and Time

Figure 2-6

Figure 2-7. Schematic of 2004 Packer Assembly (not to scale).



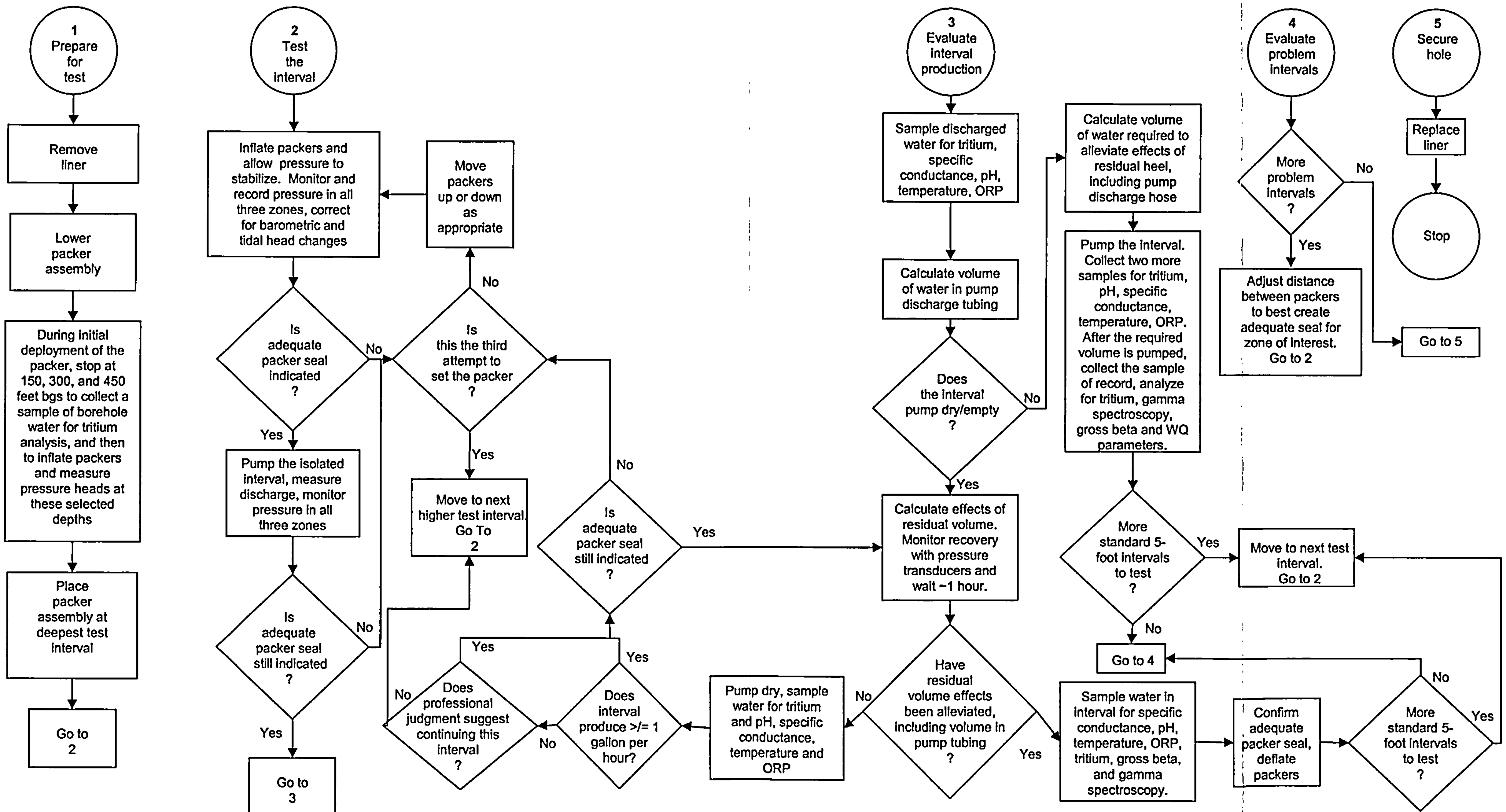


Figure 2-8 Packer Testing Flow Chart

3 March 04_Packer Test Flow Chart accepted_CWM_SB.ppt

Figure 2-9 Borehole 121A Relative Hydraulic Gradient

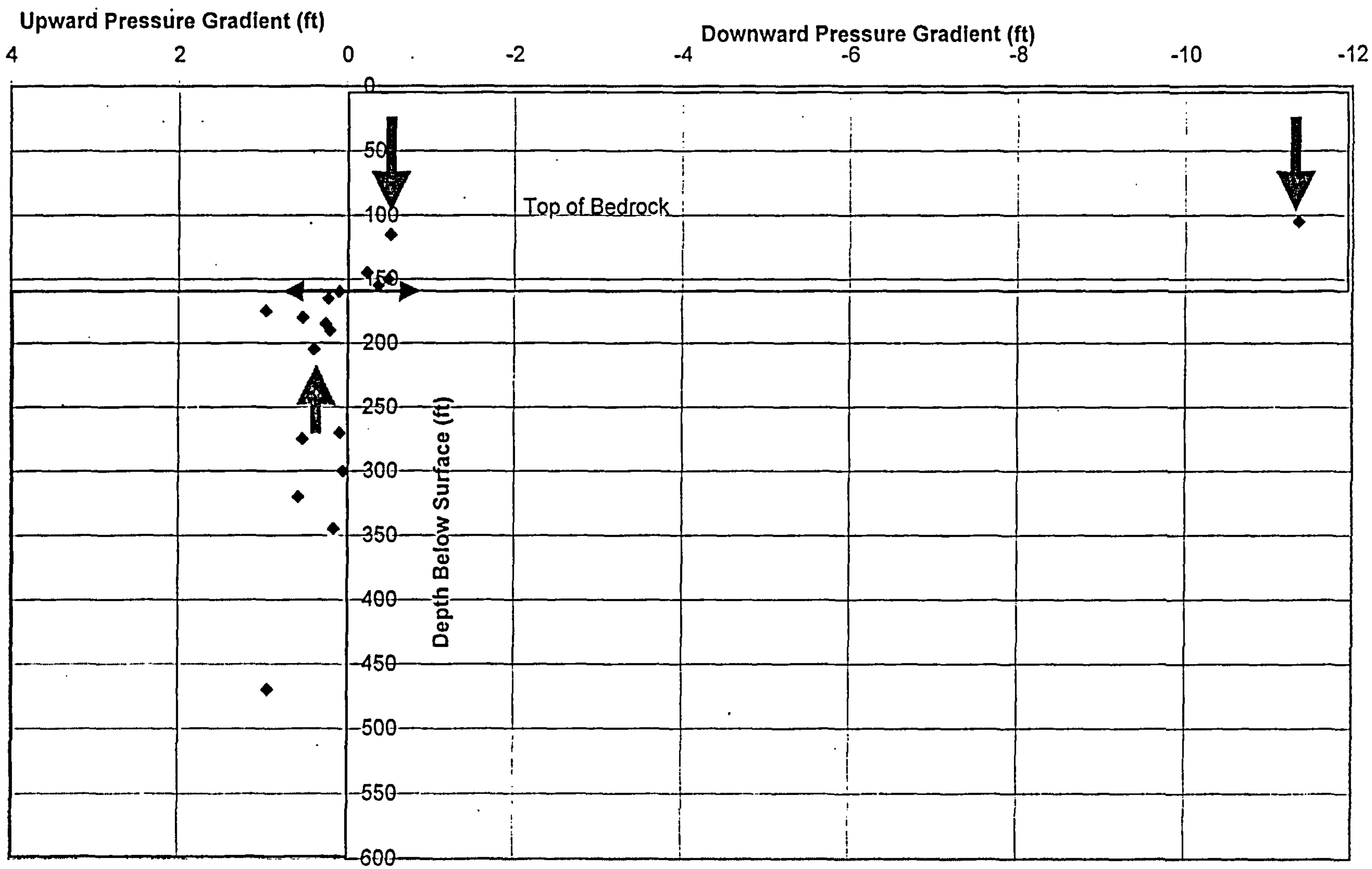
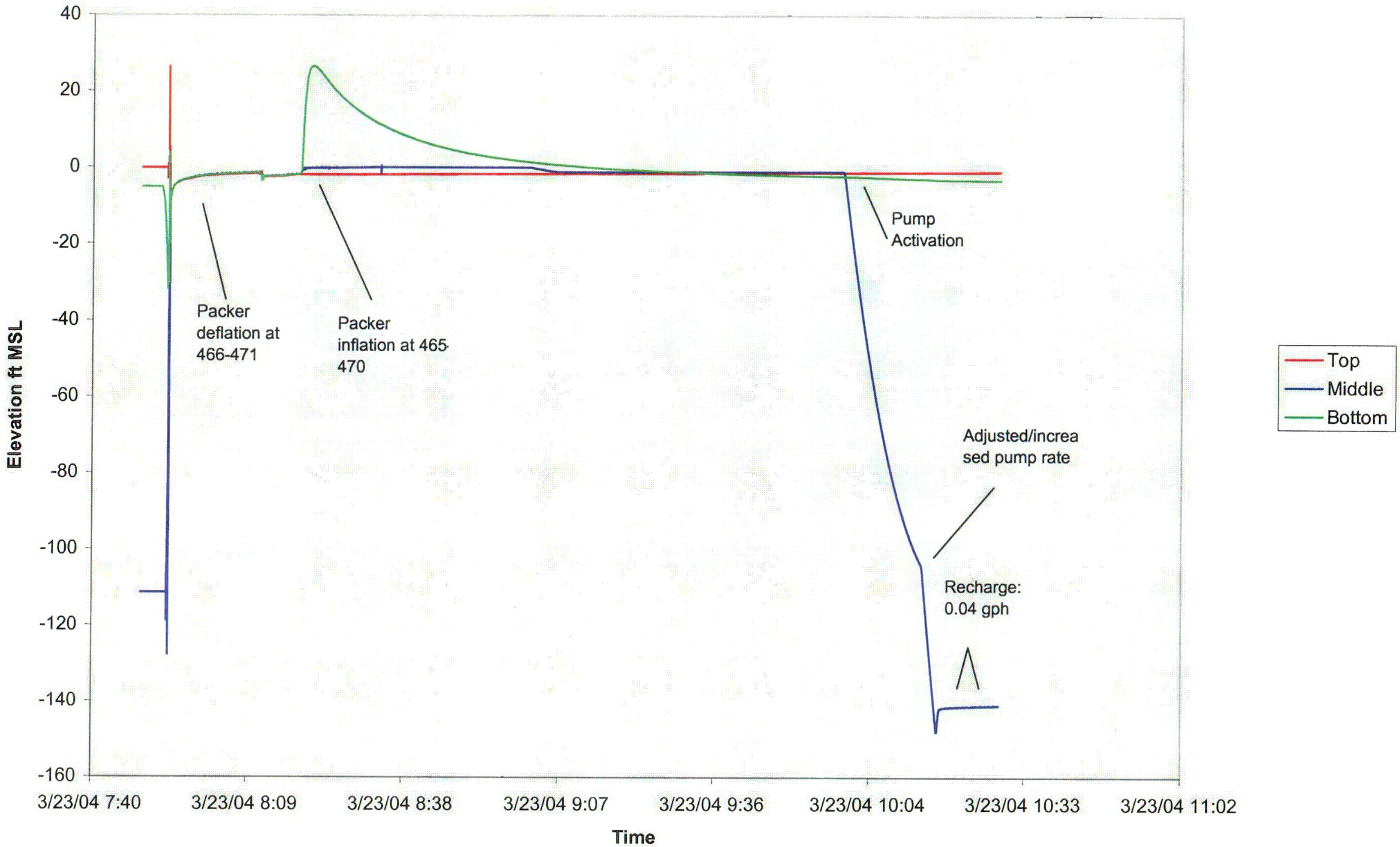
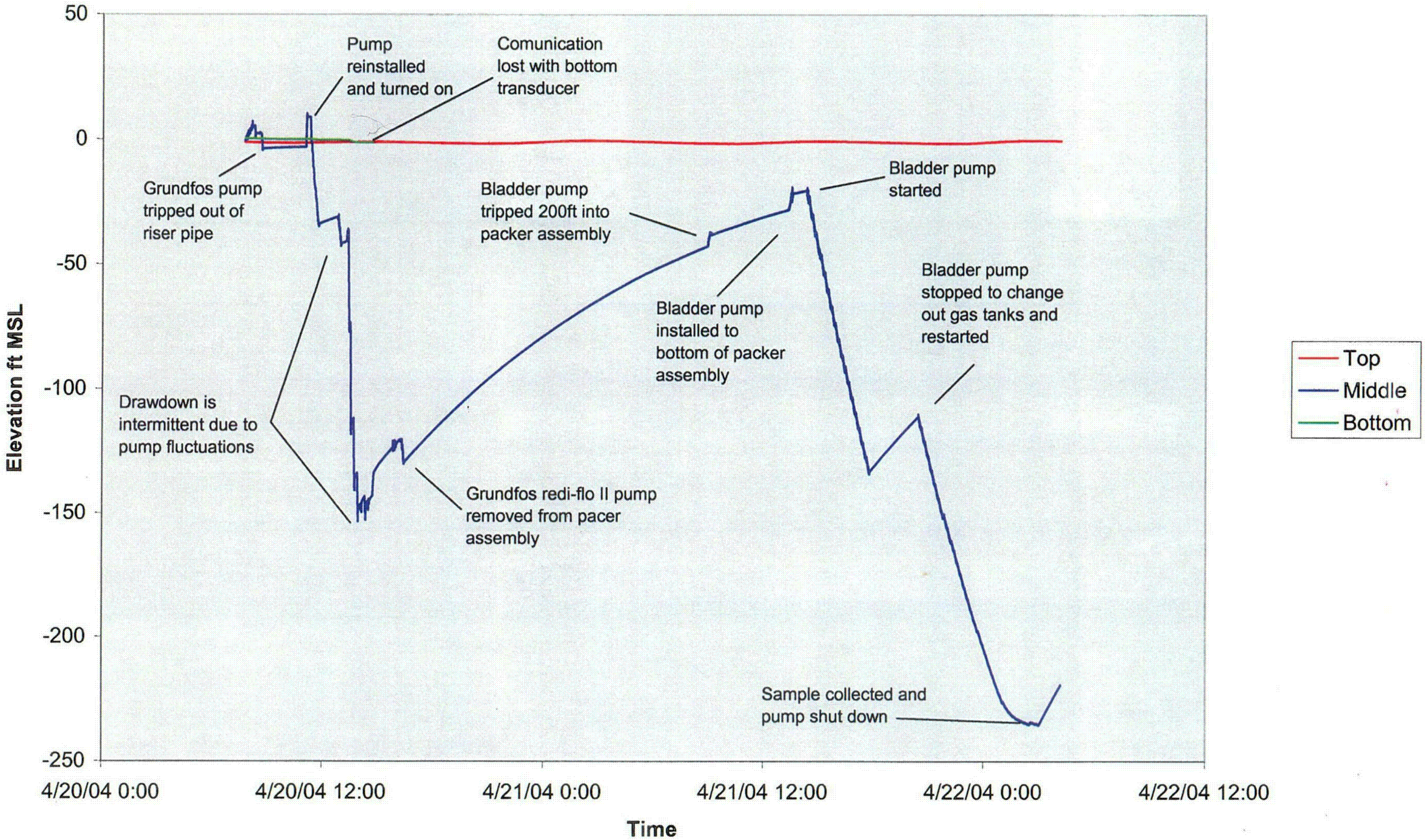


Figure 2-10 Water Elevation in Borehole 121A during Packer Isolation and Pumping at 465-470 ft b.g.s



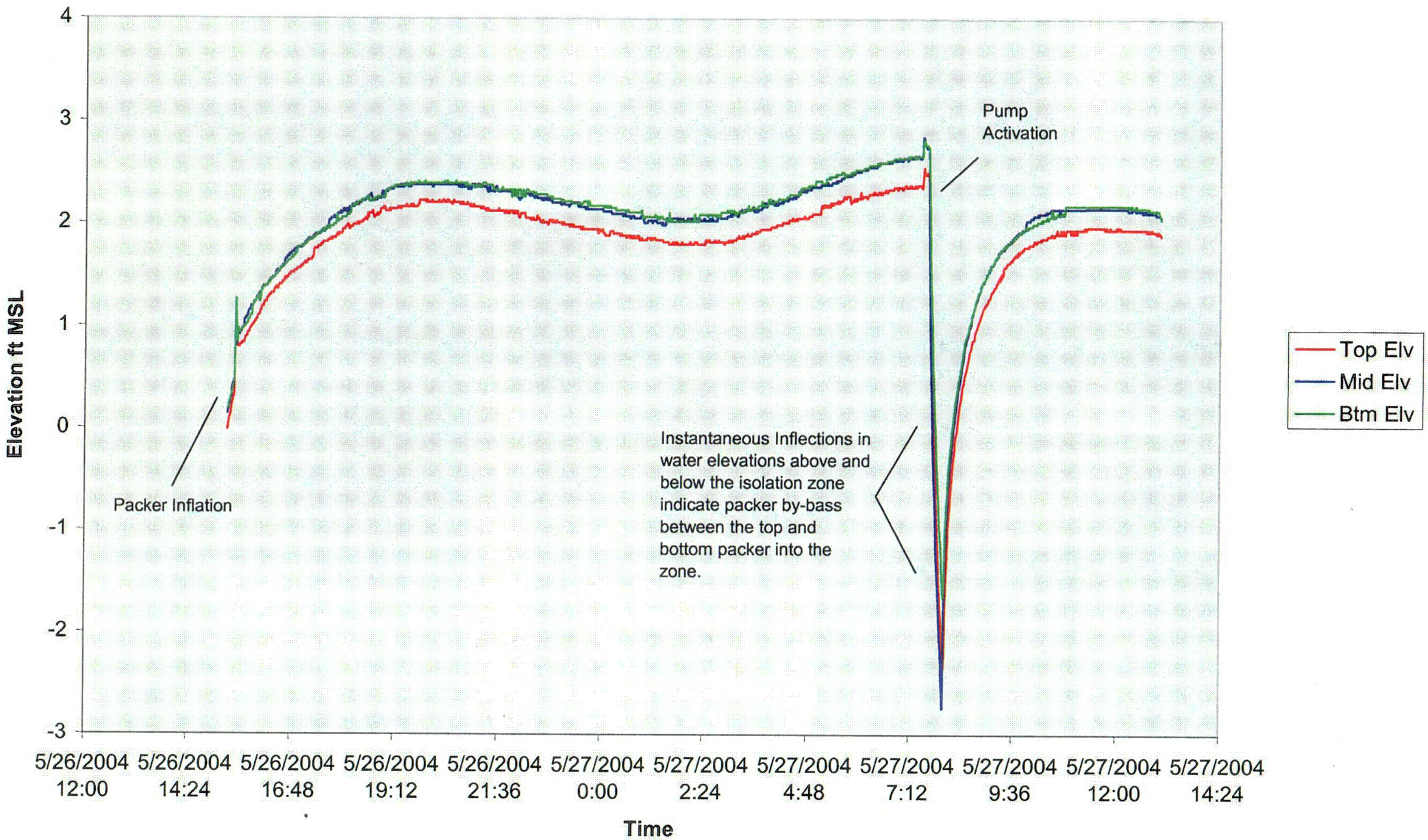
C02

Figure 2-11 Water Elevation in Borehole 121A During Packer Isolation and Interval Sampling at 317-322 ft b.g.s.



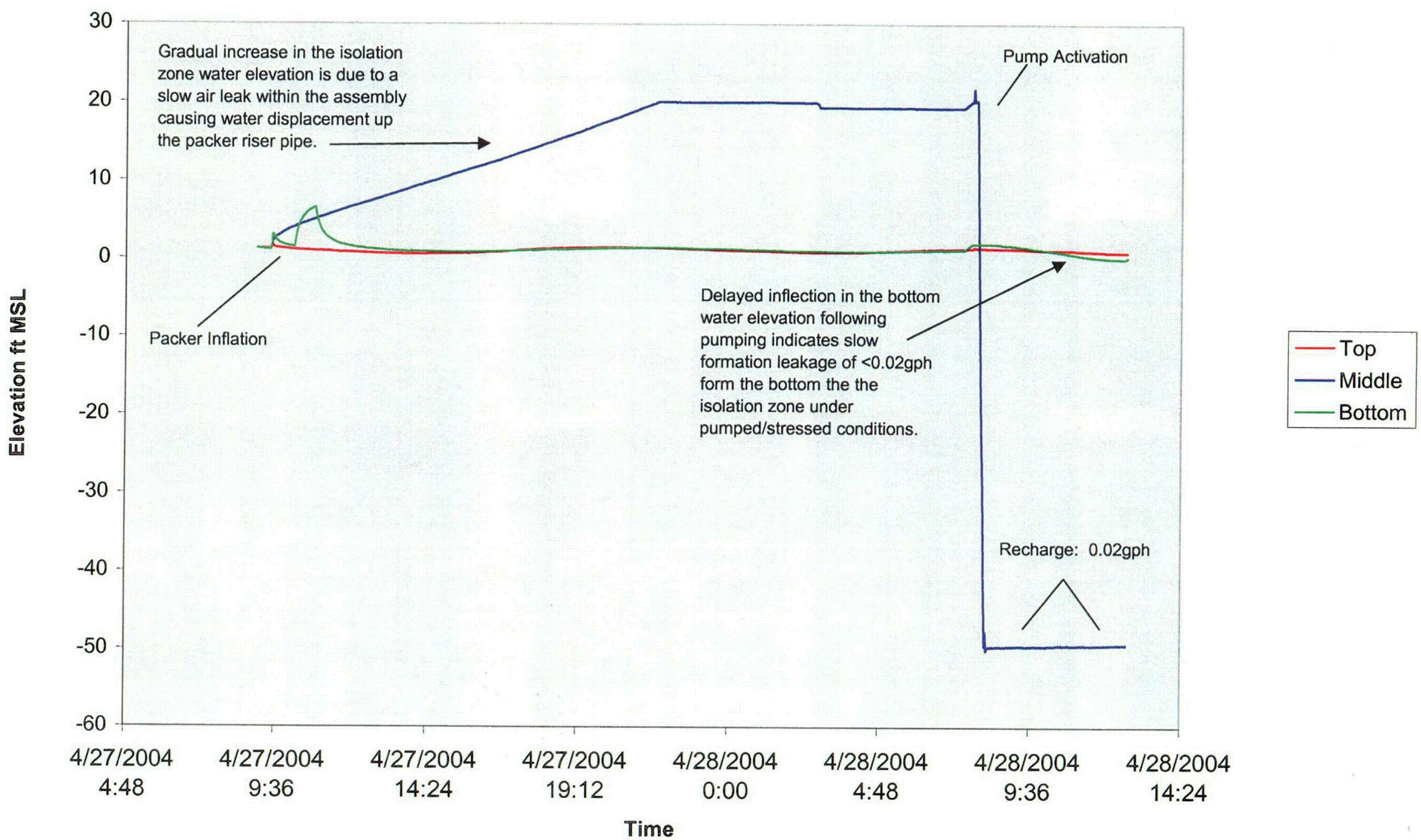
C03

Figure 2-12 Water Elevation in Borehole 121A During Packer Isolation and Pumping in Borehole 121A at 162-167 ft b.g.s.



C04

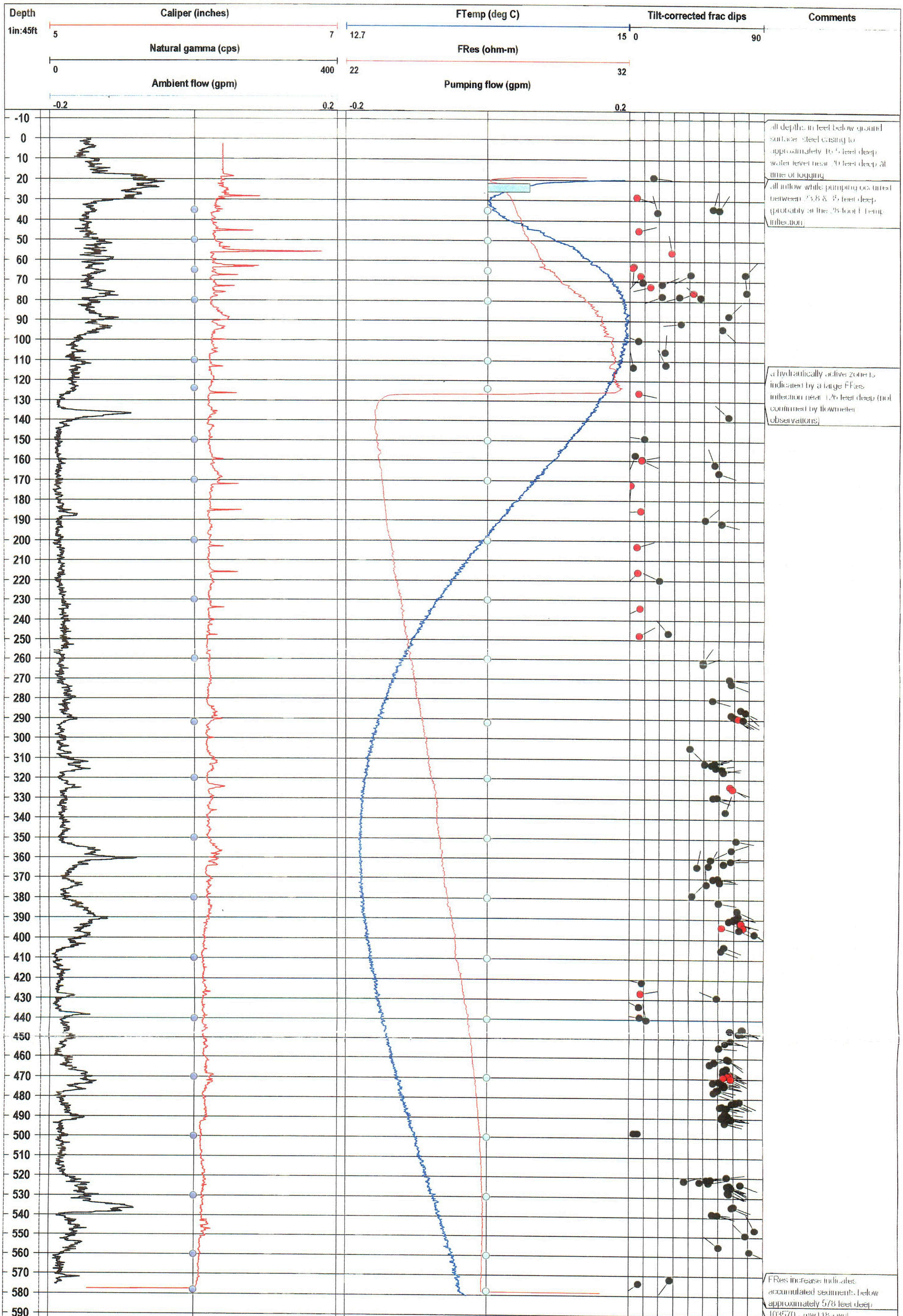
Figure 2-13 Water Elevation at Borehole 121A during Packer Isolation and Pumping at 297.5-302.5 ft b.g.s.



C05

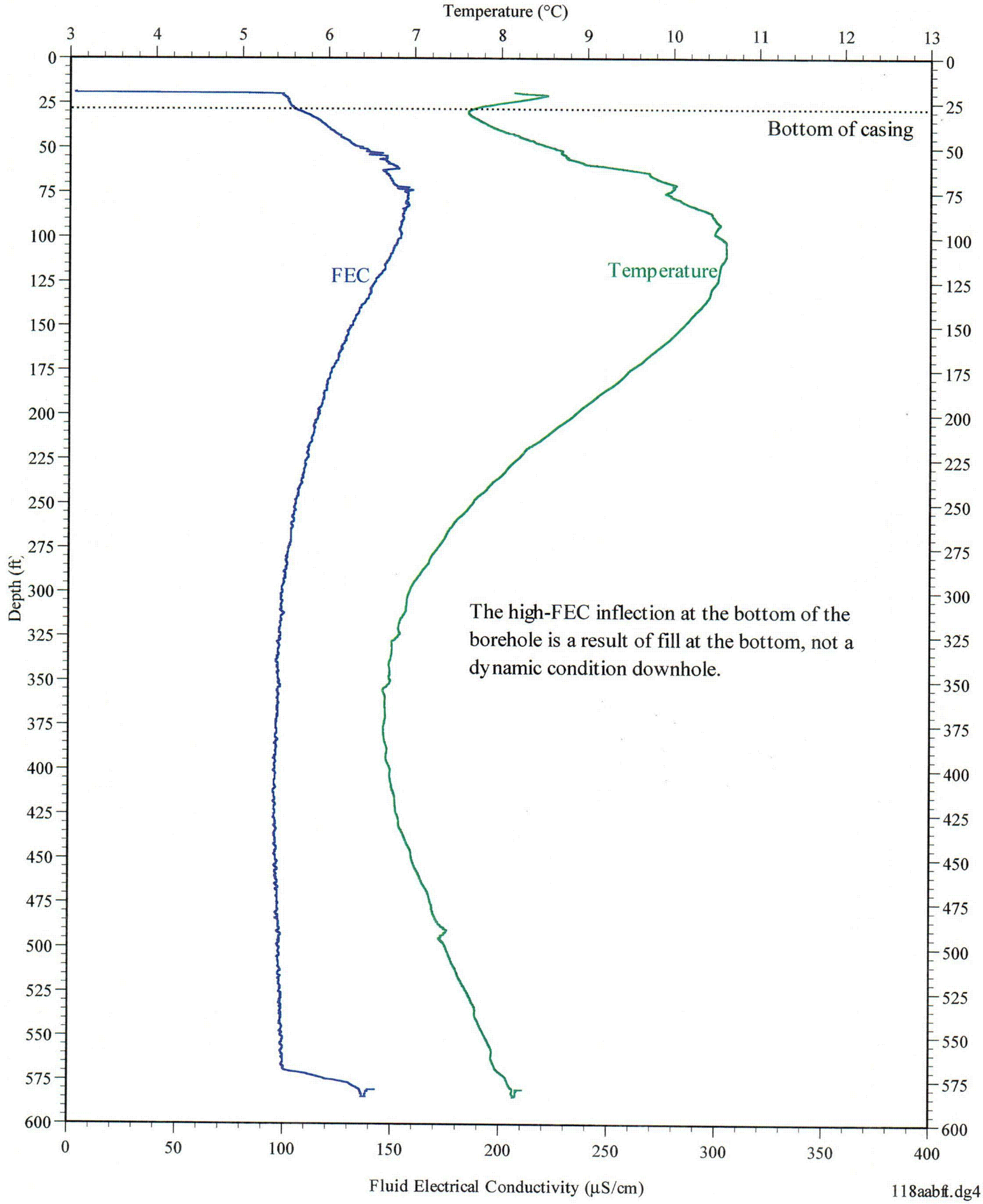
FIGURE 3-1

COMPOSITE CONVENTIONAL GEOPHYSICAL AND FLUID LOG DATA PRESENTATION FOR BH-118A (MODIFIED FROM GEOPHYSICAL APPLICATIONS, INC., 2003)



C06

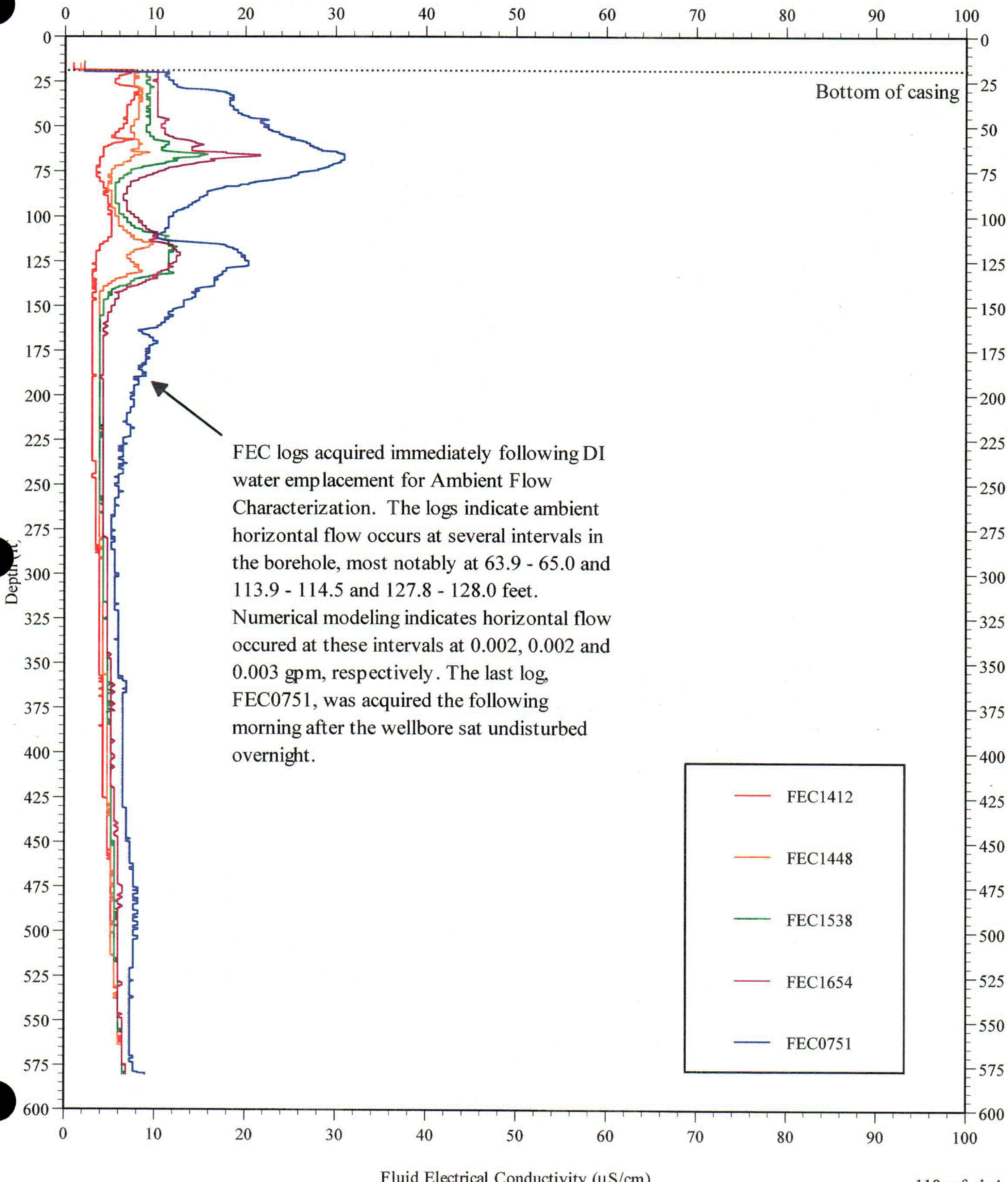
FIGURE 3-2. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; CH2M HILL; CYACO; HADDAM NECK, CT; WELLBORE: BH-118A (Data obtained from COLOG, 2004).



118aabft.dg4

C07

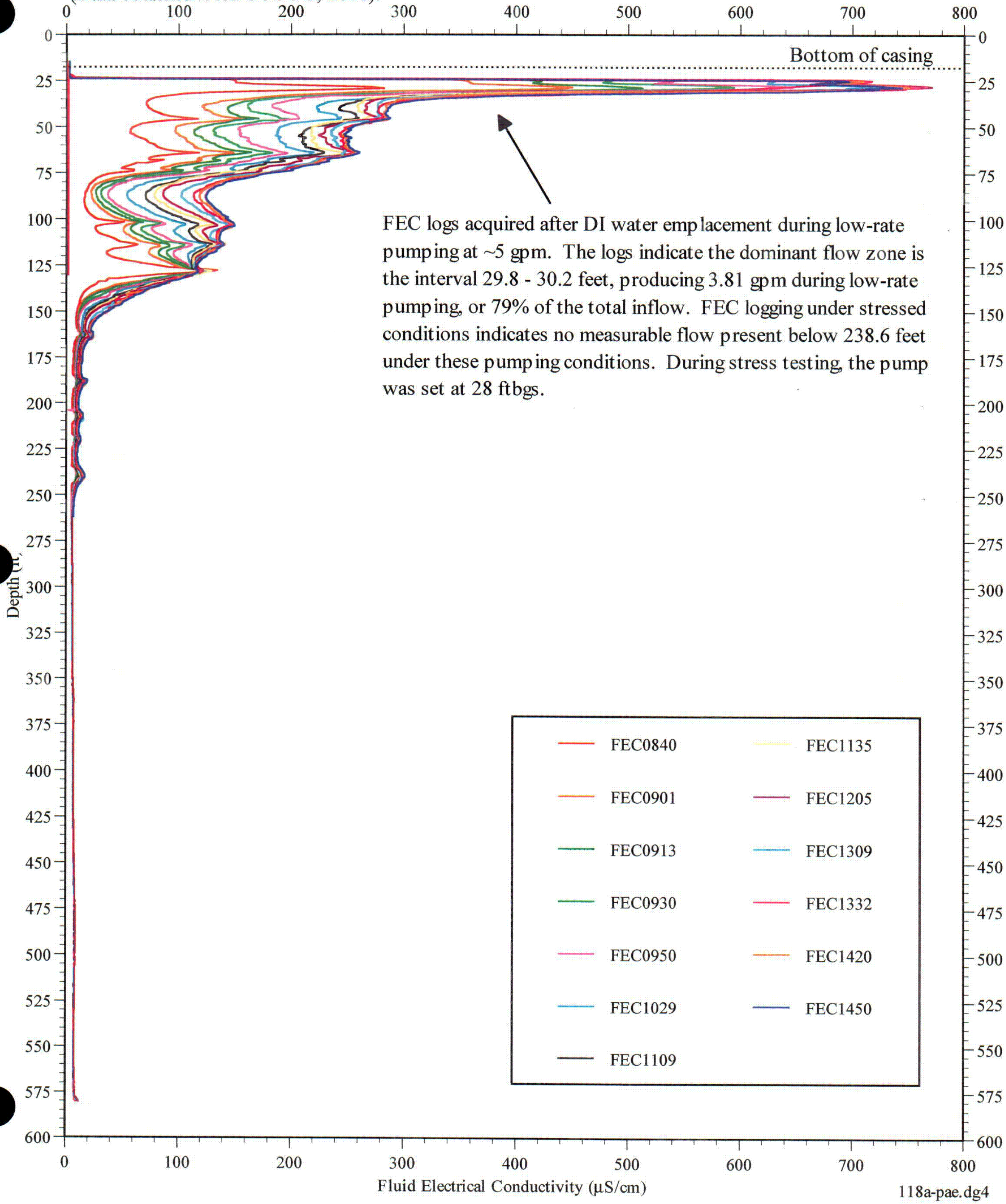
FIGURE 3-3. SUMMARY OF HYDROPHYSICAL LOGS DURING AMBIENT FLOW CHARACTERIZATION; CH2M HILL; CYACO; HADDAM NECK, CT; WELLBORE: BH-118A (Data obtained from COLOG, 2004).



