0051

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Sufco Mine
A Subsidiary of Arch Western Bituminous Group, LLC.

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Incoming
C/041/0002

November 8, 2007

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Utah Division of Oil, Gas and Mining
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Re: Summary Report of the 2007 Investigation and Proposed Mitigation Activities, North Water Spring and Joes Mill Pond Areas, November 2007, Canyon Fuel Company, LLC, SUFCO Mine C/041/002

Dear Pam:

Please find attached to this letter eight copies of the summary report detailing the findings of the additional investigations conducted in the and fall and summer 2007 in the North Water Spring and Joes Mill Ponds Study. This report includes an interpretation of the additional data that has been collected to date from the piezometers installed in August 2006 and the most recent piezometers in 2007. The summary also includes spring flow measurements for the Pines 310 spring through August 2007. Additionally, a proposal to install a ground water collection and discharge system in the canyon south and west of spring Pines 105 (North Water Spring) is presented in this summary report. It is Sufco's current plan to construct the ground water system as early in the summer of 2008 or as soon as the regulatory agencies allow. If this system for collection of ground water is successful in the Pines 105 side canyon, a similar system would be installed in the main stem of the North Water drainage upstream of Pines 310 and in the canyon upstream of Joes Mill Pond.

If you have any questions, please give Mike Davis a call at (435) 286-4421 or me at (435) 448-2669.

Sincerely,

Chris D. Hansen
Environmental Coordinator
Arch Western Bituminous Group

enclosures

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SUMMARY REPORT OF THE 2007 INVESTIGATION AND PROPOSED MITIGATION ACTIVITIES

NORTH WATER SPRING AND JOES MILL POND AREAS

NOVEMBER 2007

CANYON FUEL COMPANY, LLC
SUFCO MINE

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SUMMARY OF RESULTS OF SUMMER 2007 ACTIVITIES

Sufco submitted a proposed mitigation plan for the North Water Spring area to the Utah Division of Oil, Gas and Mining in January 2007. This plan included installation of additional piezometers in the North Water and Joes Mill Pond drainages along with the performance of a VLF survey and injection of an experimental grout curtain within the alluvial sediments in the bottom of the North Water drainage. Following is a brief summary of the results of the proposed work. Detailed information is provided in Petersen's Report titled: "Report of 2007 Hydrogeologic Field investigations; Supplemental information For the report: Investigation of Subsidence-Related Impacts to Groundwater Systems in the North Water and Joes Mill Pond areas and Proposed Groundwater Mitigation Activities, Sufco Mine 29 January 2007" and included with this summary as Attachment 1.

Piezometer Installation

Several piezometers were installed in the alluvium within the tributaries to the North Water drainage, in the main canyon upstream of spring Pines 310, and downstream of Pines 106 (North Water Spring) in late summer of 2007. Piezometers were also installed upstream of the Joes Mill Pond. The purpose of the installation of the piezometers in the tributaries to the North Water drainage was determine if ground water was present in these areas, the potential flow rate of the ground water moving through the alluvium in the canyon and tributaries, and at what depth the surface of the ground water was located. Piezometers were installed in three tributaries to the North Water drainage; the tributaries located south and west of springs Pines 105, Pines 311, and Pines 310. Ground water was found in the tributaries associated with Pines 105 and Pines 310 but no measurable ground water surface was located in the tributary associated with Pines 311. Two piezometers were also installed in the main stem of the drainage upstream of Pines 310 and existing piezometer NWP 3. Ground water was found in these two piezometers at a depth of approximately 15 to 20 feet below ground level.

Additional piezometers were installed downstream of Pines 105 as part of the experimental grout curtain injection program. The purpose of these piezometers was to determine the effectiveness of the grout curtain in changing the ground water surface upstream of the curtain.

Finally, two additional piezometers were installed in the Joes Mill Pond drainage upstream of the pond. Ground water has been found in these two piezometers at a depth of approximately 15 to 16 feet below ground surface.

VLF Survey

A preliminary VLF (Very Low Frequency) survey was conducted in the North Water Canyon area by Clements Drilling and Geophysical, Inc (Clements) in an effort to determine the locations of bedrock subsidence fractures beneath the alluvial sediments that may be conducting water away from the area. The results of Clements survey indicated that locating water transmitting natural and subsidence related fractures beneath the alluvium in the North Water drainage would be difficult. Targeting fractures

transmitting water beneath the alluvium to be filled with grout was determined by the mine to not be feasible using VLF survey methods. At this time, the mine is unaware of other geophysical methods that could reasonably be used in this area to locate the subsurface fractures with the accuracy needed to allow drilling and plugging of the fractures. Clements report on the VLF survey is contained as Attachment 2 with this summary.

Intra-alluvial Grout Curtain

Sufco originally proposed in January 2007 to install at least one experimental grout curtain in the alluvium downstream of Pines 105. A bentonite polymer product known as AquaBlok® was proposed to be injected into the alluvium to form an "intra-alluvial dam". Piezometers would be drilled upstream of the injected material to determine if the "dam" would be effective in raising the ground water levels upstream of the "dam". After further investigation and bench scale tests performed by a consultant on behalf of Sufco, it was determined this product could not be injected into the alluvium in a cost-effective or technically feasible manner. Therefore, Sufco determined instead to inject into the alluvium a bentonite slurry derived from mixing powdered bentonite, a small amount of cement, and water. The location chosen for the "dam" was downstream of Pines 105 where the canyon floor appeared to narrow (Figure 3). The first attempt at injection was terminated when, after successfully drilling and injecting bentonite slurry into three holes, the fourth hole continued to accept the slurry with little to no back pressure being developed. It was determined that bentonite was probably being injecting into a fracture at that location. While locating a fracture with the drilling activities was fortunate, the plan being executed did not include the backfilling of fractures with large volumes of bentonite via a small diameter drill hole. The location for the injection of the experimental grout dam was moved upstream approximately 50 feet and successfully completed at that location. To-date the installation of the grout curtain has resulted in only a minor change in the elevation of the alluvial ground water upstream of the curtain.

Future Mitigation Plan

Based on the results of the installation and monitoring of the additional piezometers and the installation of the grout curtain, additional mitigation is proposed for the North Water drainage area. The new proposed mitigation plan is also predicated on the discussions with and decisions made by DOGM, Manti-La Sal National Forest, Bureau of Land Management, Water Rights, and Sufco Mine personnel during a meeting held on October 12th, 2007 at the North Water site. It was suggested and agreed upon by the parties involved in the meeting that a single experimental ground water collection system be proposed to be installed in the tributary to the North Water drainage located south and west of the Pines 105 spring (North Water Spring). This proposal is based on the following assumptions:

1. Ground water is relatively shallow in the upper portion of the drainage that was tested;
2. There is ground water surface gradient in this area of the side canyon indicating water flow through the alluvium;
3. A conservative estimate of the through-put of ground water through the alluvium in this area is between 1 and 10 gpm;

3. A conservative estimate of the through-put of ground water through the alluvium in this area is between 1 and 10 gpm;
4. The distance between the collection system and discharge point is be relatively short;
5. Minimal surface disturbance will be needed to install the system; and
6. If the installed system functions properly, water will be available to the cattlemen to pump to holding tanks located on the canyon rim for the watering of cattle.

The location of the proposed ground water collection system in the drainage south and west of Pines 105 is illustrated in Figure 3. The type of pipe, screen, filter pack, etc. will be determined based on analysis of the drill cuttings by a reputable geotechnical engineering consultant. This consultant will be provided with representative samples of appropriate drill cuttings to determine grain size distribution within the alluvial sediments and to recommend appropriate filter pack and screen slot sizes for use in the collection system. The geotechnical consultant will also be asked to design or suggest a design for an appropriate discharge structure for the collection system that withstand changing climatic conditions, livestock impacts, and wildlife use. It is anticipated the work by the geotechnical consultant can be completed by April 2008. This information will be included in a proposal to DOGM and detail the final plans for installing the ground water collection system in the drainage south and west of Pines 105.

At this time Sufco anticipates using low impact equipment to install the system proposed for the drainage south and west of Pines 105. This equipment may include, but not limited to, a rubber tired backhoe, light-weight ATVs, horses or mules, a helicopter, a water truck, and pick-up trucks. Sufco would only use equipment in off-road circumstances that create minimal disturbance to vegetation and soils. Areas where soils are excavated and then replaced will be returned to their approximate original contour and reseeded. The seed mix used will be determined by Sufco and approved by DOGM and the Forest.

The only surface structure to be part of this project will be the ground water discharge structure. Sufco anticipates this structure will be located within the fence that currently is in place to protect the Pines 105 discharge location. As described previously, the discharge structure will be designed and built to withstand changing weather conditions and impacts from wildlife and livestock. No further or extraordinary protections are planned for this structure.

The performance of the Pines 105 system will be evaluated during the summer of 2008. If the performance of the ground water collection system is satisfactory, Sufco proposes to install a similar system in the main channel upstream of Pines 310 in the vicinity of piezometers NWP 48 and NWP 49 and upstream of the Joe's Mill Pond as soon as approved by the regulatory agencies. Specific designs for the second system will be prepared and approved prior to construction. If the performance of the Pines 105 system is not satisfactory, other mitigation measures will be prepared and proposed to DOGM by Sufco.

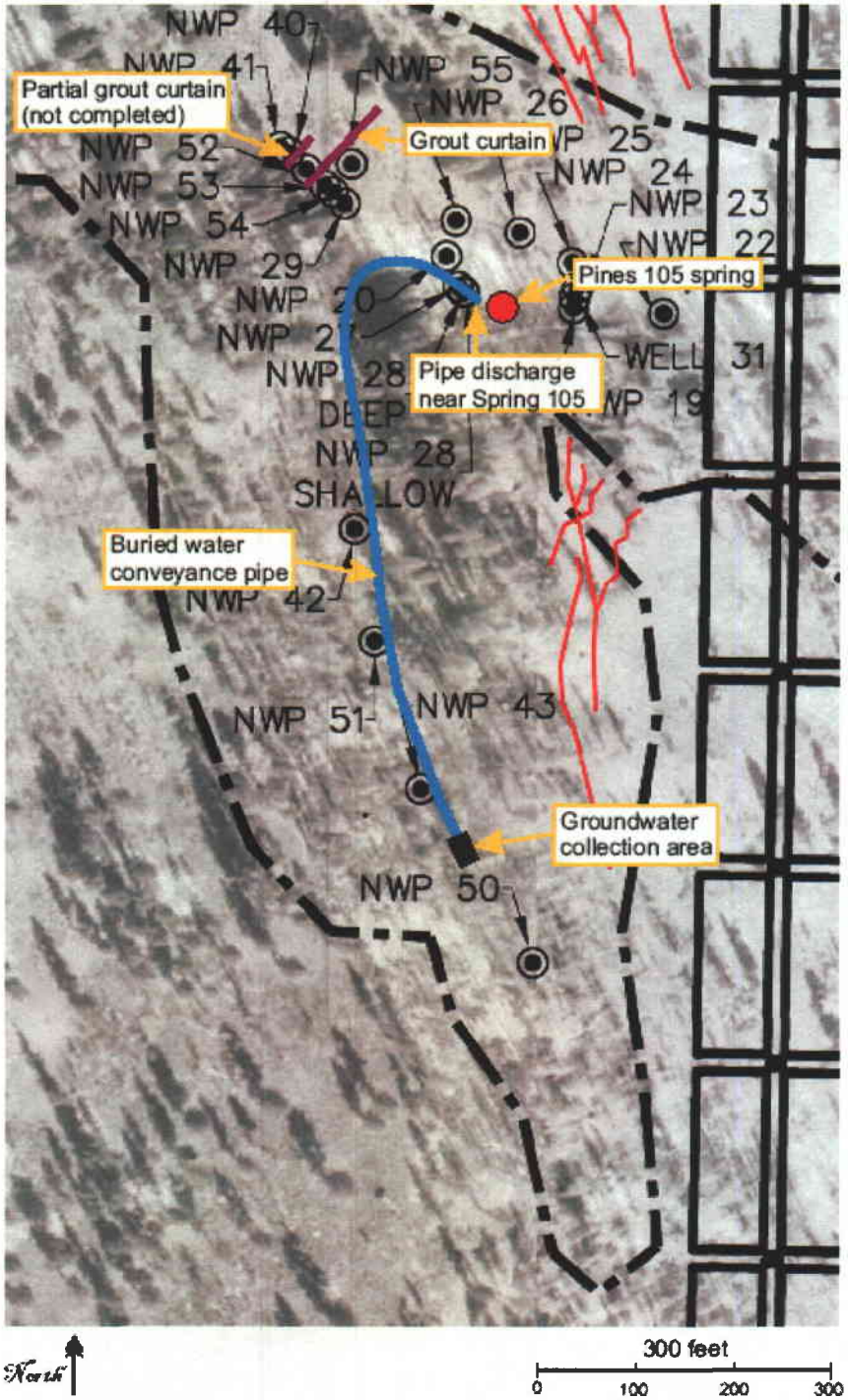

Figure 3
Grout Curtain and Proposed Pipeline Location

ATTACHMENT 1

Report of 2007 Hydrogeologic Field investigations;

Supplemental information for the report:

Investigation of Subsidence-Related Impacts to Groundwater Systems in the North Water and Joes Mill Pond areas and Proposed Groundwater Mitigation Activities, Sufco Mine

November 2007

Report of 2007 Hydrogeologic Field investigations; Supplemental information For the report:

Investigation of Subsidence-Related Impacts to Groundwater Systems in the North Water and Joes Mill Pond areas and Proposed Groundwater Mitigation Activities, Sufco Mine

7 November 2007

Canyon Fuel Company, LLC
Sufco Mine
Salina, Utah

PETERSEN HYDROLOGIC, LLC
CONSULTANTS IN HYDROGEOLOGY

Report of 2007 Hydrogeologic Field investigations; Supplemental information For the report:

Investigation of Subsidence-Related Impacts to Groundwater Systems in the North Water and Joes Mill Pond areas and Proposed Groundwater Mitigation Activities, Sufco Mine

7 November 2007

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Table of Contents

1.0 INTRODUCTION **1**

2.0 SUMMARY OF 2007 HYDROGEOLOGIC FIELD INVESTIGATIONS **3**

2.1 INSTALLATION OF ADDITIONAL ALLUVIAL PIEZOMETERS IN THE NORTH WATER CANYON AND JOES MILL POND AREAS 3
2.2 GEOLOGIC AND HYDROGEOLOGIC CHARACTERIZATION OF ALLUVIAL SEDIMENTS AND UNDERLYING CANYON BEDROCK GEOMETRY 4
2.3 MONITORING OF WATER LEVELS IN ALLUVIAL GROUNDWATER SYSTEM PIEZOMETERS 5
2.4 DETERMINATION OF APPROXIMATE HYDRAULIC CONDUCTIVITY VALUES IN ALLUVIAL GROUNDWATER SYSTEMS USING SLUG TESTING TECHNIQUES 5
2.5 MONITORING OF SPRING DISCHARGE RATES 6
2.6 INSTALLATION OF A BENTONITE GROUT CURTAIN IN NORTH WATER CANYON NEAR SPRING PINES 105 (NORTH WATER SPRING) 6
2.7 GEOPHYSICAL RESISTIVITY STUDY IN THE NORTH WATER CANYON AREA 8

3.0 DATA ANALYSIS **9**

3.1 CONDITIONS IN THE ALLUVIAL GROUNDWATER SYSTEMS 9
3.2 GEOLOGIC AND HYDROGEOLOGIC CHARACTERIZATION 11
3.3 FEASIBILITY OF PRODUCING GROUNDWATER FROM THE PINES 105 SIDE CANYON 12
3.4 EFFECTIVENESS OF GROUT CURTAIN 14

4.0 REFERENCES CITED **16**

List of Figures

Figure 1 Locations of wells and piezometers in the North Water Canyon area
Figure 2 Locations of wells and piezometers in the Joes Mill Pond area
Figure 3 Hydrostratigraphic cross-sections
Figure 4 North Water Canyon grout curtain details
Figure 5 North Water Canyon grout curtain cross-section
Figure 6 Discharge hydrographs for Pines 407 and Pines 408

List of Tables

Table 1 Completion details for piezometers and wells
Table 2 Water level data for piezometers and wells
Table 3 Slug testing results
Table 4 Discharge measurements for springs in the North Water Canyon area.
Table 5 Grout curtain construction details
Table 6 Survey elevations for wells

List of Appendices

Appendix A Geologic logs
Appendix B Water level hydrographs

Report of 2007 Hydrogeologic Field investigations; Supplemental information For the report:

Investigation of Subsidence-Related Impacts to Groundwater Systems in the North Water and Joes Mill Pond areas and Proposed Groundwater Mitigation Activities, Sufco Mine

1.0 Introduction

During 2005 and 2006, longwall mining at Canyon Fuel Company, LLC's Sufco Mine occurred beneath the North Water Canyon tributary to the East Fork of Box Canyon (Figure 1). Subsidence-related effects apparently resulted in the cessation of spring discharge to the land surface from three springs in the North Water Canyon area (Pines 105, Pines 311, and Pines 310 lower). Longwall mining and related subsidence also occurred beneath the Joes Mill Pond area, approximately ½ mile south of North Water Canyon (Figure 2). Subsequent to mining in the Joes Mill Pond area, discharge from a seep that provided water to an adjacent small stock watering pond also ceased to flow at the ground surface.

In 2006, Canyon Fuel commissioned Petersen Hydrologic, LLC to perform a hydrogeologic investigation of alluvial and shallow bedrock groundwater systems and subsidence-related

impacts in the North Water Canyon and Joes Mill Pond areas. In January 2007 a report of this investigation, including proposed mitigation activities, was prepared and submitted to the Utah Division of Oil, Gas and Mining. This report is entitled *Investigation of Subsidence-Related Impacts to Groundwater Systems in the North Water and Joes Mill Pond areas and Proposed Groundwater Mitigation Activities, Sufco Mine,* dated 29 January 2007 (Petersen Hydrologic, 2007).

During the 2007 field season, additional hydrogeologic field investigations were performed in the North Water Canyon and Joes Mill Pond areas. These field activities included:

- Installation of additional alluvial piezometers in the North Water Canyon and Joes Mill Pond areas
- Geologic and hydrogeologic characterization of alluvial sediments and underlying canyon bedrock geometry
- Determination of approximate hydraulic conductivity values in alluvial groundwater systems using slug testing techniques
- Monitoring of water levels in alluvial groundwater systems
- Monitoring of spring discharge rates
- Installation of a bentonite grout curtain in North Water Canyon near spring Pines 105 (North Water Spring)
- Geophysical resistivity study in the North Water Canyon area

This document summarizes the results of the 2007 field investigations in the North Water Canyon and Joes Mill Pond areas and is presented as supplemental information to the January 2007 report previously submitted to the Division.

The results of each of the above listed field activities are presented in the following sections of this report followed by an analysis of the hydrogeologic and geologic data.

2.0 Summary of 2007 Hydrogeologic Field Investigations

2.1 Installation of additional alluvial piezometers in the North Water Canyon and Joes Mill Pond areas

During August 2007, 18 piezometers were installed in the North Water Canyon and Joes Mill Pond areas overlying the Sufco Mine. The locations of these piezometers are shown in Figures 1 and 2. The new piezometers were installed to 1) characterize the alluvial groundwater systems in the side canyons and areas upstream of mining activities, and 2) to monitor the effectiveness of a bentonite grout curtain installed in North Water Canyon below spring Pines 105 (discussed below). The piezometers installed during 2007 were drilled and constructed by Clement Drilling and Geophysical, Inc. of Cedar Hills, Utah using a tractor-mounted PowerProbe drilling rig. Piezometers were constructed using techniques similar to those utilized in the construction of the 2006 piezometers in the adjacent areas. Piezometer completion details are presented in Table 1. The piezometers were completed using 0.010

PVC well screen and solid PVC riser pipe. Typically, a sand filter-pack was emplaced in the well annulus opposite and to about 0.5 feet above the top of the well screen. The sand filter-pack consisted of either 10-20 Colorado silica sand and/or native flowing fine-grained sand that was sometimes present in the borehole and naturally rose in the borehole upon insertion of the well screen. The annular space above the sand filter pack was filled with anhydrous bentonite chips to the ground surface. The piezometers were protected at the surface by a driven 4-inch PVC casing and cap.

2.2 Geologic and hydrogeologic characterization of alluvial sediments and underlying canyon bedrock geometry

In conjunction with the drilling and installation of the piezometers, geologic logging of sediments in drill cores was performed on the 16 boreholes for which core samples were obtained. For each stratigraphic interval, an internally-generated hydrogeologic code was also assigned. The purpose of the hydrogeologic code is to facilitate general comparisons between adjacent wells and to simplify the characterization of hydrogeologic properties. Geologic logs for each logged piezometer are presented in Appendix A.

Most wells were drilled to the interface between the alluvial sediments and the underlying Castlegate Sandstone bedrock. This facilitated the mapping of the bedrock surface underlying the alluvial sediments in both the North Water Canyon and Joes Mill Pond areas. It is noteworthy that in many locations the contact between the overlying alluvial sediments (which are primarily derived from weathering of the Castlegate Sandstone) and the

underlying weathered Castlegate Sandstone bedrock was somewhat gradational. For consistency, the drill holes were generally advanced to refusal at the depths noted in Table 1.

2.3 Monitoring of water levels in alluvial groundwater system piezometers

Water levels in piezometers in the North Water Canyon and Joes Mill Pond areas continued to be monitored during 2007. The water level measurements are presented in Table 2. Water-level hydrographs for piezometers in the North Water Canyon and Joes Mill Pond areas are presented in Appendix B. Hydrostratigraphic cross-sections showing the ground surface, the top of the saturated alluvium, and the approximate alluvium/Castlegate Sandstone bedrock interface for Pines 105 side canyon, Pines 310 side canyon, upper main North Water Canyon, and the upper Joes Mill Pond canyon are shown in Figure 3.

2.4 Determination of approximate hydraulic conductivity values in alluvial groundwater systems using slug testing techniques

Approximate values of hydraulic conductivity for the alluvial sediments in the North Water Canyon area were determined by performing slug tests on three selected piezometers during 2007. An additional piezometer was previously tested during 2006. The slug tests were performed by rapidly removing a solid metal slug from the piezometer and monitoring the water level time-recovery data using an electronic pressure transducer and data logger. Hydraulic conductivity values were calculated using methods described by Hvorslev (1951). Slug testing results are presented in Table 3.

It should be noted here that slug tests are generally considered to be useful for determining approximate values for hydraulic conductivity only. Hydraulic conductivity values determined using slug tests are generally considered valid as order-of-magnitude estimates only.

2.5 Monitoring of spring discharge rates

Spring discharge rates in the North Water Canyon area continued to be monitored during the 2007 field season. Springs Pines 105, Pines 311, and Pines 310 Lower had no discharge during 2007. Spring Pines 310 upper continued to discharge during 2007. Discharge data for springs in the North Water Canyon area are presented in Table 4.

2.6 Installation of a bentonite grout curtain in North Water Canyon near spring Pines 105 (North Water Spring)

A bentonite grout curtain was installed in the North Water Canyon area below spring Pines 105 during August 2007. The location of the grout curtain is shown on Figure 1. Construction details for the grout curtain are shown in Table 5. A conceptual diagram depicting the approximate placement of the grout curtain is shown in Figure 4. A cross-section showing water levels in the alluvial groundwater system near the grout curtain before and after its emplacement is shown in Figure 5.

The grout curtain was created by drilling nine 2 ¼ -inch holes on 10-foot centers to the base of the alluvium across the width of the North Water Canyon bottom. A bentonite/water

slurry was injected through the drill rods into the alluvial sediments using a high pressure injection pump capable of injection pressures of 1,000 psi. The grout was prepared by hand mixing drinking-water-well-quality sodium bentonite with fresh water and a very small quantity of Portland cement in containers at the project site. The grout was then hand loaded into the grout pump operating off the drill rig hydraulics. After grout pumping commenced, when pumping pressures increased substantially and additional grout could not be pumped into the alluvial sediments, the drill rods were raised a short distance in the borehole and the process was repeated. This injection process was repeated until grout had been pumped through the entire vertical extent of the borehole, from the bedrock interface to near the ground surface. This process was repeated sequentially for each of the nine boreholes. It is noteworthy that at most boreholes, as grout was being pumped through the drill rods several feet below the ground surface, bentonite slurry would often erupt at the ground surface several feet (typically 5 to 10 feet) from the injection site. This suggests the likelihood that a near continuous grout curtain was created in the subsurface, with some overlap of grouting between adjacent injection boreholes at 10-foot centers (i.e., 10- to 20-foot grout cylinder diameters on 10 foot centers).

The width of the completed grout curtain, into which approximately 6,000 gallons of bentonite slurry was pumped, is roughly 80 feet and likely extends across the entire width of the buried North Water Canyon bottom (Table 5). It is noteworthy that the base of the buried bedrock channel in the vicinity of the North Water Canyon grout curtain is relatively flat and is considerably wider (width of ~80 feet) than initially anticipated (Figure 4).

It should be noted that an initial attempt to inject grout about 30 feet below (west of) the final grout curtain location was made and subsequently aborted. The attempt to grout at this location was aborted because it was postulated that the grout was likely being injected into an open fracture in the bedrock substrate. This conclusion was based on the fact that a large quantity of grout was pumped into the base of the alluvium without a notable increase in injection pressures or grout pumping refusal. Water level data from piezometers immediately adjacent to the initial grout curtain location also indicated a rapid down-stream drop-off of water levels in this location, also suggesting the likelihood of a substantial fracture taking water at that location. Consequently, the final grout curtain location was moved up-canyon about 30 feet in an attempt to situate the curtain on a more competent portion of the bedrock surface beneath the alluvium.

2.7 Geophysical resistivity study in the North Water Canyon area

A geophysical resistivity study was performed in North Water Canyon by Clement Drilling and Geophysical, Inc. A report summarizing the findings of this study is provided under separate cover.

3.0 DATA ANALYSIS

3.1 Conditions in the alluvial groundwater systems

Water level data obtained during the 2007 field season indicate that alluvial groundwater continues to be present in appreciable quantities in the North Water Canyon and Joes Mill Pond alluvial groundwater systems. However, water levels in the alluvial groundwater systems continued to decline during 2007 (Table 2, Appendix B). It is notable that the rate of decline observed in many piezometers during 2007 is less than the rate of decline observed during 2006. This suggests the possibility that conditions may be moderating in the alluvial groundwater system as the time elapsed since the region was undermined has increased.

It is likely that at least a portion of the observed declines in water levels in the alluvial groundwater systems measured during 2007 are attributable to residual effects related to the subsidence the region experienced during 2005 and 2006. However, some of the observed declines in water levels in the alluvial groundwater systems are very likely in response to the persistent drought conditions the region has experienced during 2007. (It should be noted that long-term data are not available to characterize the natural response of the alluvial groundwater systems in the North Water Canyon and Joes Mill Pond areas to long-term climatic variability). When the North Water Canyon area was visited in April 2007, conditions were dry and it did not appear that a large snowmelt runoff/groundwater recharge event had occurred. Monthly precipitation data collected at the Sufco Mine weather station

during the past 12 months indicate that precipitation has generally been only about 50% of the long-term average at that station (Personal communication, Mike Davis, 2007). Until appreciable recharge events occur in the region (sufficient to fully recharge the groundwater in the alluvial groundwater systems), a conclusive determination of the causes of the declines in alluvial water levels in the area is problematic.

Discharge measured in Box Canyon at monitoring sites Pines 407 (Main Fork Box Canyon Creek) and Pines 408 (East Fork Box Canyon Creek) are plotted in Figure 6 (See Petersen Hydrologic, 2007; Figure 14 for site locations). It is apparent in Figure 6 that the East Fork of Box Canyon Creek has responded to seasonal and climatic variability in a manner remarkably similar to that observed in the Main Fork of Box Canyon Creek. This is important in that it strongly suggests that there has not been any significant non-climate-related change in the stream discharge characteristics in the East Fork of Box Canyon Creek (i.e., such as might be attributed to a loss of recharge to the East Fork from the North Water Canyon drainage). As discussed in the previous submittal (Petersen Hydrologic, 2007), it is highly probable that discharge from the alluvial groundwater system in North Water Canyon flows into the East Fork of Box Canyon Creek drainage. This conclusion is based largely on the fact that a large portion of the discharge in the East Fork of Box Canyon Creek (both before and after the region was undermined) emerges in the stream channel a short distance below the confluence with North Water Canyon. The fact that the slope of the land surface, and the dip of the sandstone bedrock strata in North Water Canyon (which is perched on mostly low-permeability rock strata) are both generally oriented toward the same reach of the

East Fork of Box Canyon where visibly gaining stream reaches are present also supports this conclusion. These findings support the conclusion that there has likely been little or no net loss of water from the East Fork of Box Canyon Creek drainage as a result of the subsidence of the North Water Canyon area, although the location of groundwater discharge points to the surface have been altered as a result of subsidence.

It is worthy of note that, like the North Water Canyon and Joes Mill Pond areas, the perennial East Fork of Box Canyon Creek itself was also undermined and subsided beginning in late 2003. Although some relatively short reaches of the stream temporarily went dry after subsidence effects resulted in buckled thin-bedded rock strata in the stream substrate into which surface waters flowed, the water that entered the cracked and/or buckled strata consistently re-emerged into the stream channel at downstream locations where impermeable strata prevented downward migration of the water. There is no indication that surface waters in the East Fork were diverted away from the drainage. Currently, surface water discharge in the East Fork of Box Canyon Creek occurs in a manner that is similar to pre-mining conditions.

3.2 Geologic and hydrogeologic characterization

Geologic logs of the alluvial sediments in the North Water Canyon side drainages and headwaters area, and also in the Joes Mill Pond area indicate that sands and silty sands dominate the makeup of the alluvial sediments in these areas (Appendix A). While the alluvial sediments near springs and seeps commonly contain appreciable quantities of low-

permeability organic silt and muck derived from vegetation growth in the wet spring areas, alluvial sediments in areas removed from springs consist predominantly of fine-grained sands and silty sands derived from weathering of the Castlegate Sandstone.

Clayey units (non-organic) have been observed in drill cores situated near the base of the alluvial sediments in both the North Water Canyon and Joes Mill Pond areas (Appendix A). Similar clayey units have been observed in the Castlegate Sandstone bedrock underlying some spring discharge locations. The presence of low-permeability units underlying spring discharge locations suggests that stratigraphic control of groundwater flowpath locations and groundwater discharge mechanisms is significant. The presence of natural joint systems is also likely important in controlling areas of enhanced groundwater flow potential and spring discharge locations.

3.3 Feasibility of producing groundwater from the Pines 105 side canyon

A currently proposed mitigation plan for the loss of spring discharge at the land surface in the Pines 105 area involves the collection of shallow groundwater in a side canyon in North Water Canyon adjacent to (south of) Pines 105 spring (Figure 1). Using the information obtained from the 2007 drilling and slug testing programs, it is possible to calculate an order-of-magnitude estimate of the likely rate of groundwater flow migrating through the Pines 105 side canyon. Darcy's Law, which is applicable for the calculation of such flow rates through porous media, may be represented as:

$$Q = KIA$$

Where K = hydraulic conductivity

I = hydraulic gradient

A = cross-sectional area

Assuming a value of hydraulic conductivity of 4 feet per day (the average of slug test results from the four alluvial piezometers tested), a hydraulic gradient of 0.038 (between NWP-50 and NWP-43), and a cross sectional area of 880 square feet (a saturated thickness of 12.6 feet with an approximate width of 70 feet across the canyon bottom), a daily discharge of 134 cubic feet (1,000 gallons) in the NWP-43 area is calculated. This daily volume corresponds to a continuous flow rate of about 0.7 gpm. As discussed above, because of the inherent uncertainties in the hydraulic conductivity value determined from slug testing, this result should be considered as an order-of-magnitude estimate (the cross-sectional area of the saturated alluvium near NWP-43 is also only a rough estimate). (It should be noted that the hydraulic conductivity used in this approximation is on the same order but greater than that calculated from the slug test at NWP-43. Because of the uncertainties inherent in slug testing, and the likely heterogeneity of the alluvial sediments in the area, the average of several tests in similar media has been used for the order-of-magnitude estimate).

It should also be noted that the estimates for hydraulic gradient and saturated cross-sectional area used in this calculation were obtained from field investigations performed during the

low-flow season during a time of drought. It is likely that appreciably greater quantities of water could be produced from the alluvium in the Pines 105 side canyon during the springtime high-flow season and during wetter climatic conditions than during the low-flow conditions for which the estimate given above was made.

3.4 Effectiveness of grout curtain

In conjunction with the placement of the grout curtain below Pines 105 spring, several piezometers were installed in the immediate vicinity to monitor the effectiveness of the grout curtain in raising the water levels in the alluvial groundwater system. Although water level increases to near the ground surface did not occur, modest increases in water levels up-stream of the grout curtain on the order of about a half-foot were observed within a short time subsequent to the emplacement of the grout curtain. These water level increases are likely meaningful, as water levels monitored in piezometers in the alluvial groundwater systems in almost all other locations in the region declined during the same period. This suggests that the water level increases observed near the grout curtain are likely attributable to the damming action of the grout curtain. However, such small increases in alluvial water levels in the canyon would likely not provide much benefit to ecosystems in the canyon (i.e., water levels did not rise to near the ground surface). It is possible that more substantial increases in alluvial groundwater levels near the grout curtain may be observed in the future in response to wetter climatic conditions and increased groundwater recharge.

It should also be noted that water level measurements in piezometers in the Pines 105 area indicate a more northerly component to the hydraulic gradient locally (Table 2). Consequently, it is possible that the only modest increases in water levels may be a result of some groundwater migrating to the northern side of the canyon and subsequently flowing to the northwest (toward the East Fork of Box Canyon) along pre-existing, natural joint systems, or along subsidence-induced (or subsidence-enhanced) fractures.

4.0 References Cited

Hvorslev, M.J., 1951, Time lag and soil permeability in ground water observations, U.S. Army Corps of Engineers Waterways Experimental Station, Bulletin 36, 50 p.

Petersen Hydrologic, LLC, 2007, Investigation of subsidence-related impacts to groundwater systems in the North Water and Joes Mill Pond areas and proposed groundwater mitigation activities, Sufco Mine, unpublished consulting report for Canyon Fuel Company, LLC.

Notes: All measurements are in feet below the ground surface
Sand pack used in all wells is 10-20 Colorado Silica Sand; Well screen is 0.010 slot size
Well screen and riser pipe used is flush-threaded PVC
Piezometers enclosed in 4-inch PVC surface protectors; Production wells enclosed in locking steel surface protectors.

