0005

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

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January 26, 2007

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Incoming of C/041/0002 Copy Wayne H.

Re: North Water Spring and Joes Mill Ponds Mitigation Study Report, Canyon Fuel Company, LLC, SUFCO Mine C/041/002

Dear Wayne:

Please find attached to this letter four copies of the report detailing the findings of the North Water Spring and Joes Mill Ponds Mitigation Study. This report includes an interpretation of the data collected to date from the piezometers installed in August 2006 and continued spring flow measurements for the Pines 310, and 311 springs. The report also includes a proposal to install additional piezometers in the areas of the springs and Joes Mill pond in the Spring of 2007 to more fully understand the ground water system. Additionally, a preliminary mitigation plan is presented in this report. It is Sufco's current plan to implement the mitigation plan before the end of 2007. However, the implementation of the plan will be contingent upon the findings of the installation of the additional piezometers this Spring.

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

Sincerely,
CANYON FUEL COMPANY, LLC
SUFCO Mine

Kenneth E. May
General Manager

Refer to Expandable 01 26 2007
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for additional information

Encl.

cc: Tom Lloyd - Manti-LaSal National Forest
DOGM Correspondence File

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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

Canyon Fuel Company, LLC
Sufco Mine
Salina, Utah

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

1.0 Introduction

The Sufco Mine, located approximately 9 miles west of Emery, Utah, has been in operation since 1977 (Figure 1). The mine, which produces low-sulfur bituminous coal, is owned and operated by Canyon Fuel Company, LLC (Canyon Fuel). During the winter of 2005-2006 coal mining operations in the 5 Left Pines East (5LPE) longwall panel in The Pines area progressed beneath the lower portion of the North Water Canyon and the Joes Mill Pond areas (Figure 2). Subsequent to the undermining and subsiding of these areas, discharges from spring Pines 105 and also a seep near Joes Mill Pond were impacted by mining operations and discharge to the surface from these springs ceased. Prior to the undermining of two additional springs overlying the adjacent 6LPE panel in the upper portion of the North Water Canyon area (Figure 2), Canyon Fuel commissioned a hydrogeologic investigation to characterize current hydrogeologic conditions in the North Water Canyon and Joes Mill Pond

areas. The investigation was also designed to provide information necessary to facilitate the planning and implementation of future mitigation activities at the impacted sites.

The purpose of this report is to summarize the findings of the investigation to date and to present a proposed mitigation plan for restoring hydrologic conditions in the North Water and Joes Mill Pond areas. Including this introduction, this report contains the following sections:

1. Introduction
2. History
3. Climate
4. Physiography
5. Geology
6. Presentation of Data
7. Overview of Groundwater Systems
8. Analysis of Data
9. Conclusions
10. Proposed Mitigation Plan
11. References Cited

2.0 History

Longwall mining operations at the Sufco Mine have occurred in The Pines area since the early 2000s. Prior to undermining of the East Fork of Box Canyon with the 3LPE longwall panel in late 2003, Canyon Fuel commissioned hydrogeologic investigations to evaluate the potential for subsidence-related impacts to the creek and to springs in the canyon (Petersen Hydrologic, LLC, 2003). Canyon Fuel also initiated a rigorous spring and stream discharge monitoring program in the East Fork of Box Canyon at that time. Routine monitoring of springs and streams in the East Fork of Box Canyon continues at present. Subsequent to the subsiding of the stream drainage with the 3LPE longwall panel, surface water flow in several short reaches of the East Fork channel ceased. Discharge to the surface from four springs in the canyon area diminished or ceased coincident with the subsidence of the areas. However, it is important to note that streamflow measurements above and below the subsided portions of the canyon did not indicate that any appreciable loss of surface water from the drainage basin occurred at this time. Rather, it was evident that the dry stream reaches were a result of the subsidence-related buckling of thin bedded sandstones and siltstones in the upper few feet of the stream substrate. Surface waters in the East Fork could be observed entering the subsurface through these loose, broken rock strata, only to reemerge a few tens to rarely hundreds of feet further down the canyon where the stream substrate intersected low-permeability, in-tact shale or claystone layers. This occurrence indicated that the surface water entering the shallow subsurface through the broken strata were not percolating downward to appreciable depths, but rather were likely migrating though the shallow

subsurface beneath the stream channel before encountering an underlying low-permeability layer where the water was forced back to the surface. In a similar manner, while the discharge to the surface from some of the springs in the canyon ceased at the surface after the region was subsided, visible groundwater seepage to the surface was shortly thereafter observed in new locations several tens of feet below the original spring locations (Petersen Hydrologic, LLC, 2004, 2005). This occurrence likewise suggests that the water previously discharging to the surface at the springs was not diverted into deep strata or into the mine workings, but rather the discharge locations were lowered as a result of the fracturing of brittle bedrock strata at the spring site and the groundwater subsequently migrated downward until it reached a low-permeability layer where the spring discharge was forced to the surface. During the fall of 2004, repairs were made to the stream channel in the East Fork to restore continuous surface water flow to the dry stream reaches. In some locations, this was accomplished simply by removing the loose, buckled rocks from the channel substrate, revealing the surface flow beneath. In other locations, this was accomplished by placing bentonite in the stream channel in tension cracked zones. These repairs were successful in restoring surface-water flow in essentially all the stream reaches in the East Fork channel subsided by the mining of the 3LPE panel. Monitoring of the East Fork of Box Canyon during 2005 indicated that by that time streamflow conditions had been restored to pre-mining conditions (Petersen Hydrologic, LLC, 2005).

During the winter of 2005-2006, mining of the 5LPE panel occurred beneath the lower portion of North Water Canyon (also known as the east fork of the East Fork of Box Canyon)

(Figure 2). When the North Water area was visited in the spring of 2006 after the winter snowpack had receded and the region became accessible, it was found that discharge to the surface from spring Pines 105 (also known as North Water Spring) had ceased. Pines 105, which is located in the southeast quarter of Section 11, Township 21 South, Range 5 East (Figure 2) discharges from Castlegate Sandstone bedrock on the south side of North Water Canyon. The discharge monitored at the spring between 1997 and 2005 averaged about 6.5 gpm and was utilized for seasonal watering of livestock in the North Water Canyon area. Discharge from Pines 105 also sustained riparian vegetation for some distance downstream of the spring. Discharge from Pines 105, which usually comprised most or all of the water in the drainage below the spring area, infiltrated entirely into the sandy alluvium in the bottom of the canyon before reaching the confluence with the East Fork of Box Canyon Creek. During the peak snowmelt event, surface water from the North Water drainage was sometimes observed flowing continuously from the spring area to the East Fork confluence.

During a site visit to the Joes Mill Pond area in the springtime of 2006, it was observed that a small groundwater seep that contributed water to Joes Mill Pond had also ceased flowing at the surface at some time during the previous winter. Discharge observed at the seep prior to its undermining typically ranged from wet soil with no visible flow to about 0.5 gpm, with greater flows of perhaps 2 gpm observed during the springtime discharge peak.

Prior to the undermining of the upper portion of North Water Canyon by the 6LPE panel (Figure 2), Sufco commissioned a comprehensive hydrogeologic investigation of

groundwater systems in the North Water and Joes Mill Pond areas. The purpose of the investigation was to characterize the existing hydrogeologic conditions in the North Water and Joes Mill Pond areas. The investigation was also designed to provide data to facilitate the planning and implementation of future mitigation activities at both the North Water Canyon and Joes Mill Pond sites. The hydrogeologic investigation included the drilling and installation of 36 piezometers and groundwater wells, the bi-weekly monitoring of water levels in the newly installed wells and groundwater discharge rates from springs Pines 310 and Pines 311, the installation of automated pressure transducer/data logger units in 10 select wells in the North Water Canyon Area, the performance of slug testing to evaluate sediment hydrologic conductivity, and the analysis of the hydrogeologic data collected in the investigation. The results of the hydrogeologic investigation are presented herein. It is important to note that the investigations regarding hydrogeologic conditions in the North Water Canyon and Joes Mill Pond areas are on-going at present and additional investigations are planned. Therefore, conclusions presented herein, which are based on data collected to date, should be considered preliminary in nature and subject to revision as additional information from the area is obtained.

3.0 Climate

Climatic information collected at the Sufco East Fork Weather Station during the 2006 field season (27 Apr 2006 – 12 Oct 2006) is presented in Table 1. Data collected at the weather

station include daily minimum and maximum temperatures and daily precipitation totals. Of note in the 2006 East Fork weather data are the frequent numbers of days with measurable rain in the period from late June to the end of the data record in mid October. Also of note are two torrential rainfall events that occurred including a 1.22 inch rainfall event on 19 July 2006 and a 1.79 inch rainfall event on 6 October 2006.

For analysis of regional climatic conditions, a graph of the Palmer Hydrologic Drought Index (PHDI) for Utah Region 4 is presented in Figure 3. The PHDI is a monthly value generated by the National Climatic Data Center (NCDC, 2007) that indicates the severity of a wet or dry spell. The PHDI is calculated from climatic and hydrologic parameters such as temperature, precipitation, evapotranspiration, soil water recharge, soil water loss, and runoff. Because the PHDI takes into account parameters that affect the balance between moisture supply and moisture demand, the index is a useful tool for evaluating the long-term relationship between climate and groundwater recharge and discharge. Consequently, it is a useful tool for determining whether changes in discharge in a spring or water levels in a well are related to climate or other factors. It is apparent in Figure 3 that the region experienced a period of moderate to severe wetness during the late 1990s. The region experienced near normal climatic conditions during 2000 and 2001, before transitioning to a period of moderate to extreme drought from 2002 through early 2004. The region then transitioned to a period of extreme wetness in late 2004 that continued for most of 2005, before returning to near normal conditions in 2006.

4.0 Physiography

The North Water Canyon and Joes Mill Pond areas are located in The Pines plateau area, which is part of the Wasatch Plateau physiographic province of central Utah. The plateau is hydrogeologically isolated, being bounded by precipitous cliff escarpments on the north, northwest, east, and south (Figure 4). The land surface atop The Pines plateau consists predominantly of broad, gently sloping surfaces, dissected by deeply incised, steep-walled canyons of the Box Canyon Creek drainage. A few hills punctuate the otherwise flat ground surface, rising several hundred feet above the surrounding terrain. The land surface slopes toward the northwest in The Pines area, which is roughly coincident with the dip of the sandstone bedrock that is exposed at or near the ground surface over much of the plateau. Surface water over almost all of The Pines area drains into the Box Canyon Creek drainage, which subsequently flows into Muddy Creek about two miles northwest of the North Water Canyon area. Surface waters in the North Water Canyon and Joes Mill Pond areas drain through the East Fork of Box Canyon Creek (Figure 4).

5.0 Geology

Two geologic formations are of principal interest in this investigation. These include the Castlegate Sandstone, which is exposed at the land surface or under shallow soil or alluvial

cover everywhere in the North Water Canyon and Joes Mill Pond areas, and the Blackhawk Formation, which underlies the Castlegate Sandstone and contains the economic coal seams mined in the Sufco Mine. These two geologic formations, which are both of Cretaceous age, are described briefly below.

Castlegate Sandstone

The Castlegate Sandstone is a cliff-forming unit that comprises the rim rocks of the deeply incised canyons in the study area. The sandstone is directly exposed or covered by only a thin soil or alluvial veneer on the plateau in the North Water Canyon and Joes Mill Pond areas. The Castlegate Sandstone is discomformably overlain by the Price River Formation, which forms low lying hills on the plateau in areas adjacent to the study area. The Castlegate Sandstone, which is about 200 feet thick in the study and adjacent area, is predominately massively bedded, coarse-grained sandstone with some interbeds of shale, siltstone, and conglomerate. Pervasive calcium carbonate and silica cement makes the formation well indurated and brittle. The Castlegate Sandstone was formed in a braided fluvial depositional system.

Groundwater flow in the Castlegate Sandstone in the study area occurs primarily thorough fracture and joint systems. Although some of the sandstone rocks in the Castlegate are sufficiently permeable to transmit appreciable quantities of groundwater, groundwater flow through the pore spaces in the formation is limited. This is due primarily to the presence of

mudstone drapes and bounding layers that are interbedded in the formation. Near cliff exposures and in stream bottoms, the Castlegate Sandstone becomes friable due to the dissolution of the predominantly calcium carbonate cement and is more capable of supporting shallow, active groundwater systems.

Blackhawk Formation

The Blackhawk Formation in the study area consists of lenticular, discontinuous beds of sandstone, siltstone, mudstone, shale, and coal. In the study area, the upper 500 feet of the formation has massive, fine- to medium-grained, cliff-forming sandstone units interbedded with mudstones, claystones, and shales. The number and thicknesses of sandstone units decreases toward the base of the unit. The lower 300 feet of the formation contains thinly-bedded sandstone and shale, sandstone paleochannels and the economic coal seams. The thickness of the Blackhawk Formation in the study and adjacent area is about 800 feet.

The interbedded shale and mudstone units isolate permeable sandstone paleochannels and impede groundwater movement. Consequently, groundwater flow in the formation occurs primarily through sandstone paleochannels, or occasionally through faults and fractures, while migration of groundwater across lithologies (either vertically or horizontally) is minimal.

The Blackhawk Formation is known to contain swelling clays (montmorillonite and bentonite) that tend to naturally heal mining-induced fractures in the formation.

Structure

Significant faulting has not been identified in The Pines tract area, although joints in the Castlegate Sandstone are common. The surface traces of these joints are up to a 1,000 feet in length and are usually spaced about 16 to 33 feet apart. Rock units in The Pines area strike roughly 40°E and dip 1 to 2° (about 250 feet per mile) to the northwest. Local dips of the coal seam may range up to 10 degrees in areas where underlying paleochannels caused significant differential compaction.

6.0 Presentation of Data

Information regarding piezometer installation in the North Water Canyon and Joes Mill Pond areas, including piezometer/well drilling techniques and completion information, piezometer/well locations, geologic core logging information, and the results of bi-weekly water level measurements through 23 October 2006 reduced to groundwater elevations were submitted to the Division of Oil, Gas and mining in a previous submittal (Petersen Hydrologic, LLC, 2006). Additional information presented herein includes the following. Updated maps showing locations for piezometers/wells in the North Water Canyon and Joes Mill Pond areas are shown in Figures 5 and 6, respectively. Updated water level measurements for the wells/piezometers through 4 December 2006 are presented in Table 2. Information including collar and ground surface elevation data for piezometers/wells is

presented in Table 3. Cross-sections showing groundwater elevations, saturated alluvial thicknesses, and depths to bedrock before and after subsidence in the Pines 310 and Pines 311 area are presented in Figure 7 and 8. A cross-section showing groundwater elevations measured in August 2006 and November 2006, saturated alluvial thicknesses, and depths to bedrock in the Pines 105 area is presented in Figure 9. Water level hydrographs for all piezometers and wells for 2006 are presented in Appendix A. Water level hydrographs for selected wells equipped with automated monitoring equipment (down-hole pressure transducer/data logger) units are presented in Appendix B. Discharge measurements for springs in the North Water Canyon area are presented in Table 4 and are plotted in Figures 10, 11, and 12. A generalized cross-section illustrating the hydrogeologic sequence from the land surface in the North Water Canyon area to the underlying coal seams of the Blackhawk Formation is presented in Figure 13. Stable and unstable isotopic compositions of groundwater from springs Pines 105, Pines 310 and from groundwater intercepted in the Sufco Mine underground workings in the vicinity of The Pines area are presented in Table 5. Discharge hydrographs for the Main Fork and East Fork of Box Canyon Creek are presented in Figure 14. Slug test information from a test on piezometer NWP-10 deep is presented in Appendix C.

7.0 Overview of Groundwater Systems

For informational purposes, a brief overview of the general nature of groundwater systems in The Pines and surrounding areas is presented here. This information is provided as a general framework in which to evaluate the groundwater systems in the North Water Canyon and Joes Mill Pond areas.

Groundwater systems in the Wasatch Plateau coal district are associated with one of two fundamental types of groundwater flow regime. These two regimes are described by a fairly simple conceptual model that includes "active" and "inactive" groundwater flow regimes (Mayo et. al., 2003). The operation of these two regimes is fundamentally a consequence of the vertical and horizontal heterogeneity and discontinuity rock strata in the region. A discussion of the active- and inactive-zone groundwater regimes in the Pines Tract area is presented below.

Active-Zone Groundwater Systems

Active zone groundwater systems are characterized as having good hydraulic communication with groundwater or surface-water recharge sources and for having active groundwater flow from recharge to discharge areas. Thus, they are dependent on annual recharge events and are affected by short-term climatic variability. Groundwaters discharging from active-zone groundwater systems contain elevated tritium concentrations, which is indicative of

groundwaters that have recharged in the past approximately 50. Carbon-14 contents of active-zone groundwater systems likewise indicated modern recharge.

Inactive-Zone Groundwater Systems

Inactive-zone groundwater systems are characterized by old groundwater (commonly from about 2,000 to 19,000 years) and a general lack of good hydraulic communication with the ground surface or active recharge sources (Mayo et. al., 2003). This condition is the result of the lack of recharge potential to deeper groundwater systems, either vertically or horizontally, because of 1) the abundance of low-permeability rocks in the rock sequence, and 2) the lenticular, discontinuous nature of the interbedded more permeable horizons that limits the extent of potential groundwater movement. Inactive-zone groundwater systems are not influenced by either annual recharge events or by short-term climatic variability. This is evidenced by the lack of seasonal or climatic discharge responses of groundwater inflows into the Sufco Mine. Rather, groundwater inflows encountered in the Sufco Mine typically drain rapidly after first being encountered (Personal communication, Mark Bunnell, 2005). All groundwater inflows into the Sufco Mine have been from inactive-zone systems, as evidenced by the radiocarbon ages of the waters and the lack of tritium in in-mine groundwaters, and the lack of seasonal or climatic response in discharge rates. Groundwater inflows into the Sufco Mine in the vicinity of the study area have had groundwater mean residence times ranging from about 4,000 years to 6,000 years (Table 5).

Inactive-zone groundwaters in the Blackhawk Formation in the study area are not part of a regionally continuous aquifer. Groundwater in the inactive zone occurs primarily in isolated partitions created by the discontinuous nature of bedrock hydrostratigraphic horizons. Because these partitions are isolated both vertically and horizontally by low-permeable strata, lateral migration of groundwater in the deep Blackhawk Formation is limited. Mining operations in the Sufco Mine have encountered groundwater in some portions of the mine, while other nearby locations have been dry. This condition demonstrates the limited groundwater recharge potential and the limited potential for lateral groundwater migration in the lenticular rock bodies of the Blackhawk Formation. It should be noted that appreciable quantities of groundwater have been encountered in the underground mine workings in The Pines area. However, the rate at which water is intercepted and discharged from the mine is largely dependent on the rate at which mining progresses. When mining progress is rapid and new mining areas are being penetrated, appreciable quantities of groundwater enters the mine workings as saturated sandstone paleochannels are intercepted and subsequently drained. When pauses in mining progress occur and new sandstone paleochannels are not intercepted, the amount of groundwater entering the mine decreases markedly (Personal communication, Mike Davis, 2006). This condition demonstrates the hydraulic isolation between the paleochannels (which contain groundwater of ancient origin) and shallow, active recharge sources.

In order to demonstrate that fracturing associated with longwall mining does not interconnect the mine workings with the near-surface environment and induce the downward flow of

overlying modern groundwater into the mine environment, an investigation of unstable isotopic compositions of groundwater draining from a sealed longwall gob area in the Sufco Mine was performed in 1996. Coal mining ceased in this longwall-mined area in 1989, and the outflow from that area has steadily decreased since that time. When sampled in 1996, the outflow from this subsided area had a mean ^{14}C age of 13,000 years and contained no tritium. If groundwaters from shallow, overlying systems (which contain anthropogenic carbon and tritium) were intercepted by subsidence fractures and were flowing downward into the mine, some modern water would be expected in this sample (USFS, 1999). Similarly, tritium and carbon-14 data were collected from two locations in the 14 Left longwall panel underlying The Pines area in late 2000. The absence of tritium in these samples (<0.1 TU) and the mean radiocarbon ages (4,000 to 6,000 years) are indicative of hydraulic isolation of the longwall-mining environment from shallow, active groundwater systems.

8.0 Analysis of Data

Based on the descriptions of groundwater systems presented above, it is readily apparent that spring Pines 105 discharges from a shallow active-zone Castlegate Sandstone groundwater system that is in good hydraulic communication with active groundwater recharge (USFS, 1999). This conclusion is supported by the rapid response of spring discharge rates to seasonal and climatic variability and by the unstable tritium and carbon-14 contents in water discharging from the spring (Table 5). The tritium content measured in Pines 105

groundwater (6.48 TU) indicates that the spring has a major component of recharge that is less than about 50 years old. The carbon-14 content of Pines 105 groundwater (92.55 pmC) indicates the presence anthropogenic carbon-14 and suggests that the water is of modern origin (i.e., less than about 50 years old; USFS, 1999). Isotopic data from spring Pines 310 (Tritium content of 16.4 TU; Carbon-14 content of108.69 pmC) is likewise consistent with discharge from an active-zone groundwater system. Discharge hydrographs for springs Pines 105, Pines 311, and Pines 310 are presented in Figures 10, 11, and 12. It is apparent in Figures 10, 11, and 12 and Table 4 that these springs exhibit seasonal variations in discharge rate. While long-term discharge data are not available for springs Pines 310 and 311, it is apparent in the hydrograph for Pines 105 that the spring clearly also responds to short-term climatic variability. This information supports the conclusion that these springs discharge from active-zone groundwater systems, and are not related to the deep, inactive-zone groundwater systems that are encountered in the underground workings of the Sufco coal mine. The groundwater flow directions in the Castlegate Sandstone groundwater system that supports springs in the North Water and Joes Mill Pond areas, like other Castlegate Sandstone groundwater systems in the Pines Tract area, are structurally/stratigraphically controlled (i.e., groundwater flow is in the down-dip direction within the Castlegate Sandstone toward the northwest). Groundwater discharge locations for springs Pines 105, Pines 310, and Pines 311 are all from the lower south side of North Water Canyon, just upstream of significant surface water tributaries entering North Water Canyon from the South. The similarity of the mode of occurrence of these three springs suggests similar groundwater flow and discharge characteristics for the springs. An approximate delineation

of the potential recharge area for springs in the North Water Canyon and Joes Mill Pond areas is shown on Figure 4. It is apparent on Figure 4 that based on bedrock and topographic dip, the recharge to these springs very likely occurs in the approximate region delineated. Because the Castlegate Sandstone is present everywhere at the surface in this region (i.e., there are no geologic formations overlying the Castlegate Sandstone in this area) recharge likely occurs in the shallow subsurface on the relatively bare, exposed Castlegate Sandstone surface. Because of the presence of low-permeability horizons stratigraphically underlying the Castlegate Sandstone in the stratigraphic sequence, deep groundwater circulation is likely precluded and, consequently, the groundwater flow path is likely entirely within the Castlegate Sandstone from recharge area to the spring discharge location.

The discharge locations for springs Pines 105, Pines 310, and Pines 311 are all situated on the south side of North Water Canyon (Figure 2), which is consistent with the spring discharging from the Castlegate Sandstone at the down-dip end of the groundwater system with recharge areas to the south and southeast. The discharge locations for each of these springs is situated near the intersection of the jointed Castlegate Sandstone unit intersects the bottom of the stream valley (although spring Pines 310 upper discharges at a somewhat higher elevation on the hillside about 50 feet above Pines 310 lower). The precise mechanism controlling the discharge location of these springs is not known. It is likely that the regionally prominent jointing in the Castlegate Sandstone may be a significant controlling factor. Stratigraphic heterogeneity in the Castlegate Sandstone, including the presence of interbedded low-

permeability horizons (i.e., perching layers), may also be important factors in the spring discharge location and mechanism.

The land surface in the vicinity of Pines 105 was subsided in the winter of 2005 – 2006 as mining occurred in the 5 Left Pines East longwall panel in the Sufco Mine (Figure 2). Subsidence-related tension cracks associated with the mining in the 5 Left Pines East panel were observed in the vicinity of Pines 105 when the area was visited in the spring of 2006 after the winter snows had melted and the area became accessible. Subsequently, it was observed that a significant tension crack had occurred on the south side of the North Water fork drainage, the trend of which roughly intersected the Pines 105 discharge location.

It was indicated in the Final Pines Tract Environmental Impact Statement (USFS, 1999) that springs in the Castlegate Sandstone in the Pines Tract (including springs Pines 105, Pines 310, and Pines 311) could potentially be impacted as a result of land subsidence. As noted in the Pines Tract EIS: "Groundwater systems that supply water to these springs could be affected by the dilation of preexisting fractures or tension cracks, which generally occur above longwall panel margins or ends." It seems possible that it was by this mechanism that discharges from Pines 105 and Pines 311 were impacted. Groundwater flow paths through preexisting joints, fractures, or other zones of locally increased permeability to the spring were likely altered locally as a result of dilation or enhancement of existing joints and fractures. Consequently, water levels were likely lowered in the Castlegate Sandstone groundwater system that supported Pines 105, Pines 311, and Pines 310. This condition

likely resulted from increased hydraulic conductivity associated with bedrock fracturing and perhaps also to local increases in the groundwater storage volume in the fracture network. It is unlikely that groundwater in the Castlegate Sandstone in the North Water Canyon or Joes Mill Pond areas migrated into appreciably deeper bedrock horizons. This is due to the tendency of the underlying Blackhawk Formation (and to a lesser degree the Castlegate Sandstone) to impede the vertical migration of fluids as discussed previously.

It is important to note that tension cracks associated with longwall-mining-induced subsidence are near-surface phenomena. There is no evidence to suggest these fractures extend from the mined horizon to the surface (USFS, 1999). The rocks of the Blackhawk Formation effectively impede the downward vertical migration of groundwater (USFS, 1999). Additionally, hydrophyllic clays are present in the Blackhawk Formation that can effectively heal mining-induced fractures when wetted.

It is noteworthy to compare the observed change in the discharge at the North Water Canyon springs with the recent experience of the undermining of the East Fork of Box Canyon with the 3 Left Pines East longwall panel, which is located a short distance west of the North Water Canyon area (Figure 2). After the East Fork was subsided, surface flow ceased in some reaches of the stream channel where the brittle stream substrate was cracked or buckled. The lengths of these dry reaches ranged from a few tens of feet to a few hundred feet. It is significant that discharge measurements performed before, during, and after the period of undermining demonstrated that no appreciable water was lost from the drainage as

a result of the region being subsided (Petersen Hydrologic, LLC, 2004). Rather, surface water in the dry stream reaches was temporarily diverted to the shallow subsurface where it migrated through bedrock fractures until the water intersected competent, low-permeability horizons. The flow then reemerged in the stream where the channel intersected these low-permeability horizons. Similarly, discharges in Castlegate Sandstone springs EFB-12, EFB-13, and EFB-14 ceased subsequent to the undermining. However, areas of increased groundwater discharge were observed short distances below the previous discharge locations of these springs soon after mining in the area had occurred, suggesting that the groundwater discharge locations had changed, but that there was no net loss of water to the drainage from the groundwater system that supported these springs. Discharge measurement data from the East Fork drainage above and below the spring area before and after mining supported this conclusion (Petersen Hydrologic, LLC, 2004). In summary, although local stream discharge rates in the East Fork of Box Canyon were temporarily diminished in isolated locations, and spring discharge locations were moved, there was no apparent net loss of water from the drainage. This result is attributed primarily to the fact that the rock strata underlying The Pines area do not readily support vertical migration of water into underlying strata or the mine environment. Similarly, although the discharge mechanism that previously supported groundwater discharge at the North Water Canyon springs has been changed, it is unlikely that the groundwater has migrated to appreciably deeper horizons or that any appreciable loss of groundwater from the drainage has occurred.

Alluvial Groundwater System in North Water Canyon and the Joes Mill Pond Areas

Through well drilling activities it was determined that appreciable thicknesses of alluvium are present in both North Water Canyon and the Joes Mill Pond canyon bottom areas, with thicknesses generally ranging from about 20 to 40 feet (Petersen Hydrologic, LLC, 2006).

The composition of the alluvial sediments in the North Water Canyon area is dominated by clean, fine-grained tan to gray sands with lesser amounts of interbedded dark brown to black deccomposed organic silt (muck). The alluvial sediments in the canyon bottoms sit directly on a Castlegate Sandstone erosional surface. It was apparent during drilling activities that the contact between the alluvial sands and the underlying Castlegate Sandstone bedrock was in some locations gradational. This condition was attributed to the apparent dissolution of the intragranular calcium carbonate cement of Castlegate Sandstone bedrock by interaction with migrating groundwaters undersaturated with respect to calcium carbonate, resulting in in-tact decemented Castlegate Sandstone at the interface between alluvium and bedrock. In most instances, the thickness of this transitional zone was about 3 to 6 feet. It is likely that the water-bearing and water-transmitting properties of the decemented Castlegate Sandstone bedrock would be similar to those of the alluvial sands derived from Castlegate Sandstone.

The abundance of interbedded organic material in the alluvial sediments increases in the alluvium near existing spring discharge locations. This occurrence is consistent with conditions observed presently in the canyon, where vegetation and dark, organic-rich soils are most abundant near spring locations. The fine-grained sand that comprises the bulk of the

alluvial sediments in the canyon is likely derived from the erosion and weathering of the Castlegate Sandstone bedrock. Consequently, a wedge of relative organic-free fine grained sand was common adjacent to the north canyon slope while more organic-rich sediments were common in the southern half of the canyon bottom (i.e., increased organic content associated with spring discharge locations along the southern walls of the canyon). Conditions in the Joes Mill Pond area appear similar.

A slug test in the alluvial groundwater system was performed in the Pines 310 area (piezometer NWP-10 deep). The tested well was screened in a fine-grained sand deposit about 25 feet from the spring location. The results of the slug test indicate relatively high values of hydraulic conductivity of approximately 2×10^{-3} cm/sec. The hydraulic conductivity of the decomposed organic sediment widely present in the area was not slug tested. However, based on visual observations of the sediment core samples, it is likely several orders of magnitude lower in hydraulic conductivity than is the clean, fine-grained sand.

Water level data from the piezometers/wells indicate that there is an appreciable thickness of saturated alluvium in both the North Water Canyon and the Joes Mill Pond areas. The alluvial sediments in the canyon bottoms near the spring areas are generally continuously saturated from the bedrock interface to within several feet of the ground surface (Figures 7, 8, and 9). The presence of an appreciable thickness of saturated alluvial sediments in the vicinity of the spring discharge areas is consistent with the conclusion that groundwater

discharge from springs Pines 105 and Pines 311 continues to contribute groundwater to the alluvial groundwater system in North Water Canyon, although the discharge likely now emanates from lower elevations along the canyon margin (below the ground surface).

As anticipated, groundwater flow directions in the alluvial groundwater system are generally down-canyon, with some local variability near spring discharge locations. Water levels in all monitoring wells showed overall declines from August of 2006 (when the wells were installed) to November of 2006. Some of the observed decline in alluvial water levels is likely attributable to a natural seasonal decline in the volume of groundwater in storage in the alluvial groundwater system. Such late season water level responses would be anticipated and are characteristic of many alluvial groundwater systems. However, other declines in alluvial groundwater levels are likely in response to the undermining and subsidence of the area. Most notable are the observed declines in water levels in piezometers that occurred in wells near spring Pines 311 that coincided with the subsidence of the area and the cessation of discharge from the spring (Figure 8; Appendix A). A similar, though more muted depression of groundwater levels near spring Pines 310 may also have occurred as discharge from that spring diminished (Figure 8; Appendix A). Water level data from alluvial wells in the Pines 105 area before the region was subsided are not available (the wells were not constructed until after the area was subsided and discharge from Pines 105 had ceased). However, a local depression in the water levels in wells near Pines 105 is readily apparent (Figure 9). The depression in water levels near these springs may indicate that water is being diverted from the alluvial groundwater system in these locations. However, it is noteworthy that the water

levels in wells immediately downstream of these depressions are higher than those immediately up-canyon near the springs Pines 311 and Pines 105 (Figures 8 and 9; Appendix A). This observed condition may suggest that either 1) the water being diverted from the alluvium near these springs is focused towards a point sink rather than a linear (cross-canyon) feature, or that 2) there may be another source of groundwater inflow to the alluvial groundwater system immediately below the spring discharge location.

The fact that the observed depressions in the water table surface in the North Water Canyon alluvial groundwater system are approximately coincident with the discharge locations of springs Pines 105 and Pines 311 (and possibly also Pines 310) may hint that the condition predicted in the Pines Tract EIS (that natural fracture or joint apertures in the Castlegate Sandstone that originally focused groundwater flow toward these discharge locations were dilated as a result of subsidence) has occurred. However, there is not currently sufficient information to substantiate this possibility.

Likely Fate of Groundwater previously discharging from the North Water Canyon area

Historically, water from springs in the North Water Canyon area flowed from the spring discharge area into the North Water Canyon drainage. During wet years, alluvial groundwater and/or surface flow originating higher in the drainage, which was likely sourced from discharge at springs Pines 310 and Pines 311, was also occasionally present. Surface discharge in North Water Canyon below Pines 105 during the summer and fall months (during both wet and dry years) typically persisted for a distance of about 1,200 feet

downstream before the discharge infiltrated into the thick, sandy alluvial sediments underlying the stream channel. Thus, before being subsided, Pines 105 discharge water was flowing down the North Water drainage with a trajectory toward the East Fork of Box Canyon Creek. It is assumed that the groundwater from Pines 105 continued to migrate through the sandy alluvium or shallow, weathered sandstone bedrock underlying the North Water Canyon drainage the remaining approximately 1,000 feet until the base of the alluvium or weathered bedrock through which the water was migrating intersects the competent bedrock substrate in the East Fork drainage (there is a low-permeability clay layer in the substrate of the East Fork of Box Canyon Creek about 200 feet below the confluence with North Water Canyon near monitoring point EFB-7). It is noteworthy that the trajectory of this probable groundwater flow path in lower North Water Canyon is roughly coincident with the regional stratigraphic dip of the bedrock. In other words, the groundwater would tend to migrate in that approximate direction on a planar bedrock surface even if no topographic constraints such as confining canyon walls were present.

An analysis of discharge data from the East Fork of Box Canyon drainage strongly suggests that groundwater previously discharging from impacted North Water Canyon springs remains in the East Fork drainage. It is apparent in Figure 14 that discharge at both Pines 408 (East Fork of Box Canyon Creek at the confluence with the Main Fork) and Pines 407 (Main Fork of Box Canyon Creek at the confluence with the East Fork) is highly influenced by climatic and seasonal recharge variability. Since mid-2003, discharges at Pines 407 and Pines 408 have followed very similar discharge trends (although discharge at Pines 407 is always more

than at Pines 408). This relationship demonstrates that the factors controlling discharge variability at these two monitoring points are similar (likely local climatic factors). Of significance, it is apparent that the discharge trends at both monitoring sites remain similar after December 2005 (when discharge to the surface from Pines 105 ceased) and throughout the 2006. If the total combined discharge from the North Water Springs (on the order of about 10 gpm average) were diverted away from the East Fork drainage as measured at Pines 408, the impact observed at Pines 408 would be significant and quantifiable (i.e., the potentially missing 10 gpm from the North Water Canyon springs makes up about half of the approximately 20 gpm baseflow at Pines 408). The fact that both Pines 407 and Pines 408 continue to show similar discharge variability during late 2005 and 2006, and that fact that the discharge at Pines 408 during late 2005 and 2006 appears to be consistent with typical baseflow for the site accounting for climatic conditions (i.e., 2006 was not as wet as 2005, but was wetter than 2003 and early 2004) suggests that quantifiable losses of water from the East Fork drainage has not occurred.

9.0 Conclusions

- Groundwater recharge, groundwater flow, and groundwater discharge for groundwater systems in the North Water Canyon and Joes Mill Pond areas all likely occurs at relatively shallow depths and entirely within the Castlegate Sandstone. Groundwater

recharge locations are likely in up-topographic and up-stratigraphic-dip areas within less than about 1.5 miles to the south and southeast of the spring discharge locations.

- The alluvial sediments in both the North Water Canyon and Joes Mill Pond areas consist primarily of fine grained sand derived from erosion and weathering of the Castlegate Sandstone. Interbedded lenses of decomposed organic material are present in the alluvial sediments in the alluvial deposits, although the abundance of the organic sediments is considerably less than the fine-grained sand.

- A substantial alluvial groundwater system is present in the North Water Canyon area in the vicinity of springs Pines 105, Pines 310 and Pines 311. Saturated alluvial thickness in the late fall season after subsidence of the region are generally from 10 to 20 feet in the Pines 310 and Pines 311 areas, while a saturated thickness of alluvium exceeding 10 feet was present in most locations in the Pines 105 area during the late fall season after the region had been undermined.

- The results of a single slug test performed in the Pines 310 area (piezometer NWP-10 deep) indicate a hydraulic conductivity for the fine grained sand material of approximately 2×10^{-3} cm/sec. The hydraulic conductivity of the decomposed organic sediment widely present in the area is likely several orders of magnitude lower, as estimated based on observations of sediment core samples.

- An appreciable depression in the water table surface was identified in the alluvial groundwater system adjacent to spring Pines 311 shortly after the region had been subsided. A smaller, muted depression was also evident adjacent to spring Pines 310 after the region had been undermined. Prior to undermining, depressions in the alluvial water table in these areas were minor or nonexistent. An appreciable depression in the alluvial water table surface was also identified near spring Pines 105. The appearance of these depressions after the undermining and subsidence of the area suggests that groundwater may be being diverted from the alluvium at these locations.

- Although groundwater discharge to the surface from springs Pines 105, Pines 311, Joes Mill Pond spring, and the lower spring at Pines 310 ceased in 2006 subsequent to the undermining of the area, the Castlegate Sandstone groundwater system that supported surface discharge at these springs likely continues to contribute groundwater to the East Fork of Box Canyon Creek drainage. Discharge from the groundwater system likely occurs at a lower elevation than that which occurred previously. This conclusion is not inconsistent with the observed conditions encountered with the undermining of the East Fork of Box Canyon Creek by the 3LPE panel in 2003-2004.

- The lack of any quantifiable diminution of stream flow measured in the East Fork of Box Canyon Creek subsequent to the undermining of North Water Canyon and Joes

Mill Pond area springs provides strong evidence that no loss of water from the drainage basin has occurred. The most likely discharge location for groundwater previously discharging at these springs is to the East Fork drainage (as previously). Consequently, there is likely no net loss of groundwater from the East Fork drainage as a result of the alteration of the discharge mechanisms of these springs.

- Because of the hydrogeologic characteristics of the rock strata intervening between the shallow Castlegate Sandstone and the underlying Sufco Mine workings, the possibility that groundwater previously discharging from springs in the North Water Canyon and Joes Mill Pond areas now reports to the Sufco underground mine workings is considered extremely remote. There is no evidence collected to date that would suggest that shallow groundwater could be being diverted into the mine.

10.0 Proposed Mitigation

Sufco has evaluated the data obtained from the piezometers installed in August 2006 in the North Water Canyon area including Pines 310, Pines 311 and Pines 105 and in the Joes Mill Pond area and has formulated a plan for potential mitigation for returning flow to the affected spring areas. Implementation and success of this plan is contingent upon the drilling and installation of additional piezometers in the North Water Canyon and Joes Mill Pond areas. Sufco also proposes to conduct a pilot scale test that includes the injection of a liquid

bentonite polymer into the alluvium down-gradient of North Water Spring (Pines 105) at a selected location to determine the effectiveness of forming intra-alluvial grout curtains. A description of the proposed mitigation plans is provided in the following paragraphs.

Installation and Need for Additional Piezometers

As described in previous sections of this report, groundwater is present in the alluvium from at least NWP-3 down-gradient to NWP-30. Groundwater is also likely present in one or more of the side tributaries to the main stem of the North Water Canyon drainage. Sufco proposes to drill and complete three to four additional piezometers in this side drainage up-gradient of NWP-8 to determine the depth to water, depth to bedrock, and the groundwater hydraulic gradient. Additionally, Sufco proposes to drill a similar number of piezometers in each the tributaries adjacent to and south of Pines 311 and Pines 105 springs to determine if groundwater flows though the alluvium within these tributary canyons to the North Water Canyon alluvium (Figure 15). Sufco proposes to drill and install these additional piezometers in the spring of 2007 when climatic and ground conditions allow.