118a-afc.dg4

C08

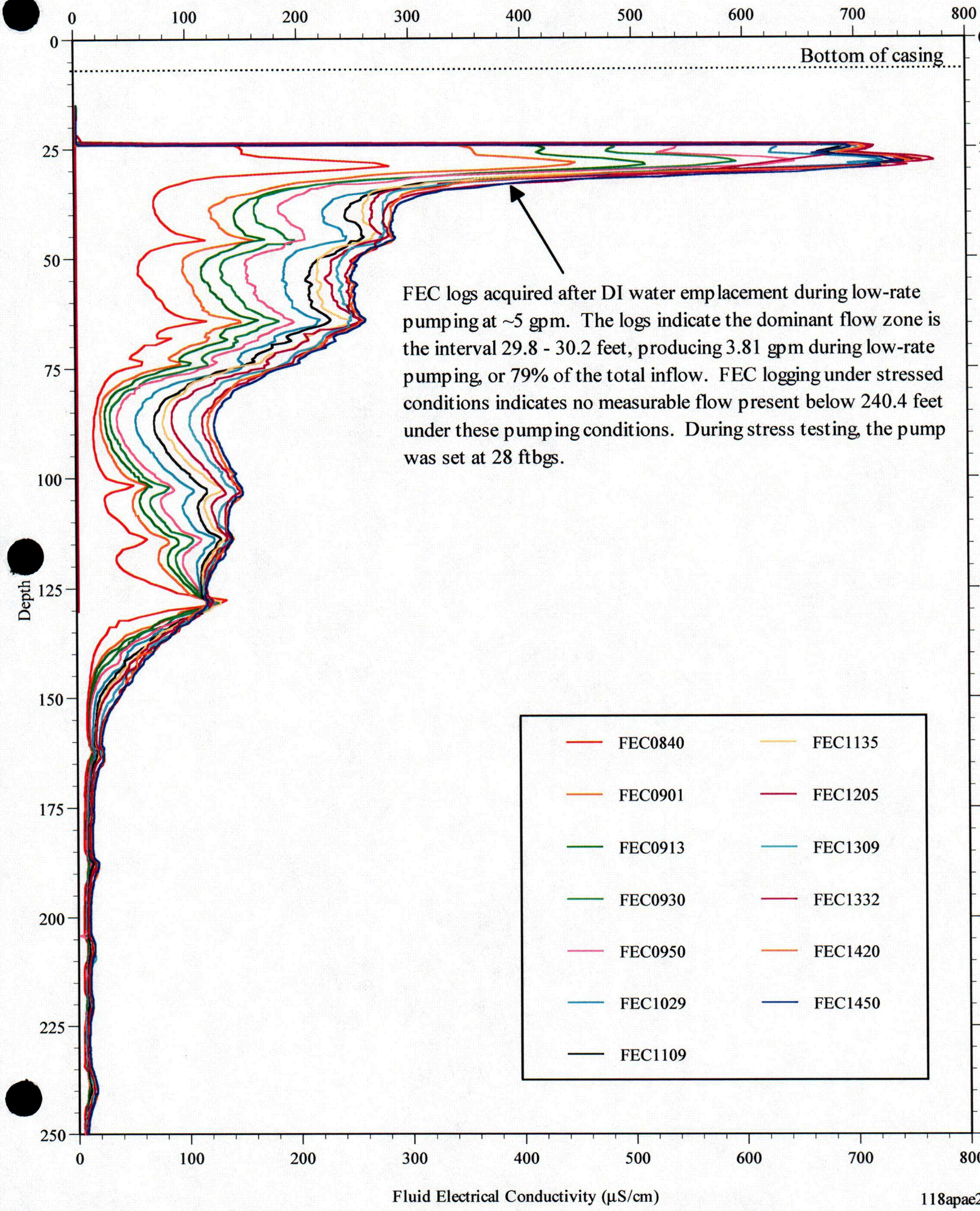
FIGURE 3-4. SUMMARY OF HYDROPHYSICAL LOGS DURING LOW-RATE PUMPING AT 5 GPM; CH2M HILL; CYACO; HADDAM NECK, CT; WELLBORE: BH-118A (Data obtained from COLOG, 2004).



118a-pae.dg4

C09

FIGURE 3-5. SUMMARY OF HYDROPHYSICAL LOGS DURING LOW-RATE PUMPING AT 5 GPM - 0 TO 250 FEET; CH2M HILL; CYACO; HADDAM NECK, CT; WELLBORE: BH-118A (Data obtained from COLOG, 2004).

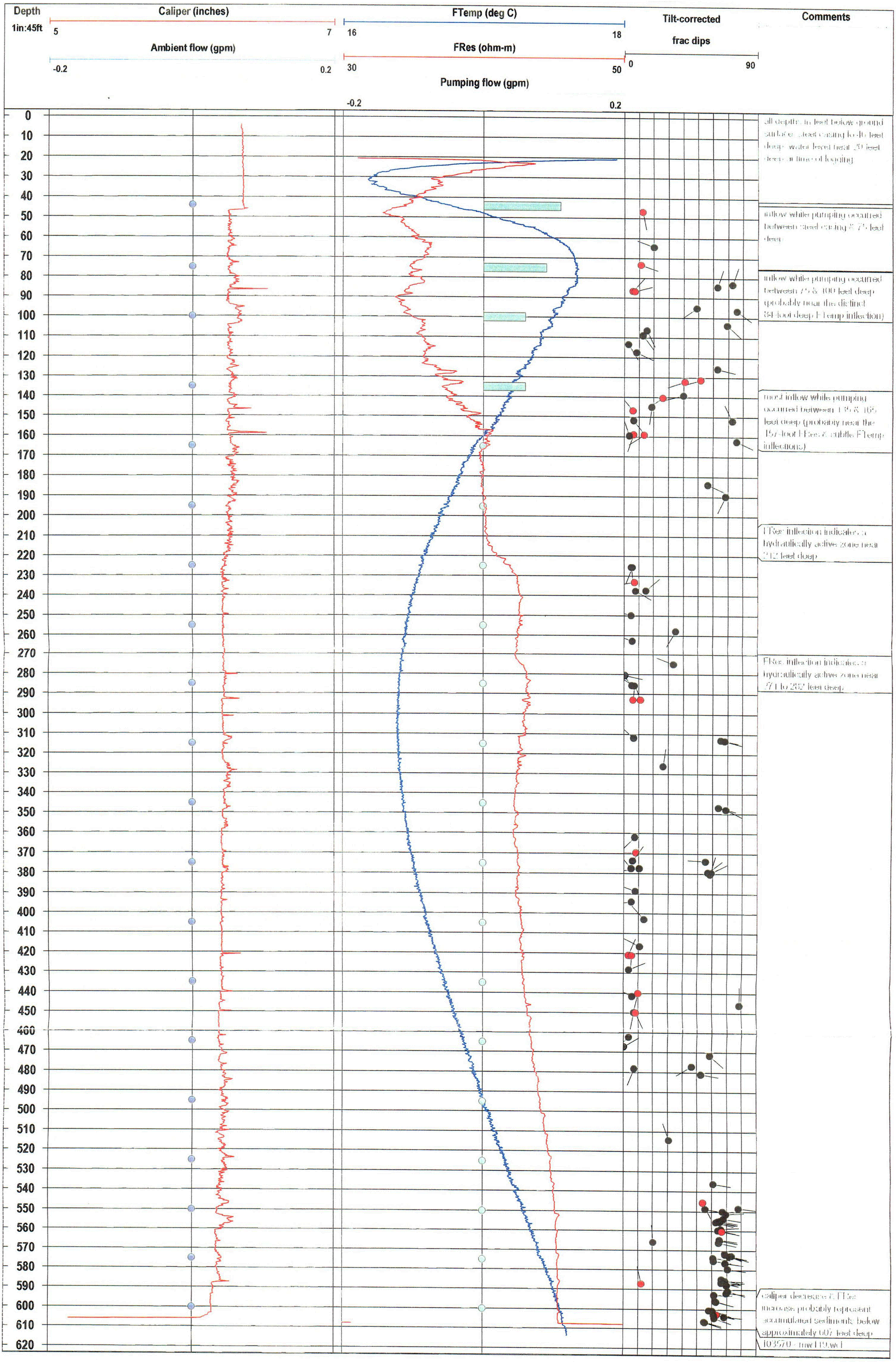


118apae2.dg4

C10

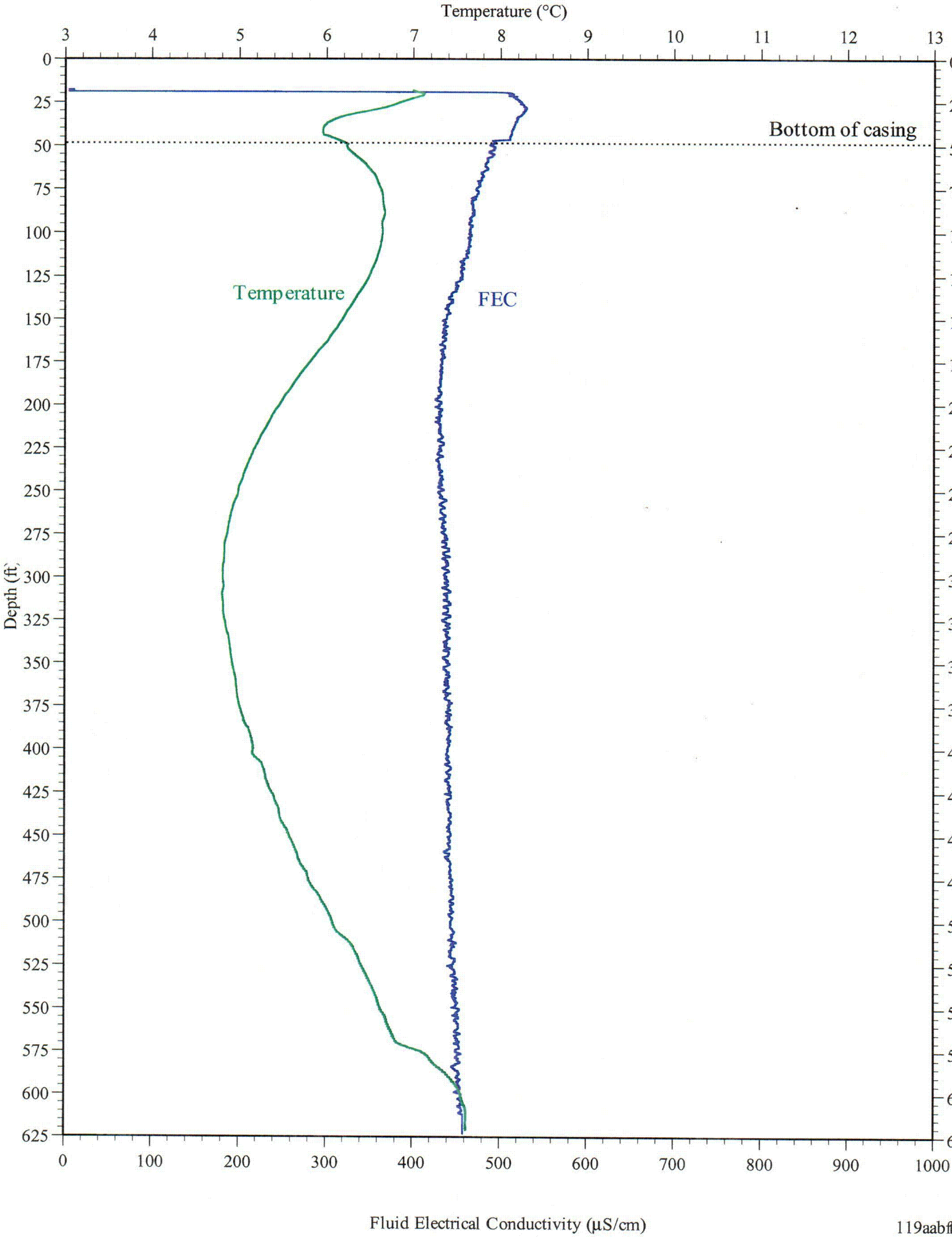
FIGURE 3-6

COMPOSITE CONVENTIONAL GEOPHYSICAL AND FLUID LOG DATA PRESENTATION FOR BH-119 (MODIFIED FROM GEOPHYSICAL APPLICATIONS, INC., 2003)



c11

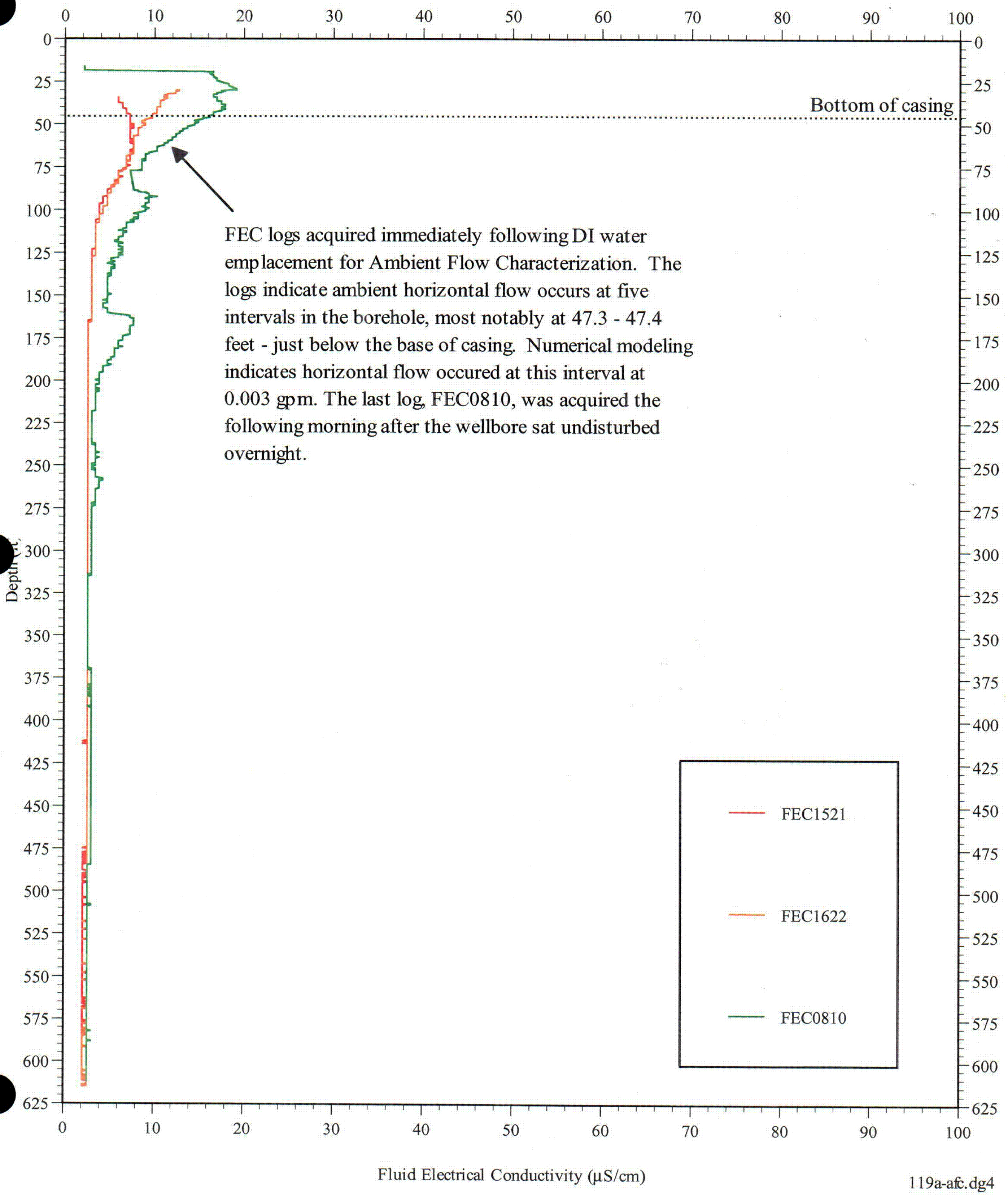
FIGURE 3-7. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; CH2M HILL; CYACO; HADDAM NECK, CT; WELLBORE: BH-119 (Data obtained from COLOG, 2004).



119aabft.dg4

C12

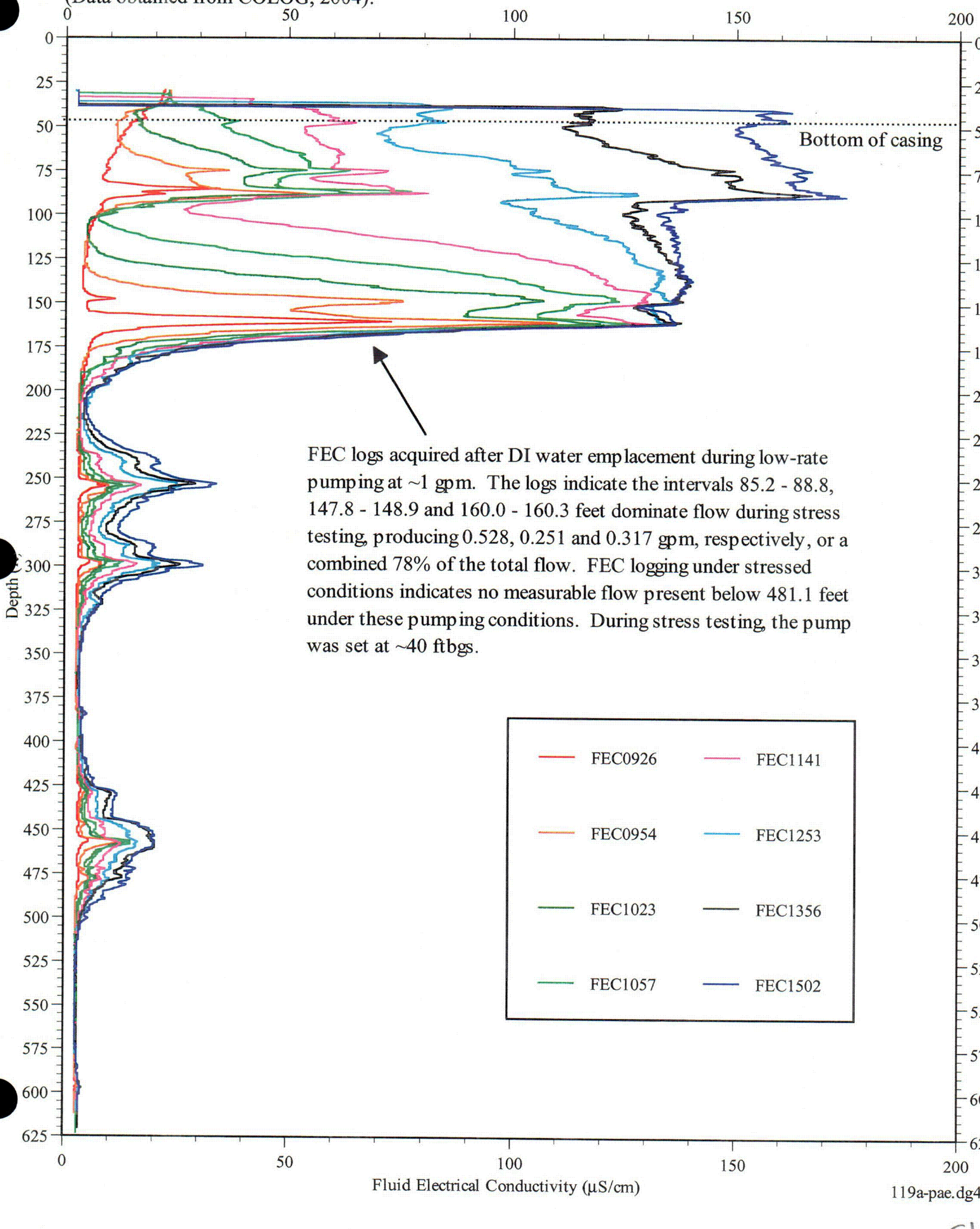
FIGURE 3-8. SUMMARY OF HYDROPHYSICAL LOGS DURING AMBIENT FLOW CHARACTERIZATION; CH2M HILL; CYACO; HADDAM NECK, CT; WELLBORE: BH-119 (Data obtained from COLOG, 2004).



119a-afc.dg4

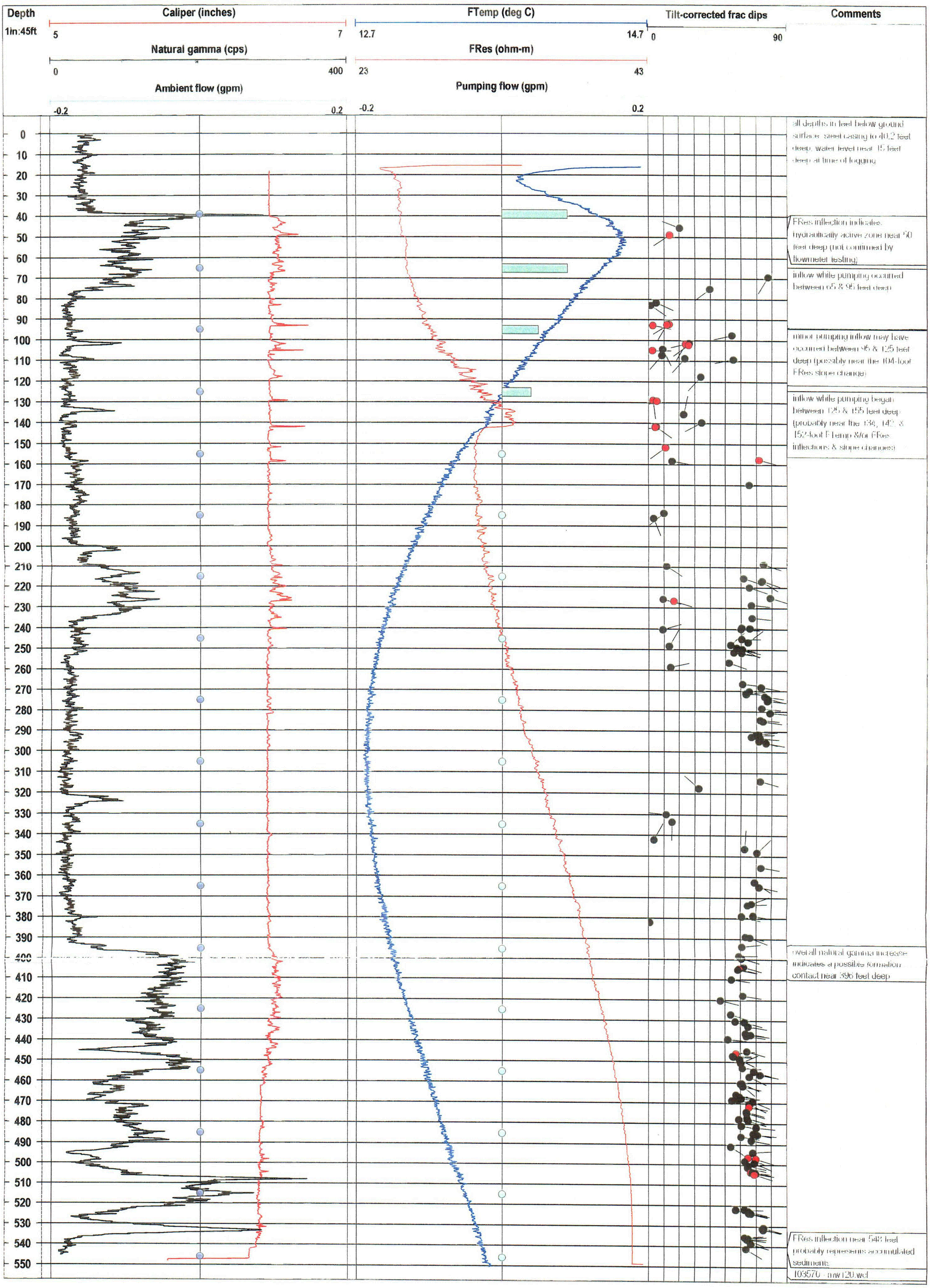
C13

FIGURE 3-9. SUMMARY OF HYDROPHYSICAL LOGS DURING LOW-RATE PUMPING AT 1 GPM; CH2M HILL; CYACO; HADDAM NECK, CT; WELLBORE: BH-119 (Data obtained from COLOG, 2004).



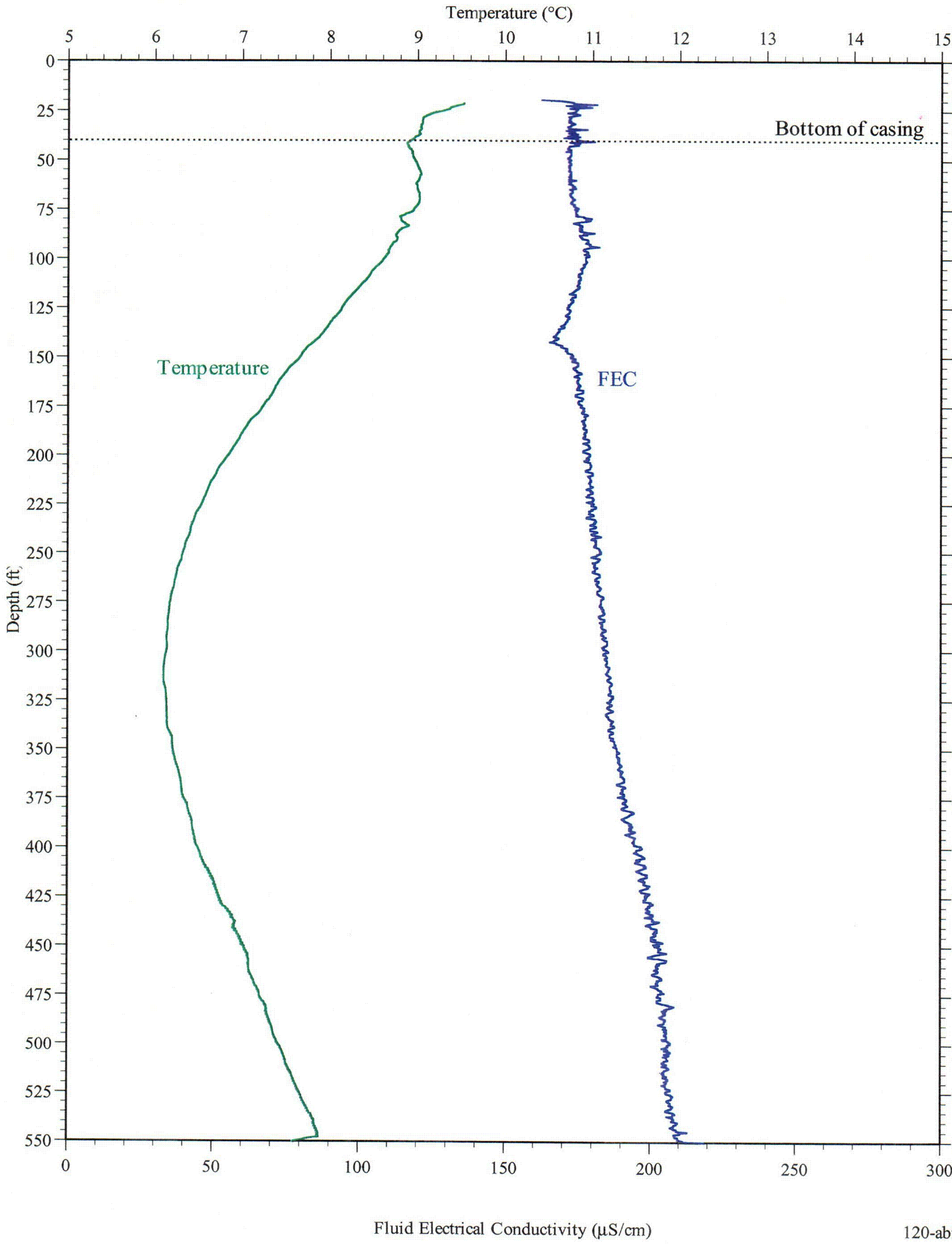
C14

FIGURE 3-10
COMPOSITE CONVENTIONAL GEOPHYSICAL AND FLUID LOG DATA PRESENTATION FOR BH-120 (MODIFIED FROM GEOPHYSICAL APPLICATIONS, INC., 2003)



C15

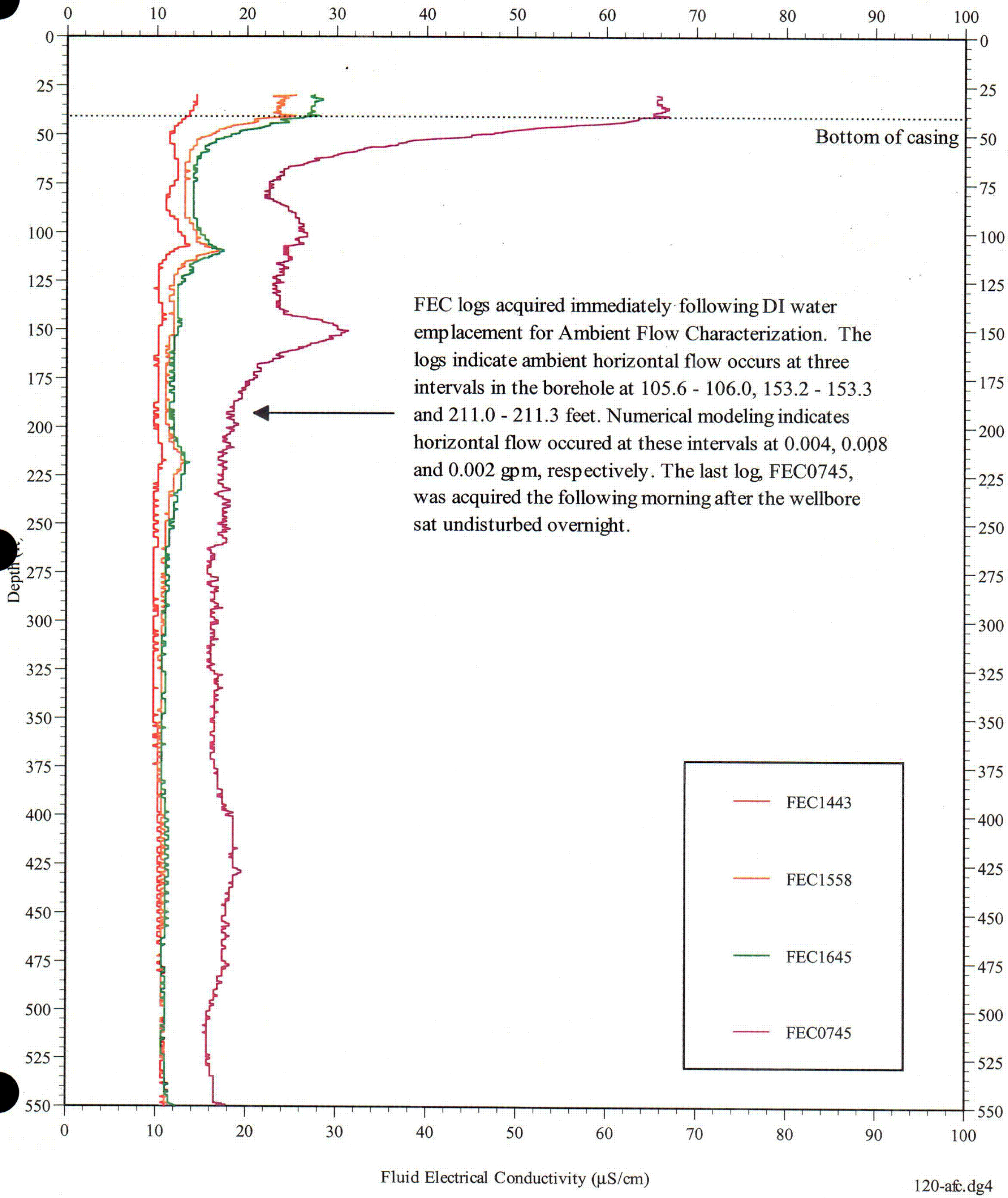
FIGURE 3-11. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; CH2M HILL; CYAPCO; HADDAM NECK, CT; WELLBORE: BH-120 (Data obtained from COLOG, 2004).



120-abft.dg4

C16

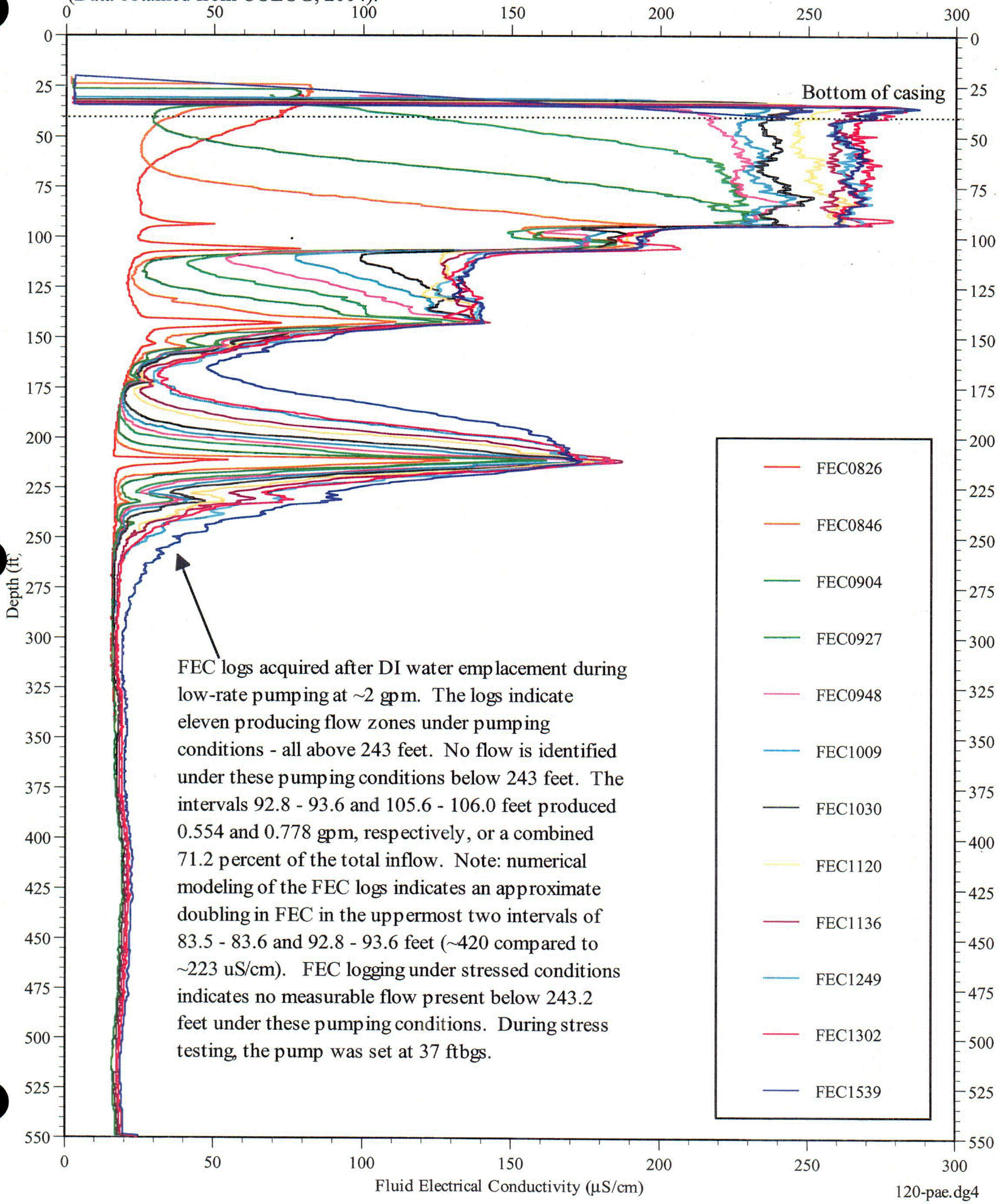
FIGURE 3-12. SUMMARY OF HYDROPHYSICAL LOGS DURING AMBIENT FLOW CHARACTERIZATION; CH2M HILL; CYAPCO; HADDAM NECK, CT; WELLBORE: BH-120 (Data obtained from COLOG, 2004).