	Area	Type	Date completed	Borehole diameter (inch)	Depth to bedrock/refusal	Screen interval From	Screen interval To	Screen length	Sand pack From	Sand pack To	Bentonite seal From	Bentonite seal To	Flov i
NWP-1	Pines 310	1-inch Piezometer	1-Aug-2006	2.25	28	8	28	20	5	12	0	5	
NWP-2	Pines 310	1-inch Piezometer	1-Aug-2006	2.25	23	3	23	20	8	9	0	8	
NWP-3	Upgradient alluvium	1-inch Piezometer	2-Aug-2006	2.25	16	6	16	10	5	13.5	0	5	
NWP-4	Pines 310	1-inch Piezometer	2-Aug-2006	2.25	38	9.7	29.7	20	9	13	0	9	
NWP-5	Pines 310	1-inch Piezometer	2-Aug-2006	2.25	29.7	8	28	20	7	10	0	7	
NWP-6	Pines 310	1-inch Piezometer	2-Aug-2006	2.25	35	4	24	20	3	8	0	3	
NWP-7	Pines 310	1-inch Piezometer	2-Aug-2006	2.25	36	8	28	20	7.5	8	0	7.5	
NWP-8	Pines 310	1-inch Piezometer	3-Aug-2006	2.25	41	4	19	15	7	13	0	7	
NWP-9	Pines 310	1-inch Piezometer	3-Aug-2006	2.25	Not encountered	8	28	20	---	---	0	6.8	
NWP-10 shallow	Pines 310	1-inch Piezometer	3-Aug-2006	2.25	Not encountered	5	10	5	4	10	0	4	
NWP-10 deep	Pines 310	1-inch Piezometer	3-Aug-2006	2.25	41	23	28	5	---	---	0	12	
NWP-11	Pines 311	1-inch Piezometer	3-Aug-2006	2.25	28	8	28	20	7	8	0	7	
NWP-12	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	40	8	28	20	7	7.5	0	7	
NWP-13	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	35	8	28	20	7	8	0	7	
NWP-14	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	35	8	28	20	7	8	0	7	
NWP-15	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	33	8	28	20	7	8	0	7	
NWP-16	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	9	4	9	5	2	7	0	2	
NWP-17	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	22	9	24	15	5	9	0	5	
NWP-18	Pines 311	1-inch Piezometer	5-Aug-2006	2.25	29	9	29	20	7	8	0	7	
NWP-19	Pines 105	1-inch Piezometer	5-Aug-2006	2.25	21	6	21	15	5	8	0	5	
NWP-20	Pines 105	1-inch Piezometer	5-Aug-2006	2.25	25	5	25	20	3	18	0	3	
NWP-21	Between Pines 105 and 311	1-inch Piezometer	15-Aug-2006	2.25	25.5	5.5	25.5	20	4	12	0	4	
NWP-22	Pines 105	1-inch Piezometer	15-Aug-2006	2.25	22.5	7.5	22.5	15	3.5	10.8	0	3.5	
NWP-23	Pines 105	1-inch Piezometer	15-Aug-2006	2.25	25	10	25	15	7	9	0	7	
NWP-24	Pines 105	1-inch Piezometer	15-Aug-2005	2.25	28.5	8.5	28.5	20	7	22.4	0	7	
NWP-25	Pines 105	1-inch Piezometer	15-Aug-2005	2.25	20.5	10.5	20.5	10	10	15.6	0	10	
NWP-26	Pines 105	1-inch Piezometer	15-Aug-2006	2.25	26.5	11.5	26.5	15	---	---	0	6.5	
NWP-27	Pines 105	1-inch Piezometer	16-Aug-2006	2.25	25	10	25	15	9	10	0	9	
NWP-28 shallow	Pines 105	1-inch Piezometer	16-Aug-2006	2.25	Not encountered	9	12	3	---	---	0	7.3	
NWP-28 deep	Pines 105	1-inch Piezometer	16-Aug-2006	2.25	22.5	19.5	22.5	3	---	---	0	10	
NWP-29	Pines 105	1-inch Piezometer	16-Aug-2006	2.25	22	7	22	15	5	12.9	0	5	
NWP-30	Lower Canyon	1-inch Piezometer	16-Aug-2006	2.25	22	7	22	15	6	13.3	0	6	
NWP-31 (4")	Pines 105	4-inch Production	16-Aug-2006	8	23	0	18	18	3	15	0.5	3	
NWP-32 (4")	Pines 311	4-inch Production	16-Aug-2006	8	Not encountered	0	14	14	3	8.5	0.5	3	
NWP-33 (4")	Pines 310	4-inch Production	17-Aug-2006	8	Not encountered	0	19	19	2.5	7	0.5	2.5	
NWP-34 (4")	Joes Mill Pond	4-inch Production	17-Aug-2006	8	11.5	1	11	10	3	4	0.5	3	
NWP-35	Joes Mill Pond	1-inch Piezometer	17-Aug-2006	2.25	18	8	18	10	7	14.5	0	7	
NWP-36	Joes Mill Pond	1-inch Piezometer	17-Aug-2006	2.25	15	5	15	10	---	---	0	4	
NWP-40	Pines 105 grout curtain area	1-inch Piezometer	3-Aug-07	2.25	25.2	2	25	23	2	25	0	2	
NWP-41	Pines 105 grout curtain area	1-inch Piezometer	2-Aug-07	2.25	25.1	3	25	22	2.5	25	0	2.5	
NWP-42	Pines 105 side canyon	1-inch Piezometer	2-Aug-07	2.25	26.8	4	26	22	3	26.8	0	3	
NWP-43	Pines 105 side canyon	1-inch Piezometer	6-Aug-07	2.25	17.2	2	17	15	2	17	0	2	
NWP-44	Pines 311 side canyon	1-inch Piezometer	7-Aug-07	2.25	24	3.5	23.5	20	24	3	0	3	
NWP-45	Pines 311 side canyon	1-inch Piezometer	7-Aug-07	2.25	22.5	8.3	22.4	14	22.5	7	0	7	
NWP-46	Pines 310 side canyon	1-inch Piezometer	6-Aug-07	2.25	19.8	2.8	18.8	16	2.5	19.8	0	2.5	
NWP-47	Pines 310 side canyon	1-inch Piezometer	5-Aug-07	2.25	19.5	3.3	18.3	15	5	19.5	0	5	
NWP-48	Upper main canyon	1-inch Piezometer	2-Aug-07	2.25	16.3	6.1	16.1	10	5	16.3	0	5	
NWP-49	Upper main canyon	1-inch Piezometer	2-Aug-07	2.25	23.5	23.3	8.3	15	8.3	23.5	0	8.3	
NWP-50	Pines 105 side canyon	1-inch Piezometer	6-Aug-07	2.25	14	2	14	12	1	14	0	1	
NWP-51	Pines 105 side canyon	1-inch Piezometer	7-Aug-07	2.25	21	6	21	15	5	21	0	5	
NWP-52	Pines 105 grout curtain area	1-inch Piezometer	28-Aug-07	2.25	25	1	21	20	3	25	0	1	
NWP-53	Pines 105 grout curtain area	1-inch Piezometer	28-Aug-07	2.25	25.5	3	25	22	3	25	0	3	
NWP-54	Pines 105 grout curtain area	1-inch Piezometer	28-Aug-07	2.25	Not encountered	0	14	14	1	16	0	1	
NWP-55	Pines 105 grout curtain area	3/4-inch Piezometer	27-Aug-07	2.25	Not encountered	0	20	20	0	15	0	5	
NWP-56	Joes Mill Pond	1-inch Piezometer	28-Aug-07	2.25	19.8	4.8	19.8	15	4	19.8	0	4	
NWP-57	Joes Mill Pond	1-inch Piezometer	28-Aug-07	2.25	23.5	3.5	23.5	20	3	23.5	0	3	

Measurements reported as depth to water in feet relative to top of PVC casing

	3-Aug-06	4-Aug-06	11-Aug-06	15-Aug-06	16-Aug-06	17-Aug-06	24-Aug-06	1-Sep-06	14-Sep-06	29-Sep-06	12-Oct-06	23-Oct-06	6
NWP-1	4.91	4.06	4.27	4.41	4.40		4.61	4.81	4.75	5.08	4.76	4.87	
NWP-2	2.70	2.72	2.92	3.02	3.01		3.15	3.39	3.63	3.91	3.65	3.75	
NWP-3	11.01	11.01	11.13	11.21	11.23		11.36	11.41	11.42	11.44	11.34	11.32	
NWP-4	3.08	3.10	3.35	3.47	3.41		3.55	3.71	4.34	4.67	4.40	4.46	
NWP-5	2.70	2.68	2.86	3.02	2.95		2.93	3.06	5.45	6.15	6.02	6.15	
NWP-6	2.80	2.75	3.07	3.16	3.08	3.05	3.08	3.24	5.51	6.06	5.85	5.73	
NWP-7	3.19	3.15	3.34	3.46	3.41		3.41	3.54	6.40	7.26	7.21	7.44	
NWP-8	8.66	8.49	8.59	8.65	8.65		8.77	8.78	9.50	9.82	9.88	9.49	
NWP-9		2.43	2.60	3.05	2.70		2.79	2.98	3.53	3.84	3.59	3.69	
NWP-10 shallow		2.94	3.17	3.29	3.23		3.39	3.60	3.71	3.91	3.64	3.79	
NWP-10 deep		1.84	1.92	2.20	2.18		2.06	2.26	3.43	3.86	4.29	4.61	
NWP-11		2.27	2.76	2.86	2.80		2.58	3.14	19.68	19.59	20.20	20.08	
NWP-12		4.29	4.42	4.67	4.51	4.48	4.14	4.94	22.52	16.29	17.36	17.42	
NWP-13		4.18	4.37	4.58	4.48		3.88	5.44	12.38	13.87	14.37	15.08	
NWP-14		3.66	3.87	4.09	4.04		3.34	5.43	9.59	12.04	12.02	12.04	
NWP-15		3.46	3.71	3.88	3.90	3.73	2.87	5.42	7.76	9.91	9.97	9.84	
NWP-16		3.64	3.23	3.52	3.39	3.35	3.30	4.43	Dry	Dry	Dry	Dry	
NWP-17		4.86	3.98	4.21	4.65	4.17	3.56	9.03	7.98	9.93	9.88	9.83	
NWP-18			5.35	5.48	5.39	5.31	4.19	4.19	9.25	10.75	10.47	10.60	
NWP-19			7.79	7.65	7.69		8.46	8.52	9.04	9.81	10.52	10.77	
NWP-20			17.21	17.44	17.36		17.35	17.60	17.58	19.14	18.08	18.16	
NWP-21				3.90	3.82	3.85	2.70	5.63	submerged	3.68	submerged	submerged	
NWP-22				7.08	7.03	7.11	7.24	7.68	8.22	9.70	8.97	8.97	
NWP-23					8.13		8.74	9.08	9.54	9.96	10.22	10.29	
NWP-24					16.91		17.21	17.48	17.72	18.05	18.09	18.14	
NWP-25					15.40		15.56	15.73	15.98	16.22	16.52	16.71	
NWP-26					17.69		18.79	18.96	19.27	19.78	20.06	20.08	
NWP-27					8.25		8.36	8.63	9.18	9.74	10.13	10.12	
NWP-28 shallow					6.92		7.18	7.39	7.83	8.31	8.50	8.55	
NWP-28 deep					8.67		8.56	8.79	9.32	9.97	10.46	10.57	
NWP-29					9.65	8.96	9.90	9.74	9.84	10.33	10.68	9.95	
NWP-30					12.30	12.42	12.95	13.30	13.84	14.75	15.42	15.86	
NWP-31 (4")							9.00	9.30	9.74	10.13	10.48	10.55	
NWP-32 (4")						3.90	3.60	6.19	6.27	9.60	9.74	9.65	
NWP-33 (4")						3.90	4.03	4.36	4.46	4.48	4.17	4.20	
NWP-34 (4")								6.73	7.03	7.37	7.68	7.80	
NWP-35								14.69	14.97	15.19	15.52	15.67	
NWP-36								10.16	10.27	10.34	10.50	10.54	
NWP-40													
NWP-41													
NWP-42													
NWP-43													
NWP-44													
NWP-45													
NWP-46													
NWP-47													
NWP-48													
NWP-49													
NWP-50													
NWP-51													
NWP-52													
NWP-53													
NWP-54													

Table 3 North Water Canyon piezometer slug testing results.

Piezometer	Area	Hydraulic conductivity estimate (ft/day)
NWP-10 deep	North Water Canyon, Pines 310 area	6.3
NWP-43	Pines 105 side canyon	1.0
NWP-47	Pines 310 side canyon	1.1
NWP-49	Upper main North Water Canyon	7.0

Note: Calculations performed using methods described by Hvorslev, 1951.

Table 4 Discharge data from Sufco North Water springs

	Date	Discharge (gpm)	
Pines 310	5/26/2006	4.56	
Pines 310	7/11/2006	4.30	
Pines 310	8/4/2006	4.24	
Pines 310	8/16/2006	3.77	
Pines 310	8/24/2006	3.68	
Pines 310	9/1/2006	3.25	
Pines 310	9/14/2006	2.60	
Pines 310	9/28/2006	0.41	
Pines 310	10/12/2006	0.60	
Pines 310	10/23/2006	0.46	
Pines 310	11/6/2006	0.5 est	Spring measuring area ice covered/frozen. Flow estimate made at Pines 310 upper site
Pines 310	11/20/2006	0.5 est	Spring measuring area ice covered/frozen. Flow estimate made at Pines 310 upper site
Pines 310	12/4/2006	0.5 est	Spring measuring area ice covered/frozen. Flow estimate made at Pines 310 upper site
Pines 310	4/27/2007	0.5 est	Flow measurement made at Pines 310 upper, lower site is dry
Pines 310	7/19/2007	0.42	Flow measurement made at Pines 310 upper, lower site is dry
Pines 310	10/4/2007	0.48	Flow measurement made at Pines 310 upper, lower site is dry
Pines 311	5/26/2006	1.26	
Pines 311	7/11/2006	0.49	
Pines 311	8/4/2006	0.37	
Pines 311	8/15/2006	0.56	
Pines 311	8/16/2006	0.30	
Pines 311	8/24/2006	0.38	
Pines 311	9/1/2006	0.11	
Pines 311	9/14/2006	0.00	
Pines 311	9/28/2006	0.00	
Pines 311	10/12/2006	0.00	
Pines 105	6/17/1997	12	
Pines 105	6/28/1997	10	
Pines 105	8/28/1997	2.61	
Pines 105	11/3/1997	10	
Pines 105	6/29/1998	3	
Pines 105	9/16/1998	11.1	
Pines 105	11/4/1998	8.33	
Pines 105	6/22/1999	9.7	
Pines 105	8/25/1999	7.8	
Pines 105	10/27/1999	7.7	
Pines 105	6/1/2000	10	
Pines 105	8/23/2000	5.88	
Pines 105	11/16/2000	7.3	
Pines 105	6/13/2001	7.89	
Pines 105	8/22/2001	5.45	
Pines 105	10/1/2001	3.66	
Pines 105	5/9/2002	5.52	
Pines 105	9/21/2002	3.56	
Pines 105	10/9/2002	5.06	
Pines 105	6/6/2003	4.89	
Pines 105	8/5/2003	4.34	
Pines 105	10/17/2003	4.34	
Pines 105	6/25/2004	4.56	
Pines 105	8/12/2004	3.92	
Pines 105	11/2/2004	3.65	
Pines 105	6/27/2005	5.88	
Pines 105	9/29/2005	9.62	
Pines 105	10/27/2005	3.66	
Pines 105	12/21/2005	9.32	
Pines 105	4/27/2006	0	

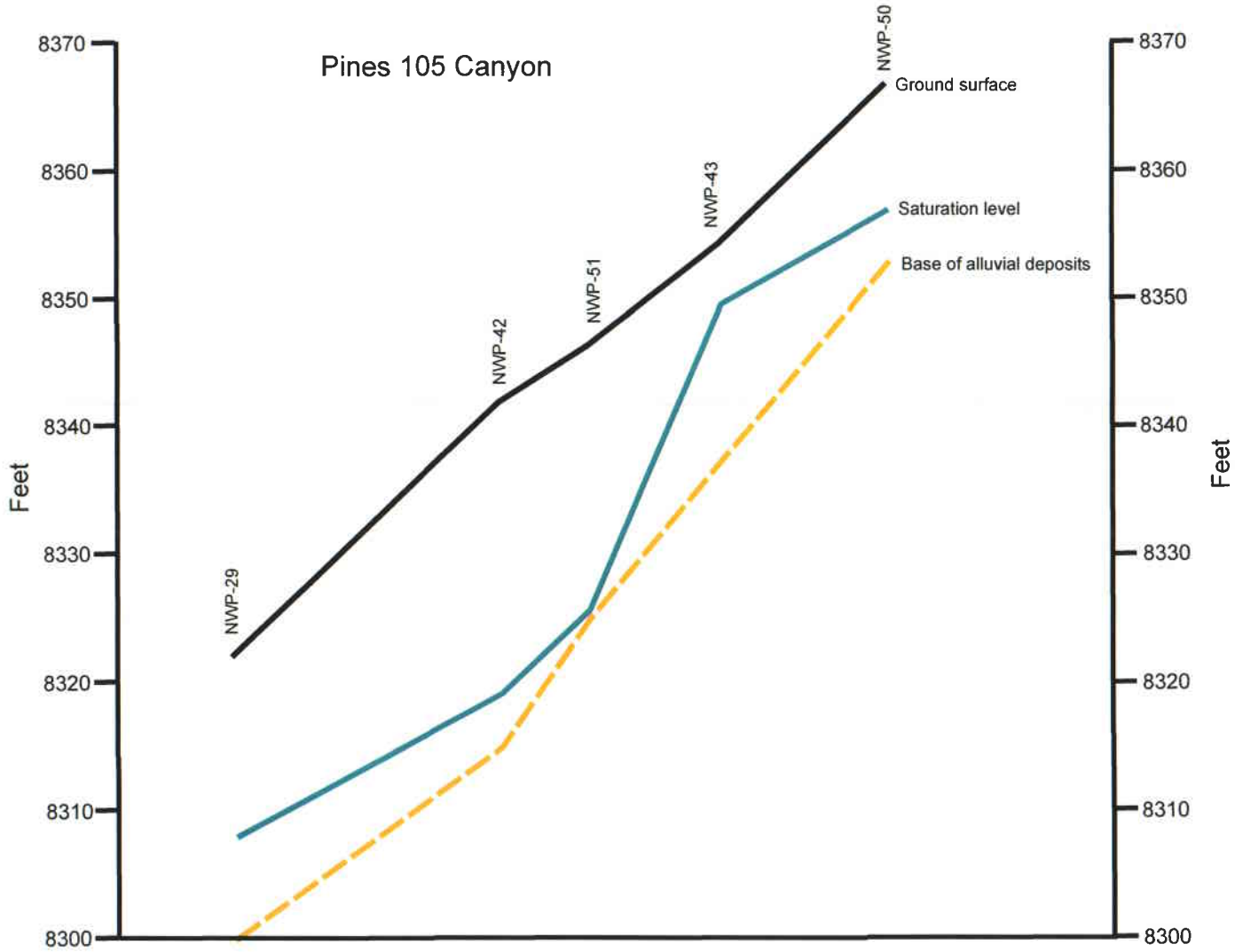
Table 5 North Water Canyon bentonite grout curtain construction details

	Depth (feet)	Grout injected	Injected gallons
Hole 1	25.5	11 bags @ 80 gallons water per bag	880
Hole 2	25.0	16 bags @ 60 gallons water per bag	960
Hole 3	26.0	16 bags @ 60 gallons water per bag	960
Hole 4	27.0	13 bags @ 60 gallons water per bag	780
Hole 5	27.5	11 bags @ 80 gallons water per bag	880
Hole 6	27.0	9 bags @ 50 gallons water per bag	450
Hole 7	28.0	8 bags @ 50 gallons water per bag	400
Hole 8	27.5	9 bags @ 50 gallons water per bag	450
Hole 9	14.0	4 bags @ 50 gallons water per bag (approximate)	200
		Total:	5960 (97 bags)

Table 6 Elevation data for wells in the North Water and Joe Mill Pond areas.

Description	Original Elevation	Subsided Elevation	Elevation Diff.
NWP01 GROUND	8368.34	8368.39	0.05
NWP01 TOP PIPE	8369.51	8369.26	-0.25
NWP02 GROUND	8366.90	8366.73	-0.17
NWP02 TOP PIPE	8367.36	8367.07	-0.29
NWP03 GROUND	N/A	8380.64	N/A
NWP03 TOP PIPE	N/A	8381.31	N/A
NWP04 GROUND	8365.64	N/A	N/A
NWP04 TOP PIPE	8366.46	8366.31	-0.15
NWP05 GROUND	8361.54	8361.20	-0.34
NWP05 TOP PIPE	8362.52	8362.20	-0.32
NWP06 GROUND	8361.63	8361.43	-0.20
NWP06 TOP PIPE	8362.63	8362.37	-0.26
NWP07 GROUND	8361.96	8361.69	-0.27
NWP07 TOP PIPE	8362.78	8362.43	-0.35
NWP08 GROUND	N/A	8369.96	N/A
NWP08 TOP PIPE	N/A	8370.71	N/A
NWP09 GROUND	8365.44	8365.29	-0.15
NWP09 TOP PIPE	8366.41	8366.01	-0.40
NWP10 DEEP GROUND	8366.90	8366.96	0.06
NWP10 DEEP TOP PIPE	8367.39	8367.39	0.00
NWP10 SHALLOW GROUND	8367.13	8367.16	0.03
NWP10 SHALLOW TOP PIPE	8367.96	8367.76	-0.20
NWP11 GROUND	8357.03	8356.05	-0.98
NWP11 TOP PIPE	8357.74	8356.75	-0.99
NWP12 GROUND	8357.01	8355.80	-1.21
NWP12 TOP PIPE	8357.83	8356.67	-1.16
NWP13 GROUND	8356.78	8355.47	-1.31
NWP13 TOP PIPE	8357.54	8356.35	-1.19
NWP14 GROUND	8355.32	8352.43	-2.89
NWP14 TOP PIPE	8356.22	8353.65	-2.57
NWP15 GROUND	8353.48	8349.36	-4.12
NWP15 TOP PIPE	8354.40	8350.13	-4.27
NWP16 GROUND	8356.10	8352.41	-3.69
NWP16 TOP PIPE	8357.15	8353.24	-3.91
NWP17 GROUND	8353.35	8348.11	-5.24
NWP17 TOP PIPE	8354.29	8349.05	-5.24
NWP18 GROUND	8350.33	8344.50	-5.83
NWP18 TOP PIPE	8351.10	8345.15	-5.95
NWP19 GROUND	8329.21	8328.92	-0.29
NWP19 TOP PIPE	8330.02	8329.66	-0.36
NWP20 GROUND	8324.88	8324.73	-0.15
NWP20 TOP PIPE	8326.04	8325.82	-0.22
NWP21 GROUND	8336.36	8331.61	-4.75
NWP21 TOP PIPE	8336.98	8332.17	-4.81
NWP22 GROUND	8330.07	8329.63	-0.44
NWP22 TOP PIPE	8330.92	8330.32	-0.60
NWP23 GROUND	8328.92	8328.59	-0.33
NWP23 TOP PIPE	8329.75	8329.26	-0.49
NWP24 GROUND	8332.14	8331.55	-0.59
NWP24 TOP PIPE	8333.12	8332.31	-0.81
NWP25 GROUND	N/A	8331.03	N/A
NWP25 TOP PIPE	N/A	8331.92	N/A
NWP26 GROUND	8326.58	8326.50	-0.08
NWP26 TOP PIPE	8327.94	8327.46	-0.48
NWP27 GROUND	8325.92	8325.50	-0.42

Description	Original Elevation	Subsided Elevation	Elevation Diff.
NWP27 TOP PIPE	8326.85	8326.54	-0.31
NWP28 DEEP GROUND	8326.25	8325.87	-0.38
NWP28 DEEP TOP PIPE	8327.03	8326.58	-0.45
NWP28 SHALLOW GROUND	8326.16	8325.84	-0.32
NWP28 SHALLOW TOP PIPE	8327.06	8326.68	-0.38
NWP29 GROUND	8322.07	8322.20	0.13
NWP29 TOP PIPE	8323.01	8322.89	-0.12
NWP30 GROUND	8311.14	8310.97	-0.17
NWP30 TOP PIPE	8312.04	8311.66	-0.38
NWP31 GROUND WELL	8328.72	8328.19	-0.53
NWP31 TOP PIPE WELL	8330.23	8329.74	-0.49
NWP32 WELL GROUND	8353.74	8348.79	-4.95
NWP32 WELL TOP PIPE	8355.33	8350.35	-4.98
NWP33 WELL GROUND	8367.14	8366.85	-0.29
NWP33 WELL TOP PIPE	8368.27	8368.00	-0.27
NWP34 TOP PIPE	N/A	8401.74	N/A
NWP34 GROUND	N/A	8400.24	N/A
NWP35 TOP PIPE	N/A	8401.68	N/A
NWP35 GROUND	N/A	8400.82	N/A
NWP36 TOP PIPE	N/A	8392.12	N/A
NWP36 GROUND	N/A	8391.42	N/A
NWP40 GROUND	N/A	8321.87	N/A
NWP40 TOP PIPE	N/A	8323.15	N/A
NWP41 GROUND	N/A	8321.77	N/A
NWP41 TOP PIPE	N/A	8323.20	N/A
NWP42 GROUND	N/A	8342.14	N/A
NWP42 TOP PIPE	N/A	8343.30	N/A
NWP43 GROUND	N/A	8354.64	N/A
NWP43 TOP PIPE	N/A	8355.98	N/A
NWP44 GROUND	N/A	8372.73	N/A
NWP44 TOP PIPE	N/A	8374.08	N/A
NWP45 GROUND	N/A	8389.14	N/A
NWP45 TOP PIPE	N/A	8390.41	N/A
NWP46 GROUND	N/A	8388.37	N/A
NWP46 TOP PIPE	N/A	8389.67	N/A
NWP47 GROUND	N/A	8404.05	N/A
NWP47 TOP PIPE	N/A	8405.45	N/A
NWP48 GROUND	N/A	8398.59	N/A
NWP48 TOP PIPE	N/A	8400.02	N/A
NWP49 GROUND	N/A	8416.39	N/A
NWP49 TOP PIPE	N/A	8417.95	N/A
NWP50 GROUND	N/A	8367.24	N/A
NWP50 TOP PIPE	N/A	8368.45	N/A
NWP51 GROUND	N/A	8346.49	N/A
NWP51 TOP PIPE	N/A	8347.80	N/A
NWP52 GROUND	N/A	8321.30	N/A
NWP52 TOP PIPE	N/A	8321.95	N/A
NWP53 GROUND	N/A	8321.50	N/A
NWP53 TOP PIPE	N/A	8322.68	N/A
NWP54 GROUND	N/A	8321.50	N/A
NWP54 TOP PIPE	N/A	8322.50	N/A
NWP55 GROUND	N/A	8323.28	N/A
NWP55 TOP PIPE	N/A	8324.07	N/A
NWP56-GRND	N/A	8408.08	N/A
NWP56-TOPPIPE	N/A	8409.14	N/A
NWP57-GRND	N/A	8418.74	N/A
NWP57-TOPOPIPE	N/A	8419.65	N/A



PETERSEN HYDROLOGIC, LLC
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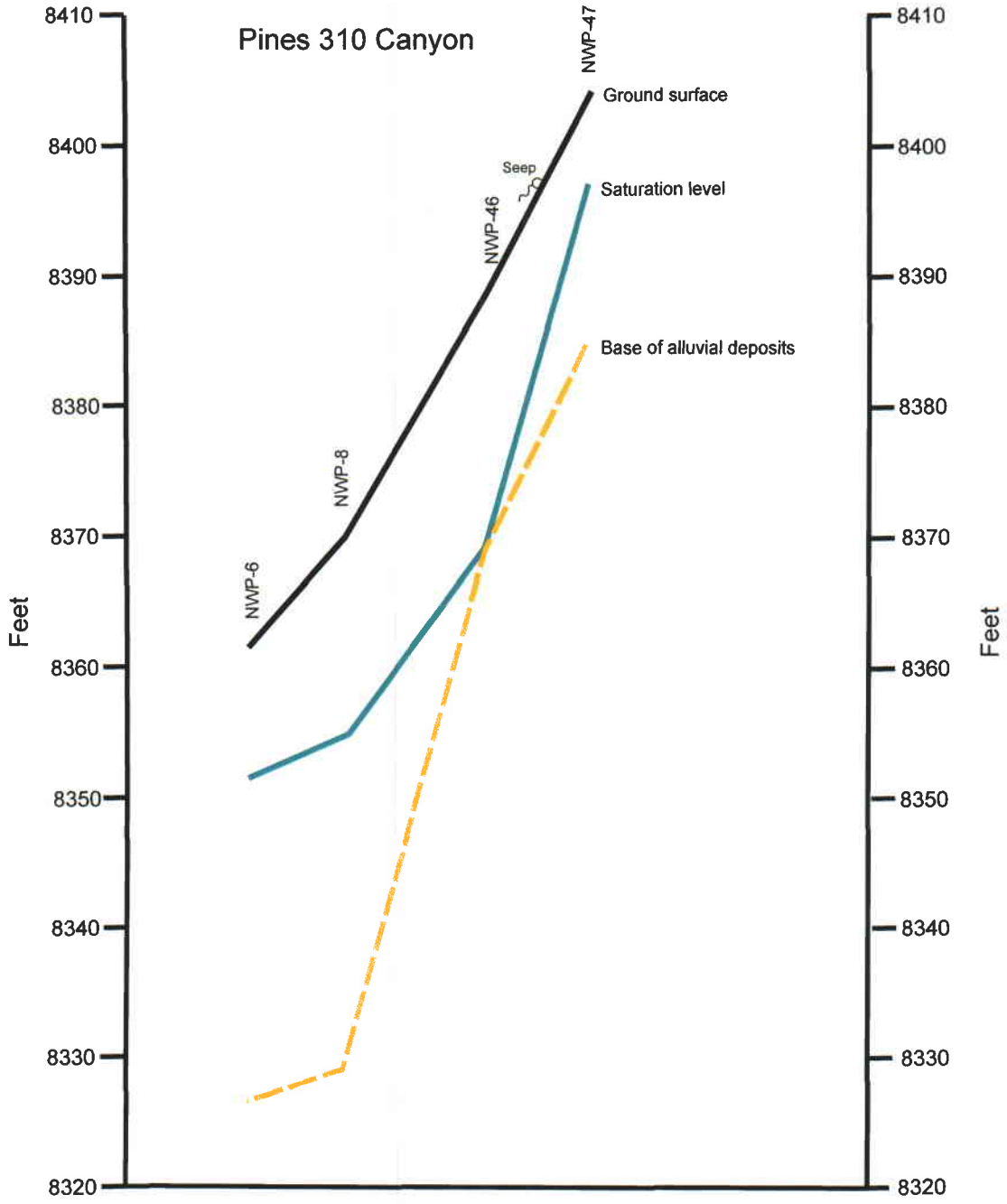
0 100 200 300
300 feet

Figure 3a Hydrogeologic section for Pines 105 side canyon.



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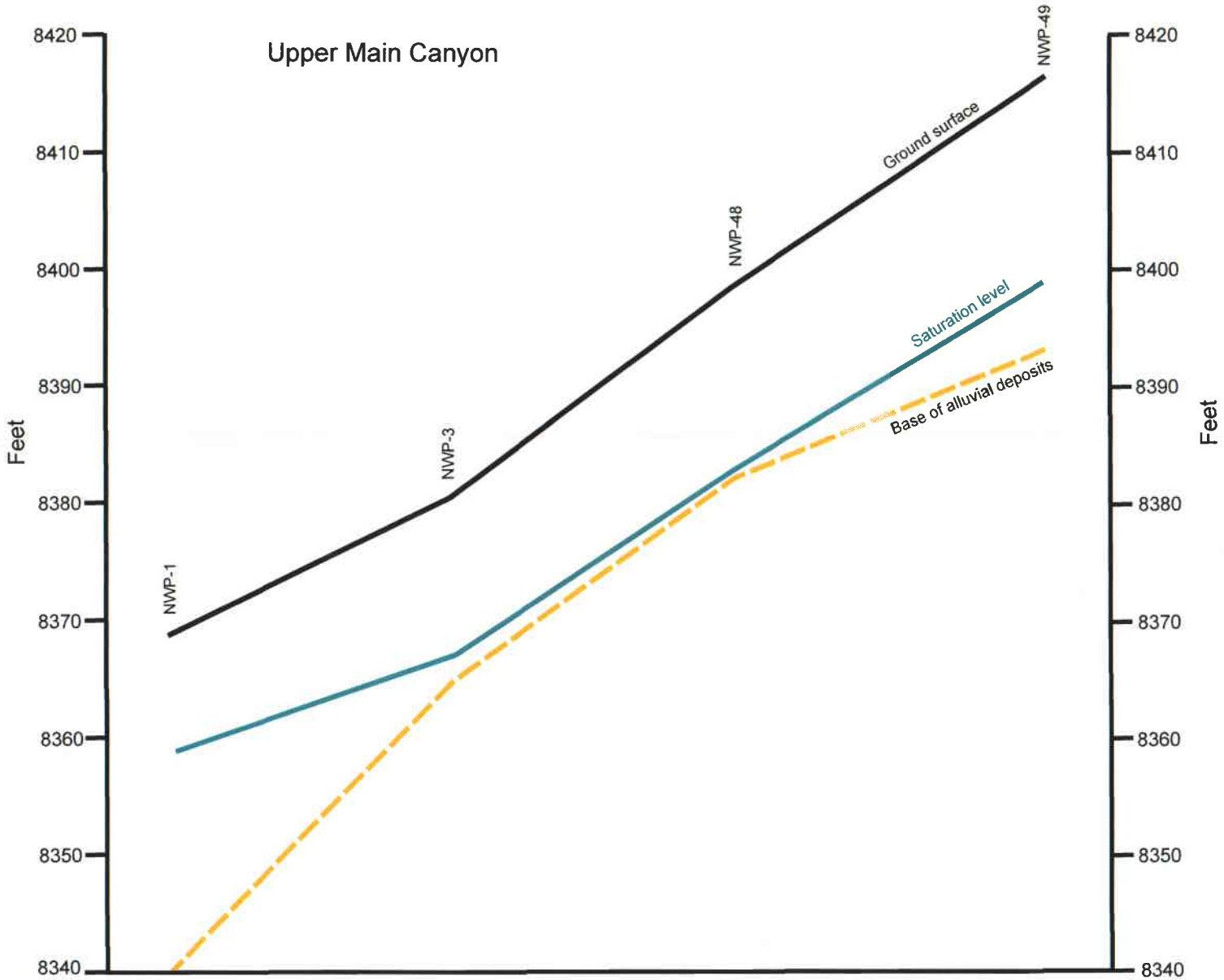
0 100 200 300
300 feet

Figure 3b Hydrogeologic section for Pines 310 side canyon.



PETERSEN HYDROLOGIC, LLC
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0 100 200 300
300 feet

Figure 3c Hydrogeologic section for upper main canyon.