Sufco anticipates that installation of the additional piezometers in the side tributaries will confirm that groundwater is flowing through the alluvium of the side drainages and contributing to the groundwater found in the main stem of the North Water Canyon down-gradient of Pines 310. If this assumption is confirmed, Sufco proposes to install a groundwater intercept and piping system in the alluvium of the tributaries to capture a portion of the flow and transport it to the spring discharge areas of Pines 310, Pines 311, and Pines

105. This intercept system would consist first of an appropriate length of perforated pipe encased in a gravel pack on the up-gradient end of the collection system and buried below the frost line. The perforated pipe would be located up-gradient of the spring locations at an appropriate distance and elevation to generate sufficient head to produce a discharge at the spring locations sufficient to replace the flow that has been presently redirected into the shallow alluvium. Solid pipe will be connected to the perforated pipe and will run from the collection area to the discharge location. The pipe material, design of the discharge structure, and depth of burial will be sufficient to withstand the effects of climate change and impacts from wildlife and livestock grazing. If necessary, a valve may be connected to the groundwater collection and discharge system to regulate flows. Figure 15 illustrates the potential locations for the groundwater and discharge systems in the North Water Canyon area. Figure 16 shows the potential locations for the groundwater and discharge systems in the Joes Mill Pond area.

The installation of the piezometers in the spring of 2007 may indicate the construction of a groundwater collection system is feasible in only one or two of the tributaries to the North Water drainage. For example, if groundwater is found in sufficient quantities only in the tributaries adjacent to springs Pines 310 and/or Pines 311, groundwater collection systems would be constructed in these tributaries. Additional piping will then be added to the system to carry water down-gradient to the Pines 105 spring area. This will require the excavation and backfilling of a trench in the alluvium from the Pines 310 or 311 spring areas down-gradient to the Pines 105 spring area. Sufco believes this task could be performed with

minimal disturbance using a rubber tired backhoe and employing approved reclamation methods.

Assuming the proposed groundwater collection and discharge system is successful, Sufco will work with the Forest Service to repair the surface-water collection sump at Pines 105 that is used to pump water to the watering trough located on the north canyon rim. This work would be completed before the 2008 grazing period.

Sufco proposes to drill and install three to four additional piezometers up-gradient of Joes Mill Pond to determine whether groundwater is present in the alluvium upstream of the pond in sufficient quantities to install a similar collection system as proposed for the North Water area. If water is found in the alluvium in sufficient quantities, the collection system will be installed in a manner similar to the process described in the preceding paragraphs.

VLF Survey

Sufco proposes to conduct a VLF (Very Low Frequency) survey of the North Water area in an effort to determine the location, if possible, of the subsidence cracks in the Castlegate Sandstone underlying the alluvium in the canyon floor. It is assumed that fractures with apertures large enough to contain water can be located using this type of resistivity survey. Locating the cracks will aid in the interpretation of the data collected from the currently installed piezometers and other potential mitigation efforts. Sufco proposes to perform this survey in the spring of 2007. This type of survey does not result in surface disturbances.

Essentially, the survey process includes walking the area of concern following a set grid pattern while holding a radio receiver and data collection instrument.

The survey and data collected during this survey will be conducted and analyzed by a consultant qualified to perform this task. It is anticipated that a map of subsurface subsidence cracks in the Castlegate Sandstone can be created and compared to the existing map that illustrates the location of surface cracks located on the North Water Canyon rims.

Intra-alluvial Grout Curtain(s)

Sufco is exploring the potential for constructing grout curtains within the alluvium at selected locations within North Water Canyon. Sufco has contacted a hydrogeologic consultant that has experience using AquaBlok®, a liquid bentonite polymer, to reduce loss of water in unlined ditches and canals. The consultant is currently researching the feasibility of injecting this liquid into the permeable alluvial sands that line the bottom of North Water Canyon. If technically feasible, Sufco will drill several closely spaced injection holes in a line perpendicular to the axis of the canyon gradient and inject the AquaBlok® liquid from the underlying bedrock surface up to within a few feet of the ground surface. The number and spacing of the holes will be dependent upon the distance which the AquaBlok® can reasonably be expected to infiltrate the pore spaces of the alluvium. The injection holes will be located to create a curtain of the polymer that extends through the width of the alluvium on the canyon floor. It is anticipated that injecting the liquid will result in overlapping columns or cones of low-permeability sand and AquaBlok®. These overlapping columns or

cones will impede the flow of groundwater through the alluvium at the location of the injected material, thus creating a "dam" within the alluvium. This will result in restoring of the groundwater surface to within a few feet of ground surface at, and for a distance upstream, of the "dams".

The maximum depth of the injection holes is expected to be less than 35 feet. Sufco currently anticipates the holes can be drilled using the same or similar drill rig that was used to install the North Water and Joes Mill Pond piezometers in August 2006. Very little disturbance occurred to the vegetation and soils by using a small, rubber-tire mounted drill rig. There may be a need for the use of water storage tanks (Frac Tanks) and water lines from the tanks to the injection hole locations. The tanks could be located on the north canyon rim and the water lines laid on the surface from the tanks to the holes.

To determine the feasibility and success of injecting AquaBlok® into the alluvium and producing the "dams" or grout curtains, Sufco proposes to conduct a pilot field study. The study will consist of drilling an appropriate number of holes in the canyon alluvium at a point downstream of Pines 105 and injecting the polymer to create the grout curtain. The proposed site is located approximately 100 feet northwest of NWP-29 in an area where the canyon floor width appears to be minimal. Several holes would be drilled adjacent to the injection locations to observe the development of the grout curtain. Additionally, three to four temporary piezometers may be established up- and down-gradient of the curtain to monitor effectiveness of the grout curtain. At the conclusion of the study, the results will be

evaluated and the potential for installing additional curtains will be investigated. A more complete proposal for the pilot study will be submitted to the Division for consideration of implementation after the AquaBlok® consultant submits more feasibility data to Sufco. It is anticipated that information will be available by mid-February 2007.

The purpose of the grout curtains may be two-fold, depending upon the results of the VLF survey and field study. If using AquaBlok® is feasible to create the "dams" or grout curtains and the subsidence cracks underlying the alluvium can be accurately located with the VLF survey, the "dams" could be located directly above or within close proximity of the cracks. Additionally, it may also be feasible to inject the AquaBlok® directly into a crack, thus impeding the flow of groundwater into the fracture if, indeed, water is flowing into the fracture.

Mitigation Summary and Timing

The success of several portions of this mitigation proposal are predicted on the results of installing additional piezometers, evaluation of the feasibility of injecting AquaBlok®, a successful field test of injecting AquaBlok®, and conducting a VLF survey. Therefore, it seems reasonable to present a proposed sequence of events and process to be followed in this mitigation plan. Below is a proposed schedule of events followed by assumptions and justifications for moving forward with each aspect of the mitigation.

1. February 28, 2007 – Submit detailed proposal to Division indicating if injection of AquaBlok® in the alluvium of the North Water Canyon is feasible and how it will be accomplished during the field study.

2. Spring/Summer 2007 – Obtain appropriate permits and permissions and install additional piezometers in the North Water and Joes Mill Pond areas. The date of initiating work will be dependant upon climatic conditions, soil conditions, snow cover, and other environmental factors.

3. Spring 2007 – Conduct the VLF survey.

4. June – July 2007 - Evaluate data collected from new piezometers and VLF survey.

5. End of July 2007 – Submit detailed proposal for construction of groundwater intercept system and proposed grout curtain field study.

6. August – September 2007 – Install groundwater intercept system and grout curtains.

7. January 2008 – Submit report detailing installation of systems and results.

Assumptions and Justifications:

1. It is assumed that AquaBlok® can be used to create the "dams" or grout curtains. If this product is not available or will not work, other potential methods can be discussed with the Division and Forest Service. The attractiveness of using this product is that it can be injected with minimal disturbance and costs. Construction of other types of grout curtains will be much more expensive and may require a great deal of disturbance including road building and excavation of very wide and deep trenches.

2. Drilling the additional piezometers will determine the feasibility of constructing the groundwater intercept system. Sufco assumes the water is present in the alluvium based on the known general hydrogeology of the Pines Tract area and field observations of the spring areas. If water is not found in

the alluvium of any the tributaries, other methods of mitigation will be discussed with the Division and Forest.

3. The VLF survey will be conducted independent of the results of drilling and construction of the additional piezometers.

4. After construction of the piezometers, data will be collected for several weeks so that an evaluation may be made of the natural groundwater conditions in these tributaries can be made. The results of the VLF survey will be evaluated for future use in this mitigation plan, i.e. can the data be used to help locate grout curtains.

5. Assuming water is found in one or more of the tributaries at locations that would allow for the construction and operation of a groundwater collection system, a detailed construction plan will be created and submitted to the Division. The plan will include maps, cross-sections, and a description of the construction and reclamation activities.

6. The groundwater collection systems will be installed after permission is received to proceed. Sufco would like to complete this portion of the plan prior to October 2007. If feasible, the grout curtains could be installed at the same time as the installation of the groundwater intercept system to reduce the time period in which construction activities are taking place. It is anticipated the effectiveness of the injection of the AquaBlok® can be determined within one or two weeks of the completion of the field study. Therefore, the construction of additional grout curtains could take place while the equipment is still in the field.

7. The collection of data after the installation of the groundwater intercept system and grout curtains through the later part of 2007 will allow Sufco to determine the success of the projects. Therefore, it seems reasonable to submit a report detailing the completion and success or failure of the project(s) in the first month of January 2008. Additional evaluations of the project(s), including reclamation success, will be made in 2008. Appropriate follow-up reports will be submitted to the Division regarding these findings.

11.0 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.

Mayo, A.L., Morris, T.H., Peltier, S., Petersen, E.C., Payne, K., Holman, L.S., Tingey, D., Fogel, T., Black, B.J., Gibbs, T.D., 2003, Active and inactive groundwater flow systems: Evidence from a stratified, mountainous terrain, GSA Bulletin v. 115; no. 12; p. 1456-1472.

National Climatic Data Center, 2007, On-line climatic data, http://www.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgrg3.html

Petersen Hydrologic, LLC, 2003, Probable hydrologic consequences of coal mining of the 3 Left Panel Modification Area at the Sufco Mine, unpublished consulting report prepared for Canyon Fuel Company, LLC, Salina, Utah.

Petersen Hydrologic, LLC, 2004, Report of hydrologic monitoring of the East Fork of Box Canyon Creek, 2003-2004, unpublished consulting report prepared for Canyon Fuel Company, LLC, Salina, Utah.

Petersen Hydrologic, LLC, 2005, Report of hydrologic monitoring of the East Fork of Box Canyon Creek, 2005, unpublished consulting report prepared for Canyon Fuel Company, LLC, Salina, Utah.

Petersen Hydrologic, LLC, 2006, Results of drilling and piezometer/well installation in the area of Pines 105, 310, 311 springs and Joes Mill Pond spring area, Canyon Fuel Company, LLC, Sufco Mine C/041/002, unpublished consulting report prepared for Canyon Fuel Company, LLC, Salina, Utah.

USFS, 1999, Pines Tract Project, Final Environmental Impact Statement, Manti-La Sal National Forest.

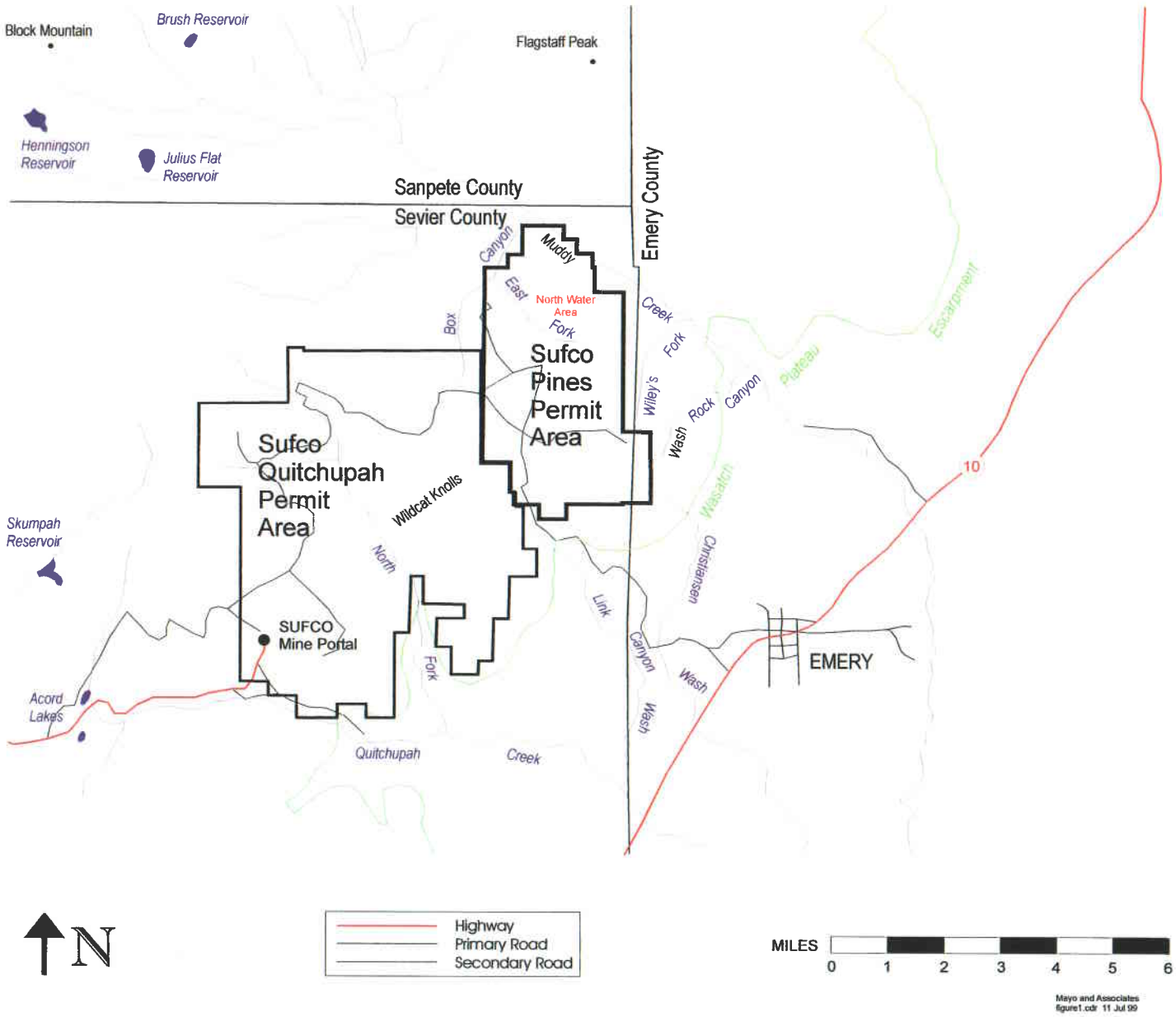

Figure 1 Location of the Sufco Mine area.

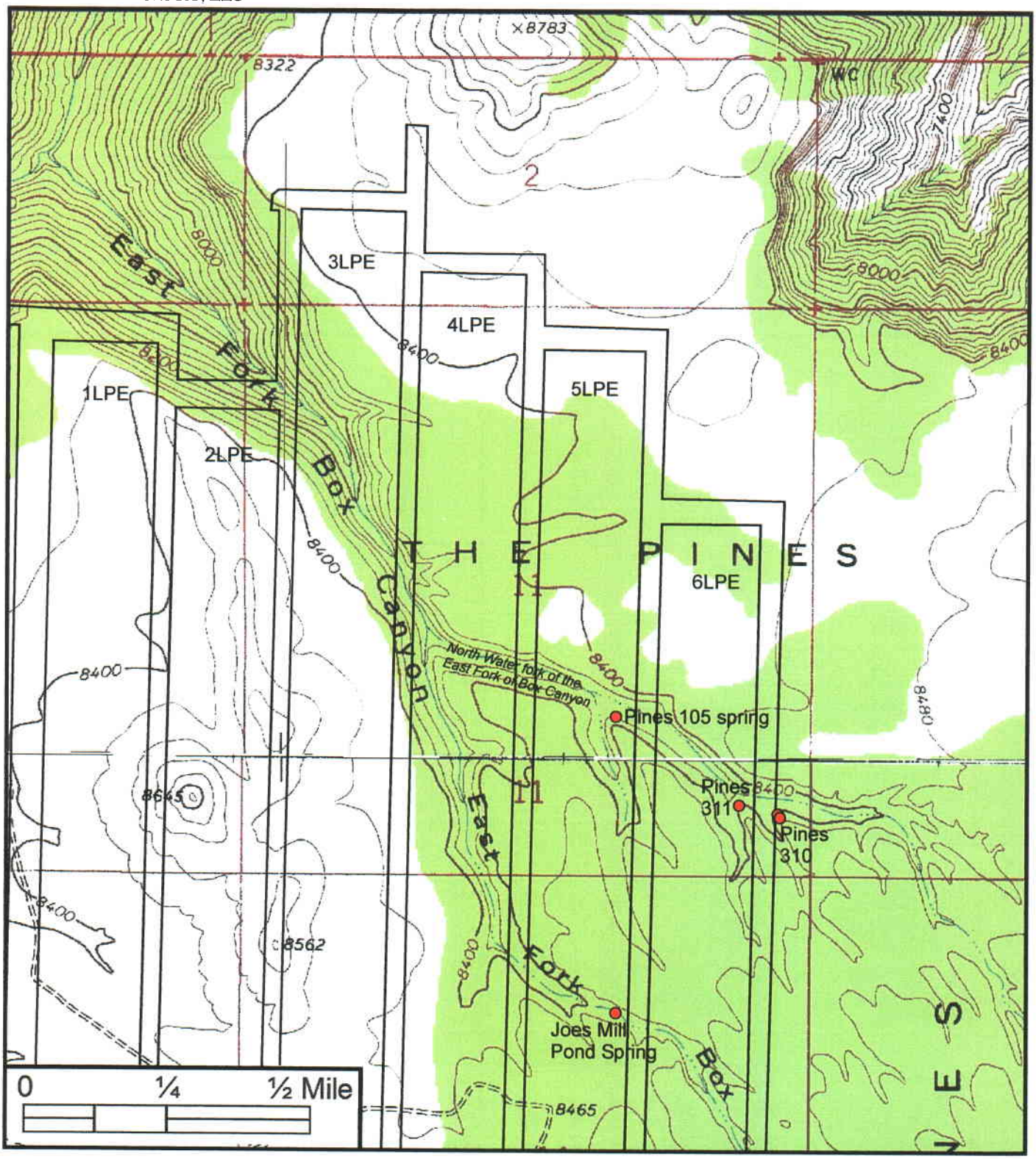

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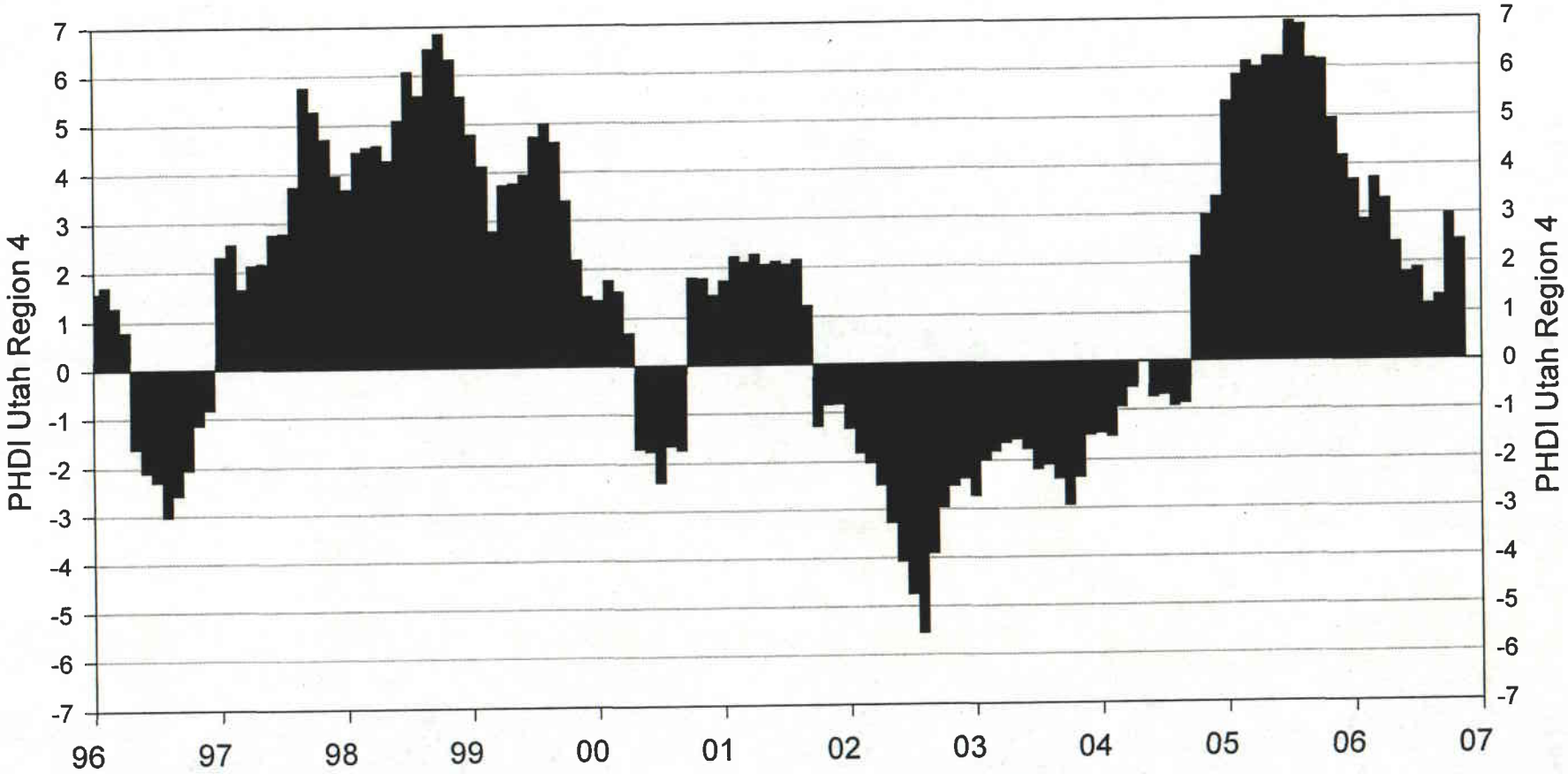
Figure 2 Location of the North Water and Joes Mill Pond areas and Sufco Mine longwall panels.



-1 to -2 Mild Drought
-2 to -3 Moderate Drought
-3 to -4 Severe Drought
-4 to -5 Extreme Drought

1 to 2 Mild Wet Spell
2 to 3 Moderate Wet Spell
3 to 4 Severe Wet Spell
4 to 5 Extreme Wet Spell

Figure 3 Plot of the Palmer Hydrologic Drought Index (PHDI) for Utah Region 4.

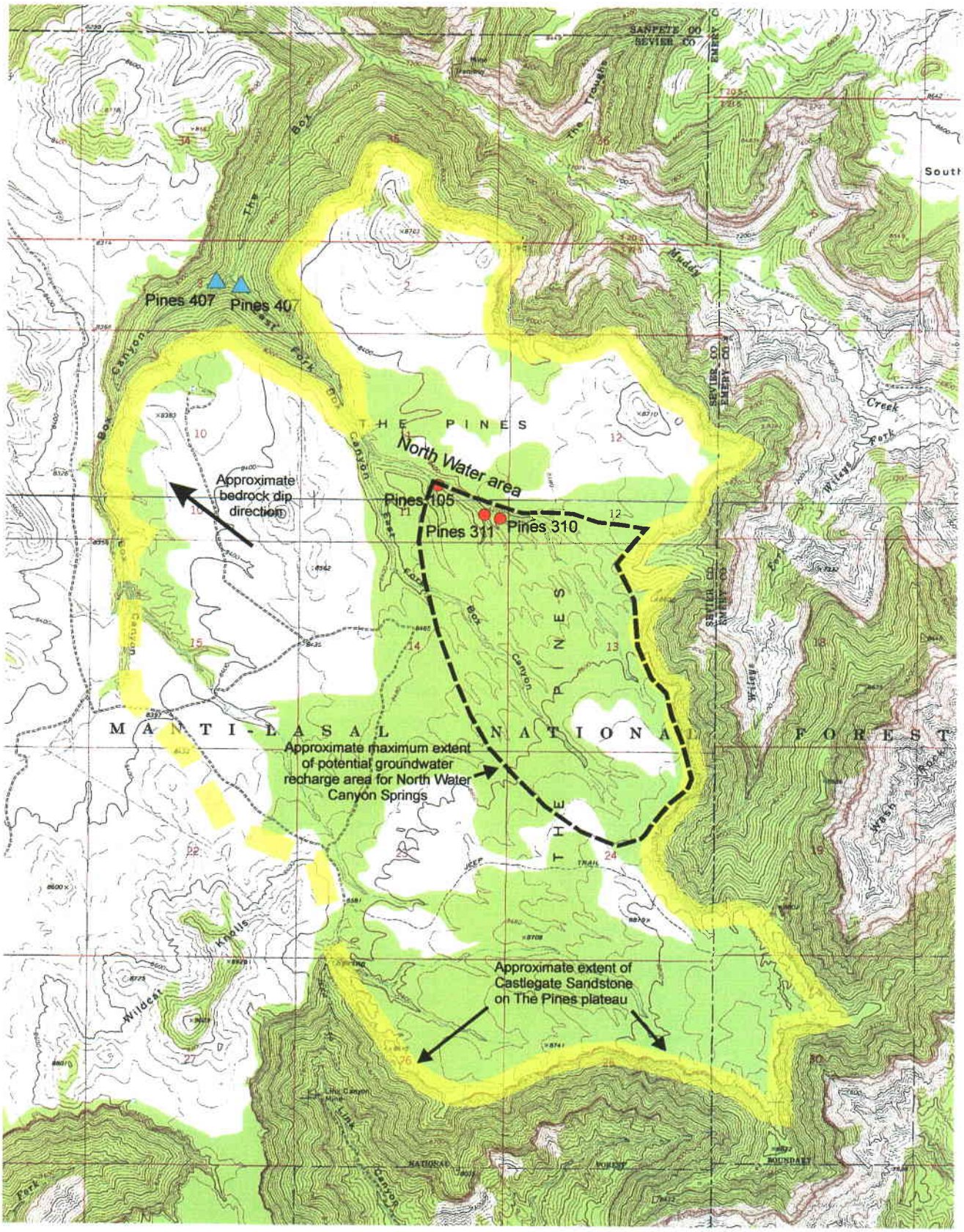
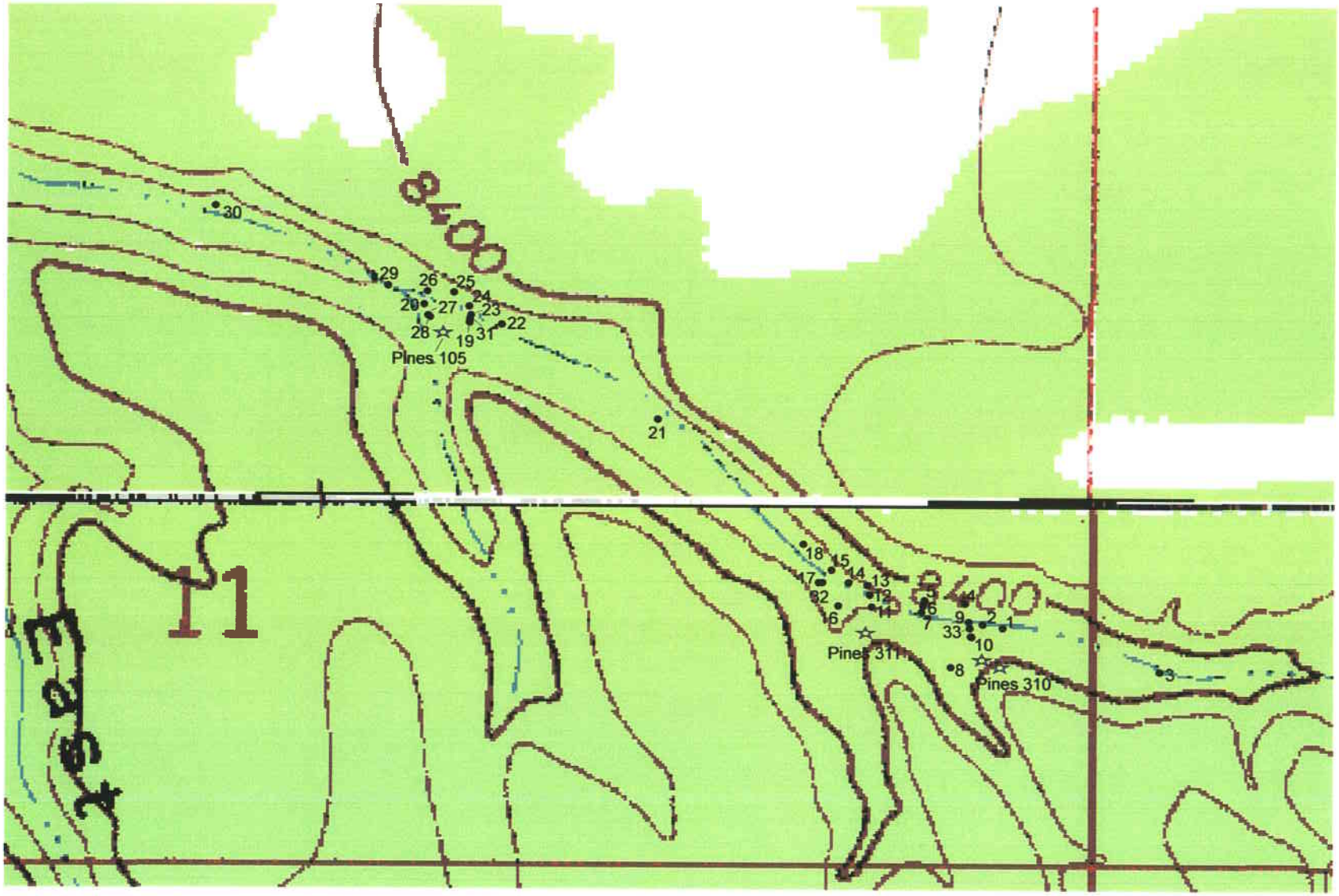


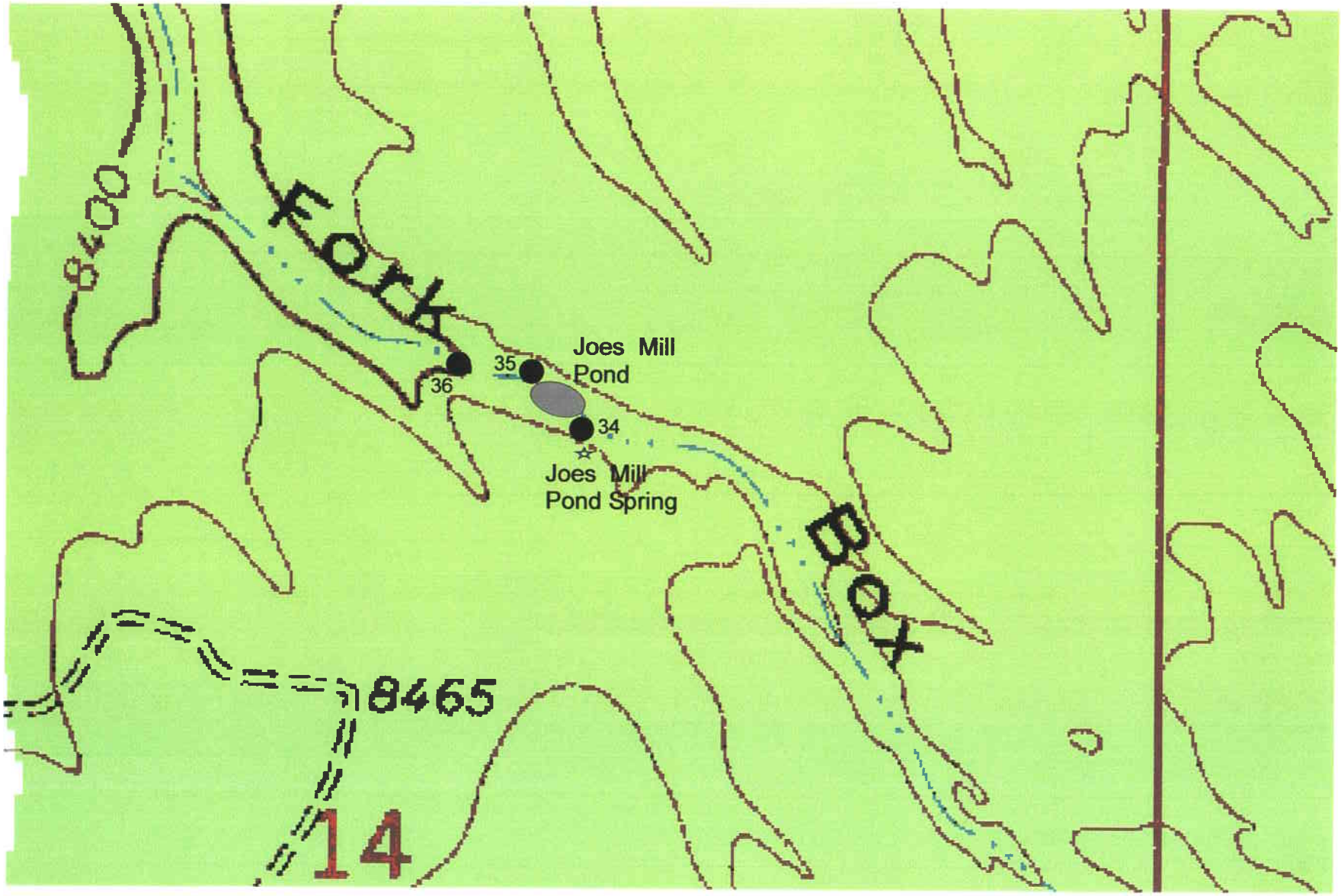
Figure 4 Location of Castlegate Sandstone plateau and potential recharge area for North Water Canyon area springs.



☆ Spring location

• Piezometer/well location

Figure 5 Piezometer/well locations in the Pines 105 and Pines 310/311 areas.



☆ Spring location

• Piezometer/well location

Figure 6 Piezometer/well locations in the Joes Mill Pond area.

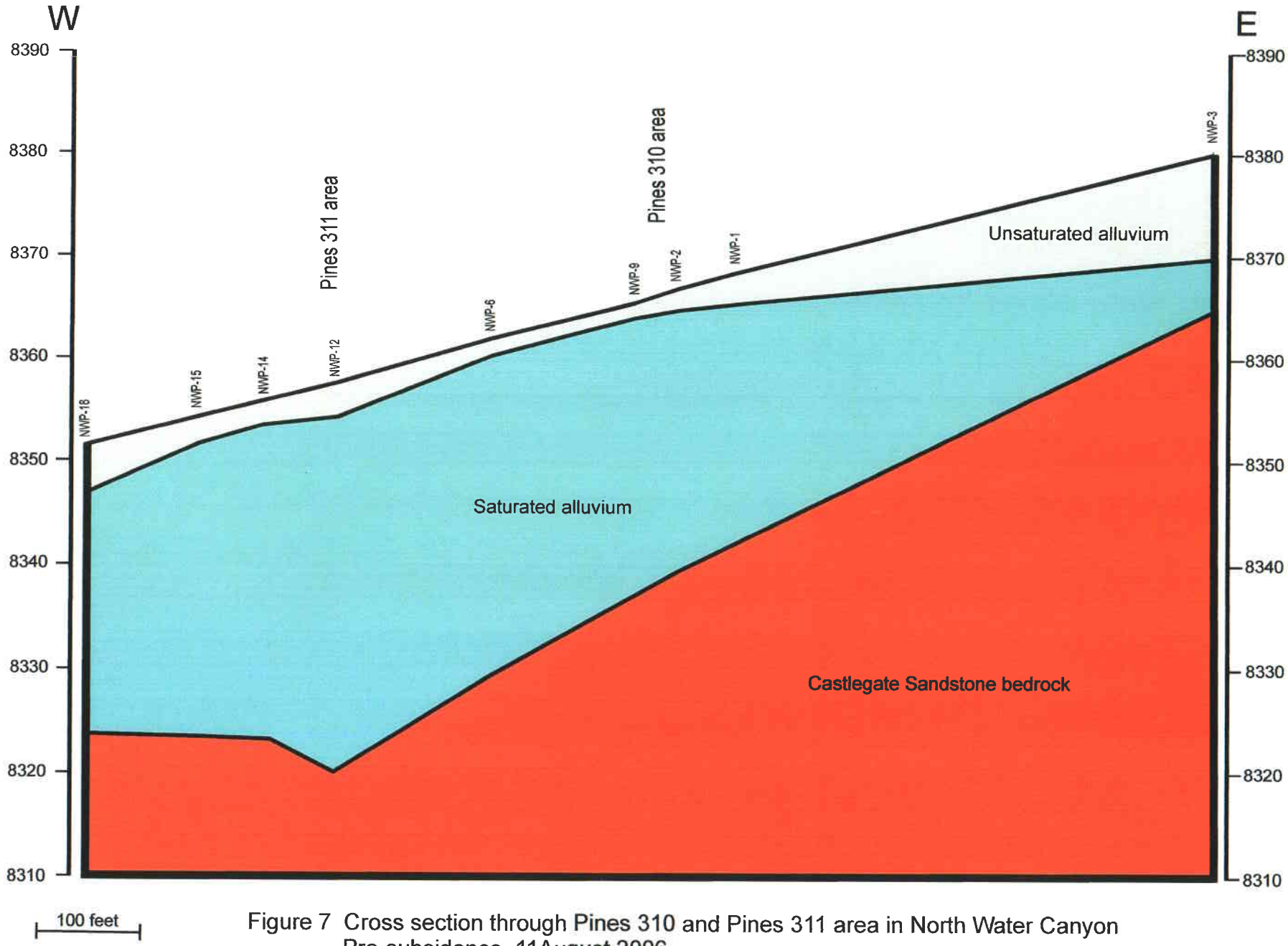


Figure 7 Cross section through Pines 310 and Pines 311 area in North Water Canyon Pre-subsidence, 11August 2006.