120-afc.dg4

C17

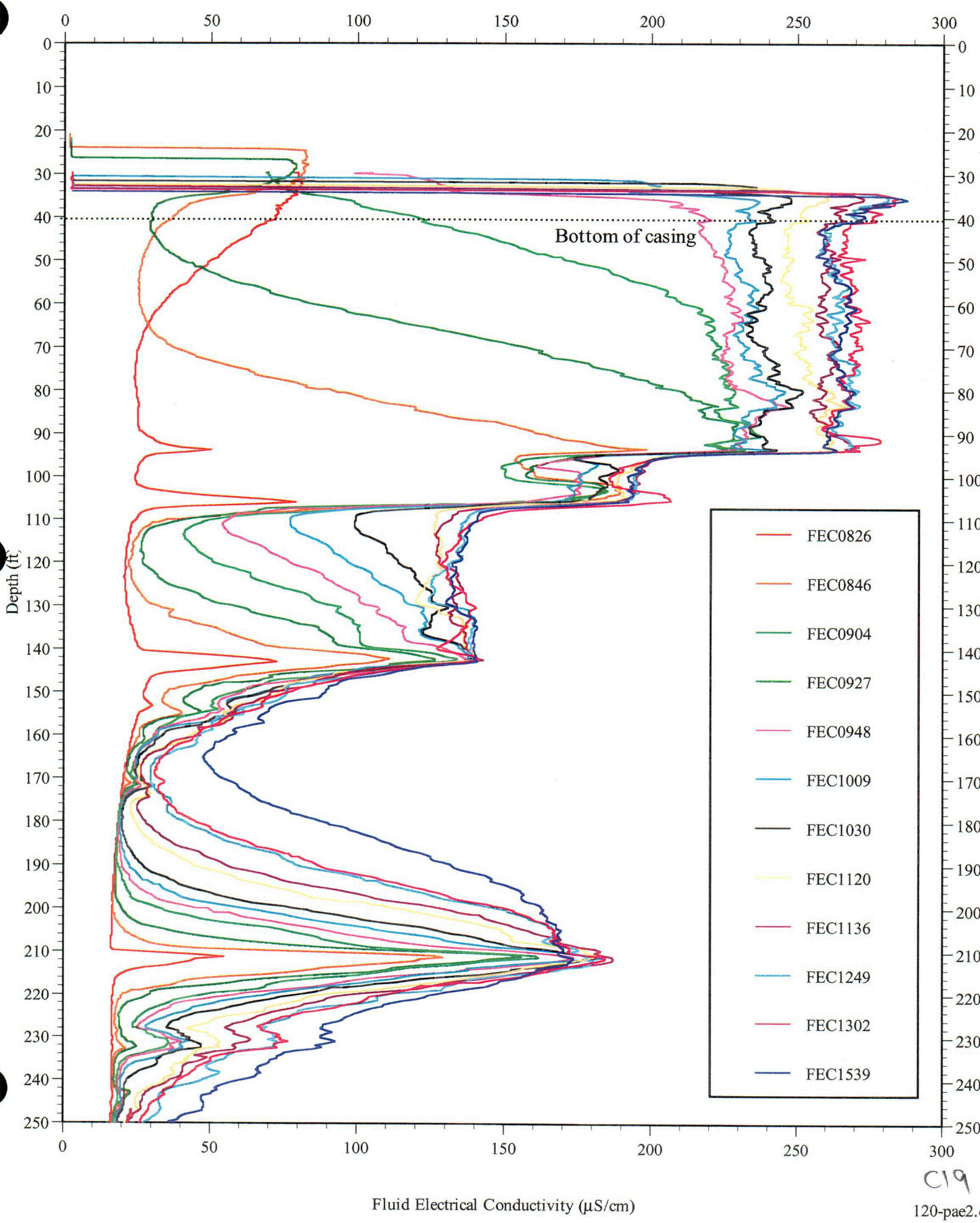
FIGURE 3-13. SUMMARY OF HYDROPHYSICAL LOGS DURING LOW-RATE PUMPING AT 2 GPM; CH2M HILL; CYAPCO; HADDAM NECK, CT; WELLBORE: BH-120
(Data obtained from COLOG, 2004).



120-pae.dg4

C18

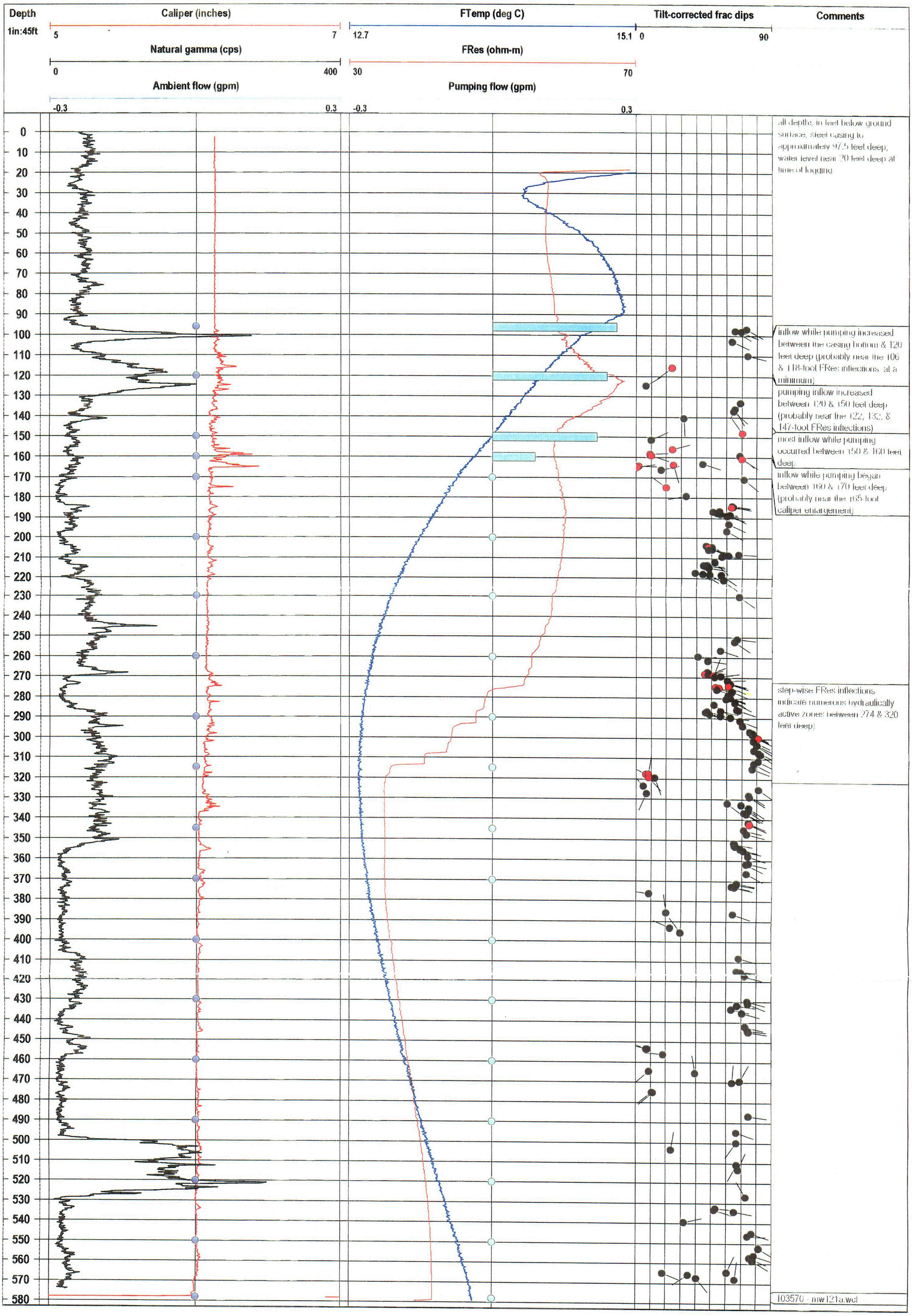
FIGURE 3-14. SUMMARY OF HYDROPHYSICAL LOGS DURING LOW-RATE PUMPING AT 2 GPM - 0 TO 250 FEET; CH2M HILL; CYAPCO; HADDAM NECK, CT; WELLBORE: BH-120 (Data obtained from COLOG, 2004).



C19

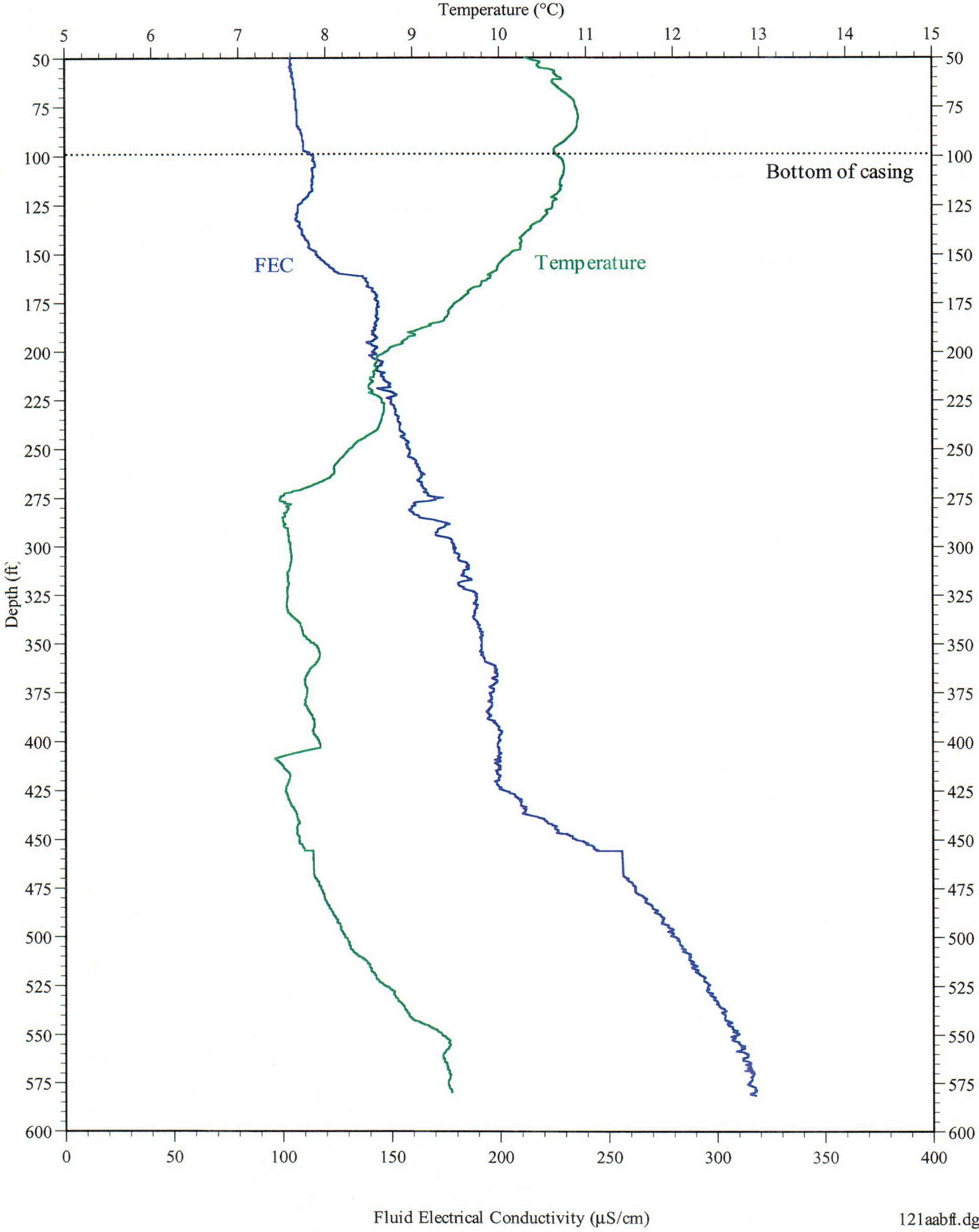
120-pae2.dg4

FIGURE 3-15
COMPOSITE CONVENTIONAL GEOPHYSICAL AND FLUID LOG DATA PRESENTATION FOR BH-121A (MODIFIED FROM GEOPHYSICAL APPLICATIONS, INC., 2003)



CZO

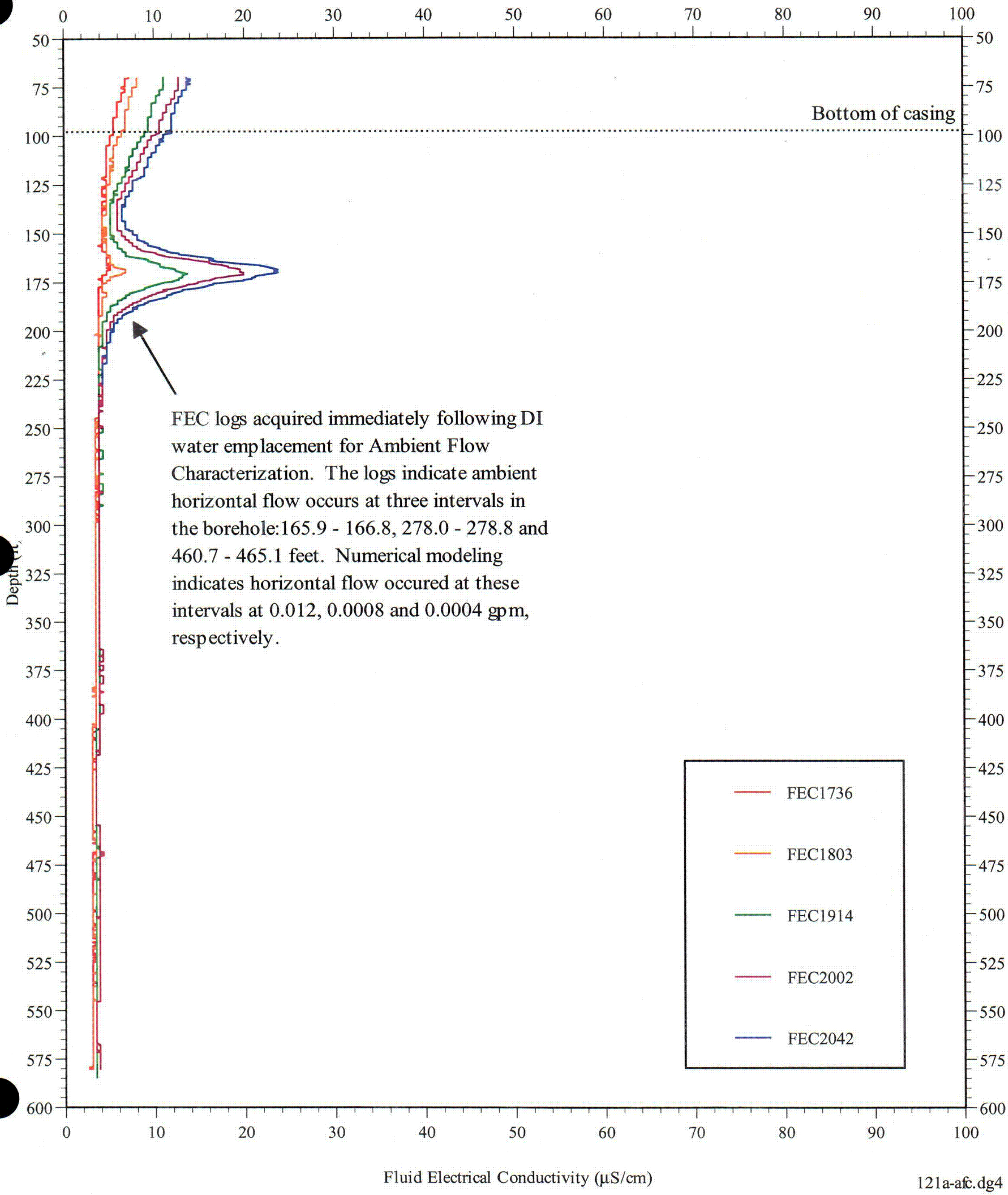
FIGURE 3-16. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; CH2M HILL; CYAPCO; HADDAM NECK, CT; WELLBORE: BH-121A (Data obtained from COLOG, 2004).



121aabft.dg4

C21

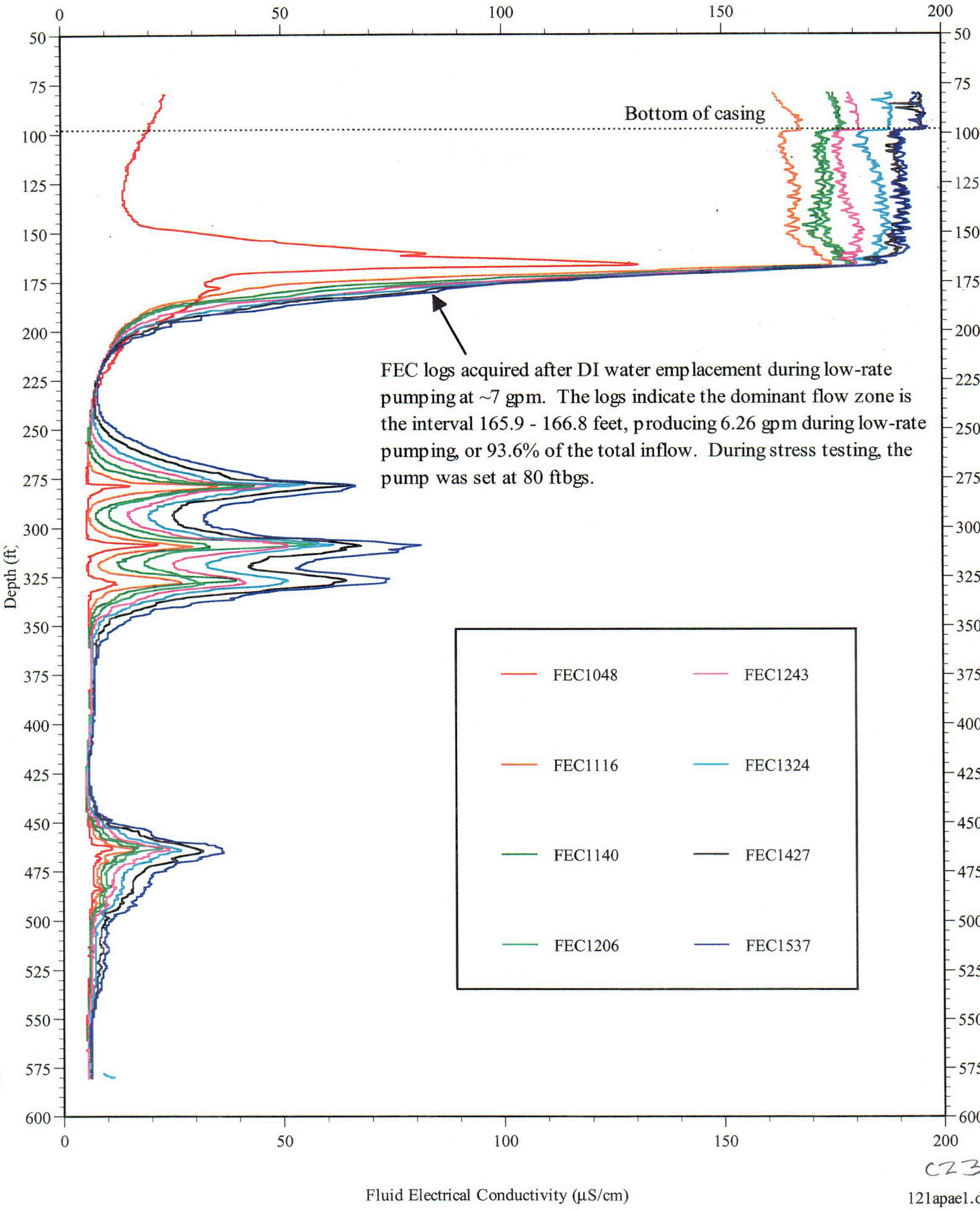
FIGURE 3-17. SUMMARY OF HYDROPHYSICAL LOGS DURING AMBIENT FLOW CHARACTERIZATION; CH2M HILL; CYAPCO; HADDAM NECK, CT; WELLBORE: BH-121A (Data obtained from COLOG, 2004).



121a-afc.dg4

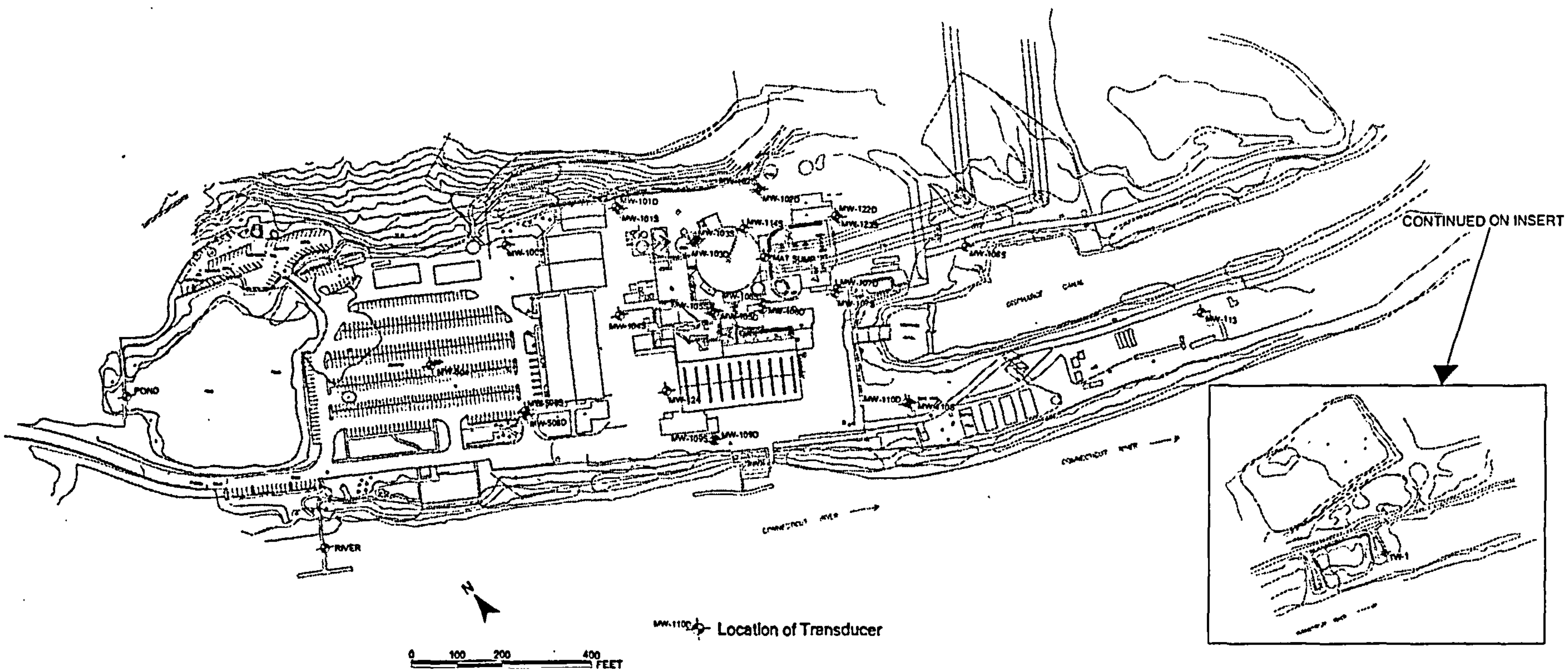
C22

FIGURE 3-18. SUMMARY OF HYDROPHYSICAL LOGS DURING LOW-RATE PUMPING AT 7 GPM; CH2M HILL; CYAPCO; HADDAM NECK, CT; WELLBORE: BH-121A (Data obtained from COLOG, 2004).



C23

121apae1.dg4

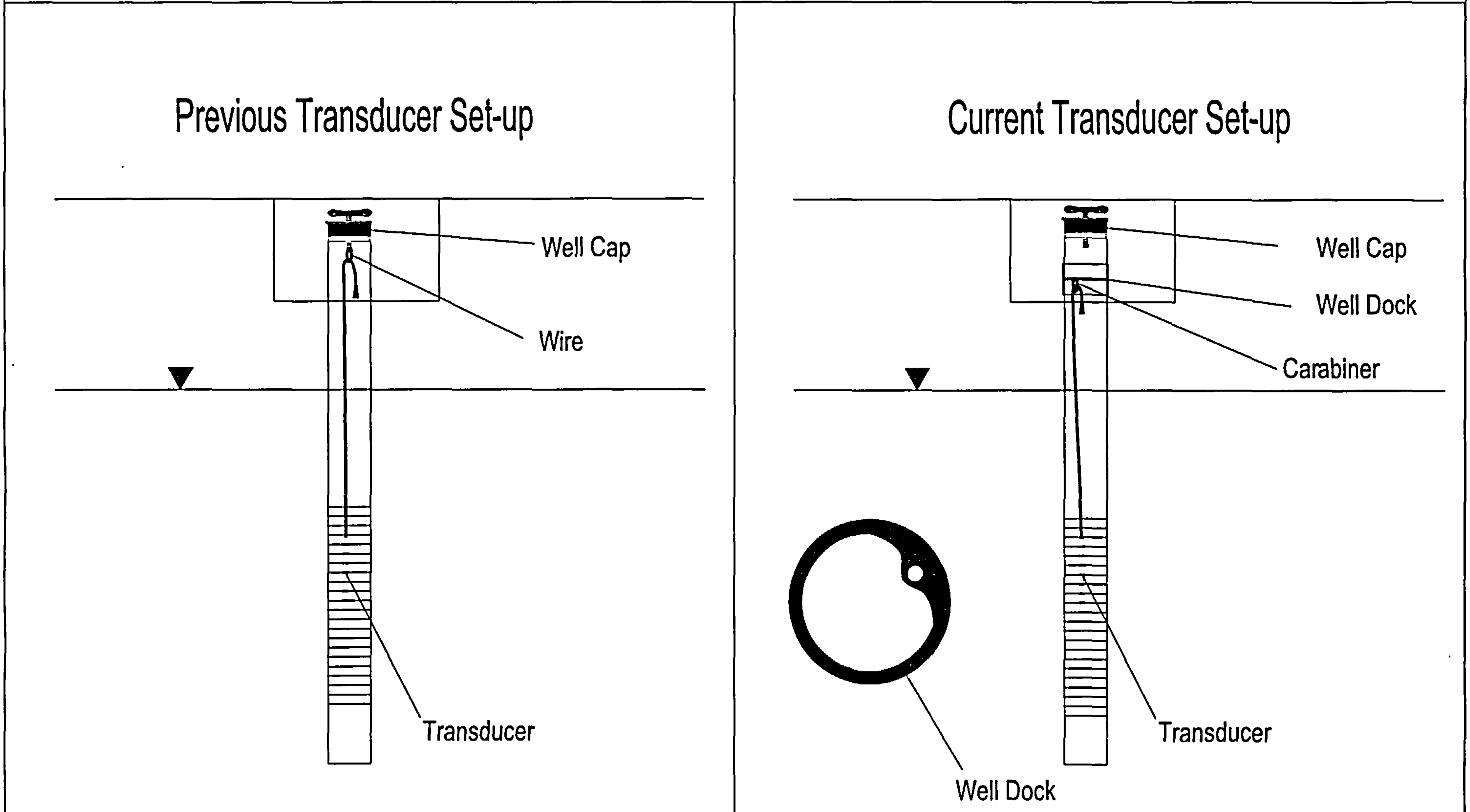


Notes: (1) Transducer locations are approximate locations
(2) Base map obtained from Malcolm Pirnie, April 2002

CH2MHILL

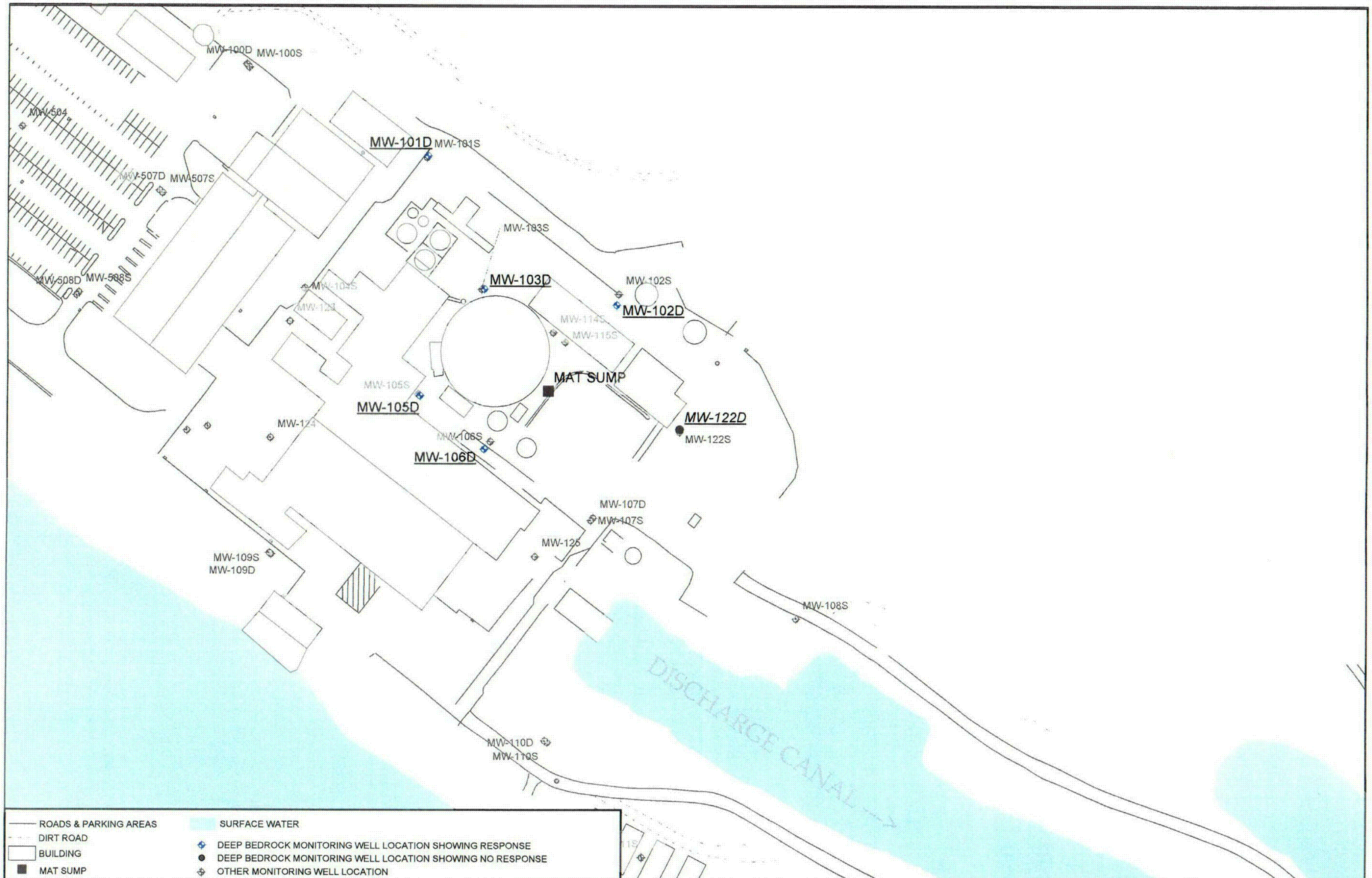
FIGURE 4-1

LOCATION OF WATER LEVEL TRANSDUCERS HADDAM NECK PLANT (HNP)



TITLE
Figure 4-2
Modification of Transducer
Task 2
HNP

	DWG NO	REV
CH2MHILL	transducer modification.tcw	1



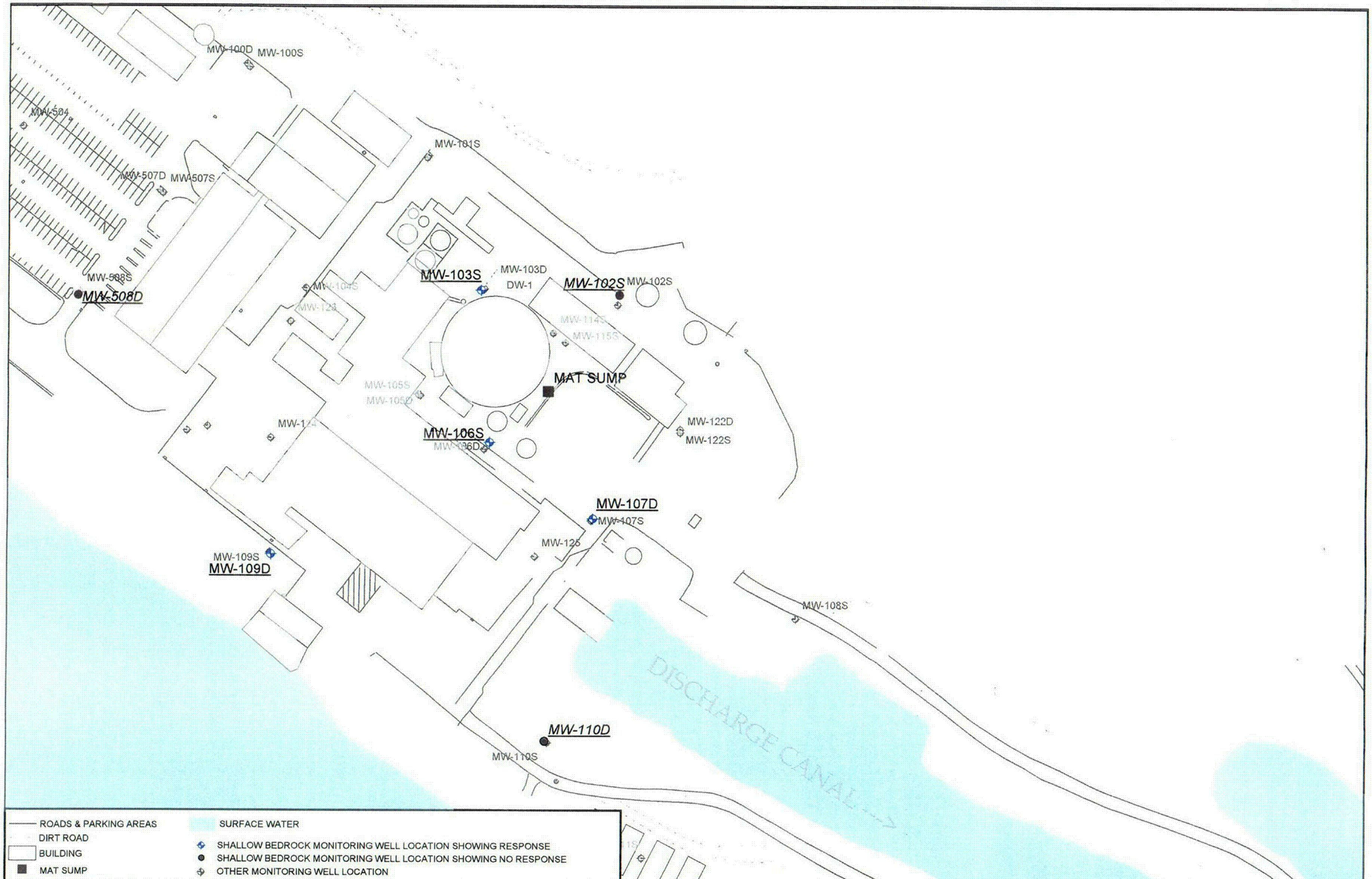
CH2MHILL

MAT SUMP INTERUPTIONS CORRESPOND TO RIVER STAGE RISES, MASKING POSSIBLE MINOR CONNECTION

FIGURE 4-3
RESPONSE TO MAT SUMP IN THE DEEP BEDROCK AQUIFER
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_2004\Mat_Sump_Response_Deep_BR.mxd BBODINSO 10/21/2004