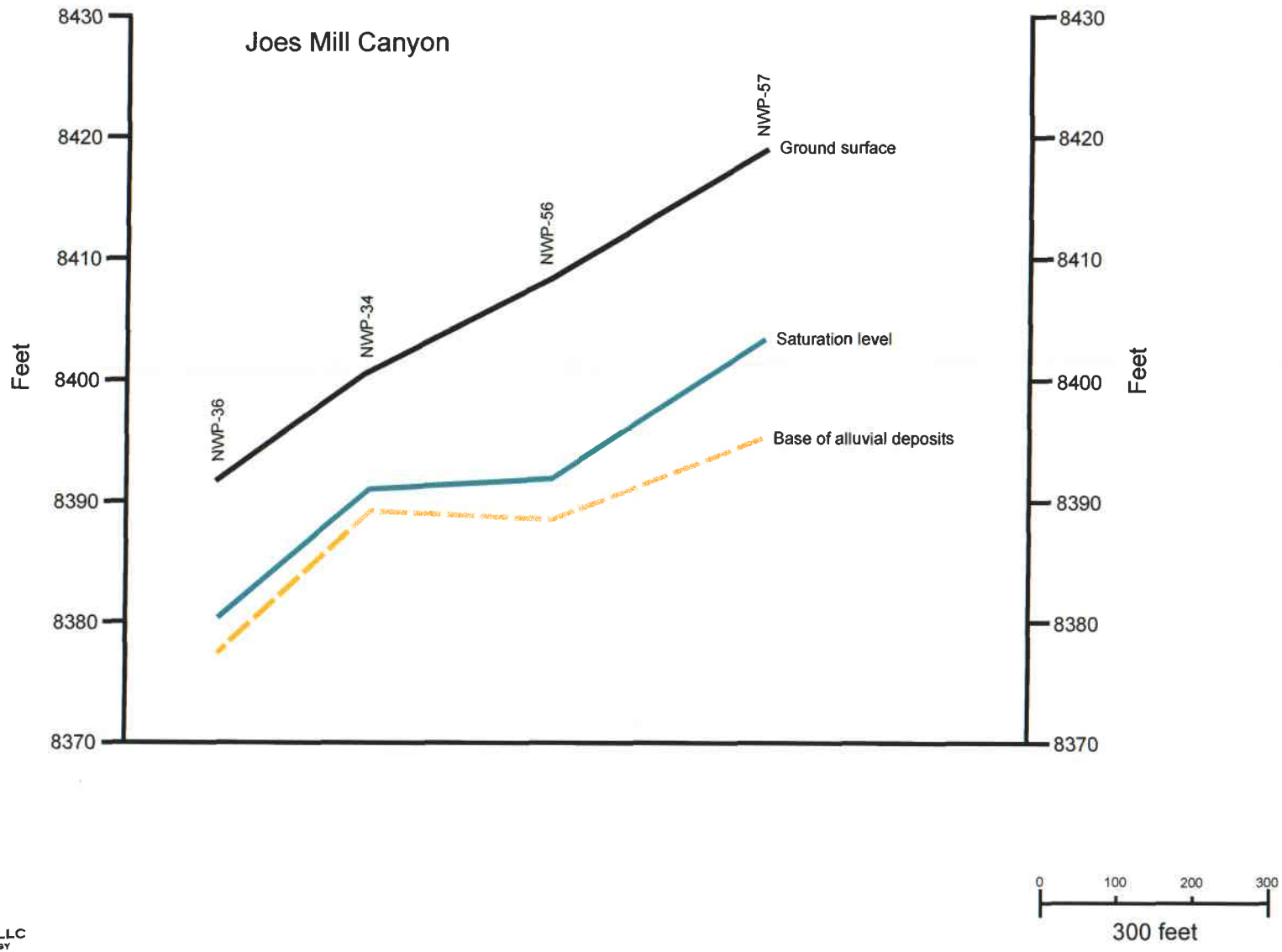

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Figure 3d Hydrogeologic section for Joes Mill Pond canyon.

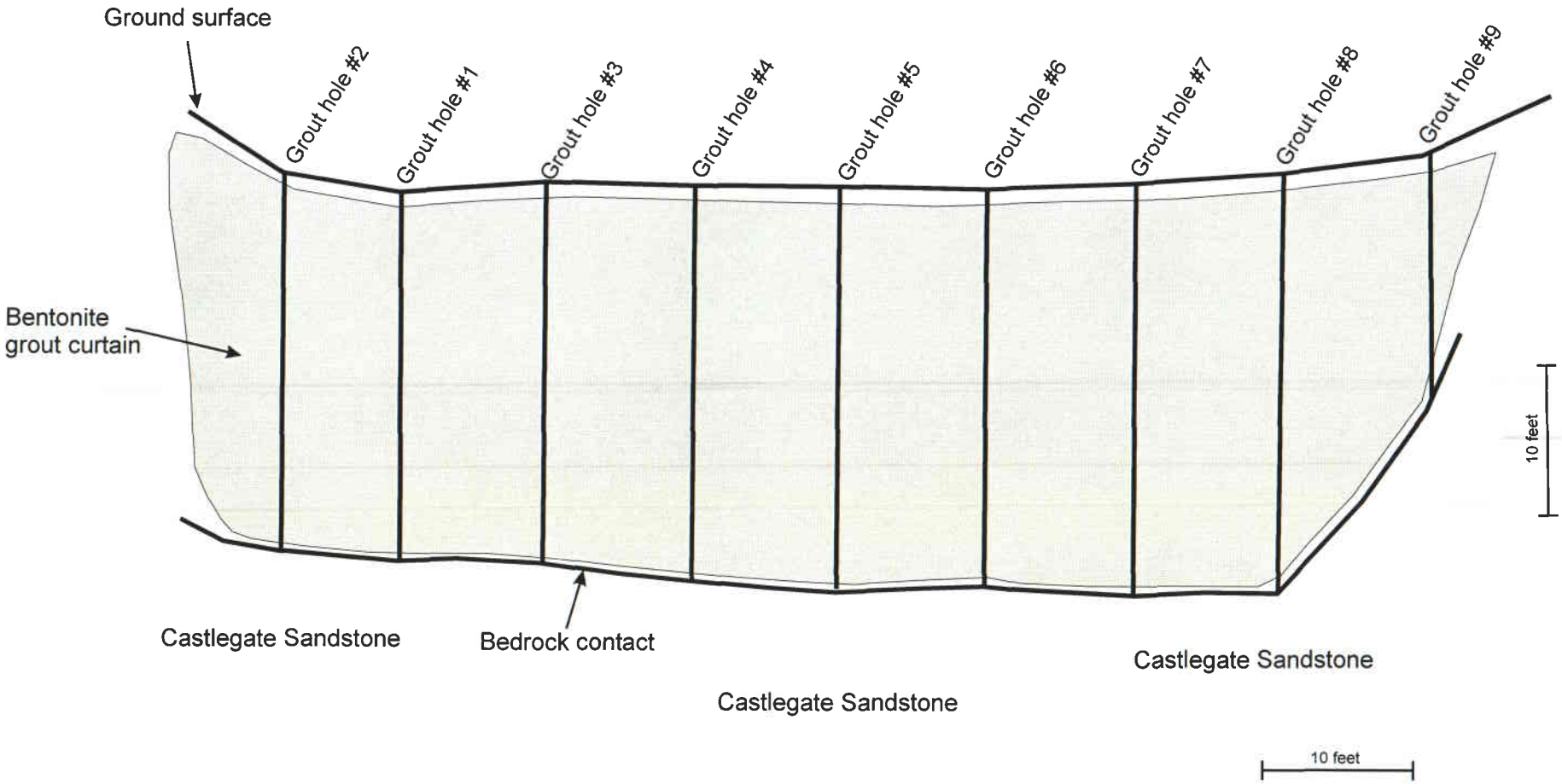

Figure 4 Conceptual diagram showing approximate extent of North Water Canyon grout curtain.

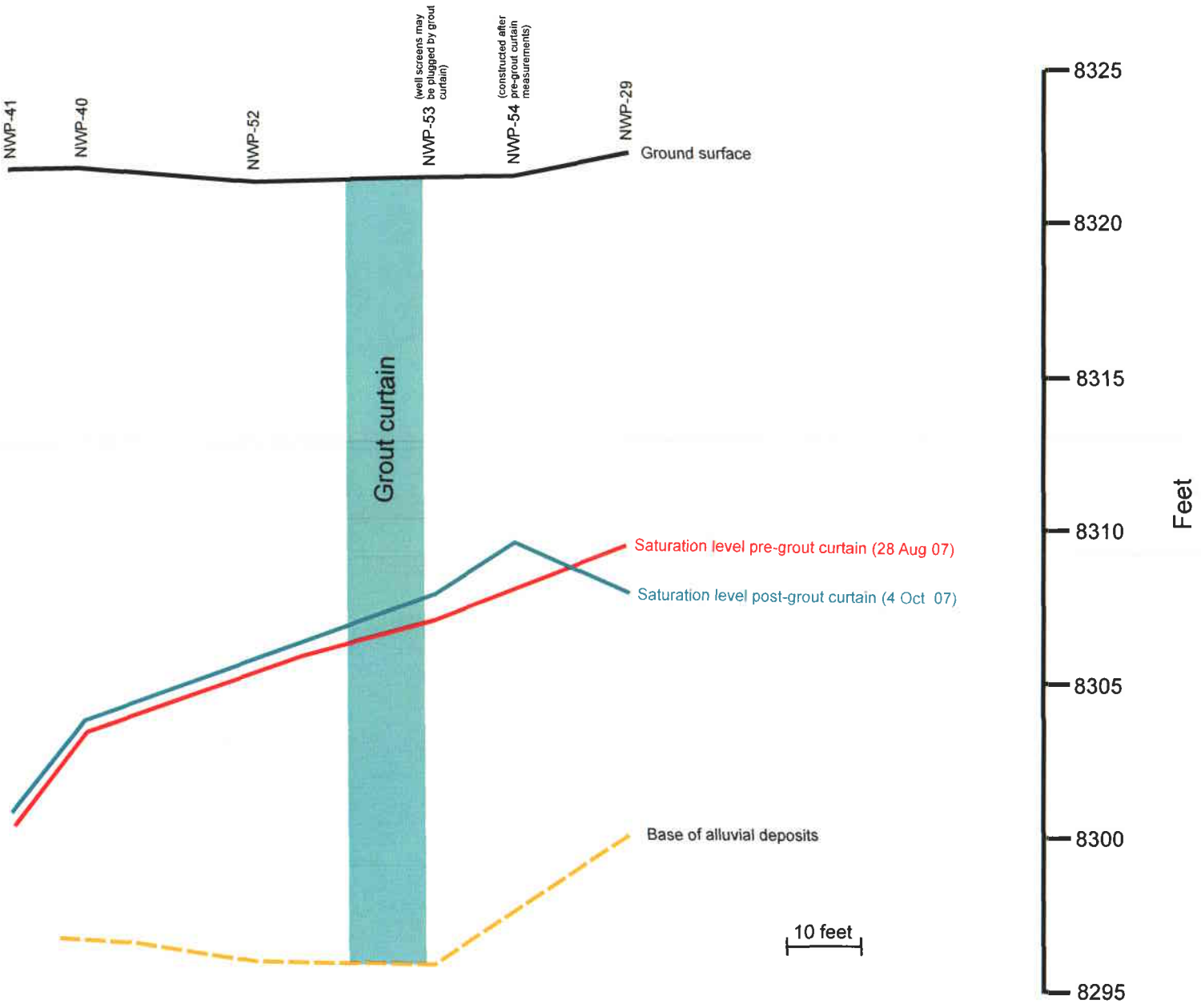

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Figure 5 Grout curtain below Pines 105 spring area.

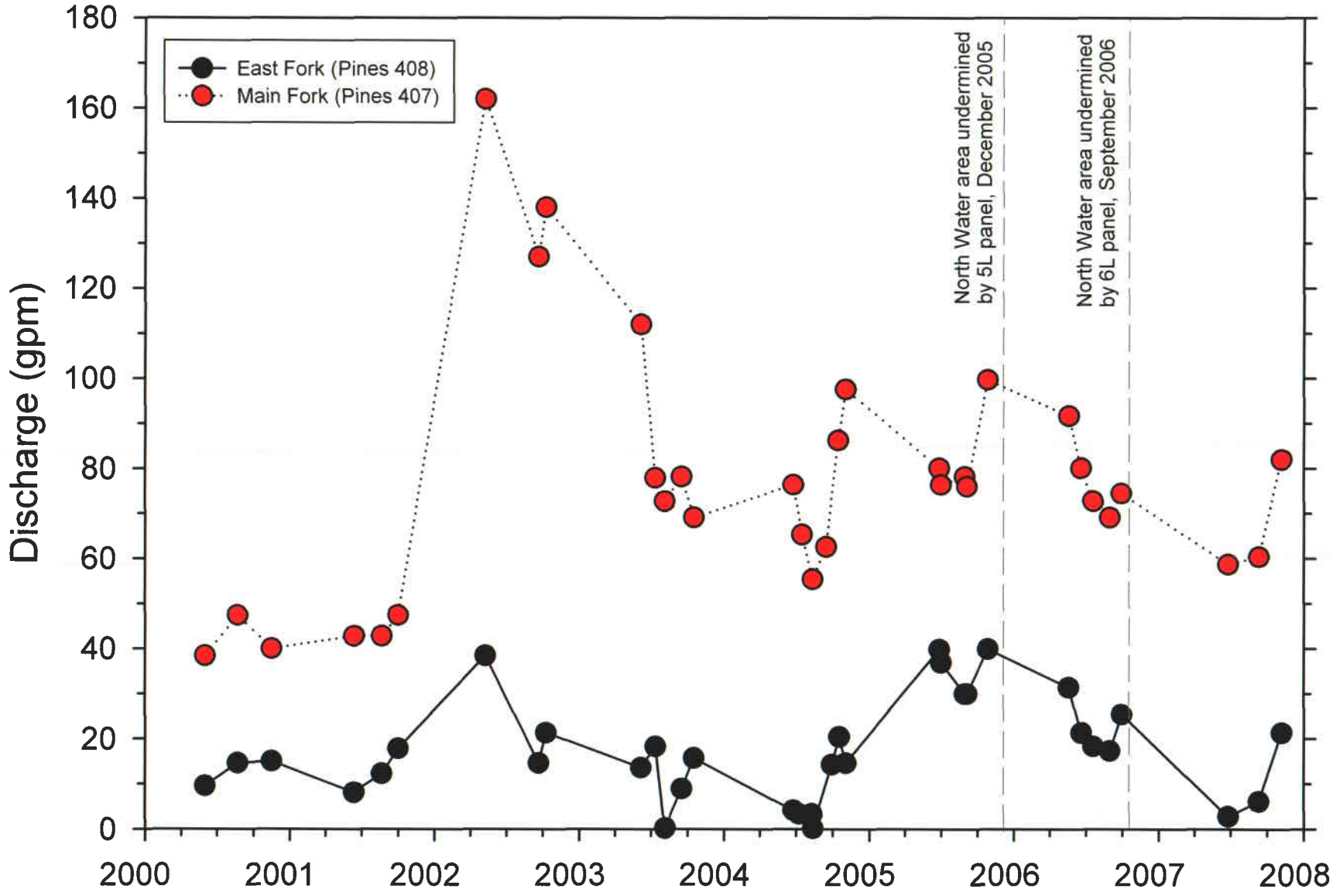

Figure 6 Discharge hydrographs for the Main Fork and East Fork of Box Canyon Creek.

Appendix A

Geologic Logs

Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-40**
Date drilled: 3-Aug-07

Interval (feet)	Code	Description
0-0.3	OSND	Dark brown to black organic soil
0.3-3	FGS	Medium gray fine grained sand and silt, high organic content
3-9	OSLT	Dark brownish black to black organic silt/muck with interbedded wood chuncks and roots, plastic
9-9.4	WOOD	Wood (log), decomposing, wet
9.4-10	OSLT	Dark brownish black to black organic silt/muck
10-10.3	FGS	Gray fine grained sand
10.3-11.5	OSLT	Dark brown to black organic silt/muck and woody material
11.5-11.7	FGS	Gray fine grained sand
11.7-14	OSLT	Dark brown organic silt/muck and decaying roots/vegetation
14-17	FGS	Medium to dark gray fine grained sand, zones of high organic content, mostly sand
17-18	OSLT	Dark brown organic silt/muck, decomposing organic matter
18-18.8	OSND	Dark gray organic rich sand, silty
18.8-21.2	FGS	Medium gray fine grained sand, some pebbles
21.2-21.6	CLAY	Soft gray silty clay, wet
21.6-24.6	FGS	Gray fine grained sand with cobbles/pebbles
24.6-25.2	CLAY	Hard, dense silty clay

Key:	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

PETERSEN HYDROLOGIC, LLC
CONSULTANTS IN HYDROGEOLOGY

Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-41**
Date drilled: 2-Aug-07

Interval (feet)	Code	Description
0-0.3	OSND	Dark brown to black sandy organic soil
0.3-0.6	FGS	Gray fine grained sand, dry
0.6-1.9	FGS	Grayish brown silt and very fine grained sand, some organics and wood/roots
1.9-2.3	WOOD	Wood chunks
2.3-10	OSLT	Dark grayish black to black organic silt/muck with interbedded chuncks of wood and roots, plastic, three fine grained sand layers each about 0.2 inches thick interbedded
10-10.5	FGS	Medium gray fine grained sand
10.5-11	OSLT	Black fine grained organic silt/muck and wood
11-11.3	OSND	Gray to black fine grained sand, very high organic content
11.3-13	OSLT	Dark brownish black organic silt and decayed vegetation and roots
13-17.5	FGS	Medium to dark gray fine grained sand, banded zones of darker, higher organic content sand, mostly sand
17.5-18	OSLT	Brownish black organic silt/muck
18-18.2	FGS	Medium gray fine grained sand
18.2-18.8	OSND	Dark brownish black organic sand, high organic content
18.8-22	FGS	Gray fine grained sand, wet, silty with some organic content
22-22.4	FGS	Gray fine grained sand, transition to bedrock
22.4-22.9	CLAY	Medium gray silty clay, plastic, with fine grained sand
22.9-25.1	BDRK	Gray fine grained sand with cobbles, pebbles, hard Castlegate Sandstone at bottom

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

PETERSEN HYDROLOGIC, LLC
CONSULTANTS IN HYDROGEOLOGY

Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-42**
Date drilled: 2-Aug-07

Interval (feet)	Code	Description
0-0.3	OSND	Organic rich sandy soil
0.3-4	FGS	Medium brownish gray silty fine grained sand
4-8	FGS	As above (poor recovery, 30%)
8-12	FGS	Poor recovery (50%), silty grayish brown fine grained sand, some silt and small pebbles
12-15	FGS	As above, Castlegate Sandstone rock at 15 feet
15-22.3	FGS	Gray fine grained sand, uniform
22.3-22.9	FGS	Silty, clayey fine grained sand, lower K, wet
22.9-26	FGS	Highly weathered sandstone or fine grained sand, orange and light gray, some small pebbles
26-26.8	BDRK	Harder, orange/gray Castlegate Sandstone, weathered

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

PETERSEN HYDROLOGIC, LLC
CONSULTANTS IN HYDROGEOLOGY

Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-43**
Date drilled: 6-Aug-07

Interval (feet)	Code	Description
0-3	FGS	Tan silty fine grained sand, dries hard
3-6	FGS	Gary and tan mottled silty sand, some clay contenet, dries very hard
6-8	INTBD	As above, with more clay, some zones with large percentages of clay content
8-12	INTBD	Dark brownish gray clayey, silty sand, about 40% of interval is clay rich (can form ribbon)
12-16	FGS	Pebbley zone in matrix of fine grained sand, gray to tan, slightly clayey in places and may be weathered Castlegate Sandstone
16-17.2	BDRK	Tan fine grained sand and weathered Castlegate Sandstone (uniform)

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

PETERSEN HYDROLOGIC, LLC
CONSULTANTS IN HYDROGEOLOGY

Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-44**
Date drilled: 7-Aug-07

Interval (feet)	Code	Description
0-4	FGS	Tanish gray silty fine grained sand, dries hard
4-8	FGS	Dark brown to brown silty fine grained sand, minor organics
8-12	FGS	Very soft, easy drilling, silty fine grained sand, tan and grayish tan
12-16	FGS	Gray and tan and dark brown silty fine grained sand, some hard zones, some 1/2 inch organic rich sandy zones
16-21	FGS	Brownish tan fine grained sand with a 1.5-inch organic sand zone at 18 feet
21-21.6	CLAY	Clayey silty sand, dark gray
21.6-24	BDRK	Medium gray fine grained sand with pebbles grading to weathered Castlegate sandstone

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-45**
Date drilled: 7-Aug-07

Interval (feet)	Code	Description
0-4	OSND	3-inch organic sandy soil, remainder silty brown and grayish brown silty fine grained sand
4-8	FGS	Dark brown and medium brown fine grained sand, some silty content, easy drilling, soft
8-12	FGS	Tan and brown fine grained sand, soft
12-16	FGS	Tan fine grained sand, some small pebbles
16-20	FGS	Tan fine grained sand and increasing pebble content, most <1/4 inch, 3/4 inch organic silt layer at 18 feet
20-22.5	FGS	As above, root or old twig at 20 feet, some larger 3/4-inch pebbles

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-46**
Date drilled: 6-Aug-07

Interval (feet)	Code	Description
0-4	OSND	3-inch organic sandy soil, then tan, silty fine grained sand
4-13.5	FGS	Tanish gray silty fine grained sand
13.5-14.5	FGS	Gray, creamy fine grained sand and small 1/8 to 1/4-inch rounded pebbles
14.5-16	FGS	As above, but orange and oxidized
16-19.8	FGS	Orange-gray fine grained sand, cleaner, dark orange and tiger-striped in bottom 1 foot

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

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Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-47**
Date drilled: 6-Aug-07

Interval (feet)	Code	Description
0-2	OSND	Organic rich silty sand and soil, brown
2-4	FGS	Tan fine grained silty sand, hard and compacted
4-8	FGS	Gray and light gray fine grained sand, three 1-inch silty sand zones with increased organic content
8-12	FGS	Light brownish gray fine grained sand, clean
12-13	FGS	Brownish silty fine grained sand, 1-inch clayey zone, also 1-inch pebble
13-14.5	FGS	Orange and tan weathered conglomerate of sand and small, 1/8 inch pebbles
14.5-17.5	FGS	Tanish gray fine grained sand
17.5-18.2	CLAY	Grayish orange silty clay, hard, dense
18.2-19.5	BDRK	Fine grained sand, pebbles, weathered Castleage Sandstone

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

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Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-48**
Date drilled: 2-Aug-07

Interval (feet)	Code	Description
0-4	FGS	Dark chocolate brown fine grained silty sand
4-8	FGS	Dark chocolate brown fine grained silty sand
8-12	FGS	Dark chocolate brown fine grained silty sand; 2-inch orange sanstone cobble at 15 feet
12-16	FGS	Light to medium gray fine grained sandstone, 1-inch organic sand layer at 18.5 feet
16-16.4	FGS	Clean, light gray fine grained sand

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

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Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-49**
Date drilled: 2-Aug-07

Interval (feet)	Code	Description
0-4	F	Dark brown silty fine grained sand
4-8	F	Dark brown silty fine grained sand
8-12	F	Grayish brown fine grained sand
12-16	F	Grayish and light grayish brown fine grained sand
16-20	F	Light gray fine grained sand
20-23.5	BDRK	Light gray fine grained sand, orange-gray weathered castlegate sandstone in bottom 0.5 feet

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

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Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-50**
Date drilled: 6-Aug-07

Interval (feet)	Code	Description
0-5.5	FGS	Tan - grayish tan silty fine grained sand, dries hard
5.5-6.8	CLAY	Sandy, clayey fine grained sand, somewhat plastic, dark grayish brown color, probably low K
6.8-7.8	FGS	Brownish gray fine grained sand
7.8-9.5	CLAY	Mineral clay, dark grayish color, sand horizons interbedded, about 40% clayey zones, 60% sandy zones
9.5-12	FGS	Medium tan fine grained silty sand
12-12.3	FGS	Clayey, silty sand, dark brown
12.3-14	FGS	Grayish tan and tan fine grained sand, slightly clayey 6-inch zone at about 13.5 feet

Key:	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-51**
Date drilled: 7-Aug-07

Interval (feet)	Code	Description
0-4	FGS	Tan silty fine grained sand, dries hard
4-8	FGS	Light brown fine grained sand
8-12	FGS	Light tan fine grained sand, Iron oxidized zones at about 11 feet and from 8-8.5 feet
12-15	FGS	Tan fine grained sand
15-16	FGS	Whitish conglomerate/ pebbley sand, hard
16-19	FGS	Medium gray fine grained sand with some pebbles, likely weathered Castlegate Sandstone
19-20	FGS	Gray and yellowish fine grained sand with pebbles
20-21	FGS	Hard clayey silt, yellowish gray and dark brown

Key:	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

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Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-52**
Date drilled: 28-Aug-07

Interval (feet)	Code	Description
0-3	FGS	Grayish brown silty fine grained sand, minor organic content, some roots
3-10	OSLT	Dark brown to black organic muck and silt with wood chunks and a few 1-inch sand stringers, low K
10-12	OSND	Dark gray to black organic fine grained sand with silt
12-14	FGS	Wet, medium gray fine grained sand, cement color
14-15.5	CLAY	Silty clay, medium gray color, wet, low K
15.5-18.5	FGS	Silty fine grained sand, medium gray
18.5-23.5	FGS	Brownish gray fine grained sand, uniform
23.5-25	CLAY	Silty clay, hard and dry, medium gray and yellowish gray

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

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Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-53**
Date drilled: 28-Aug-07

Interval (feet)	Code	Description
0-2	FGS	Grayish brown fine grained sand and silty soil, organic with roots
2-10	OSLT	Dark brown to black organic silt/muck with some 1 to 2-inch sand stringers, low K
10-11	OSND	Dark gray fine grained organic sand with silt
14-15	CLAY	Medium gray silty clay, low K
15-22.5	FGS	Fine grained sand, tanish, brownish gray
22.5-25.5	CLAY	Silty clay, hard and dry, yellowish gray and medium gray

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

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Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-56**
Date drilled: 28-Aug-07

Interval (feet)	Code	Description
0-6.5	FGS	Tan fine grained silty sand
6.5-10	OSND	Dark gray and gray sandy organic fine grained sand and silt with interbedded fine grained sand, gray
10-11	OSLT	Black organic silt and organic rich fine grained sand
11-16	FGS	Medium gray fine grained sand and silt, some organic rich sand zones
16-18.5	FGS	Gray fine grained sand with pebbles, clean, not silty
18.5-19.8	BDRK	Gray and orange fine grained sand with pebbles, probably weathered Castlegate Sandstone

Key:		
	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

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Sufco, North Water Piezometers
Geologic log
Geologist: Erik Petersen, PG

Piezometer: **NWP-57**
Date drilled: 28-Aug-07

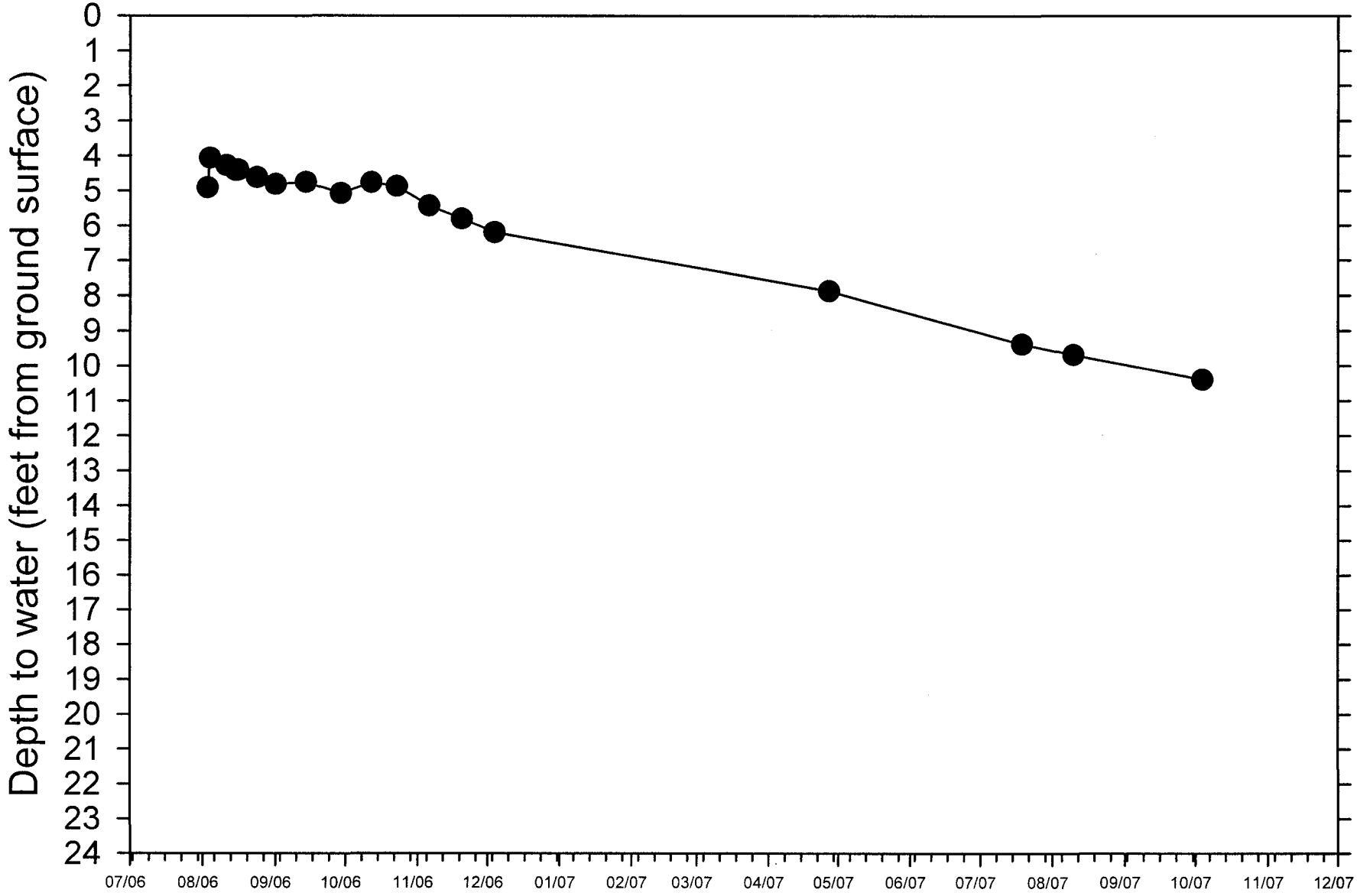
Interval (feet)	Code	Description
0-6.5	FGS	Medium chocolate brown silty and very-fine grained sand with minor organic content, soil like
6.5-9	FGS	Tanish brown silty fine grained sand, hard
9-11.5	FGS	Grayish brown and reddish stained fine grained silty sand, mottled appearance, minor organic content
11.5-14	FGS	Dark gray silty fine grained sand with high organic content, all kind of silty, apparently low K
14-19	FGS	Medium to dark gray fine grained silty sand, some 1-inch more organic rich silty zones
19-21	FGS	Fine grained sand, light gray, clean
21-22	INTBD	Silt, some sand and clay content, medium gray
22-23.5	BDRK	Light gray to orange fine grained sand and pebbles, weathered Castlegate Sandstone, hard clayey silt at base

Key:	FGS	Fine-grained sand
	OSLT	Organic silt/muck
	OSND	Organic-rich sand
	INTBD	Interbedded fine-grained sand and organic silt/muck
	WOOD	Wood or woody material
	BDRK	Bedrock
	CLAY	Clay/shale

Appendix B

Water Level Hydrographs

NWP-1


Depth to water (feet from ground surface)
0
1
2
3
4
5
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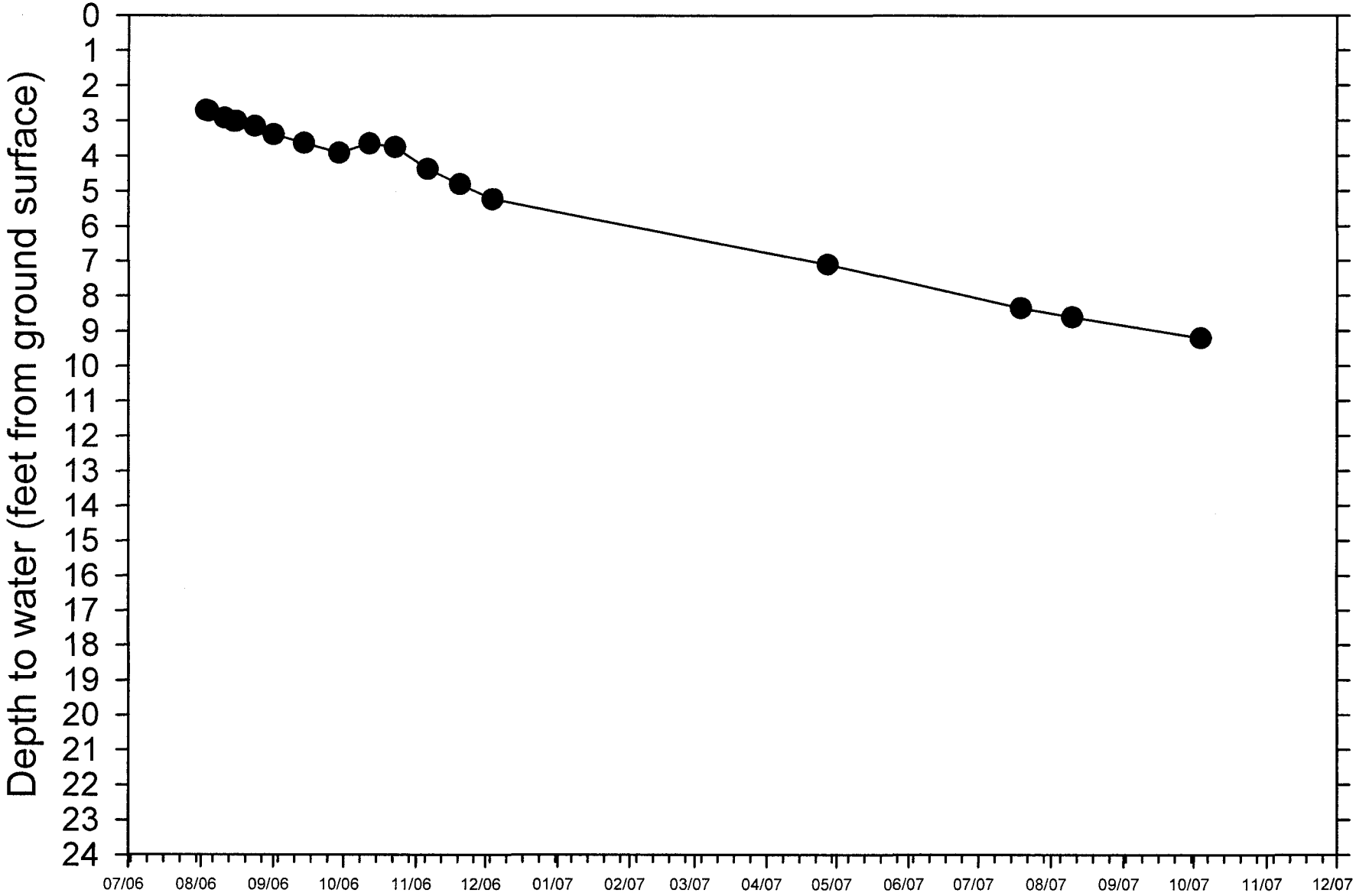
NWP-2