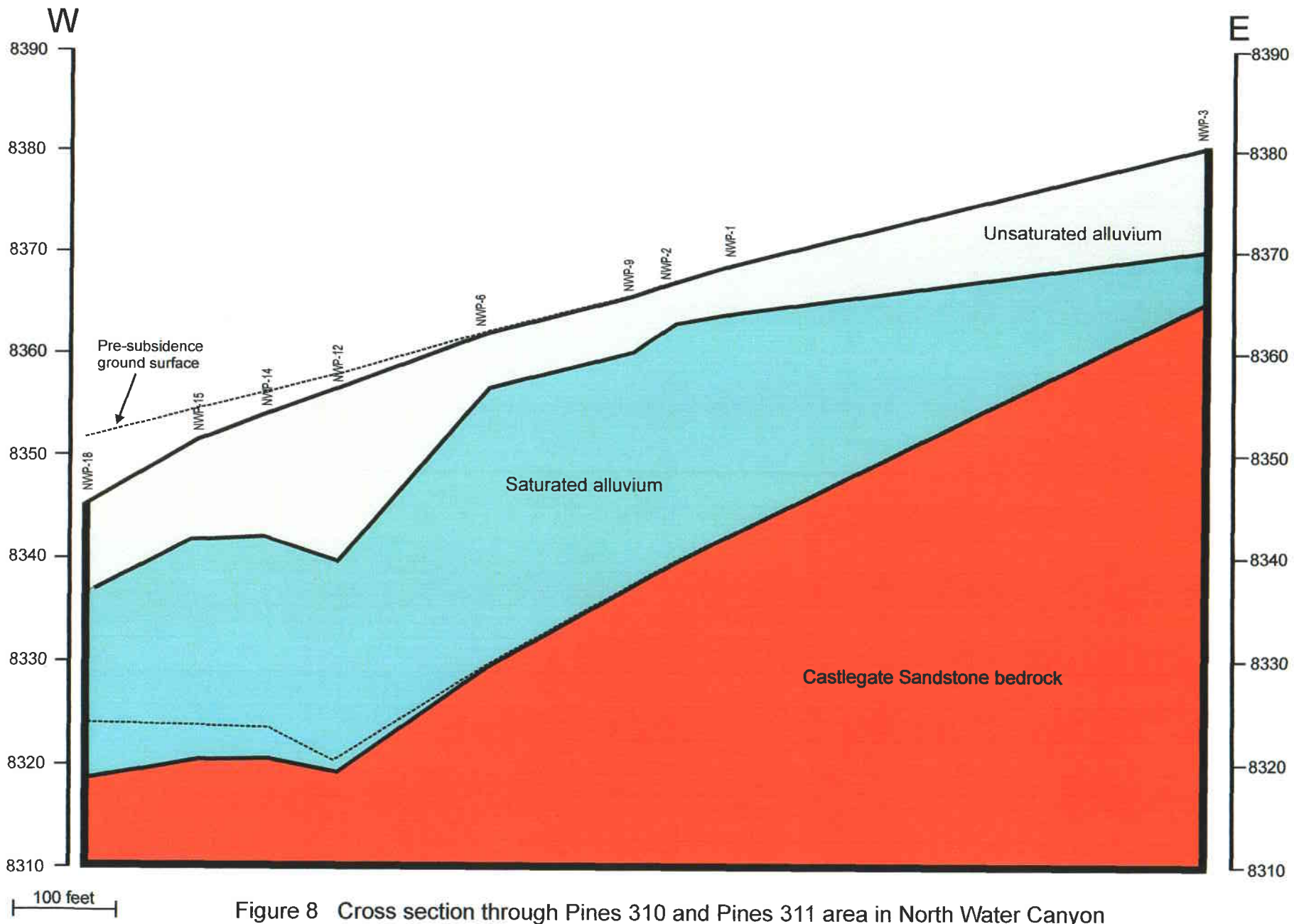


Figure 8 Cross section through Pines 310 and Pines 311 area in North Water Canyon Post-subsicence, 20 November 2006.

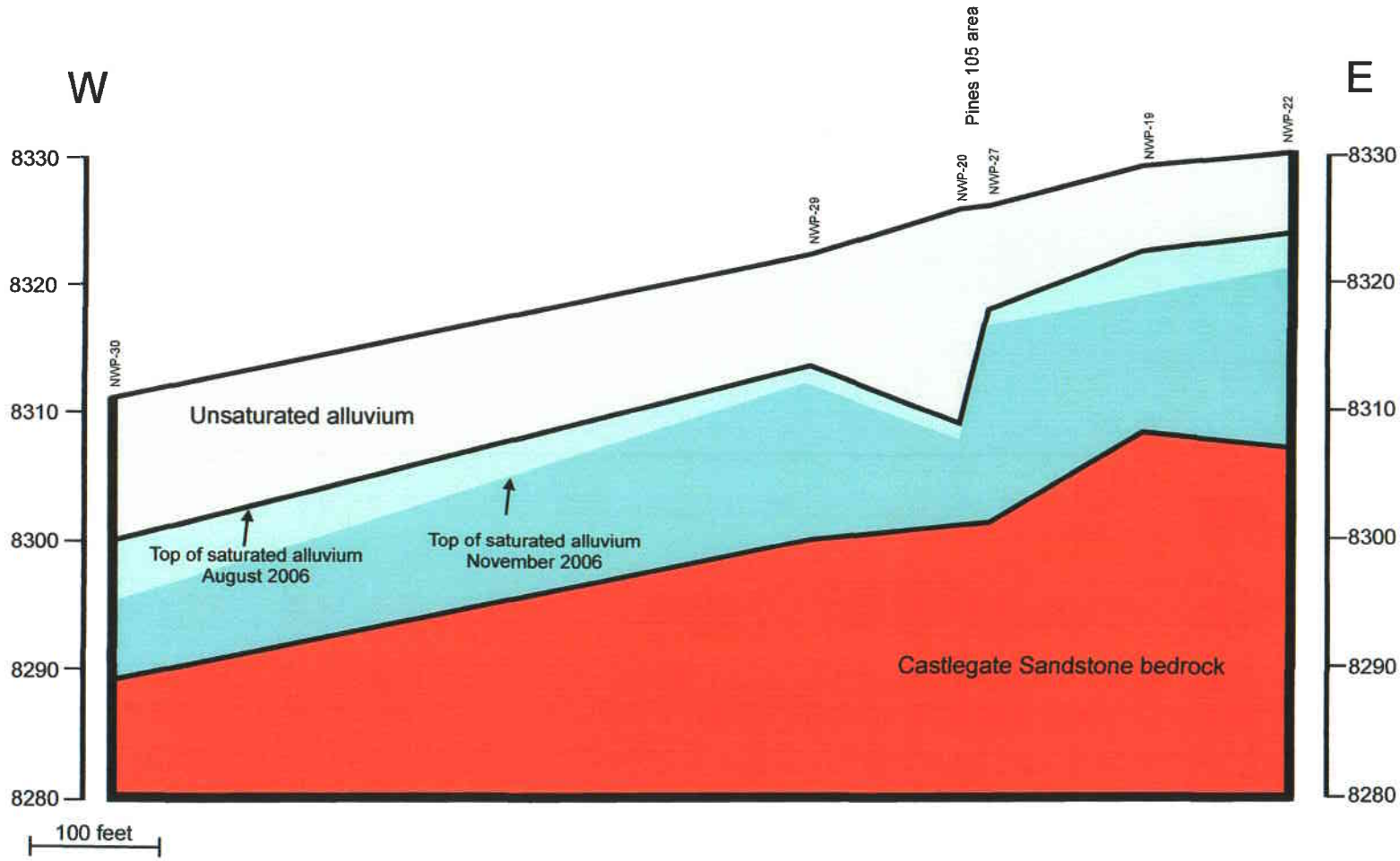


Figure 9 Cross section through Pines 105 area in North Water Canyon
16 August 2006, 20 November 2006.

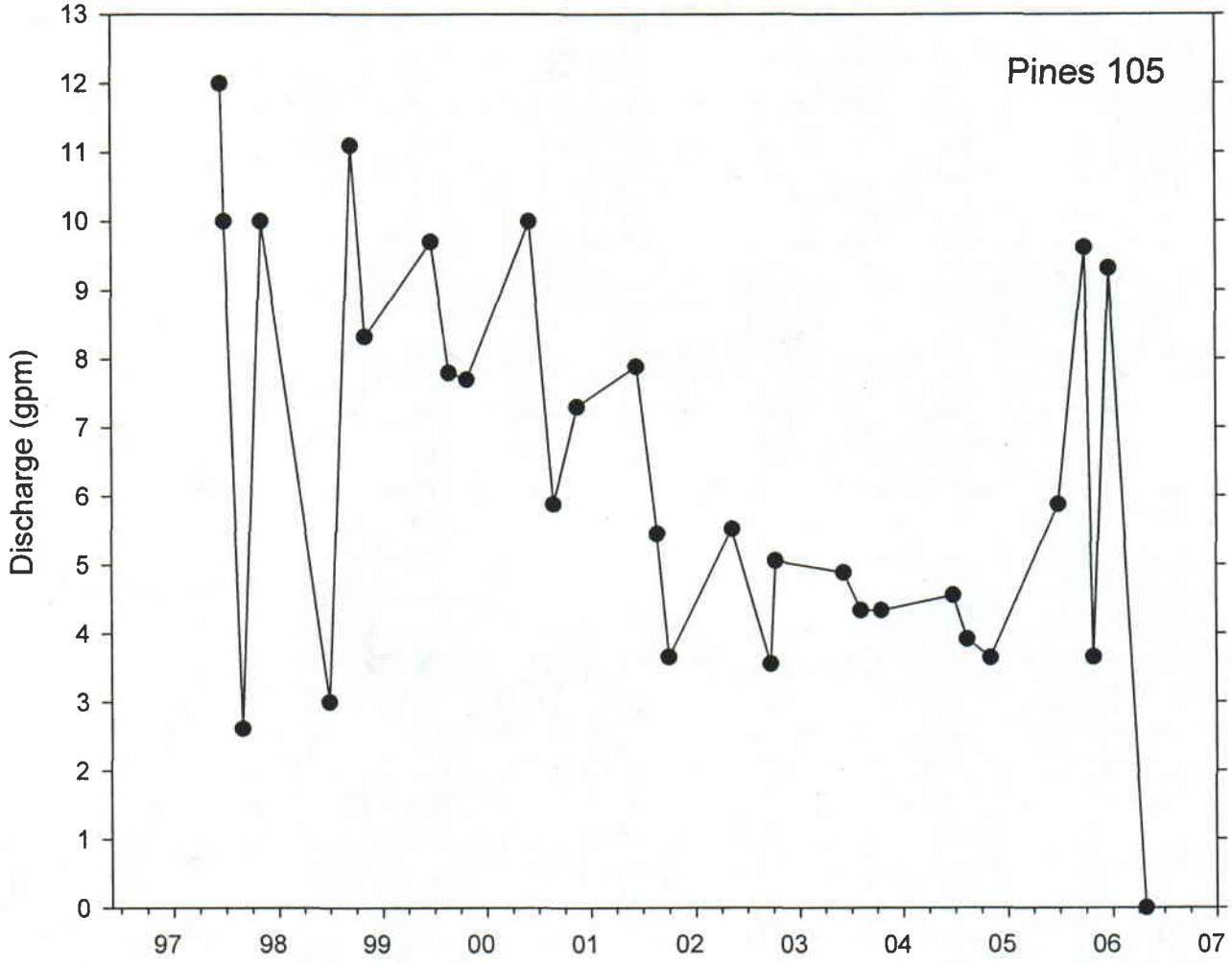


Figure 10 Discharge hydrograph for spring Pines 105, 1997-2006.

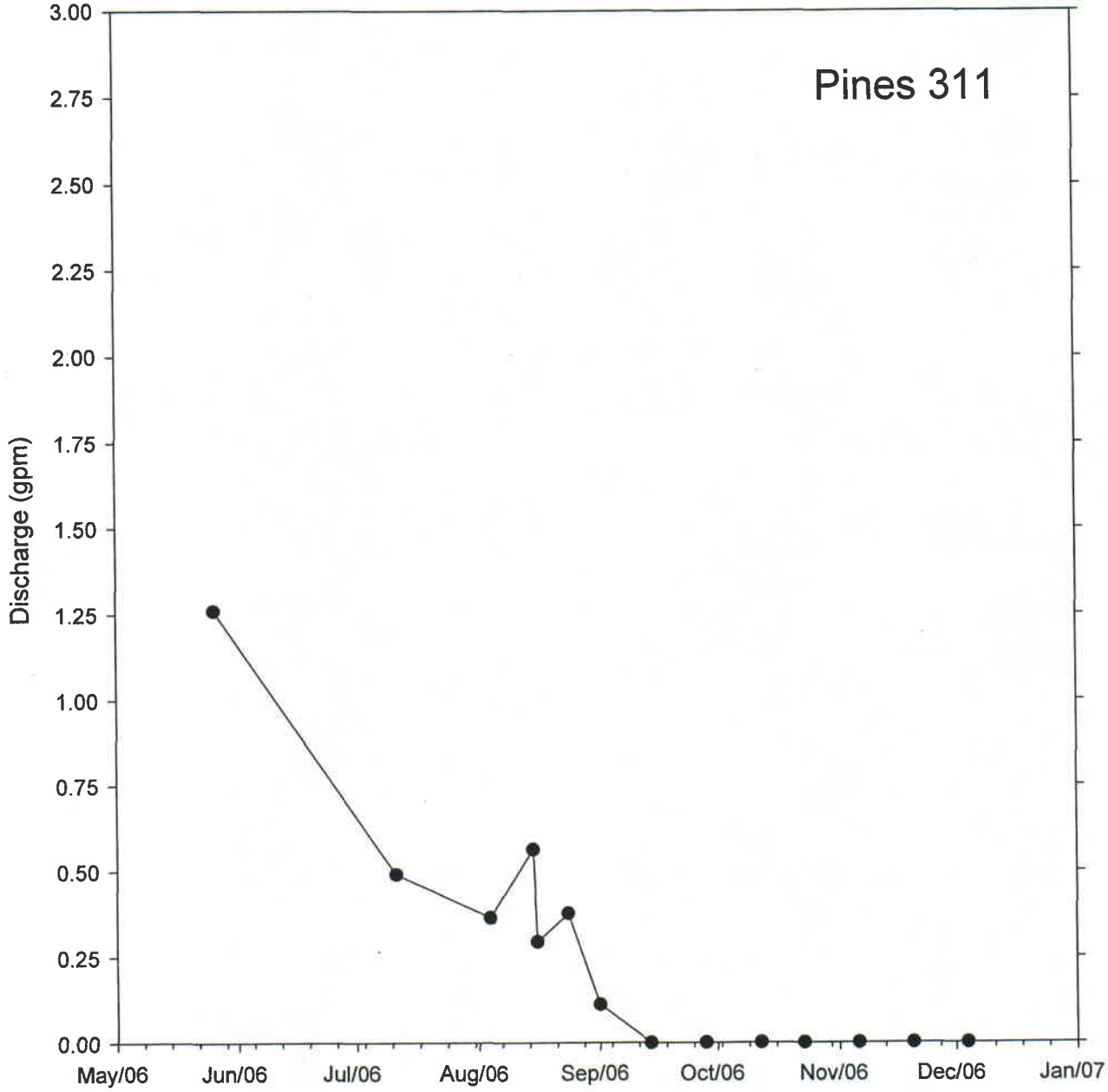


Figure 11 Discharge hydrograph for Pines 311.

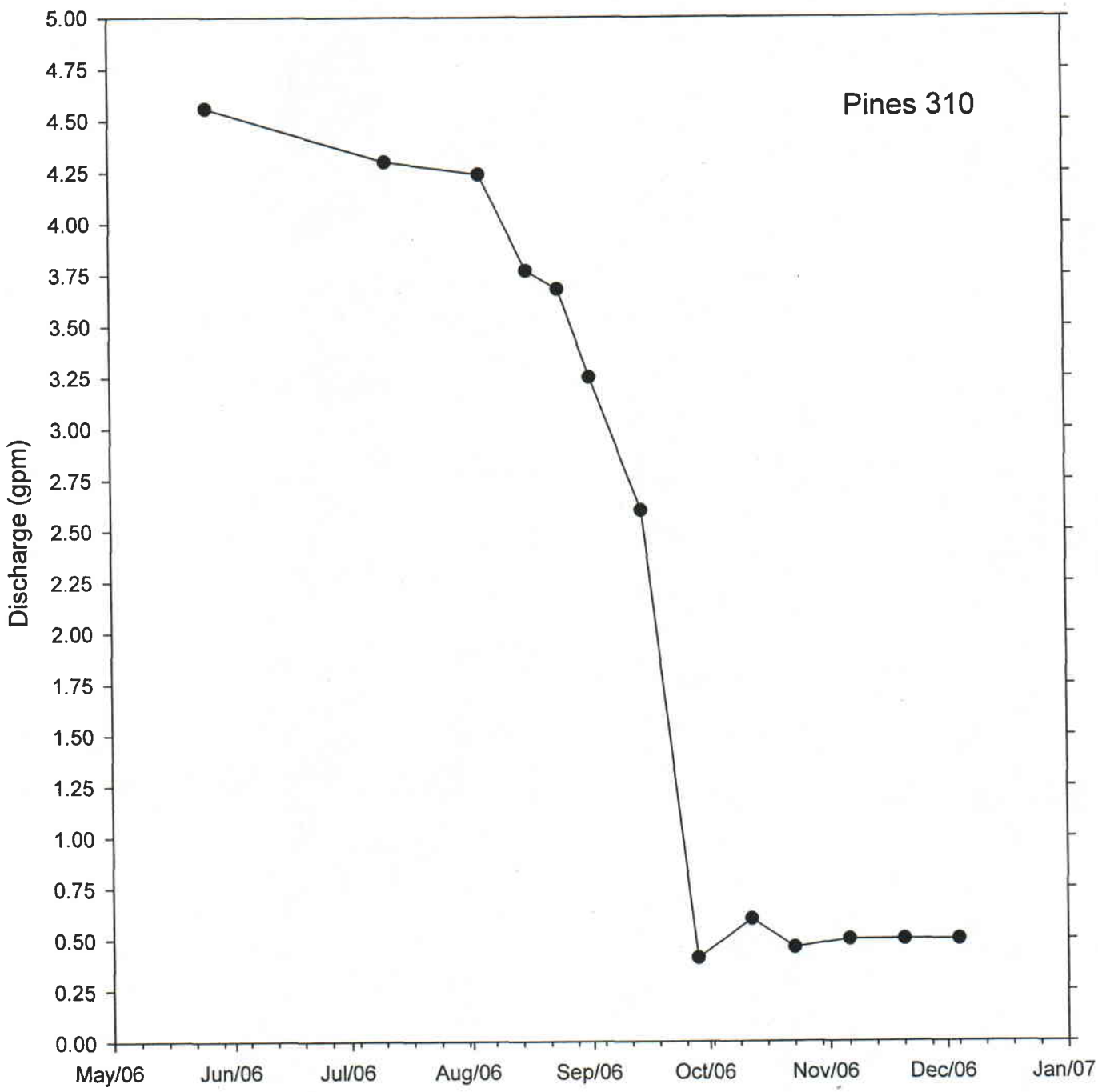


Figure 12 Discharge hydrograph for Pines 310

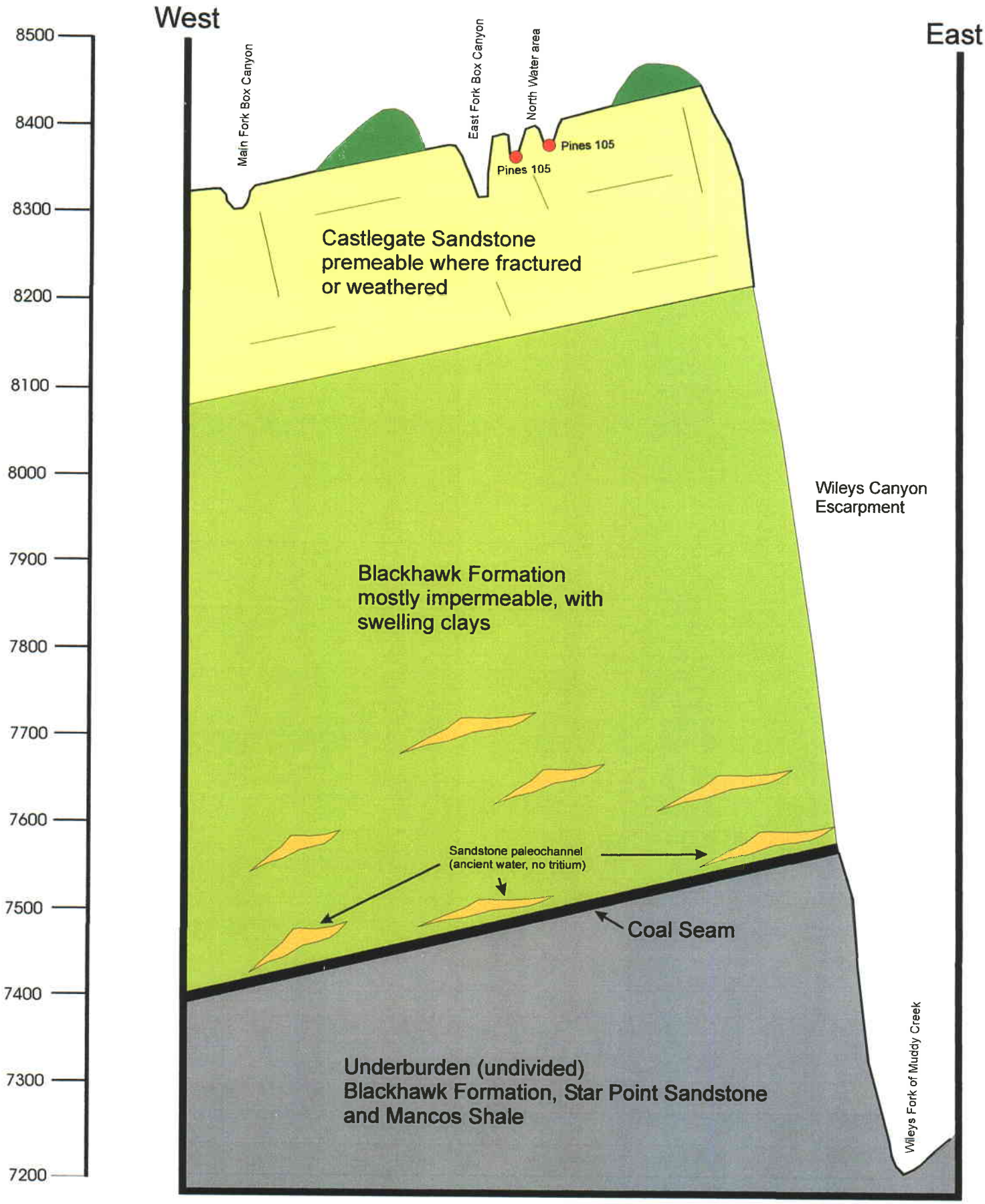


Figure 13 Generalized cross-section through the North Water area

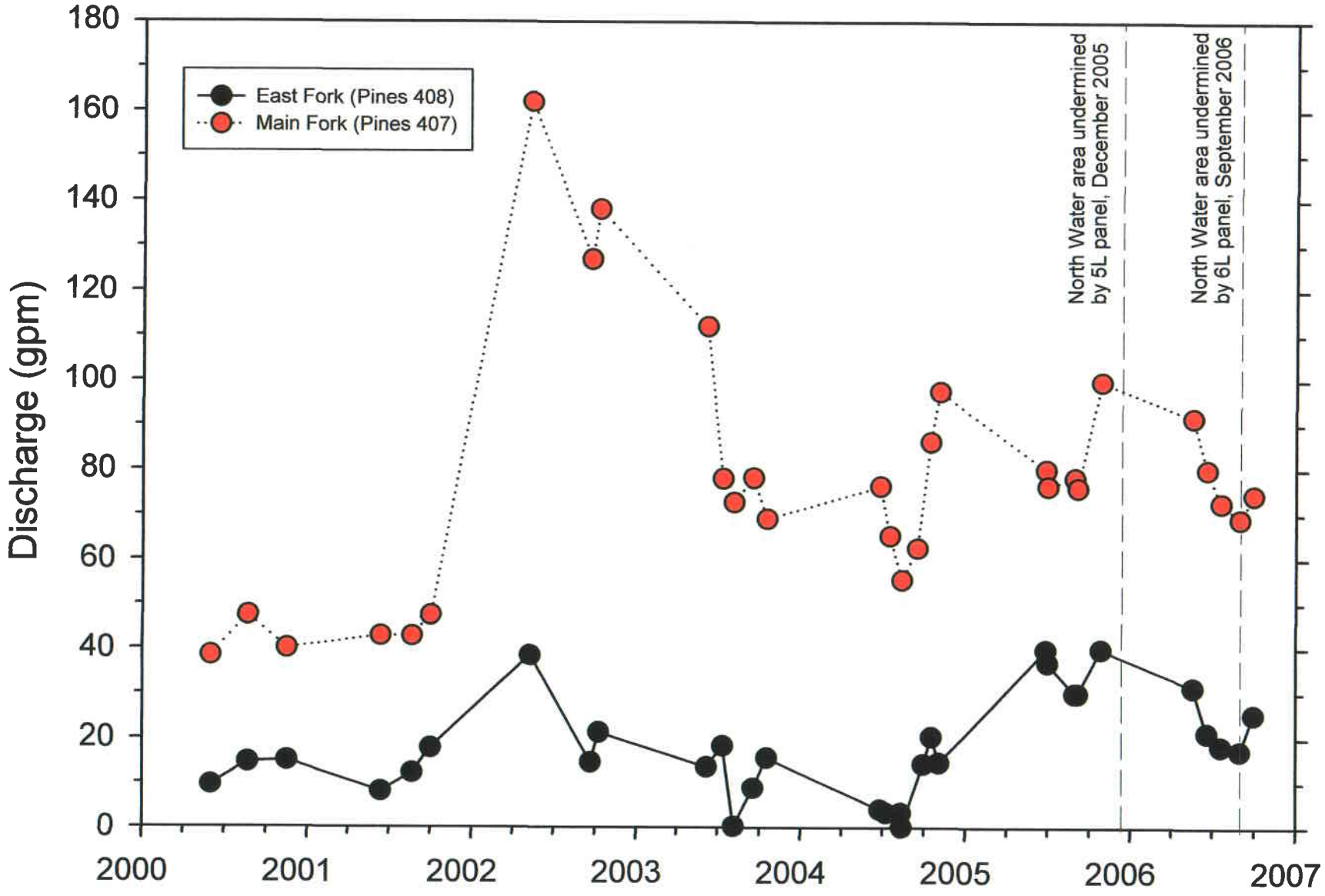
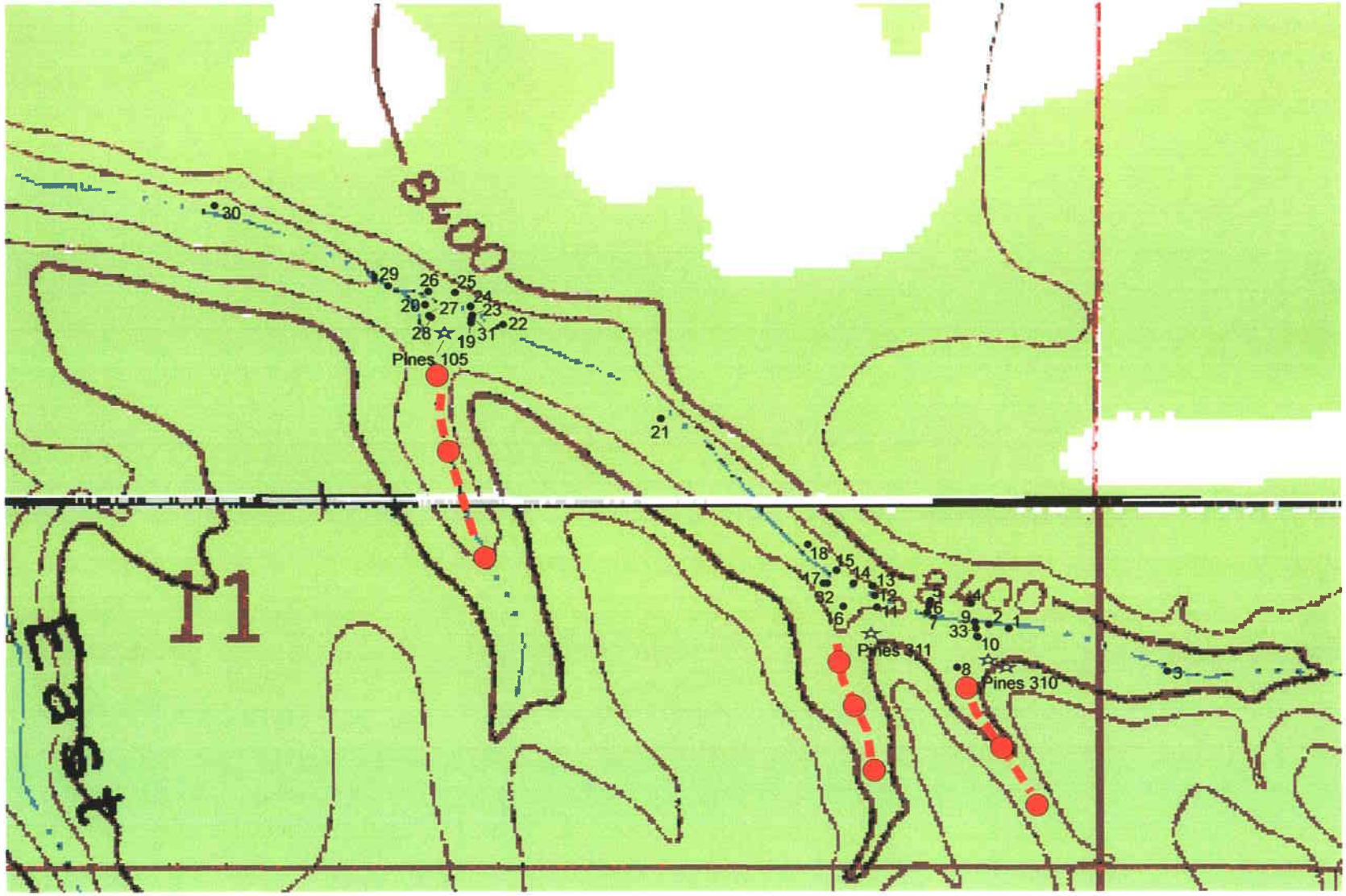


Figure 14 Discharge hydrographs for the Main Fork and East Fork of Box Canyon Creek.



Proposed approximate piezometer location

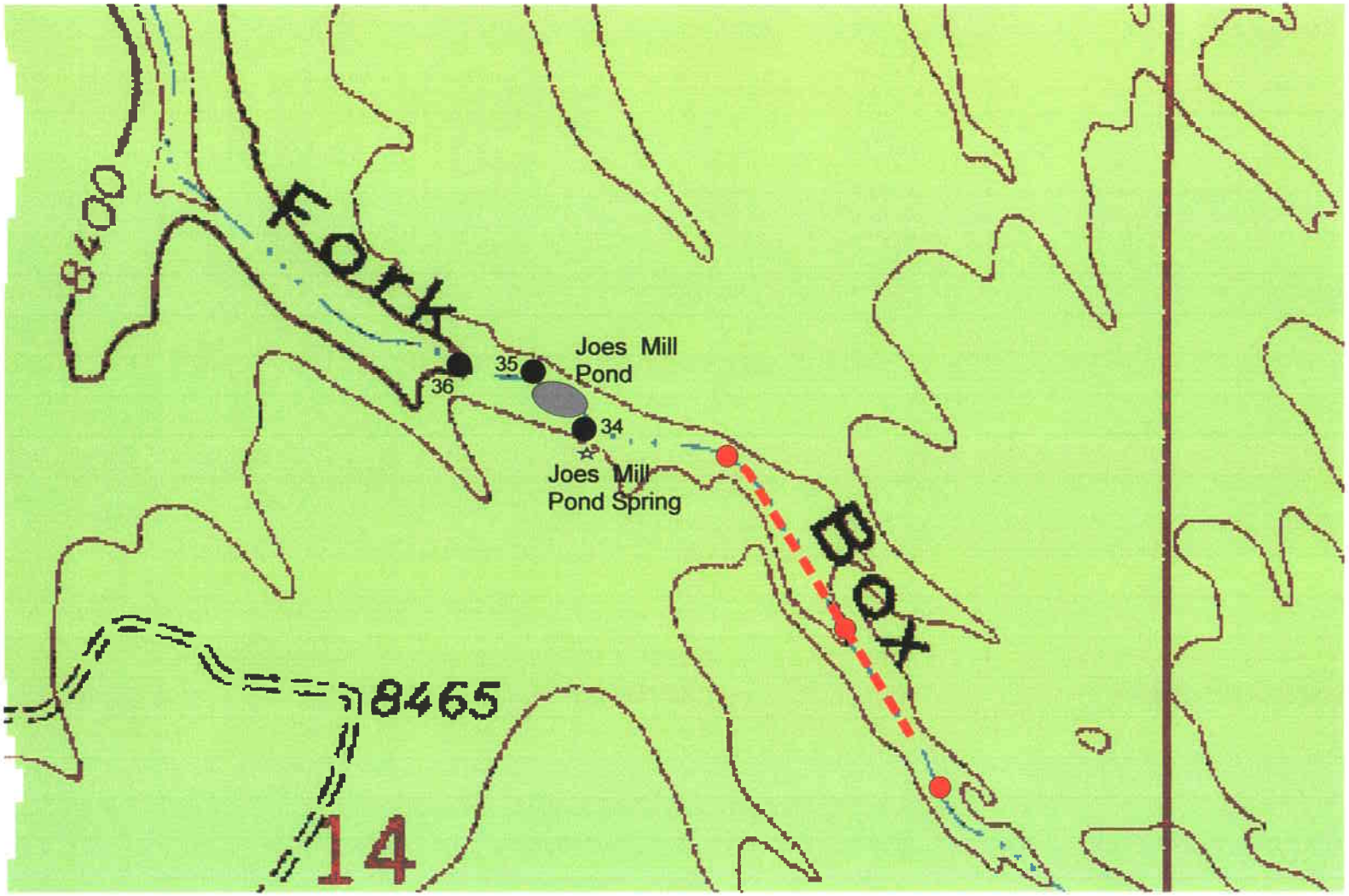
Proposed approximate groundwater collection system location

Spring location

Piezometer/well location

Note: Proposed locations are approximate, actual locations will be determined based on conditions in field.

Figure 15 Proposed approximate piezometer and alluvial groundwater collection system locations in the North Water area



Proposed approximate piezometer location

Proposed approximate groundwater collection system location

Spring location

Piezometer/well location

Note: Proposed locations are approximate, actual locations will be determined based on conditions in field.

Figure 16 Proposed approximate piezometer and alluvial groundwater collection system locations in the Joes Mill Pond area.

Table 1 Sufco East Fork Weather Station
2006 Data Summary

Date	Minimum Temperature	Maximum Temperature	Precipitation Total
April 2006			
4/27/2006	33.7	65.3	0
4/28/2006	25.7	58.0	0
4/29/2006	18.9	58.9	0
4/30/2006	29.0	58.1	0
May 2006			
5/1/2006	20.7	62.8	0
5/2/2006	26.5	63.9	0
5/3/2006	31.9	62.5	0
5/4/2006	30.6	55.9	0.09
5/5/2006	26.2	53.3	0.02
5/6/2006	22.0	55.0	0
5/7/2006	24.9	58.6	0
5/8/2006	31.8	58.1	0
5/9/2006	26.0	53.2	0
5/10/2006	21.3	56.6	0
5/12/2006	25.0	72.0	0
5/13/2006	29.9	69.7	0
5/14/2006	33.4	69.6	0
5/15/2006	33.3	70.4	0
5/16/2006	27.7	73.2	0
5/17/2006	28.9	75.5	0
5/18/2006	30.1	75.6	0
5/19/2006	38.6	72.4	0.21
5/20/2006	33.2	73.5	0
5/21/2006	33.1	74.2	0
5/22/2006	40.9	64.0	0
5/23/2006	33.9	65.6	0
5/24/2006	27.5	75.0	0
5/25/2006	28.7	77.0	0
5/26/2006	35.1	78.3	0
5/27/2006	31.8	62.7	0
5/28/2006	20.9	40.6	0.02
5/29/2006	11.9	56.7	0
5/30/2006	15.0	62.7	0
5/31/2006	23.1	70.3	0
May Summary	**11.9**	**78.3**	**0.34**
June 2006			
6/1/2006	25.5	78.3	0
6/2/2006	28.6	79.1	0
6/3/2006	37.8	77.2	0

Date	Minimum Temperature	Maximum Temperature	Precipitation Total
6/4/2006	33.1	81.4	0
6/5/2006	40.6	82.1	0
6/6/2006	36.4	87.1	0
6/7/2006	41.8	79.9	0
6/8/2006	38.8	64.4	0.41
6/9/2006	34.2	67.5	0.04
6/10/2006	33.4	75.1	0
6/11/2006	29.9	79.3	0
6/12/2006	29.6	79.1	0
6/13/2006	25.7	74.4	0
6/14/2006	41.9	63.5	0
6/15/2006	38.7	56.9	0
6/16/2006	37.3	63.1	0
6/17/2006	27.8	76.6	0
6/18/2006	31.0	81.5	0
6/19/2006	32.7	82.9	0
6/20/2006	38.7	77.8	0
6/21/2006	33.2	79.5	0
6/22/2006	34.2	78.1	0
6/23/2006	31.7	84.0	0
6/24/2006	31.6	84.1	0
6/25/2006	31.0	80.7	0
6/26/2006	35.3	76.0	0
6/27/2006	32.1	79.6	0
6/28/2006	39.7	74.3	0.17
6/29/2006	39.9	76.5	0
6/30/2006	38.7	75.6	0.11
June Summary	**25.5**	**87.1**	**0.73**
July 2006			
7/1/2006	41.9	72.8	0.1
7/2/2006	46.0	75.5	0.04
7/3/2006	44.1	77.9	0
7/4/2006	48.8	75.9	0.11
7/5/2006	44.8	71.8	0.02
7/6/2006	50.1	71.9	0.07
7/7/2006	41.5	68.9	0.32
7/8/2006	44.5	65.4	0
7/9/2006	44.6	76.9	0
7/10/2006	40.5	70.5	0.22
7/11/2006	40.5	73.6	0.04
7/12/2006	40.1	80.7	0.01
7/13/2006	40.8	83.3	0
7/14/2006	38.1	87.5	0
7/15/2006	40.8	89.5	0
7/16/2006	46.7	87.7	0
7/17/2006	50.0	86.0	0

Date	Minimum Temperature	Maximum Temperature	Precipitation Total
7/18/2006	45.3	84.3	0
7/19/2006	47.1	80.5	1.22
7/20/2006	44.9	78.5	0.06
7/21/2006	48.2	84.4	0
7/22/2006	51.5	84.7	0
7/23/2006	46.4	85.8	0
7/24/2006	49.9	85.9	0.07
7/25/2006	54.3	75.8	0.17
7/26/2006	47.4	82.7	0
7/27/2006	44.5	82.7	0
7/28/2006	43.5	84.6	0
7/29/2006	49.1	85.5	0
7/30/2006	57.1	73.7	0.41
7/31/2006	49.3	73.4	0.38
July Summary	**38.1**	**89.5**	**3.24**
August 2006			
8/1/2006	42.6	67.3	0.01
8/2/2006	40.6	68.7	0
8/3/2006	46.2	66.0	0.13
8/4/2006	43.6	63.5	0.05
8/5/2006	40.5	69.5	0
8/6/2006	40.5	75.8	0
8/7/2006	42.1	73.2	0.33
8/8/2006	42.4	77.8	0
8/9/2006	43.1	76.8	0
8/10/2006	39.1	77.3	0.01
8/11/2006	42.4	76.3	0.04
8/12/2006	43.5	75.2	0
8/13/2006	40.1	73.4	0
8/14/2006	38.6	76.6	0
8/15/2006	42.6	72.8	0.14
8/16/2006	38.6	69.3	0.09
8/17/2006	39.5	76.9	0
8/18/2006	37.4	77.5	0
8/19/2006	36.0	79.8	0
8/20/2006	39.9	75.9	0
8/21/2006	41.2	78.0	0
8/22/2006	45.8	79.4	0
8/23/2006	39.3	76.5	0.06
8/24/2006	41.9	75.6	0.12
8/25/2006	39.0	71.0	0.38
8/26/2006	36.9	68.2	0
8/27/2006	31.8	70.2	0
8/28/2006	32.4	74.2	0
8/29/2006	32.6	79.4	0
8/30/2006	34.1	79.3	0

Date	Minimum Temperature	Maximum Temperature	Precipitation Total
8/31/2006	40.8	77.3	0
August Summary	**31.8**	**79.8**	**1.36**
September 2006			
9/1/2006	33.7	75.9	0
9/2/2006	33.6	76.5	0
9/3/2006	31.4	77.5	0
9/4/2006	34.7	75.6	0
9/5/2006	35.1	74.0	0.03
9/6/2006	43.1	71.9	0.14
9/7/2006	37.1	63.8	0.01
9/8/2006	40.1	61.9	0
9/9/2006	34.2	66.3	0.19
9/10/2006	33.8	64.2	0.03
9/11/2006	29.8	69.8	0
9/12/2006	32.0	73.6	0
9/13/2006	30.8	75.3	0
9/14/2006	33.1	64.6	0.52
9/15/2006	33.8	57.8	0.19
9/16/2006	23.2	42.3	0.03
9/17/2006	21.4	48.1	0
9/18/2006	18.4	59.2	0
9/19/2006	20.6	63.2	0
9/20/2006	31.3	44.8	0.06
9/21/2006	31.3	47.4	0.04
9/22/2006	26.4	38.5	0.1
9/23/2006	16.9	46.7	0
9/24/2006	19.2	55.9	0
9/25/2006	19.9	60.7	0
9/26/2006	20.5	67.8	0
9/27/2006	26.1	67.8	0
9/28/2006	25.1	69.7	0
9/29/2006	25.4	69.5	0
9/30/2006	21.8	72.8	0
September Summary	**16.9**	**77.5**	**1.34**
October 2006			
10/1/2006	29.4	68.0	0
10/2/2006	34.4	62.5	0.03
10/3/2006	31.2	61.7	0.01
10/4/2006	31.5	54.8	0
10/5/2006	33.0	49.7	0.29
10/6/2006	35.3	45.5	1.79
10/7/2006	26.6	56.3	0
10/8/2006	24.7	55.4	0
10/9/2006	29.0	41.8	0.26