C24



CH2MHILL

MAT SUMP INTERUPTIONS CORRESPOND TO RIVER STAGE RISES, MASKING POSSIBLE MINOR CONNECTION

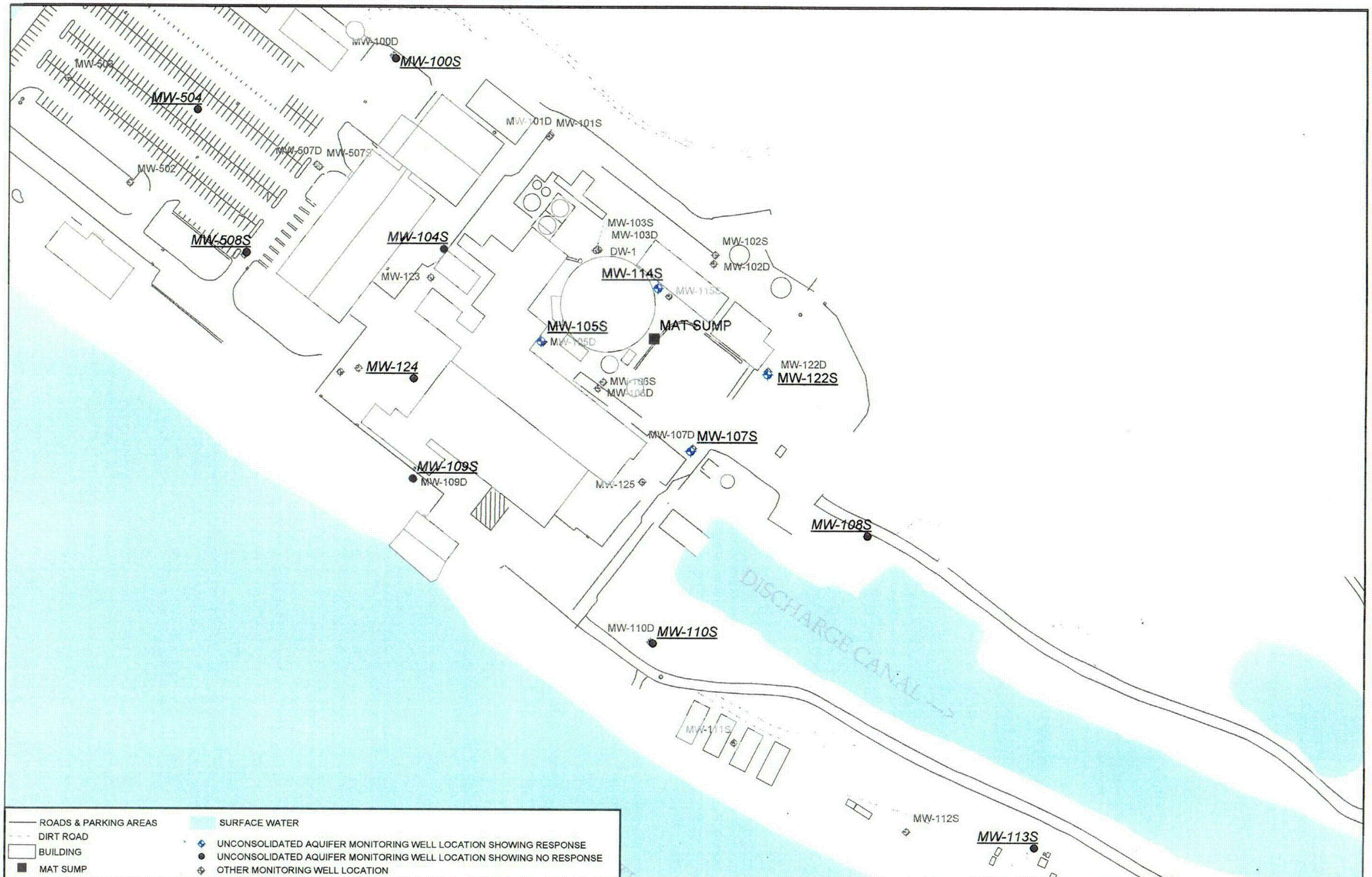
N

0 125 250 500 Feet

FIGURE 4-4
RESPONSE TO MAT SUMP IN THE SHALLOW BEDROCK AQUIFER, JANUARY - AUGUST 2004
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_2004\Mat_Sump_Response_Shallow_BR.mxd BBODINSO 10/21/2004

C25



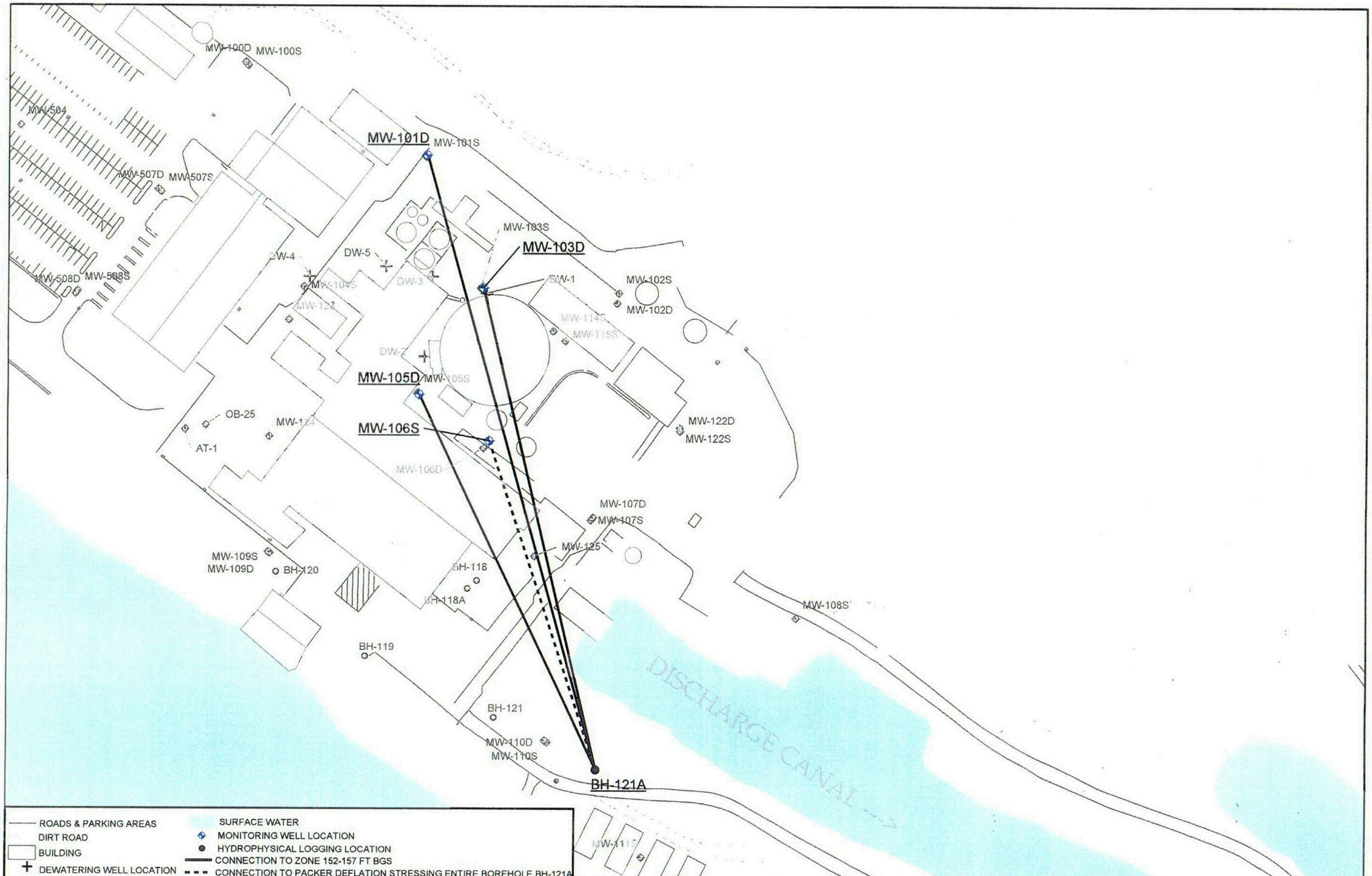
CH2MHILL

MAT SUMP INTERUPTIONS CORRESPOND TO RIVER STAGE RISES, MASKING POSSIBLE MINOR CONNECTION

FIGURE 4-5
RESPONSE TO MAT SUMP IN THE UNCONSOLIDATED AQUIFER
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_2004\Mat_Sump_Response_Unconsolidated.mxd BBODINSO 10/21/2004

C26

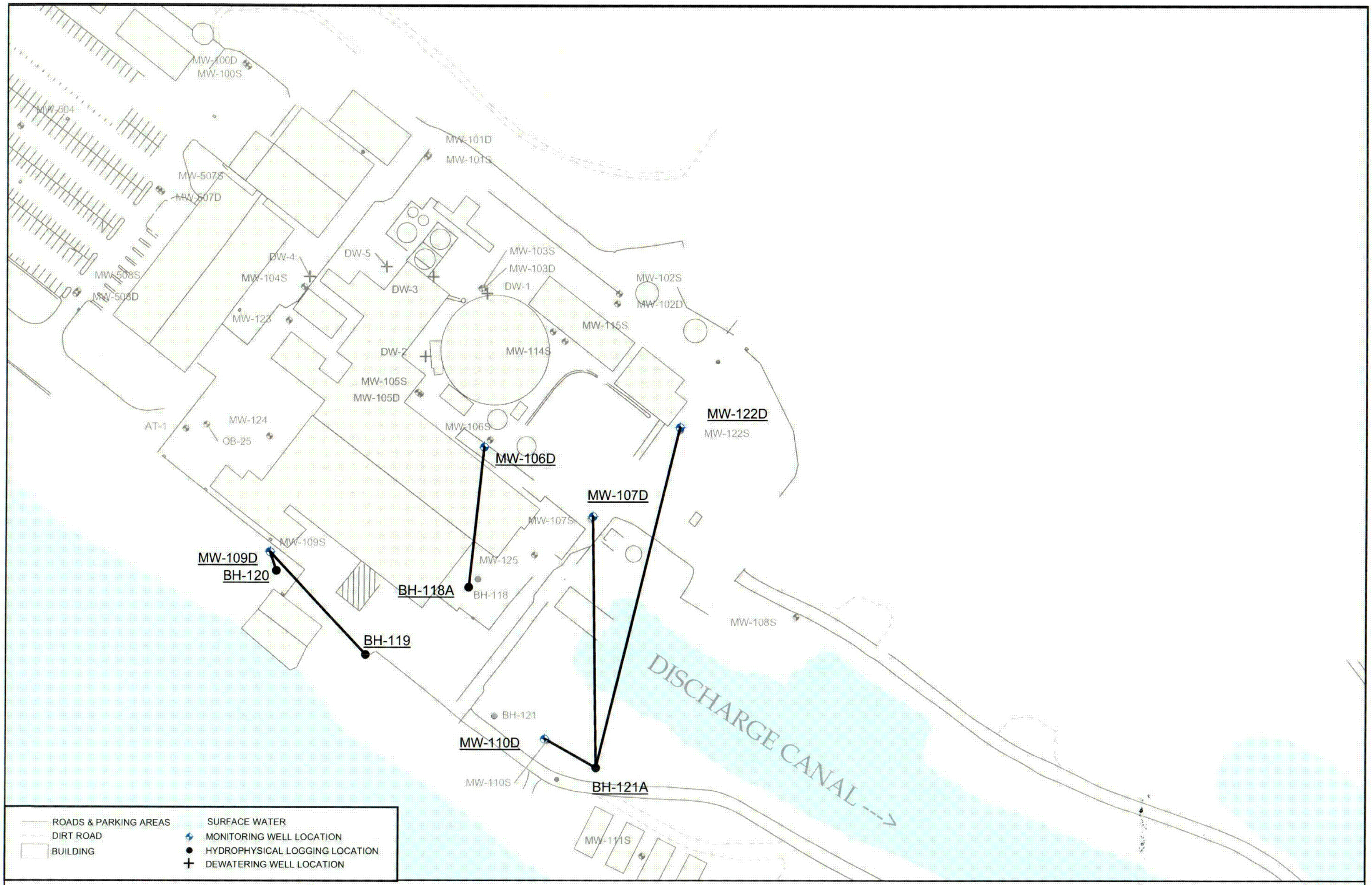


CH2MHILL

FIGURE 4-6
MONITORING WELLS SHOWING RESPONSE TO PACKER TESTING IN BH-121A
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_2004\Packer_test_BH-121A.mxd BBODINSO 10/21/2004

C27



N

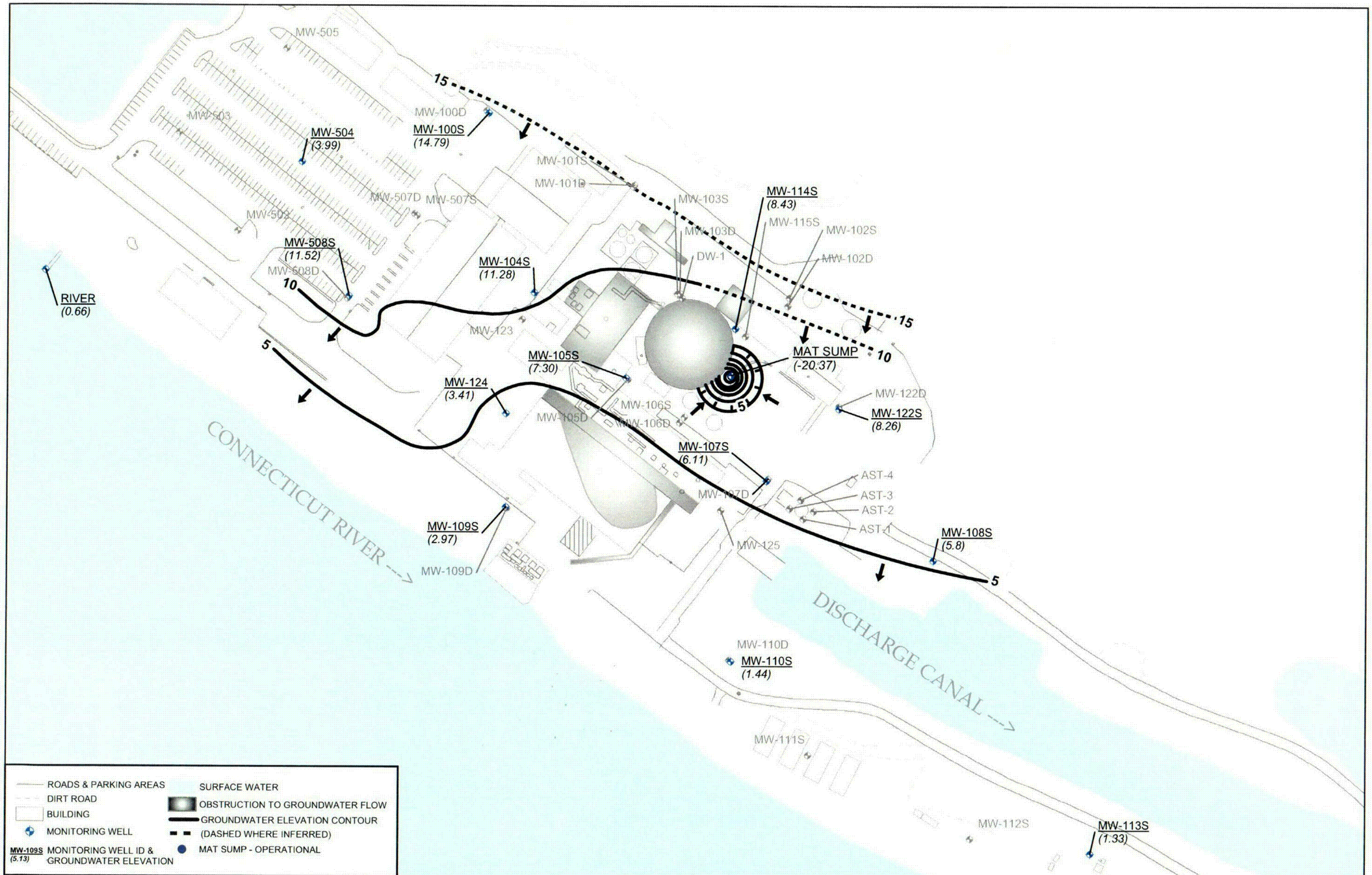
0 125 250 500 Feet

CH2MHILL

FIGURE 4-7
MONITORING WELLS SHOWING RESPONSE TO PUMPING IN BEDROCK BOREHOLES DURING HYDROPHYSICAL LOGGING
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_2004\MW_Response_BR.mxd BBODINSO 11/9/2004

C28



Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

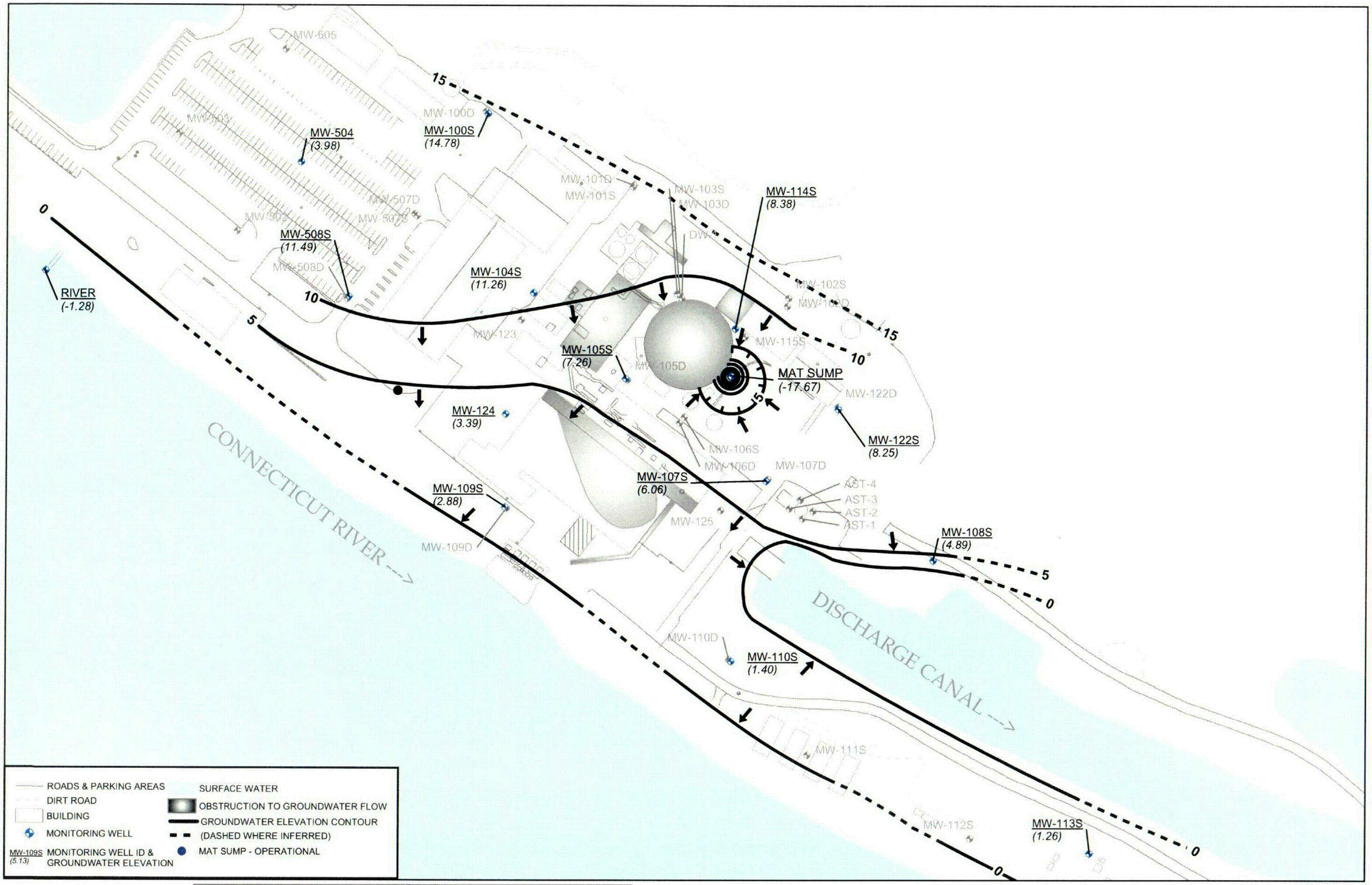
N

0 125 250 Feet

FIGURE 4-8
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED MATERIAL OF THE CONNECTICUT YANKEE HADDAN NECK PLANT FEBRUARY 12, 2004 4:35 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_2_04.mxd BBODINSO 11/8/2004

C29



Shallow Bedrock Aquifer Assumptions

1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

N

0 125 250 Feet

CH2MHILL

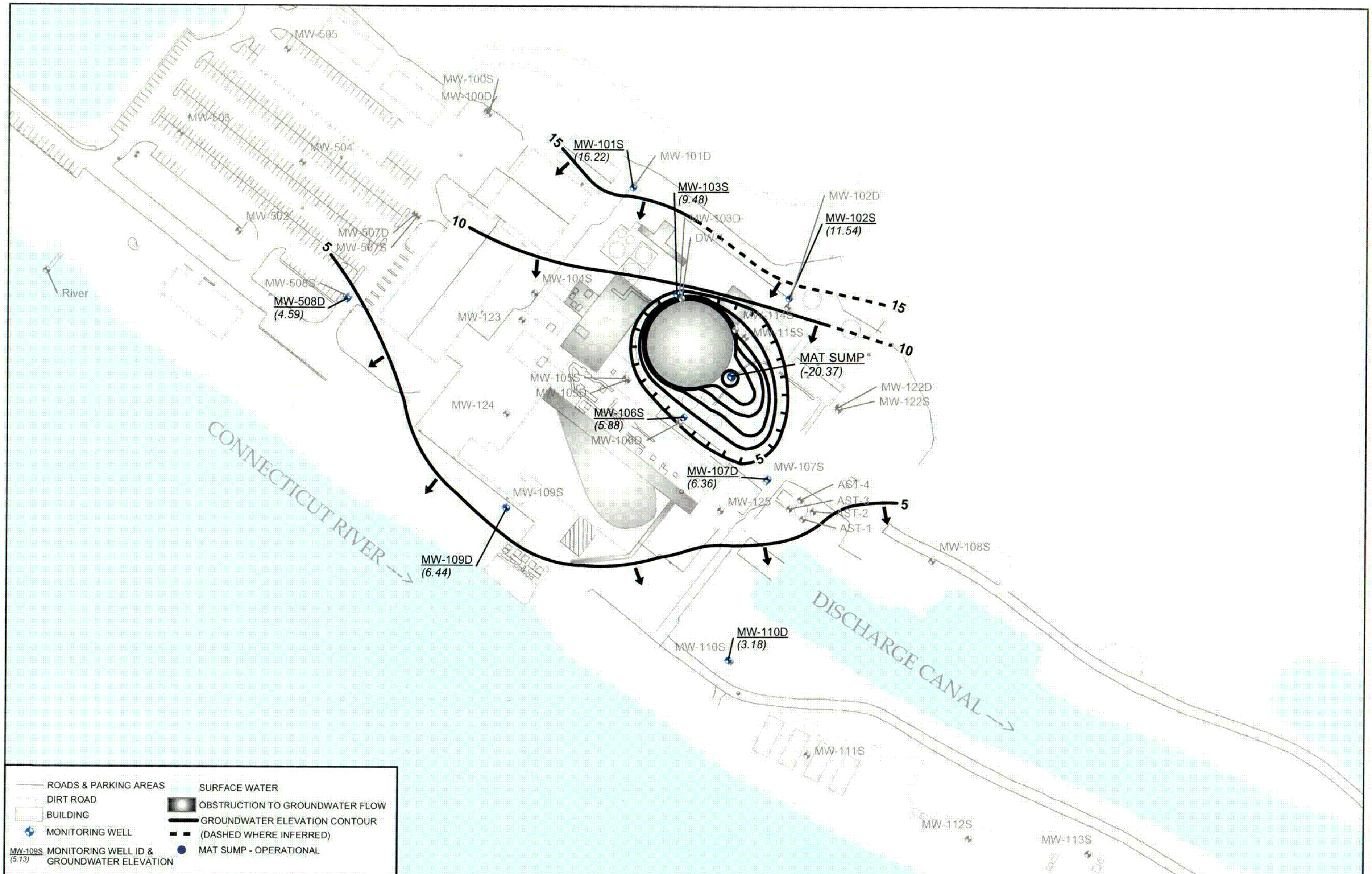
FIGURE 4-9

GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS OF THE CONNECTICUT YANKEE HADDAN NECK PLANT FEBRUARY 12, 2004 11:35 LOW TIDE

HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_2_04_Low.mxd BBODINSO 11/8/2004

C30



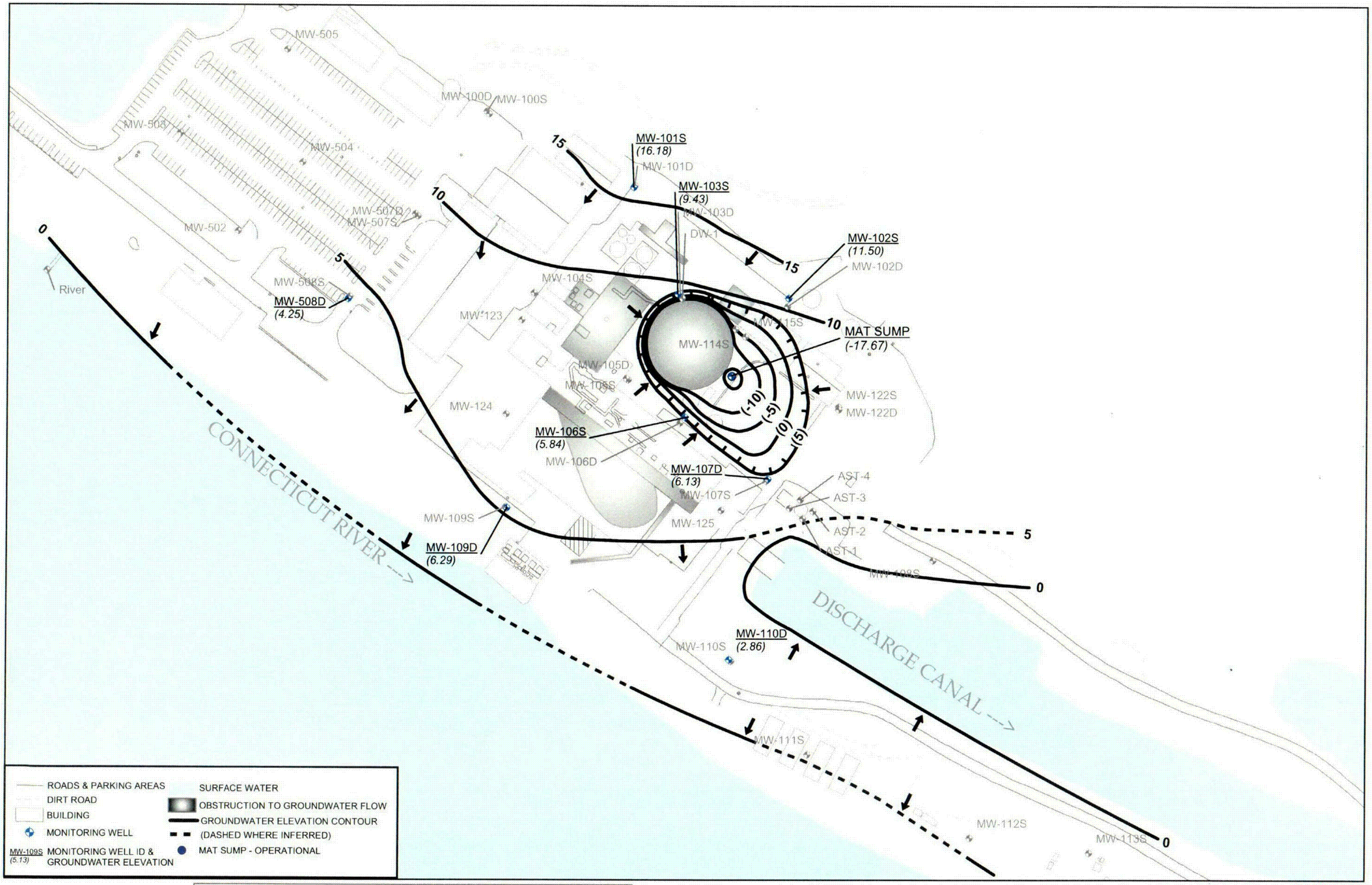
Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

FIGURE 4-10
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT FEBRUARY 12, 2004 4:35 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_SHALLOW_BR_2_04.mxd BBODINSO 11/8/2004

C31



CH2MHILL

Shallow Bedrock Aquifer Assumptions

1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

N

0 125 250 Feet

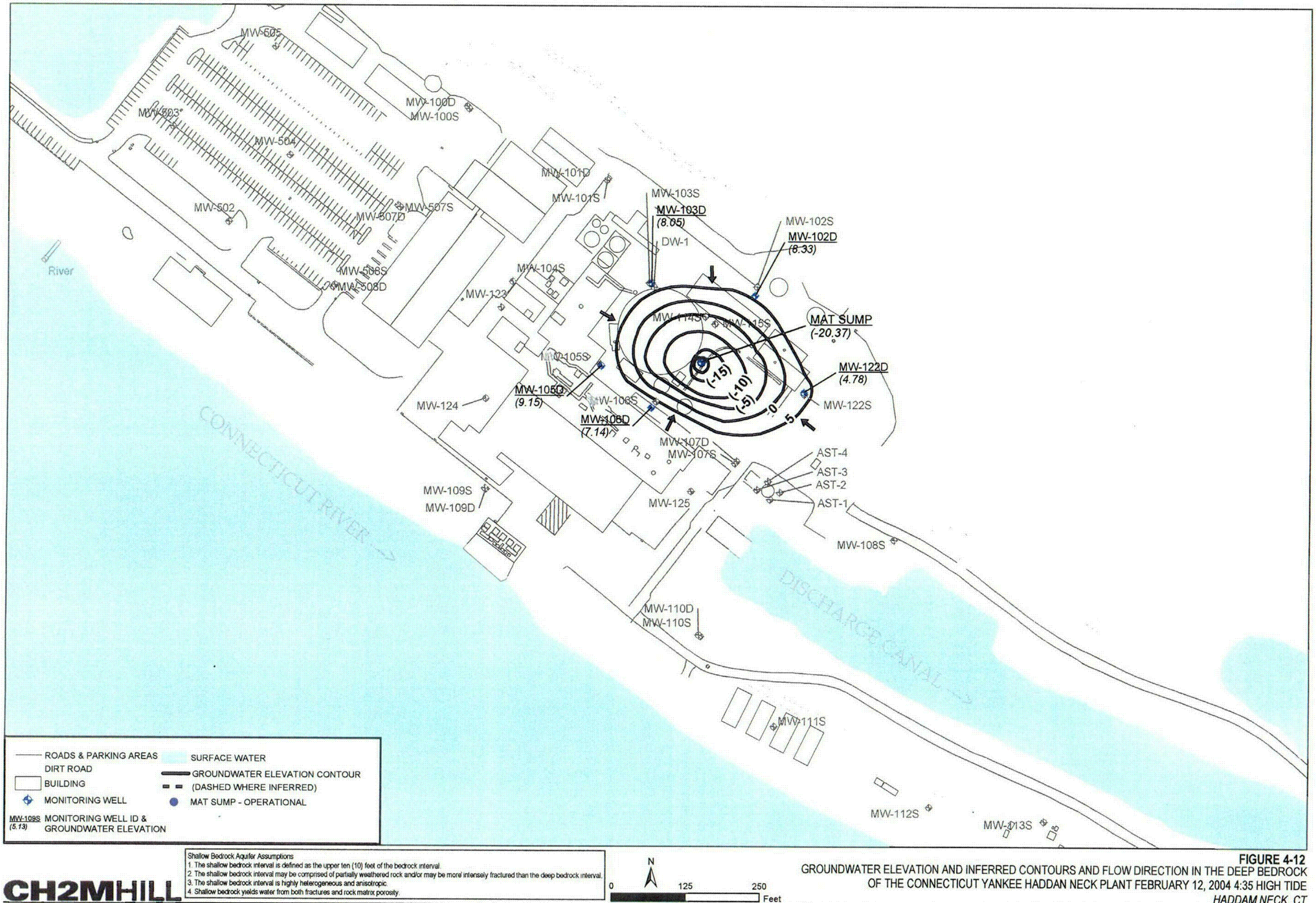
FIGURE 4-11

GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT FEBRUARY 12, 2004 11:35 LOW TIDE

HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_SHALLOW_BR_2_04_Low.mxd BBODINSO 11/8/2004

C32



Shallow Bedrock Aquifer Assumptions

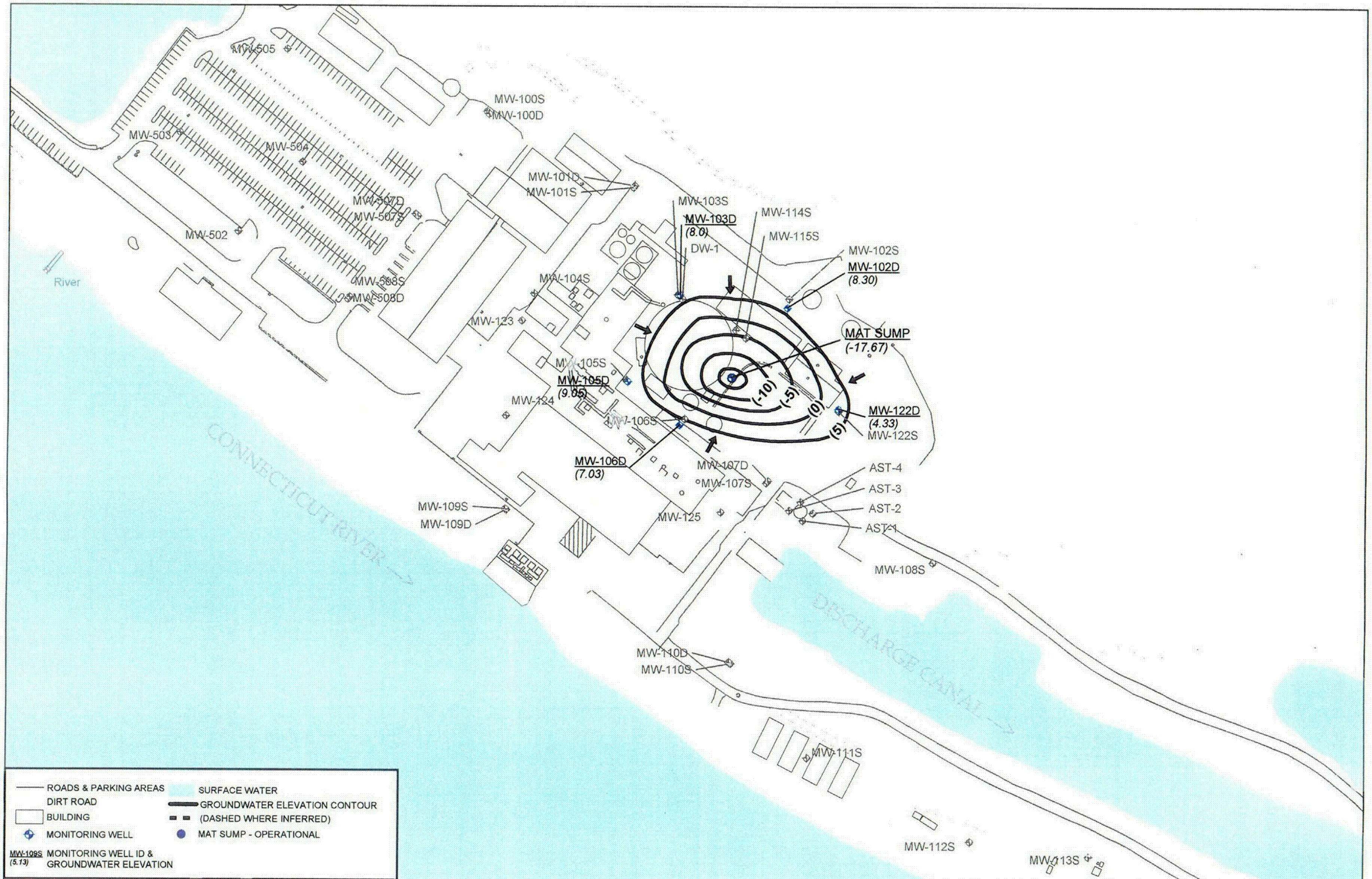
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

FIGURE 4-12
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE DEEP BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT FEBRUARY 12, 2004 4:35 HIGH TIDE
HADDAM NECK, CT

CH2MHILL

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_DEEP_BR_2_04_HIGH.mxd BBODINSO 11/8/2004

C33



Shallow Bedrock Aquifer Assumptions

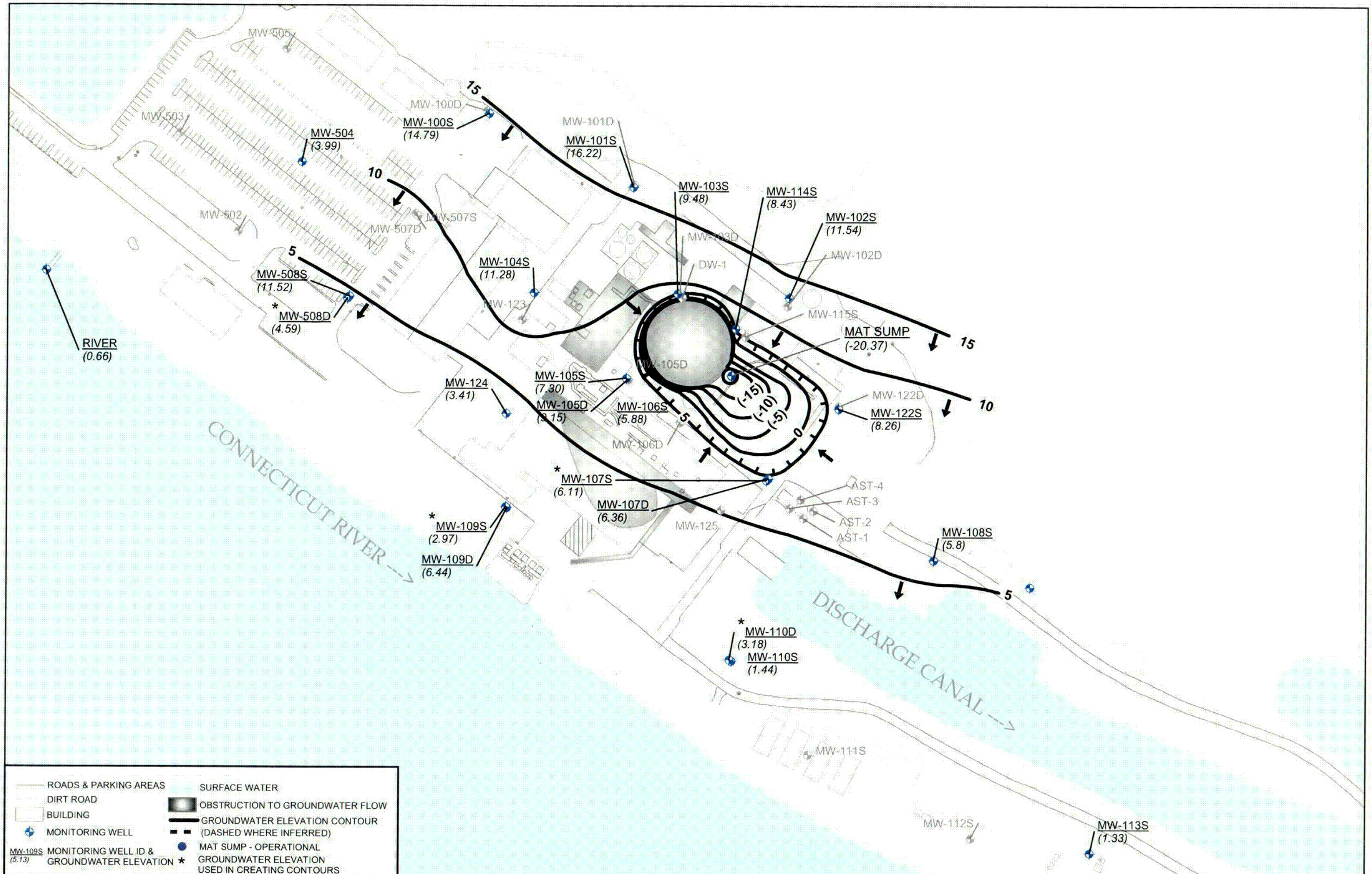
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