Depth to water (feet from ground surface)
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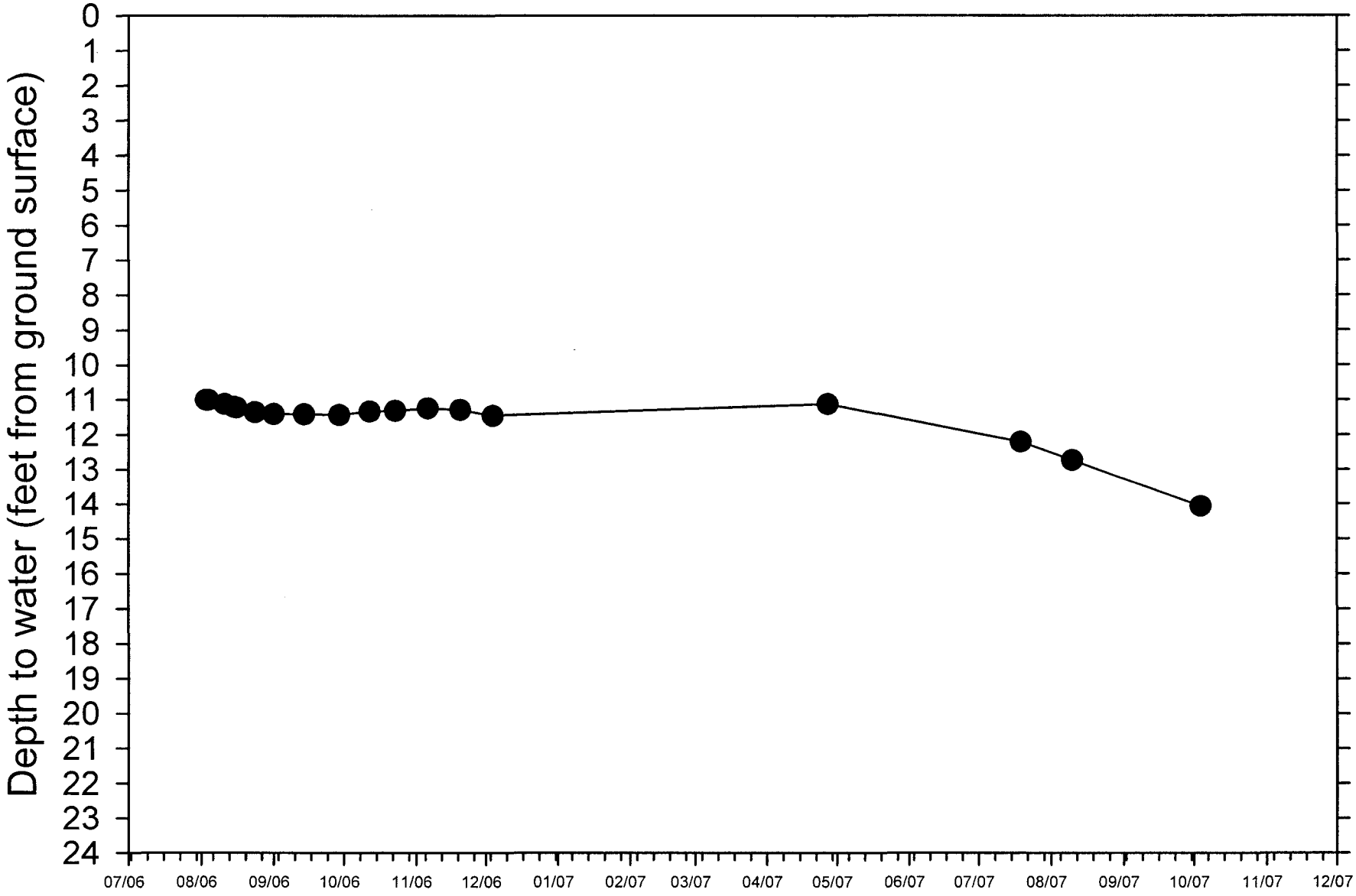
NWP-3


Depth to water (feet from ground surface)
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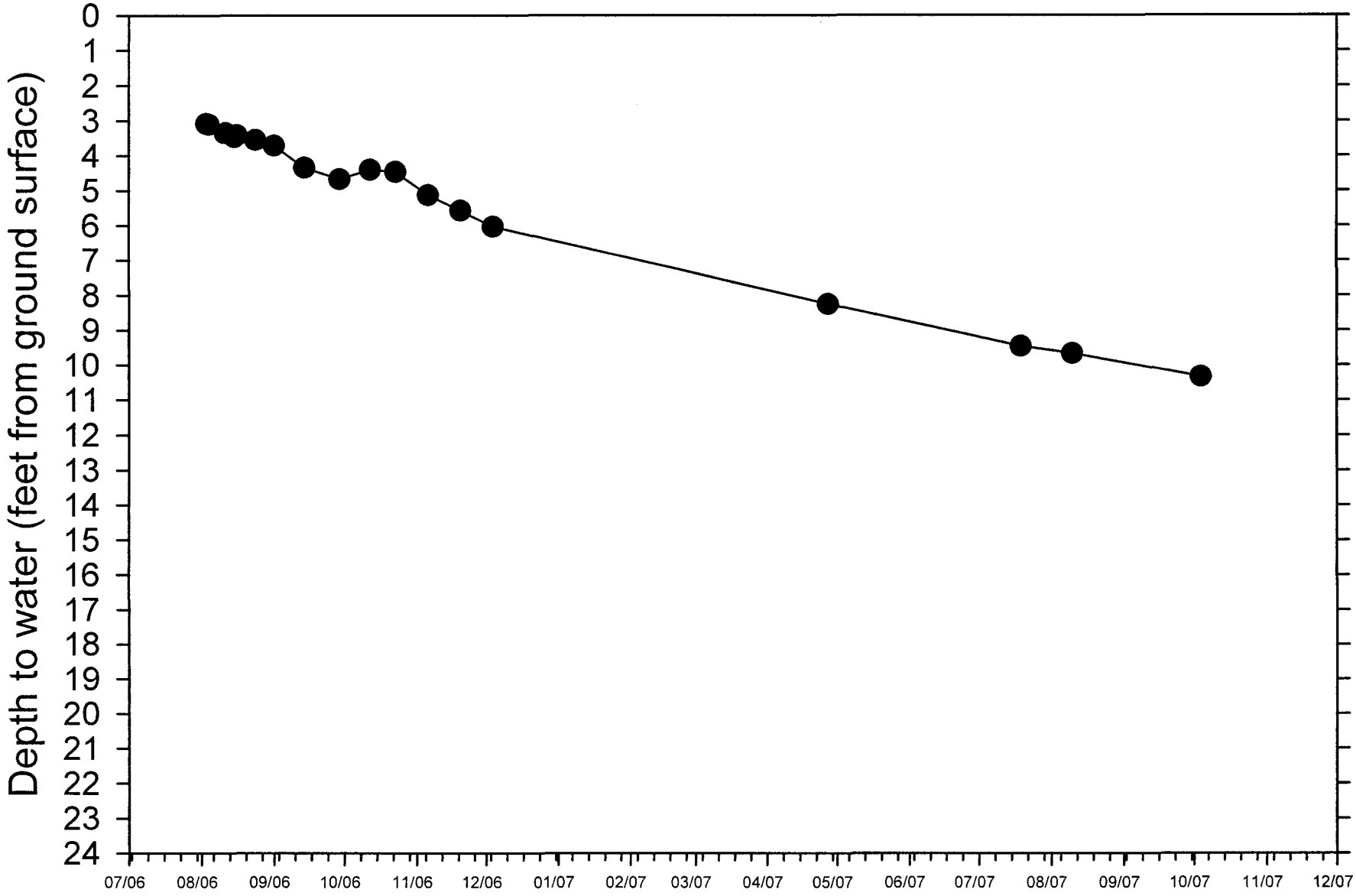
NWP-4


Depth to water (feet from ground surface)
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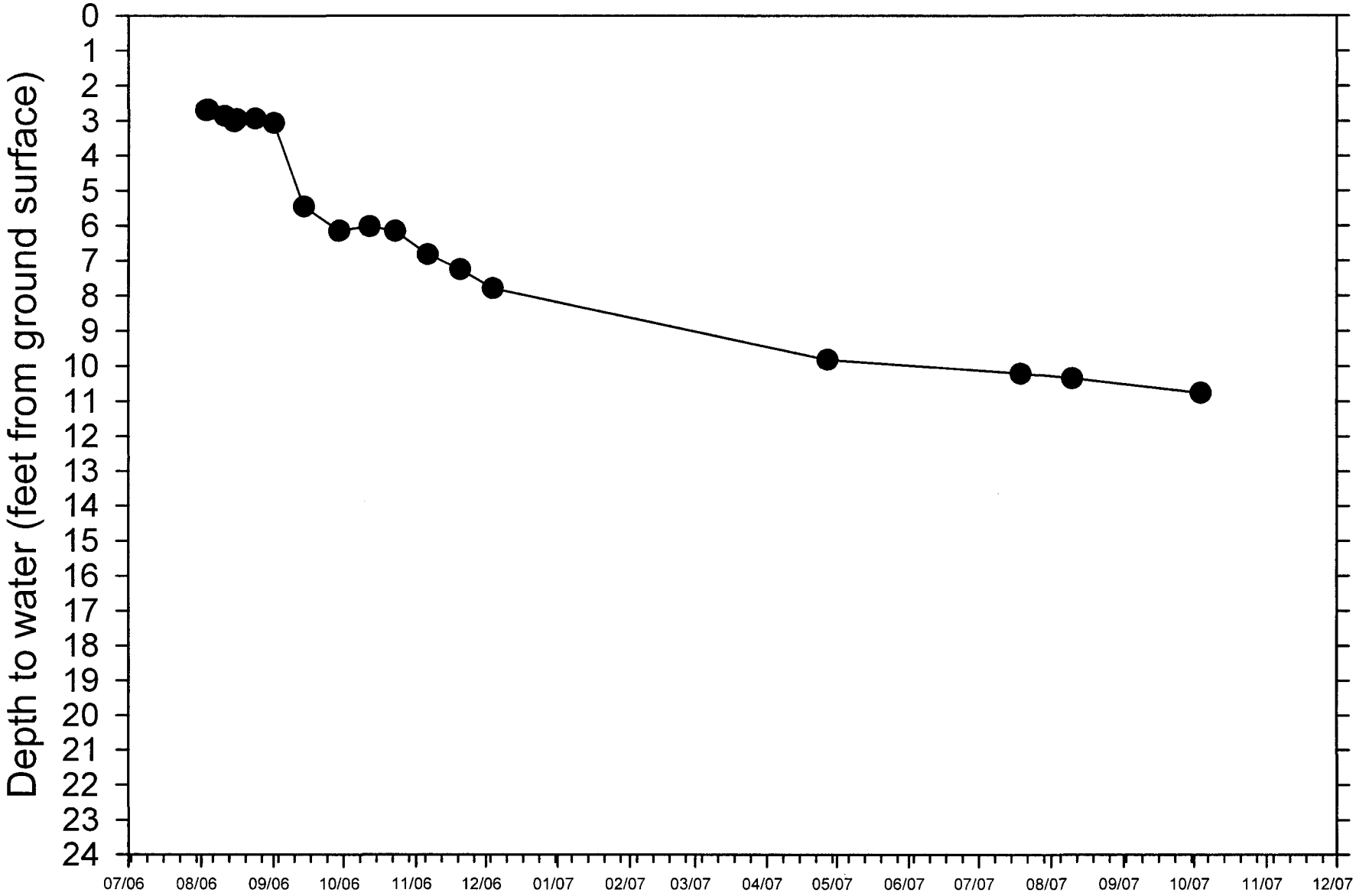
NWP-5


Depth to water (feet from ground surface)
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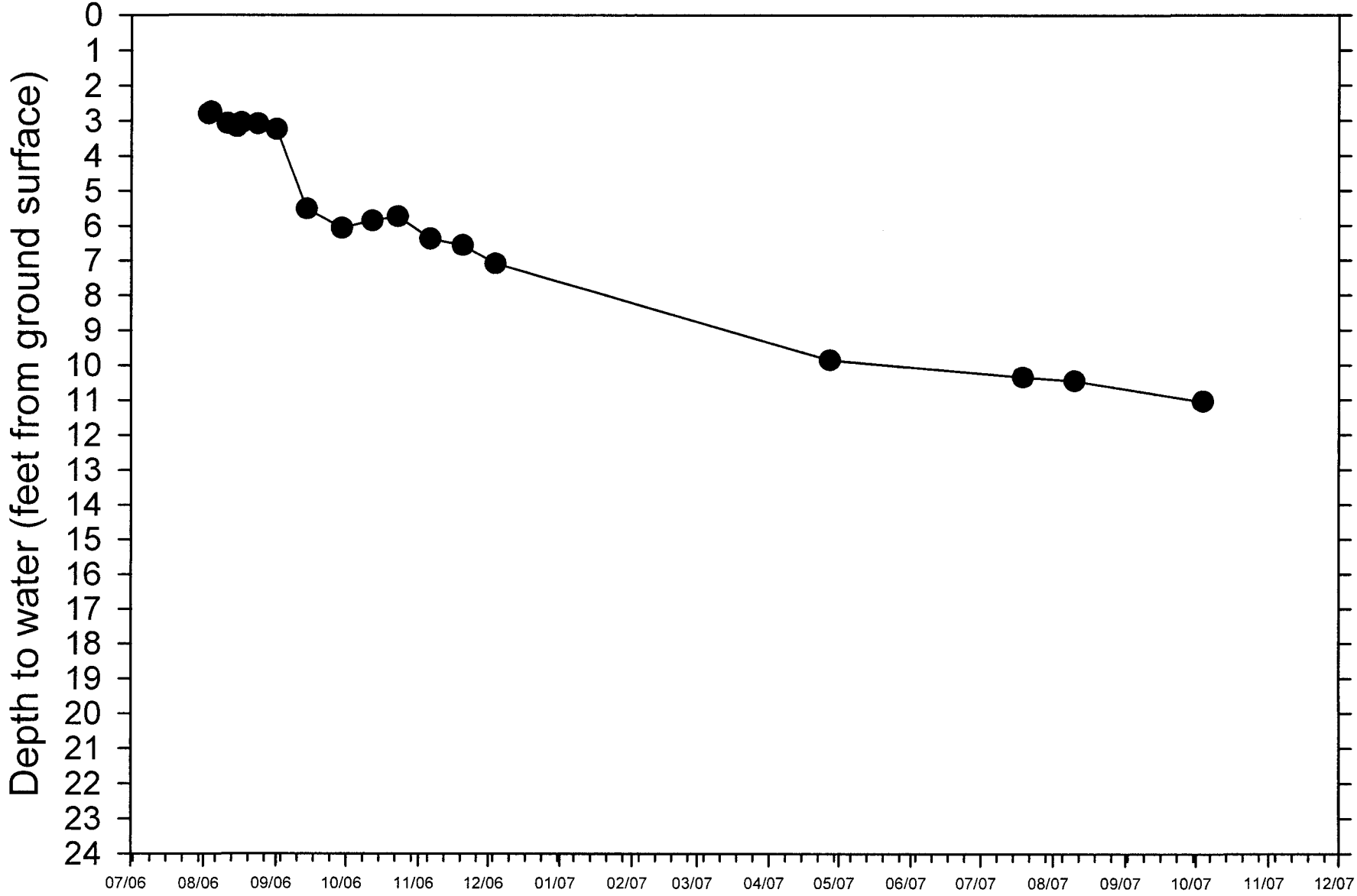
NWP-6


Depth to water (feet from ground surface)
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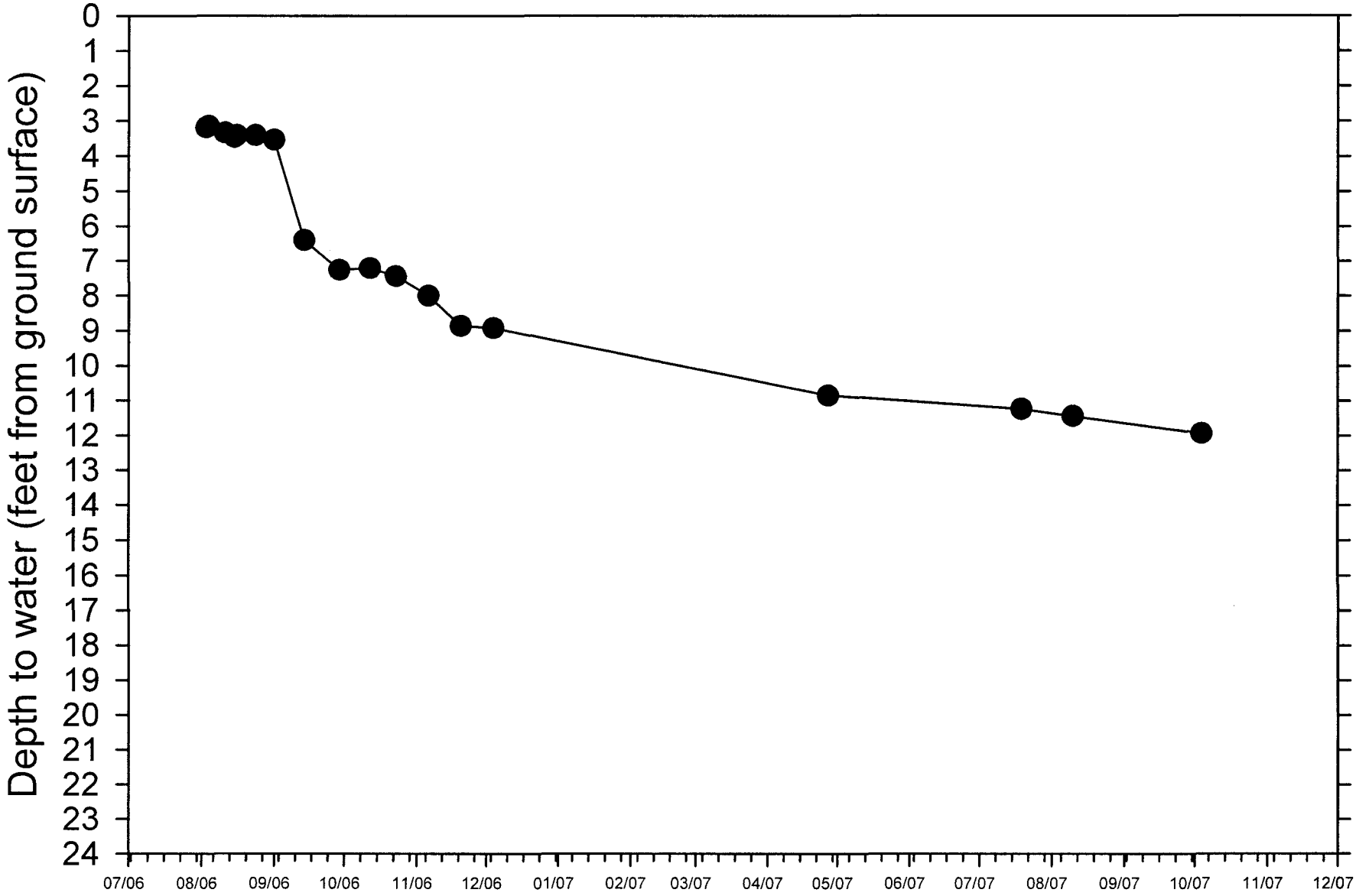
NWP-7


Depth to water (feet from ground surface)
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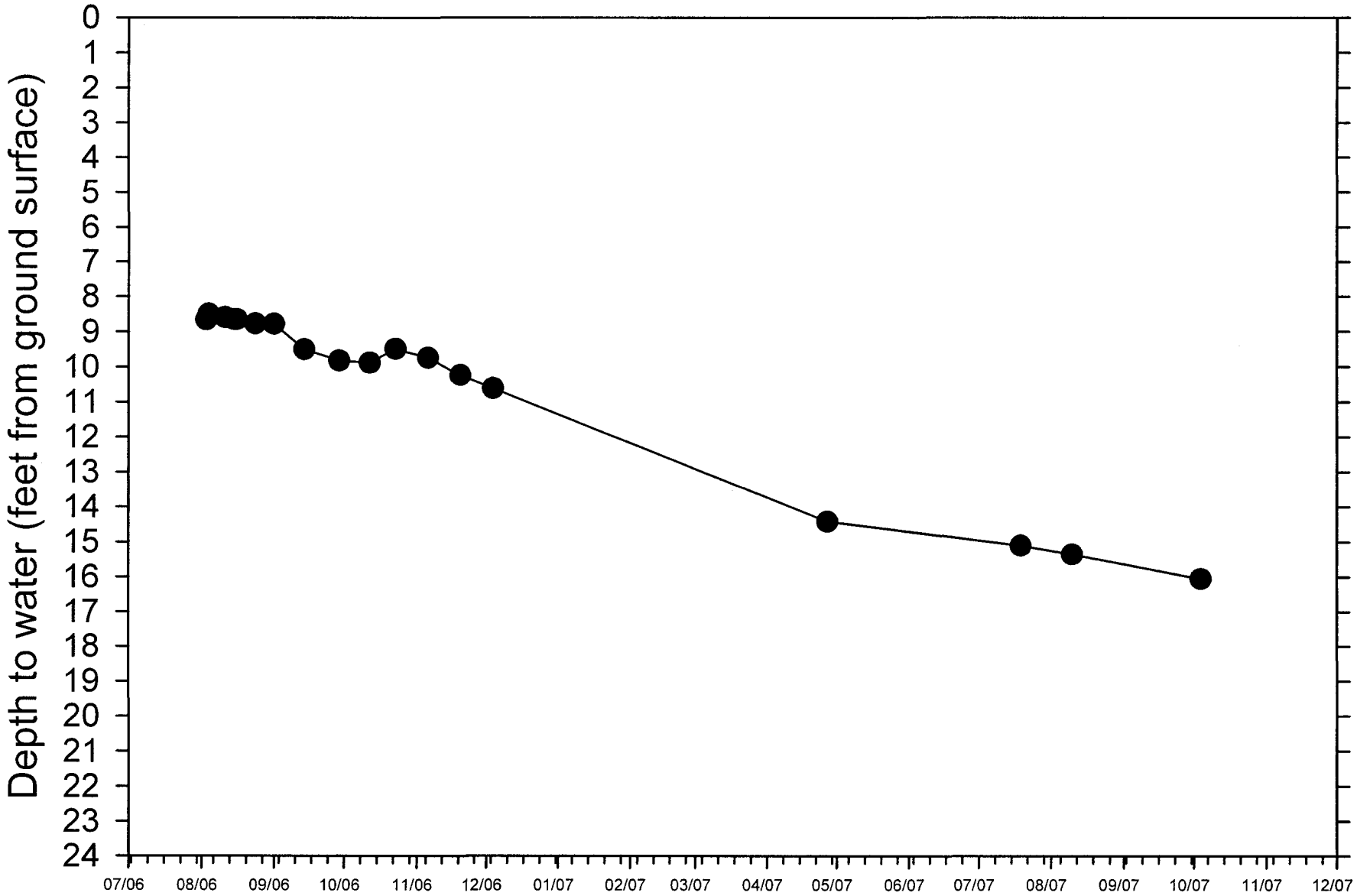
NWP-8


Depth to water (feet from ground surface)
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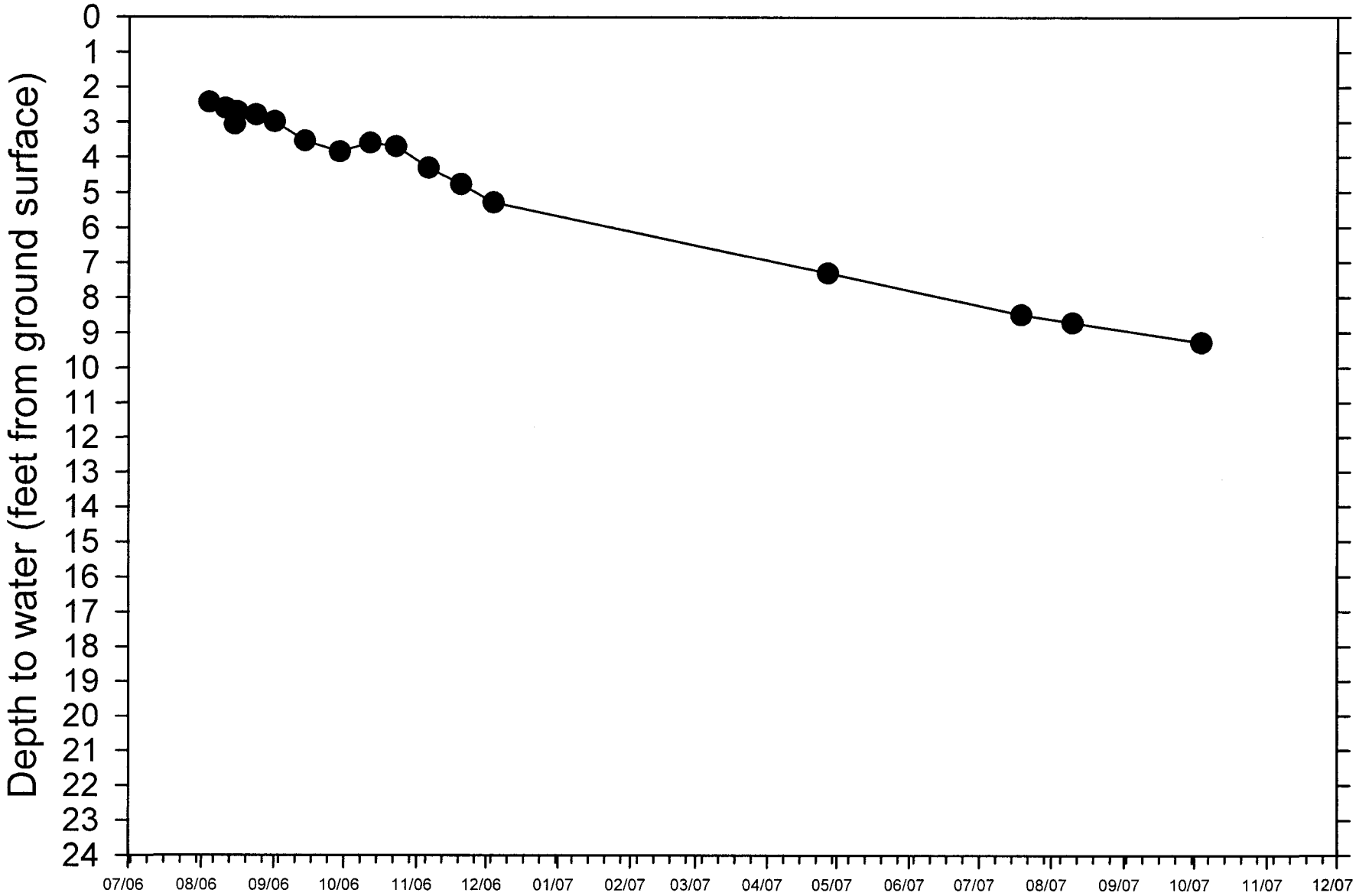
NWP-9


Depth to water (feet from ground surface)
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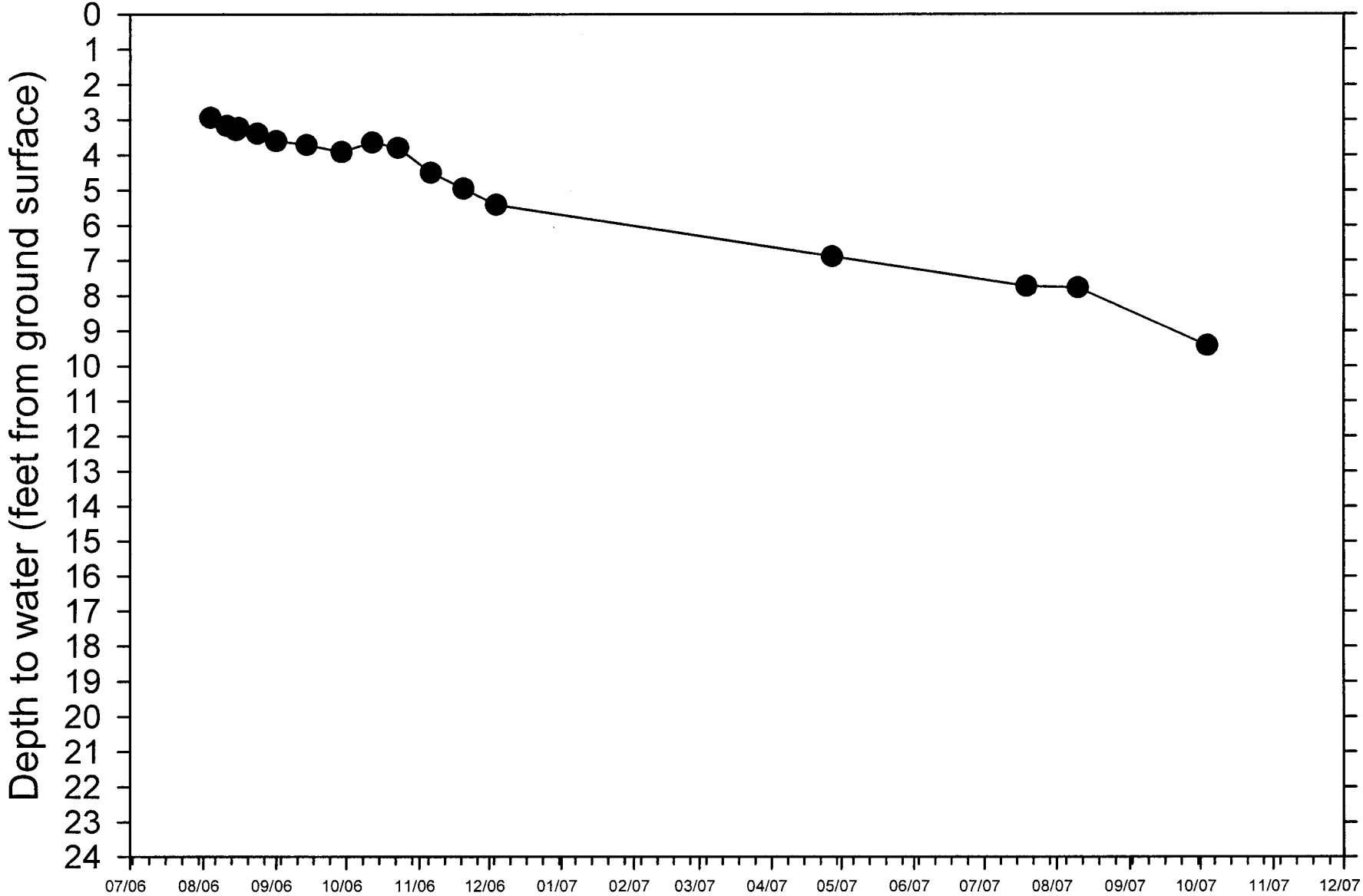
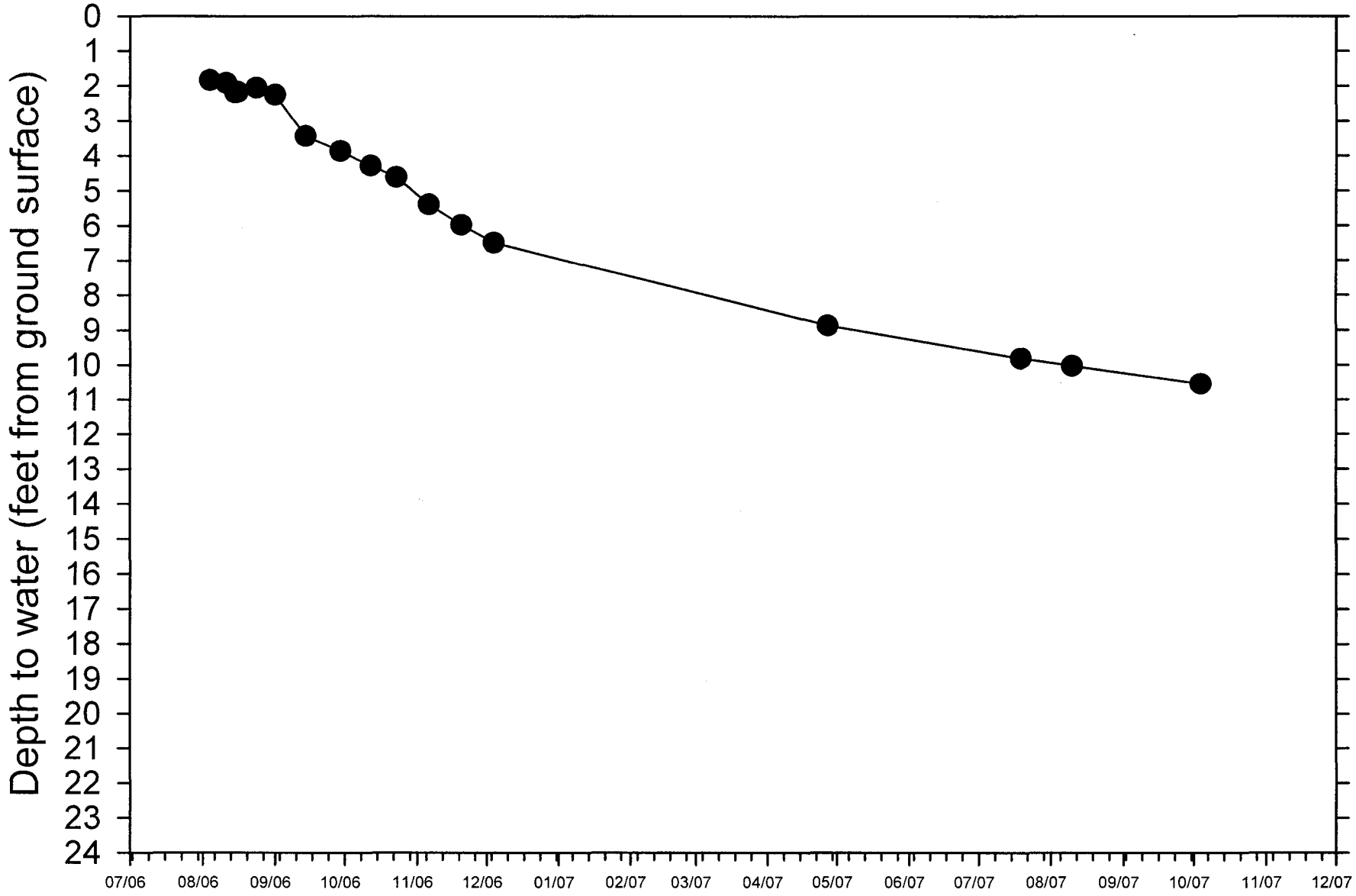
NWP-10 Shallow



NWP-10 Deep


Depth to water (feet from ground surface)
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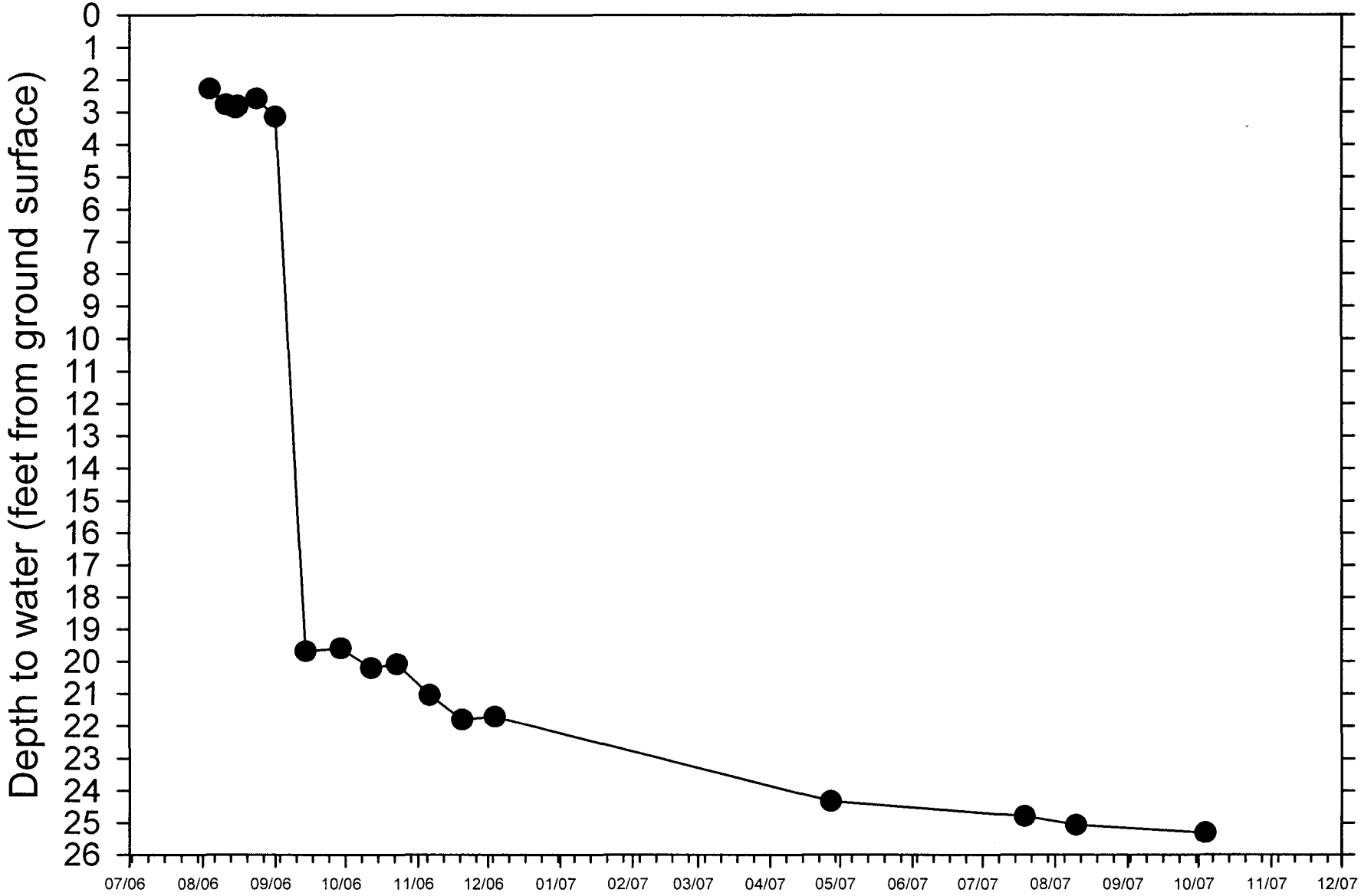
NWP-11