Date	Minimum Temperature	Maximum Temperature	Precipitation Total
10/10/2006	22.6	44.8	0.47
10/11/2006	25.2	52.4	0.01
10/12/2006	24.3	59.0	0
October Summary (Partial month)	**22.6**	**68.0**	**2.86**

9.87 inches 27 April to 12 October 2006

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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
NWP-16		3.64	3.23	3.52	3.39	3.35	3.30	4.43	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
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
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
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
NWP-21				3.90	3.82	3.85	2.70	5.63	submerged	3.68	submerged	submerged	2.80	3.43	4.10
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
NWP-23					8.13		8.74	9.08	9.54	9.96	10.22	10.29	10.61	10.80	Cap frozen
NWP-24					16.91		17.21	17.48	17.72	18.05	18.09	18.14	18.33	18.61	18.93
NWP-25					15.40		15.56	15.73	15.98	16.22	16.52	16.71	17.00	17.11	17.39
NWP-26					17.69		18.79	18.96	19.27	19.78	20.06	20.08	20.31	20.28	20.18
NWP-27					8.25		8.36	8.63	9.18	9.74	10.13	10.12	10.32	10.49	10.73
NWP-28 shallow					6.92		7.18	7.39	7.83	8.31	8.50	8.55	8.83	9.17	Cap frozen
NWP-28 deep					8.67		8.56	8.79	9.32	9.97	10.46	10.57	10.75	10.94	Cap frozen
NWP-29					9.65	8.96	9.90	9.74	9.84	10.33	10.68	9.95	10.25	10.89	10.86
NWP-30					12.30	12.42	12.95	13.30	13.84	14.75	15.42	15.86	16.53	16.83	17.65
NWP-31 (4")							9.00	9.30	9.74	10.13	10.48	10.55	10.90	11.06	Cap frozen
NWP-32 (4")						3.90	3.60	6.19	6.27	9.60	9.74	9.65	10.50	11.07	11.69
NWP-33 (4")						3.90	4.03	4.36	4.46	4.48	4.17	4.20	5.30	5.76	6.30
NWP-34 (4")								6.73	7.03	7.37	7.68	7.80	8.01	Inaccessible	Inaccessible
NWP-35								14.69	14.97	15.19	15.52	15.67	15.86	Inaccessible	Inaccessible
NWP-36								10.16	10.27	10.34	10.50	10.54	10.64	Inaccessible	Inaccessible

Table 3 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

Description	Original Elevation	Subsided Elevation	Elevation Diff.
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
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

Table 4 Discharge data from Sufco North Water springs

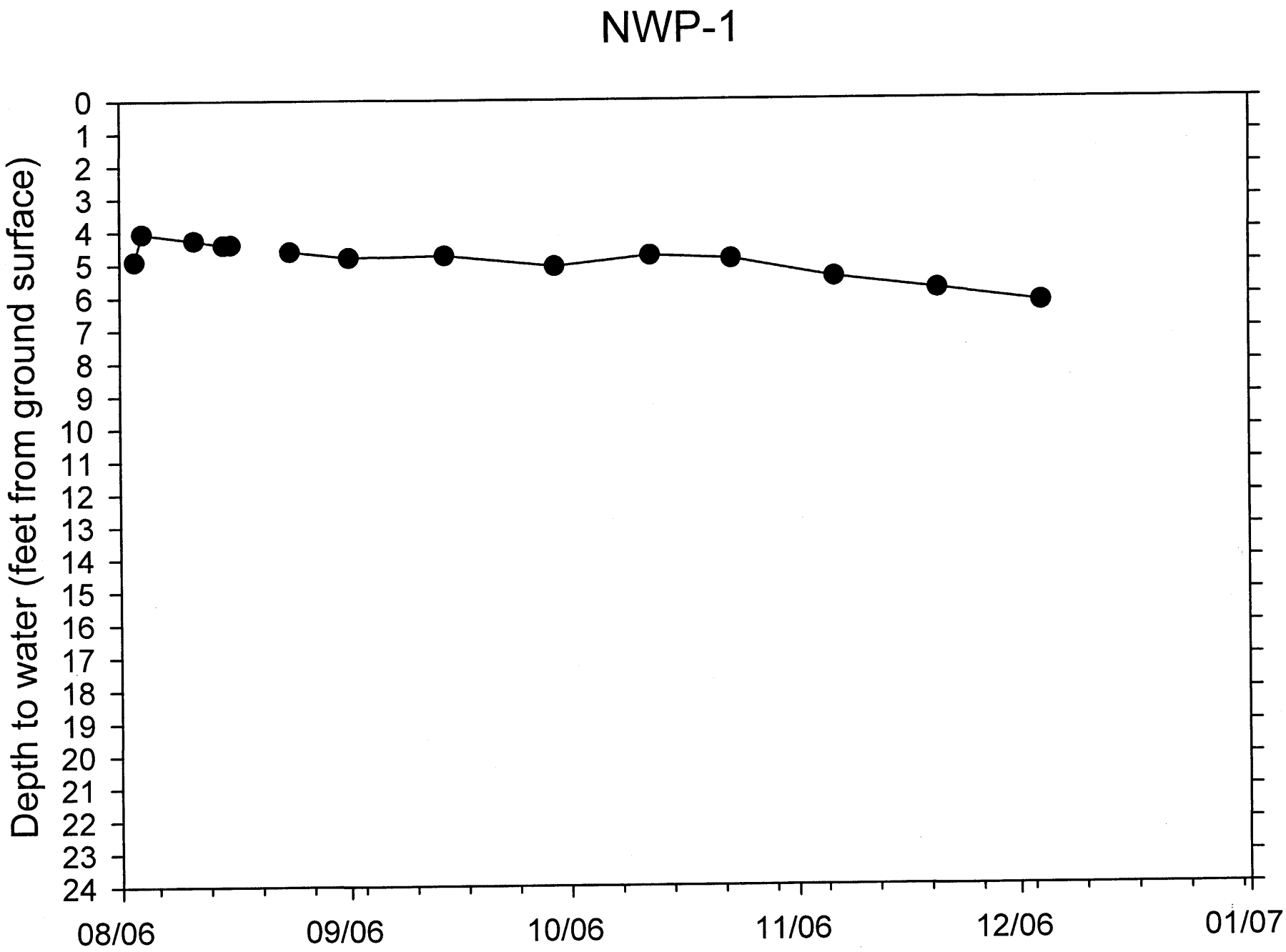
	Date	Discharge (gpm)	
Pines 310	5/26/2006	4.56	
Pines 310	7/11/2006	4.30	
Pines 310	8/4/2006	4.24	
Pines 310	8/16/2006	3.77	
Pines 310	8/24/2006	3.68	
Pines 310	9/1/2006	3.25	
Pines 310	9/14/2006	2.60	
Pines 310	9/28/2006	0.41	
Pines 310	10/12/2006	0.60	
Pines 310	10/23/2006	0.46	
Pines 310	11/6/2006	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 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 Isotopic compositions of groundwaters and surface waters in the North Water Canyon area and the Sufco Mine underground workings in The Pines area.

		δ^2H (‰)	$\delta^{18}O$ (‰)	Tritium (TU)	$\delta^{13}C$ (‰)	^{14}C (pmC)	Groundwater "age" radiocarbon years
Springs, Pines Area							
Pines 105	6/28/1997	-116.0	-16.1	6.48	-15.6	92.55	modern
Pines 310	11/3/1997	-118.8	-15.8	16.4	-14.0	108.69	modern
Sufco Mine underground (Pines Area)							
14 Left Setup Room	9/20/2000			0.07	-9.9	31.42	4,000
14 Left E2 XC101	9/20/2000			0.01	-10.2	24.45	6,000

Appendix A

Water level hydrographs for piezometers/wells


NWP-1
Depth to water (feet from ground surface)
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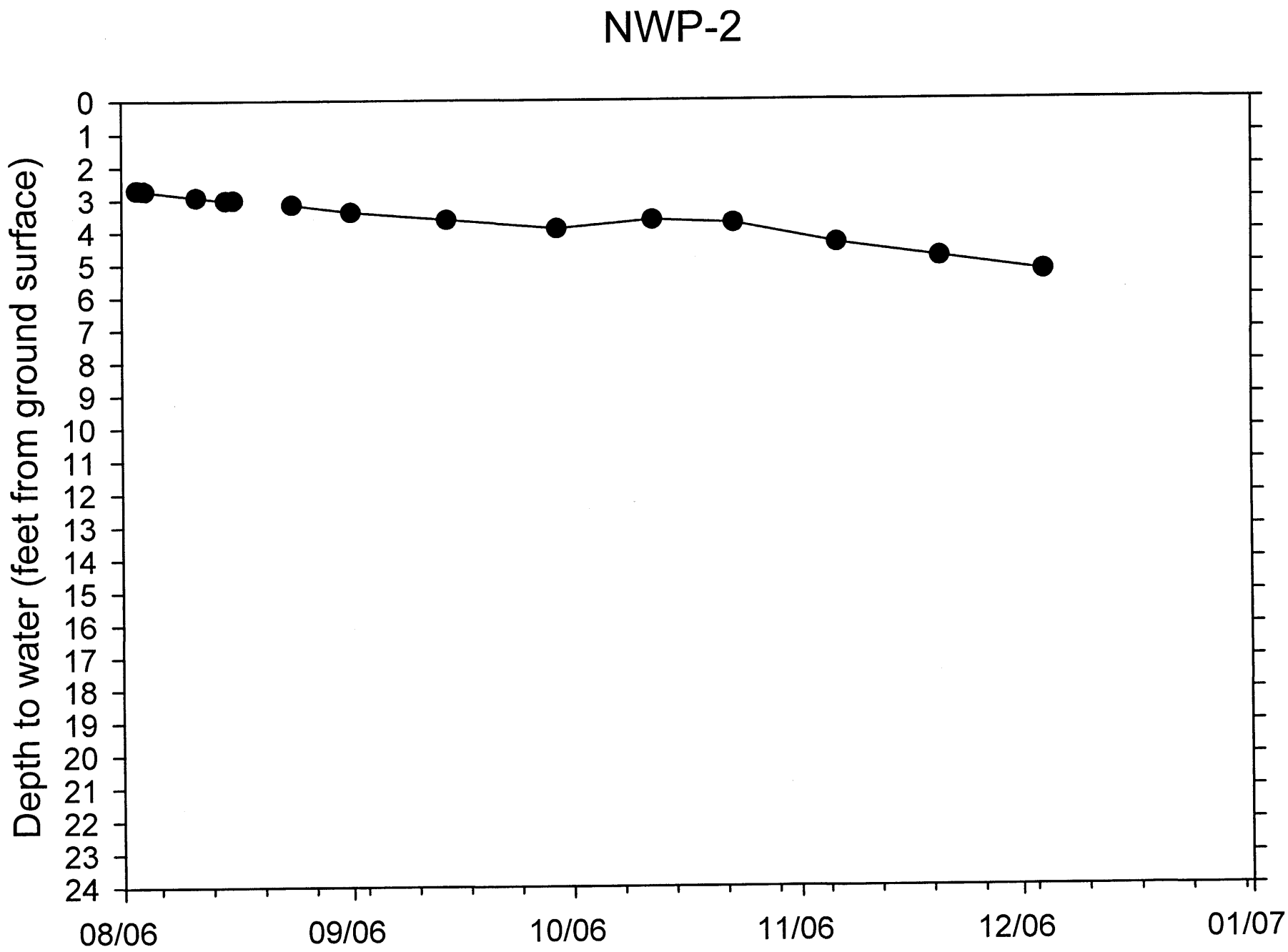
NWP-2
Depth to water (feet from ground surface)
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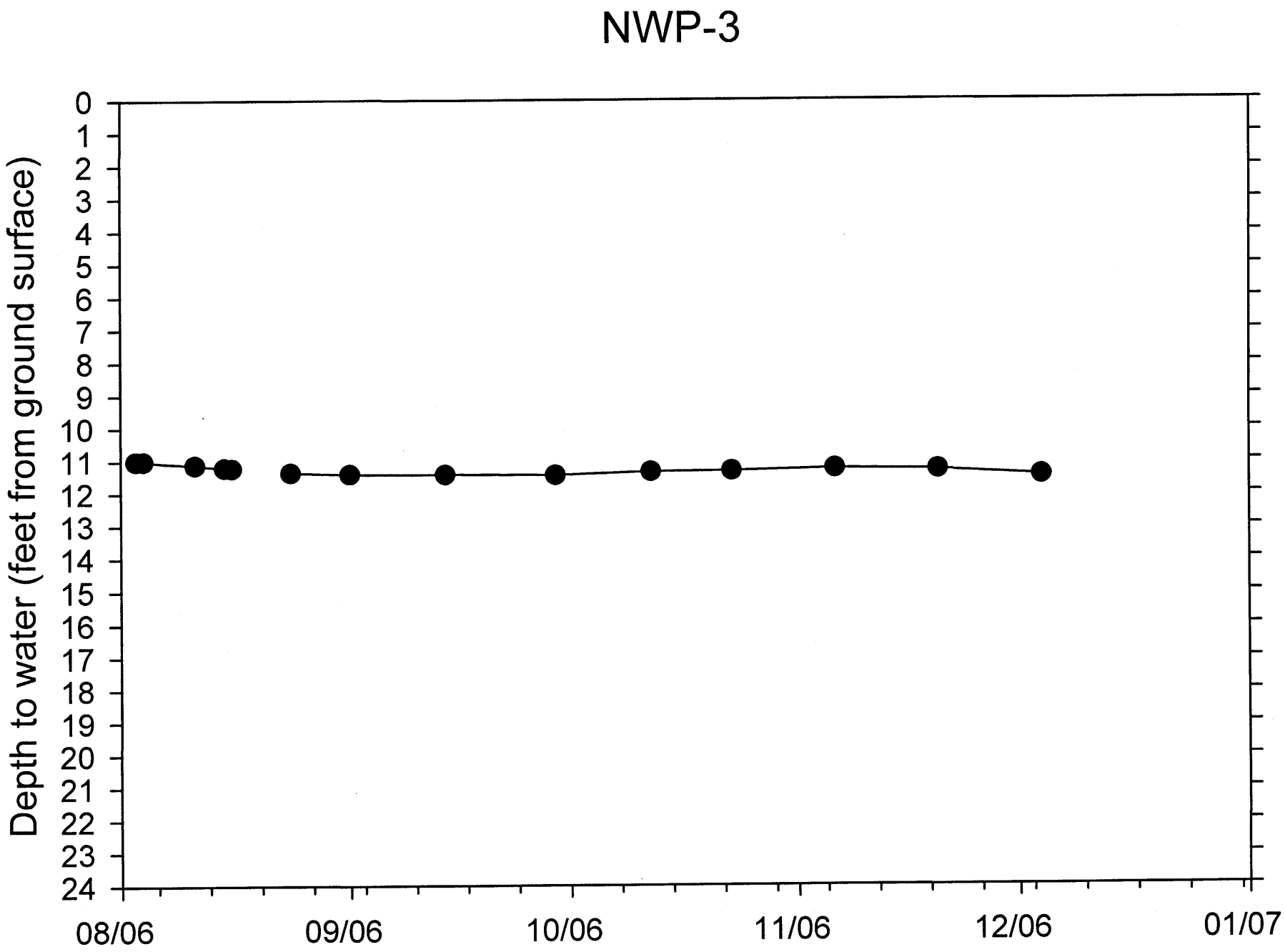
NWP-3
Depth to water (feet from ground surface)
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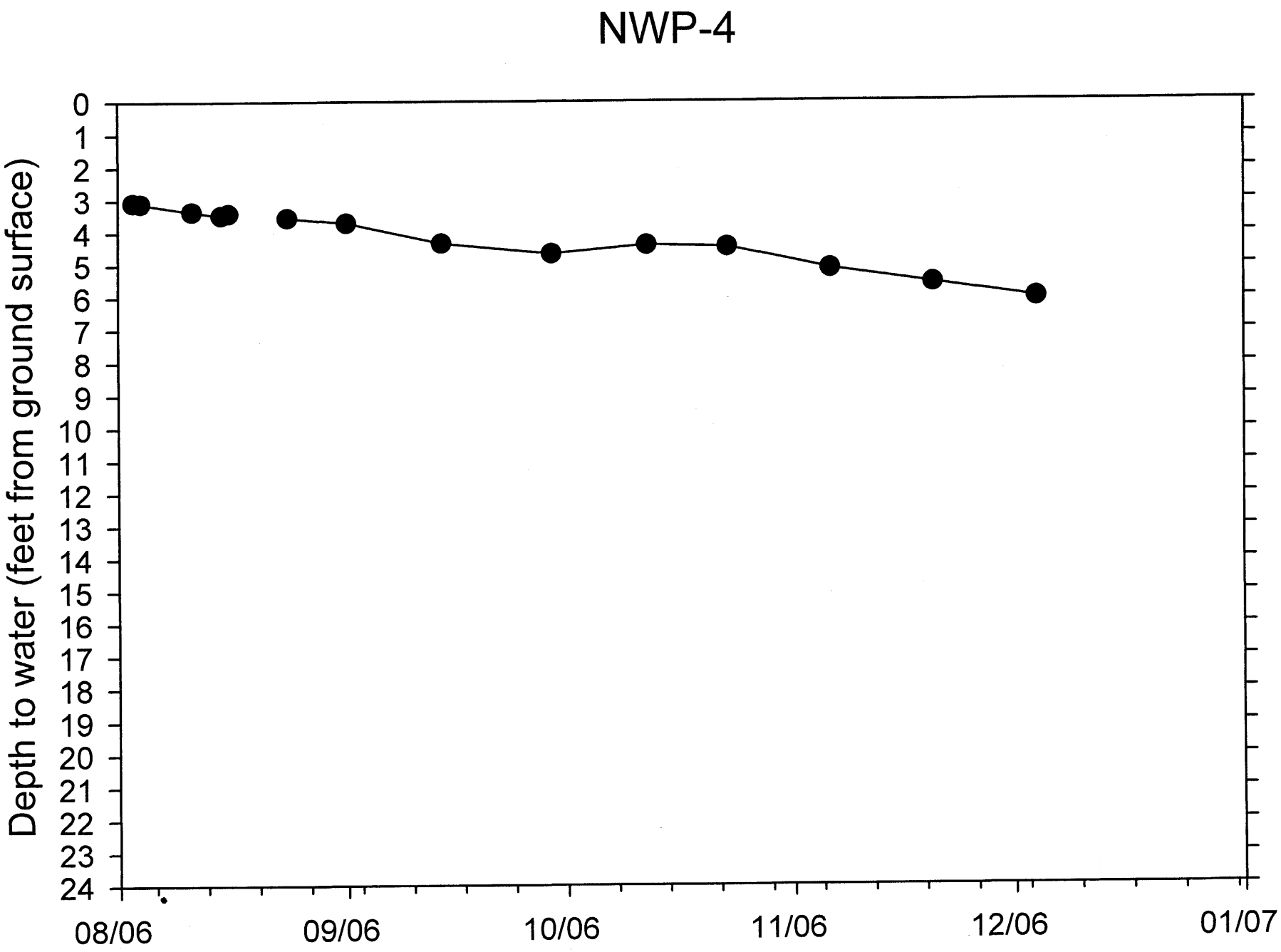
NWP-4
Depth to water (feet from ground surface)
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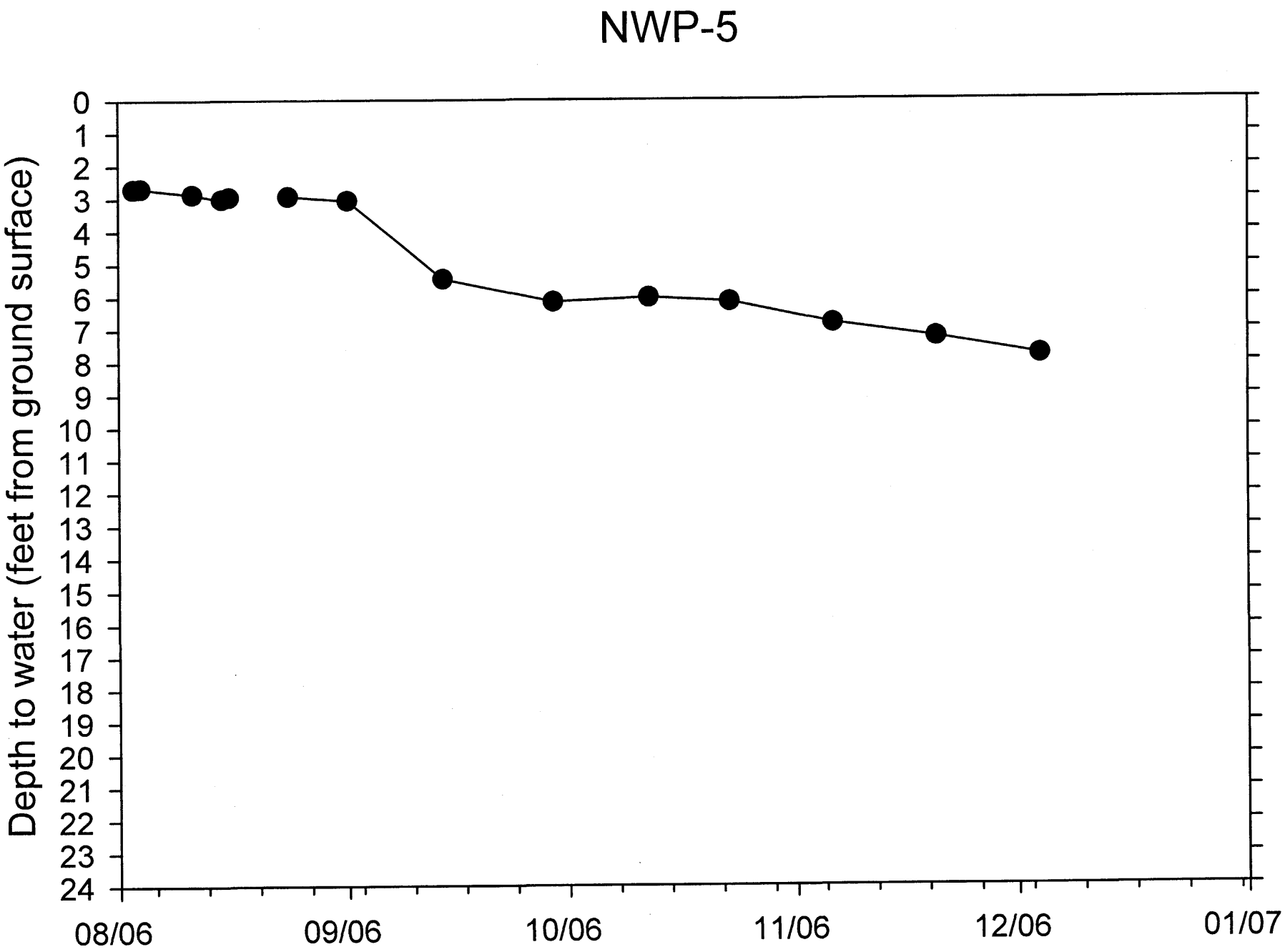
NWP-5
Depth to water (feet from ground surface)
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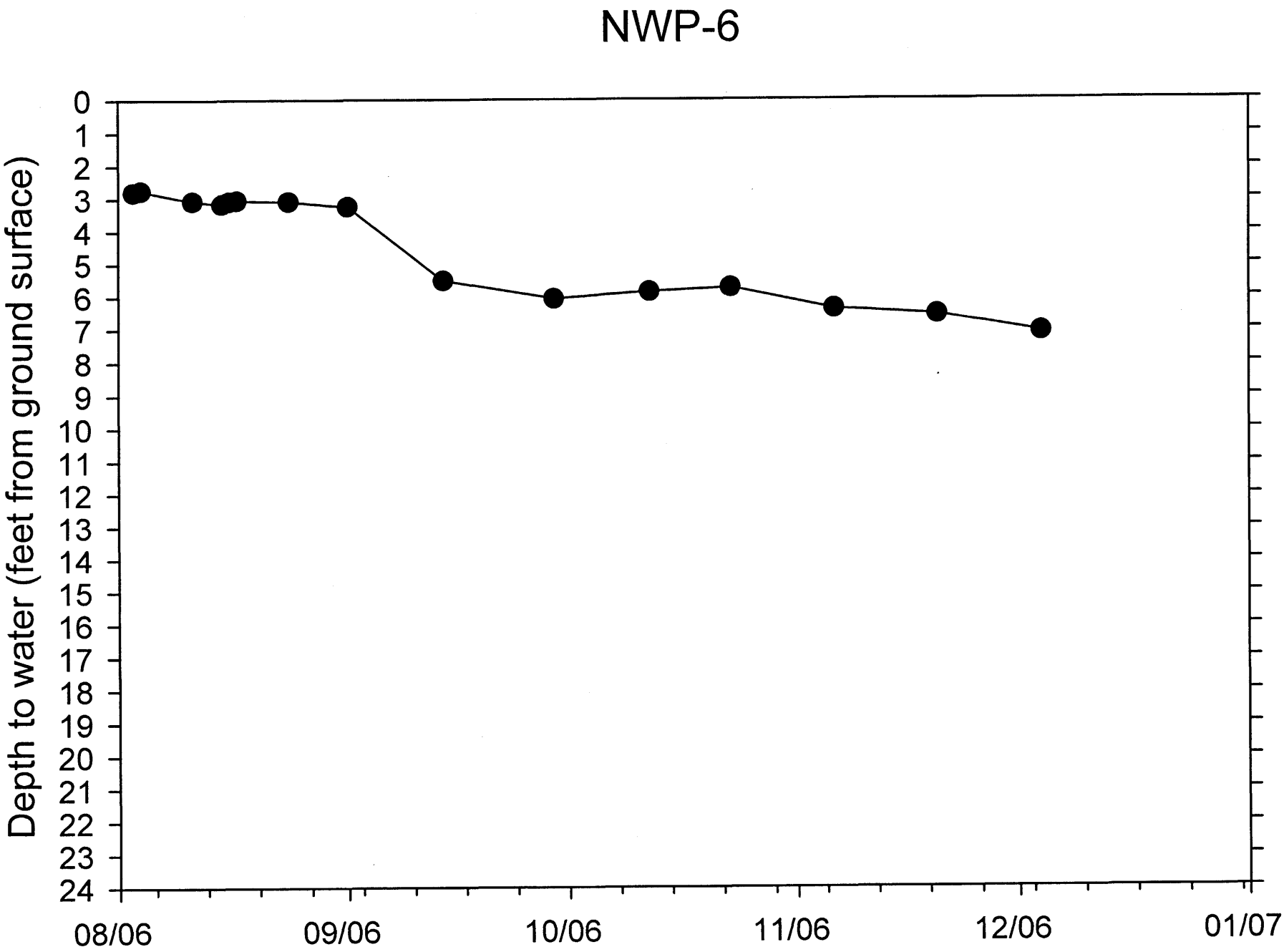
NWP-6
Depth to water (feet from ground surface)
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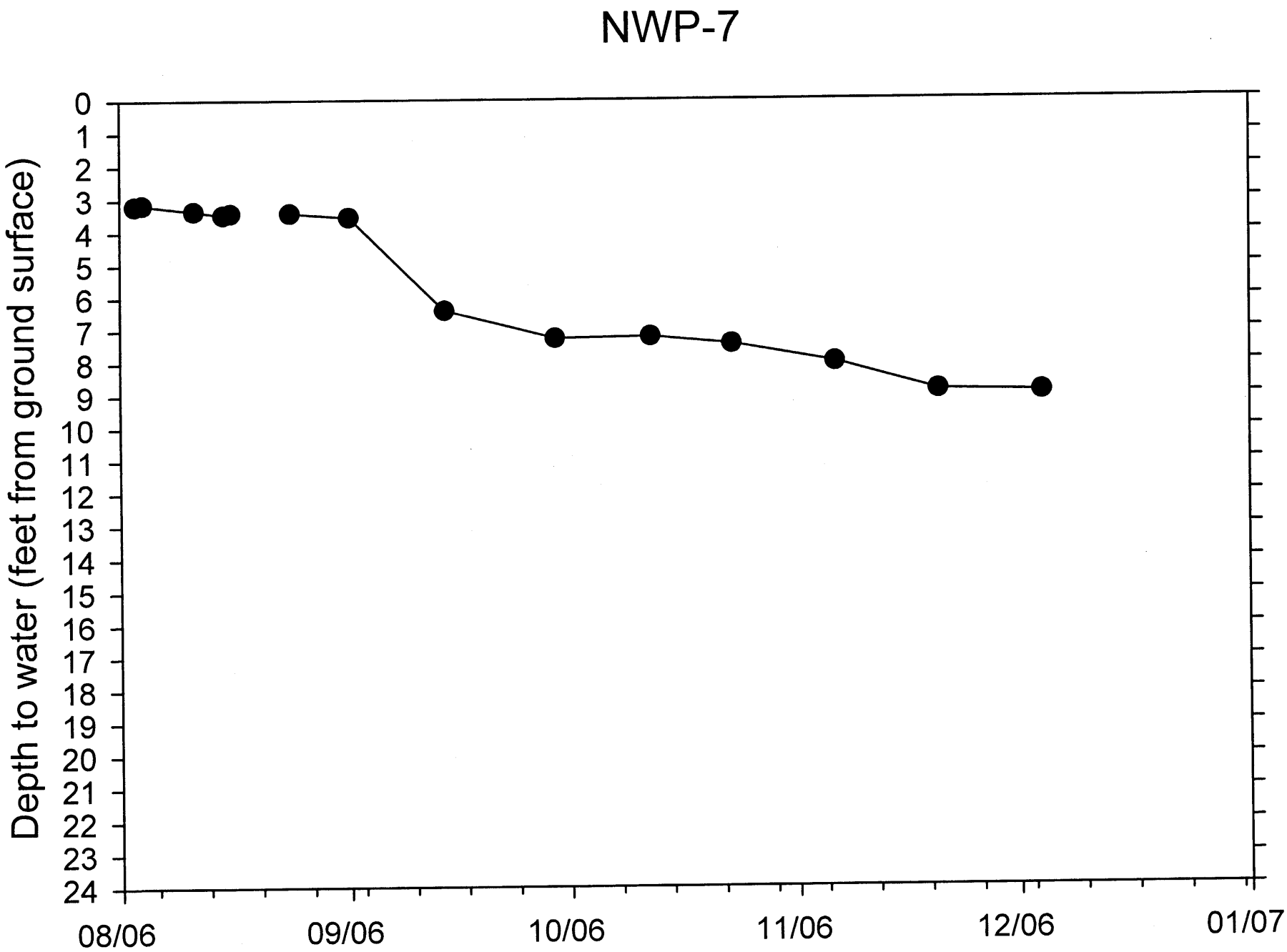
NWP-7
Depth to water (feet from ground surface)
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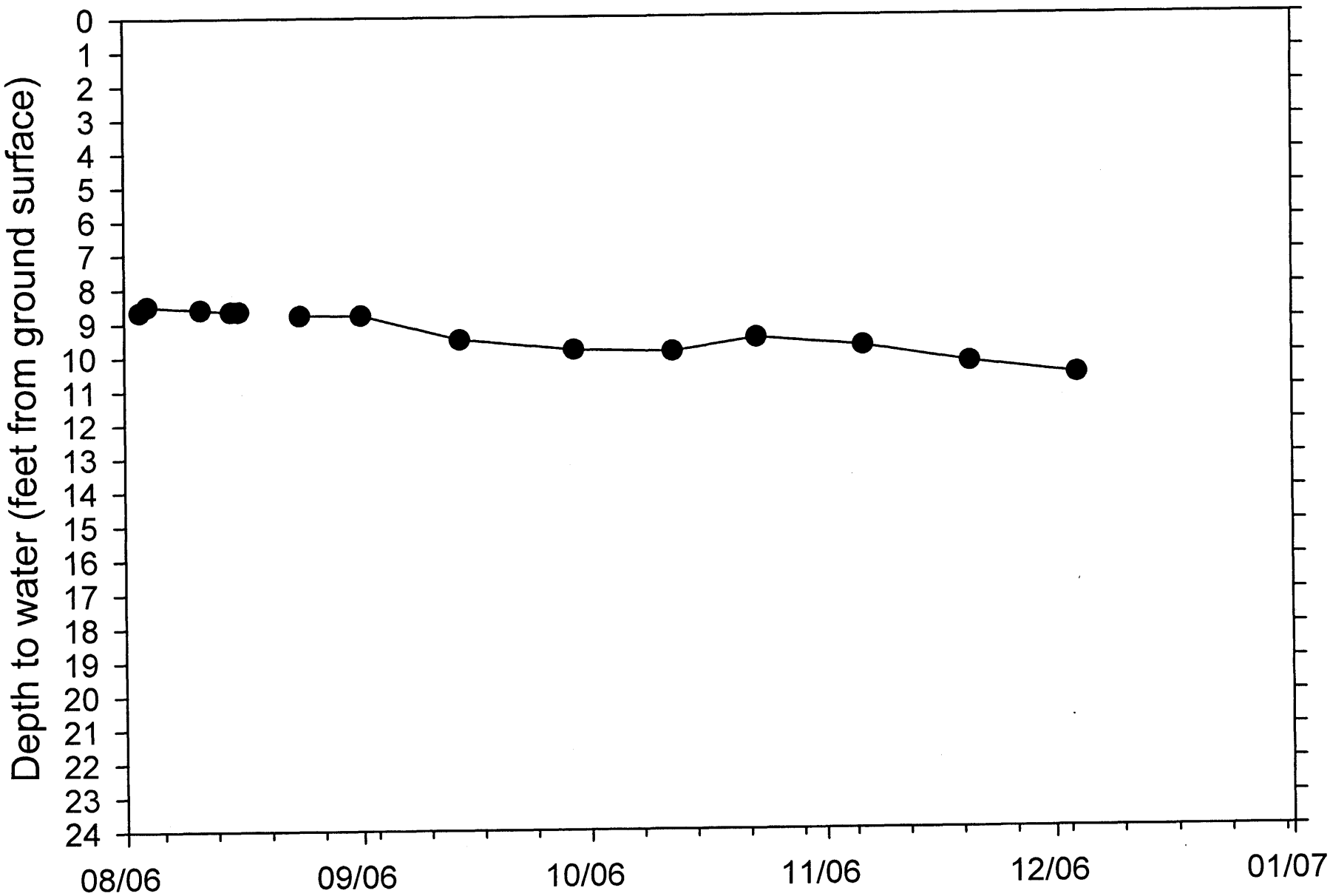
NWP-8