FIGURE 4-13
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE DEEP BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT FEBRUARY 12, 2004 11:35 LOW TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_DEEP_BR_2_04_Low.mxd BBODINSO 11/8/2004

C34



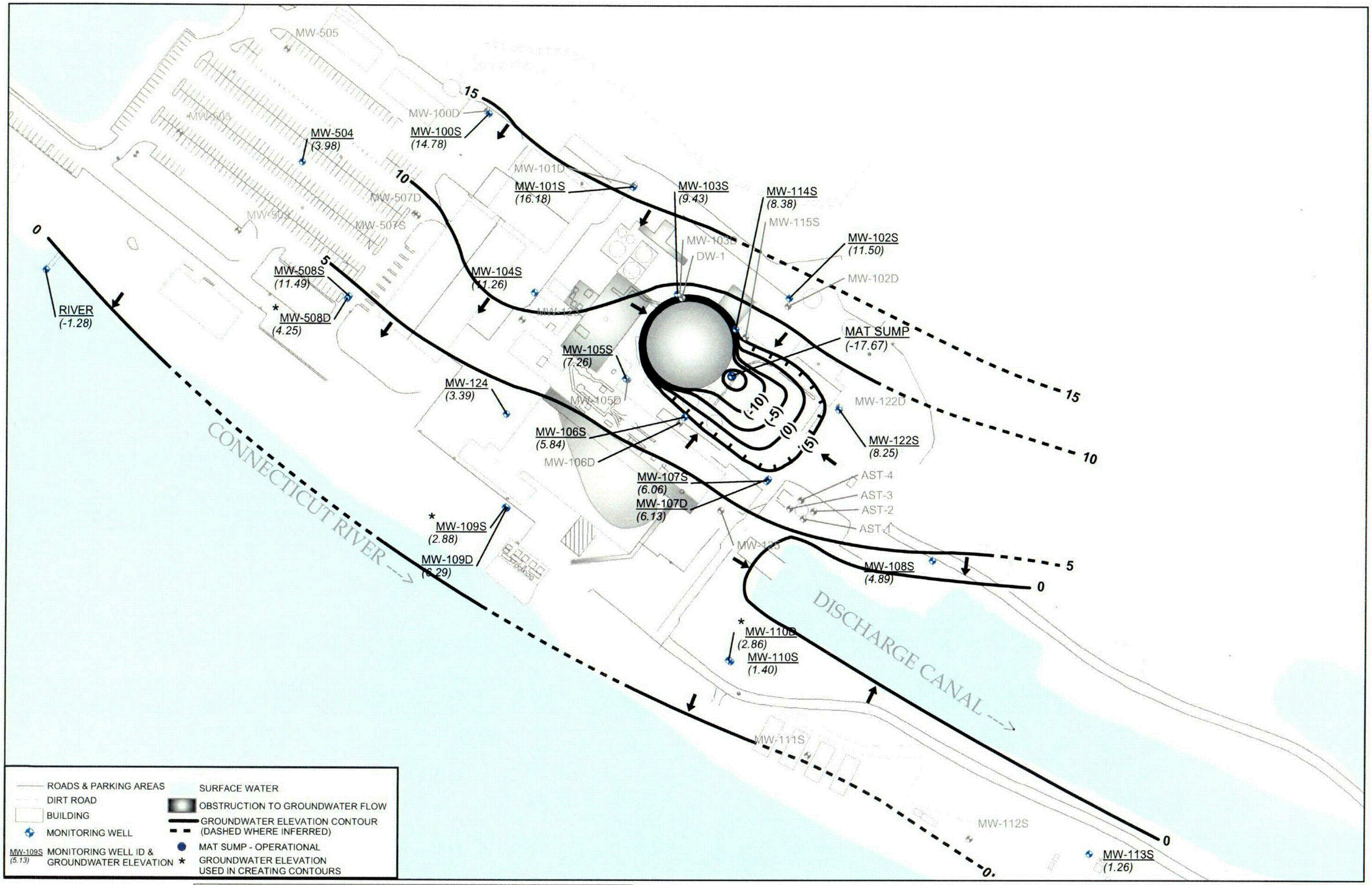
Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

FIGURE 4-14
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED MATERIAL AND SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT FEBRUARY 12, 2004 4:35 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_SHALLOW_BR_2_04.mxd BBODINSO 11/9/2004

C35



Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

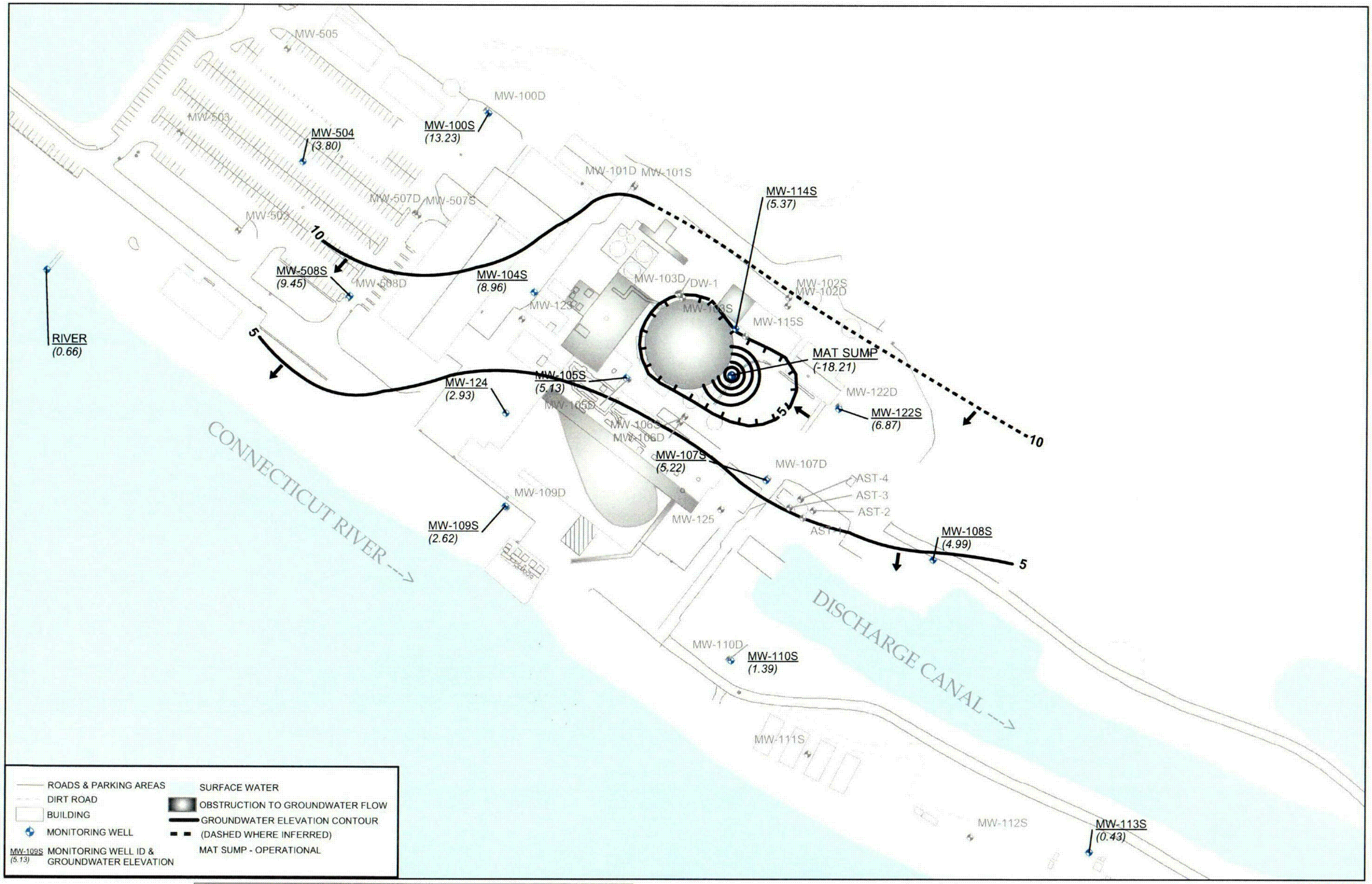
N
0 125 250 Feet

FIGURE 4-15
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS AND SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT FEBRUARY 12, 2004 11:35 LOW TIDE
HADDAM NECK, CT

CH2MHILL

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_SHALLOW_BR_2_04_Low.mxd BBODINSO 11/9/2004

C36



CH2MHILL

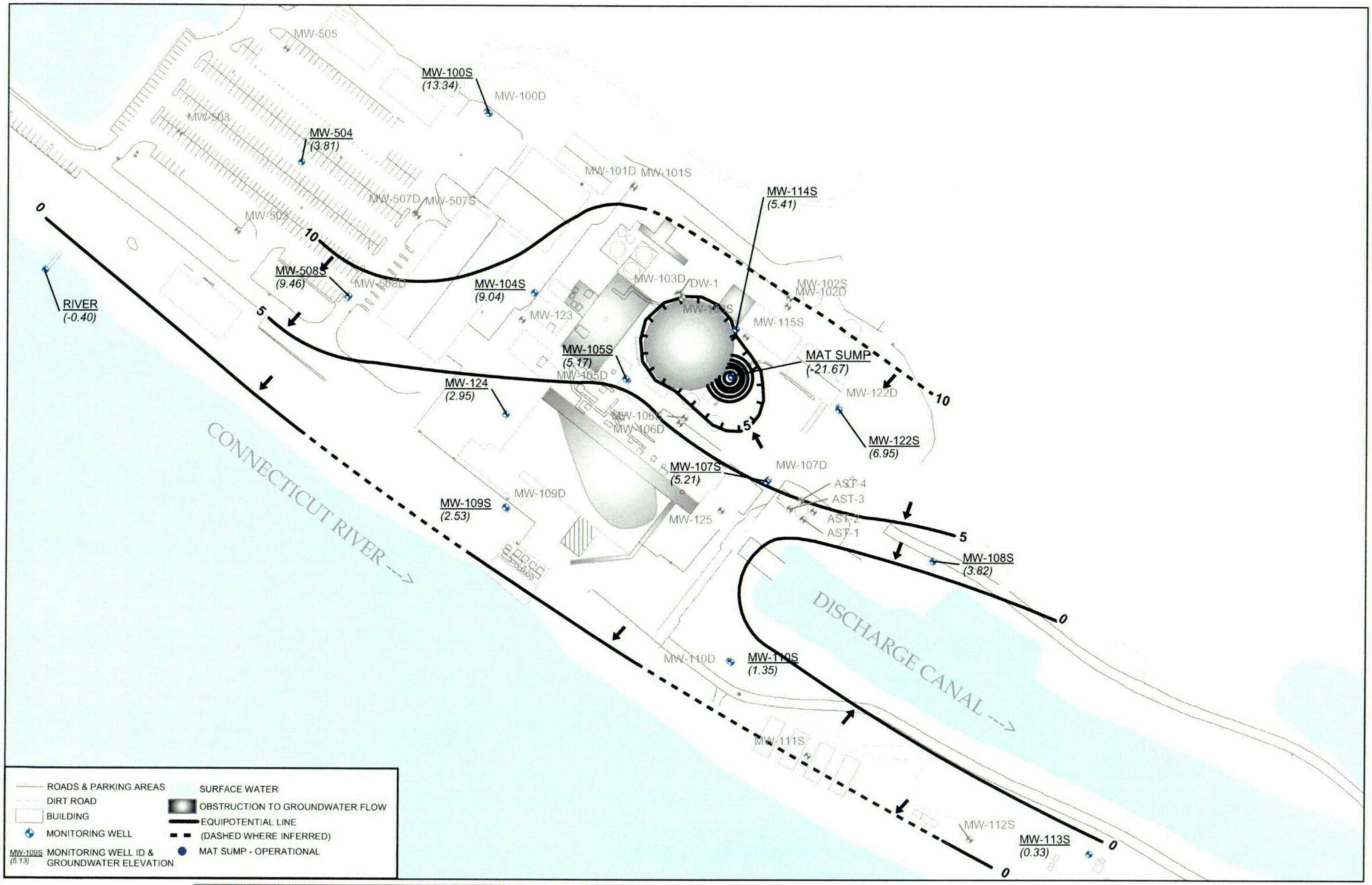
Shallow Bedrock Aquifer Assumptions

1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

FIGURE 4-16
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS OF THE CONNECTICUT YANKEE HADDAN NECK PLANT JUNE 12, 2004 21:00 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_6_04.mxd BBODINSO 11/8/2004

C37



Shallow Bedrock Aquifer Assumptions

1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

N

0 125 250 Feet

CH2MHILL

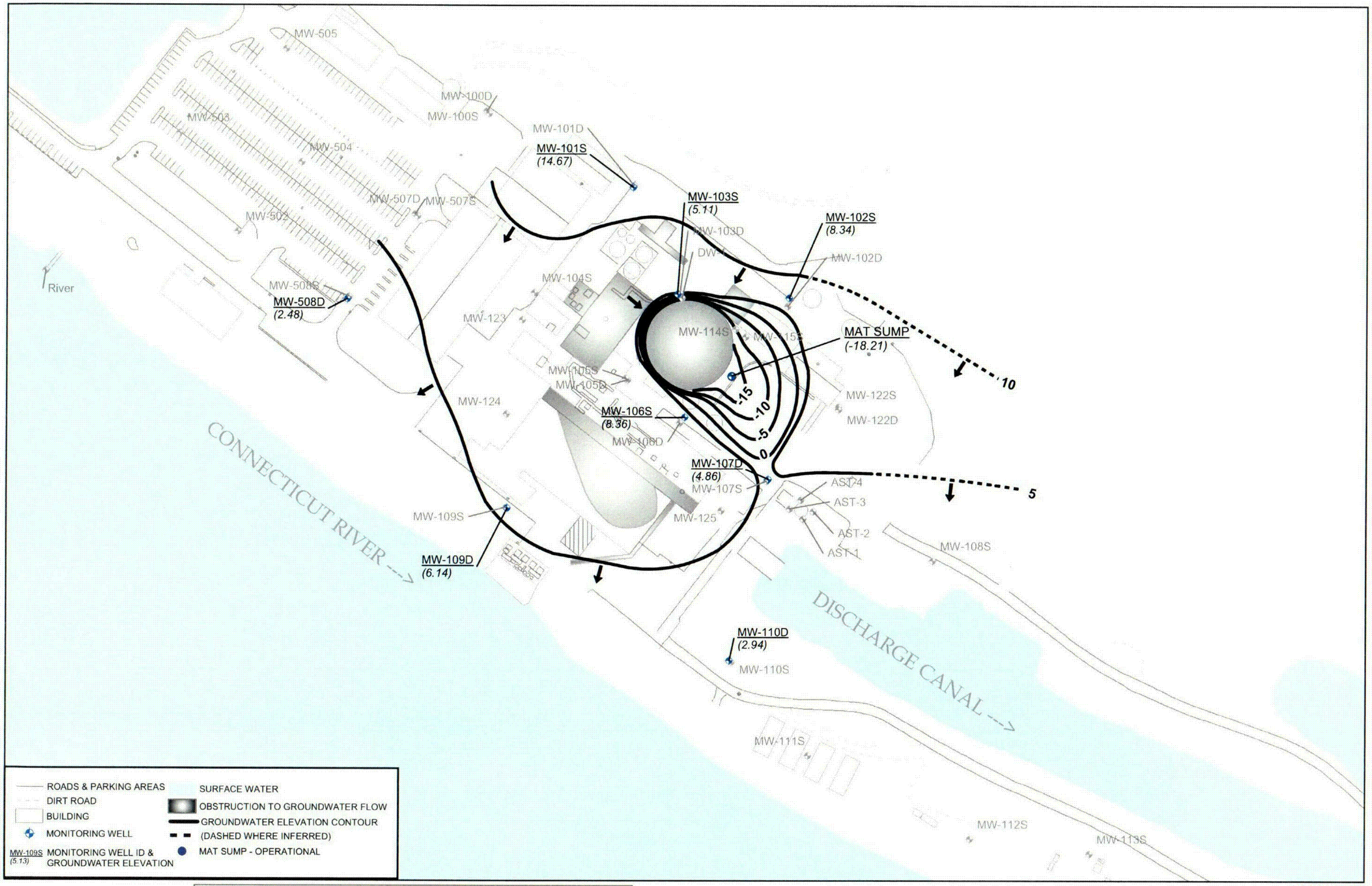
FIGURE 4-17

GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS OF THE CONNECTICUT YANKEE HADDAN NECK PLANT JUNE 12, 2004 15:10 LOW TIDE

HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_6_04_Low.mxd BBODINSO 11/8/2004

C38



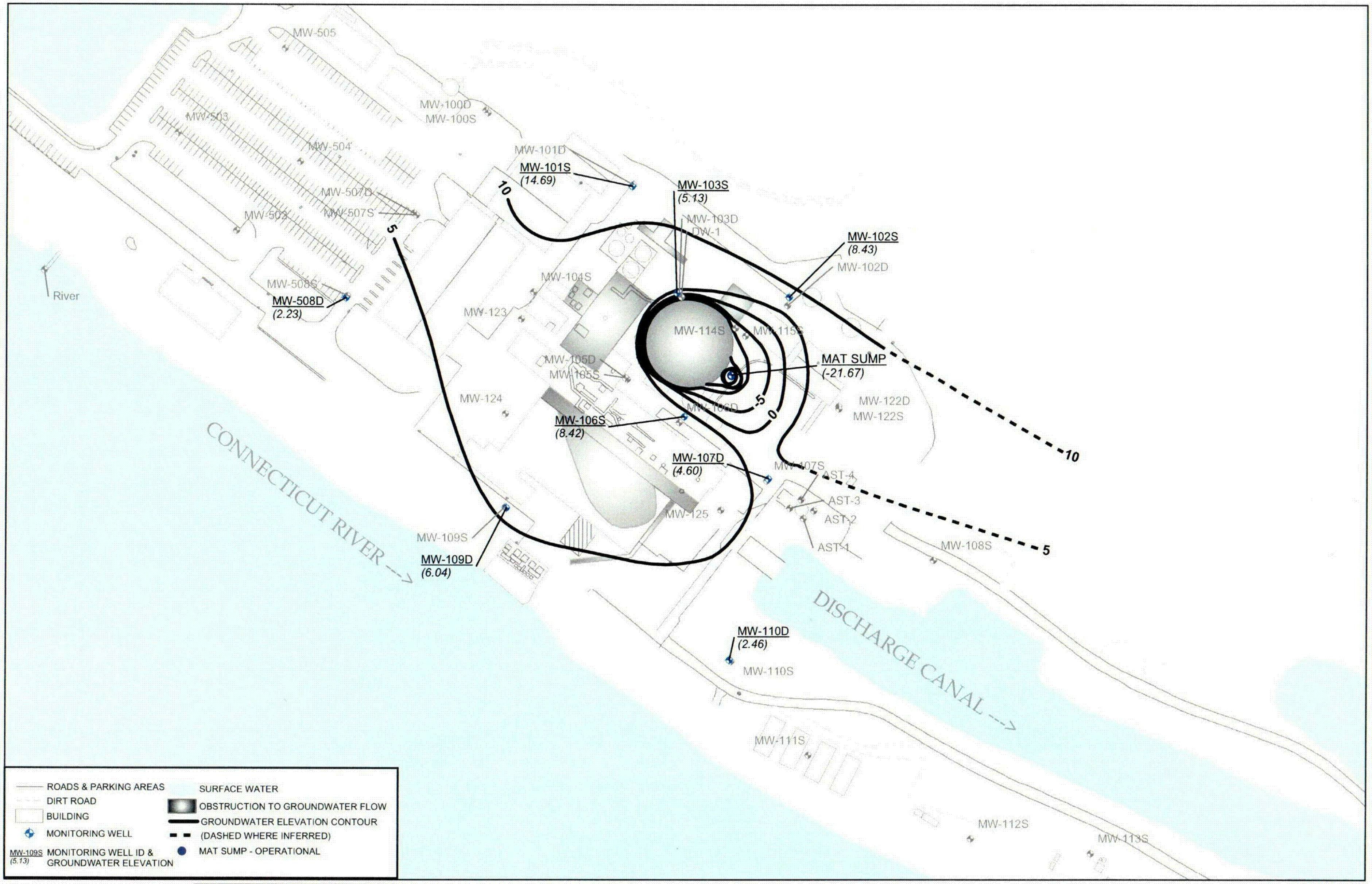
Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

FIGURE 4-18
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT JUNE 12, 2004 21:00 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_SHALLOW_BR_6_04.mxd BBODINSO 11/8/2004

C39



CH2MHILL

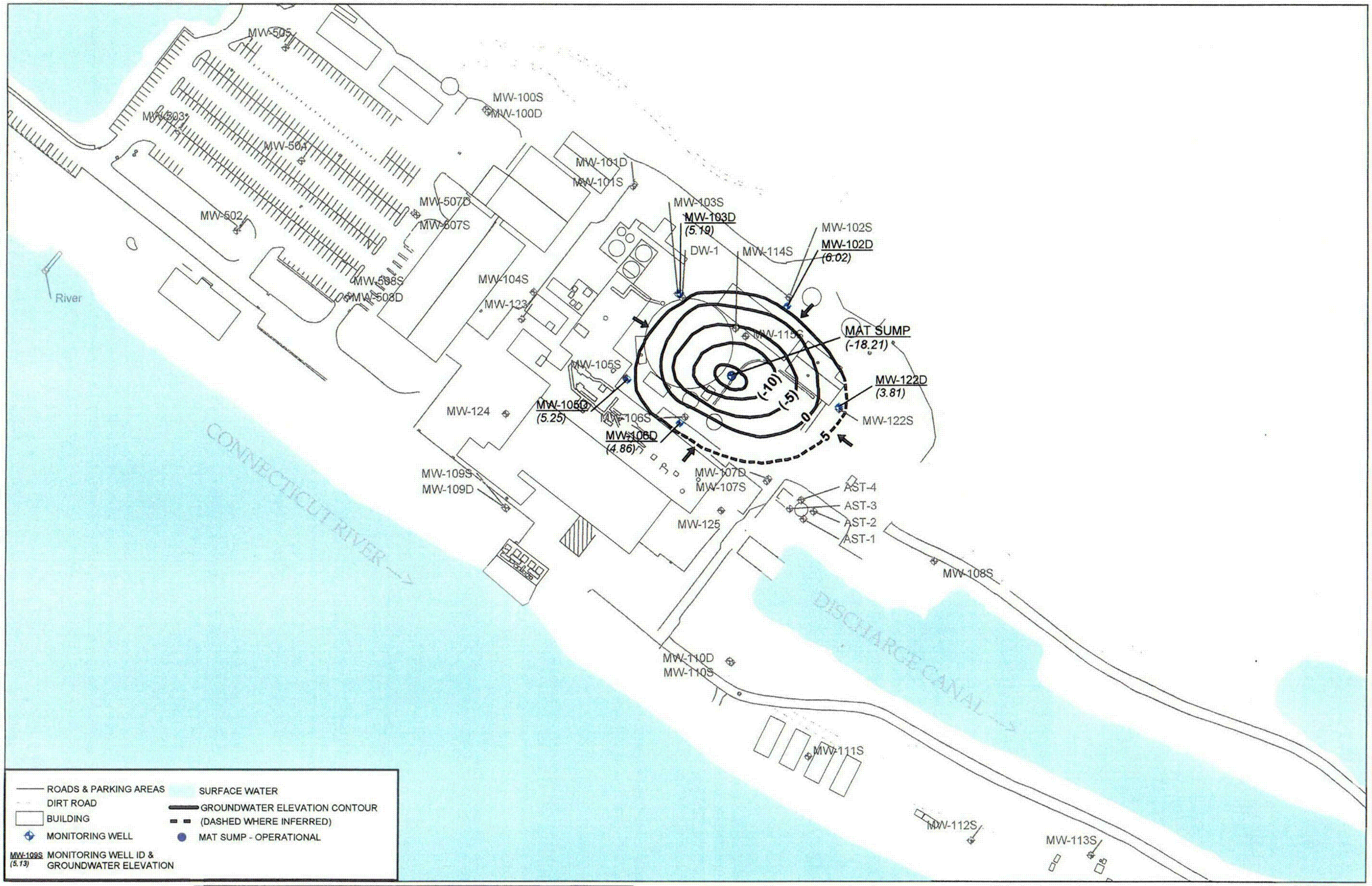
Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

N
0 125 250 Feet

FIGURE 4-19
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT JUNE 12, 2004 15:10 LOW TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_SHALLOW_BR_6_04_Low.mxd JHenderson 10/7/2004

C40



Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

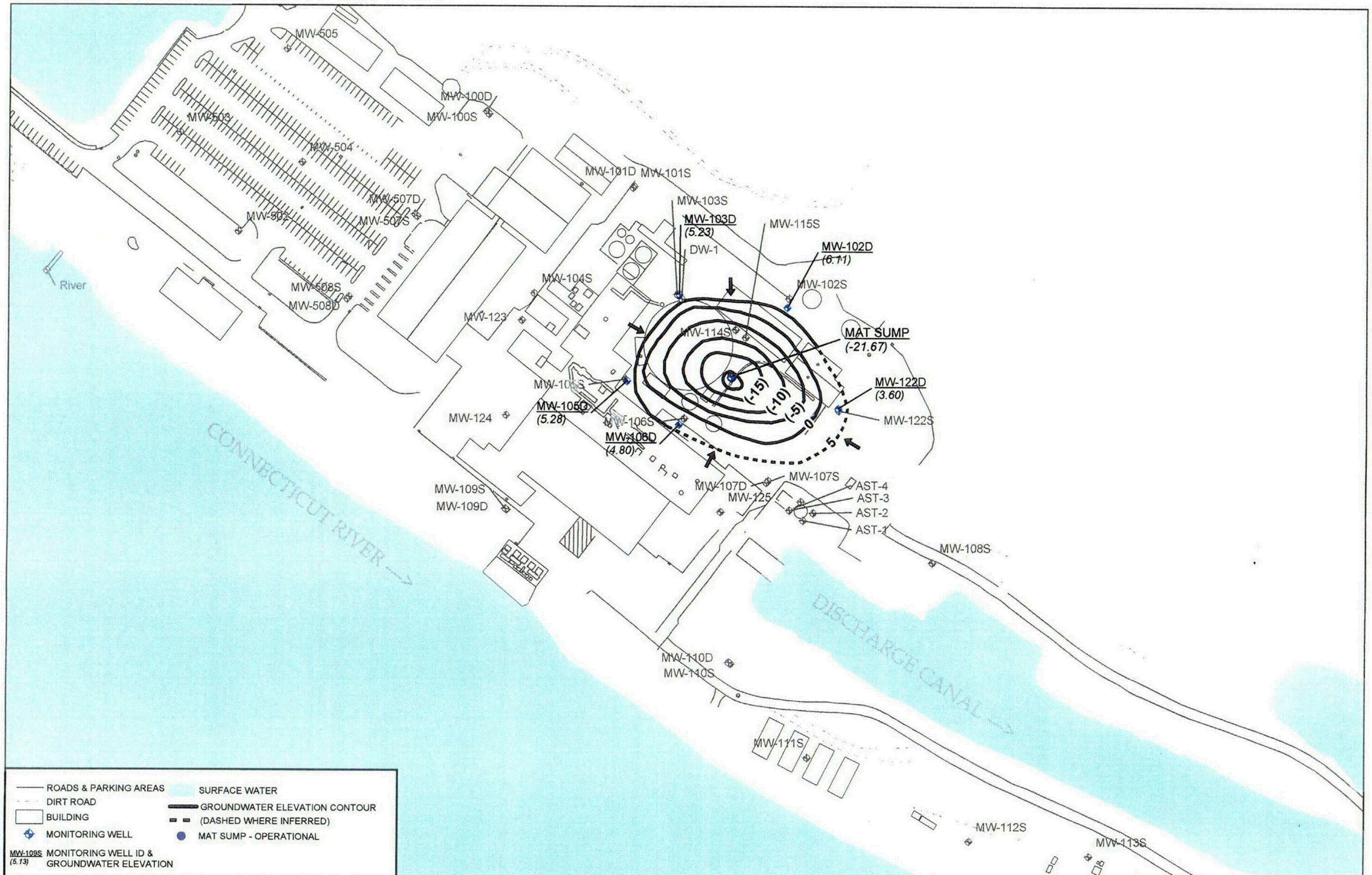
N

0 125 250 Feet

FIGURE 4-20
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE DEEP BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT JUNE 12, 2004 21:00 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_DEEP_BR_6_04_HIGH.mxd BBODINSO 11/8/2004

C41



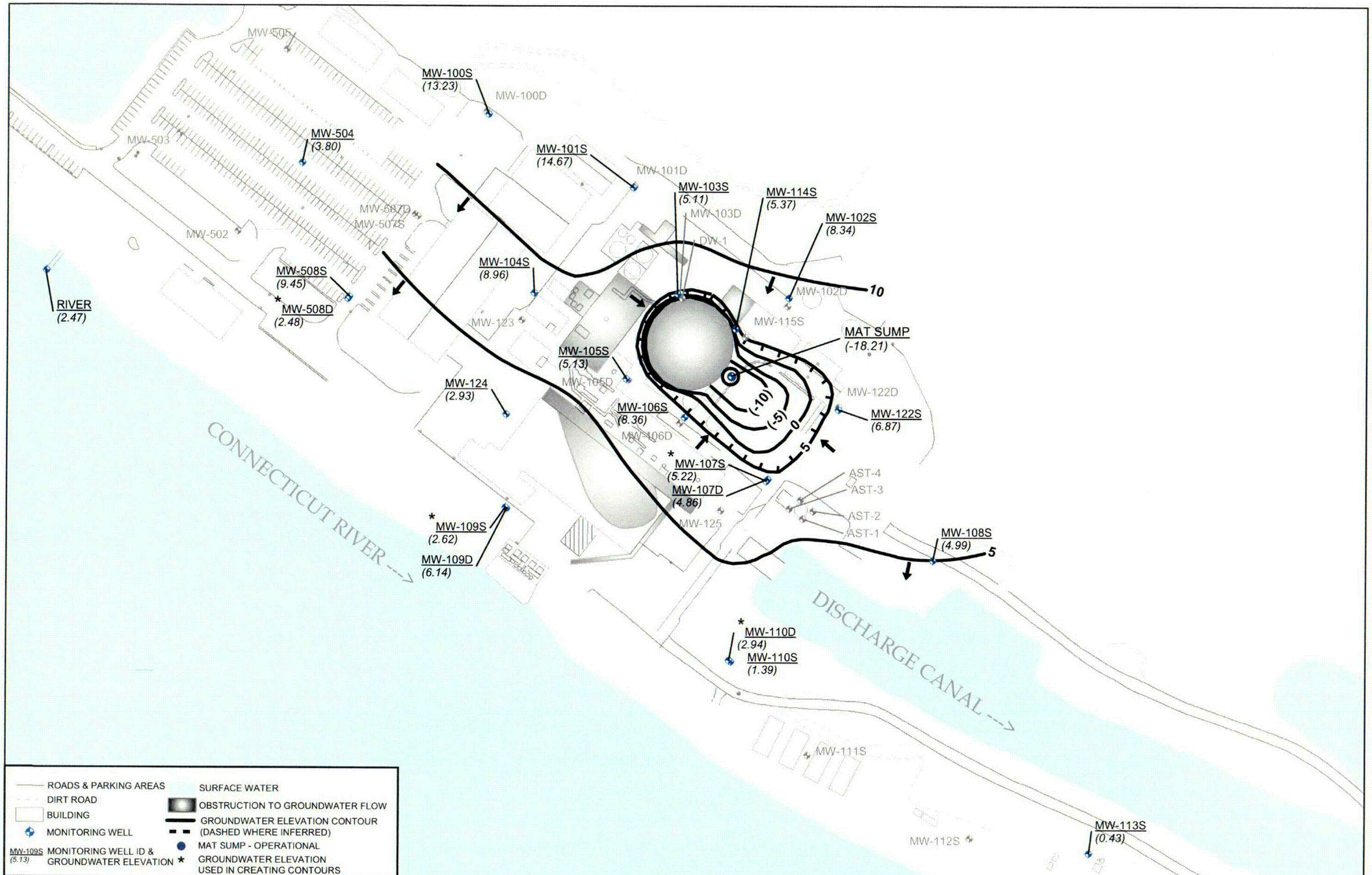
Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

FIGURE 4-21
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE DEEP BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT JUNE 12, 2004 15:10 LOW TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_DEEP_BR_6_04_LOW.mxd BBODINSO 11/8/2004

C42



Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

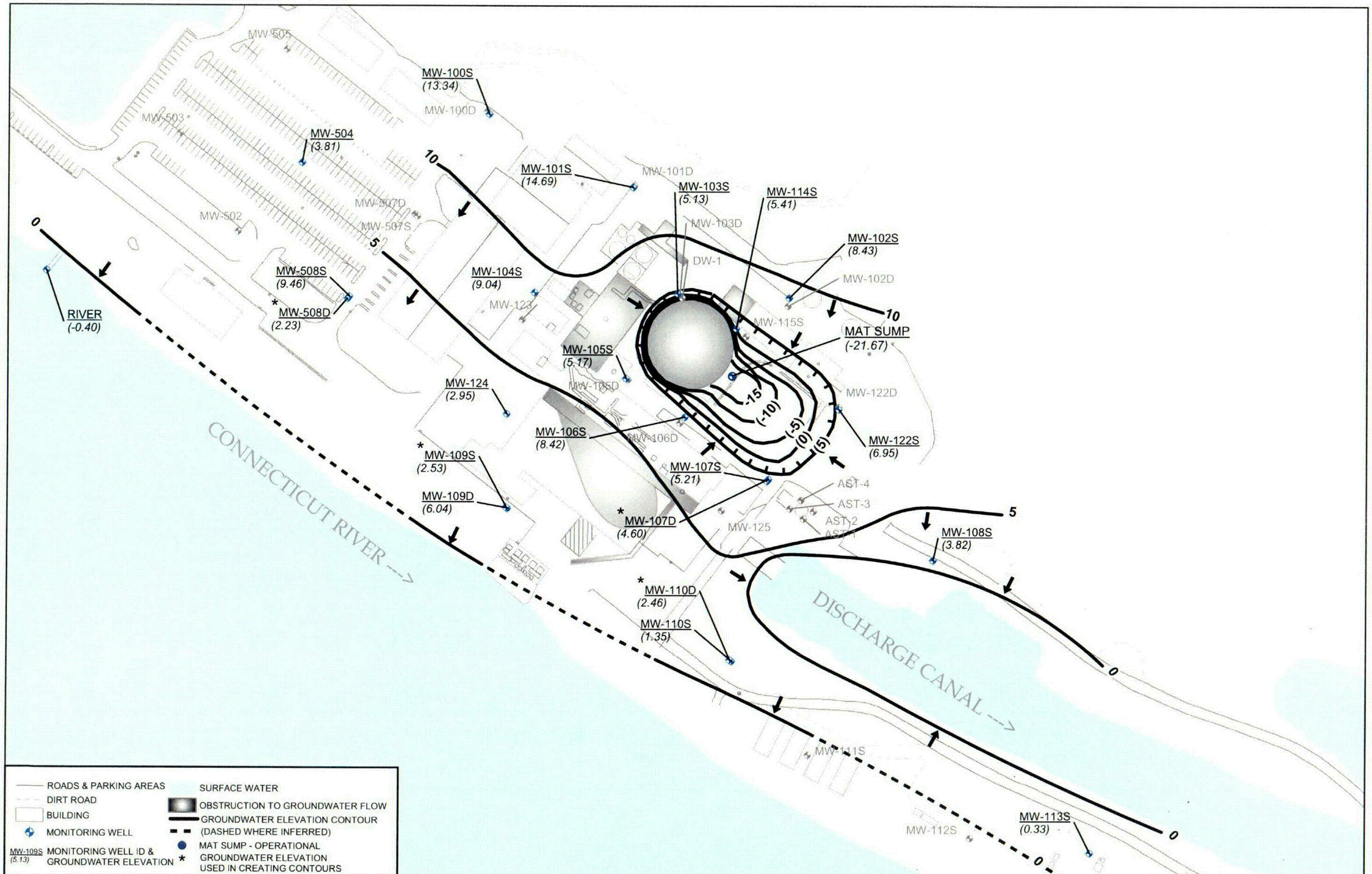
CH2MHILL

N
0 125 250 Feet

FIGURE 4-22
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED MATERIAL AND SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT JUNE 12, 2004 21:00 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_SHALLOW_BR_6_04.mxd BBODINSO 11/9/2004