Depth to water (feet from ground surface)
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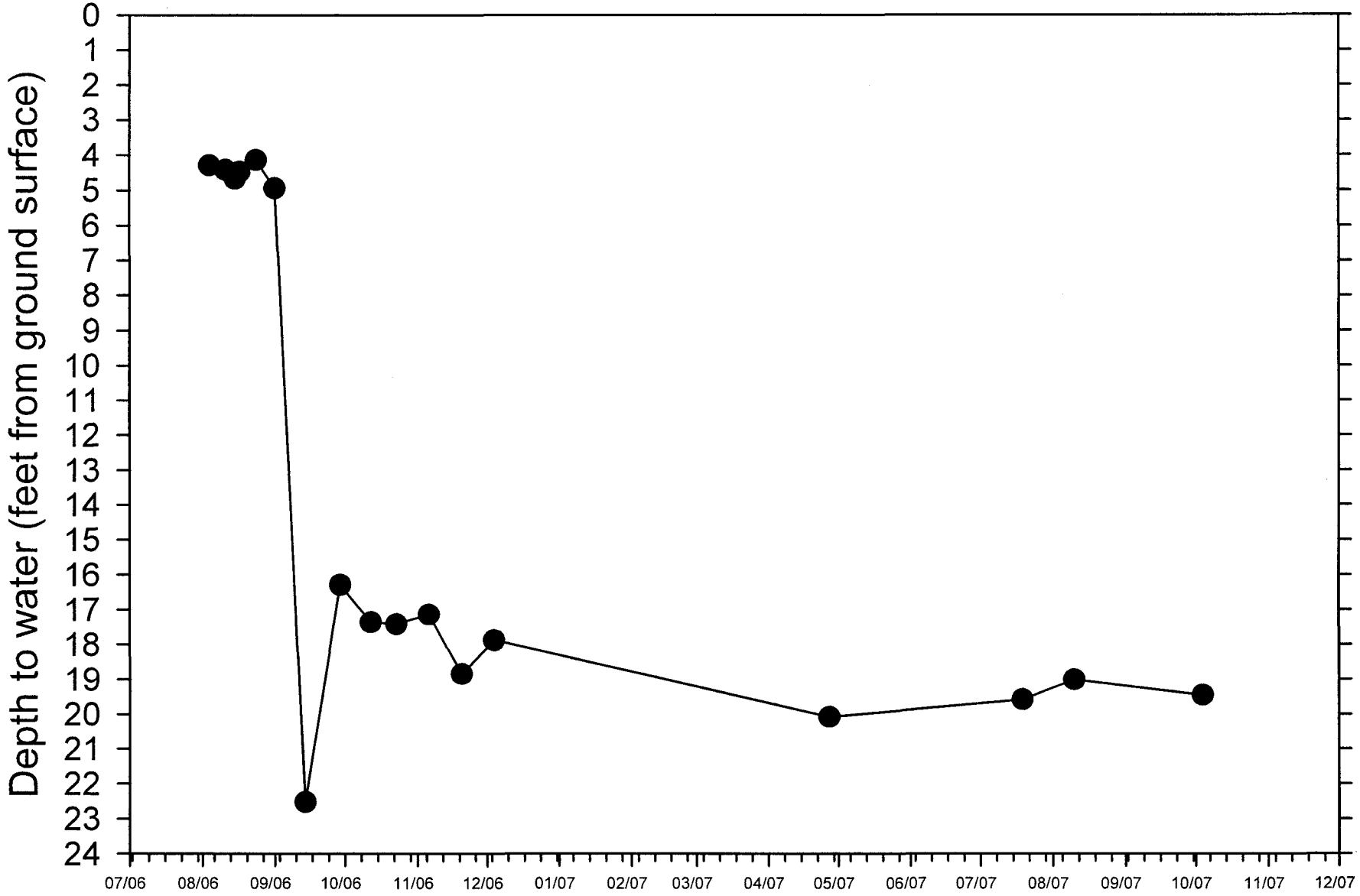
NWP-12


Depth to water (feet from ground surface)
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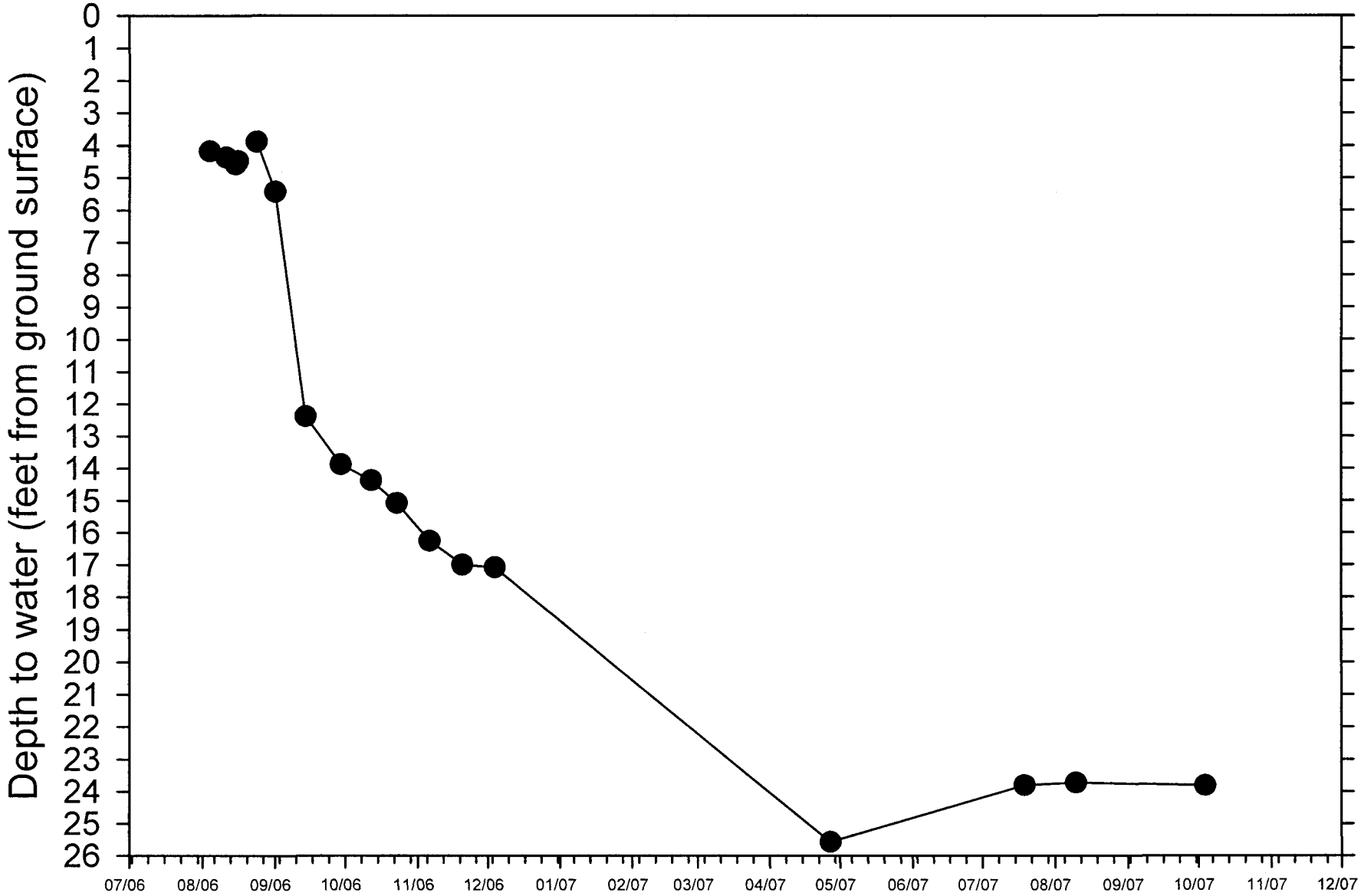
NWP-13


Depth to water (feet from ground surface)
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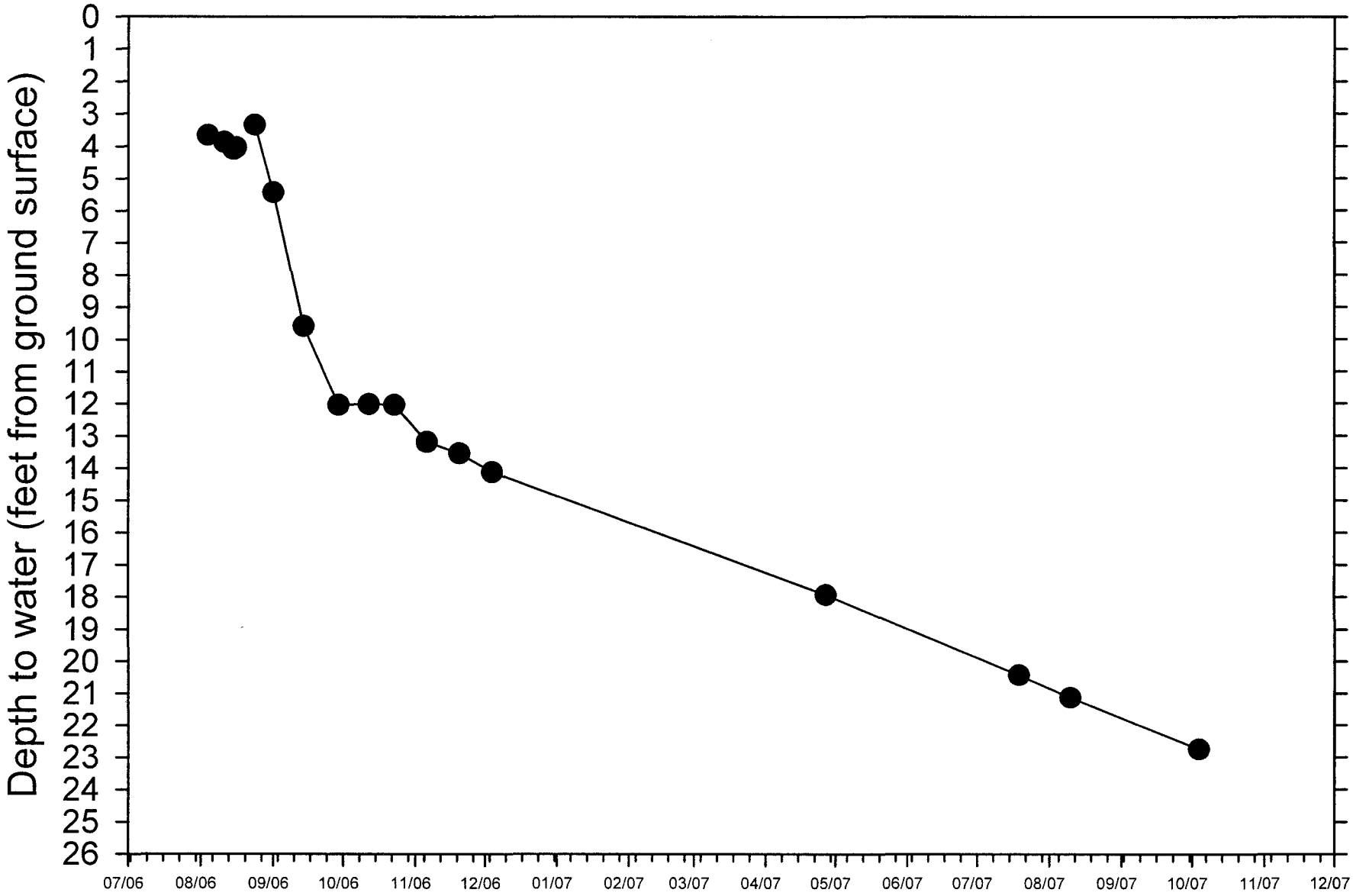
NWP-14


Depth to water (feet from ground surface)
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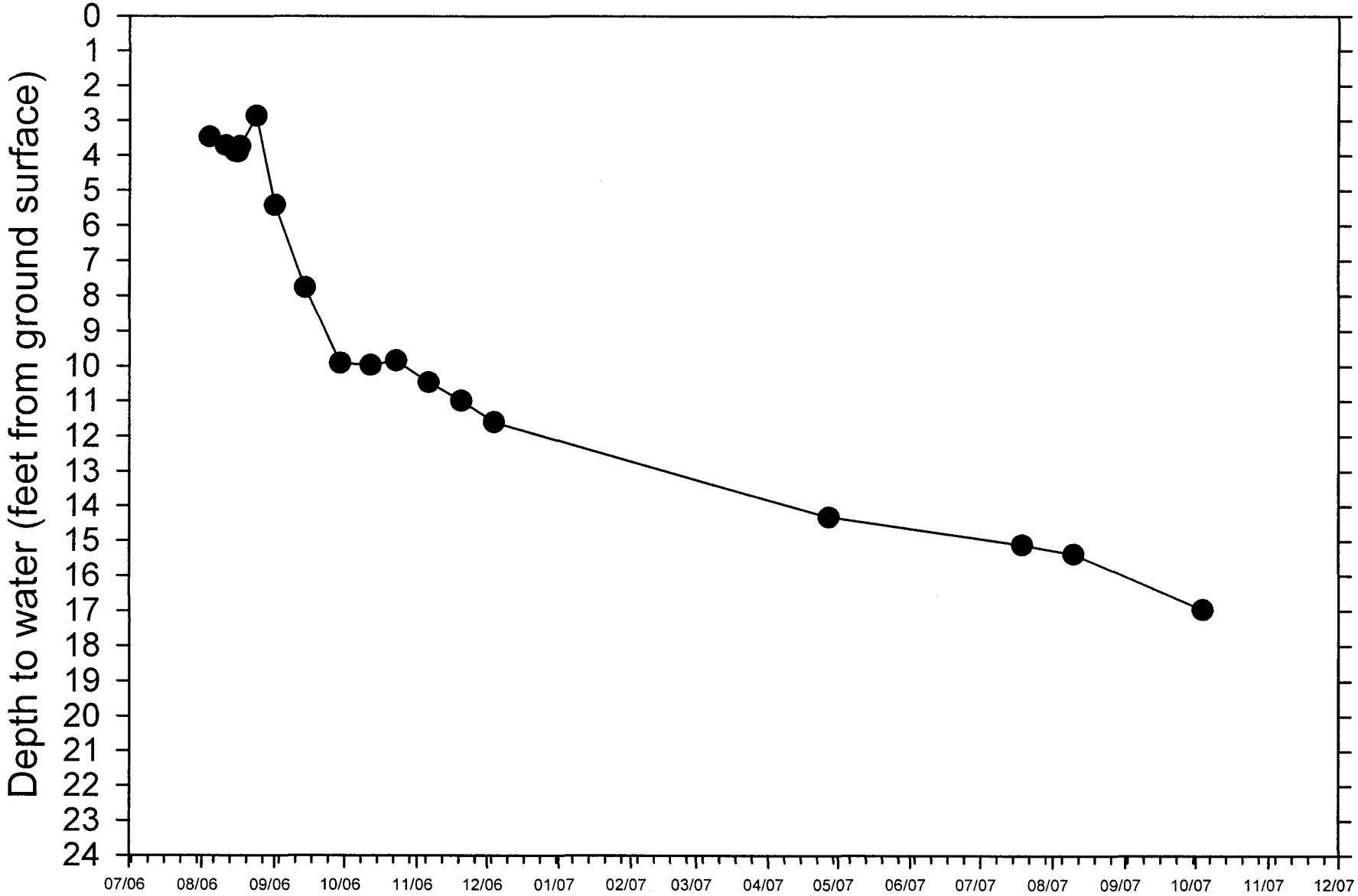
NWP-15


Depth to water (feet from ground surface)
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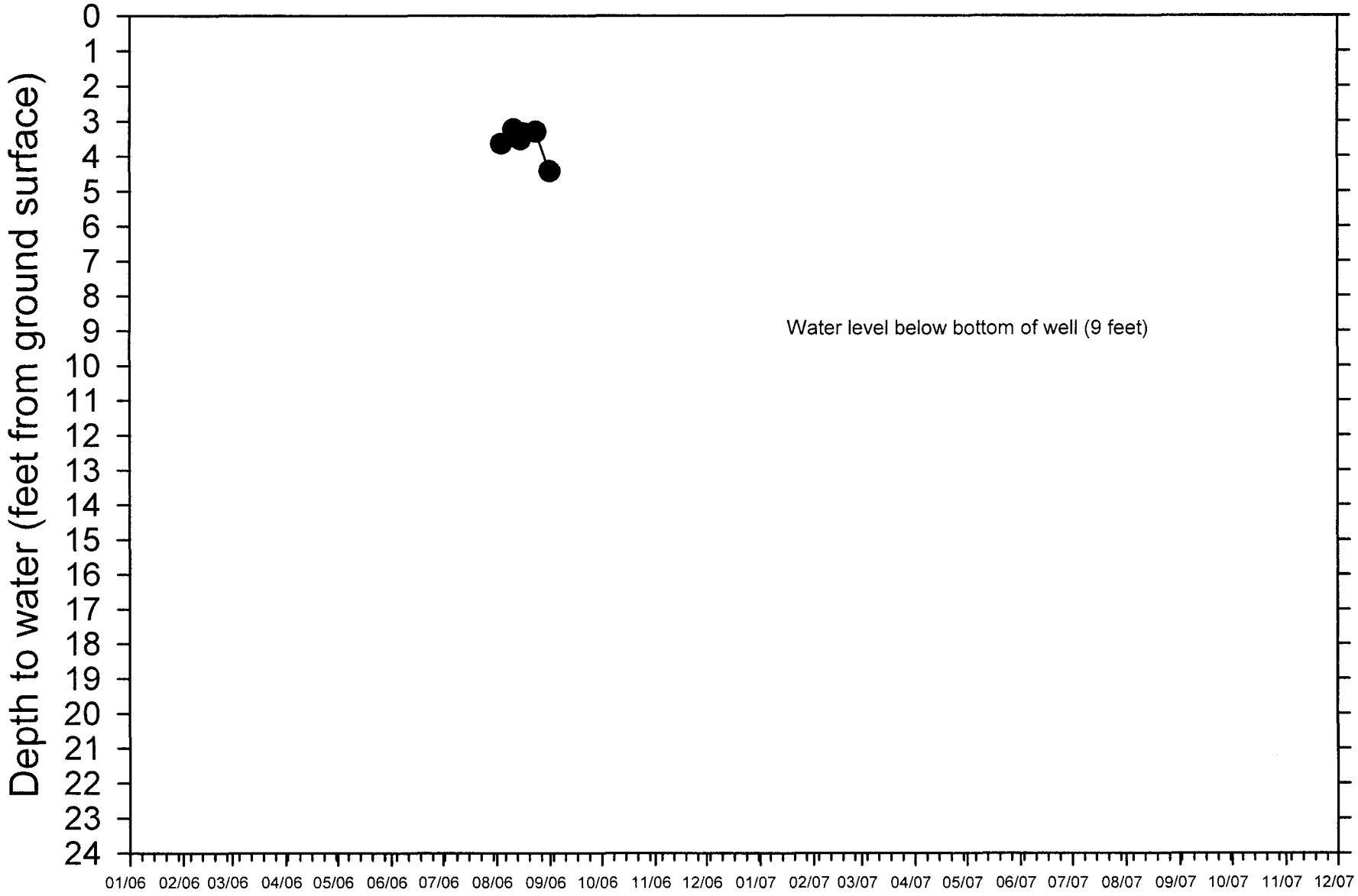
NWP-16


Depth to water (feet from ground surface)
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Water level below bottom of well (9 feet)
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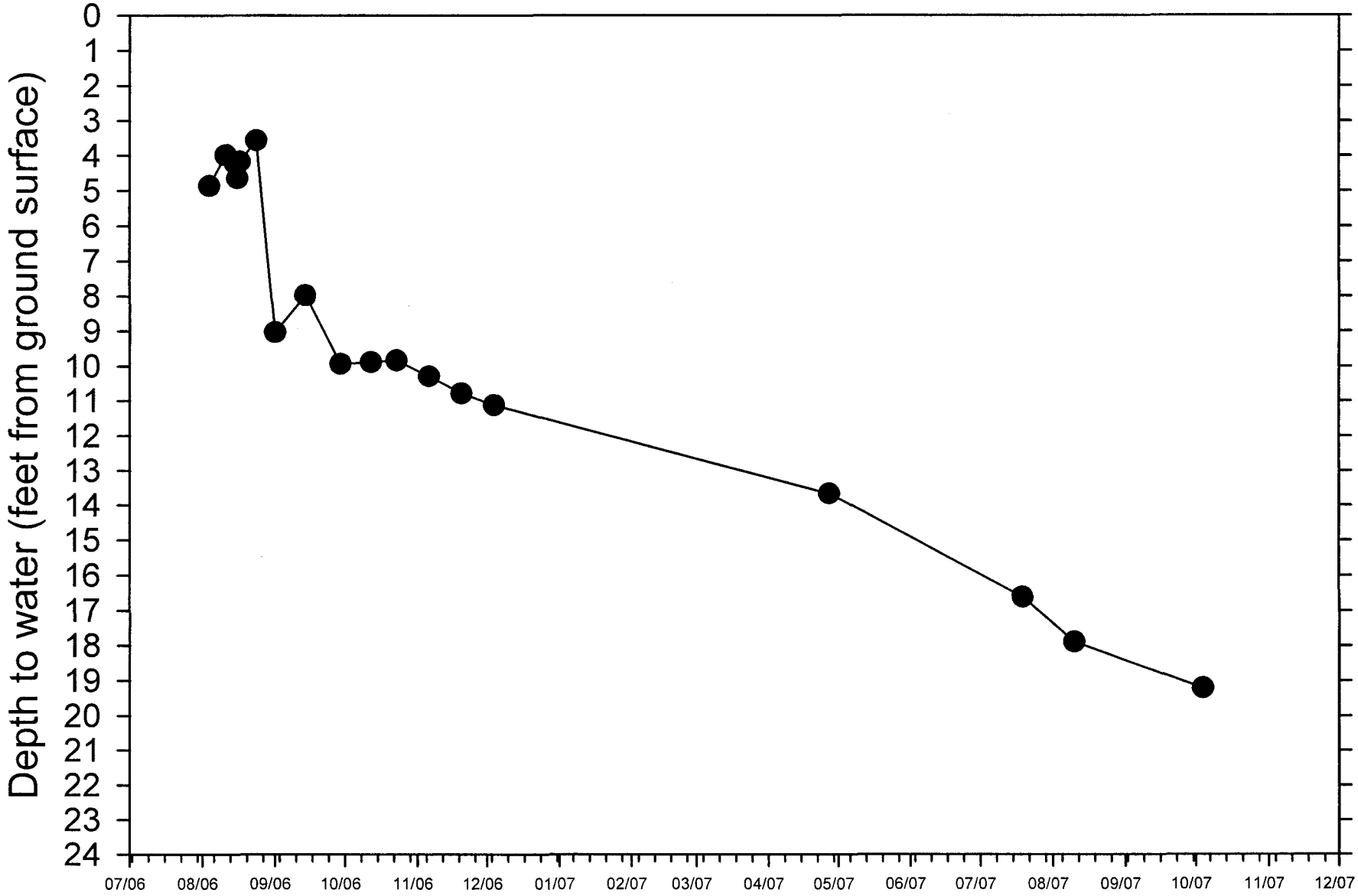
NWP-17


Depth to water (feet from ground surface)
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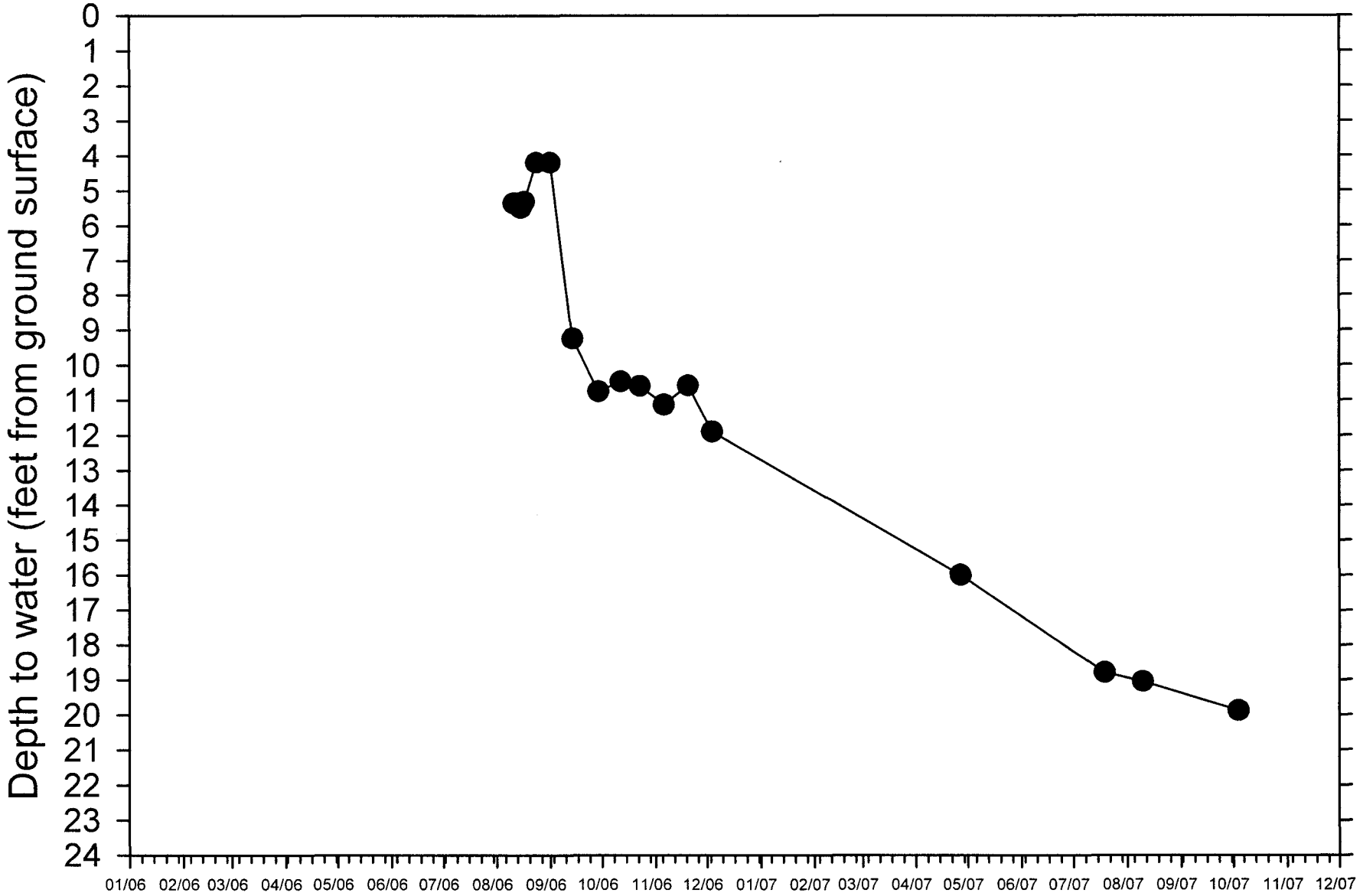
NWP-18


Depth to water (feet from ground surface)
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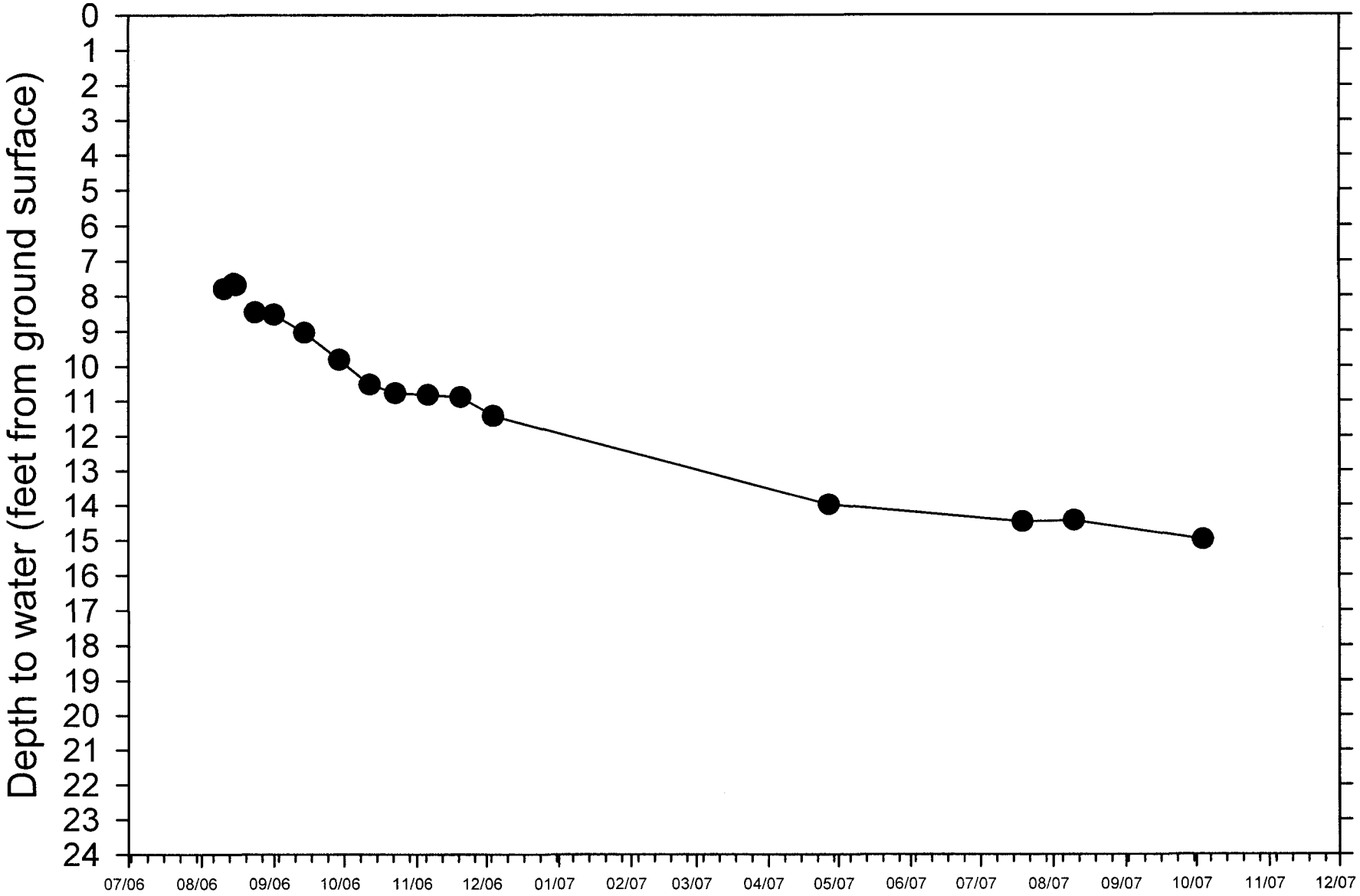
NWP-19


Depth to water (feet from ground surface)
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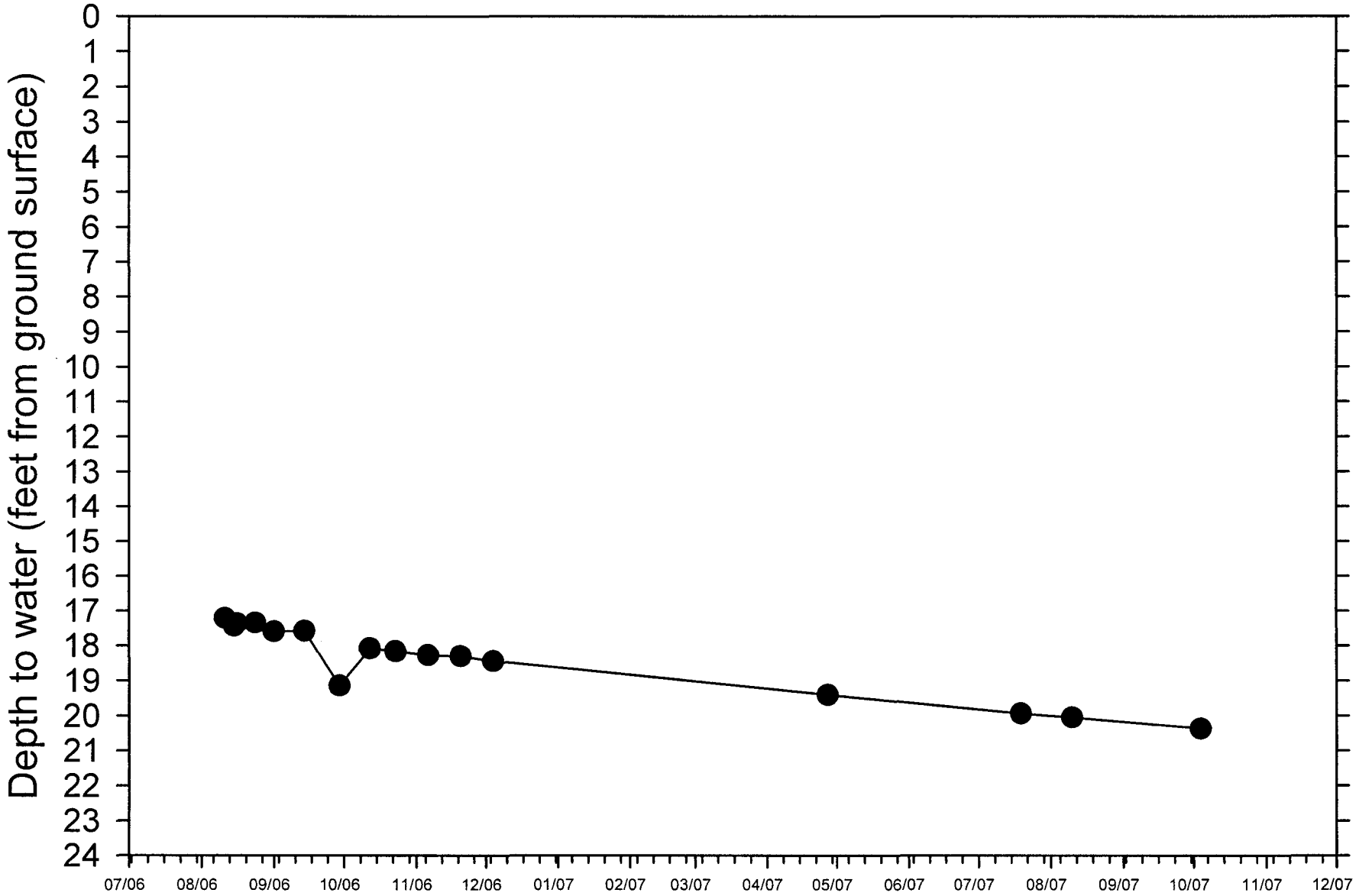
NWP-20