Depth to water (feet from ground surface)
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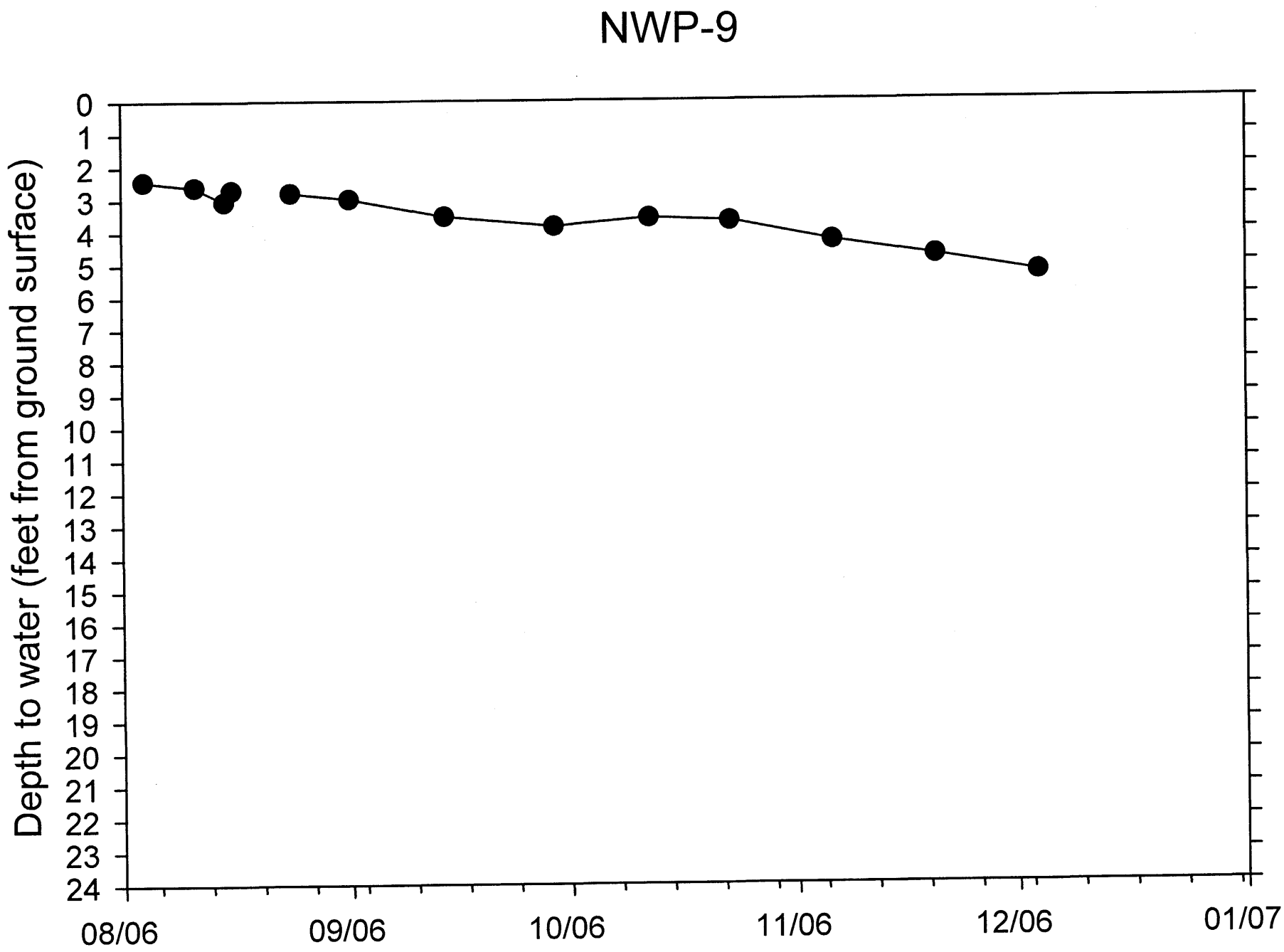
NWP-9
Depth to water (feet from ground surface)
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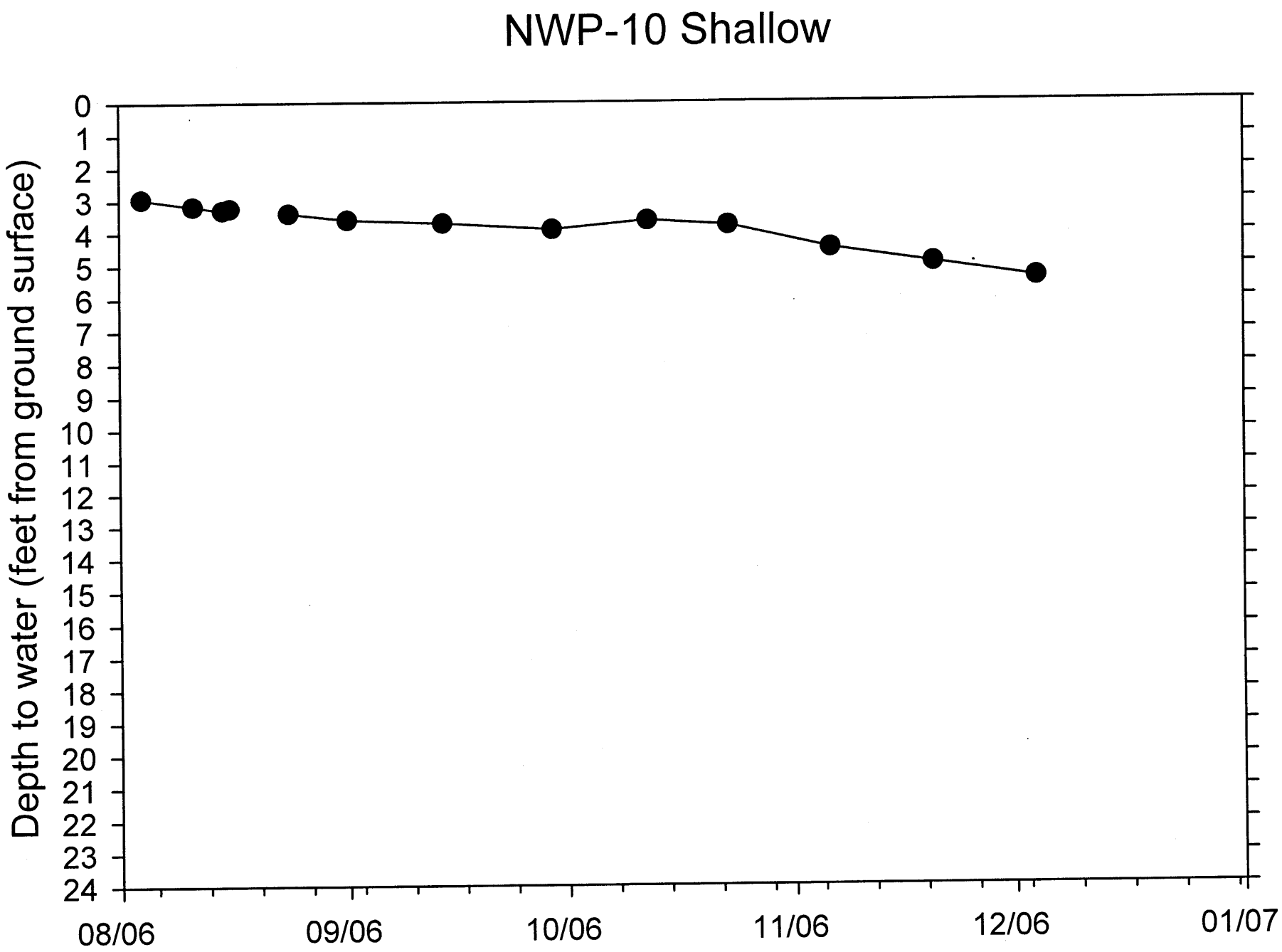
NWP-10 Shallow
Depth to water (feet from ground surface)
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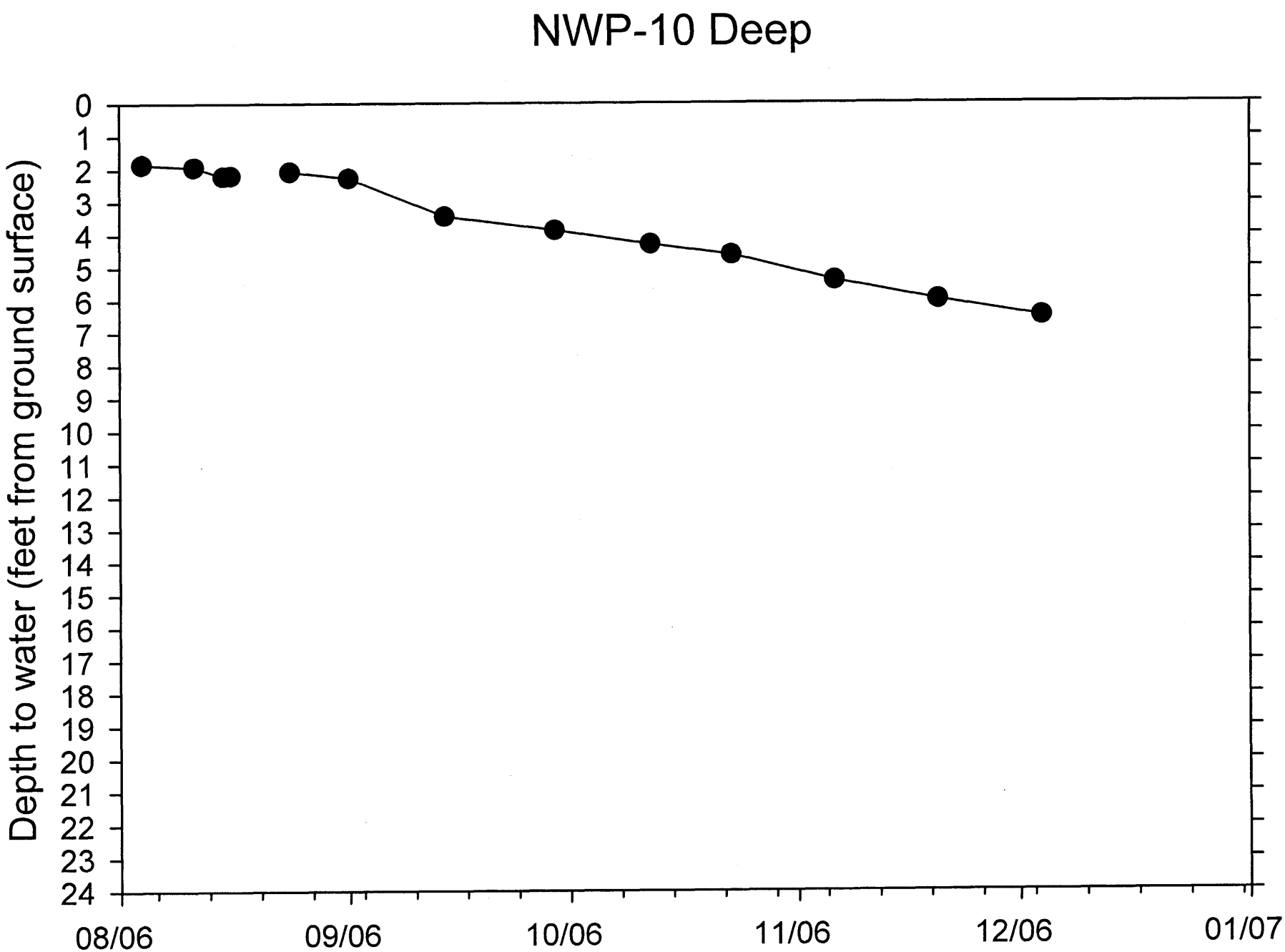
NWP-10 Deep
Depth to water (feet from ground surface)
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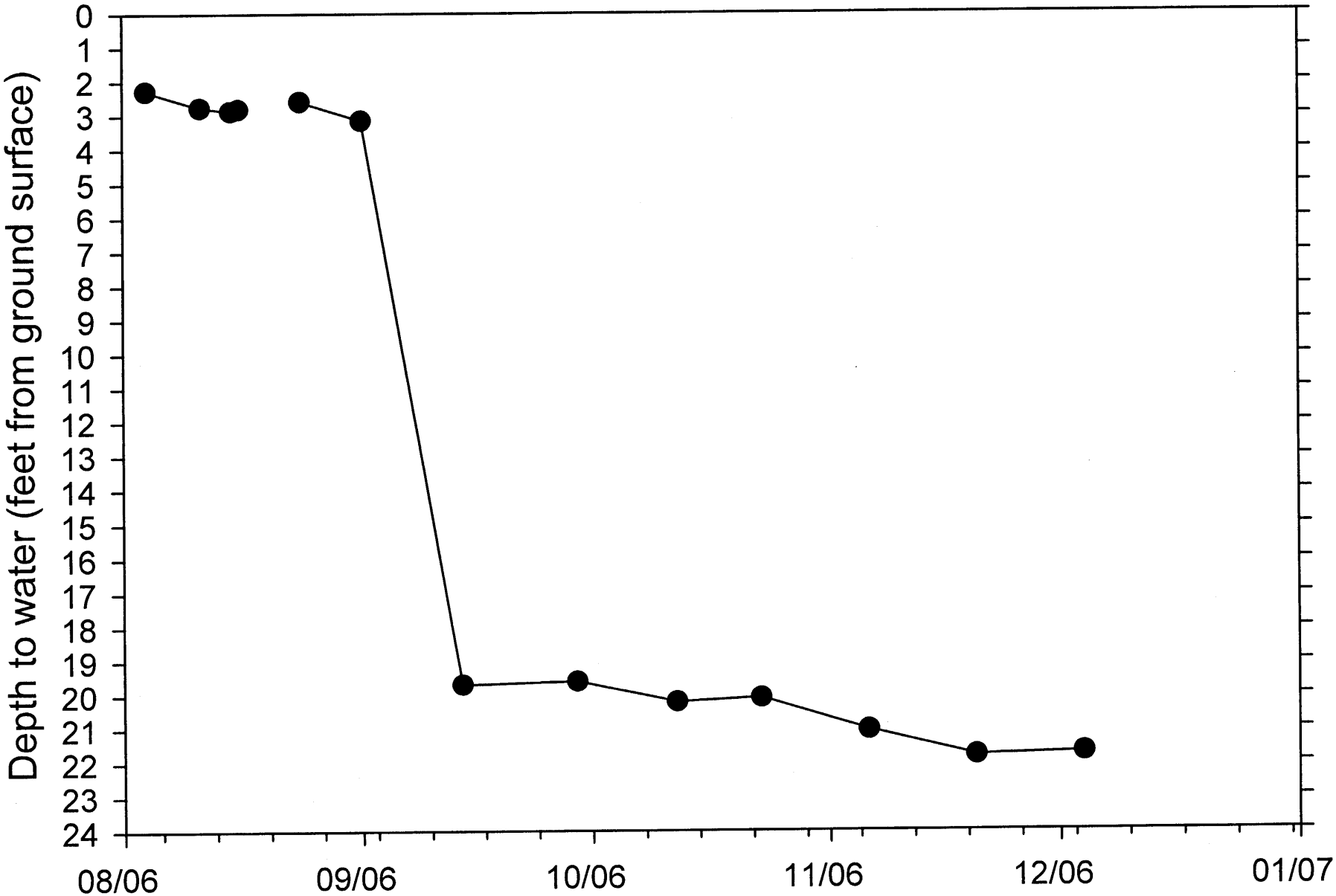
NWP-11


Depth to water (feet from ground surface)
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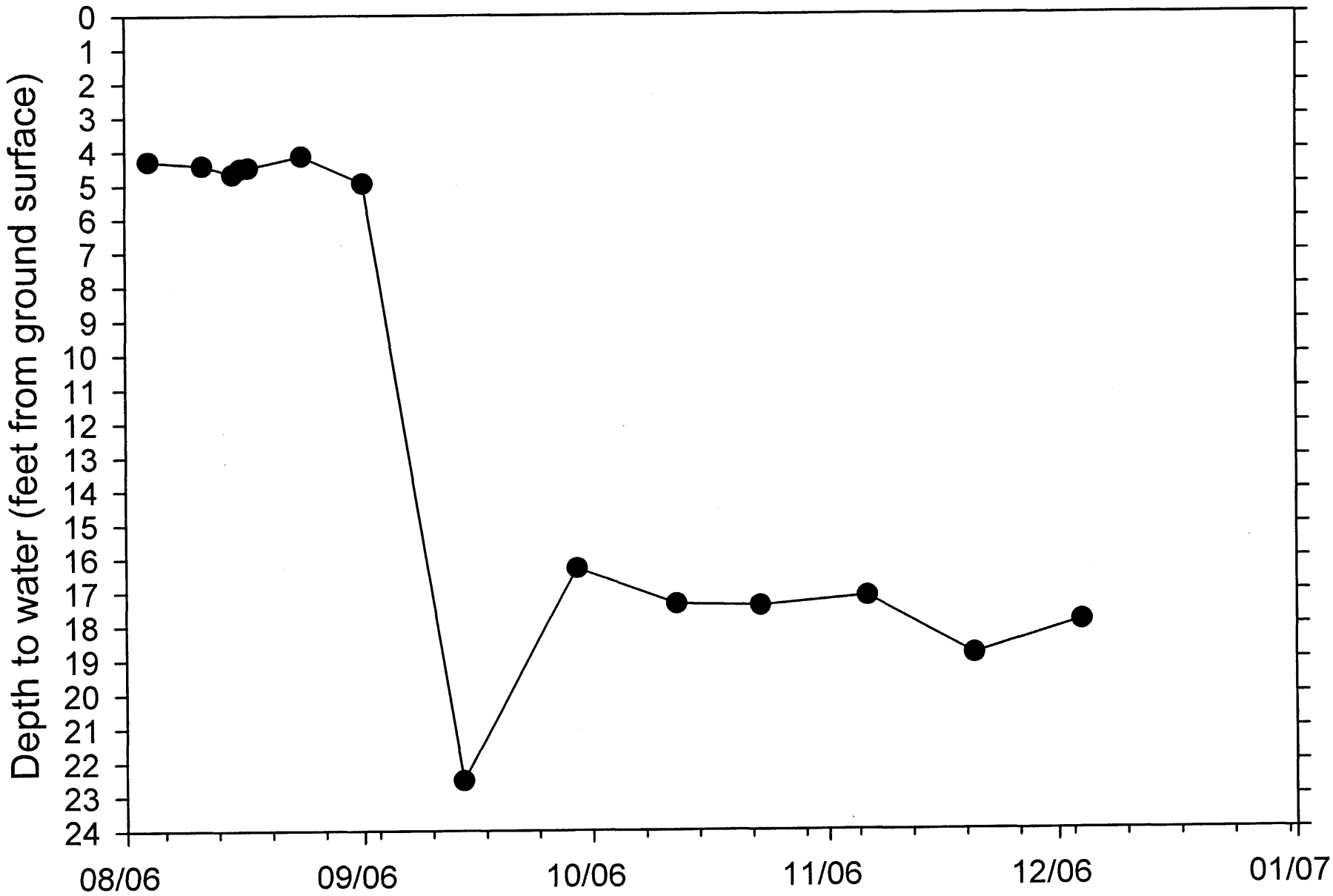
NWP-12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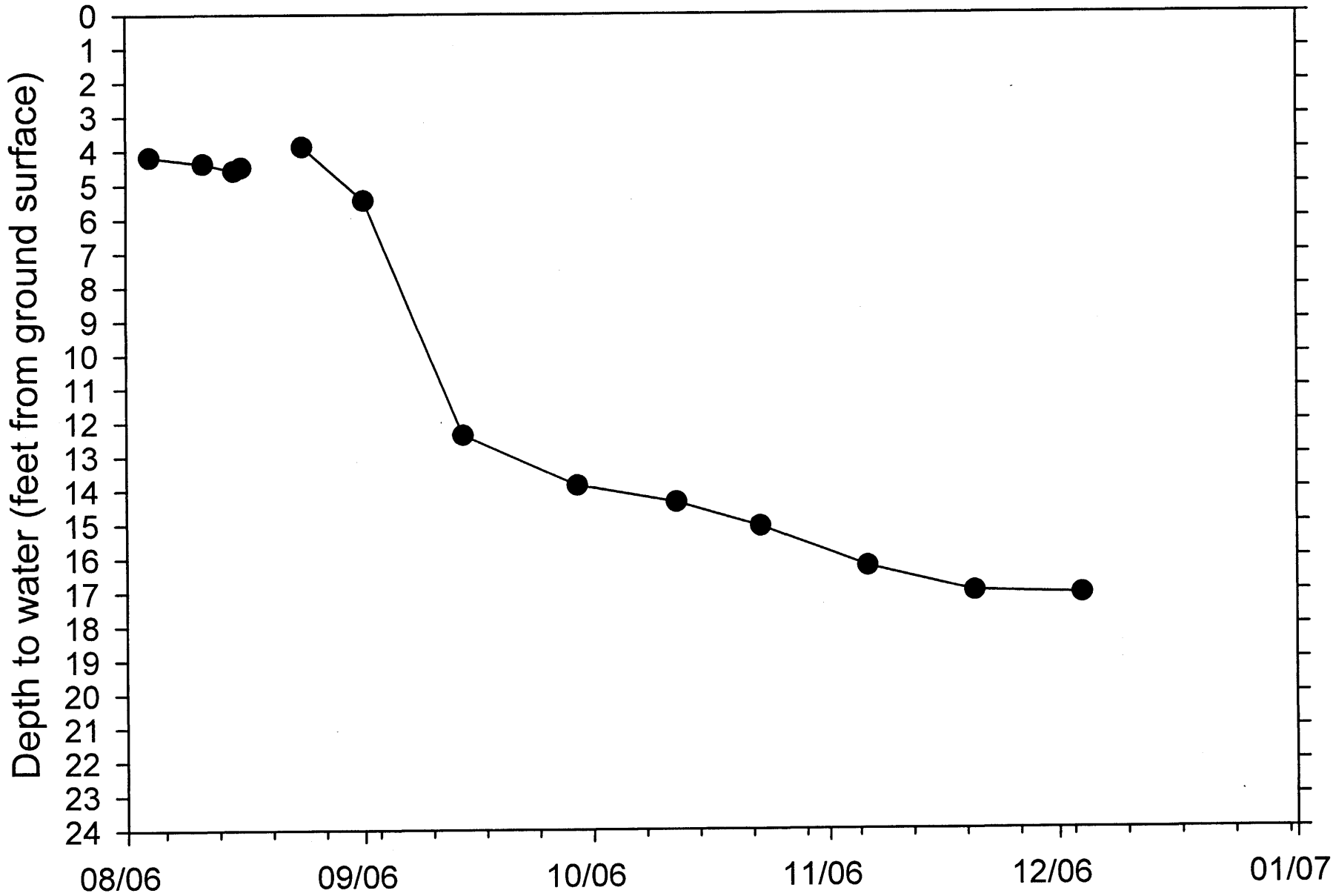
NWP-13


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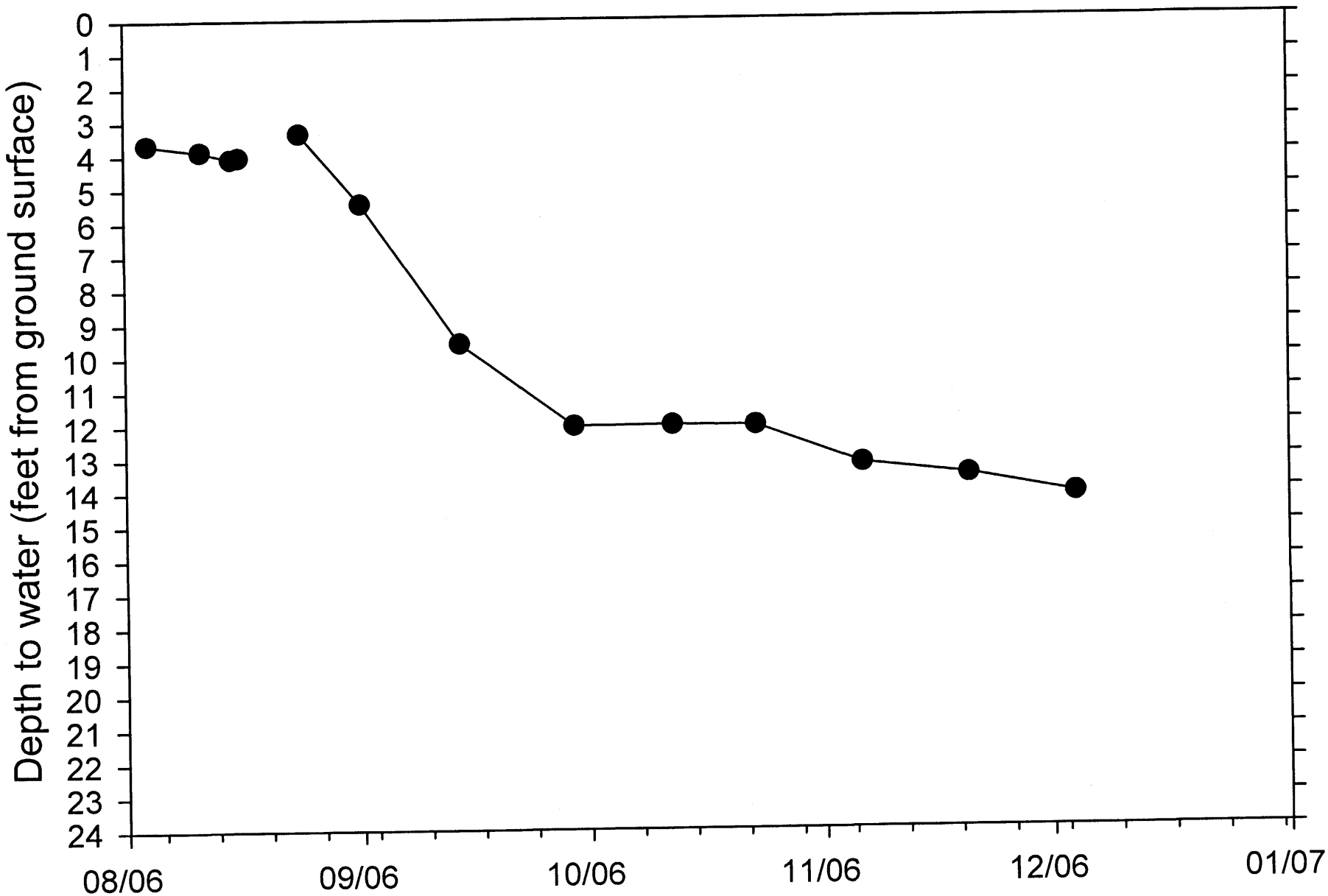
NWP-14


Depth to water (feet from ground surface)
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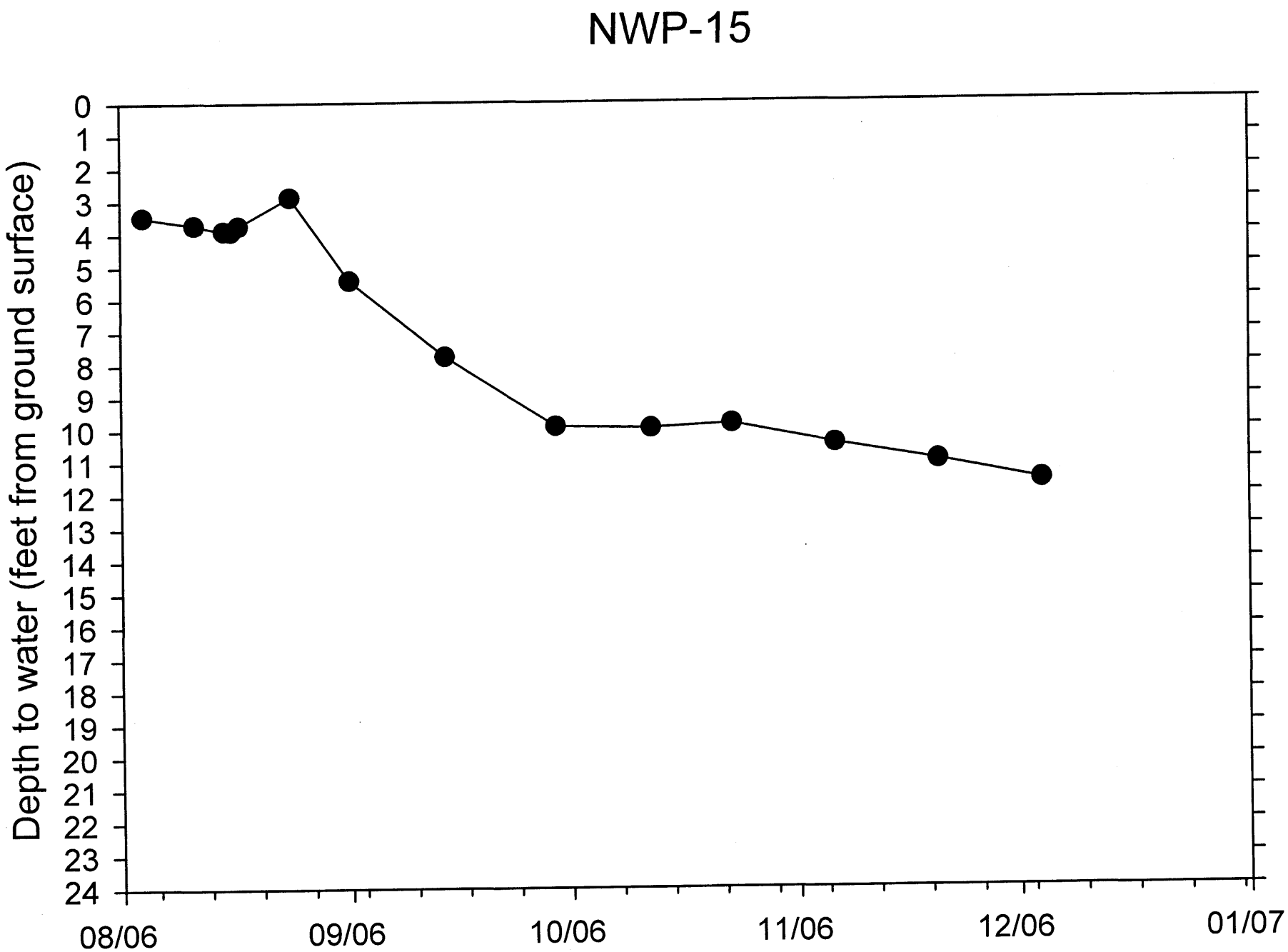
NWP-15
Depth to water (feet from ground surface)
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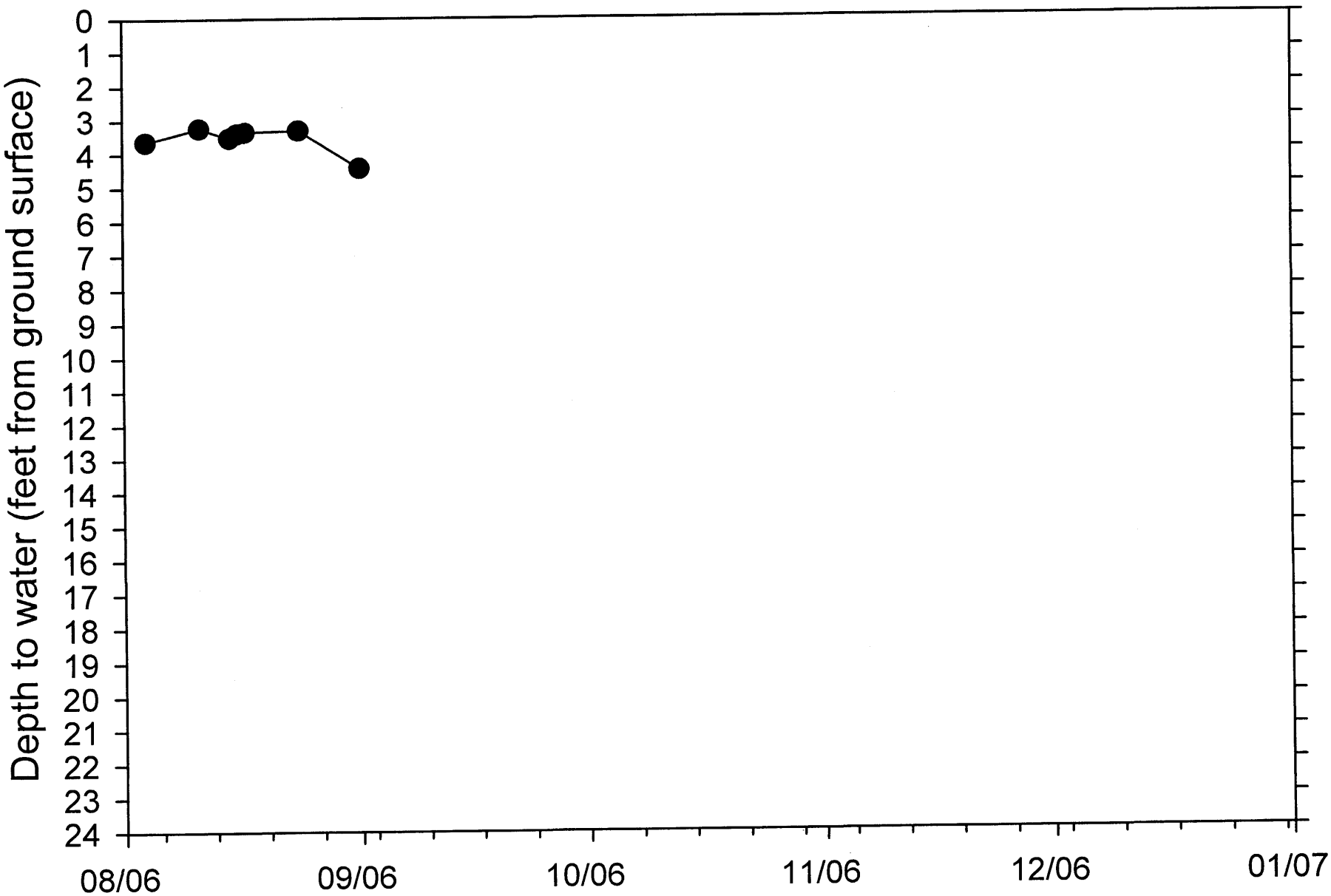
NWP-16


Depth to water (feet from ground surface)
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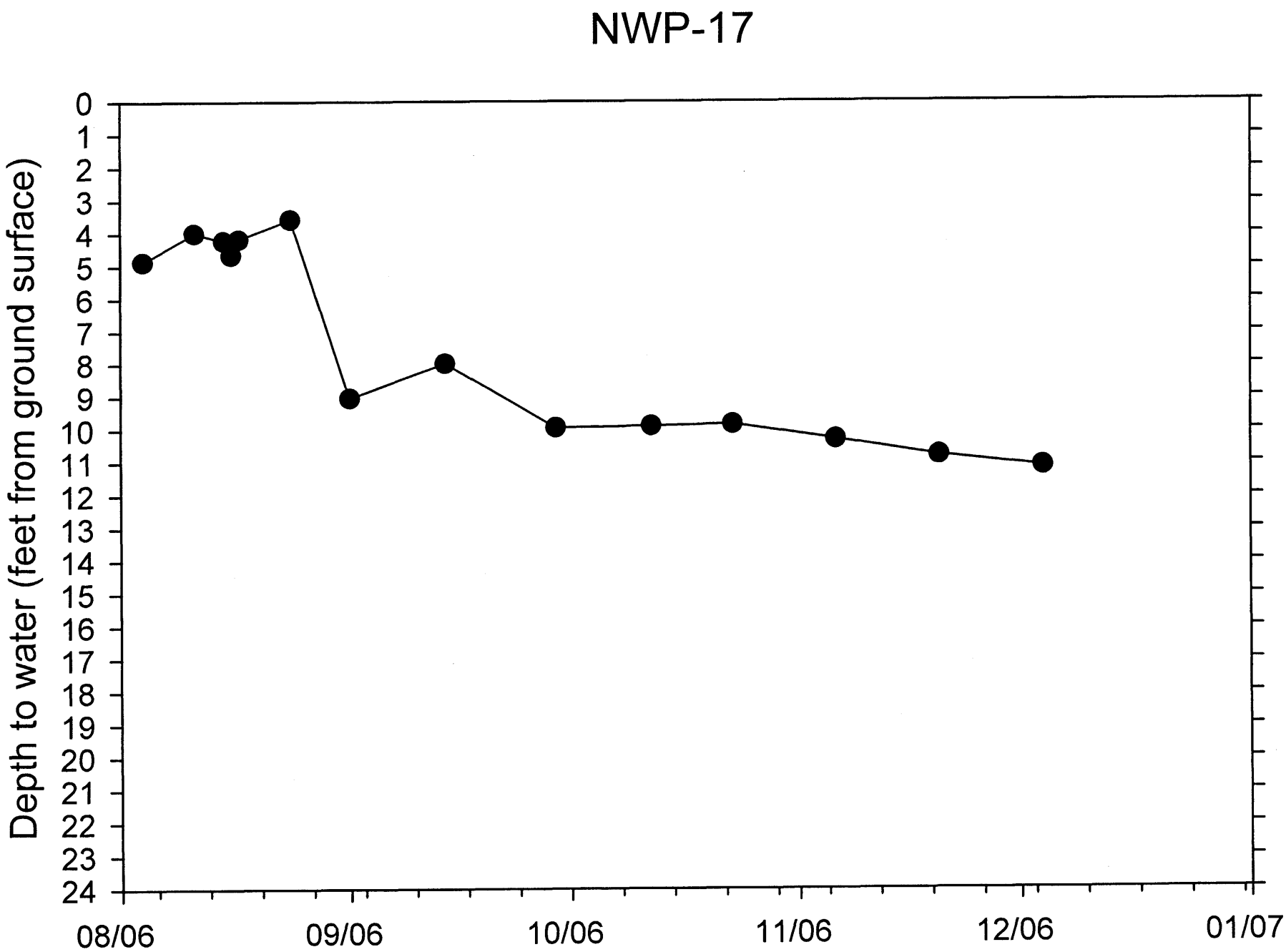
NWP-17
Depth to water (feet from ground surface)
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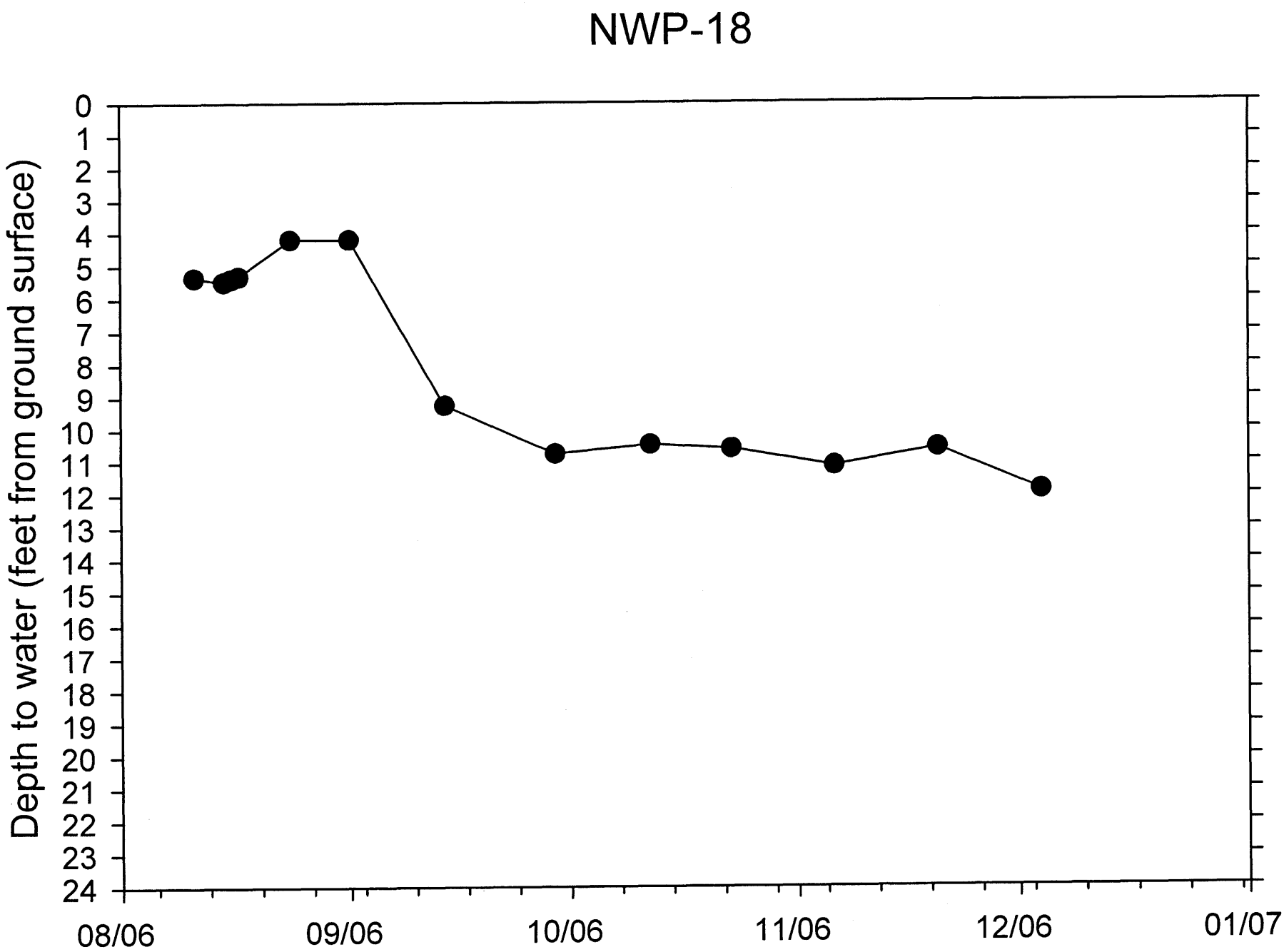
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Depth to water (feet from ground surface)
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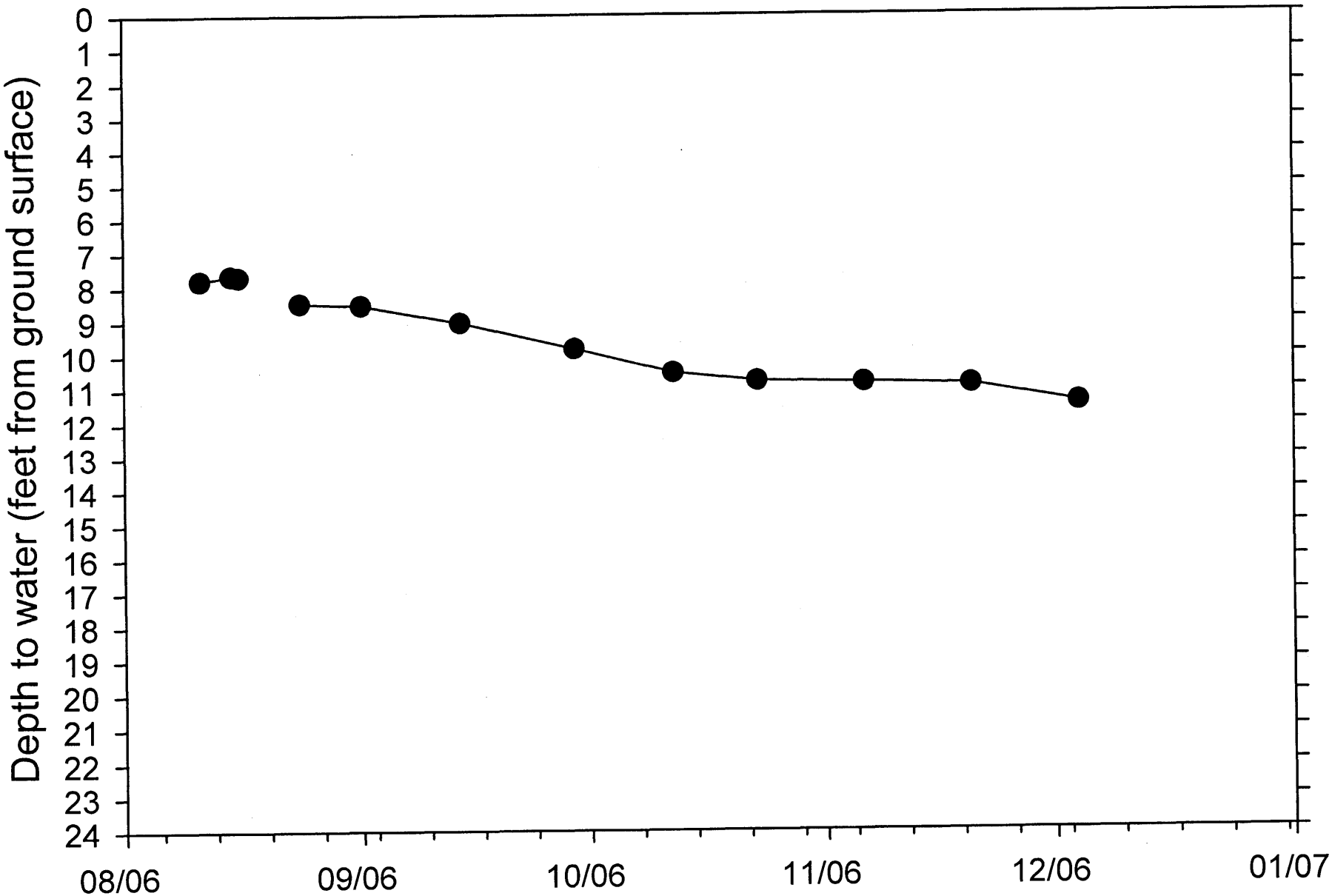
NWP-19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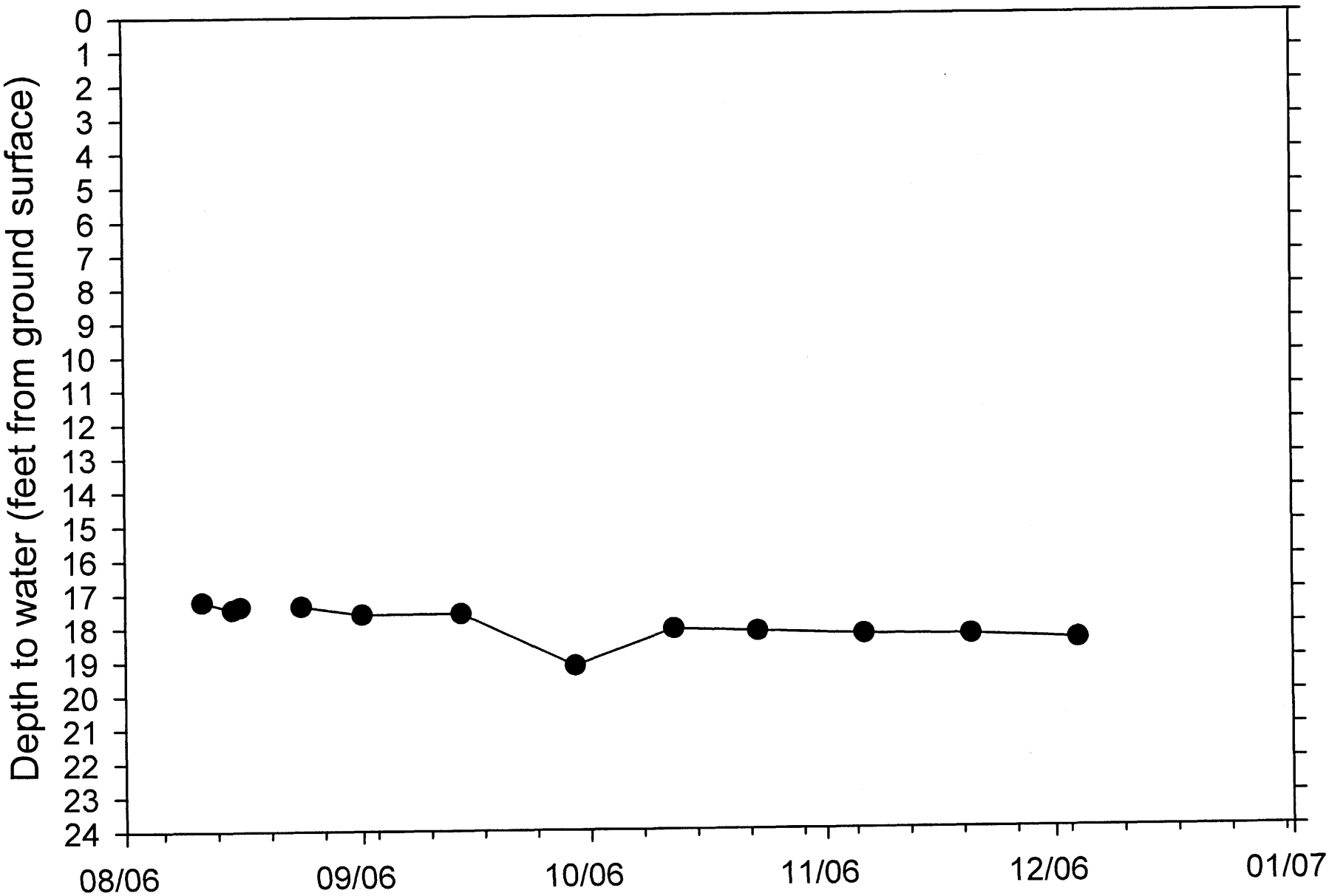
NWP-20