C43



Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

N

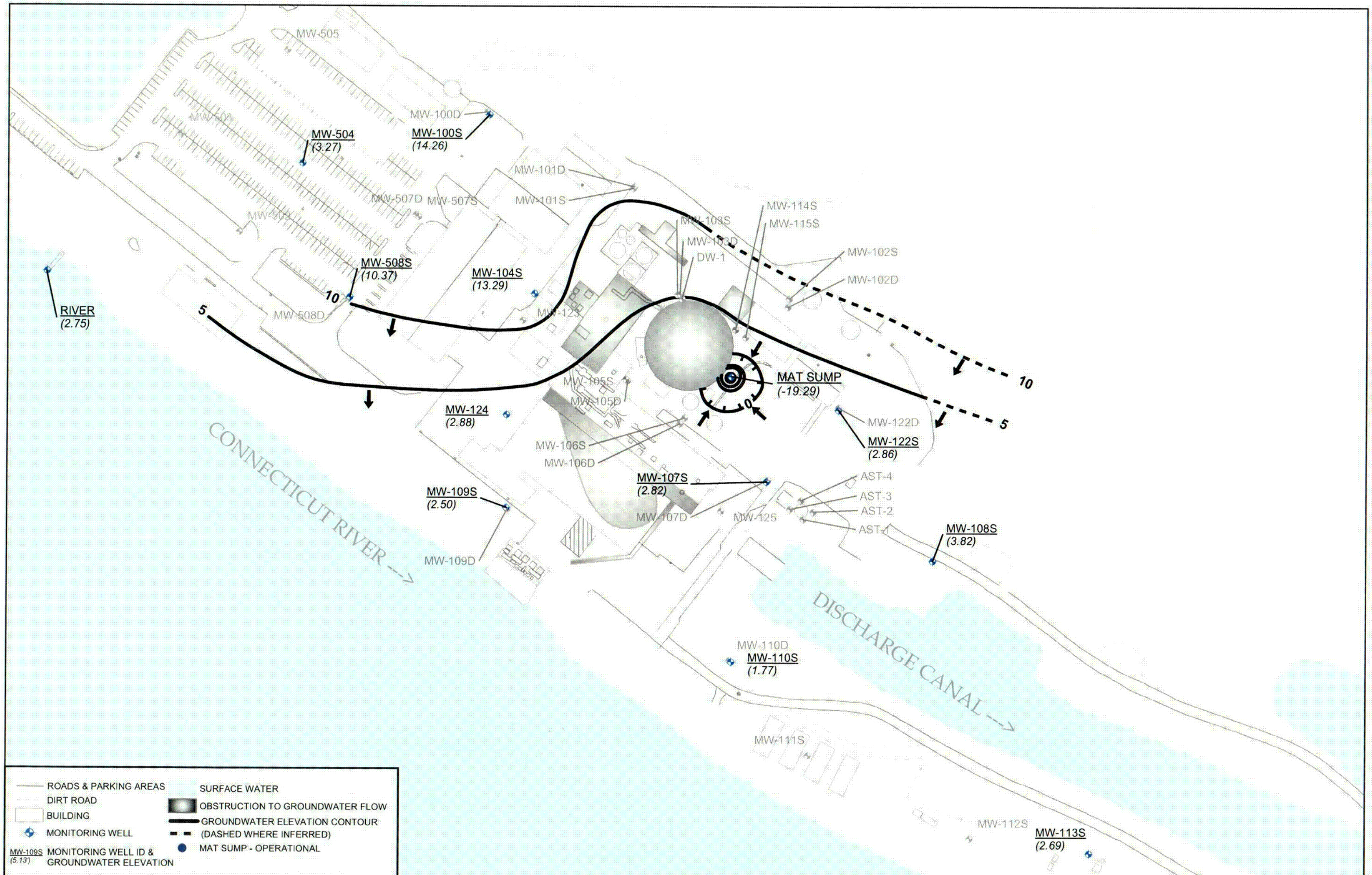
0 125 250 Feet

FIGURE 4-23
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS AND SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT JUNE 12, 2004 15:10 LOW TIDE
HADDAM NECK, CT

CH2MHILL

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_SHALLOW_BR_6_04_Low.mxd BBODINSO 11/9/2004

C44



CH2MHILL

Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

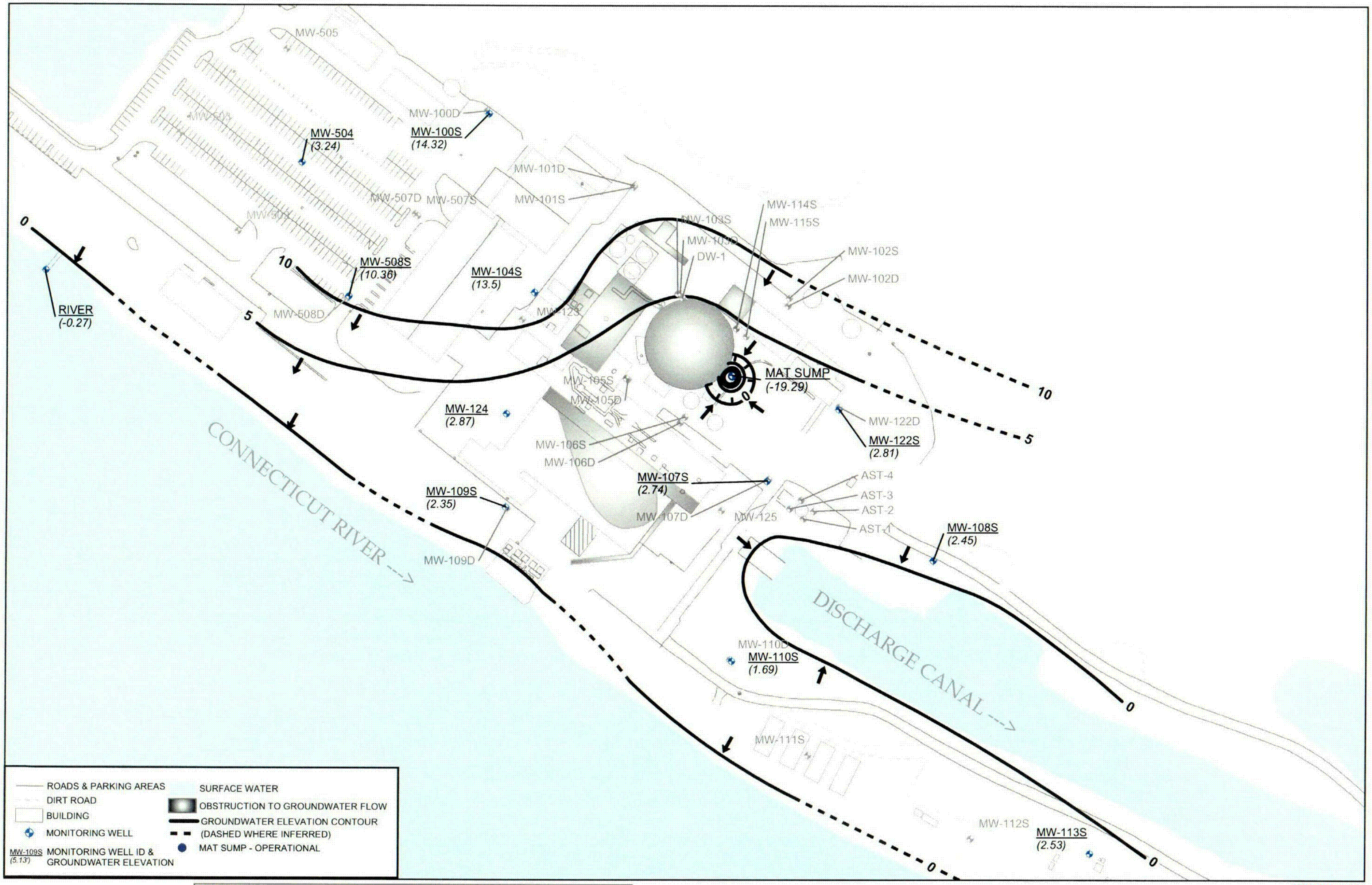
N

0 125 250 Feet

FIGURE 4-24
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS OF THE CONNECTICUT YANKEE HADDAN NECK PLANT AUGUST 22, 2004 17:15 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_8_04_HIGH.mxd BBODINSO 11/8/2004

C45



Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

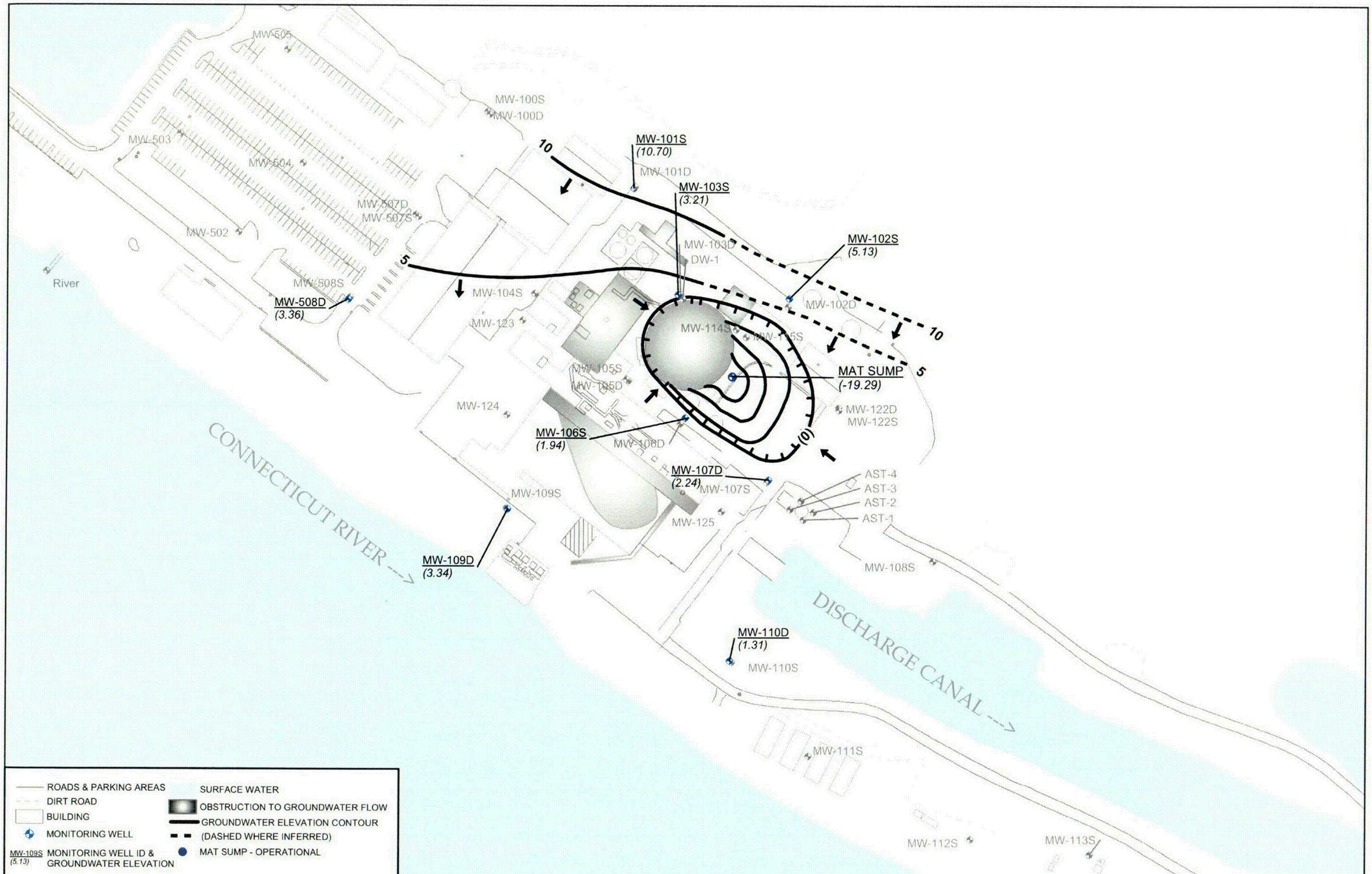
N

0 125 250 Feet

FIGURE 4-25
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS OF THE CONNECTICUT YANKEE HADDAN NECK PLANT AUGUST 22, 2004 11:15 LOW TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_8_04_Low.mxd BBODINSO 11/9/2004

C46



CH2MHILL

Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

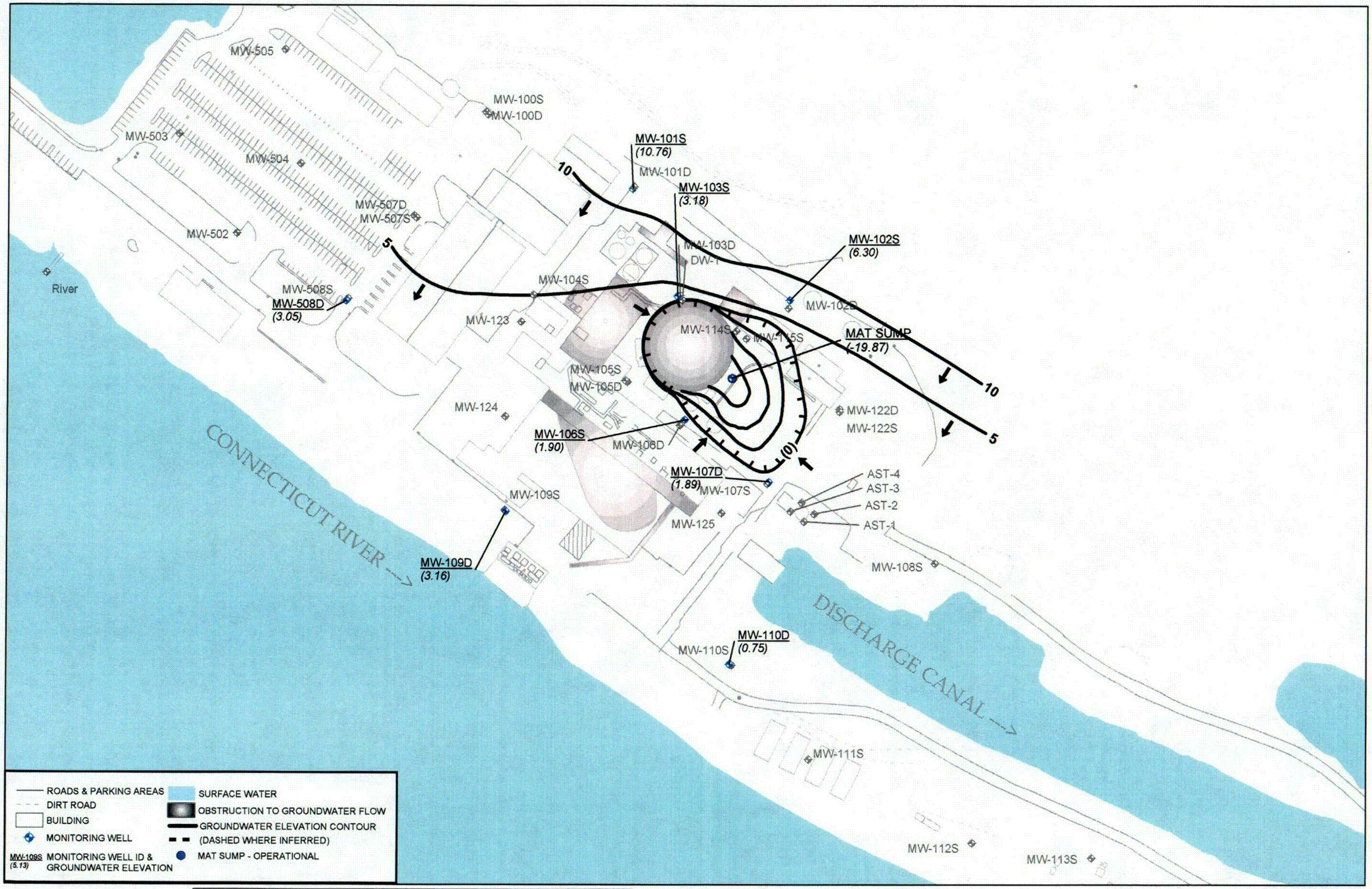
N

0 125 250 Feet

FIGURE 4-26
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT AUGUST 22, 2004 17:15 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_SHALLOW_BR_8_04_HIGH.mxd BBODINSO 11/8/2004

C47



CH2MHILL

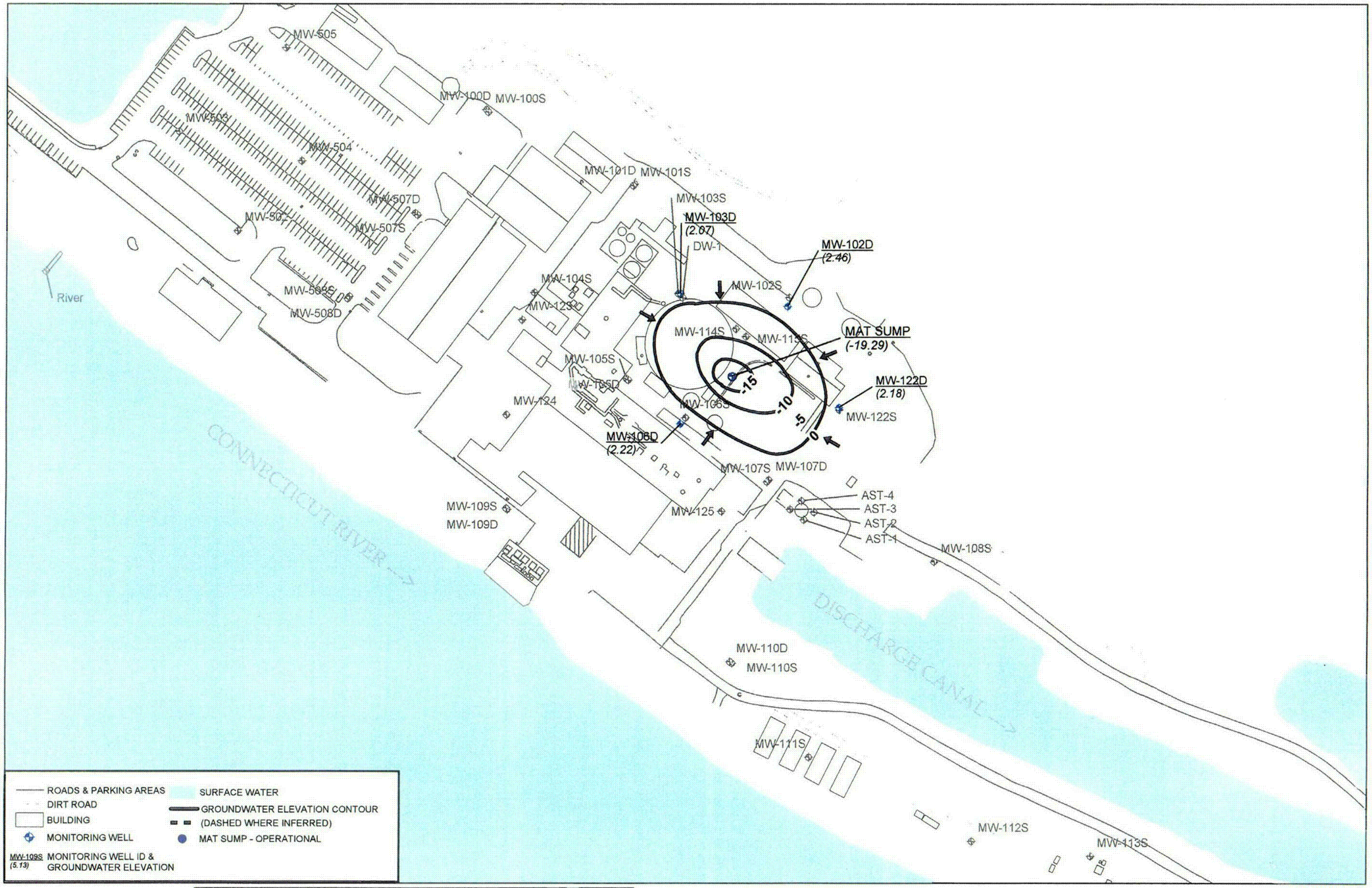
Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

N
0 125 250 Feet

FIGURE 4-27
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT AUGUST 22, 2004 11:15 LOW TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_SHALLOW_BR_8_04_Low.mxd BBODINSO 11/8/2004

C48



CH2MHILL

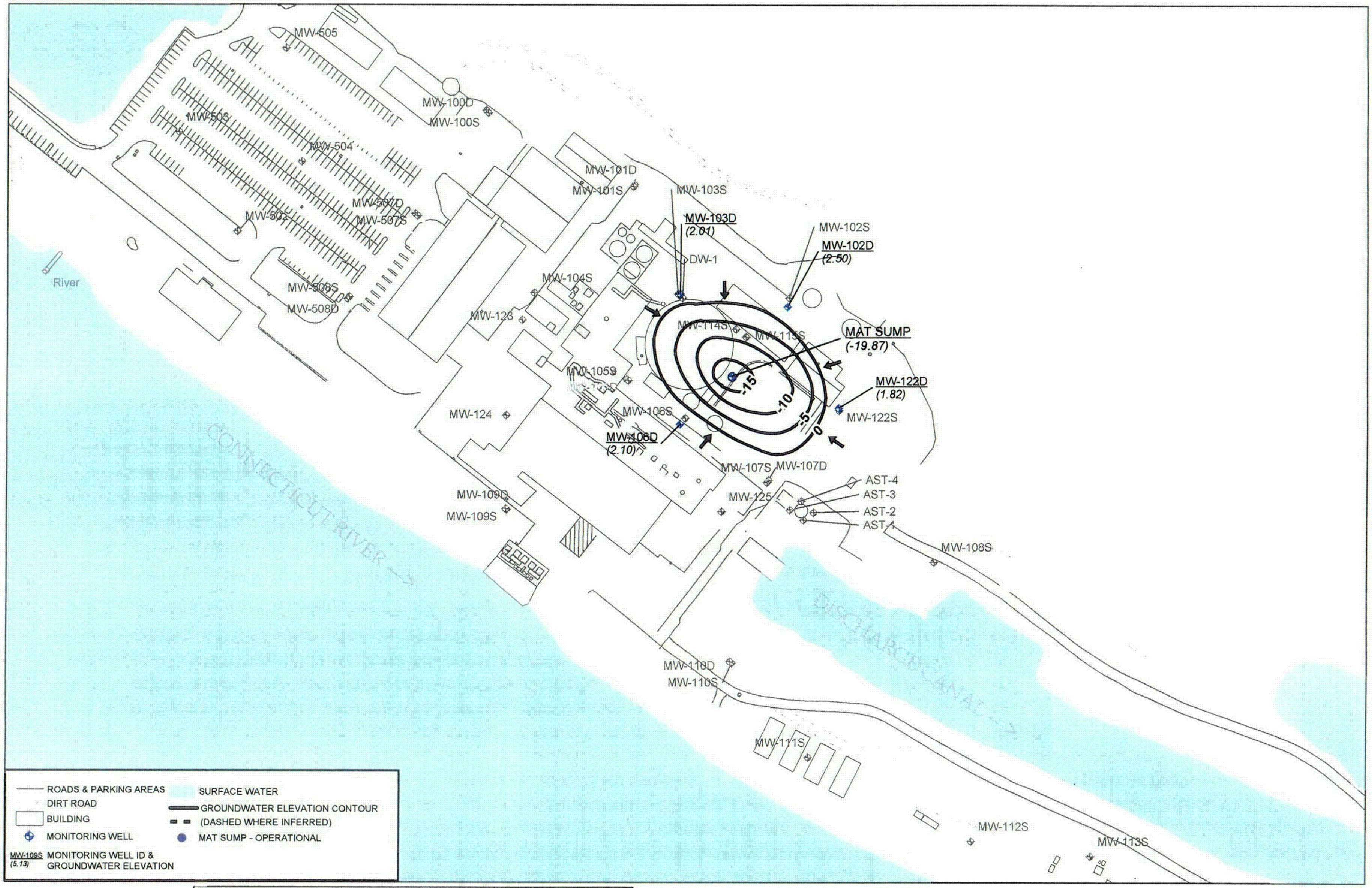
Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

N
0 125 250 Feet

FIGURE 4-28
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE DEEP BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT AUGUST 22, 2004 21:00 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_DEEP_BR_8_04_HIGH.mxd BBODINSO 11/8/2004

C49



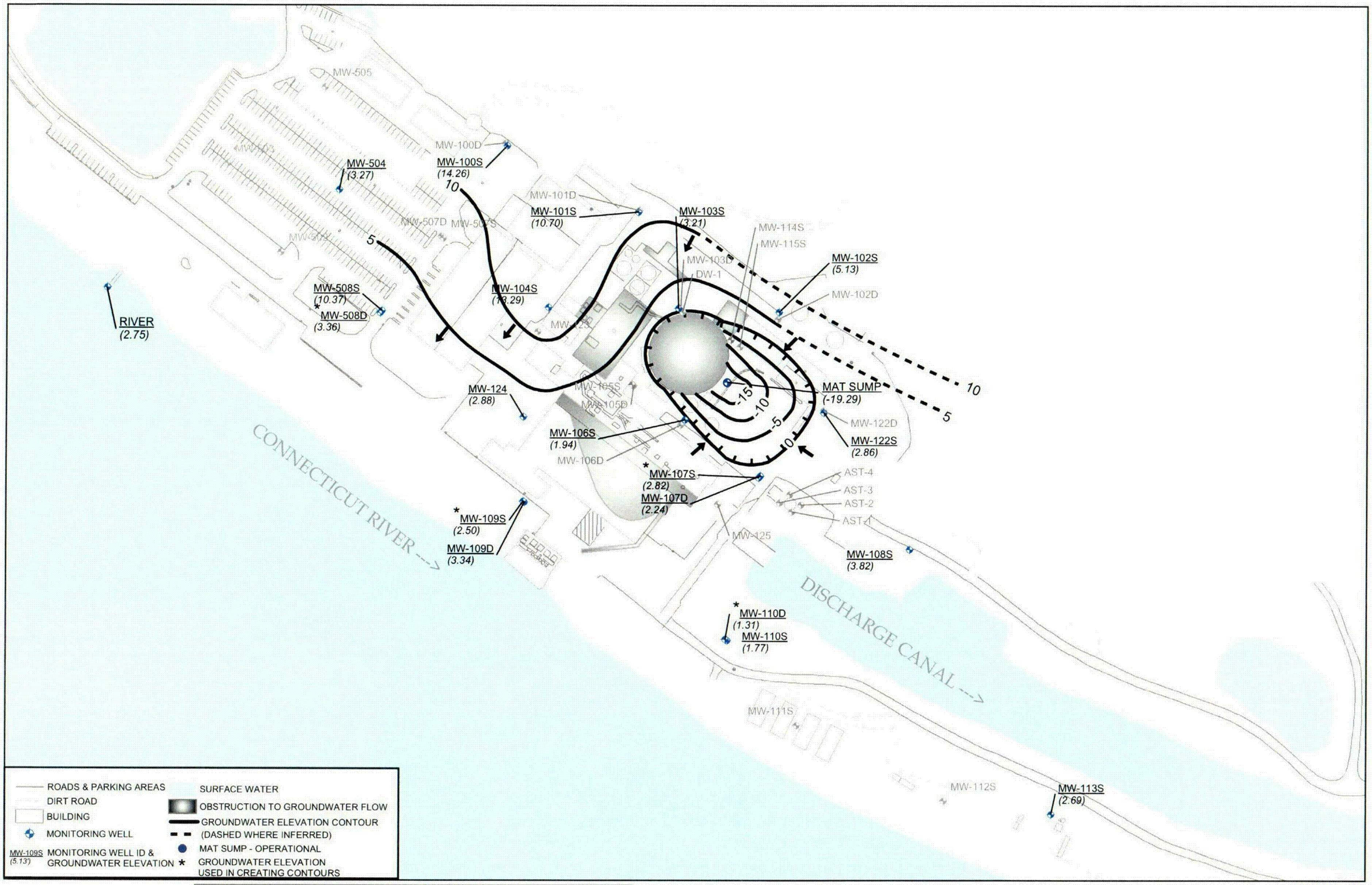
Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

FIGURE 4-29
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE DEEP BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT AUGUST 22, 2004 11:15 LOW TIDE
HADDAM NECK, CT

CH2MHILL

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_DEEP_BR_8_04_LOW.mxd BBODINSO 11/8/2004

C50



Shallow Bedrock Aquifer Assumptions

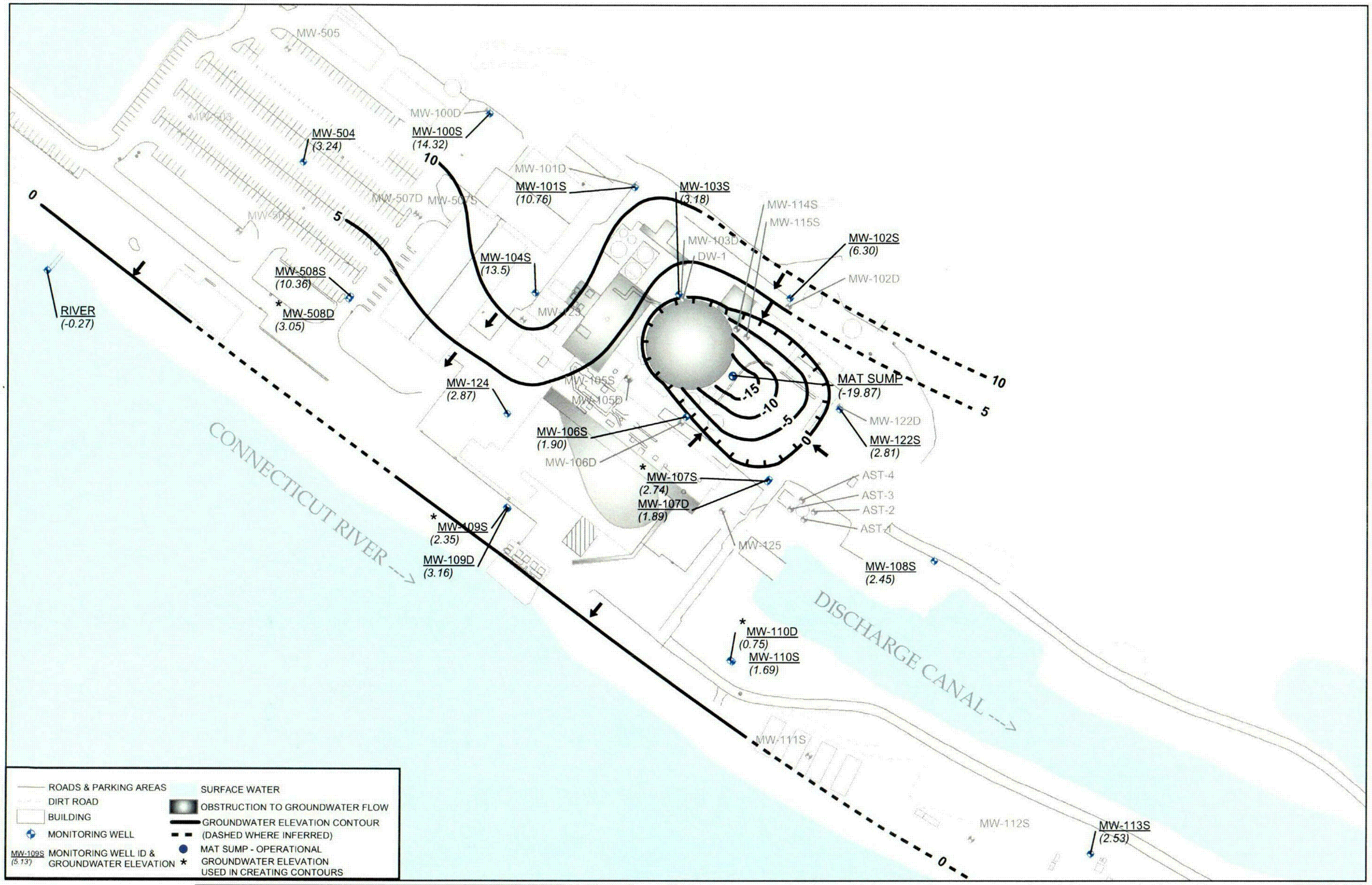
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

FIGURE 4-30
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS AND SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT AUGUST 22, 2004 17:15 HIGH TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_SHALLOW_BR_8_04_HIGH.mxd BBODINSO 11/9/2004

C51



Shallow Bedrock Aquifer Assumptions
1. The shallow bedrock interval is defined as the upper ten (10) feet of the bedrock interval.
2. The shallow bedrock interval may be comprised of partially weathered rock and/or may be more intensely fractured than the deep bedrock interval.
3. The shallow bedrock interval is highly heterogeneous and anisotropic.
4. Shallow bedrock yields water from both fractures and rock matrix porosity.