Depth to water (feet from ground surface)
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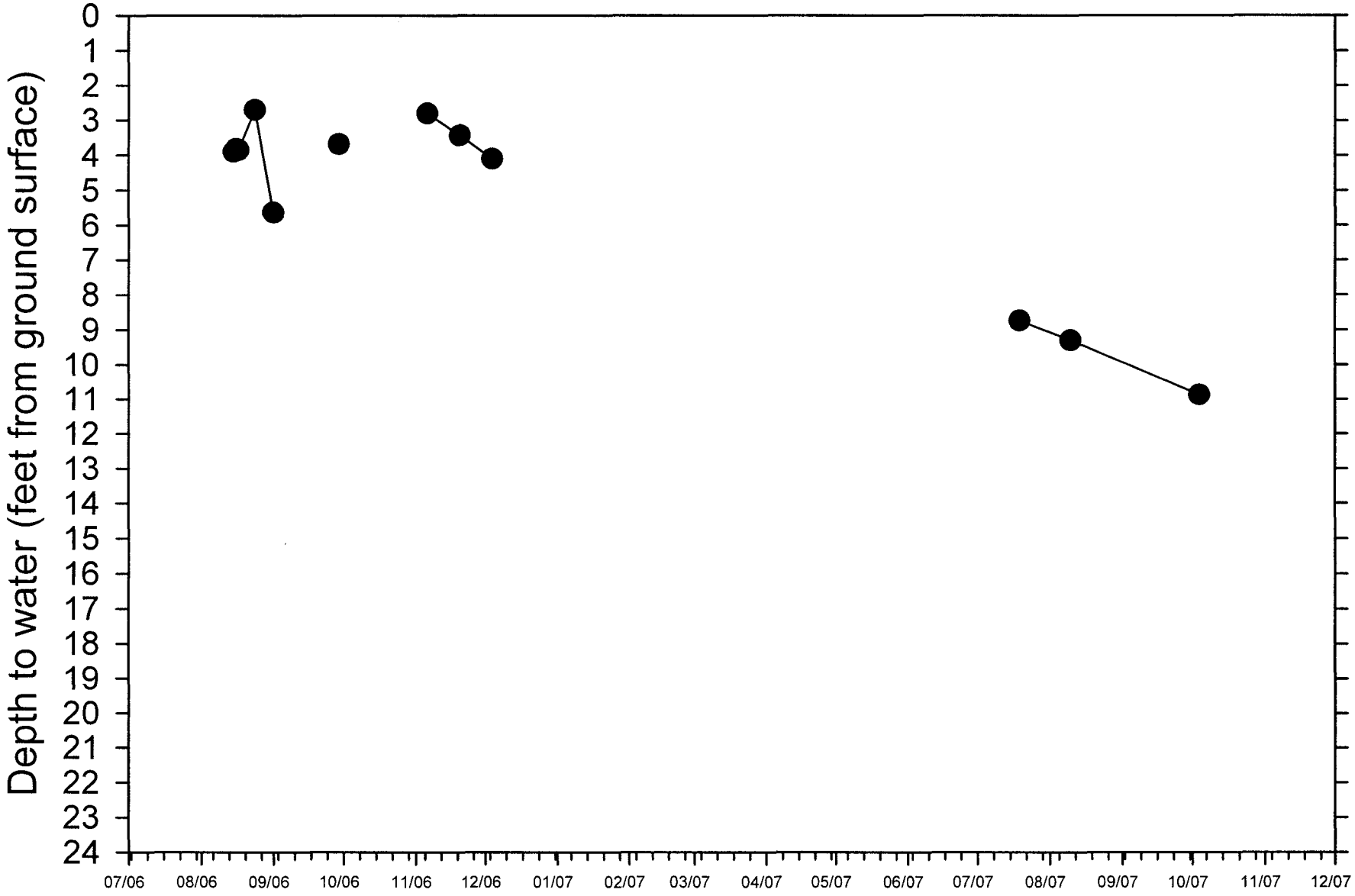
NWP-21


Depth to water (feet from ground surface)
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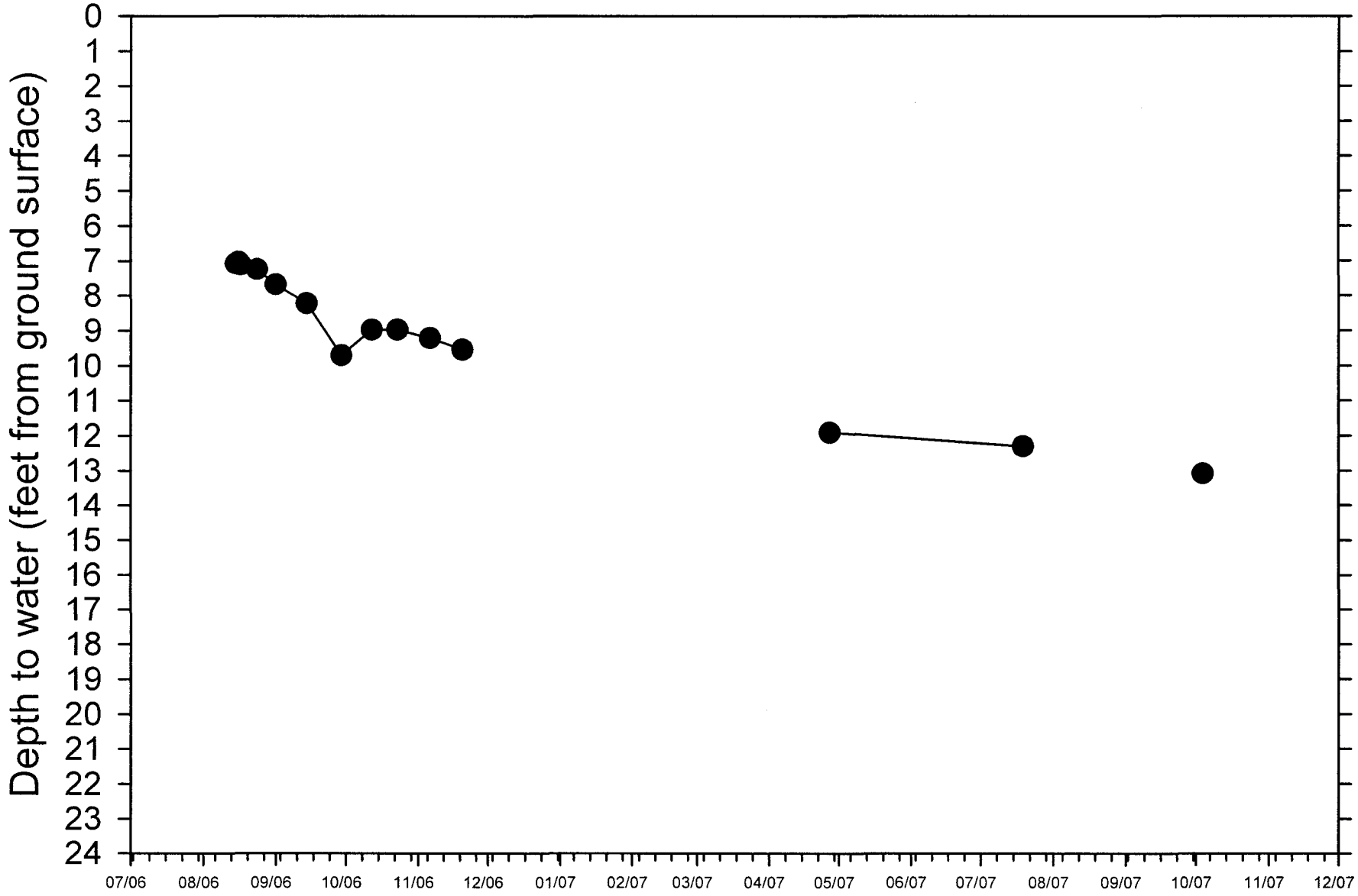
NWP-22


Depth to water (feet from ground surface)
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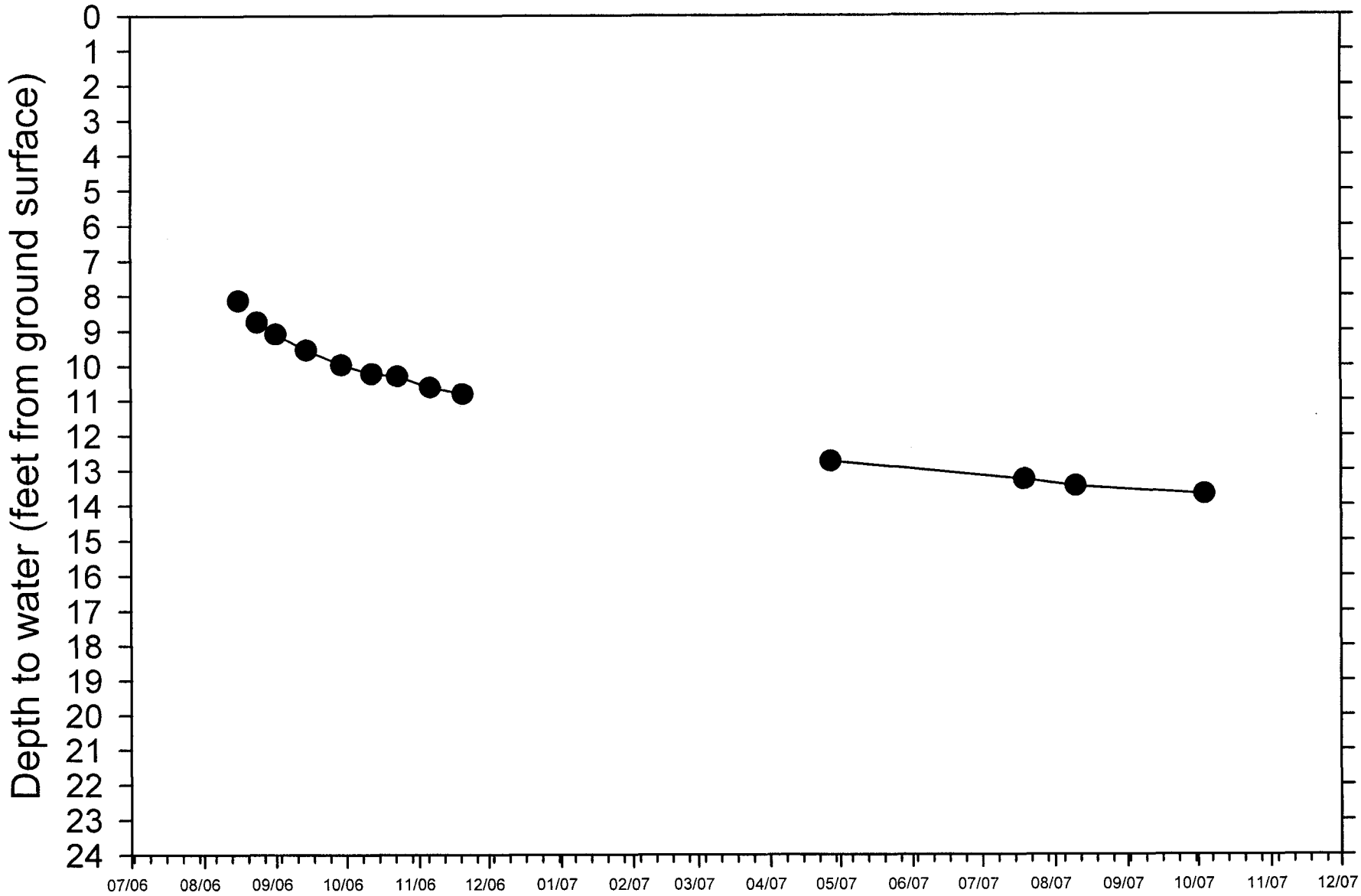
NWP-23


Depth to water (feet from ground surface)
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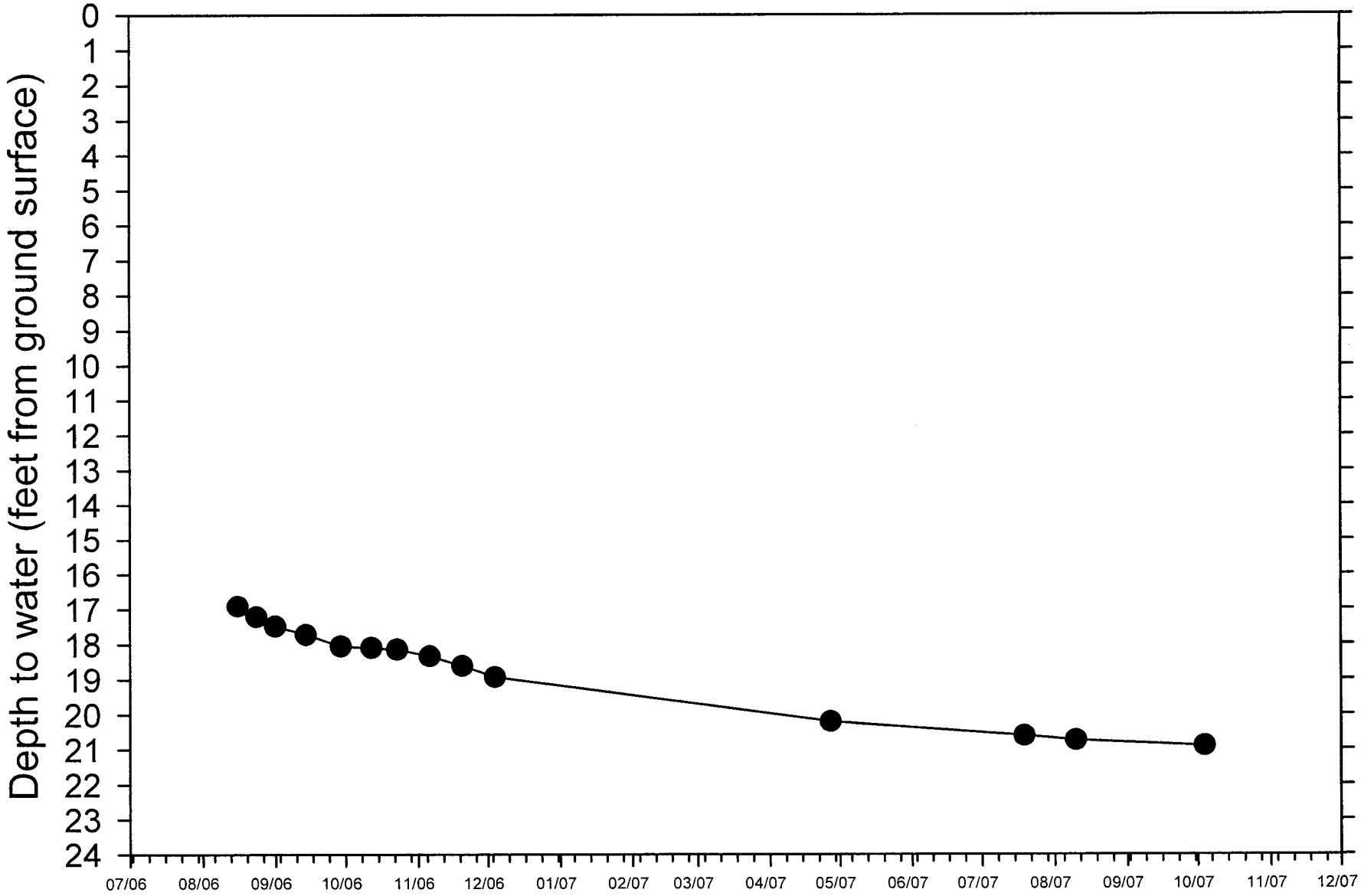
NWP-24


Depth to water (feet from ground surface)
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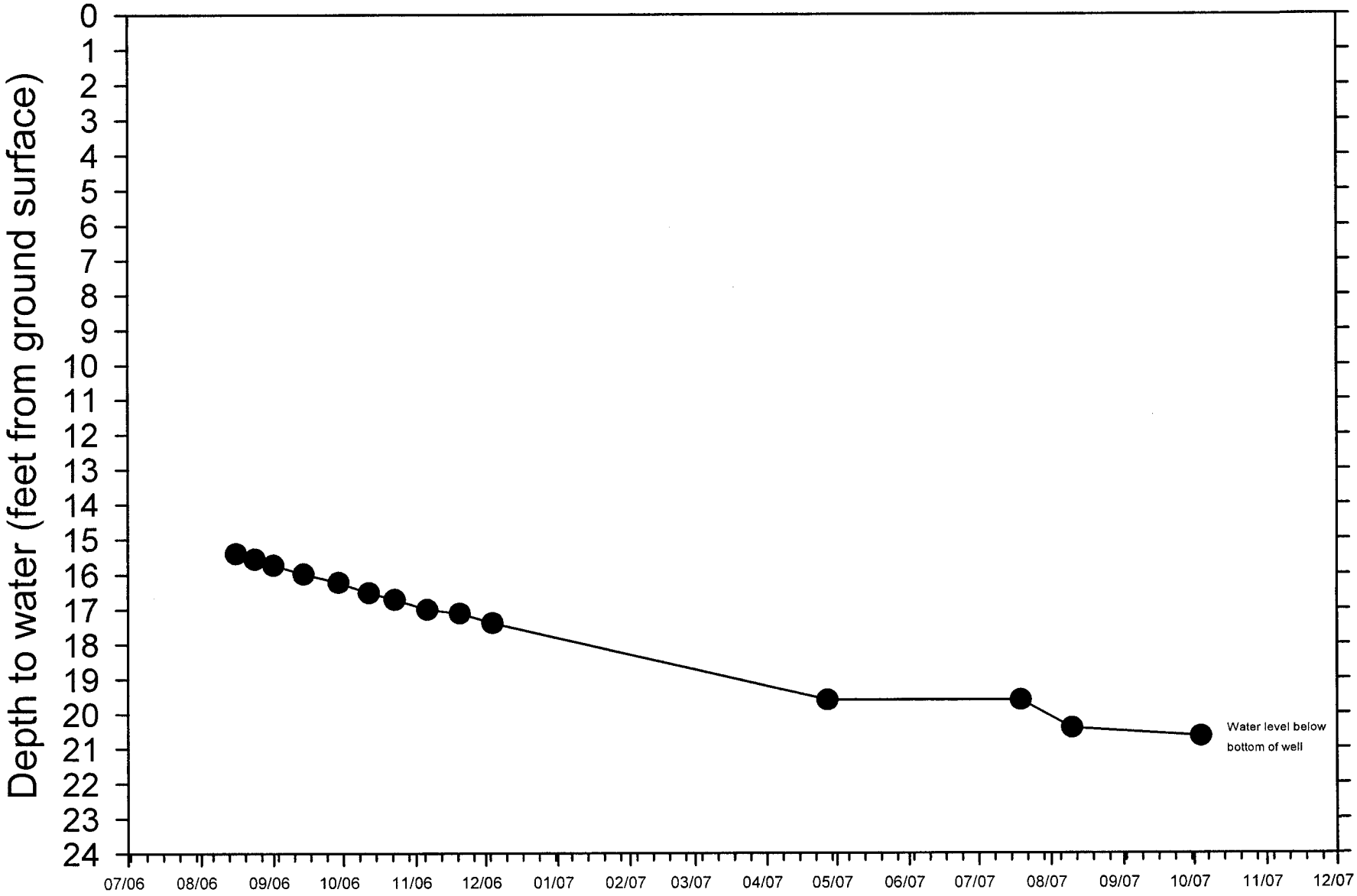
NWP-25


Depth to water (feet from ground surface)
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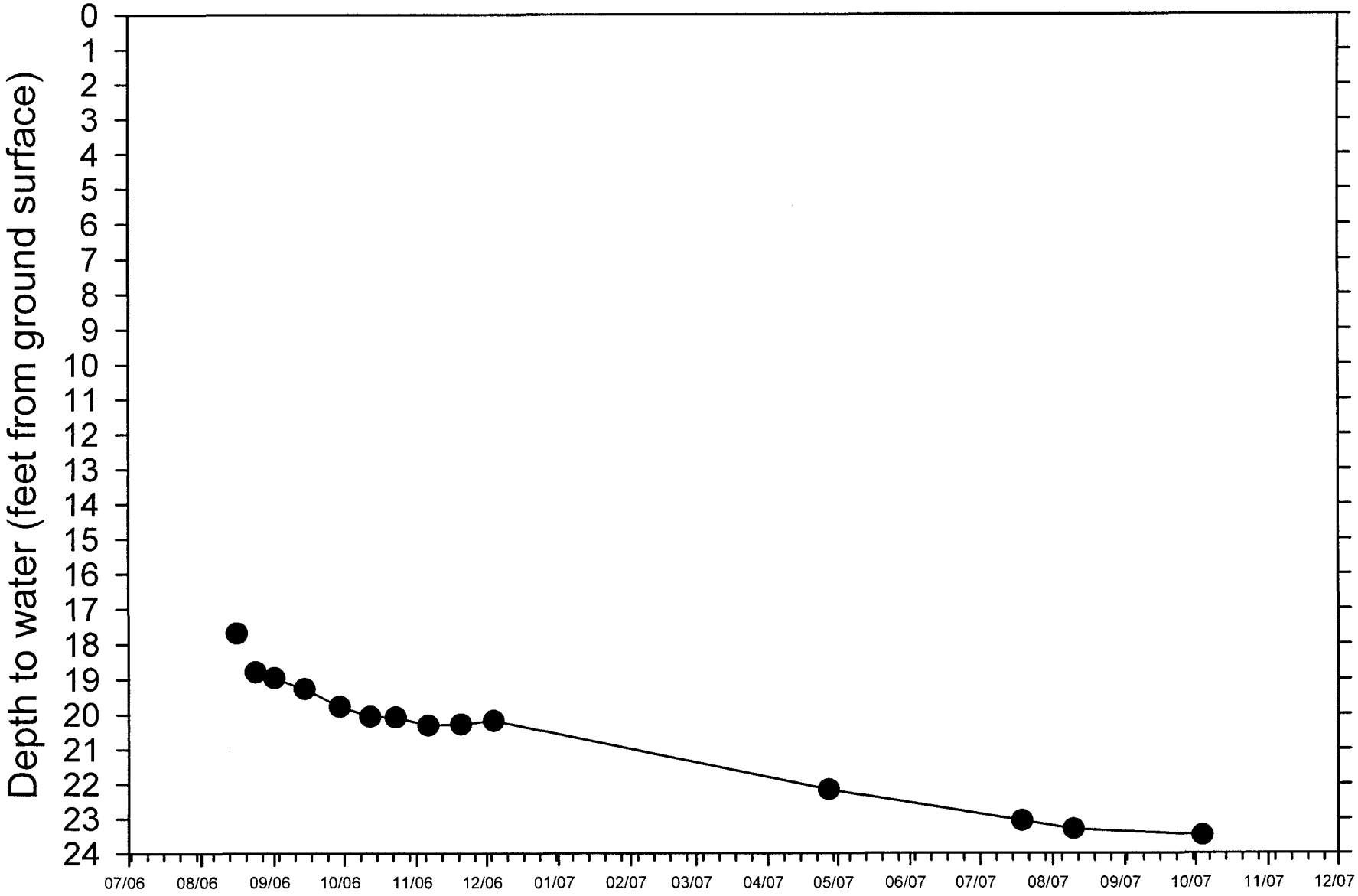
Water level below bottom of well

NWP-26


Depth to water (feet from ground surface)
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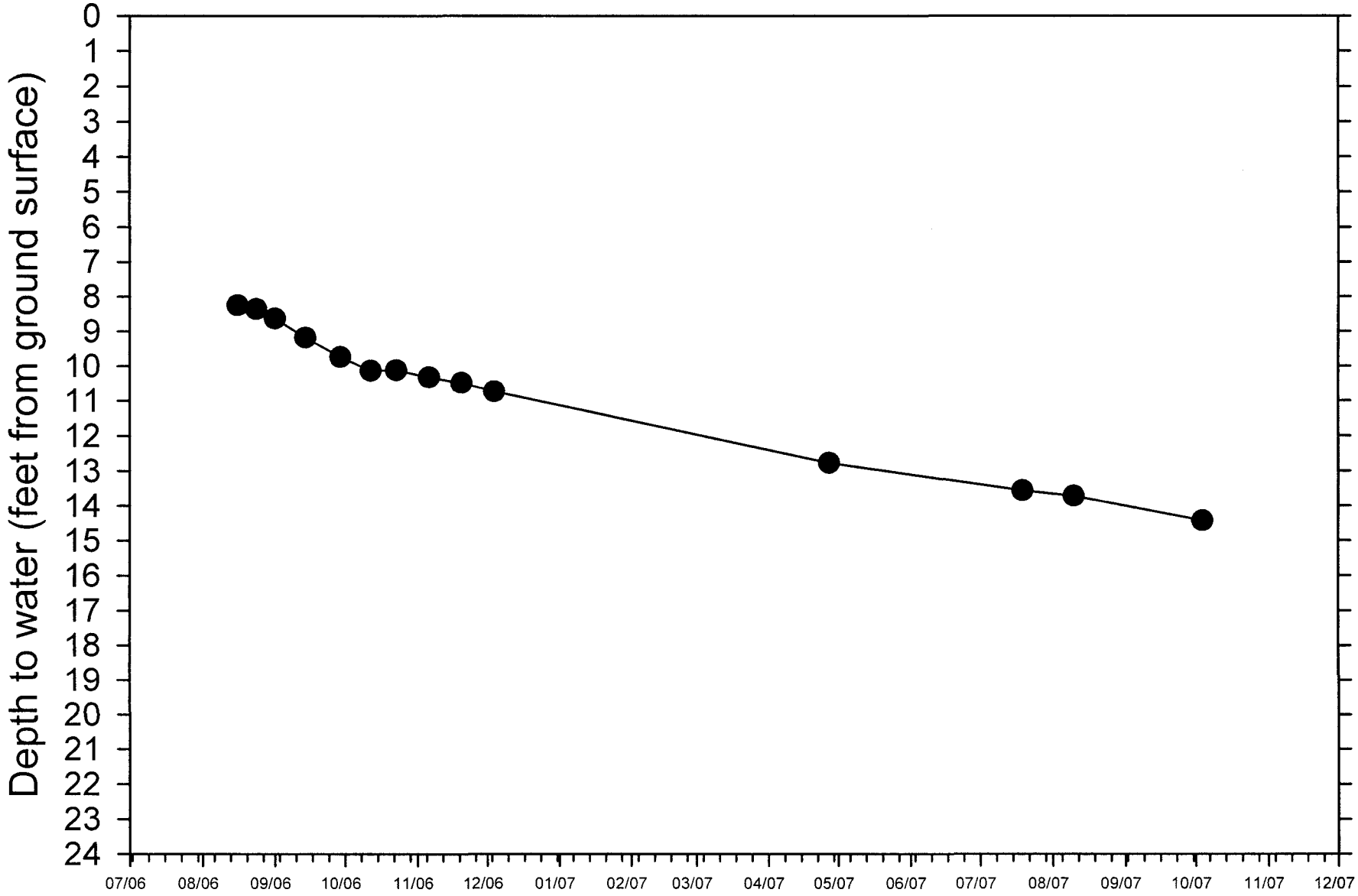
NWP-27


Depth to water (feet from ground surface)
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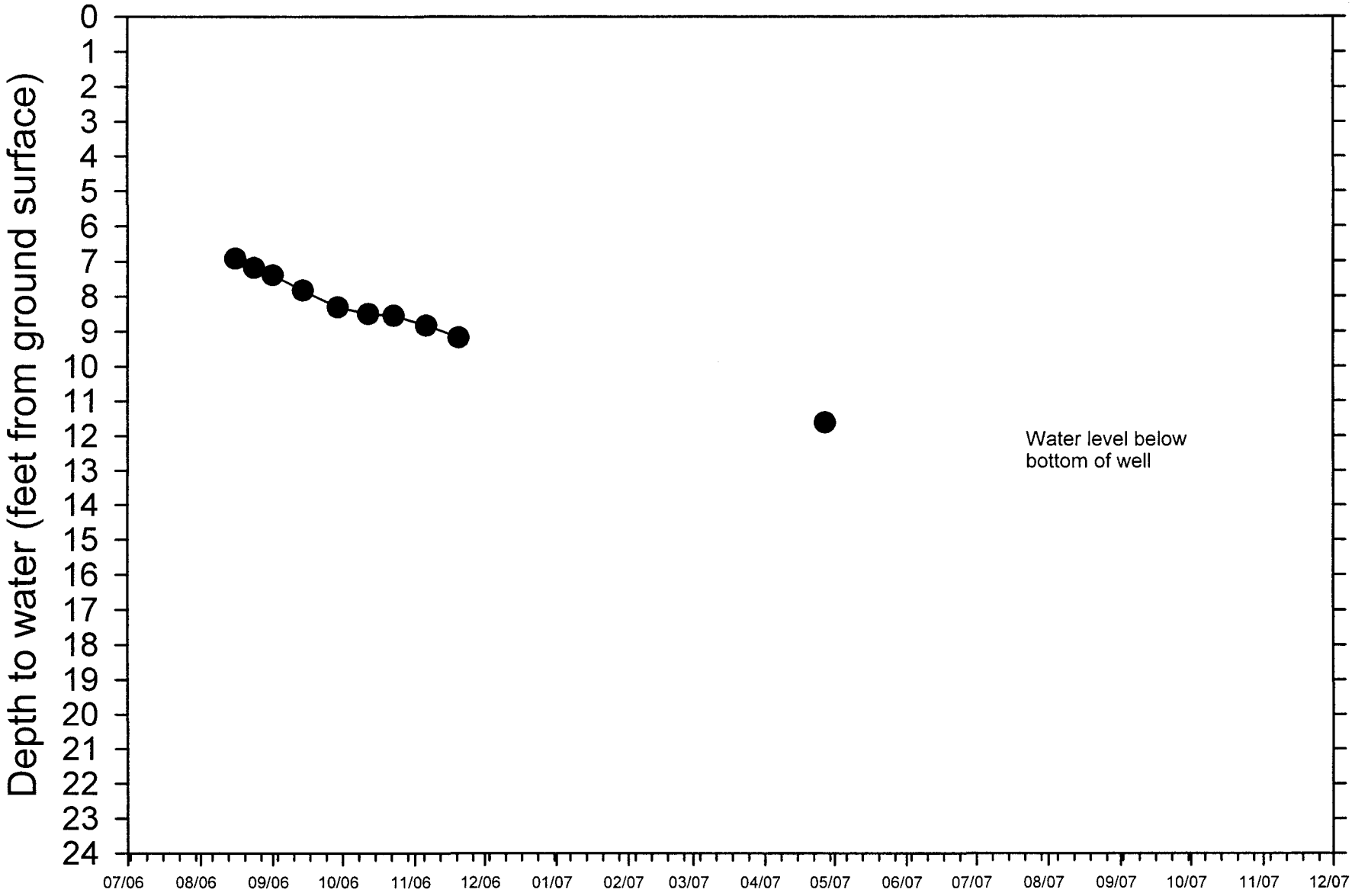
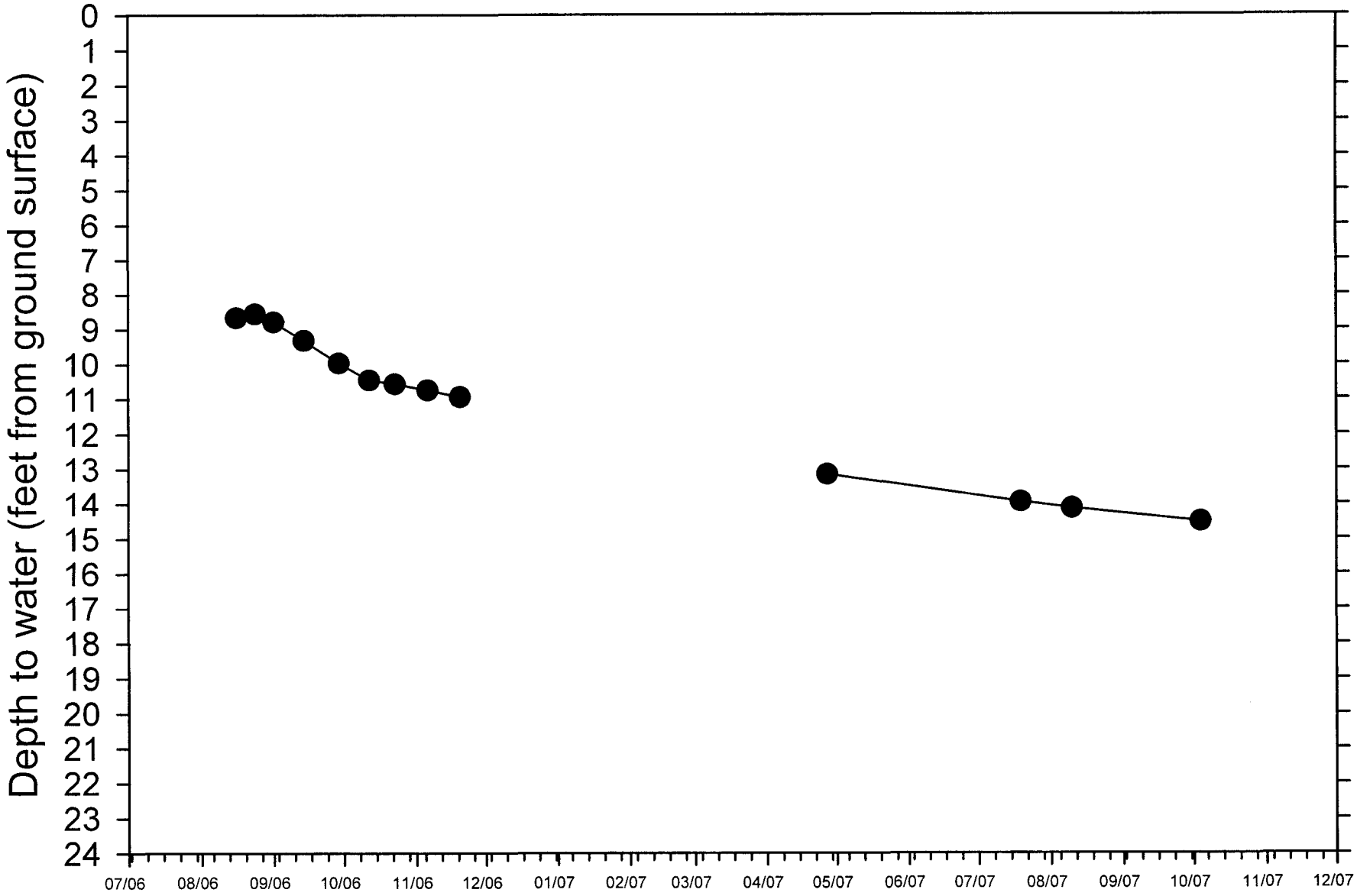
NWP-28 Shallow