Depth to water (feet from ground surface)
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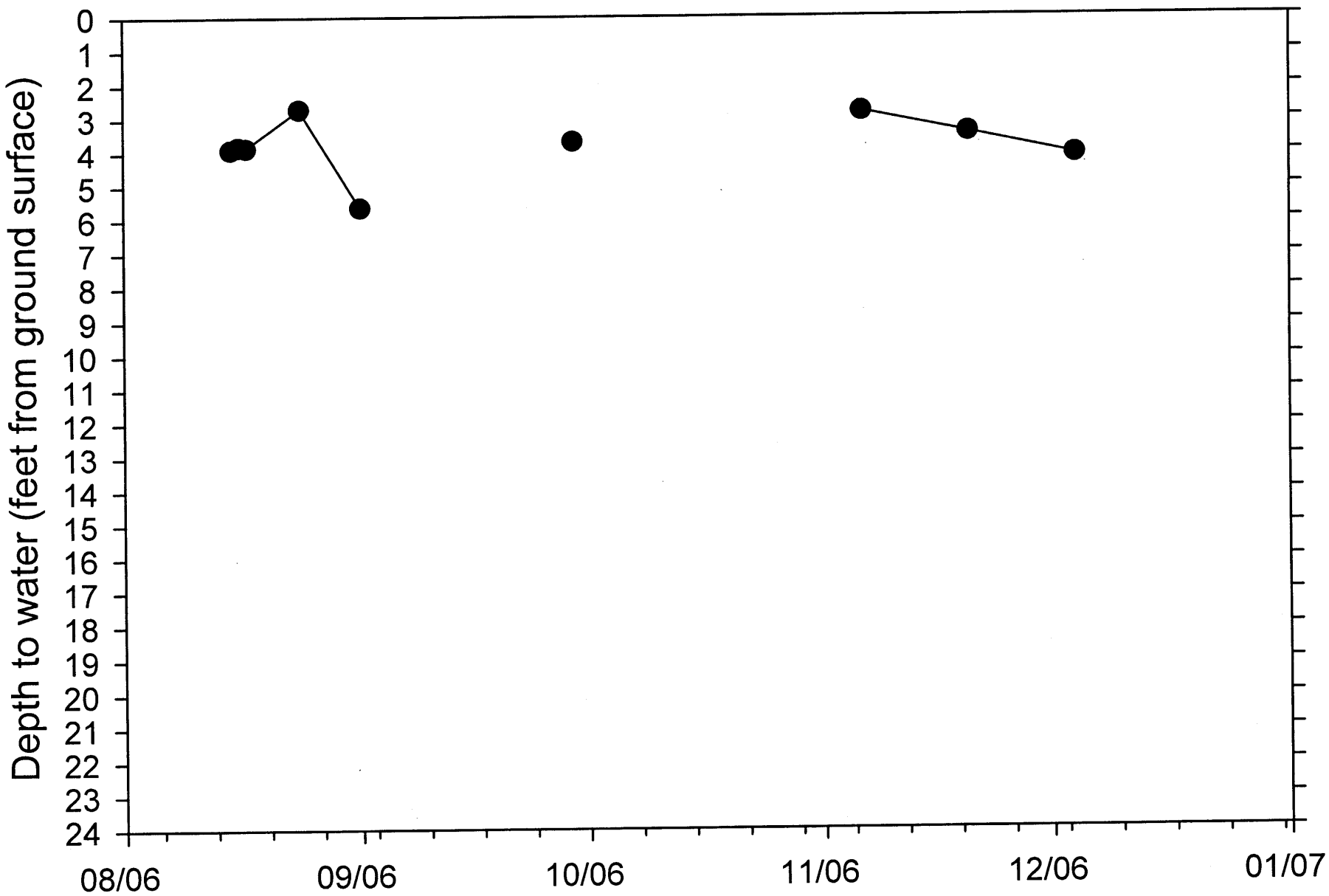
NWP-21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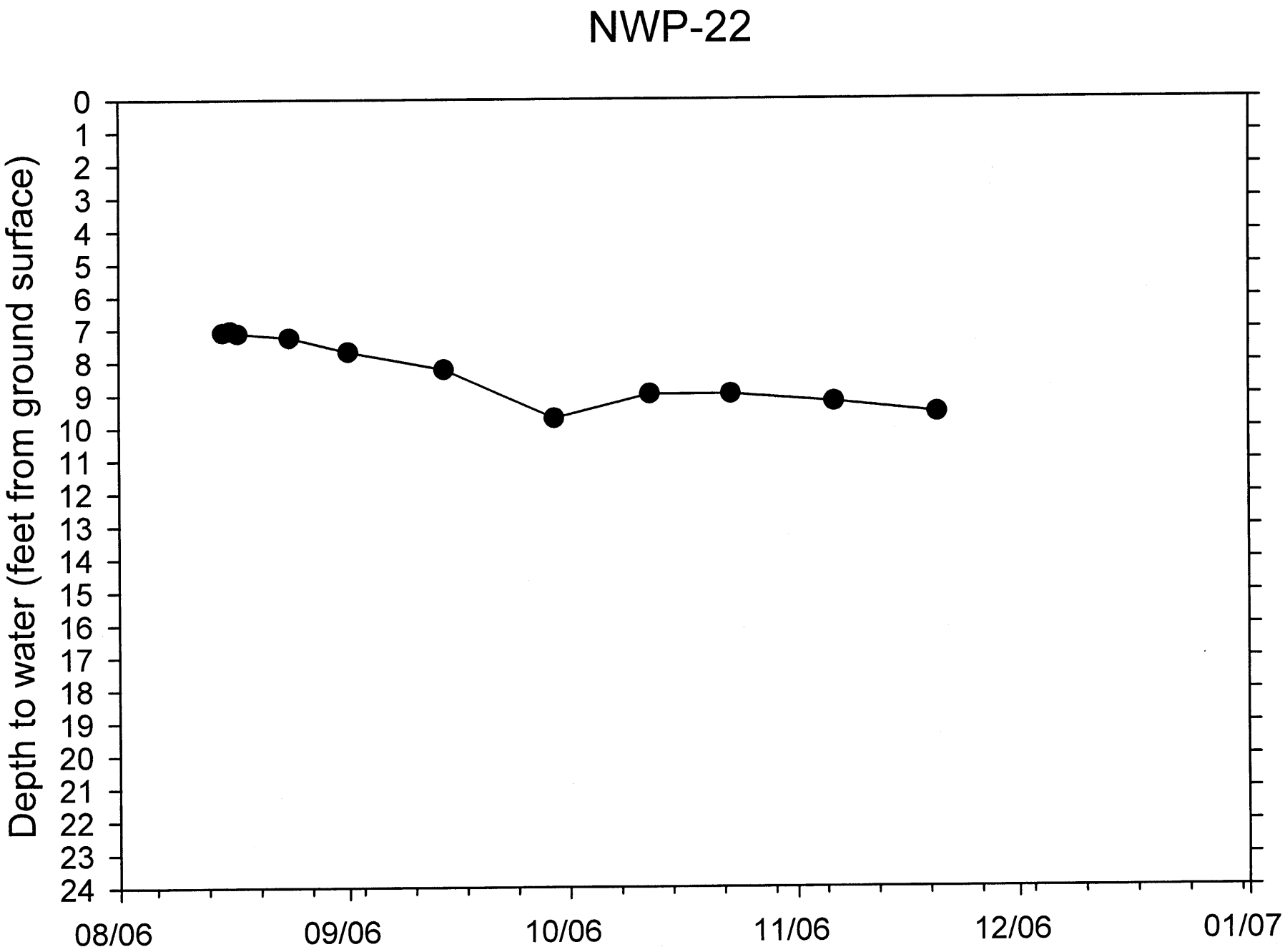
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Depth to water (feet from ground surface)
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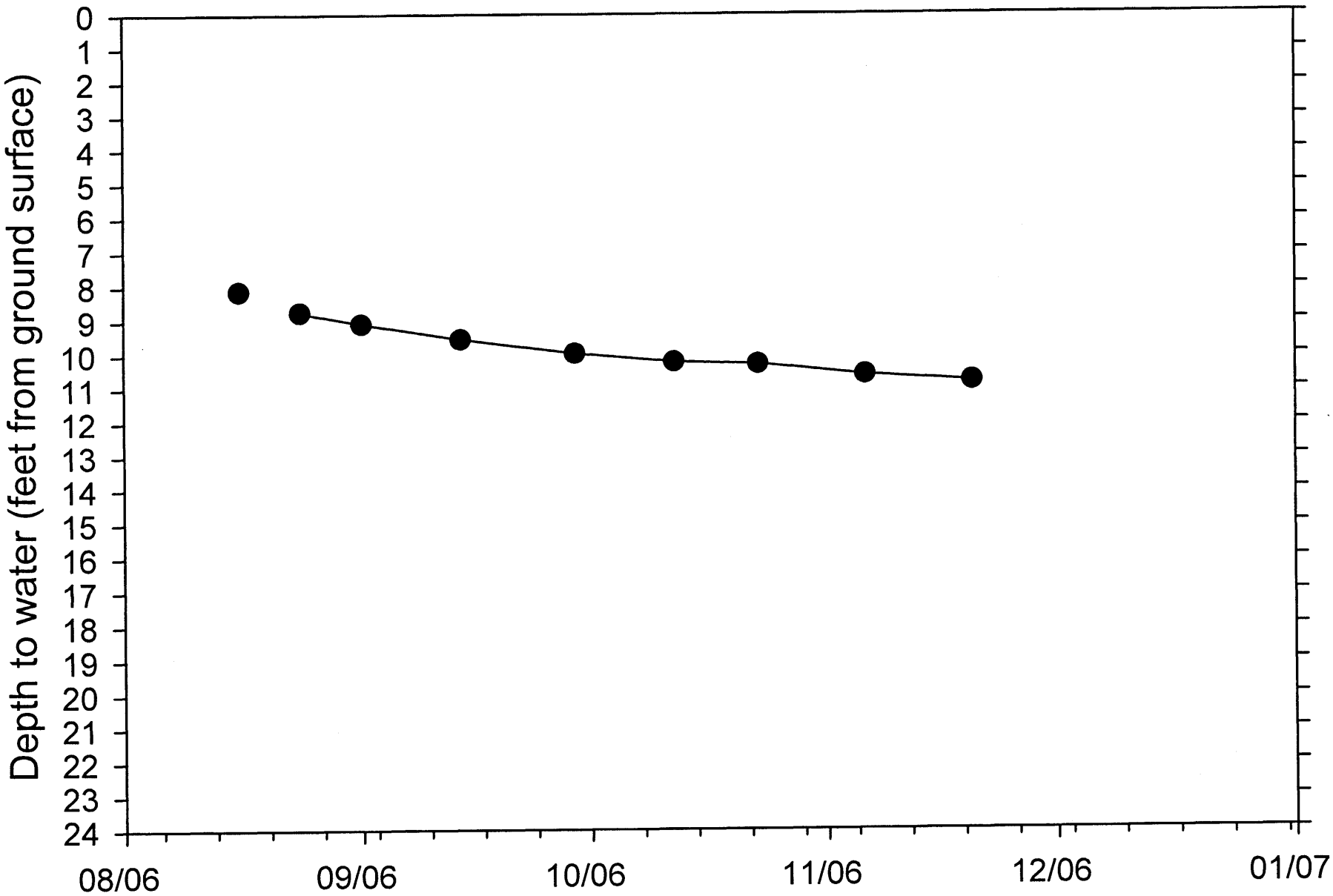
NWP-23


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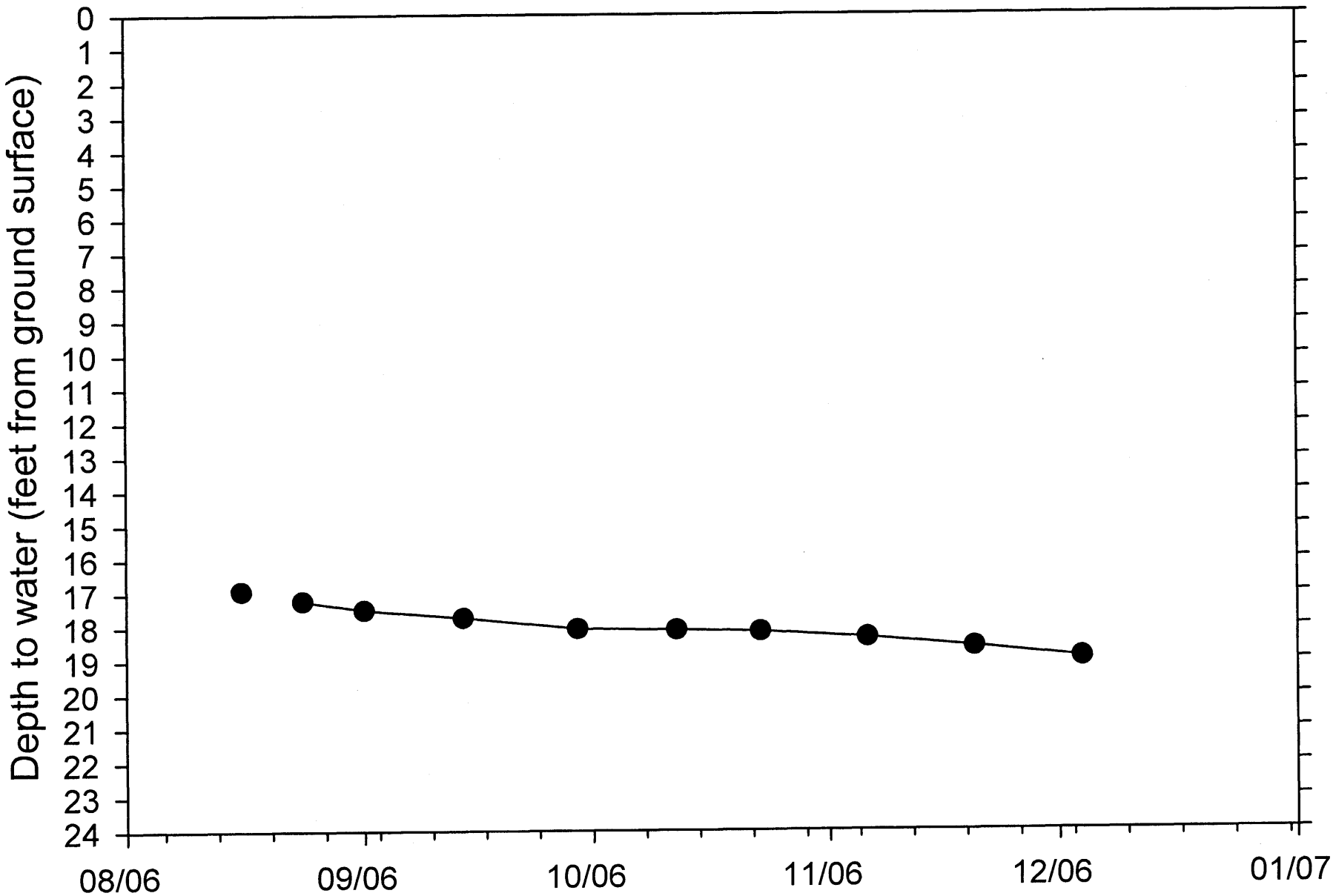
NWP-24


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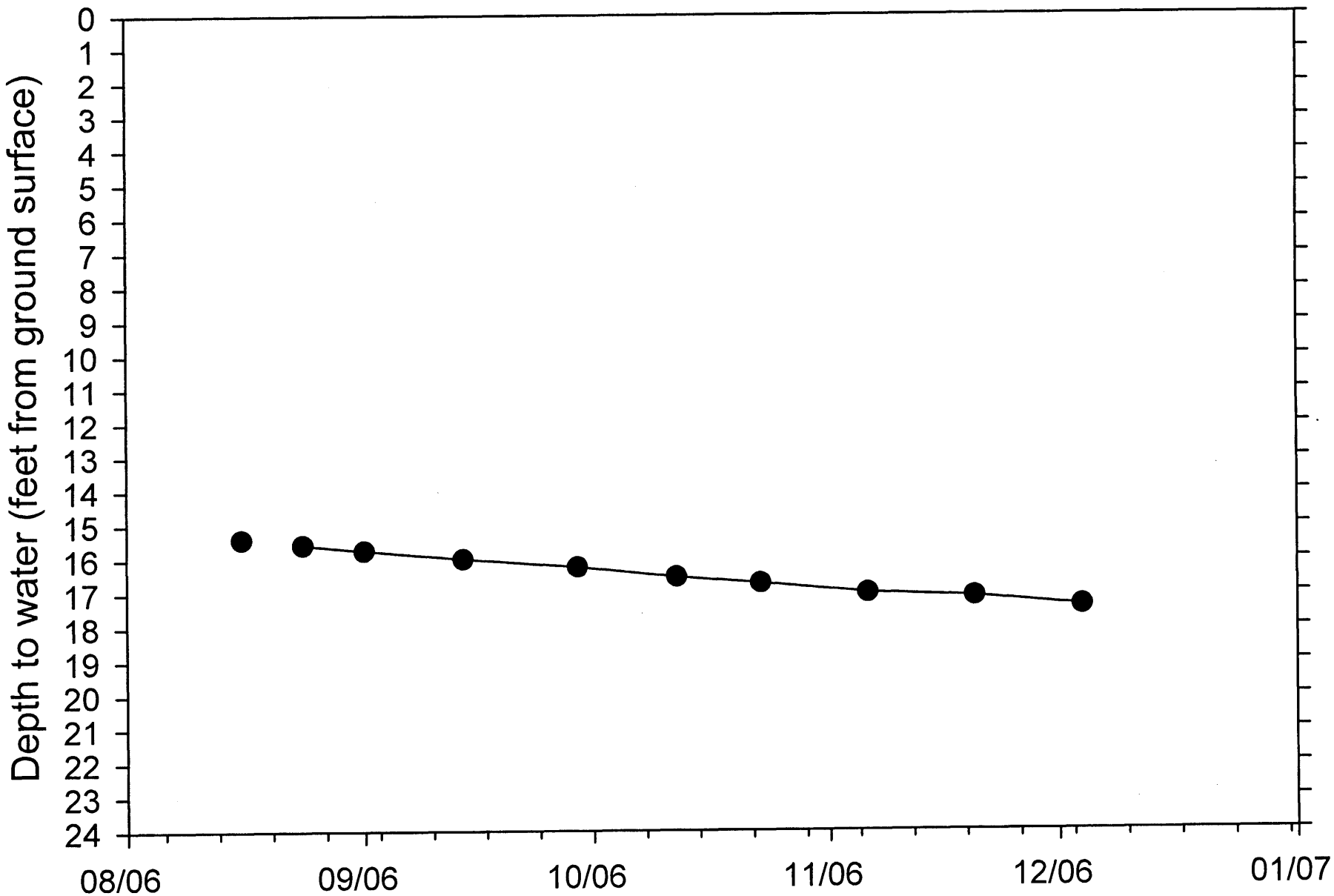
NWP-25


Depth to water (feet from ground surface)
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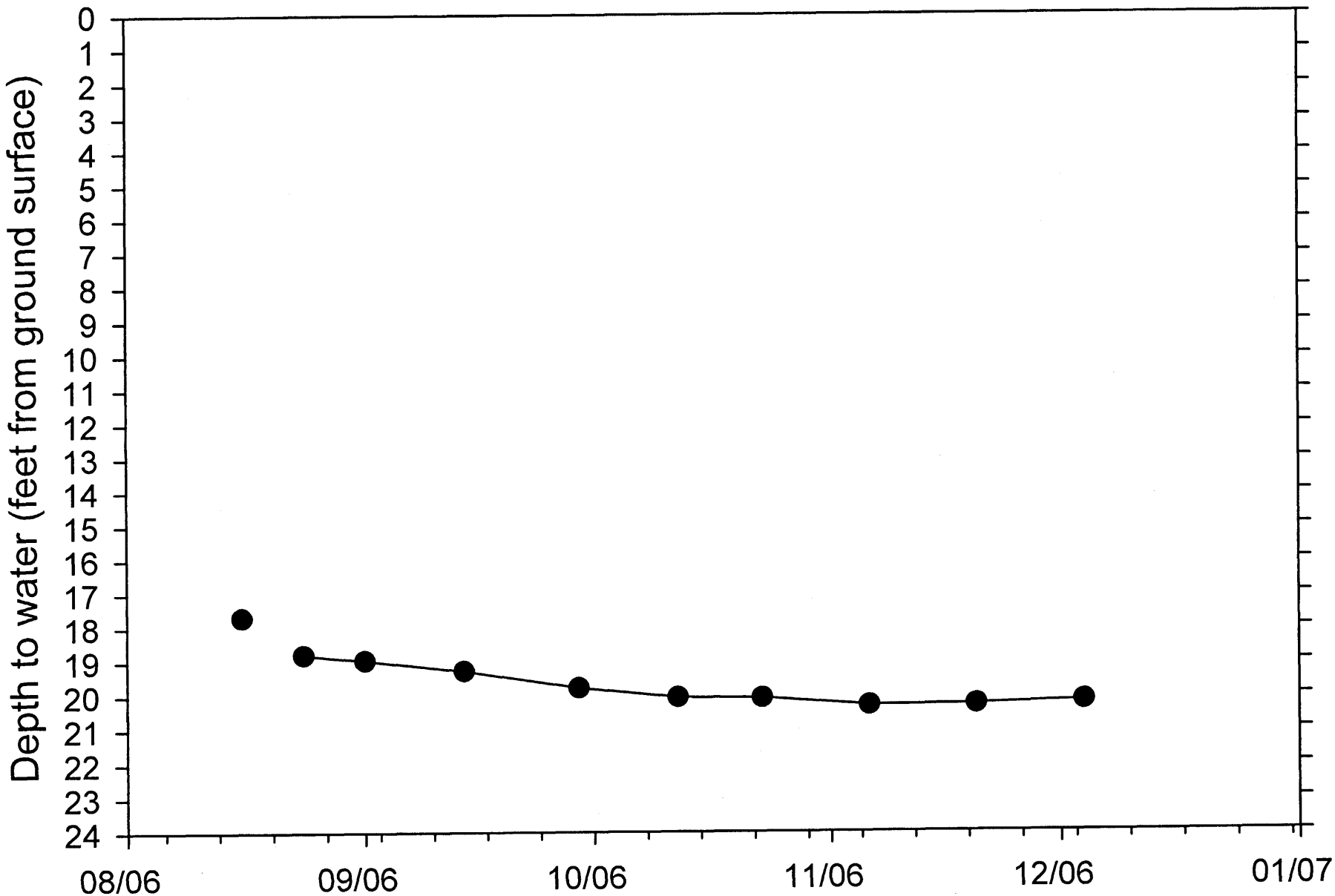
NWP-26


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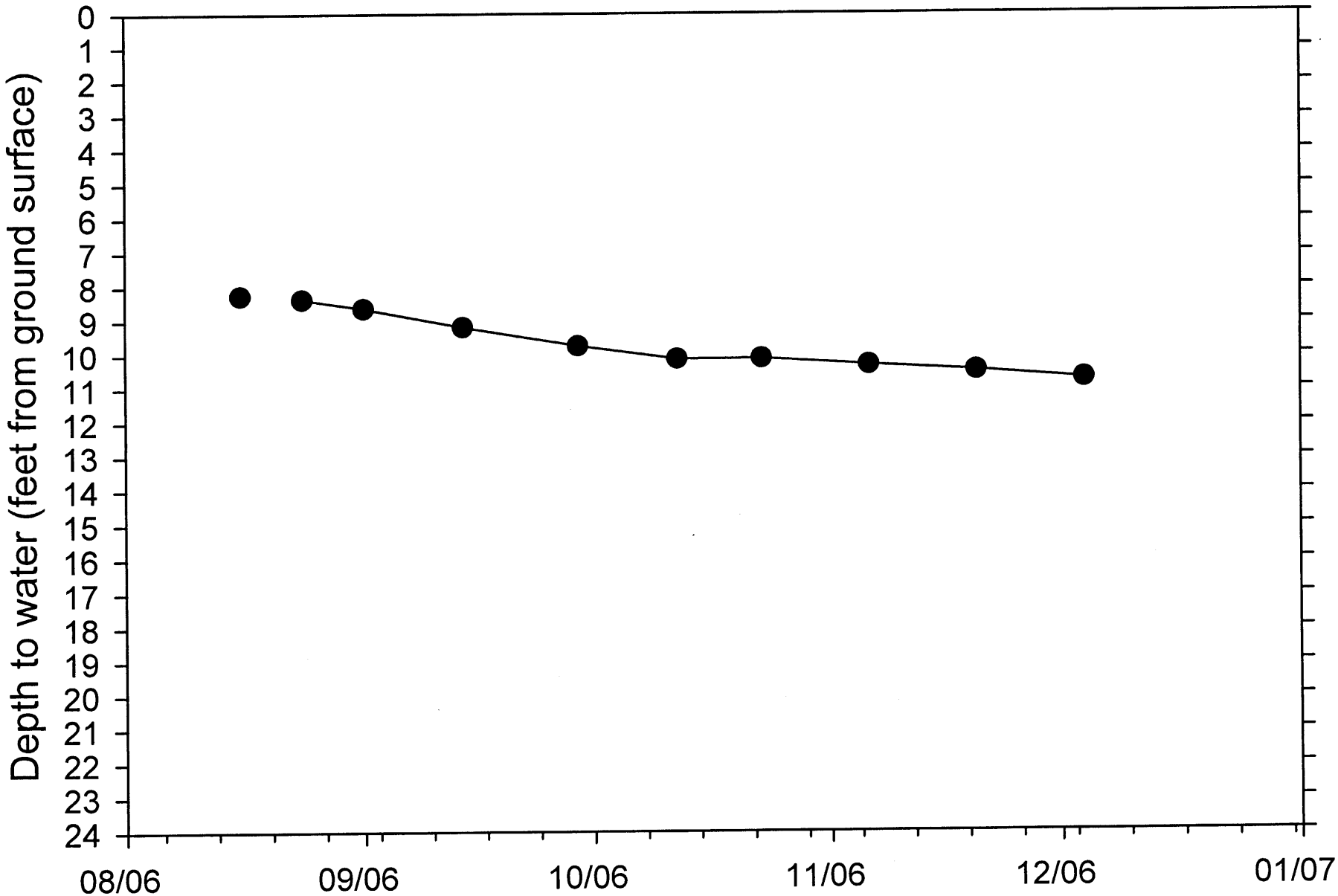
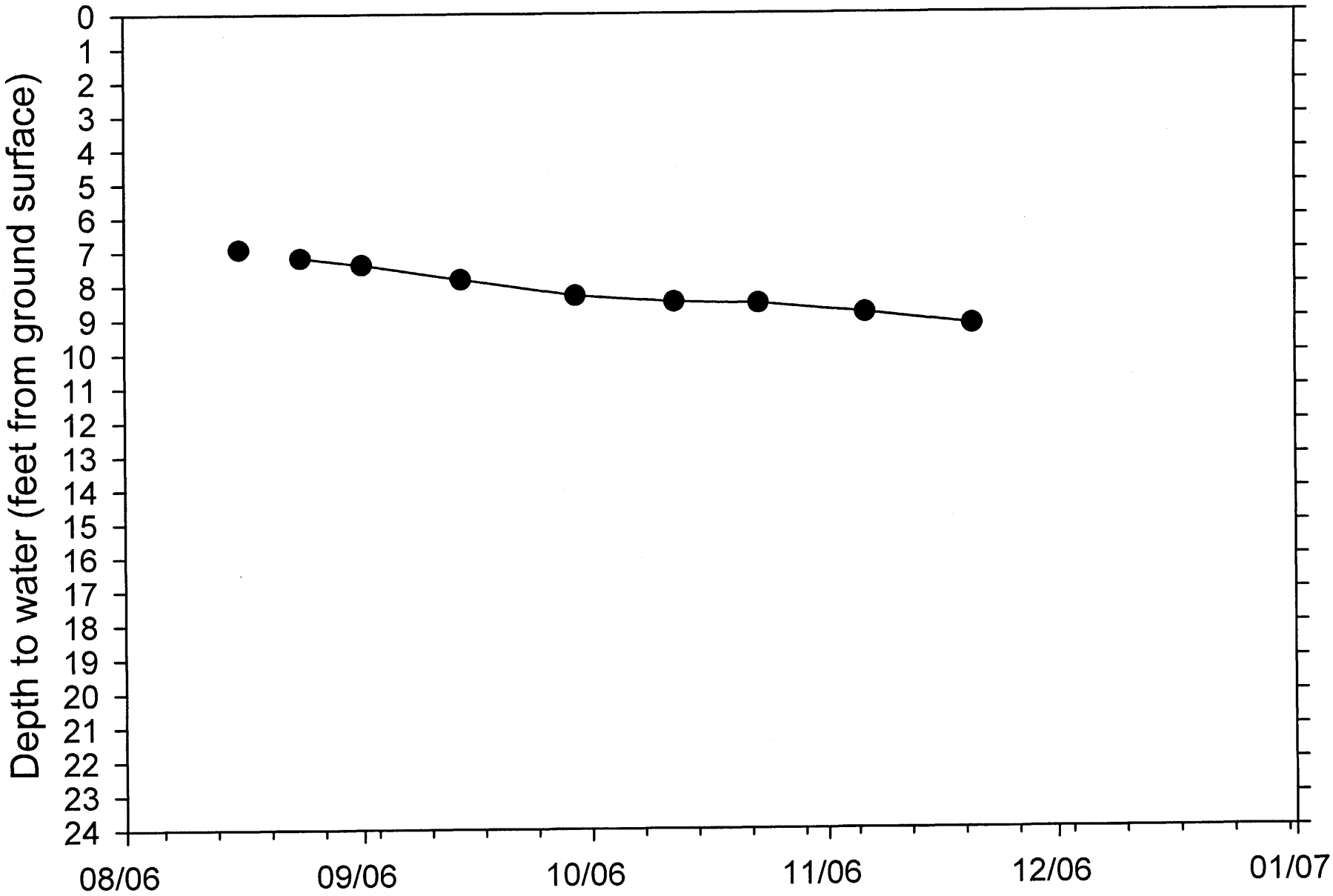
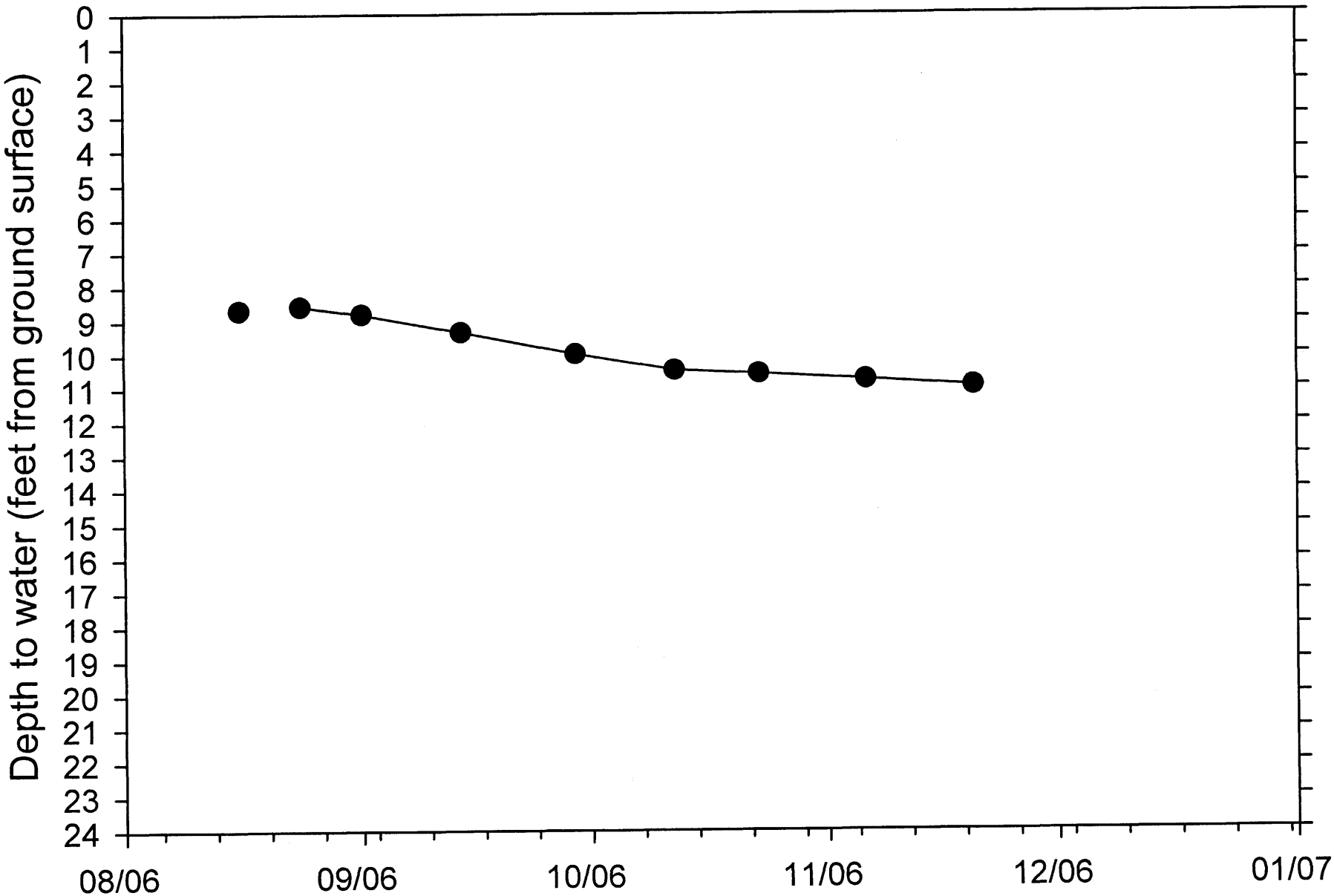
NWP-27


Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

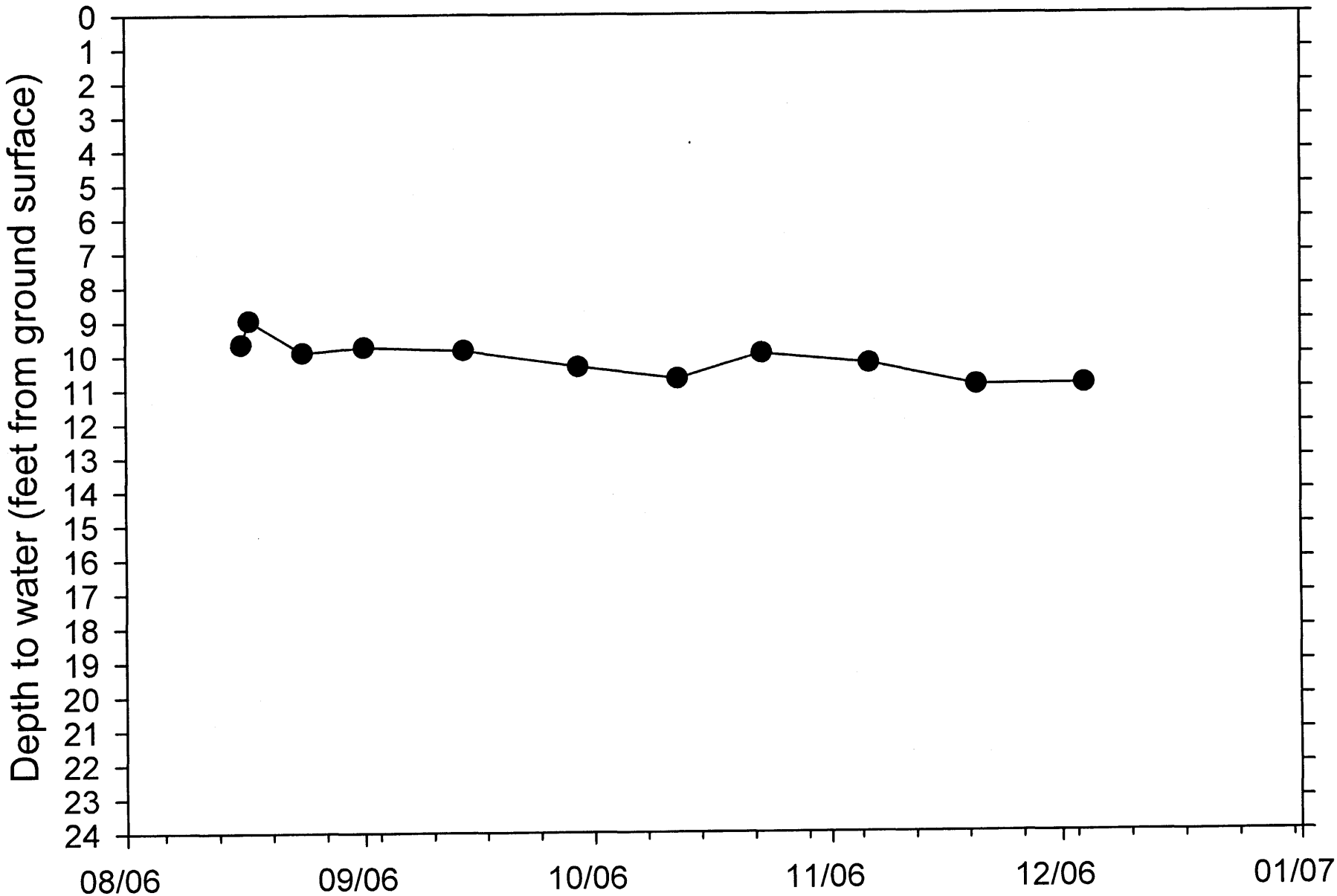
NWP-28 Shallow



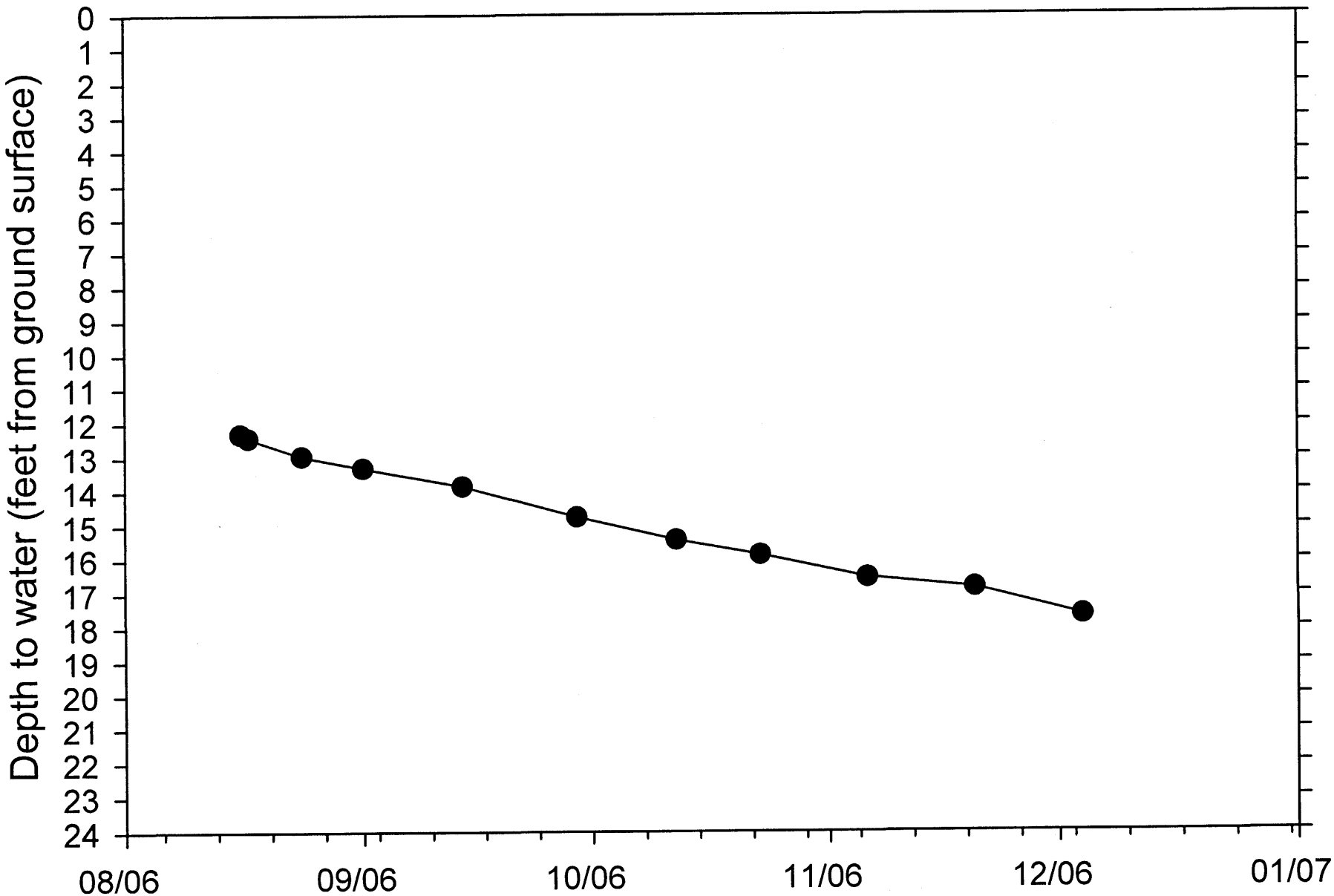
NWP-28 Deep

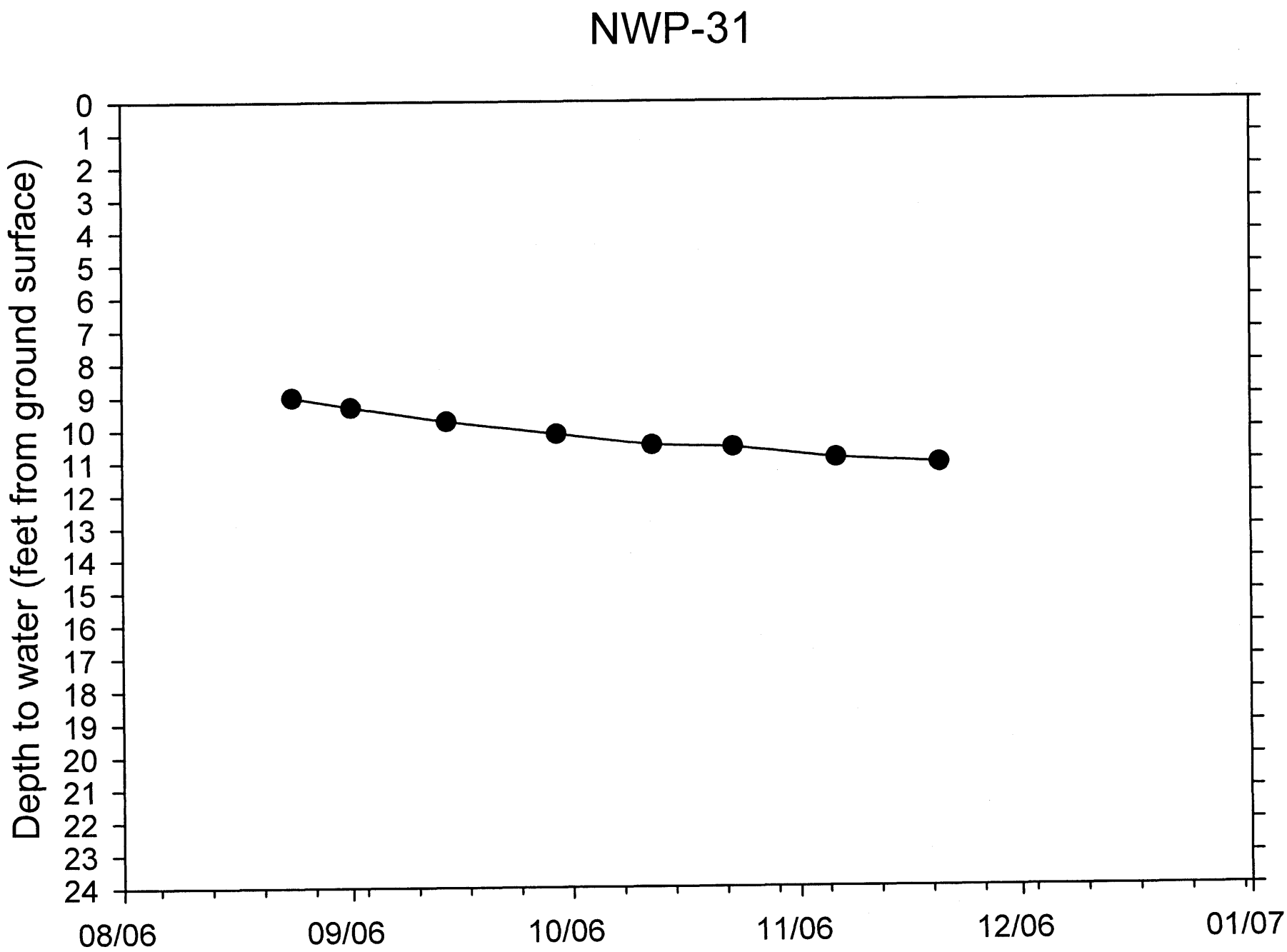

Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

NWP-29

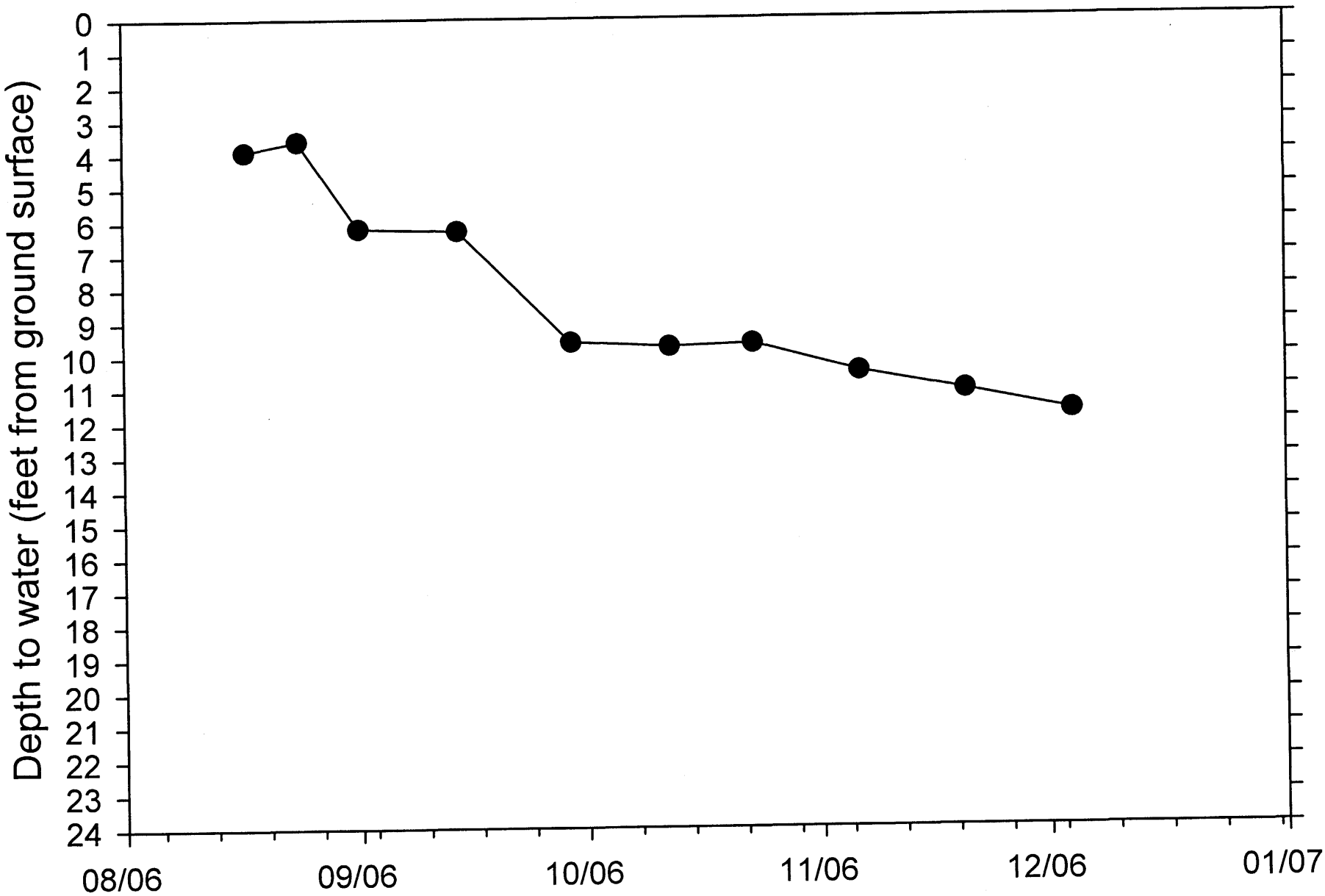

Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

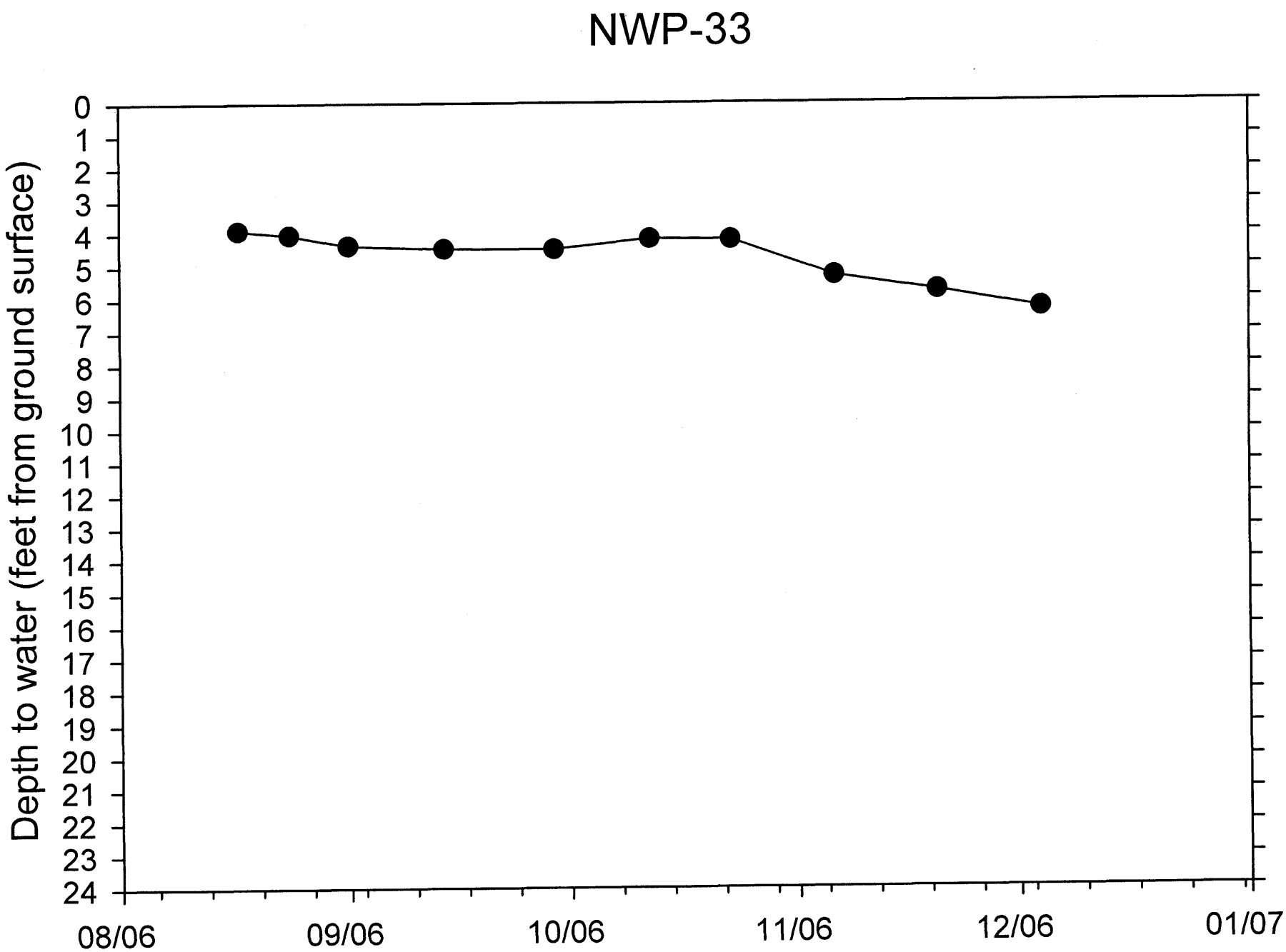
NWP-30


Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

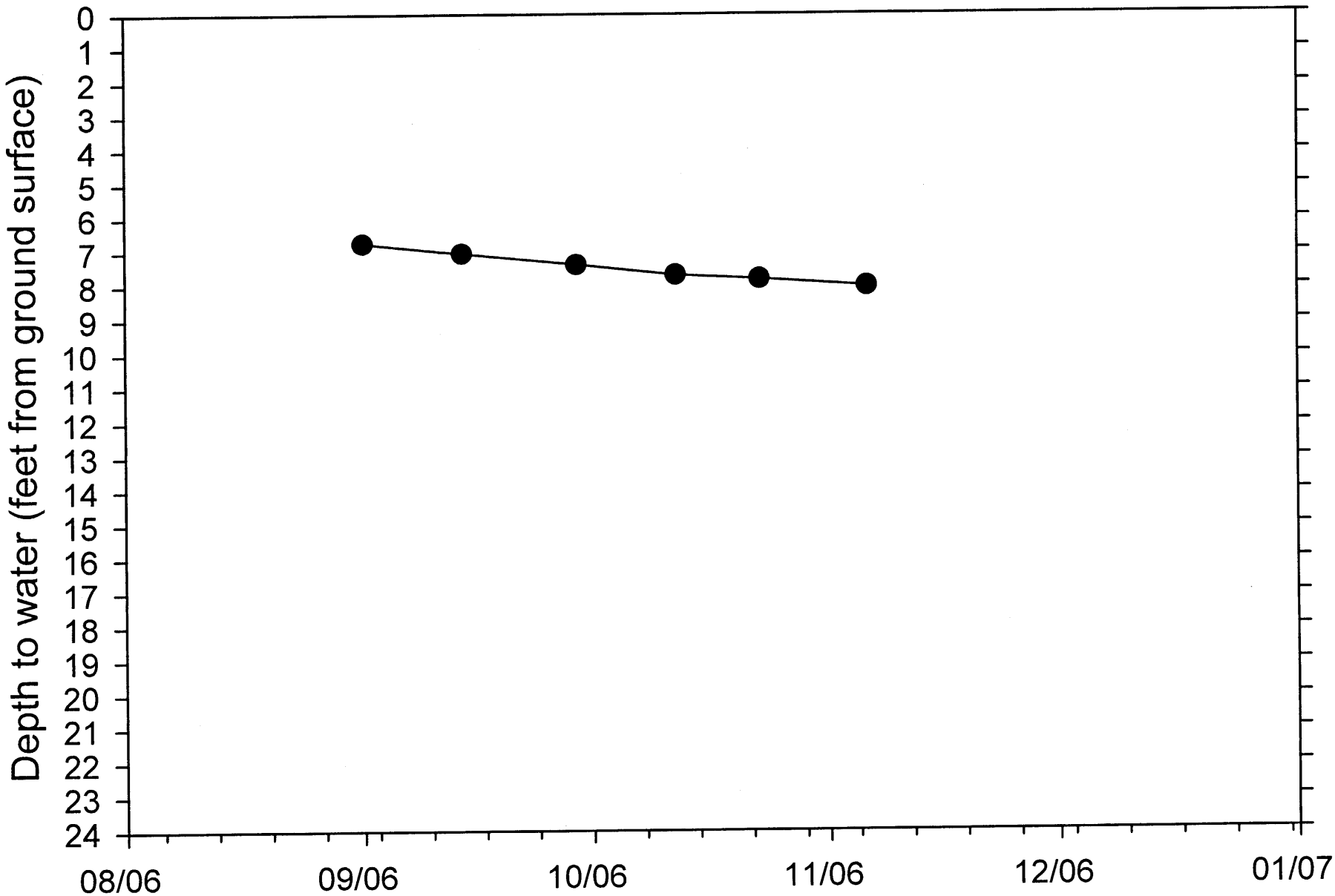

NWP-31
Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

NWP-32

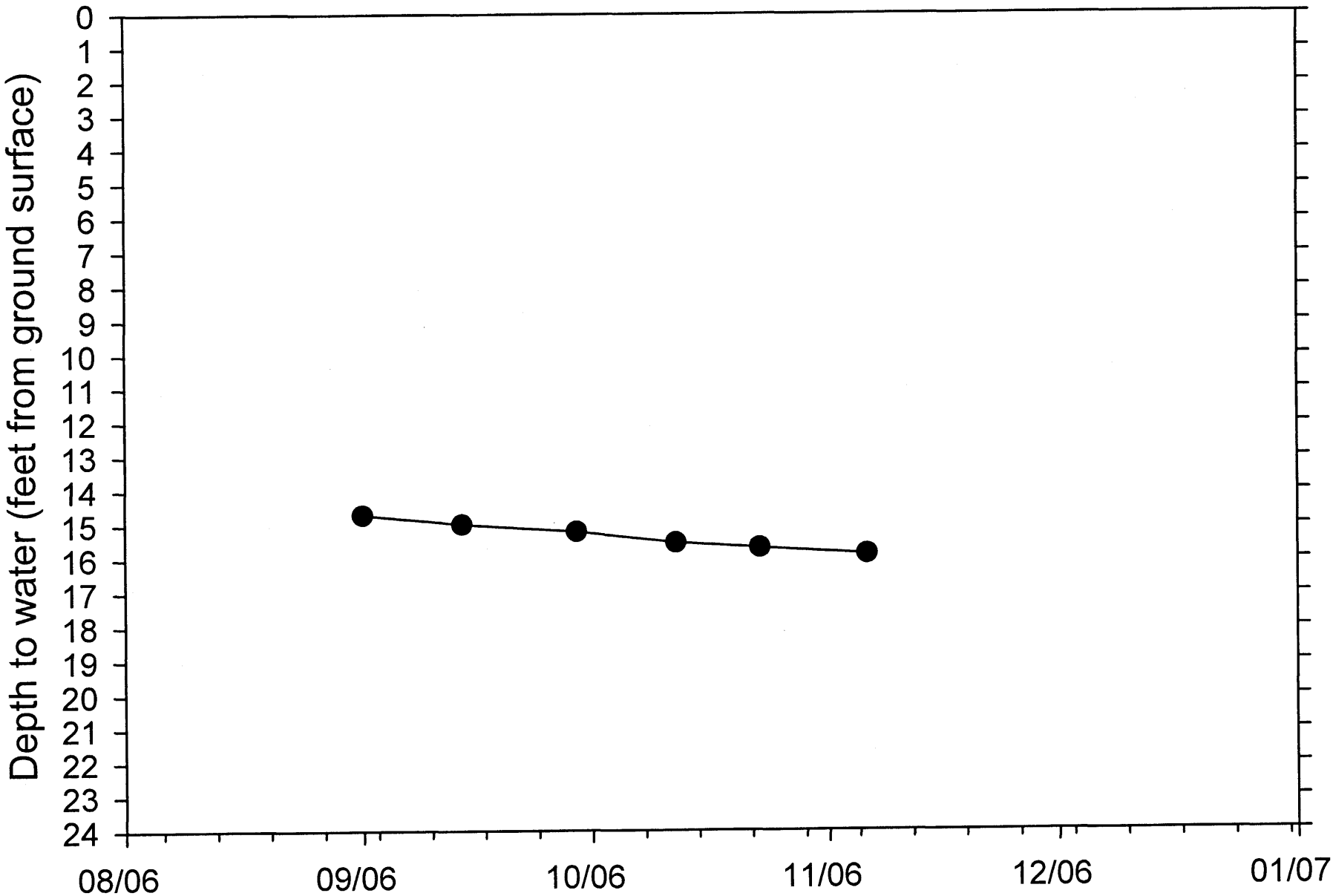

Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

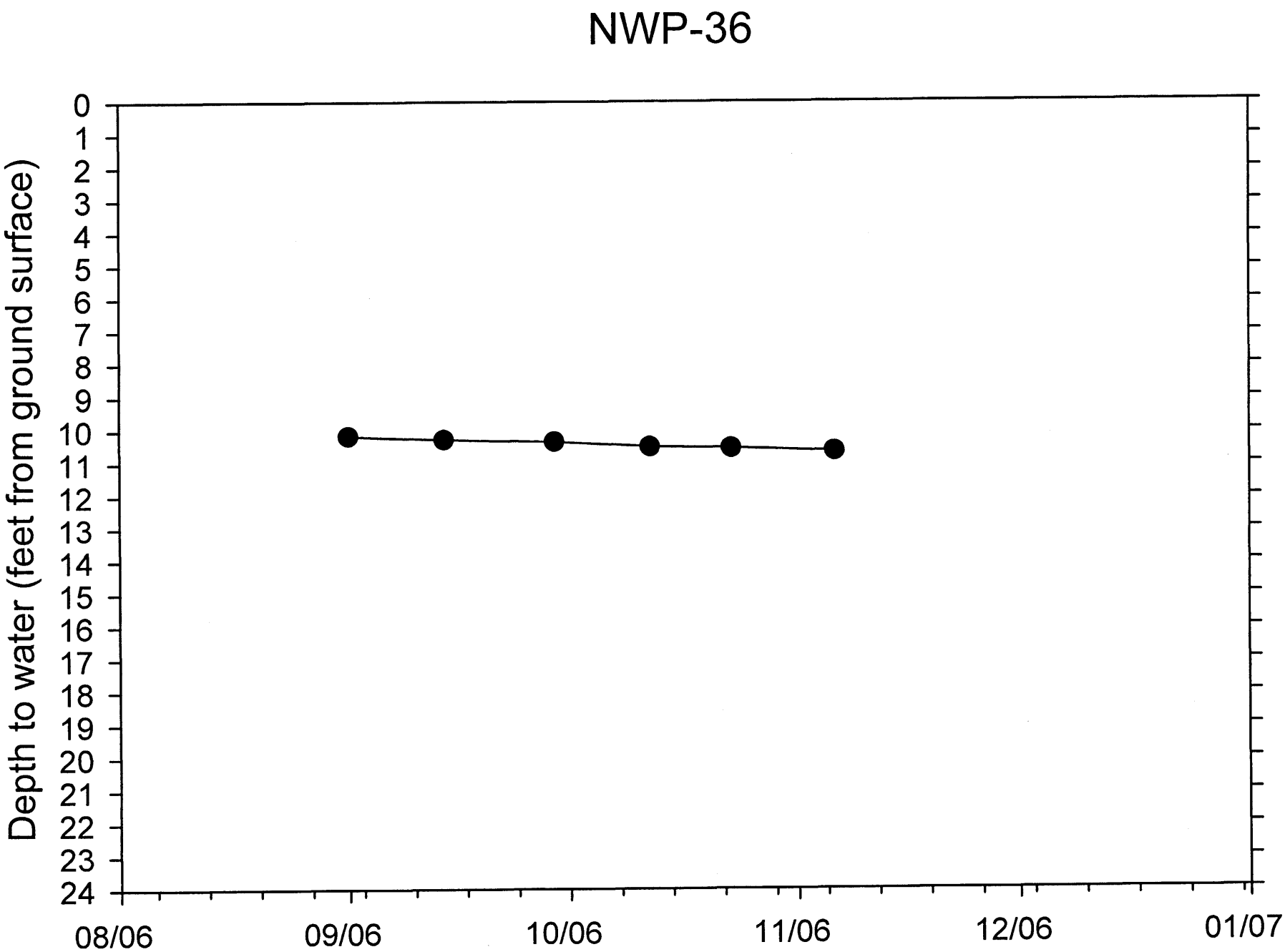

NWP-33
Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

NWP-34


Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

NWP-35

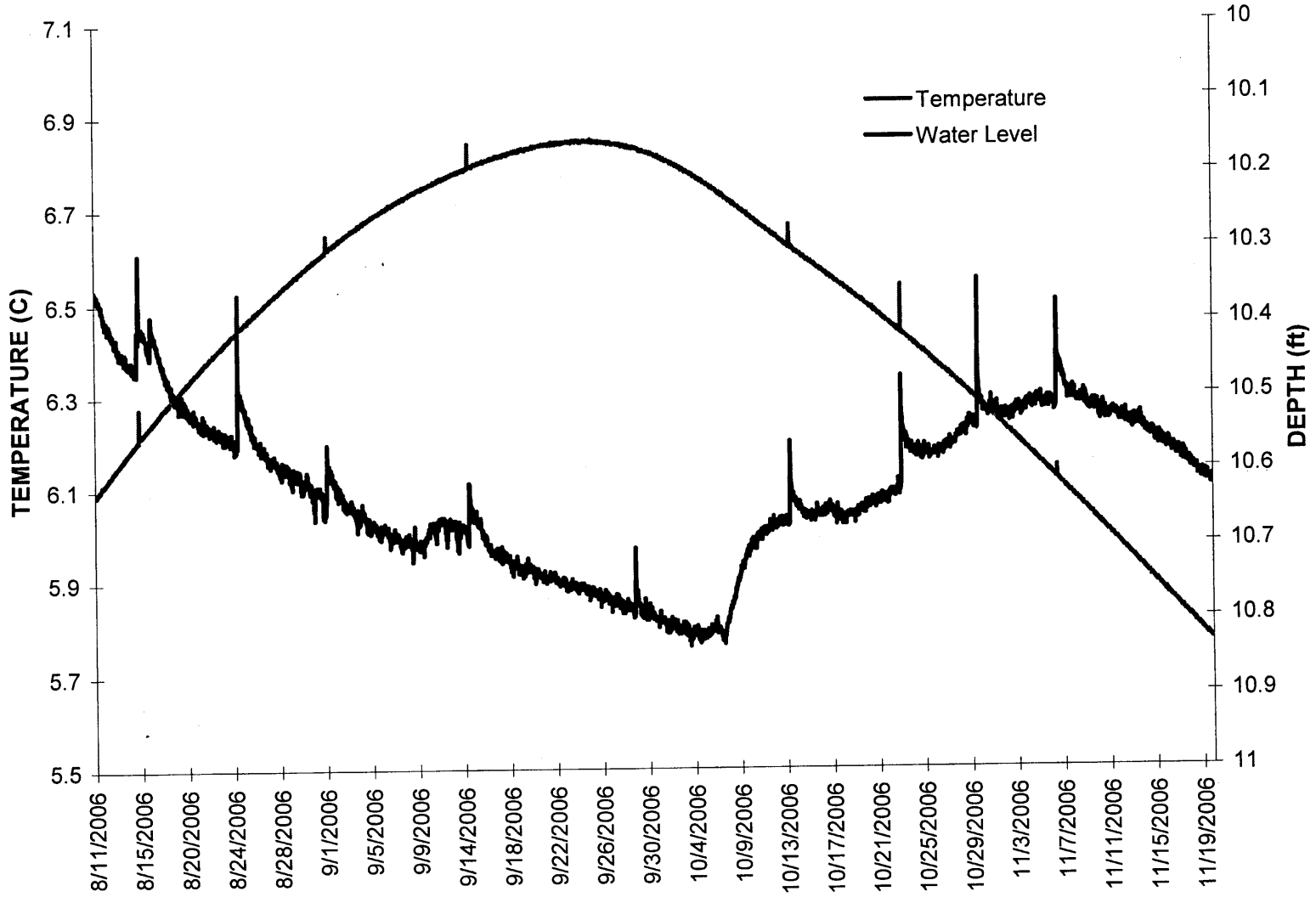

Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07


NWP-36
Depth to water (feet from ground surface)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
08/06
09/06
10/06
11/06
12/06
01/07

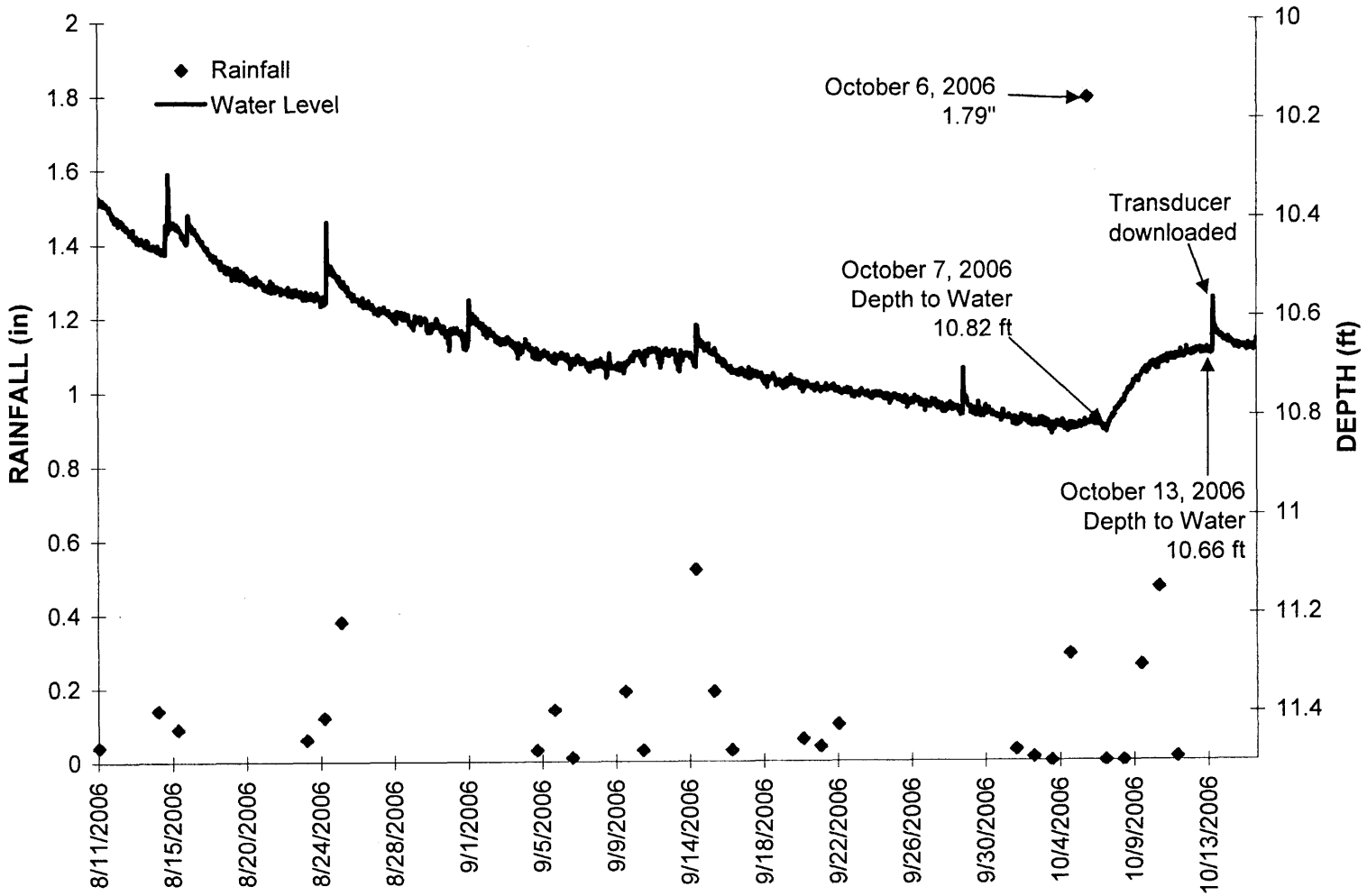
Appendix B

Transducer water level data for piezometers/wells

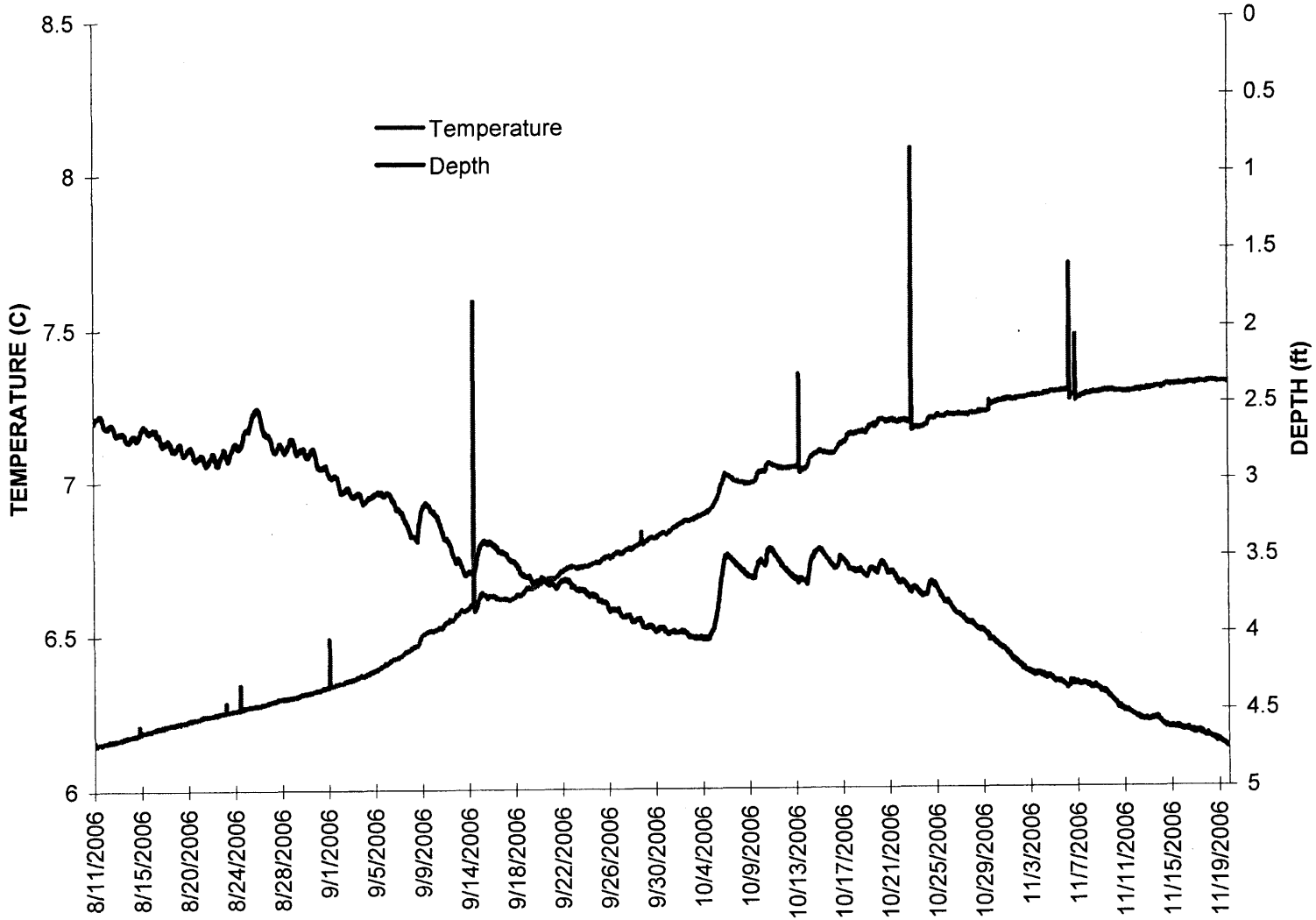
NWP-3


Temperature
Water Level
TEMPERATURE (C)
DEPTH (ft)
7.1
6.9
6.7
6.5
6.3
6.1
5.9
5.7
5.5
10
10.1
10.2
10.3
10.4
10.5
10.6
10.7
10.8
10.9
11
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