CH2MHILL

N

0 125 250 Feet

FIGURE 4-31
GROUNDWATER ELEVATION AND INFERRED CONTOURS AND FLOW DIRECTION IN THE UNCONSOLIDATED DEPOSITS AND SHALLOW BEDROCK OF THE CONNECTICUT YANKEE HADDAN NECK PLANT AUGUST 22, 2004 11:15 LOW TIDE
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\Pot_Map_UNCONSOLIDATED_SHALLOW_BR_8_04_Low.mxd BBODINSO 11/9/2004

C52

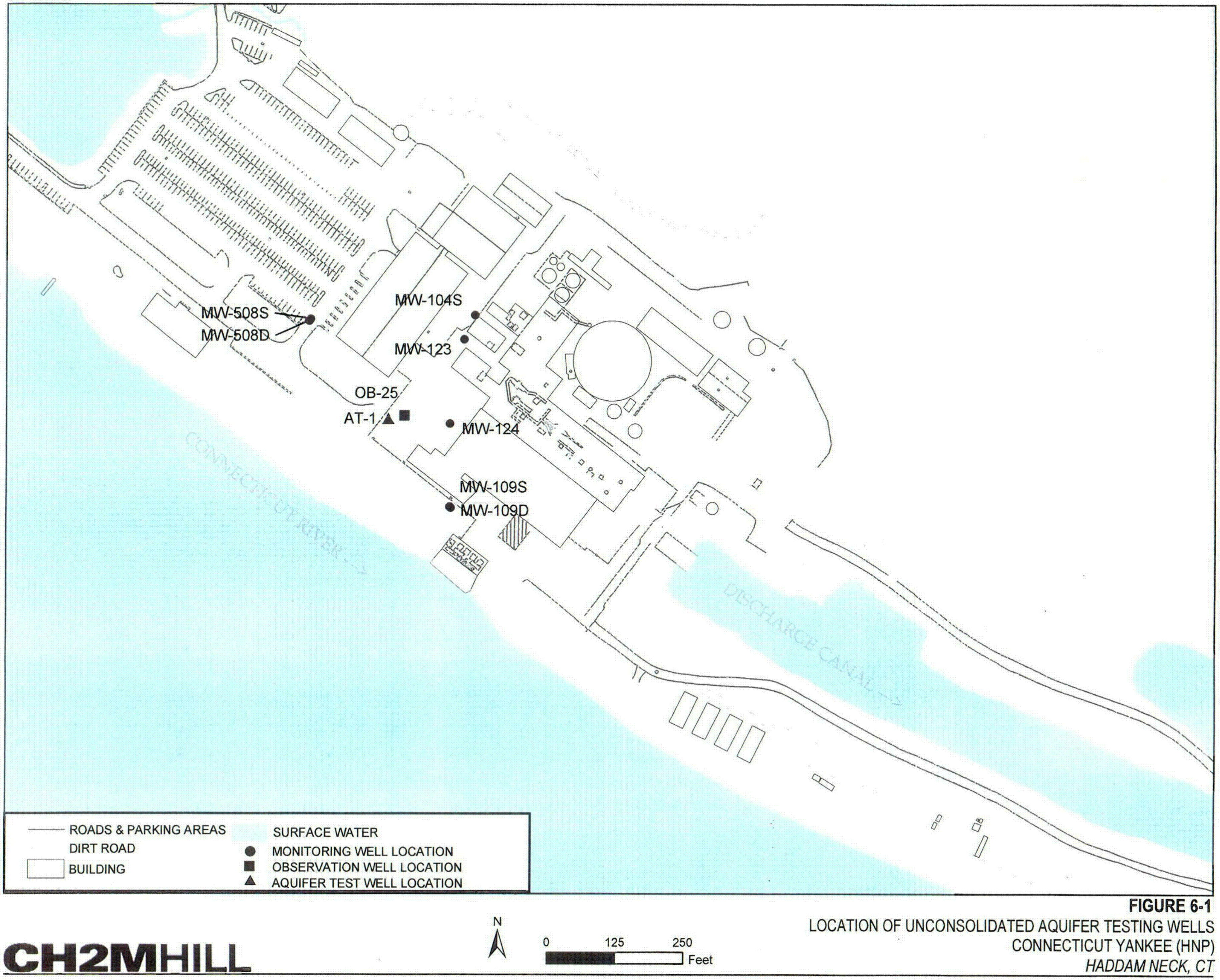


FIGURE 6-1
LOCATION OF UNCONSOLIDATED AQUIFER TESTING WELLS
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

\\boomer\H\projects3\CT_Yankee\MXD\GW_Monitoring_Report_9_04\AQUIFER_TEST_WELL.mxd JHenderson 10/7/2004

C53

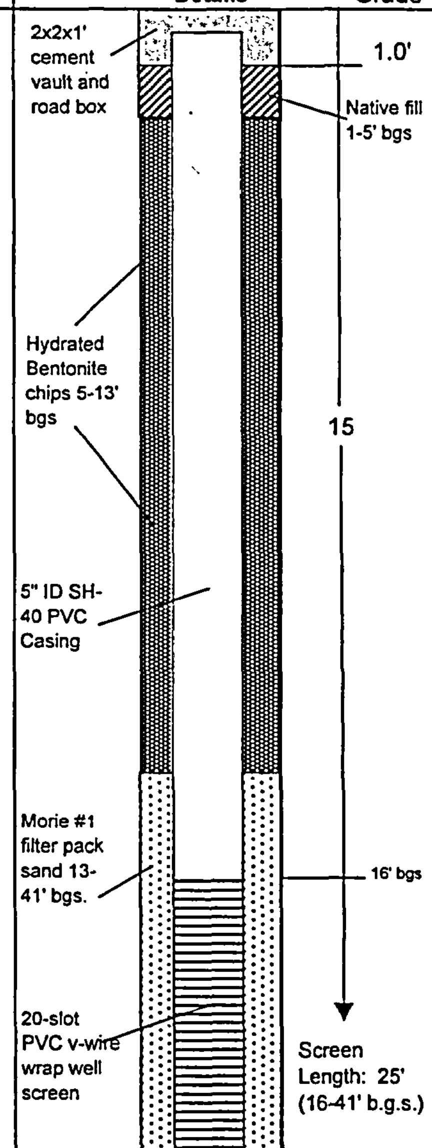
Figure 6-2

CYAPCO CY Decommissioning Project	Subsurface Log	Hole No.: AT-1 Sheet: 1 of 4	Date started: 09/07/2004 Date Finished: 09/09/2004

Client: Connecticut Yankee	Drilling method:	8 1/4" hollow stem auger (cut and wash, 4 inch inside diameter casing at depth below 32)	
Location: Haddam CT.	Sampling method:	Split spoon (140 lb hammer)	
Project No.: P. Manager: Charles Miller	Drilling Co.: ADT Geologist: Matt Darois	Driller: Marty Harrington D. Helper: Eric Ramey Drill Rig: B-59 and F-10	Weather:

Depth (ft.)	Sample No.	Sample Depth (ft.)	Sample Blows per 6"	Sample "N"	Sample Recovery (ft.)	Sample Description
	1	4-6'	4			Light brown m to f sand fill, no odor, dry.
			6			
			7			
			14			
6				13	1.4'	
	2	6-8'	20			6-7': same as above. 7-8' f to m dark brown silty sand, trace m gravel. Buried A/B horizon (native fill), no odor, dry.
			21			
			32			
			41			
8				53	1.35'	
	3	8-10'	25			8-9.7': 1" of black organics rich sand at aprox 8'. Fine to vf red-brown silty sand with trace m-f gravel. 2 medium size amphibolite gneiss cobbles from 9-9.5', moist, no odor. 9.7-10': abrupt change in lithology to a light brown m to f sand, trace silt, poorly sorted, slight iron staining at the lithologic contact, slightly moist, no odor.
			24			
			37			
			54			
				61	1.4'	
10						
	4	10-12'	22			light brown-red m to f sand, coarser and more sorted than above. Coarse gravel fragments at 10.3', dry, no odor.
			37			
			57			
			31			
12				94	1.3'	
	5	12-14'	11			Red-brown m to fine sand, well sorted, trace rounded medium gravel, dry, no odor, very loose (similar to above).
			11			
			12			
			12			
16				23	1.4	
	6	14-16'	12			Same as above.
			10			
			12			
			11			
				22	1.2	

Well Details — Grade



Sample Types:

S=Split Spoon: 2" dia. T= Shelby Tube: ______

R= Rock Core: ______ O = ______

Backfill Well Key

Concrete — Native Fill

Sand — Bentonite

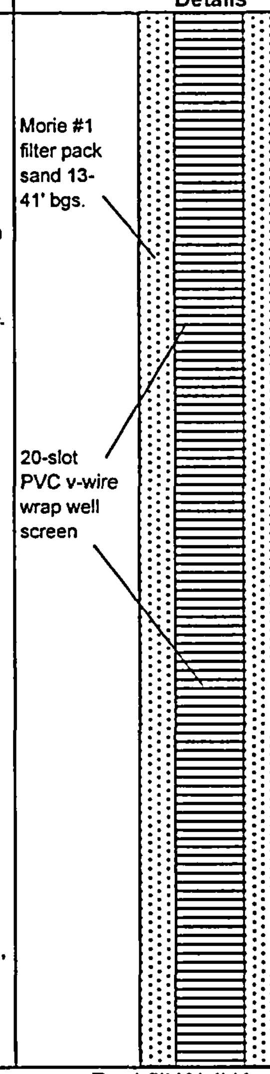
KEY: AND= 50%, SOME=49-30%, LITTLE=29-10%, TRACE=<10% C= COARSE, M= MEDIUM, F= FINE

N = ASTM D1586

CYAPCO CY Decommissioning Project	Subsurface Log	Hole No.: AT-1 Sheet: 2 of 4	Date started: 09/07/2004 Date Finished: 09/09/2004
Client: Connecticut Yankee Location: Haddam CT.	Drilling method: 8 1/4" hollow stem auger (cut and wash, 4 inch inside diameter casing at depth below 32) Sampling method: Split spoon (140 lb hammer)		
Project No.: P. Manager: Charles Miller	Drilling Co.: ADT Geologist: Matt Darois	Driller: Marty Harrington D. Helper: Eric Ramey Drill Rig: B-59 and F-10	Weather:

Depth (ft.)	Sample No.	Sample Depth (ft.)	Blows per 6"	"N"	Recovery (ft.)	Sample Description
	7	16-18'	5			Similar to above, bottom 0.25' of spoon is wet, sub angular m to f gravel lodged in tip of shoe.
			7			
			7			
			10			
18				14	1.25'	
	8	18-20'	14			Gray-brown m to fine sand, sand is micacious (abundant feldspar frags.), trace sub angular fine gravel, saturated, no odor.
			6			
			4			
			5			
20				10	1.1'	
	9	20-22'	2			Gray m to f sand, well sorted, less feldspar-mica than above, saturated, no odor.
			2			
			5			
			6			
22				7	1.0'	
	10	22-24'	15			Same as above.
			10			
			12			
			15			
24				22	1.2'	
	11	24-26'	16			Same as above, Bottom 0.1' f to m red to light brown sand, trace silt, wet, no odor.
			26			
			21			
			20			
26				47	1.8'	
	12	26-28'	7			red-brown fine sand, firm, well sorted, wet, no odor.
			22			
			33			
			34			
28				55	1.8'	
	13	28-30'	4			Red-brown fine sand, less firm than above, well sorted, no coarser grained materials in sample.
			15			
			20			
			18			
				35	1.5'	

Well Details



Sample Types:
S=Split Spoon: 2" dia. T= Shelby Tube:
R= Rock Core: O =

Backfill Well Key: Concrete, Sand, Native Fill, Bentonite

N = ASTM D1586

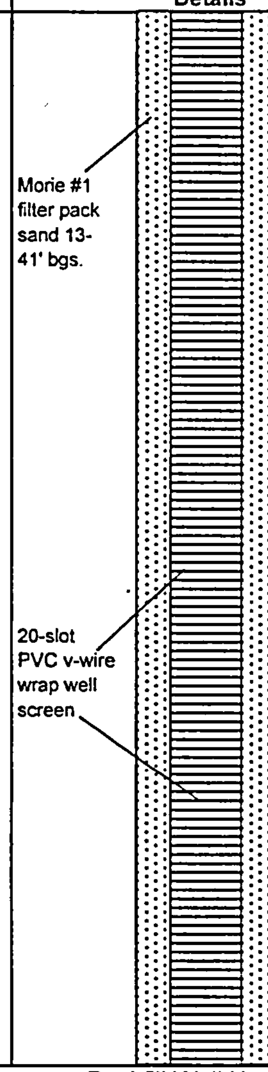
KEY: AND= 50%, SOME=49-30%, LITTLE=29-10%, TRACE=<10% C= COARSE, M= MEDIUM, F= FINE

CYAPCO CY Decommissioning Project	Subsurface Log	Hole No.: AT-1 Sheet: 3 of 4	Date started: 09/07/2004 Date Finished: 09/09/2004

Client: Connecticut Yankee	Drilling method: 8 1/4" hollow stem auger (cut and wash, 4 inch inside diameter casing at depth below 32)
Location: Haddam CT.	Sampling method: Split spoon (140 lb hammer)
Project No.:	Drilling Co.: ADT
P. Manager: Charles Miller	Geologist: Matt Darois
Driller: Marty Harrington	Weather:
D. Helper: Eric Ramey	
Drill Rig: B-59 and F-10	

Depth (ft.)	Sample No.	Sample Depth (ft.)	Sample Blows per 6"	Sample "N"	Sample Recovery (ft.)	Sample Description
	14	30-32'	5			Same as above.
			12			
			23			
			33			
32				35	1.5'	
						Flowing sands at aprox. 30' b.g.s. sand locked the 4.25" augers. The augers were removed from the boring and drilling was advanced using drive and wash inside 4" temp casing.
	15	32-34'	15			m to f red-brown sand , firm, trace fine subangular gravel, trace silt. Less sorted than above, no odor.
			23			
			26			
			28 .			
34'				49	1.1'	
	16	34-36'	18			f to m red-brown sand, some silt, some m to f rounded sub angular gravel (basalt frags.), no odor, angular sand stone coarse gravel frag in top of spoon @ apron 34' bgs, firm.
			25			
			29			
			41			
36'				54	1.15'	
	17	36-38'	16			f to m red-brown sand, some silt, trace fine sub angular gravel, trace rounded gravel, sorted to poorly sorted, less firm than above, no odor.
			18			
			21			
			21			
38'				39	1.0'	
	18	38-40'	17			f to m silty red brown sand, some fine subangular gravel, poorly sorted, no odor. Gravel consists of basalt, red sandstone and quartz-albite frags.
			18			
			16			
			17			
40'				34	1.25'	

Well Details



Sample Types:
S=Split Spoon: 2" dia.   T= Shelby Tube: ______
R= Rock Core: ______   O = ______

Backfill Well Key
Concrete   Native Fill
Sand   Bentonite

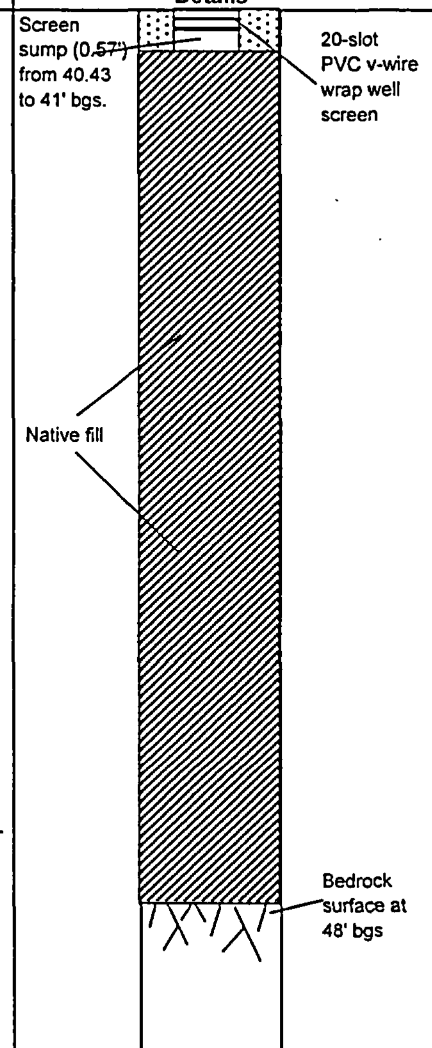
KEY: AND= 50%, SOME=49-30%, LITTLE=29-10%, TRACE=<10% C= COARSE, M= MEDIUM, F= FINE

N = ASTM D1586

CYAPCO CY Decommissioning Project	**Subsurface Log**	**Hole No.:** AT-1 **Sheet:** 4 of 4	**Date started:** 09/07/2004 **Date Finished:** 09/09/2004
Client: Connecticut Yankee **Location:** Haddam CT.	**Drilling method:** 8 1/4" hollow stem auger (cut and wash, 4 inch inside diameter casing at depth below 32) **Sampling method:** Split spoon (140 lb hammer)		
Project No.: **P. Manager:** Charles Miller	**Drilling Co.:** ADT **Geologist:** Matt Darois	**Driller:** Marty Harrington **D. Helper:** Eric Ramey **Drill Rig:** B-59 and F-10	**Weather:**

Depth (ft.)	Sample No.	Sample Depth (ft.)	Blows per 6"	"N"	Recovery (ft.)	Sample Description
	19	40-42'	10			Top 0.65' of spoon (40-41.5') silty f red-brown sand, dry. Bottom 0.5' of spoon: Abrupt change in lithology to Till, brown to Dark brown moist, abundant rounded to subangular coarse sand and fine gravel consisting of weathered gneiss and basalt frags, till is loose consisting of more course groined materials than fines, fine fraction of till is dark brown to black in color. Dark color material in till fines may be organic silts/clays.
			15			
			24			
			19			
42				39	1.15'	
	20	42-44'	26			42-43.6' bgs: same as above. Bottom of spoon transitions to a brown sandy silt some angular to subangular f to m gravel, some clay. 43.6-44' bgs: glacio-fluvial deposits consisting of 1-2" lenses of brown sandy silty, some angular to subangular f to m gravel, some clay (20-30% clayey silt) and red clayey silt (25-35% clay) lenses 1 -2" thick with trace subangular medium gravel. Gravel within glacio-fluvial deposits are predominately gneiss frags, material is firm to dense, moist evidence of redox and Iron staining throughout sample.
			25			
			32			
			26			
44				57	1.1'	
	21	44-46'	25			Till, light brown to olive brown sandy dense till. Abundant angular to subangular m to c gravel, abundant m cobbles, gravel and cobble fraction consists of quartz-albite and gneiss frags throughout sample. 0.1' lens of red clayey silt at aprox 44.5' bgs embedded in till, moist, till is mottled with evidence of Redox and Iron staining.
			32			
			59			
			70			
46'				91	1.1	
	22	46-48'	57			Top of spoon: Till, light gray to olive-brown till and weathered rock, abundant coarse gravel and cobble frags consisting of gneiss and albite-quartz, 0.1' layer of red-brown clayey silt at aprox 47' above albite-quartz cobble/weathered rock frag. Sample may be weathered bedrock with more resistant rock remaining as gravel and cobble frags. The matrix of the finer grained materials consists of biotite, quartz and albite (pegmatite) indicative of the regional bedrock formation. Sample is dense, moist. Refusal at 48' bgs
			53			
			62			
			100/3"			
48'				115	1.25	

Well Details



Sample Types:
S=Split Spoon: 2" dia. T= Shelby Tube: ______
R= Rock Core: ______ O = ______