NWP-28 Deep


Depth to water (feet from ground surface)
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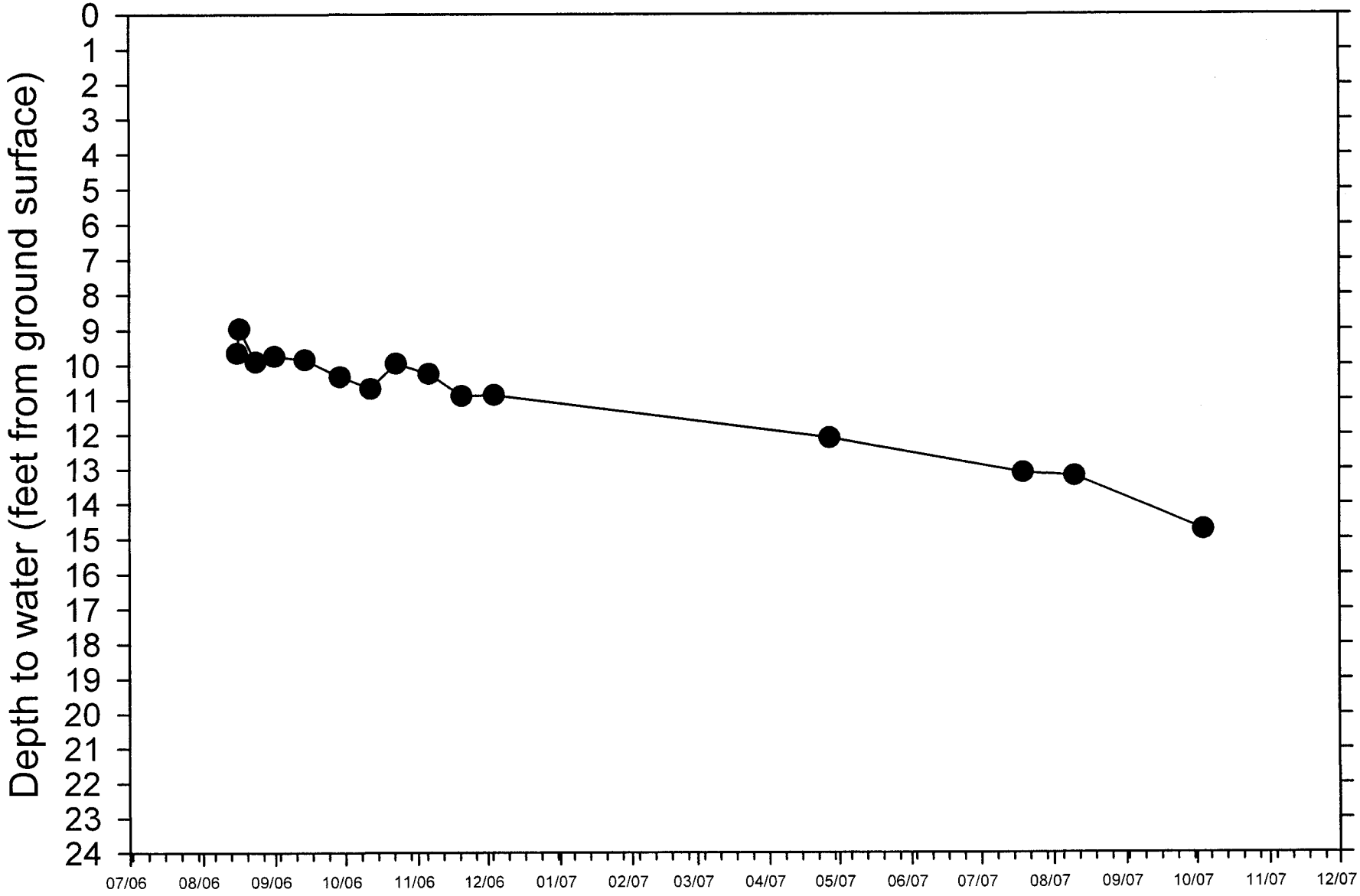
NWP-29


Depth to water (feet from ground surface)
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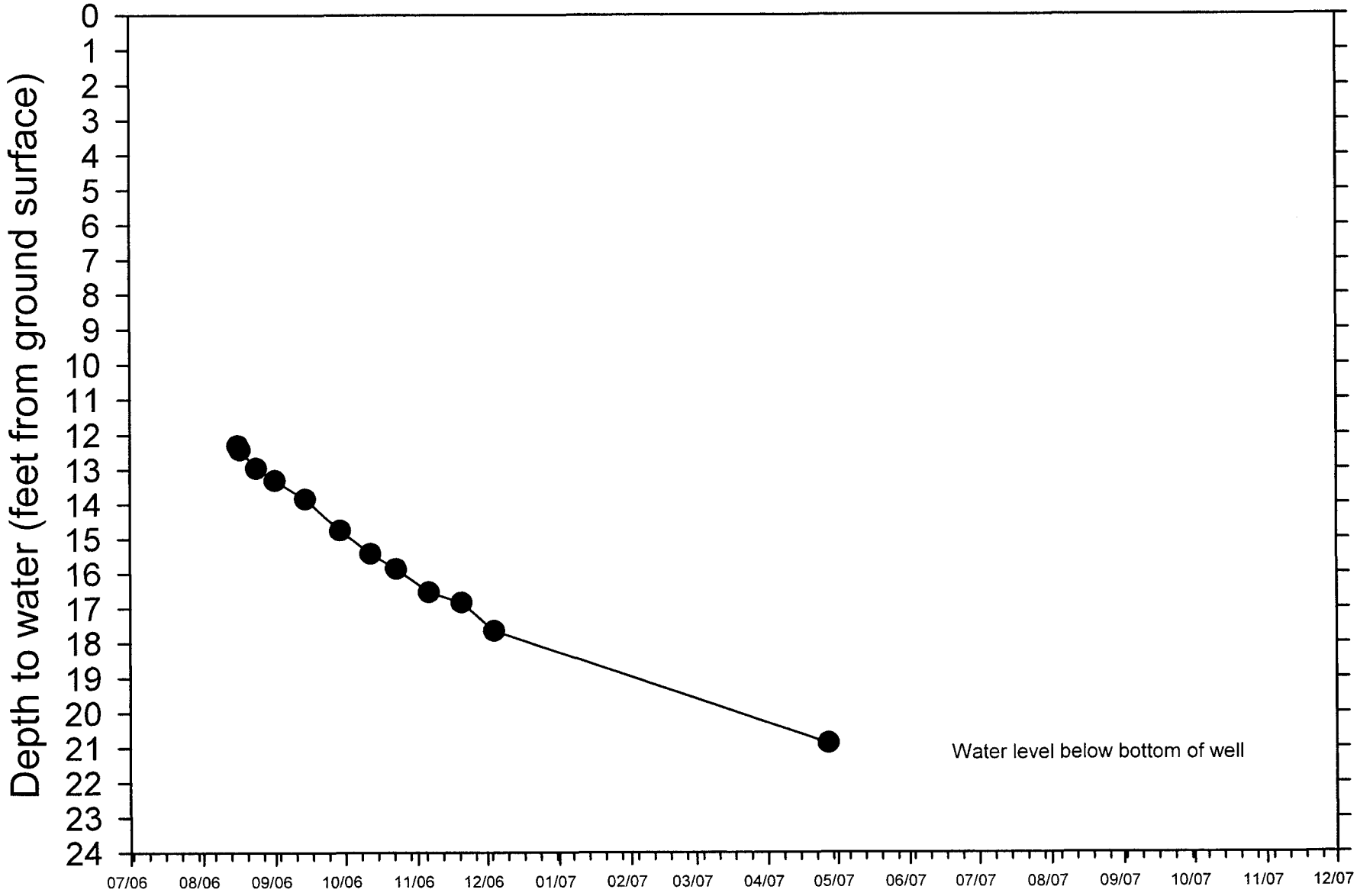
NWP-30


Depth to water (feet from ground surface)
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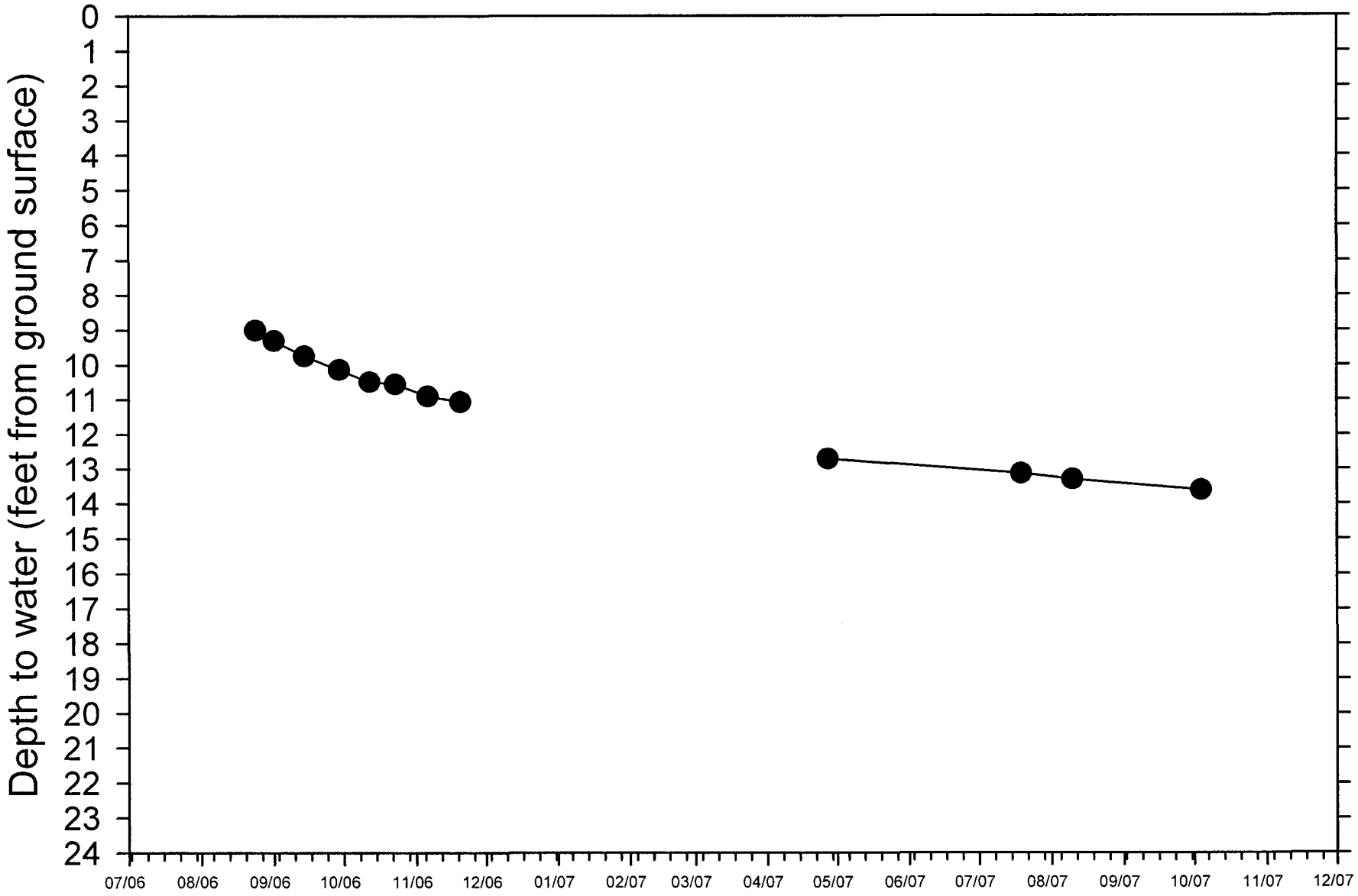
Water level below bottom of well

NWP-31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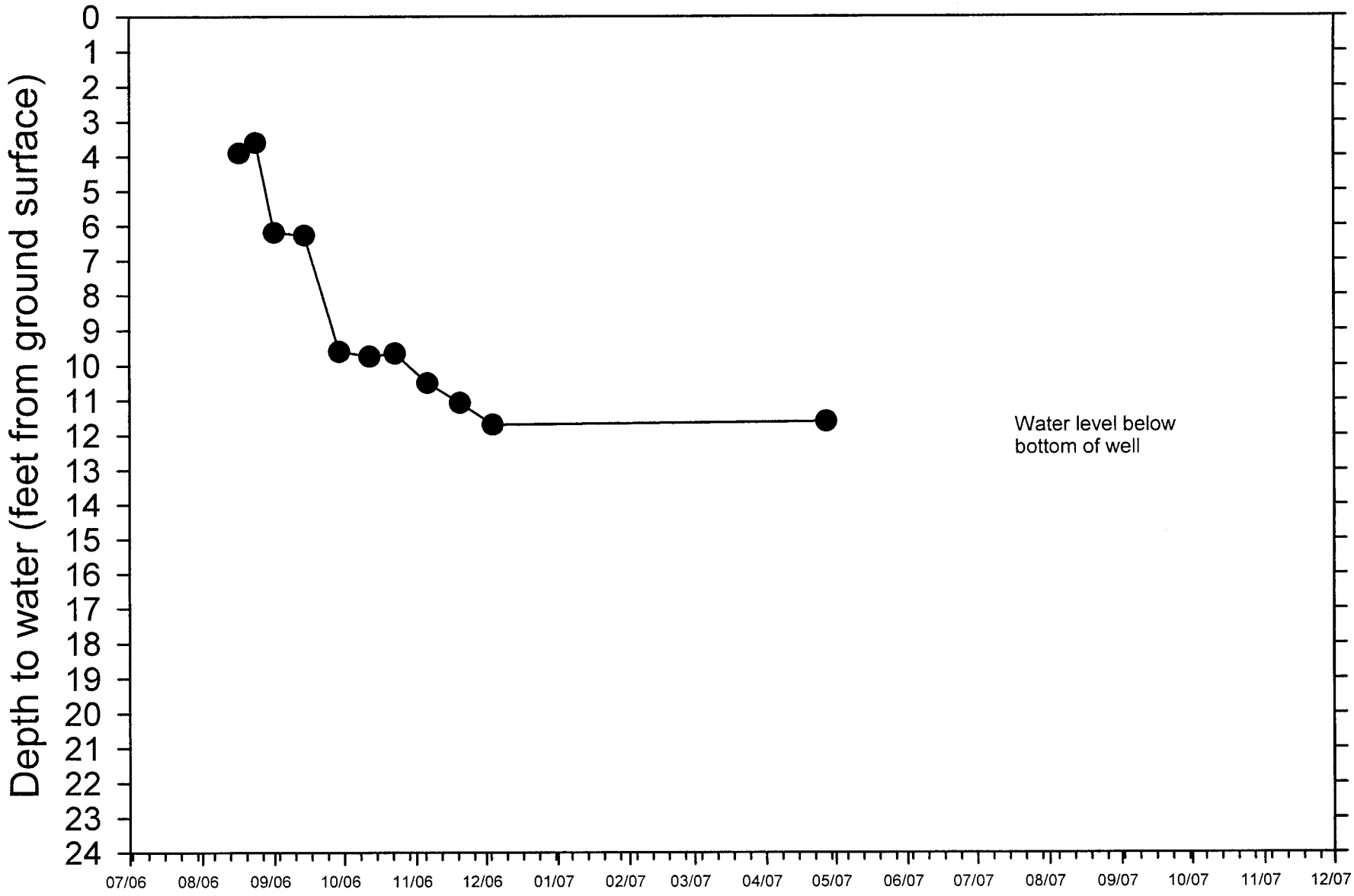
NWP-32


Depth to water (feet from ground surface)
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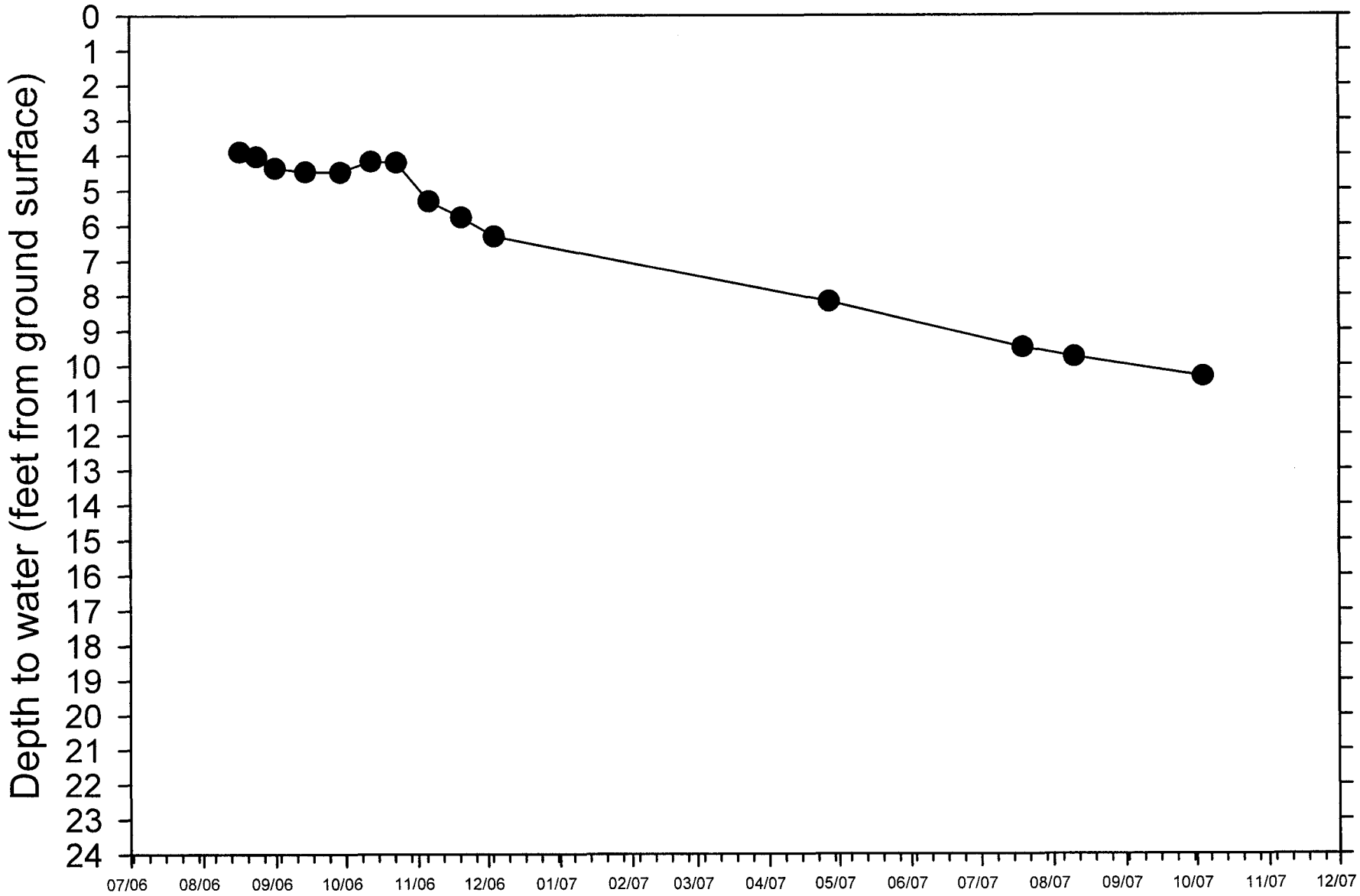
Water level below
bottom of well

NWP-33


Depth to water (feet from ground surface)
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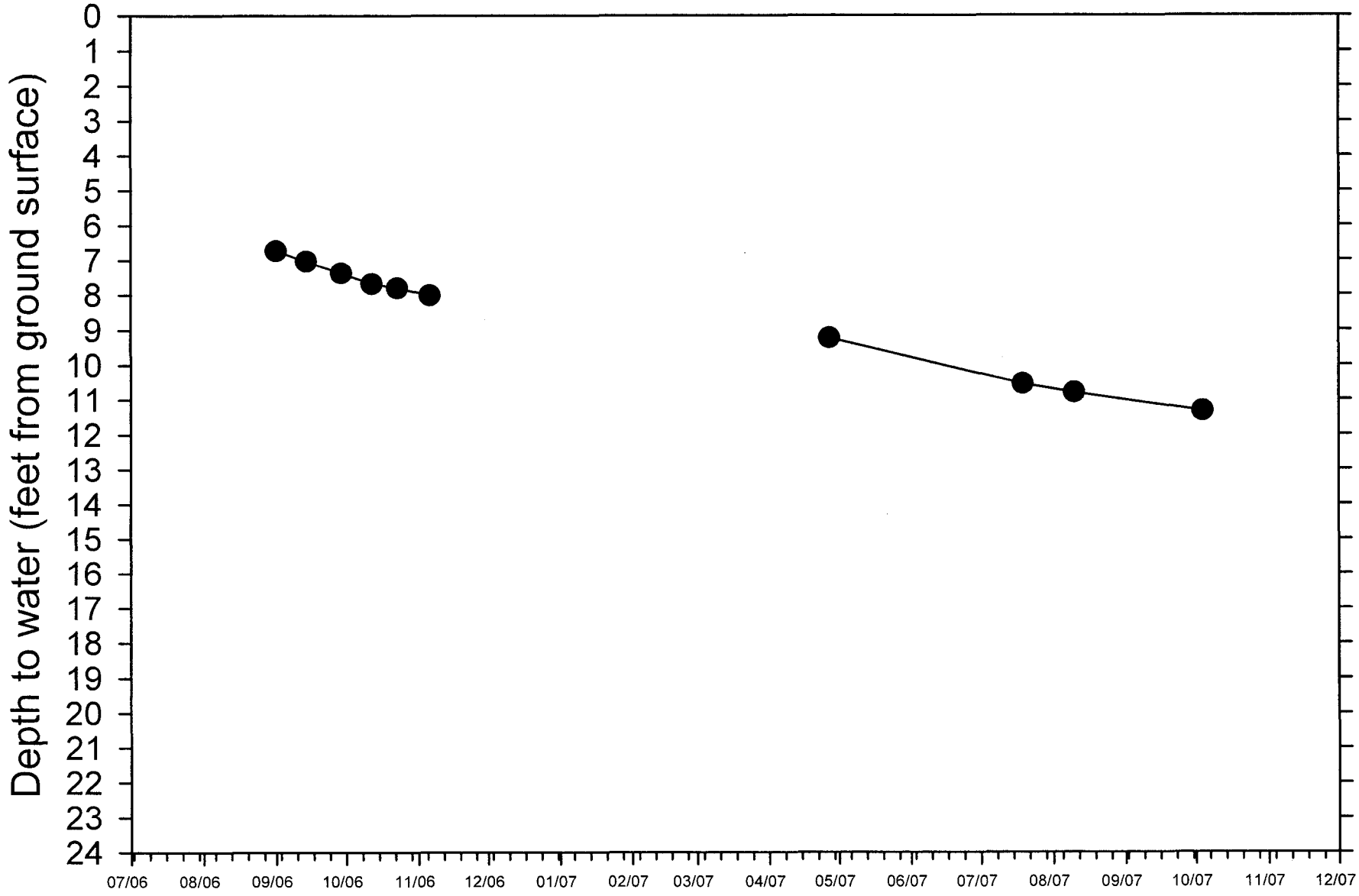
NWP-34


Depth to water (feet from ground surface)
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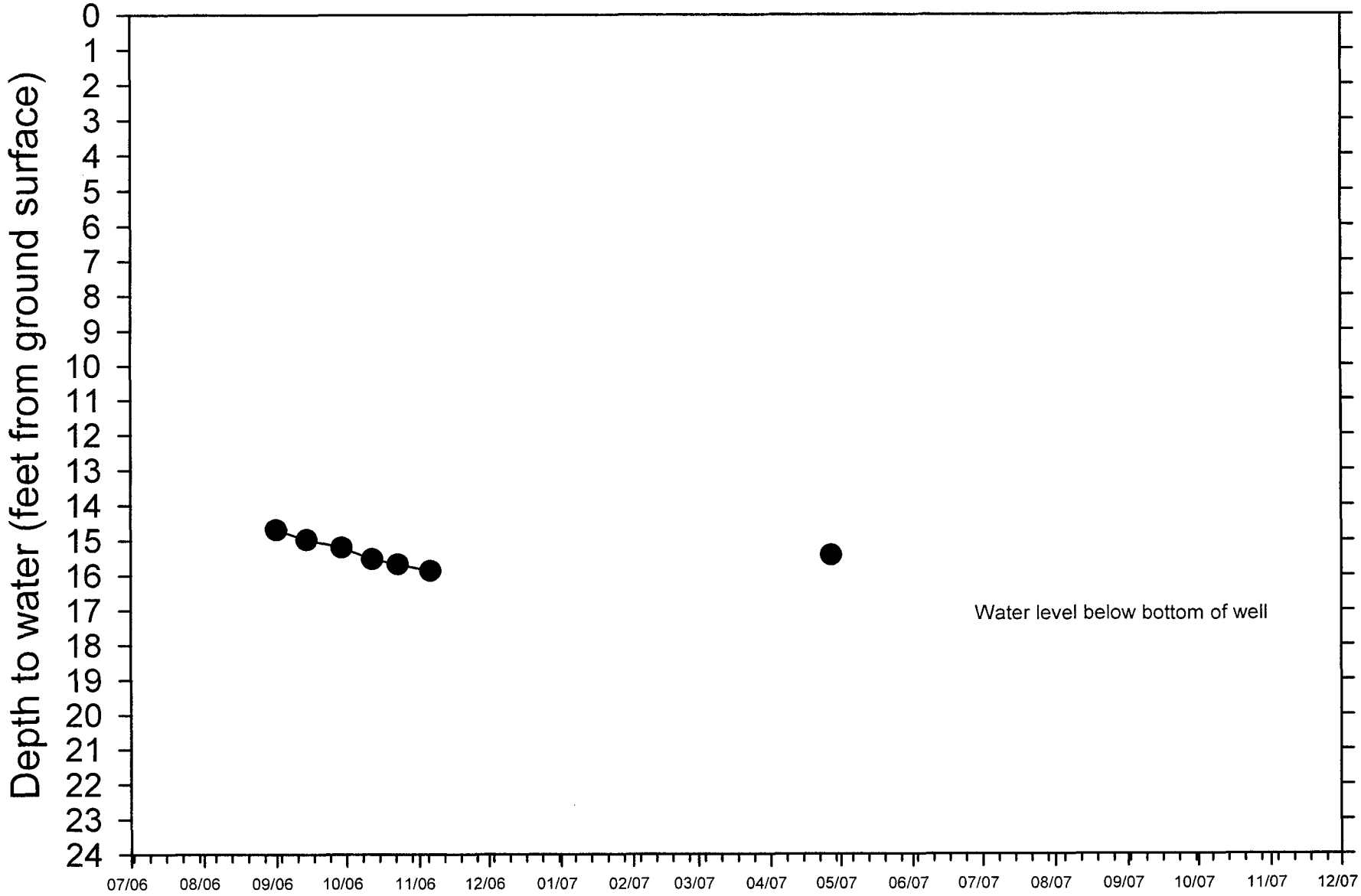
NWP-35


Depth to water (feet from ground surface)
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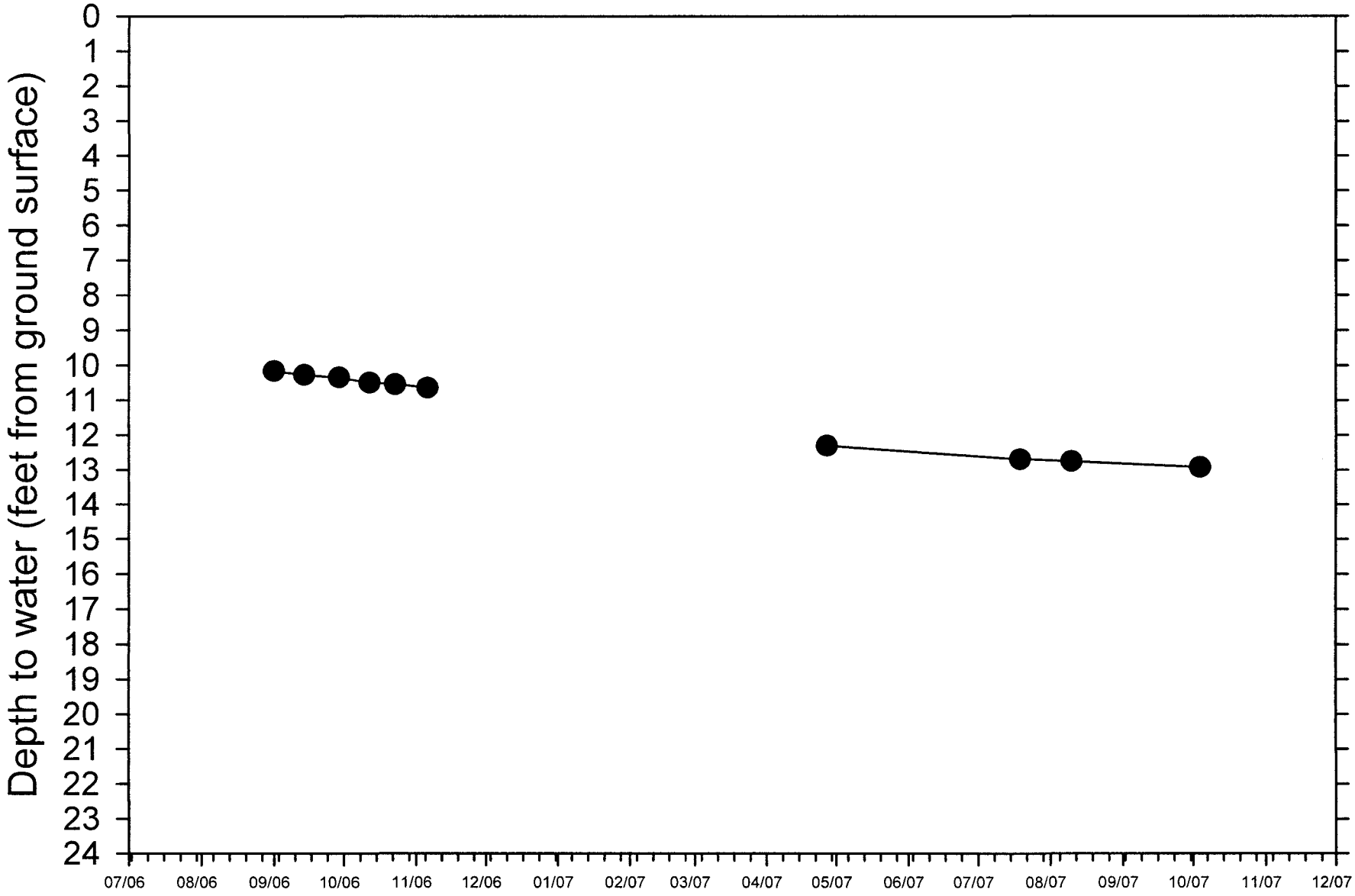
Water level below bottom of well

NWP-36


Depth to water (feet from ground surface)
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ATTACHMENT 2

Clement Drilling and Geophysical, Inc
Letter Report Summarizing Results of VLF Survey in North Water Spring Area

October 2007

CLEMENT DRILLING
& GEOPHYSICAL, INC.

4114 West 9950 North
Cedar Hills, Utah 84062
Phone 801-372-3685
Fax 801-785-5748

October 30, 2007

Chris Hansen
SUFCO Mine

Dear Mr. Hansen,

This letter report summarizes the methodology and results of the soil resistivity testing conducted by Clement Drilling & Geophysical, Inc. at the North Water area near the East Fork of Box Canyon at the SUFCO Mine. The purpose of the soil resistivity testing was to determine the feasibility of utilizing resistivity surveys to locate zones of bedrock fractures related to subsidence.

Soil Resistivity Testing

Two resistivity lines were measured at the project site using a Wenner 4 pin array to determine the apparent soil resistivity of the shallow subsurface material. The first line was centered on piezometer NWP-22. The second line was centered on piezometer NWP-3. The data were collected utilizing an Ultra MiniRes resistivity meter. Line1 (NWP-22) consisted of fourteen readings with electrode spacings starting at 3.7 feet and increasing to 270 feet and was run in an area where subsidence related fracturing has been observed. Line 2 (NWP-3) consisted of eleven readings with electrode spacings starting at 2.7 feet and increasing to 70 feet and was run in an area beyond the effects of the mining related fracturing. Data collection consisted setting electrodes at the proper spacing, connecting the electrodes to the meter and measuring the soil resistance to the current input into the earth by the resistivity meter. The apparent resistivity was calculated from the measured resistance. Tables 1 and 2 present the results of the soil resistivity survey.

Results

Table 3 presents a comparison of the results of the two resistivity lines. In the shallow material there is a significant difference in the resistivity of the soil. This difference is due to the shallow soil types at the locations of the lines. In the NWP-22 area the soils contain significant amounts of organic clays and soil moisture, which decrease soil resistivity. In the NWP-3 area the shallow soils are primarily dry fine-grained sand, which have high resistivity. As the spacing of the survey increased and approached the anticipated depth of bedrock the difference between the resistivity in the two lines became less significant. The A spacing of the electrodes approximately corresponds to the depth of the resistivity measurement. From the 19 to the 27 foot measurements the difference between the readings decreases dramatically and thereafter is statistically insignificant.

The ability to distinguish the subsidence related fractures is dependent on some difference in the nature or size of the subsidence related fractures relative to the pre-existing regional

jointing that is present in the area or a difference in the fluids present in the two types of fractures. Based on the results of the resistivity survey, it appears that the differences between the two fracture types and the fracture-filling fluids are not significant enough to reliably distinguish between them.

Please feel free to contact me if you have any questions regarding the results of the geophysical testing. I appreciate the opportunity to work with you on this project.

Sincerely,
Clement Drilling & Geophysical, Inc.

Craig M. Clement

Craig M. Clement, P.G.