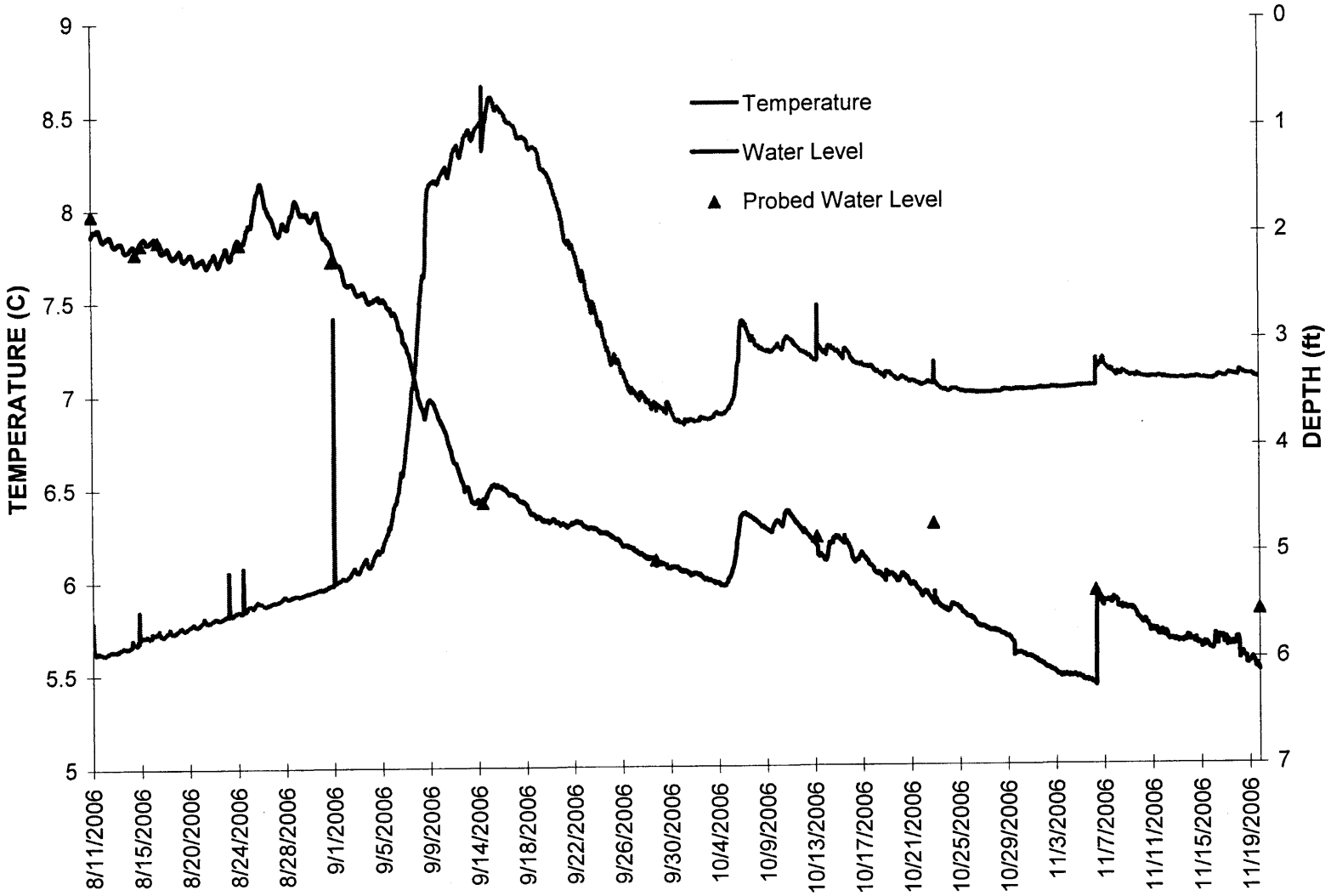
NWP-3 AND RAINFALL
8-11-07 THRU 10-12-07



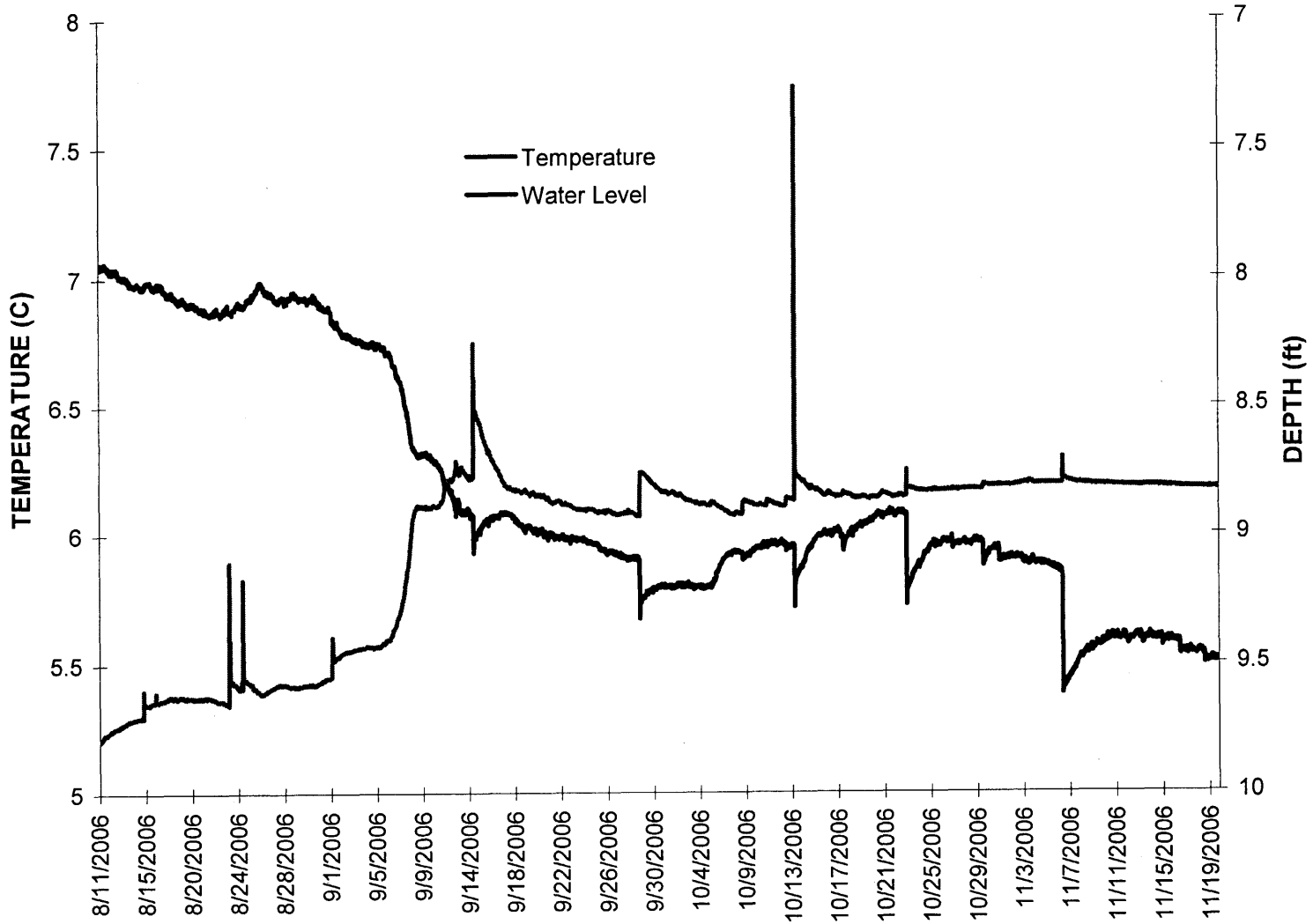
NWP-4


Temperature
Depth
TEMPERATURE (C)
DEPTH (ft)
8.5
8
7.5
7
6.5
6
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

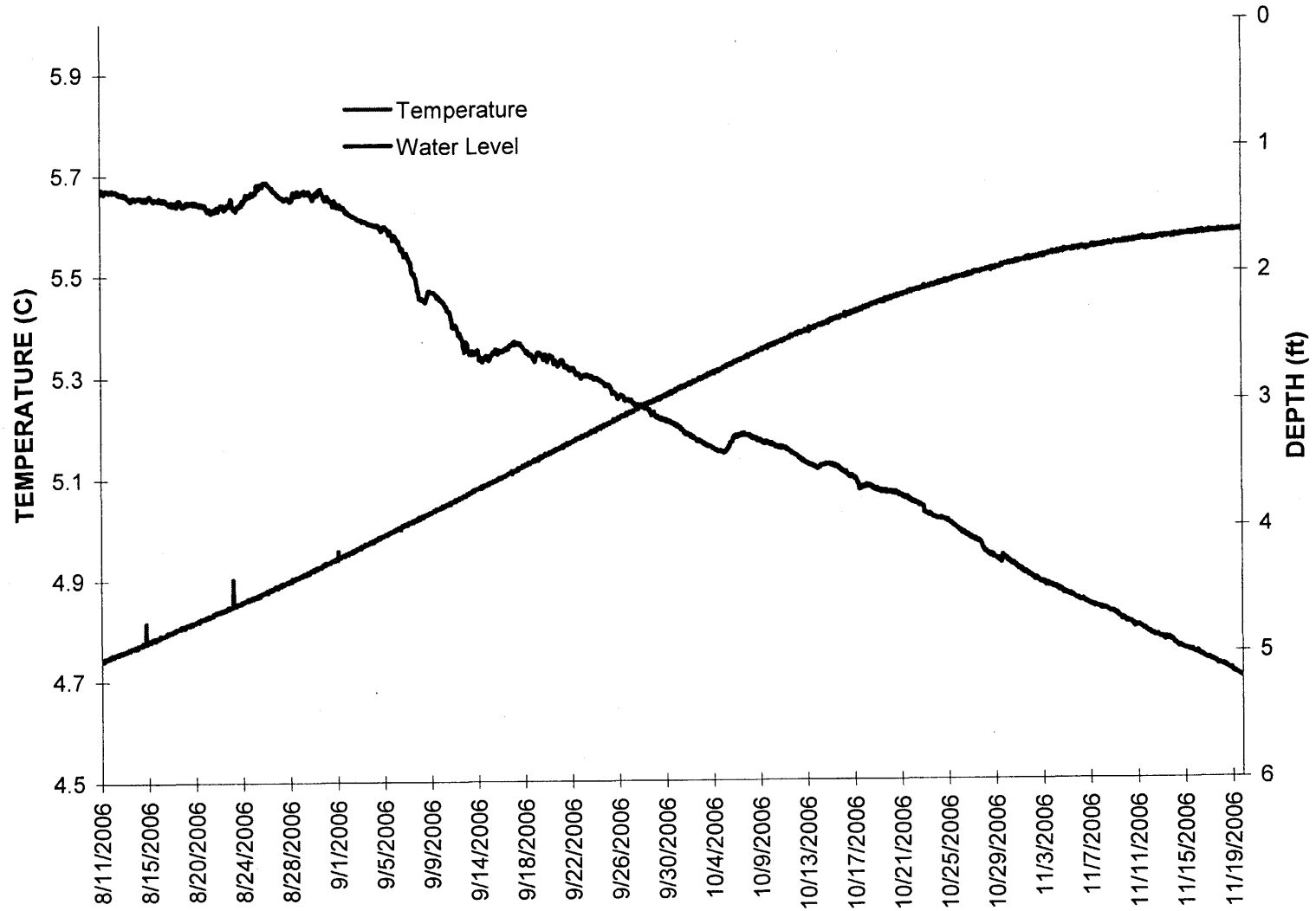
NWP-6


Temperature
Water Level
Probed Water Level
TEMPERATURE (C)
DEPTH (ft)
9
8.5
8
7.5
7
6.5
6
5.5
5
0
1
2
3
4
5
6
7
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

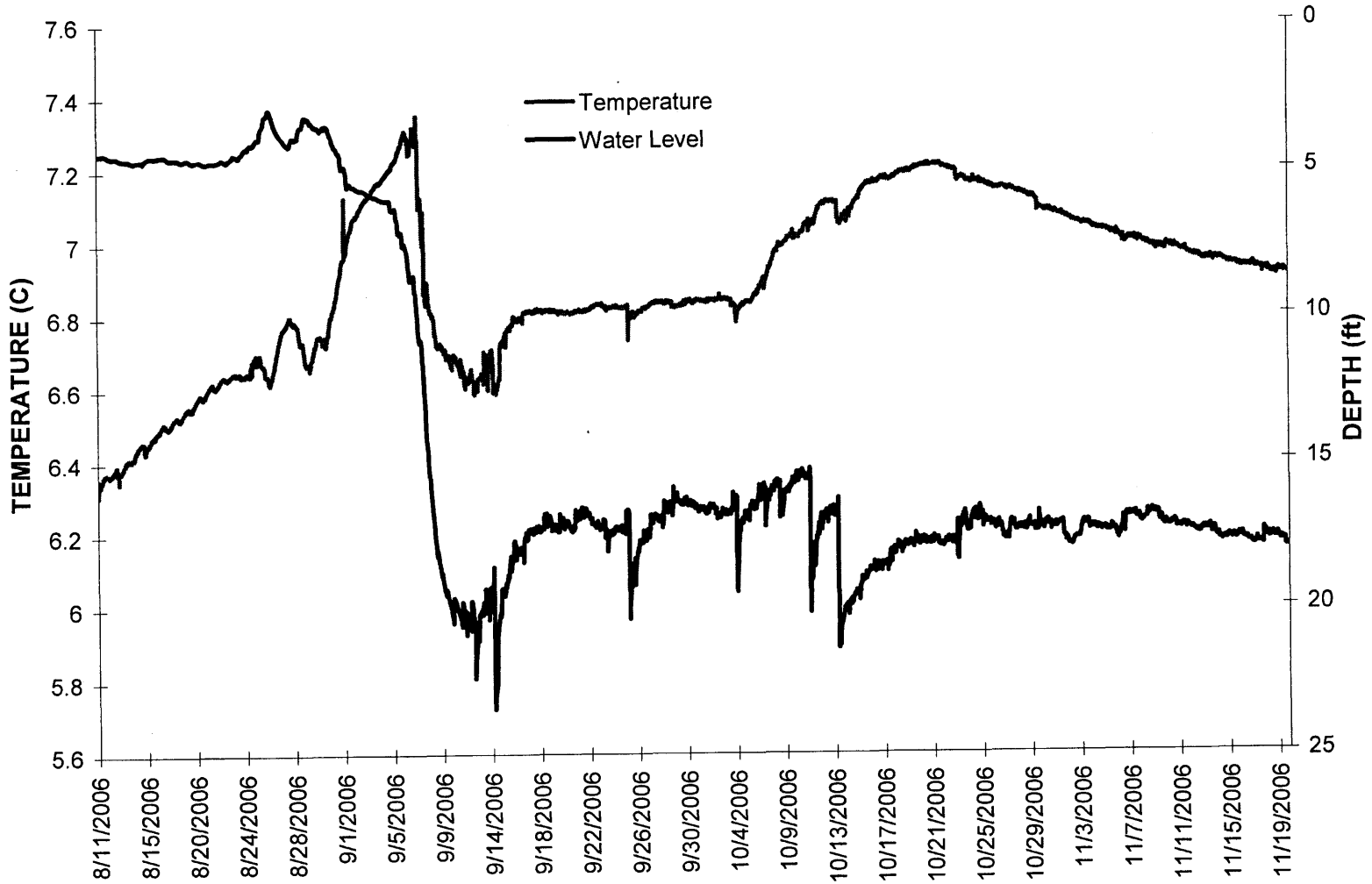
NWP-8


Temperature
Water Level
TEMPERATURE (C)
DEPTH (ft)
8
7.5
7
6.5
6
5.5
5
7
7.5
8
8.5
9
9.5
10
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

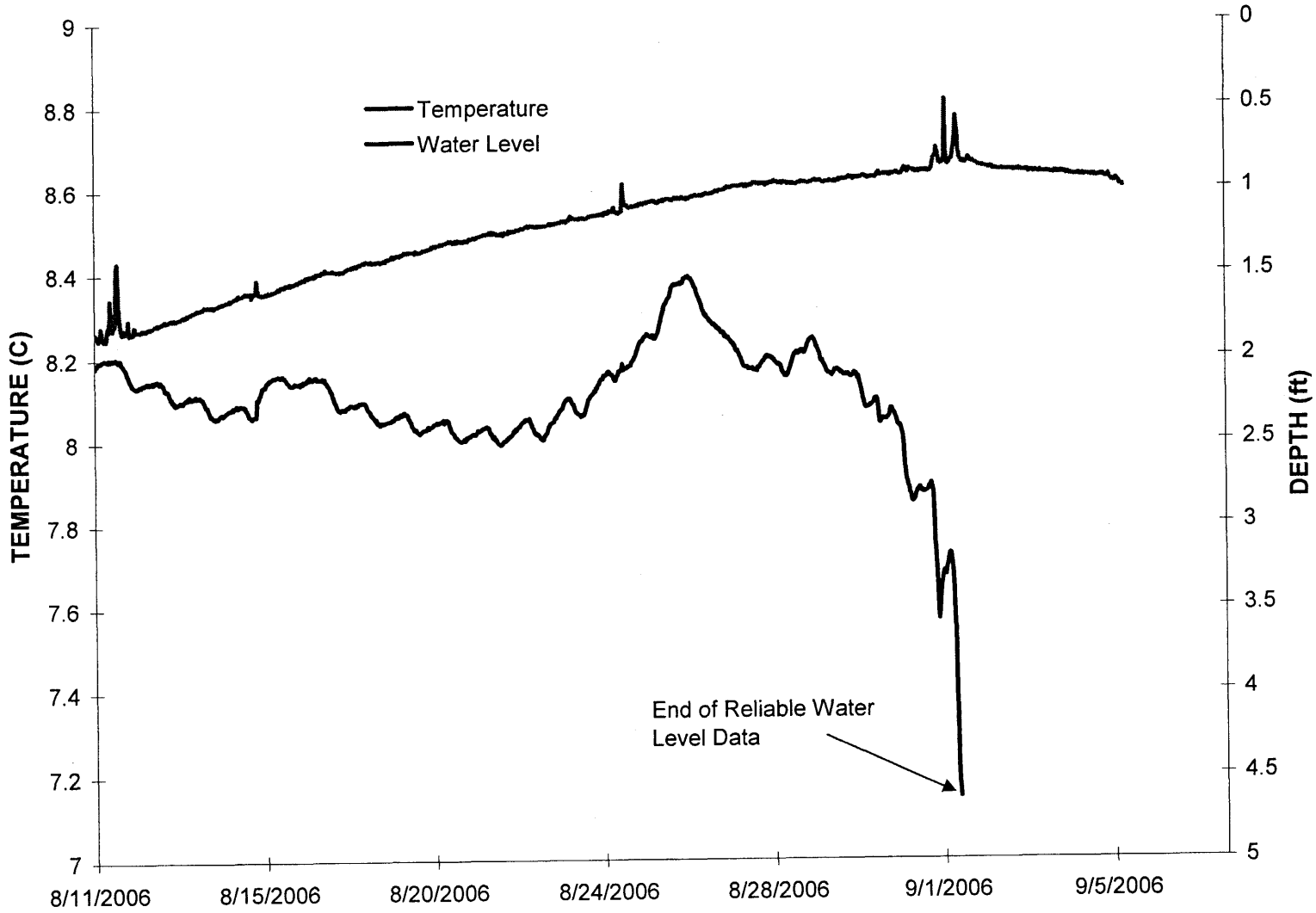
NWP-10 DEEP


Temperature
Water Level
TEMPERATURE (C)
DEPTH (ft)
5.9
5.7
5.5
5.3
5.1
4.9
4.7
4.5
0
1
2
3
4
5
6
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

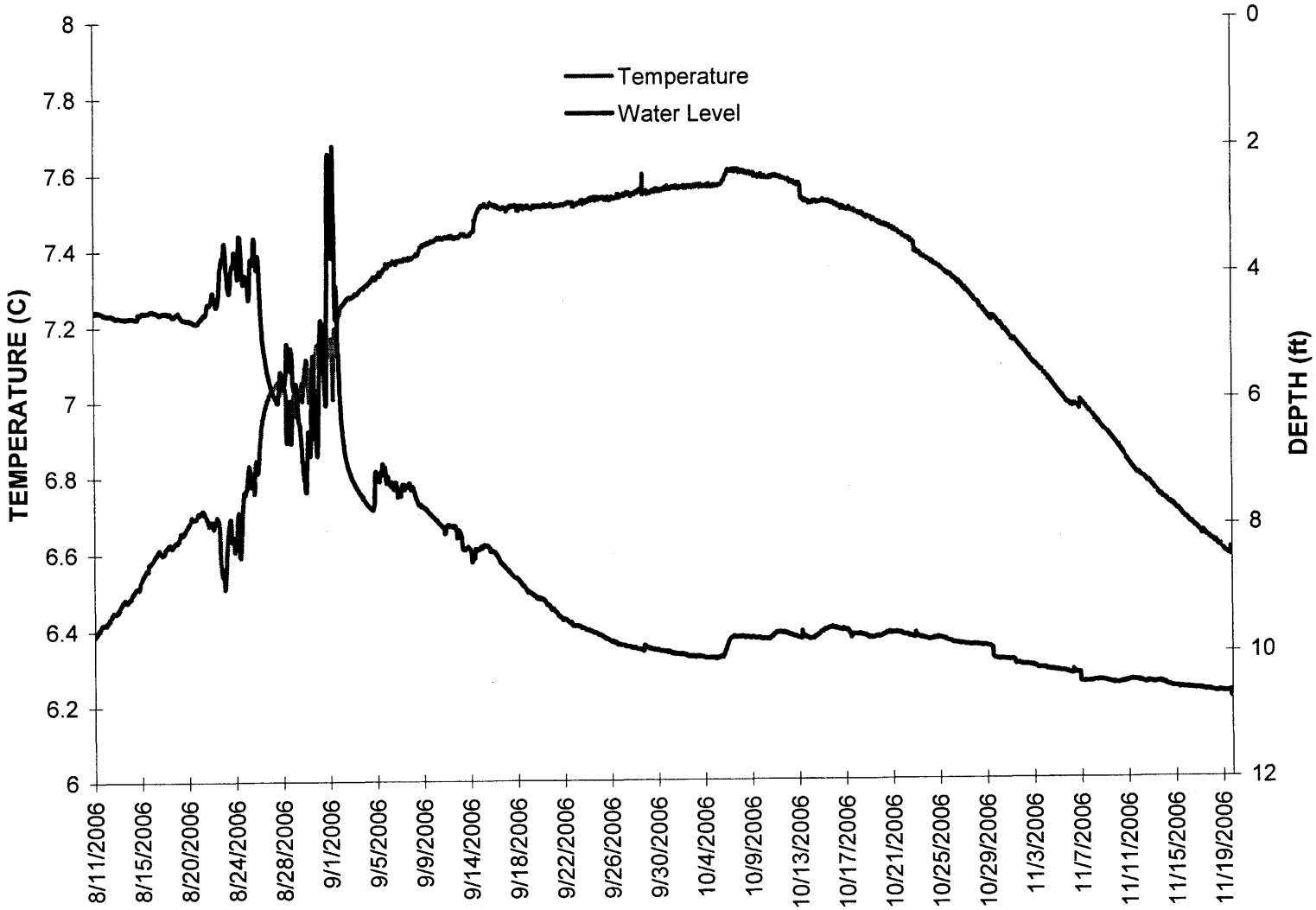
NWP-12


Temperature
Water Level
TEMPERATURE (C)
DEPTH (ft)
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
0
5
10
15
20
25
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

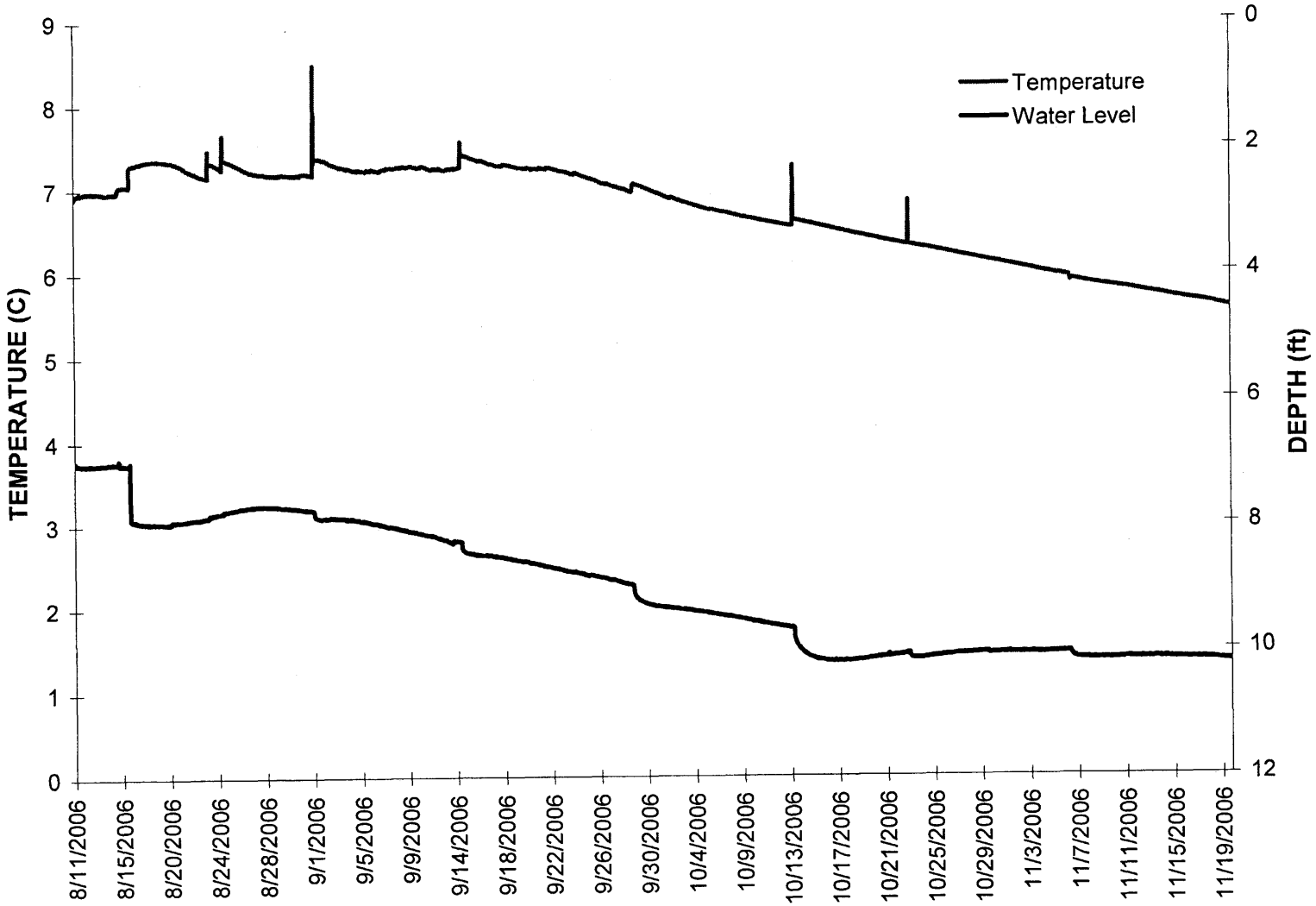
NWP-16


Temperature
Water Level
TEMPERATURE (C)
DEPTH (ft)
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
End of Reliable Water Level Data

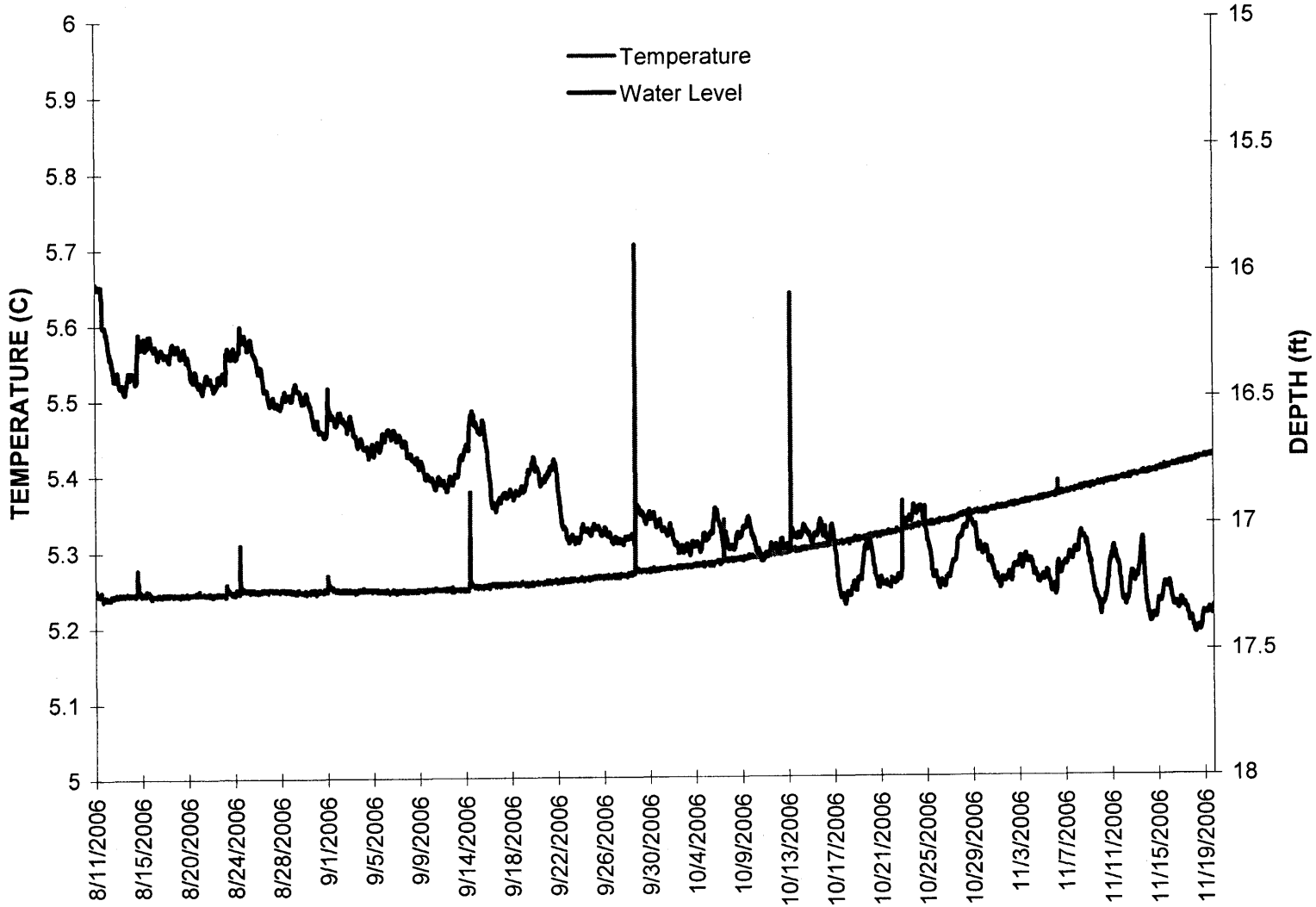
NWP-18


Temperature
Water Level
TEMPERATURE (C)
DEPTH (ft)
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
0
2
4
6
8
10
12
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

NWP-19


Temperature
Water Level
TEMPERATURE (C)
DEPTH (ft)
0
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

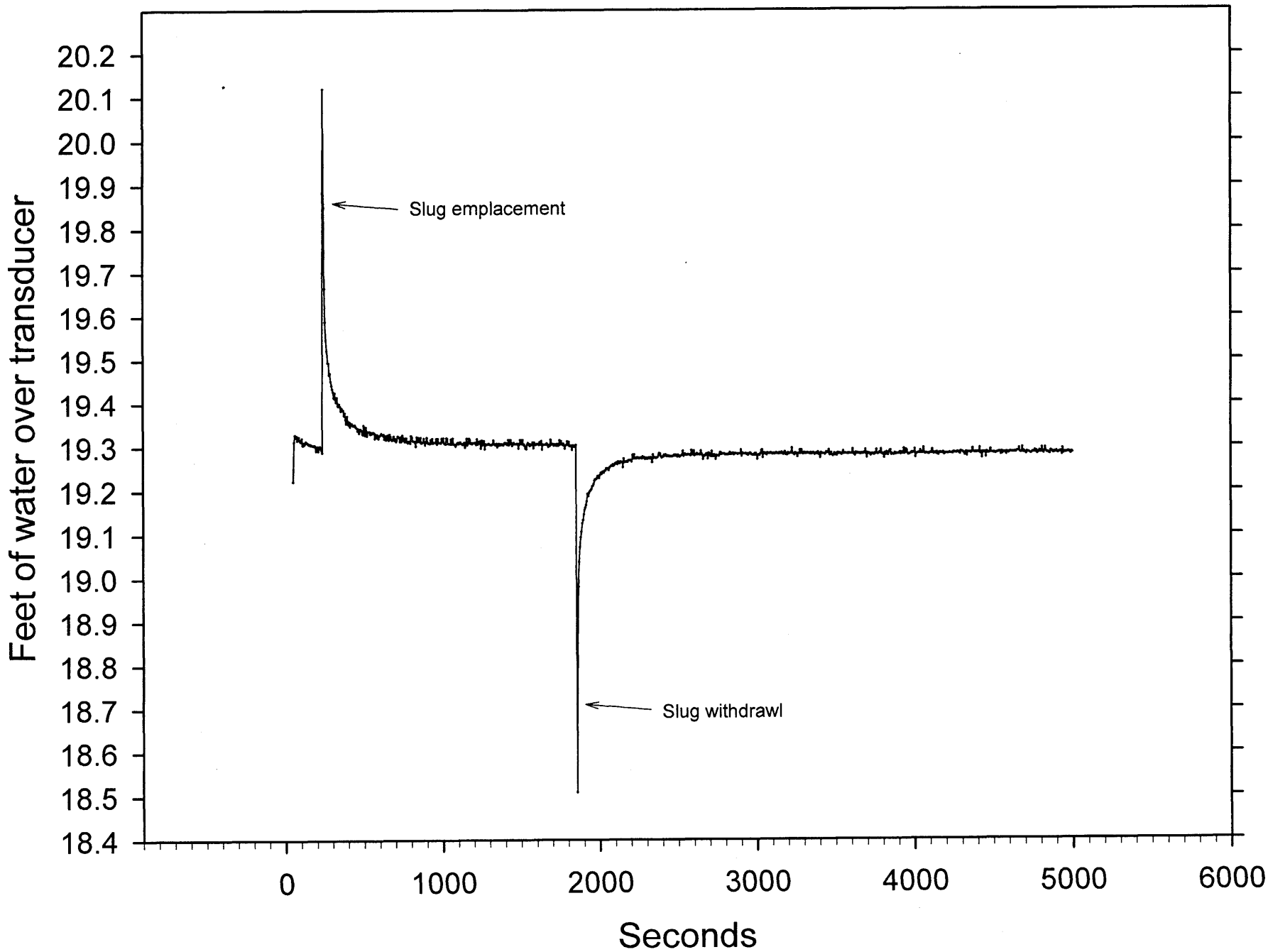
NWP-20


Temperature
Water Level
TEMPERATURE (C)
DEPTH (ft)
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
15
15.5
16
16.5
17
17.5
18
8/11/2006
8/15/2006
8/20/2006
8/24/2006
8/28/2006
9/1/2006
9/5/2006
9/9/2006
9/14/2006
9/18/2006
9/22/2006
9/26/2006
9/30/2006
10/4/2006
10/9/2006
10/13/2006
10/17/2006
10/21/2006
10/25/2006
10/29/2006
11/3/2006
11/7/2006
11/11/2006
11/15/2006
11/19/2006

Appendix C

Slug test data for NWP-10 test

NWP-10 slug test data



NWP-10 slug test information, compiled for analysis by Hvorslev method.

Seconds	W.L.	h (feet drawdown)	h/ho (percentage recovery)
0	18.509	0.781	100.00
5	18.851	0.439	56.21
10	18.981	0.309	39.56
15	19.038	0.252	32.27
20	19.072	0.218	27.91
25	19.094	0.196	25.10
30	19.107	0.183	23.43
35	19.126	0.164	21.00
40	19.133	0.157	20.10
45	19.146	0.144	18.44
50	19.157	0.133	17.03
55	19.162	0.128	16.39
60	19.168	0.122	15.62
65	19.176	0.114	14.60
70	19.193	0.097	12.42
75	19.188	0.102	13.06
80	19.195	0.095	12.16
85	19.199	0.091	11.65
90	19.201	0.089	11.40
95	19.204	0.086	11.01
100	19.21	0.08	10.24
105	19.211	0.079	10.12
110	19.216	0.074	9.48
115	19.223	0.067	8.58
120	19.226	0.064	8.19
125	19.226	0.064	8.19
130	19.228	0.062	7.94
135	19.233	0.057	7.30
140	19.231	0.059	7.55
145	19.229	0.061	7.81
150	19.236	0.054	6.91
155	19.24	0.05	6.40
160	19.238	0.052	6.66
165	19.243	0.047	6.02
170	19.243	0.047	6.02
175	19.241	0.049	6.27
180	19.246	0.044	5.63
185	19.246	0.044	5.63
190	19.251	0.039	4.99
195	19.25	0.04	5.12
200	19.25	0.04	5.12
205	19.246	0.044	5.63
210	19.252	0.038	4.87
215	19.254	0.036	4.61
220	19.256	0.034	4.35
225	19.256	0.034	4.35
230	19.259	0.031	3.97
235	19.256	0.034	4.35
240	19.258	0.032	4.10
245	19.262	0.028	3.59

Seconds	W.L.	h (feet drawdown)	h/ho (percentage recovery)
250	19.261	0.029	3.71
255	19.264	0.026	3.33
260	19.26	0.03	3.84
265	19.266	0.024	3.07
270	19.263	0.027	3.46
275	19.262	0.028	3.59
280	19.266	0.024	3.07
285	19.265	0.025	3.20
290	19.265	0.025	3.20
295	19.253	0.037	4.74
300	19.273	0.017	2.18
305	19.264	0.026	3.33
310	19.265	0.025	3.20
315	19.266	0.024	3.07
320	19.267	0.023	2.94
325	19.265	0.025	3.20
330	19.269	0.021	2.69
335	19.269	0.021	2.69
340	19.27	0.02	2.56
345	19.269	0.021	2.69
350	19.266	0.024	3.07
355	19.281	0.009	1.15
360	19.273	0.017	2.18
365	19.282	0.008	1.02
370	19.273	0.017	2.18
375	19.273	0.017	2.18
380	19.275	0.015	1.92
385	19.274	0.016	2.05
390	19.275	0.015	1.92
395	19.273	0.017	2.18
400	19.274	0.016	2.05
405	19.274	0.016	2.05
410	19.275	0.015	1.92
415	19.273	0.017	2.18
420	19.277	0.013	1.66
425	19.275	0.015	1.92
430	19.276	0.014	1.79
435	19.272	0.018	2.30
440	19.273	0.017	2.18
445	19.274	0.016	2.05
450	19.272	0.018	2.30
455	19.274	0.016	2.05
460	19.275	0.015	1.92
465	19.273	0.017	2.18
470	19.276	0.014	1.79
475	19.273	0.017	2.18
480	19.264	0.026	3.33
485	19.282	0.008	1.02
490	19.274	0.016	2.05
495	19.276	0.014	1.79
500	19.275	0.015	1.92
505	19.274	0.016	2.05

Seconds	W.L.	h (feet drawdown)	h/ho (percentage recovery)
510	19.275	0.015	1.92
515	19.276	0.014	1.79
520	19.281	0.009	1.15
525	19.285	0.005	0.64
530	19.284	0.006	0.77
535	19.278	0.012	1.54
540	19.275	0.015	1.92
545	19.276	0.014	1.79
550	19.277	0.013	1.66
555	19.281	0.009	1.15
560	19.279	0.011	1.41
565	19.282	0.008	1.02
570	19.279	0.011	1.41
575	19.278	0.012	1.54
580	19.28	0.01	1.28
585	19.278	0.012	1.54
590	19.279	0.011	1.41
595	19.278	0.012	1.54
600	19.278	0.012	1.54
605	19.278	0.012	1.54
610	19.278	0.012	1.54
615	19.279	0.011	1.41
620	19.281	0.009	1.15
625	19.279	0.011	1.41
630	19.281	0.009	1.15
635	19.28	0.01	1.28
640	19.277	0.013	1.66
645	19.281	0.009	1.15
650	19.279	0.011	1.41
655	19.277	0.013	1.66
660	19.279	0.011	1.41
665	19.28	0.01	1.28
670	19.281	0.009	1.15
675	19.29	0	0.00
680	19.278	0.012	1.54
685	19.28	0.01	1.28
690	19.283	0.007	0.90
695	19.281	0.009	1.15
700	19.28	0.01	1.28
705	19.281	0.009	1.15
710	19.282	0.008	1.02
715	19.281	0.009	1.15
720	19.281	0.009	1.15
725	19.279	0.011	1.41
730	19.291	-0.001	-0.13
735	19.283	0.007	0.90
740	19.281	0.009	1.15
745	19.29	0	0.00