N = ASTM D1586

Backfill Well Key
Concrete / Native Fill
Sand / Bentonite

KEY: AND= 50%, SOME=49-30%, LITTLE=29-10%, TRACE=<10% C= COARSE, M= MEDIUM, F= FINE

Figure 6-3
Step Drawdown Test

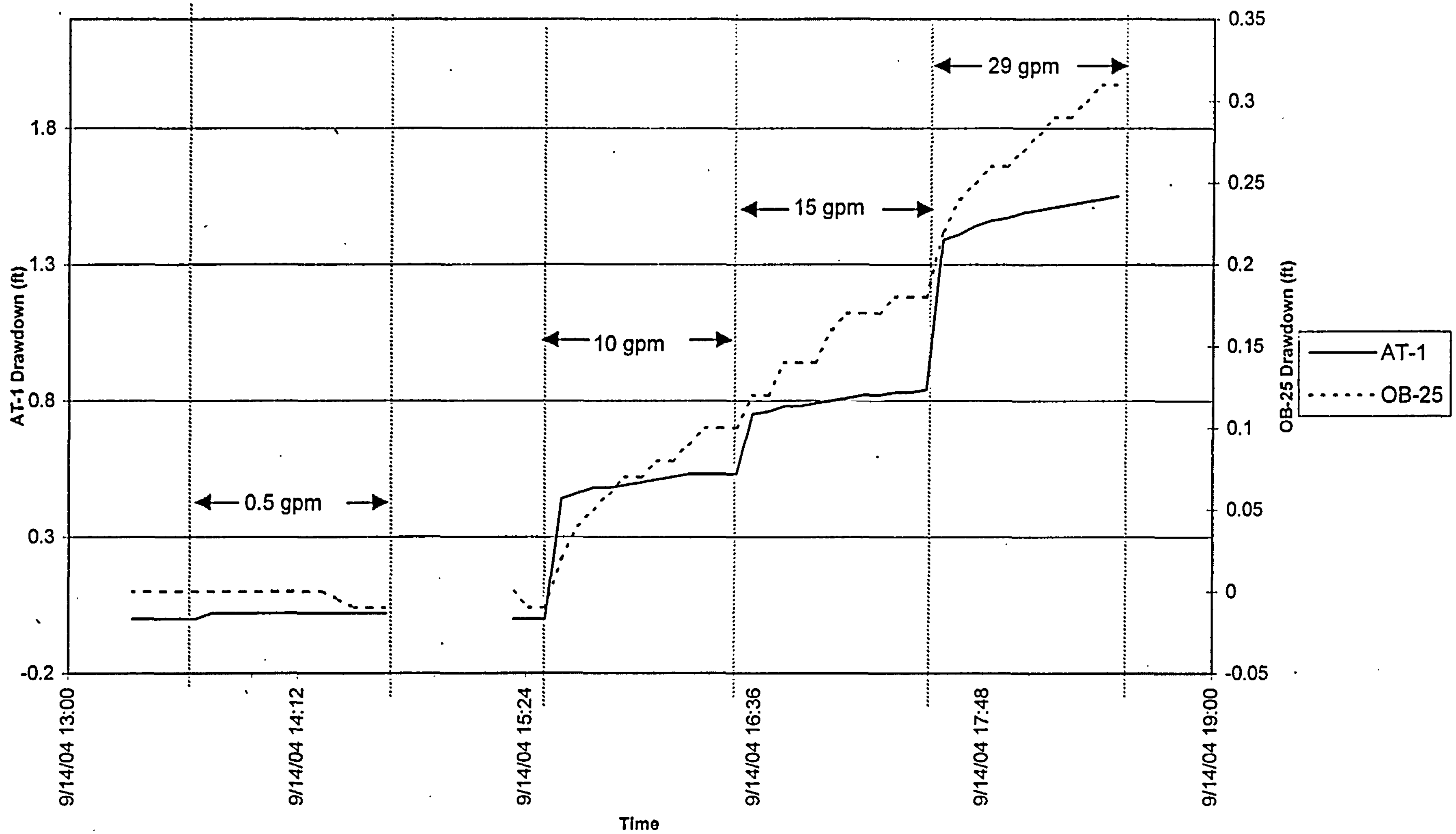


Figure 6-4
AT-1 Response to Constant-Rate Pumping Test
September 2004

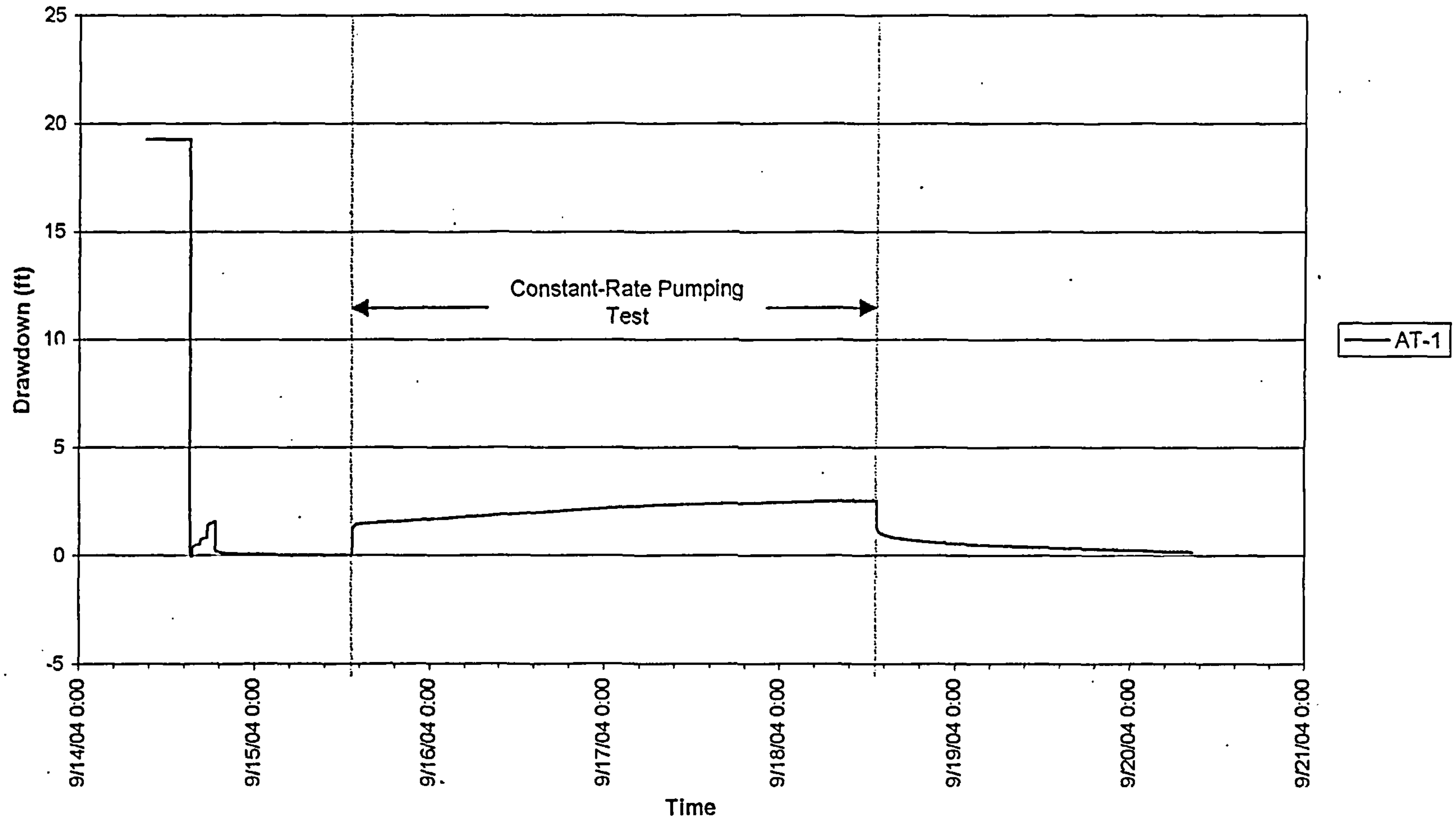


Figure 6-5
OB-25 Response to Constant-Rate Pumping Test
September 2004

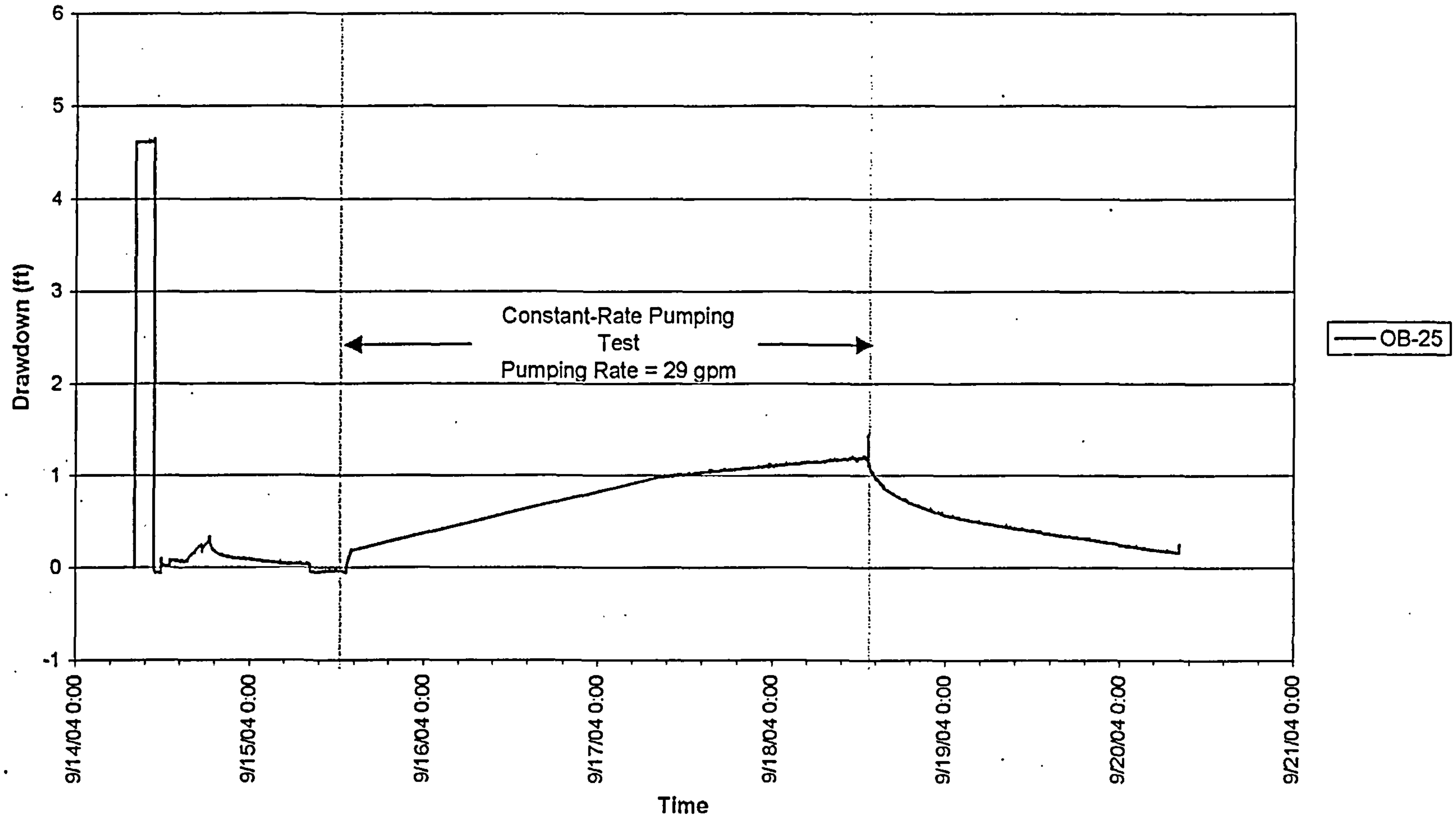


Figure 6-6
MW-104 Response to Constant-Rate Pumping Test
September 2004

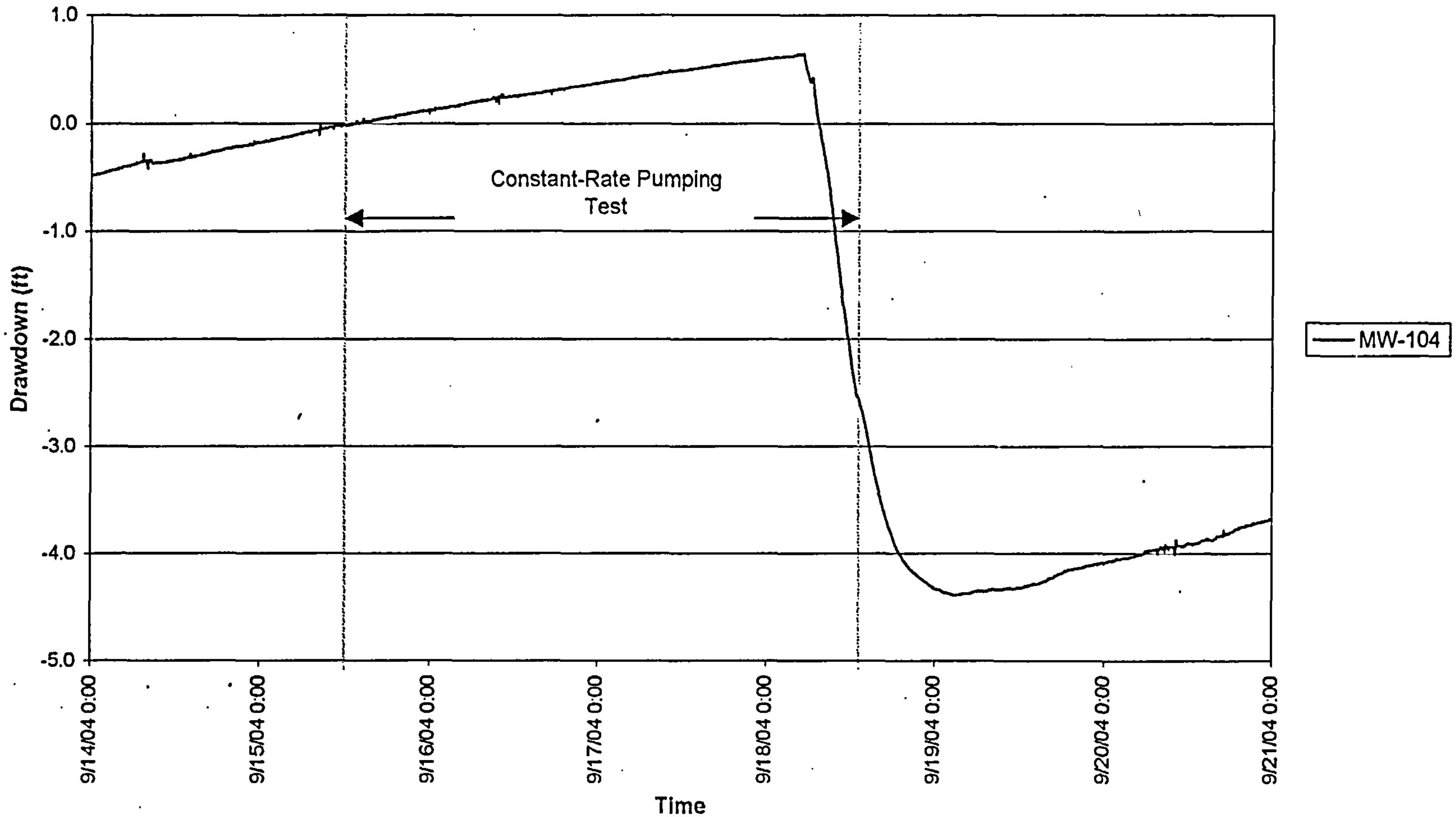


Figure 6-7
MW-508D Response to Constant-Rate Pumping Test
September 2004

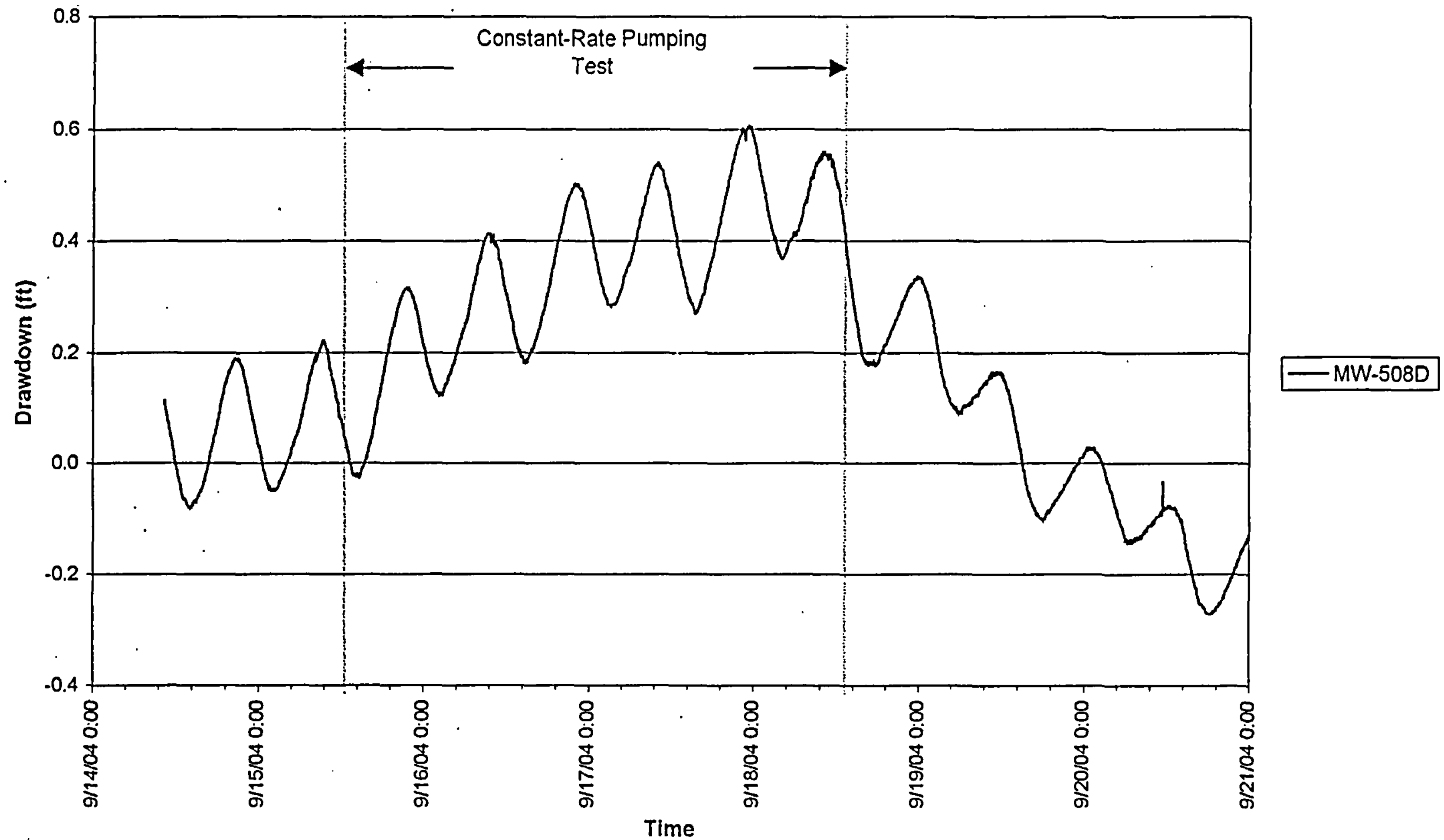


Figure 6-8
MW-508S Response to Constant-Rate Pumping Test
September 2004

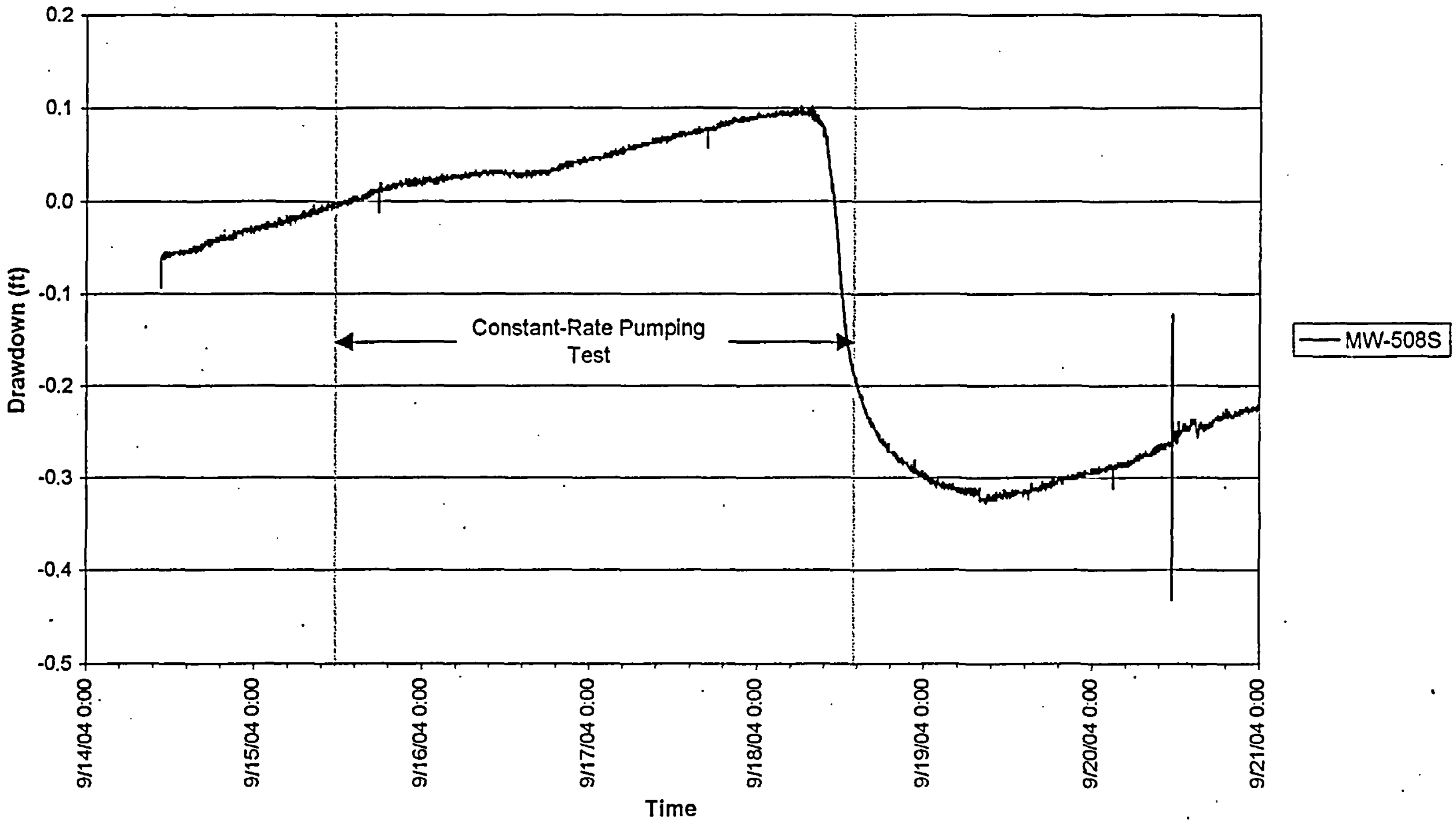


Figure 6-9
MW-123 Response to Constant-Rate Pumping Test
September 2004

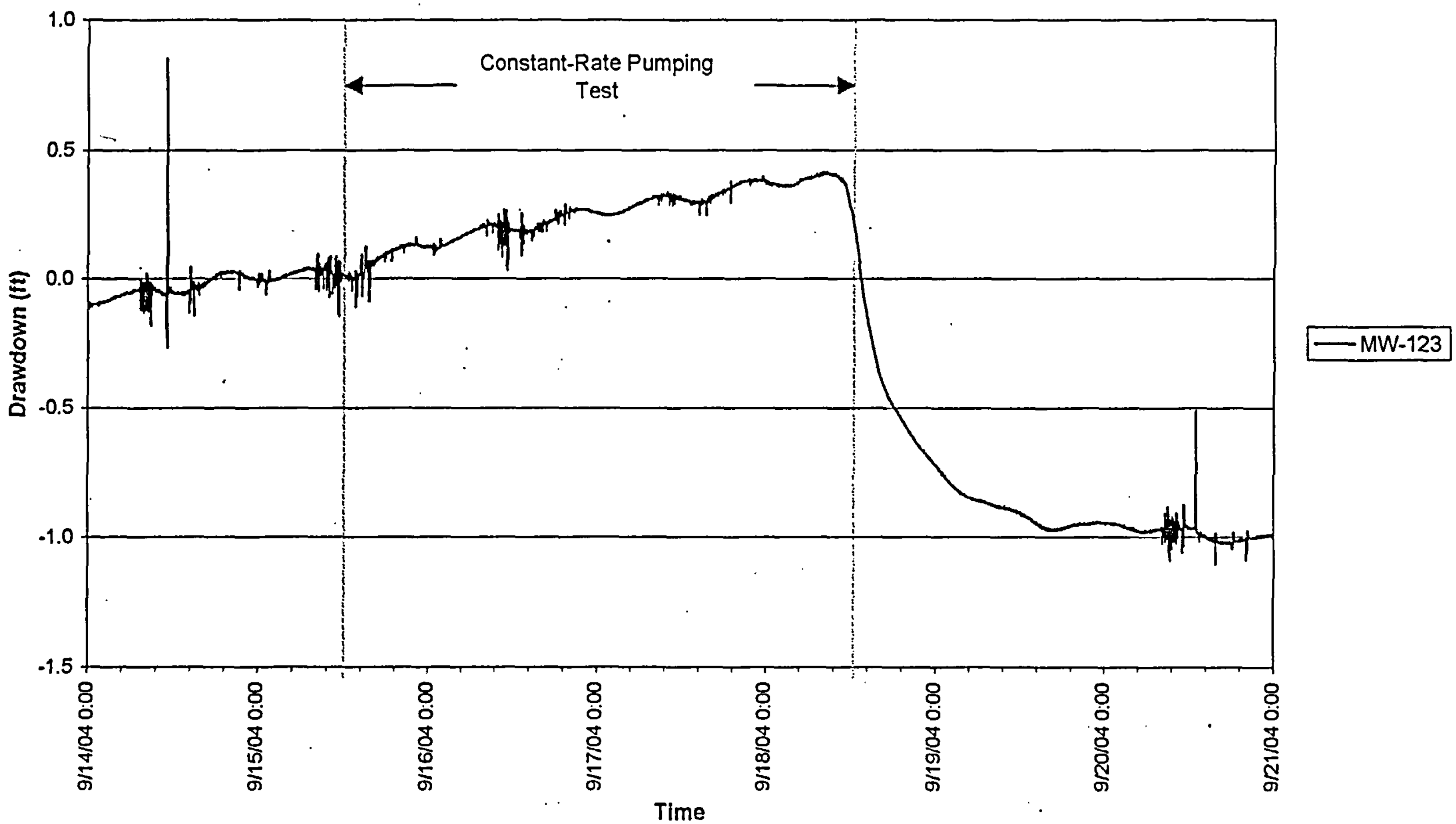


Figure 6-10
MW-124 Response to Constant-Rate Pumping Test
September 2004

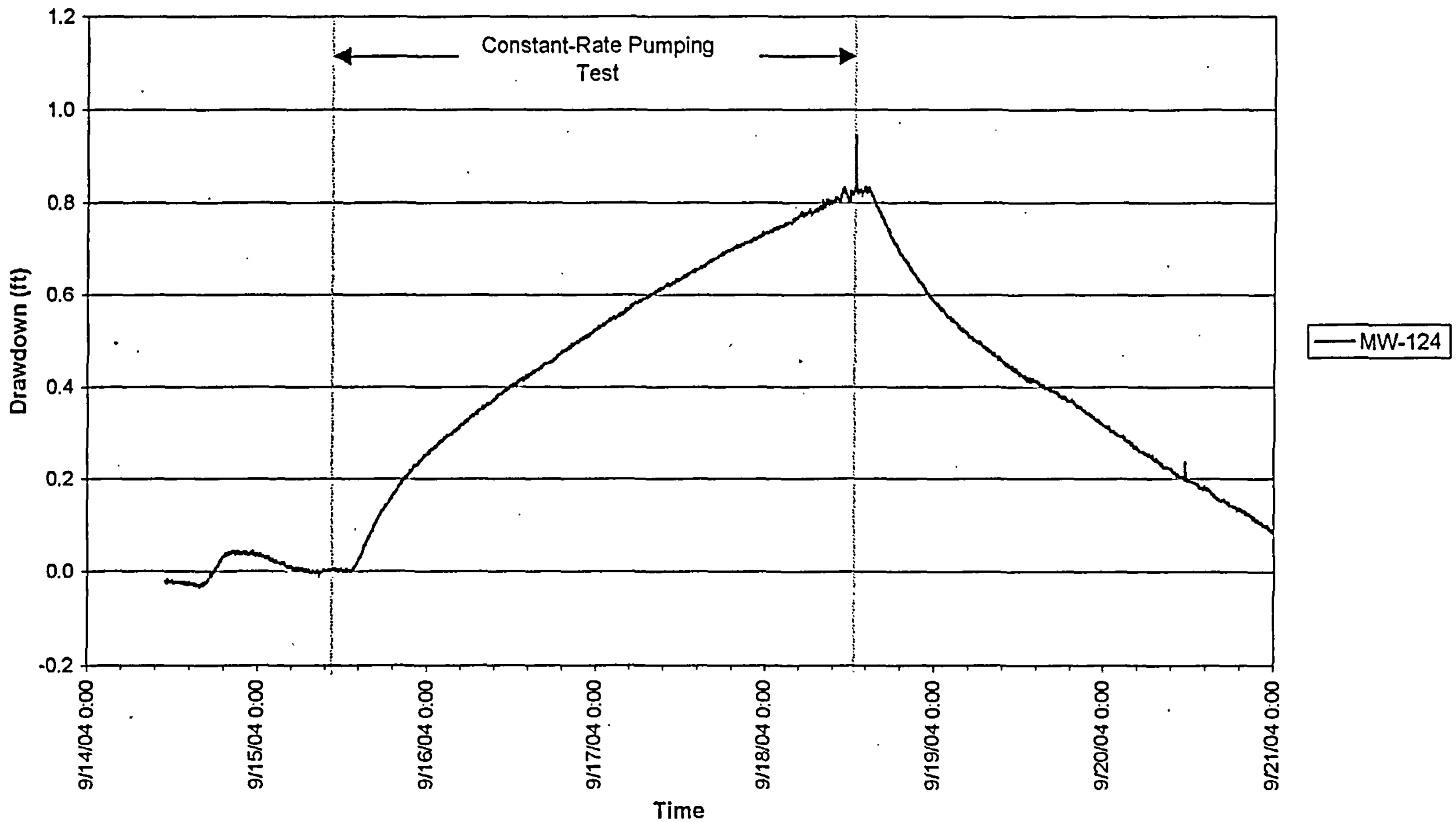


Figure 6-11
MW-109D Response to Constant-Rate Pumping Test
September 2004

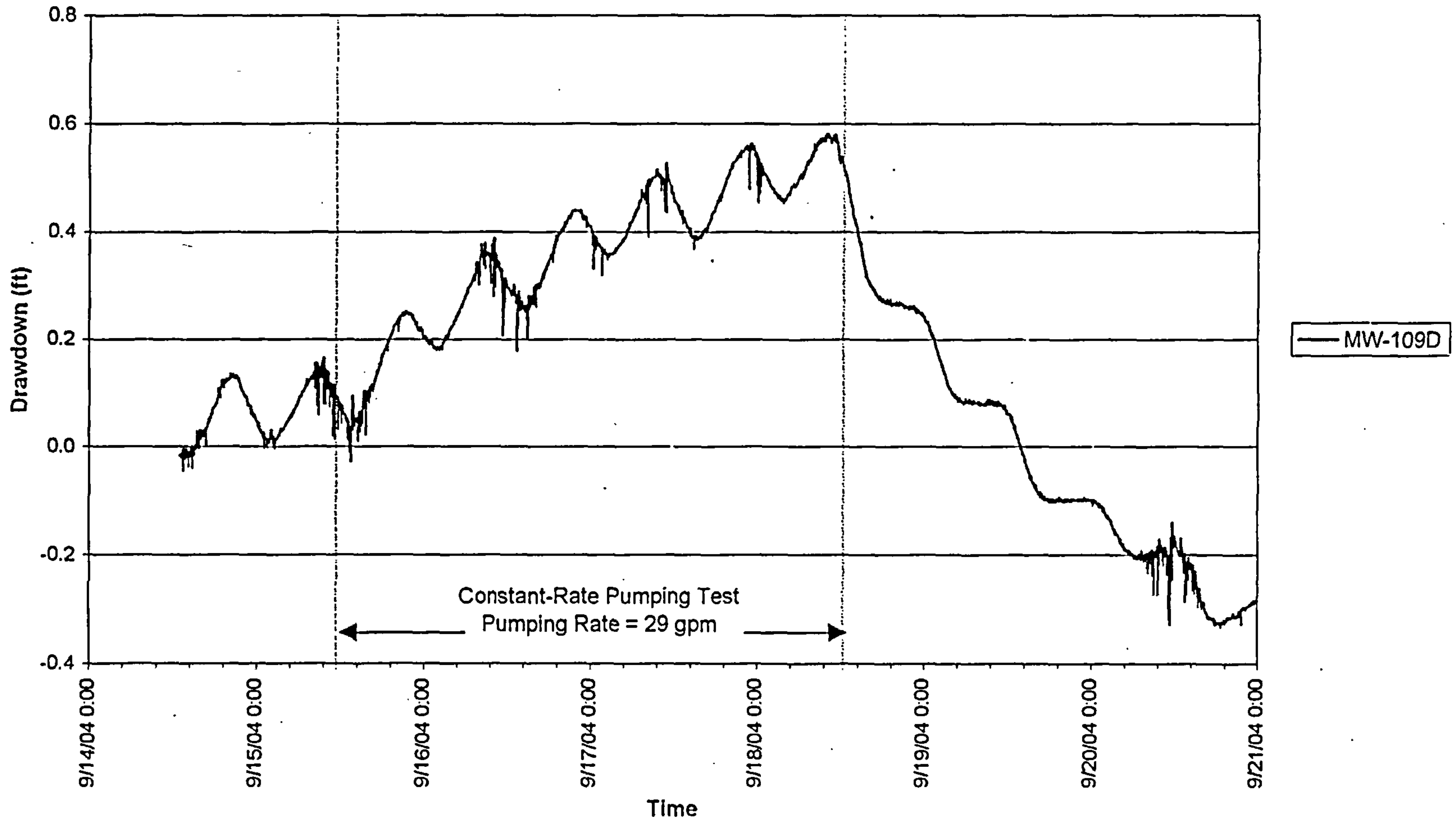
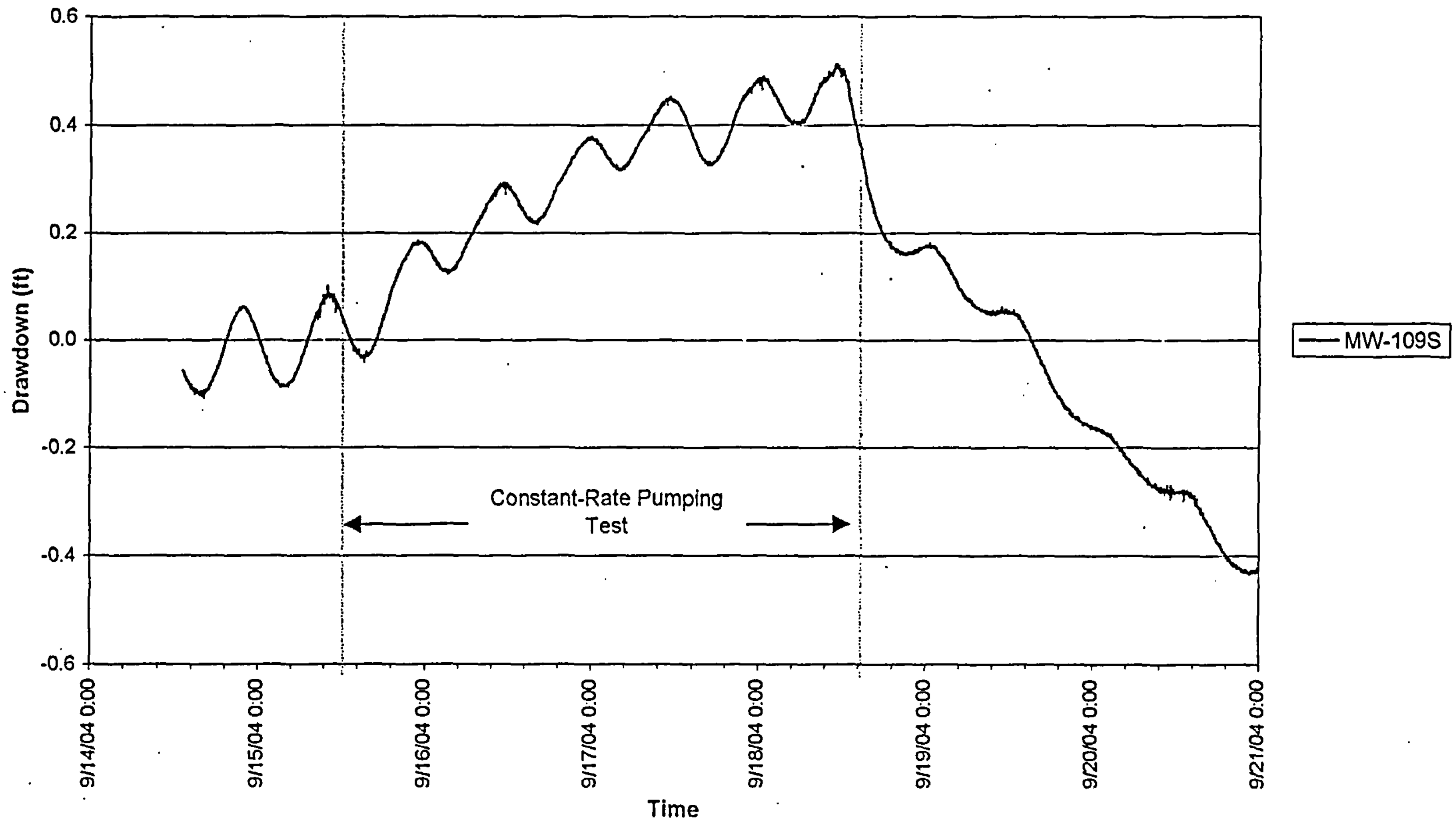


Figure 6-12
MW-109S Response to Constant-Rate Pumping Test
September 2004



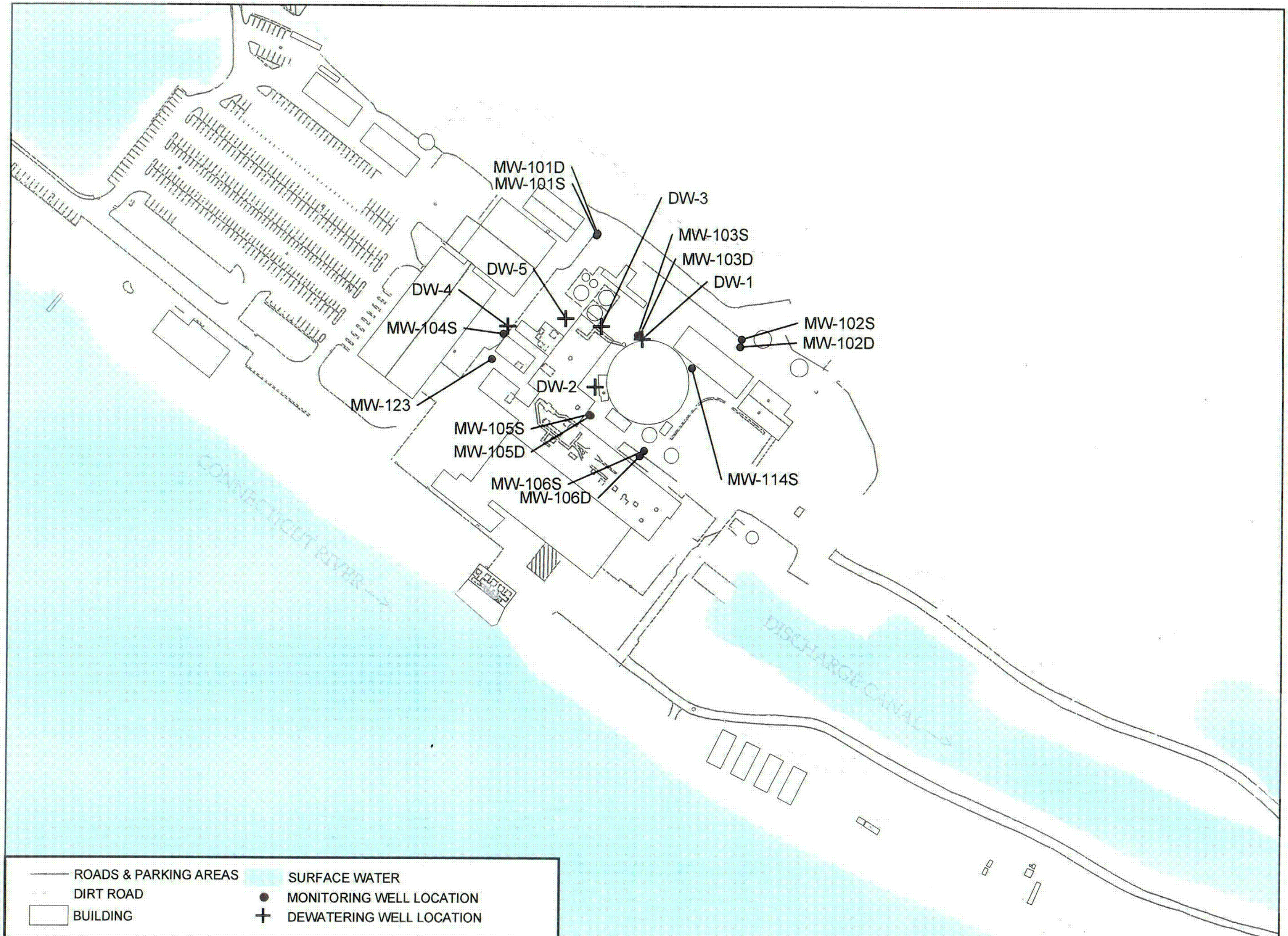


FIGURE 6-13
LOCATION OF DEWATERING WELLS AND PROXIMAL MONITORING WELLS
CONNECTICUT YANKEE (HNP)
HADDAM NECK, CT

CH2MHILL

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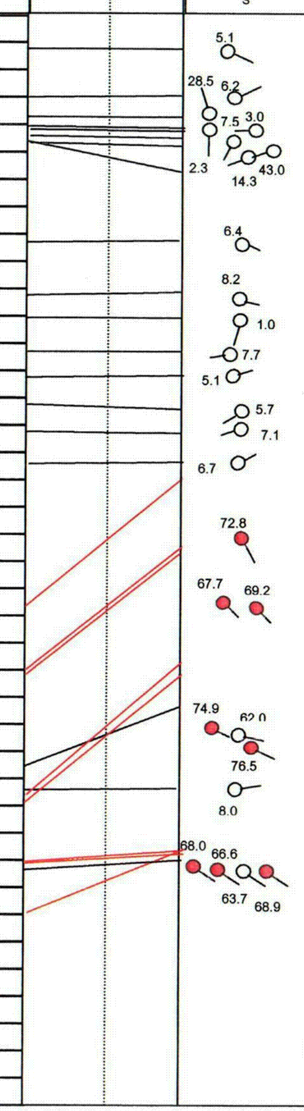
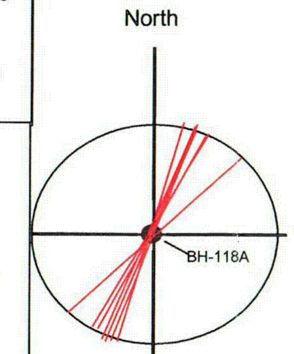
C54

Figure 7-1 Summary Of Borehole 118A Bedrock Characterization.
Packer Testing, Hydrophysics, Geophysics.

Depth (ft bgs) 6 Inch Steel Casing Set To 18 Feet BGS	Hydrophysical Tritium Concentrations (pCi/L) From HNP Onsite Laboratory	Producing Zones Identified With Hydrophysics* (ft bgs)	Hydrophysical Estimated Ambient Flow (gpm)	Hydrophysical Estimated Flow During Pumping (gpm)	Packer Testing Yield[1] (Pack Interval), **gpm**	Proposed Discrete Monitoring Intervals. (ft bgs)
15					(3 - 24): **<0.01**	
30	1850	29.8 - 30.2	0.000	3.81		25 - 35
45	8,550	45.9 - 46.1	0.001	0.185	(22-45): **11.24**	
60	7,330	63.9 - 65.0	0.002	0.238	(43-66): **>10**	45 - 65
75	6,300; 4,290	68.3-68.4; 73.9-74.0	0.000	0.132, 0.211		
90						
105	2,790	101.8 - 101.9	0.000	0.048	(85-108): **0.14**	
120	3,390	113.9 - 114.5	0.002	0.053		100 - 130
135	2,550	127.8 - 128.0	0.003	0.106		
150						
165	NS	161.7 - 161.8	0.000	0.008	(148-171): **>5**	150 - 165
180					(154-177): **>10**	
195	NS	187.2 - 187.3	0.000	0.005		
210	NS	206.0 - 206.1	0.000	0.004		
225	NS	219.8 - 219.9	0.001	0.003		
240	NS	238.5 - 238.6	0.000	0.005		225 - 240
255					(238-261): **0.01**	
270						
285						
300						
315						
330						
345						
360						
375						
390						
405						
420					(274-570): <0.01	
435						
450						
465						
480						
495						
510						
525						
540						
555						
570						
TD: 578'						

Proposed Discrete Monitoring Intervals. | Borehole Fracture Trace[2] (Cross Section Of Borehole Looking South) | Approximate Dip Direction and Angle[2]





Plot shows strike of high angle fractures (~70°) in red intercepted by the borehole.[2]

*Detectable flow during ambient conditions
*Detectable flow during pumping conditions

Ft bgs= Feet below ground Surface
NS= Not Sampled
GPM= Gallons per minute

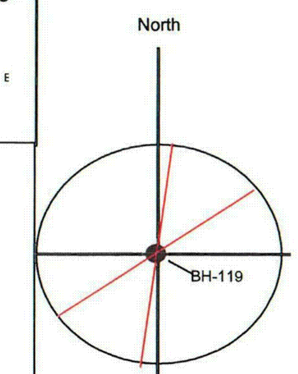
[1] Packer testing derived yield values are calculated by measuring the recharge of a packer interval after evacuating the water from the zone. (2003 packer testing)

[2]Borehole fracture trace and dip direction analysis shows all fractures identified as "Hydraulically-active" based on conventional geophysics and fluid logs. These interpretations are subjective judgment based upon available data (Geophysical Applications, 2003). Hydrophysical logging data from COLOG, 2004 Indicates fractures with dip angles aproximately 65 degrees or greater

C55

Figure 7-2 Summary Of Borehole 119 Bedrock Characterization.
Packer Testing, Hydrophysics, Geophysics.

Depth (ft bgs) 6 Inch Steel Casing Set To 40 Feet BGS	Hydrophysical Tritium Concentrations (pCi/L) From HNP Onsite Laboratory	Producing Zones Identified With Hydrophysics* (ft bgs)	Hydrophysical Estimated Ambient Flow (gpm)	Hydrophysical Estimated Flow During Pumping (gpm)	Packer Testing Yield[1] (Pack Interval), gpm	Proposed Discrete Monitoring Intervals. (ft bgs)	Proposed Discrete Monitoring Intervals.	Borehole fracture trace[2] (Cross section of borehole looking south)	Approximate Dip Direction and angle[2]
40									
55	7,550	47.3 - 47.4	0.003	0.158	(42-65): no data	45-55			
70									
85	7,340	74.4 - 74.5		0.169	(63-86): no data	70-90			
100	5,540	85.2 - 88.8	0.001	0.438	(85-107): no data				
115									
130					(115-128): no data				
145					(126-149): no data				
160	2,186	147.8 - 148.9		0.251		155-165			
175	1,520	160.0 - 160.3	0.001	0.273	(143-166): no data				
190	NS	178.4 - 184.0		0.008	(170-193): **0.03**				
205					(191-214): **0.04**				
220									
235					(212-235): **0.11**				
250	NS	236.0-236.1, 241.2-241.4		0.002, 0.003	(233-256): **0.01**				
265	<1,100, NS	253.0-254.5, 262.2-263.8		0.013, 0.004		250-265			
280					(254-277): **<0.01**				
295	NS	288.1 - 288.3		0.002	(275-298): **0.07**				
310	1,170	297.2 - 299.3		0.015		295-305			
325	NS	318.7 - 321.5		0.002	(296-319): **0.03**				
340					(317-340): **0.01**				
355					(338-361): **<0.01**				
370									
385	NS	384.2 - 385.5		0.001	(359-380): **0.02**				
400					(387-408): no data				
415					(400-420): **0.01**				
430	NS	426.7 - 430.9		0.003					
445					(418-441): **0.03**				
460	1,570	456.4 - 456.7		0.012	(439-462): **0.23**	450-460			
475	NS	472.0 - 481.1		0.004	(460-483): **0.01**				
490									
505									
520									
535									
550									
565									
580									
595									
610									
TD: 612									



Plot shows strike of high dip angle fractures (~65°) in red intercepted by the borehole.

*Detectable flow during ambient conditions
*Detectable flow during pumping conditions

Ft bgs= Feet below ground Surface
NS= Not Sampled
GPM= Gallons per minute

[1] Packer testing derived yield values are calculated by measuring the recharge of a packer interval after evacuating the water from the zone. (2003 packer testing)

[2]Borehole fracture trace and dip direction analysis shows all fractures identified as "Hydraulically-active" based on conventional geophysics and fluid logs. These interpretations are subjective judgment based upon available data (Geophysical Applications, 2003). Hydrophysical logging data from COLOG, 2004
Indicates fractures with dip angles aproximately 65 degrees or greater

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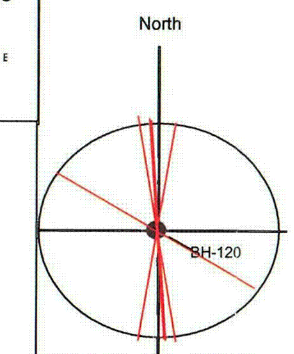
Figure 7-3 Summary Of Borehole 120 Bedrock Characterization.
Packer Testing, Hydrophysics, Geophysics.

Depth (ft bgs) 6 Inch Steel Casing Set To 40 Feet BGS	Hydrophysical Tritium Concentrations (pCi/L) From HNP Onsite Laboratory	Producing Zones Identified With Hydrophysics* (ft bgs)	Hydrophysical Estimated Ambient Flow (gpm)	Hydrophysical Estimated Flow During Pumping (gpm)	Packer Testing Yield[1] (Pack Interval), **gpm**	Proposed Discrete Monitoring Intervals. (ft bgs)	Proposed Discrete Monitoring Intervals.	Borehole fracture trace[2] (Cross section of borehole looking south)	Approximate Dip Direction and angle[2]
40									
55					(42-65): 0.03				
70									
85	15,413	83.5 - 83.6		0.045	(63-86): 0.04	75 - 95			
100	1,458	92.8 - 93.6		0.554	(84-107): 11.18				
115	1,459	105.6 - 106.0	0.004	0.778		100 - 110			
130	<1,200	130.1 - 130.4		0.079	(105-161): 28.65				
145	<1,200	142.4 - 142.9		0.264					
160	<1,200	153.2 - 153.3	0.008	0.026		150 - 160			
175	<1,200	171.1 - 171.2		0.008	(147-170): 0.08				
190					(168 - 191): <0.01				
205					(210-233): 1.03				
220	<833	211.0 - 211.3	0.002	0.074		205 - 215			
235	<1,200	228.9 - 232.8		0.016	(231-254): 0.03				
250	NS	238.1-238.2, 242.3-243.2		0.008, 0.004		235 - 245			
265					(252-275): <0.01				
280									
295					(275 - 298): 0.01				
310									
325									
340									
355									
370									
385									
400									
415					(296 - 527): <0.01				
430									
445									
460									
475									
490									
505									
520									
535									
TD: 550'									



Plot shows strike of high dip angle fractures (~65°) in red intercepted by the borehole.

*Detectable flow during ambient conditions
*Detectable flow during pumping conditions

Ft bgs= Feet below ground Surface
NS= Not Sampled
GPM= Gallons per minute

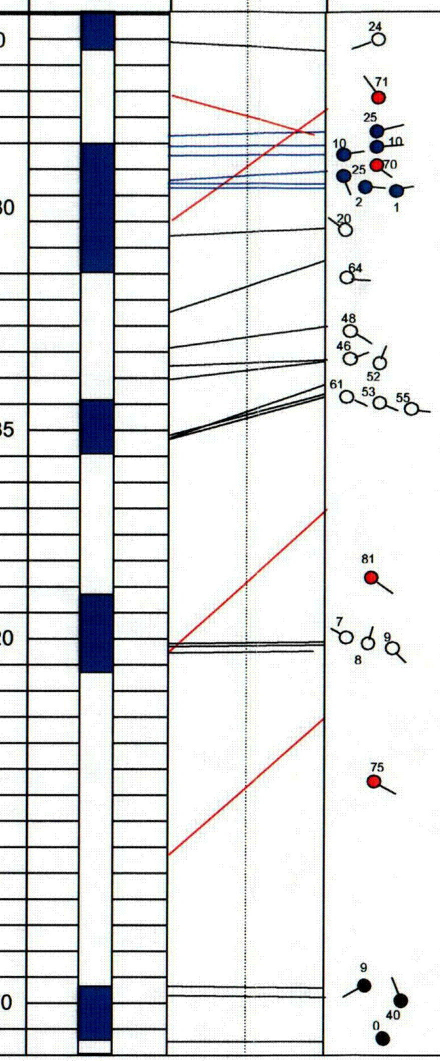
[1] Packer testing derived yield values are calculated by measuring the recharge of a packer interval after evacuating the water from the zone. (2003 packer testing)

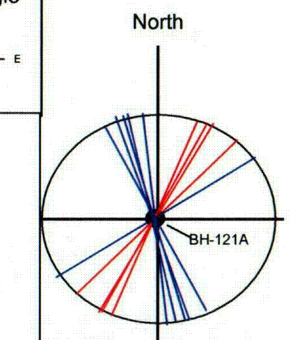
[2]Borehole fracture trace and dip direction analysis shows all fractures identified as "Hydraulically-active" based on conventional geophysics and fluid logs. These interpretations are subjective judgment based upon available data (Geophysical Applications, 2003). Hydrophysical logging data from COLOG, 2004
Indicates fractures with dip angles aproximately 65 degrees or greater

Figure 7-4 Summary Of Borehole 121A Bedrock Characterization.
Packer Testing, Hydrophysics, Geophysics.

Packer Test Interval (ft bgs) 6 Inch Steel Casing Set to 95 Feet BGS	Packer Testing Boron Concentration (ug/L)	Packer Testing Tritium Concentration (pCi/L)	Hydrophysical Tritium Concentrations (pCi/L) From HNP Onsite Laboratory	Producing Zones Identified With Hydrophysics* (ft bgs)	Hydrophysical Estimated Ambient Flow (gpm)	Hydrophysical Estimated Flow During Pumping (gpm)	Packer Testing Yield[1] (Packer Interval), **gpm**	Head Differential[2] (ft) (H_{bottom}-H_{top})	Locations Of Bedrock Aquifer Response to Packer Testing at Distance From BH-121A[3]	Respected Head Gradients Between Observed Response and Packer Testing Location[4] (ft)	Proposed Discrete Monitoring Intervals. (Ft bgs)
103-108	45.2	1,290					0.0068	-11.37			100-110
114-119							n/a	-0.52			
145-150							0.0008	-0.24			
147-152							n/a	-0.49			
152-157	214	2,430					0.0108	-0.38	MW-105D,103S,101D	0.009, 0.007, 0.01	
157-162			NS	160.4-160.5	0.012	0.18	n/a	0.18			
162-167	189 (153-176 ft b.g.s.)	8,170 (153-176 ft b.g.s.)	7,322	165.9-166.8	NMF	6.26	n/a	0.22			
168-173							0.0005	0.21			160 - 180
173-178			8,645	177.6-177.7	0.0008	0.09	n/a	0.42			
178-183	215	6,060					0.0400	0.53			
183-188							0.00003	0.26			
188-193							0.0003	0.21			
203-208							0.0007	0.28			
266-271							0.0027	0.08			
271-276											
273-278							n/a	0.53			275 - 285
278-283			<1260	278.0-278.8	NMF	0.029					
283-288											
288-293											
293-298											
297.5-302.5							n/a	0.02			
298-303											
303-308											
308-313			<1270	308.4-309.0	NMF	0.032					305 - 320
317-322	338	496*					0.0400	0.58			
313-318											
318-323											
323-328			<1250	326.1-328.5	NMF	0.037	0.0042				
335-340											
340-345							<0.0002	0.15			
345-350											
350-355											
353-358											
441-446											
446-451											
451-456											
456-461											
465-470			<1270	460.7-465.1	0.0004	0.008	0.0007	0.94			460 - 470
TD: 582'			NS	467.1-469.7	NMF	0.003					
			NS	483.1-483.2	NMF	0.003					

Proposed Monitoring Intervals. | Borehole Fracture Trace[5] (Cross Section of Borehole Looking South) | Approximate Dip Direction and Angle[5]





Plot shows strike of high angle fractures (>70°) in red intercepted by BH-121A. Sub-horizontal fractures shown in blue are inferred to be hydraulically active and continuous along their respective strike direction.

*Detectable flow during ambient conditions
*Detectable flow during pumping conditions

NMF= No Measured Flow
Ft bgs= Feet Below Ground Surface
GPM= Gallons Per Minute
NS= Not Sampled

[1]Packer testing derived yield values are calculated by observing recharge to the packer interval following a pumping event.

[2] Vertical head differentials are calculated by subtracting the head pressure below the packer by the head pressure above the packer during isolated static conditions. Positive (green) values indicate an upward differential, negative values (orange) indicate downward differential values.

[3] Locations where aquifer responses where observed in distant bedrock monitoring wells instrumented with data logging pressure transducers recording at 5 min intervals. Only packer interval specific responses are reported.

[4] Head gradients were calculated using head measurements below the packer assembly during isolation events and simultaneous head measurements at the respected monitoring locations.

[5]Borehole fracture trace and dip direction analysis shows all fractures identified as "Hydraulically-active" based on conventional geophysics and fluid logs. These interpretations are subjective judgment based upon available data (Geophysical Applications, 2003). Fractures indicated with black dip angle plots were reported as closed features with geophysical analysis but had detectable flow during hydrophysical testing. Hydrophysical logging data from COLOG, 2004 Indicates fracture sets that induced hydraulic responses in distant bedrock monitoring wells. Indicates fractures with dip angles equal to or greater than 70 degrees.

* Note: Field blank sample contained 3H at 338 pCi/L +/-130 (Lab MDA= 206) This value appears to be a system artifact.

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