TABLES

Table 1

Wenner Sounding						
Sounding No.:			**Date:**	**Operator:**		
NWP-22			**7/18/2007**	**Craig Clement**		
Project:	SUFCO North Water					
Electrode Spacing (A)				Factor	Resistance (R in Ohm)	Apparent Resistivity (Ohm-meters)
A (ft)	A (m)	A/2	3A/2	(2xπxA)		(2xPIxAxR)
3.7	1.13	1.85	5.55	23.2	11.86	84.04
5	1.52	2.5	7.5	31.4	4.711	45.11
7	2.13	3.5	10.5	44.0	6.662	89.31
10	3.05	5	15	62.8	4.897	93.78
14	4.27	7	21	87.9	4.015	107.65
19	5.79	9.5	28.5	119.3	3.424	124.59
27	8.23	13.5	40.5	169.6	2.812	145.40
37	11.28	18.5	55.5	232.4	2.321	164.46
50	15.24	25	75	314.0	1.908	182.70
70	21.34	35	105	439.6	1.528	204.84
100	30.48	50	150	628.0	1.137	217.75
140	42.67	70	210	879.2	0.804	215.57
190	57.91	95	285	1193.2	0.602	219.05
270	82.30	135	405	1695.6	0.389	201.14

Table 2

Wenner Sounding						
Sounding No.:			**Date:**	**Operator:**		
NWP-3			**7/18/2007**	**Craig Clement**		
Project:	SUFCO North Water					
Electrode Spacing (A)				Factor	Resistance (R in Ohm)	Apparent Resistivity (Ohm-meters)
A (ft)	A (m)	A/2	3A/2	(2xπxA)		(2xPIxAxR)
2.7	0.82	1.35	4.05	17.0	12	62.05
3.7	1.13	1.85	5.55	23.2	21	148.80
5	1.52	2.5	7.5	31.4	138.7	1328.13
7	2.13	3.5	10.5	44.0	59.9	803.01
10	3.05	5	15	62.8	30.3	580.28
14	4.27	7	21	87.9	16.1	431.67
19	5.79	9.5	28.5	119.3	9.1	331.12
27	8.23	13.5	40.5	169.6	3.2	165.47
37	11.28	18.5	55.5	232.4	2.7	191.32
50	15.24	25	75	314.0	1.9	181.94
70	21.34	35	105	439.6	1.5	201.09

Table 3

A Spacing (ft) Approximately = to depth	NWP-22 Apparent Resistivity (Ohm-meters)	NWP-3 Apparent Resistivity (Ohm-meters)	Difference (Ohm-meters)	Percent Difference
2.7		62.04972		
3.7	84.04	148.8044	64.76536	77.07
5	45.11	1328.132	1283.022	2844.17
7	89.31	803.0077	713.6982	799.13
10	93.78	580.2798	486.4966	518.75
14	107.65	431.6669	324.0183	301.00
19	124.59	331.1234	206.5336	165.77
27	145.40	165.4659	20.06274	13.80
37	164.46	191.32	26.85566	16.33
50	182.70	181.9359	0.766046	0.42
70	204.84	201.0871	3.753625	1.87
100	217.75			
140	215.57			
190	219.05			
270	201.14			

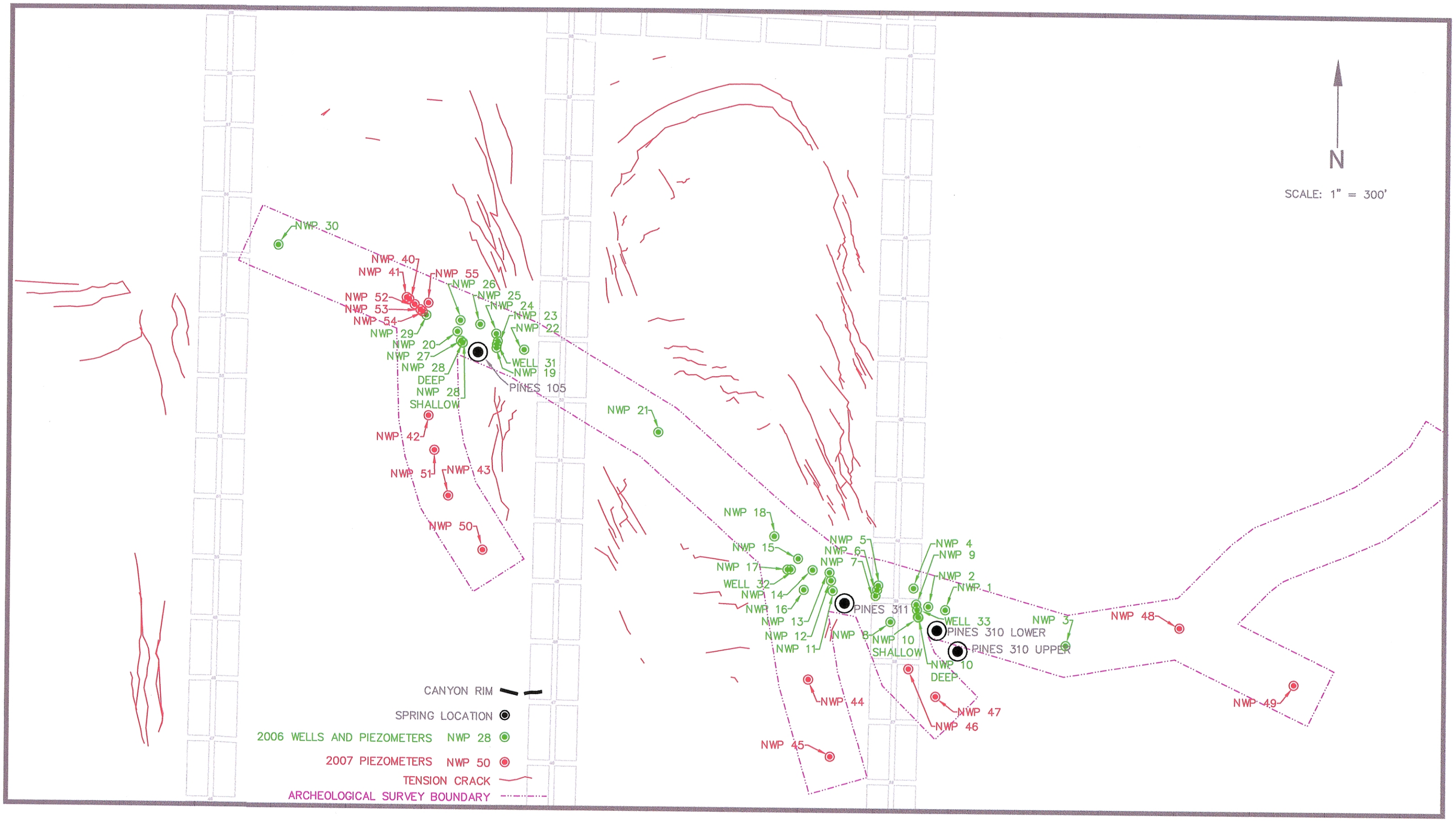


FIGURE 1
NORTH WATER PIEZOMETER LOCATIONS

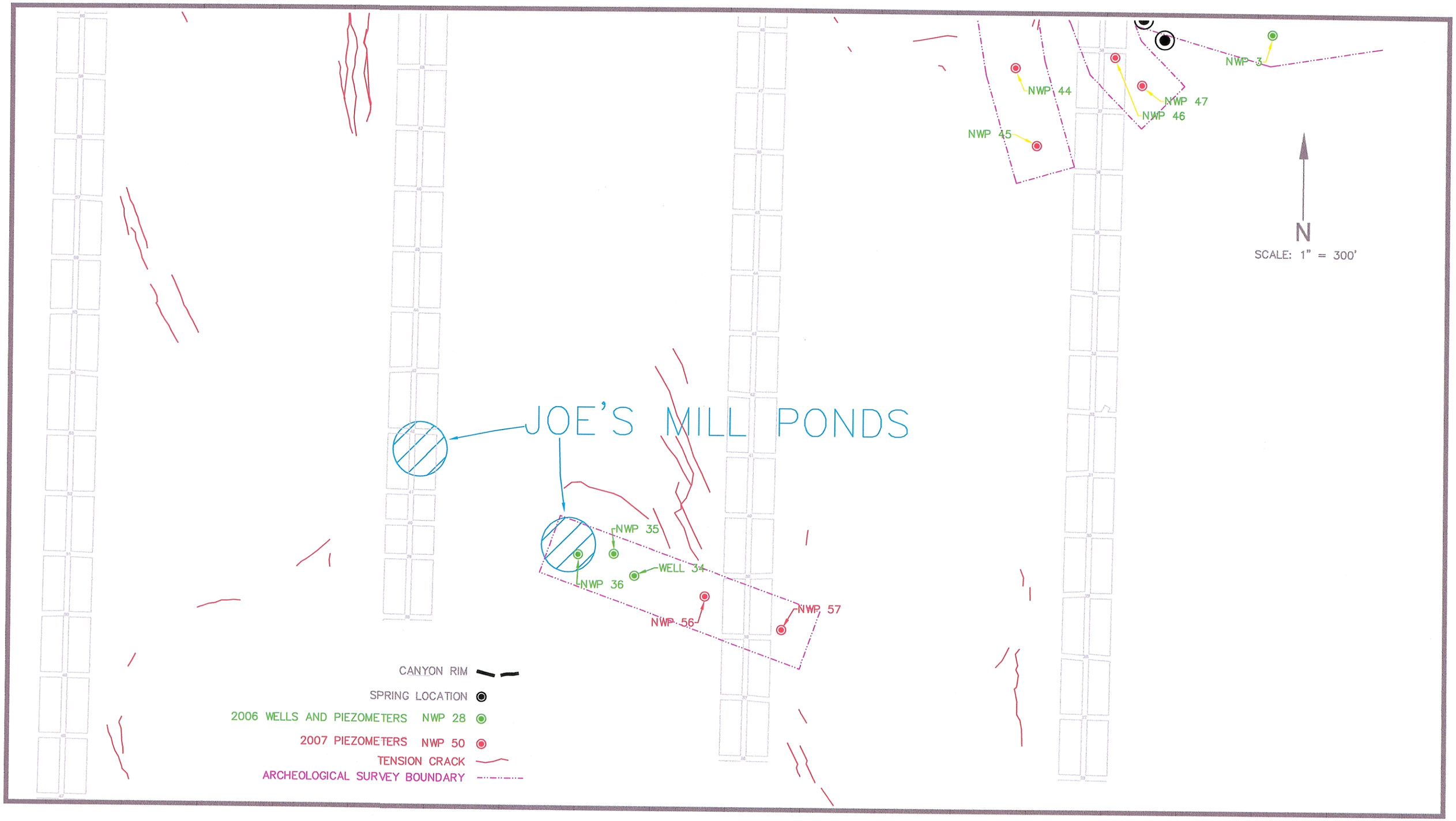
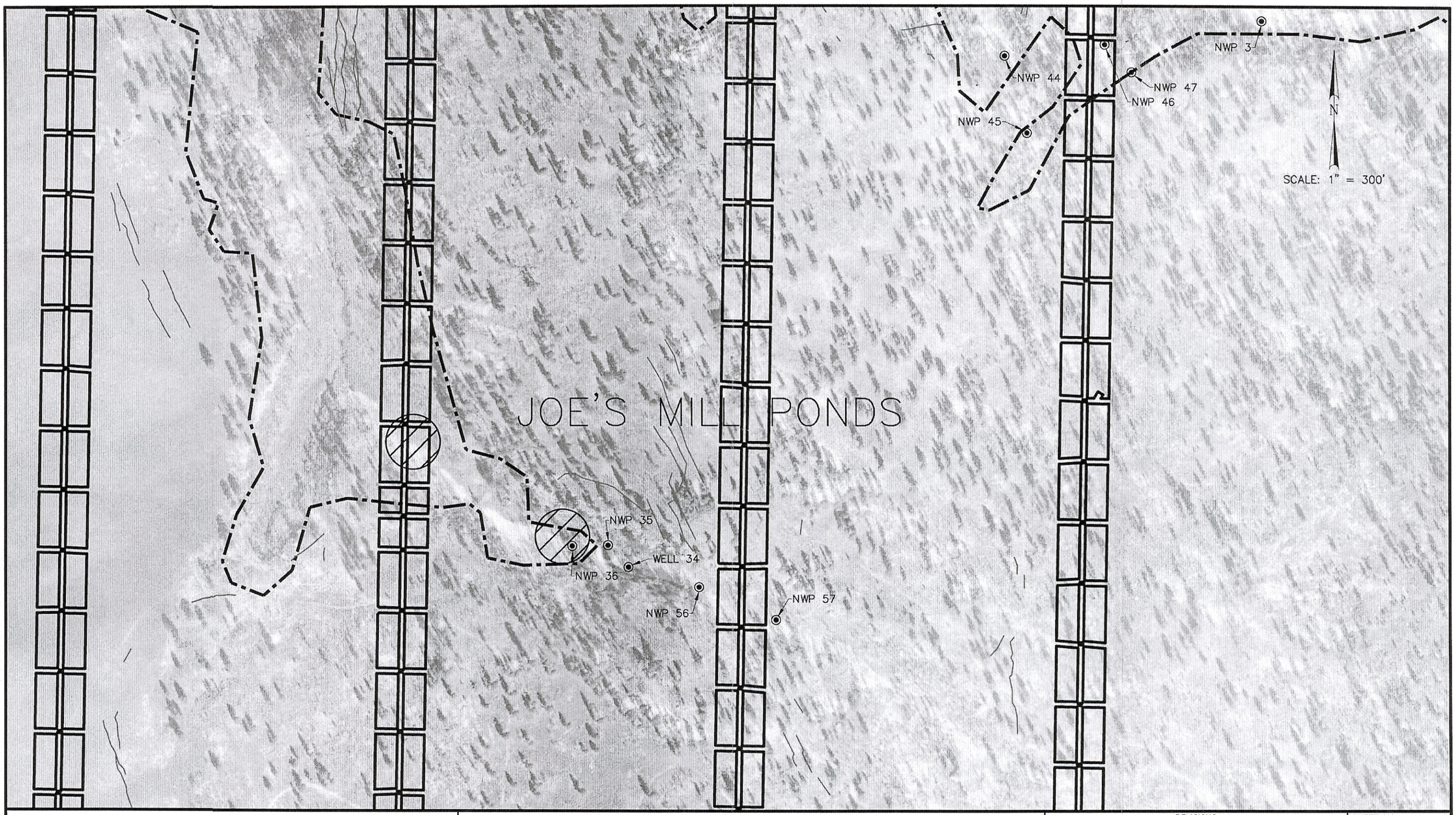


FIGURE 2
JOE'S MILL POND PIEZOMETER LOCATIONS



Canyon Fuel Company, LLC
SUFCO Mine
397 South 800 West - Salina, UT 84654
(435) 286-4880 Phone
(435) 286-4499 Fax

Joes Mill Area

Subsidence Crack & Monitoring Well Locations

SCALE: 1" = 300'	DATE: Sept. 2007	DRAWN BY: K.B.B.	ENGINEER: M.L.D.	CHECKED BY: M.L.D.
FILE NAME: H:\				

REVISIONS

NO.	DATE	REQ. BY	DWG. BY	REMARKS

SHEET NO. 1

Figure 2 Locations of piezometers in the Joes Mill area.

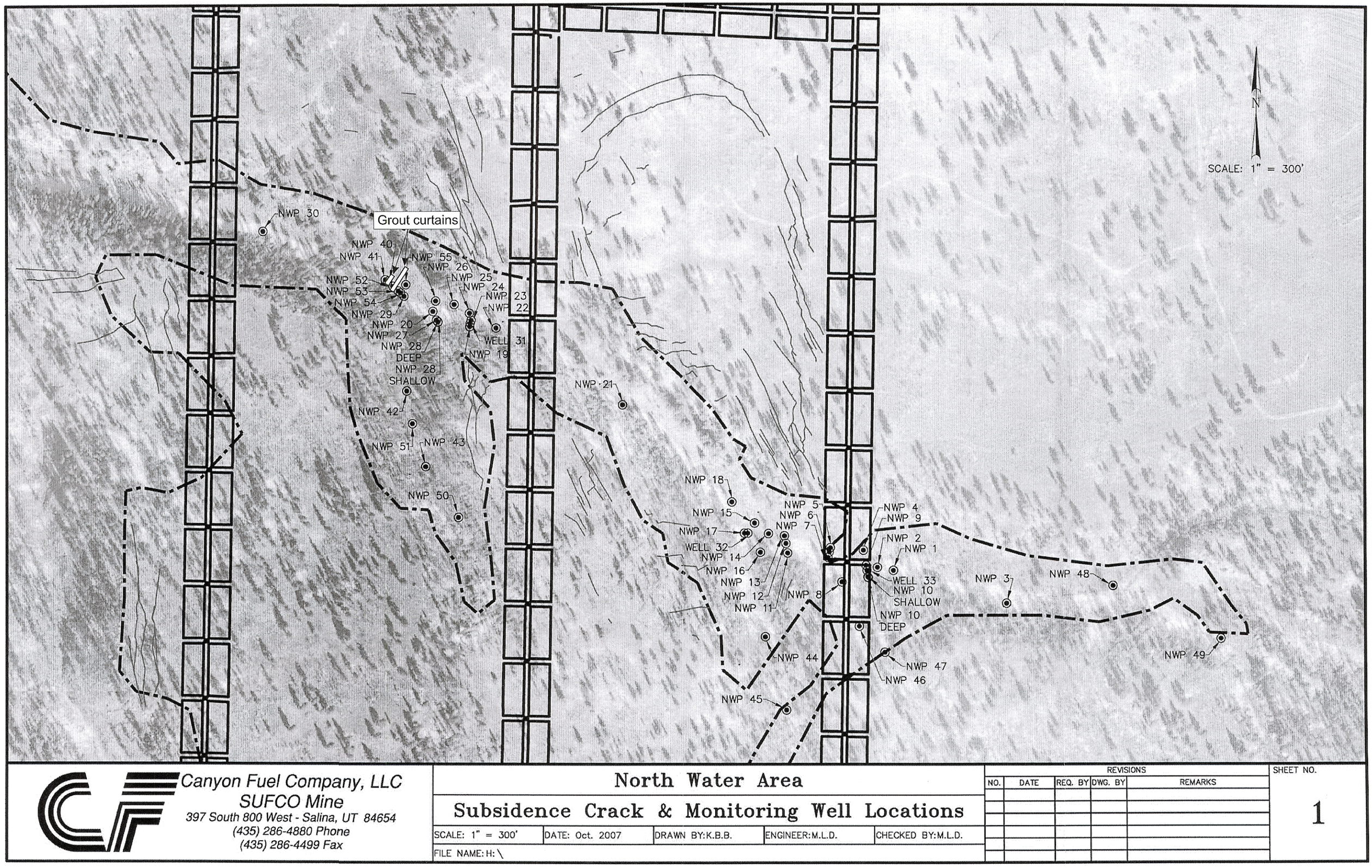


Figure 1 Locations of piezometers and grout curtains in the North Water Canyon area.

Table 1 Completion details for piezometers and production wells in the North Water Canyon and Joes Mill Pond areas, Sufco Mine.

PETERSEN HYDROLOGIC, LLC Well completion info.xls

Notes: All measurements are in feet below the ground surface
Sand pack used in all wells is 10-20 Colorado Silica Sand; Well screen is 0.010 slot size
Well screen and riser pipe used is flush-threaded PVC
Piezometers enclosed in 4-inch PVC surface protectors; Production wells enclosed in locking steel surface protectors.

						Screen interval			Sand pack		Bentonite seal		Flowing sand	Sampled interval		Direct push interval		8-inch augered interval		Concrete surface seal	
	Area	Type	Date completed	Borehole diameter (inch)	Depth to bedrock/refusal	From	To	Screen length	From	To	From	To	infil to	From	To	From	To	From	To	From	To
NWP-1	Pines 310	1-inch Piezometer	1-Aug-2006	2.25	28	8	28	20	5	12	0	5	12	0	28	---	---	---	---	---	---
NWP-2	Pines 310	1-inch Piezometer	1-Aug-2006	2.25	23	3	23	20	8	9	0	8	9	0	23	---	---	---	---	---	---
NWP-3	Upgradient alluvium	1-inch Piezometer	2-Aug-2006	2.25	16	6	16	10	5	13.5	0	5	13.5	0	16	---	---	---	---	---	---
NWP-4	Pines 310	1-inch Piezometer	2-Aug-2006	2.25	38	9.7	29.7	20	9	13	0	9	13	0	30	30	38	---	---	---	---
NWP-5	Pines 310	1-inch Piezometer	2-Aug-2006	2.25	29.7	8	28	20	7	10	0	7	10	0	29.7	---	---	---	---	---	---
NWP-6	Pines 310	1-inch Piezometer	2-Aug-2006	2.25	35	4	24	20	3	8	0	3	8	0	26	26	35	---	---	---	---
NWP-7	Pines 310	1-inch Piezometer	2-Aug-2006	2.25	36	8	28	20	7.5	8	0	7.5	8	0	26	26	36	---	---	---	---
NWP-8	Pines 310	1-inch Piezometer	3-Aug-2006	2.25	41	4	19	15	7	13	0	7	13	0	24	24	41	---	---	---	---
NWP-9	Pines 310	1-inch Piezometer	3-Aug-2006	2.25	Not encountered	8	28	20	---	---	0	6.8	6.8	---	---	0	28	---	---	---	---
NWP-10 shallow	Pines 310	1-inch Piezometer	3-Aug-2006	2.25	Not encountered	5	10	5	4	10	0	4	10	---	---	0	10	---	---	---	---
NWP-10 deep	Pines 310	1-inch Piezometer	3-Aug-2006	2.25	41	23	28	5	---	---	0	12	12	0	24	24	41	---	---	---	---
NWP-11	Pines 311	1-inch Piezometer	3-Aug-2006	2.25	28	8	28	20	7	8	0	7	7	0	28	---	---	---	---	---	---
NWP-12	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	40	8	28	20	7	7.5	0	7	7.5	---	---	0	40	---	---	---	---
NWP-13	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	35	8	28	20	7	8	0	7	7	---	---	0	35	---	---	---	---
NWP-14	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	35	8	28	20	7	8	0	7	8	0	28	28	35	---	---	---	---
NWP-15	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	33	8	28	20	7	8	0	7	8	0	28	28	33	---	---	---	---
NWP-16	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	9	4	9	5	2	7	0	2	7	0	9	---	---	---	---	---	---
NWP-17	Pines 311	1-inch Piezometer	4-Aug-2006	2.25	22	9	24	15	5	9	0	5	9	0	24	---	---	---	---	---	---
NWP-18	Pines 311	1-inch Piezometer	5-Aug-2006	2.25	29	9	29	20	7	8	0	7	8	0	29	---	---	---	---	---	---
NWP-19	Pines 105	1-inch Piezometer	5-Aug-2006	2.25	21	6	21	15	5	8	0	5	8	0	21	---	---	---	---	---	---
NWP-20	Pines 105	1-inch Piezometer	5-Aug-2006	2.25	25	5	25	20	3	18	0	3	18	0	25	---	---	---	---	---	---
NWP-21	Between Pines 105 and 311	1-inch Piezometer	15-Aug-2006	2.25	25.5	5.5	25.5	20	4	12	0	4	12	0	25.5	---	---	---	---	---	---
NWP-22	Pines 105	1-inch Piezometer	15-Aug-2006	2.25	22.5	7.5	22.5	15	3.5	10.8	0	3.5	10.8	0	22.5	---	---	---	---	---	---
NWP-23	Pines 105	1-inch Piezometer	15-Aug-2006	2.25	25	10	25	15	7	9	0	7	9	---	---	0	25	---	---	---	---
NWP-24	Pines 105	1-inch Piezometer	15-Aug-2005	2.25	28.5	8.5	28.5	20	7	22.4	0	7	22.4	0	28.5	---	---	---	---	---	---
NWP-25	Pines 105	1-inch Piezometer	15-Aug-2005	2.25	20.5	10.5	20.5	10	10	15.6	0	10	15.6	0	20.5	---	---	---	---	---	---
NWP-26	Pines 105	1-inch Piezometer	15-Aug-2006	2.25	26.5	11.5	26.5	15	---	---	0	6.5	6.5	0	26.5	---	---	---	---	---	---
NWP-27	Pines 105	1-inch Piezometer	16-Aug-2006	2.25	25	10	25	15	9	10	0	9	10	0	25	---	---	---	---	---	---
NWP-28 shallow	Pines 105	1-inch Piezometer	16-Aug-2006	2.25	Not encountered	9	12	3	---	---	0	7.3	7.3	---	---	0	12	---	---	---	---
NWP-28 deep	Pines 105	1-inch Piezometer	16-Aug-2006	2.25	22.5	19.5	22.5	3	---	---	0	10	10	---	---	0	22.5	---	---	---	---
NWP-29	Pines 105	1-inch Piezometer	16-Aug-2006	2.25	22	7	22	15	5	12.9	0	5	12.9	0	22	---	---	---	---	---	---
NWP-30	Lower Canyon	1-inch Piezometer	16-Aug-2006	2.25	22	7	22	15	6	13.3	0	6	13.3	0	22	---	---	---	---	---	---
NWP-31 (4")	Pines 105	4-inch Production	16-Aug-2006	8	23	0	18	18	3	15	0.5	3	15	---	---	---	---	0	23	0	0.5
NWP-32 (4")	Pines 311	4-inch Production	16-Aug-2006	8	Not encountered	0	14	14	3	8.5	0.5	3	8.5	---	---	---	---	0	24	0	0.5
NWP-33 (4")	Pines 310	4-inch Production	17-Aug-2006	8	Not encountered	0	19	19	2.5	7	0.5	2.5	7	---	---	---	---	0	19	0	0.5
NWP-34 (4")	Joes Mill Pond	4-inch Production	17-Aug-2006	8	11.5	1	11	10	3	4	0.5	3	4	---	---	---	---	0	14.5	0	0.5
NWP-35	Joes Mill Pond	1-inch Piezometer	17-Aug-2006	2.25	18	8	18	10	7	14.5	0	7	14.5	0	18	---	---	---	---	---	---
NWP-36	Joes Mill Pond	1-inch Piezometer	17-Aug-2006	2.25	15	5	15	10	---	---	0	4	4	0	14	---	---	---	---	---	---
NWP-40	Pines 105 grout curtain area	1-inch Piezometer	3-Aug-07	2.25	25.2	2	25	23	2	25	0	2	---	0	25.2	---	---	---	---	---	---
NWP-41	Pines 105 grout curtain area	1-inch Piezometer	2-Aug-07	2.25	25.1	3	25	22	2.5	25	0	2.5	---	0	25.1	---	---	---	---	---	---
NWP-42	Pines 105 side canyon	1-inch Piezometer	2-Aug-07	2.25	26.8	4	26	22	3	26.8	0	3	---	0	26.8	---	---	---	---	---	---
NWP-43	Pines 105 side canyon	1-inch Piezometer	6-Aug-07	2.25	17.2	2	17	15	2	17	0	2	---	0	17.2	---	---	---	---	---	---
NWP-44	Pines 311 side canyon	1-inch Piezometer	7-Aug-07	2.25	24	3.5	23.5	20	24	3	0	3	---	0	24	---	---	---	---	---	---
NWP-45	Pines 311 side canyon	1-inch Piezometer	7-Aug-07	2.25	22.5	8.3	22.4	14	22.5	7	0	7	---	0	22.5	---	---	---	---	---	---
NWP-46	Pines 310 side canyon	1-inch Piezometer	6-Aug-07	2.25	19.8	2.8	18.8	16	2.5	19.8	0	2.5	---	0	19.8	---	---	---	---	---	---
NWP-47	Pines 310 side canyon	1-inch Piezometer	5-Aug-07	2.25	19.5	3.3	18.3	15	5	19.5	0	5	---	0	19.5	---	---	---	---	---	---
NWP-48	Upper main canyon	1-inch Piezometer	2-Aug-07	2.25	16.3	6.1	16.1	10	5	16.3	0	5	---	0	16.3	---	---	---	---	---	---
NWP-49	Upper main canyon	1-inch Piezometer	2-Aug-07	2.25	23.5	23.3	8.3	15	8.3	23.5	0	8.3	---	0	23.5	---	---	---	---	---	---
NWP-50	Pines 105 side canyon	1-inch Piezometer	6-Aug-07	2.25	14	2	14	12	1	14	0	1	---	0	14	---	---	---	---	---	---
NWP-51	Pines 105 side canyon	1-inch Piezometer	7-Aug-07	2.25	21	6	21	15	5	21	0	5	---	0	21	---	---	---	---	---	---
NWP-52	Pines 105 grout curtain area	1-inch Piezometer	28-Aug-07	2.25	25	1	21	20	3	25	0	1	---	0	25	---	---	---	---	---	---
NWP-53	Pines 105 grout curtain area	1-inch Piezometer	28-Aug-07	2.25	25.5	3	25	22	3	25	0	3	---	0	25.5	---	---	---	---	---	---
NWP-54	Pines 105 grout curtain area	1-inch Piezometer	28-Aug-07	2.25	Not encountered	0	14	14	1	16	0	1	---	---	---	0	16	---	---	---	---
NWP-55	Pines 105 grout curtain area	3/4-inch Piezometer	27-Aug-07	2.25	Not encountered	0	20	20	0	15	0	5	---	---	---	0	20	---	---	---	---
NWP-56	Joes Mill Pond	1-inch Piezometer	28-Aug-07	2.25	19.8	4.8	19.8	15	4	19.8	0	4	---	0	19.8	---	---	---	---	---	---
NWP-57	Joes Mill Pond	1-inch Piezometer	28-Aug-07	2.25	23.5	3.5	23.5	20	3	23.5	0	3	---	0	23.5	---	---	---	---	---	---

Table 2 Sufco North Water area piezometers, water level data

PETERSEN HYDROLOGIC, LLC, North Water Piezometers water levels.xls

Measurements reported as depth to water in feet relative to top of PVC casing

	3-Aug-06	4-Aug-06	11-Aug-06	15-Aug-06	16-Aug-06	17-Aug-06	24-Aug-06	1-Sep-06	14-Sep-06	29-Sep-06	12-Oct-06	23-Oct-06	6-Nov-06	20-Nov-06	4-Dec-06	27-Apr-07	19-Jul-07	10-Aug-07	28-Aug-07	4-Oct-07
NWP-1	4.91	4.06	4.27	4.41	4.40		4.61	4.81	4.75	5.08	4.76	4.87	5.43	5.80	6.19	7.87	9.38	9.69		10.48
NWP-2	2.70	2.72	2.92	3.02	3.01		3.15	3.39	3.63	3.91	3.65	3.75	4.37	4.80	5.23	7.10	8.35	8.61		9.20
NWP-3	11.01	11.01	11.13	11.21	11.23		11.36	11.41	11.42	11.44	11.34	11.32	11.25	11.29	11.46	11.13	12.21	12.74		14.07
NWP-4	3.08	3.10	3.35	3.47	3.41		3.55	3.71	4.34	4.67	4.40	4.46	5.13	5.57	6.03	8.25	9.46	9.67		10.34
NWP-5	2.70	2.68	2.86	3.02	2.95		2.93	3.06	5.45	6.15	6.02	6.15	6.82	7.25	7.79	9.82	10.21	10.35		10.76
NWP-6	2.80	2.75	3.07	3.16	3.08	3.05	3.08	3.24	5.51	6.06	5.85	5.73	6.37	6.55	7.08	9.85	10.34	10.45		11.04
NWP-7	3.19	3.15	3.34	3.46	3.41		3.41	3.54	6.40	7.26	7.21	7.44	8.00	8.86	8.92	10.85	11.23	11.43		11.93
NWP-8	8.66	8.49	8.59	8.65	8.65		8.77	8.78	9.50	9.82	9.88	9.49	9.74	10.24	10.61	14.42	15.10	15.35		16.05
NWP-9		2.43	2.60	3.05	2.70		2.79	2.98	3.53	3.84	3.59	3.69	4.30	4.76	5.28	7.30	8.48	8.71		9.27
NWP-10 shallow		2.94	3.17	3.29	3.23		3.39	3.60	3.71	3.91	3.64	3.79	4.50	4.95	5.41	6.88	7.73	7.77		9.41
NWP-10 deep		1.84	1.92	2.20	2.18		2.06	2.26	3.43	3.86	4.29	4.61	5.39	5.98	6.49	8.87	9.82	10.03		10.55
NWP-11		2.27	2.76	2.86	2.80		2.58	3.14	19.68	19.59	20.20	20.08	21.04	21.80	21.71	24.32	24.79	25.06		25.30
NWP-12		4.29	4.42	4.67	4.51	4.48	4.14	4.94	22.52	16.29	17.36	17.42	17.14	18.84	17.88	20.08	19.58	19.01		19.45
NWP-13		4.18	4.37	4.58	4.48		3.88	5.44	12.38	13.87	14.37	15.08	16.26	17.00	17.08	25.57	23.80	23.72		23.81
NWP-14		3.66	3.87	4.09	4.04		3.34	5.43	9.59	12.04	12.02	12.04	13.19	13.54	14.12	17.93	20.42	21.13		22.75
NWP-15		3.46	3.71	3.88	3.90	3.73	2.87	5.42	7.76	9.91	9.97	9.84	10.46	10.99	11.60	14.31	15.11	15.37		16.96
NWP-16		3.64	3.23	3.52	3.39	3.35	3.30	4.43	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry		Dry
NWP-17		4.86	3.98	4.21	4.65	4.17	3.56	9.03	7.98	9.93	9.88	9.83	10.29	10.78	11.12	13.66	16.61	17.89		19.21
NWP-18			5.35	5.48	5.39	5.31	4.19	4.19	9.25	10.75	10.47	10.60	11.13	10.58	11.89	15.99	18.79	19.05		19.88
NWP-19			7.79	7.65	7.69		8.46	8.52	9.04	9.81	10.52	10.77	10.82	10.88	11.42	13.98	14.48	14.44	15.30	14.99
NWP-20			17.21	17.44	17.36		17.35	17.60	17.58	19.14	18.08	18.16	18.27	18.30	18.44	19.41	19.94	20.05	20.18	20.37
NWP-21				3.90	3.82	3.85	2.70	5.63	submerged	3.68	submerged	submerged	2.80	3.43	4.10		8.74	9.30		10.87
NWP-22				7.08	7.03	7.11	7.24	7.68	8.22	9.70	8.97	8.97	9.21	9.54	Cap frozen	11.91	12.30	---	13.21	13.08
NWP-23					8.13		8.74	9.08	9.54	9.96	10.22	10.29	10.61	10.80	Cap frozen	12.74	13.26	13.45	14.17	13.68
NWP-24					16.91		17.21	17.48	17.72	18.05	18.09	18.14	18.33	18.61	18.93	20.20	20.61	20.74	21.29	20.90
NWP-25					15.40		15.56	15.73	15.98	16.22	16.52	16.71	17.00	17.11	17.39	19.61	20.42	20.66	Dry	Dry
NWP-26					17.69		18.79	18.96	19.27	19.78	20.06	20.08	20.31	20.28	20.18	22.16	23.06	23.30	23.87	23.48
NWP-27					8.25		8.36	8.63	9.18	9.74	10.13	10.12	10.32	10.49	10.73	12.77	13.56	13.72	13.91	14.43
NWP-28 shallow					6.92		7.18	7.39	7.83	8.31	8.50	8.55	8.83	9.17	Cap frozen	11.62	Dry	Dry	Dry	Dry
NWP-28 deep					8.67		8.56	8.79	9.32	9.97	10.46	10.57	10.75	10.94	Cap frozen	13.15	13.95	14.13	14.29	14.51
NWP-29					9.65	8.96	9.90	9.74	9.84	10.33	10.68	9.95	10.25	10.89	10.86	12.10	13.10	13.21	13.51	14.74
NWP-30					12.30	12.42	12.95	13.30	13.84	14.75	15.42	15.86	16.53	16.83	17.65	20.87	Dry	Dry		Dry
NWP-31 (4")							9.00	9.30	9.74	10.13	10.48	10.55	10.90	11.06	Cap frozen	12.71	13.13	13.30	13.97	13.61
NWP-32 (4")						3.90	3.60	6.19	6.27	9.60	9.74	9.65	10.50	11.07	11.69	11.60	Dry	Dry		Dry
NWP-33 (4")						3.90	4.03	4.36	4.46	4.48	4.17	4.20	5.30	5.76	6.30	8.18	9.49	9.76		10.33
NWP-34 (4")								6.73	7.03	7.37	7.68	7.80	8.01	Inaccessible	Inaccessible	9.23	10.55	10.80		11.33
NWP-35								14.69	14.97	15.19	15.52	15.67	15.86	Inaccessible	Inaccessible	15.42	Dry	Dry		Dry
NWP-36								10.16	10.27	10.34	10.50	10.54	10.64	Inaccessible	Inaccessible	12.30	12.69	12.75		12.92
NWP-40																		18.95	19.67	19.29
NWP-41																		22.27	22.85	22.22
NWP-42																		22.58	23.43	23.45
NWP-43																		5.75		6.11
NWP-44																		Dry		Dry
NWP-45																		Dry		Dry
NWP-46																		Dry		Dry
NWP-47																		8.30		8.49
NWP-48																		15.39		16.02
NWP-49																		18.55		19.42
NWP-50																		10.07	10.98	11.16
NWP-51																		21.05		21.78
NWP-52																			15.89	15.58
NWP-53																			15.39	14.68
NWP-54																				12.84
NWP-55																				19.32
NWP-56																				17.37
NWP-57																				16.24