HYDROLOGIC CONDITIONS RELATED TO THE HOG CANYON RIPARIAN RESTORATION PROJECT, DINOSAUR NATIONAL MONUMENT

Larry Martin

and

Joel Wagner

Technical Report NPS/NRWRD/NRTR-92/13

United States Department of the Interior • National Park Service

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October, 1992

United States Department of the Interior
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Washington, D.C.

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ABSTRACT

Hog Canyon supports both a riparian wetland community along a perennial stream and adjacent wet meadow communities sustained by a high water table. Long-term grazing by domestic livestock has significantly altered both vegetative ecosystems and stream channel morphology. In the lower part of the canyon, the stream is incised in a ditch approximately 1 to 2 feet wide and up to 5 to 6 feet deep. This incision is directly related to past ditching efforts by agricultural interests in attempts to divert the streamflow for irrigation purposes.

In 1989, a small population of the federally threatened orchid species *Spiranthes diluvialis* was discovered along the incised stream in lower Hog Canyon. Subsequent monitoring in 1991 indicated a population of more than 100 plants, mostly found in a wet meadow adjacent to an incised reach of the stream. This perennial orchid is endemic to low elevation mesic or wet meadows along perennial streams and springs. It typically occupies sandy, upper floodplain sites with moist soils and shallow water tables. In September, 1990, an interdisciplinary team of hydrologists, botanists, soil scientists, and park resource managers met to develop a plan for evaluating riparian conditions and management opportunities for Hog Canyon, with primary objectives of restoring the stream to natural conditions and increasing habitat for *Spiranthes diluvialis.*

Hydrogeologic data collected in this investigation show that in the area of concern, there is close interconnection between the ground water and surface water systems. The alluvial aquifer fills up nearly to the ground surface during the winter and spring when evapotranspiration losses are minimal. The alluvial aquifer discharges water to the creek in places where the creek has been artificially incised below the water table. This deep incision has likely resulted in lowering the water table in the lower canyon, causing the vegetative ecosystem to change from a wet meadow complex (orchid habitat) to a more xeric community. Evapotranspiration losses from the alluvial aquifer are exacerbated by drainage of the water table toward the artificially incised stream channel.

In addition to the wet meadow, the "moist streamside zone" along the perennial stream appears to be important orchid habitat in Hog Canyon. Therefore, the longer the stream channel (i.e., a sinuous channel rather than a straight ditch), the more potential streamside orchid habitat. When the stream is at or near the surface, this zone may extend 1 to 2 feet or more on either side of the stream in the Green River loam. When the stream flows through the deep, narrow channels with essentially vertical walls, development of the moist streamside zone is very limited. The authors conclude that additional potential streamside and wet meadow orchid habitat would be created by eliminating the straight ditch and returning the stream to a sinuous channel in its more natural position on the surface of the alluvium.

The total yield of water from Hog Canyon is not expected to change as a result of riparian restoration or stream relocation projects. The timing of runoff from the canyon may change as a result of more water being temporarily stored as ground water and subsequently released over a longer period of time. Hydrologic monitoring will continue for the duration of any restoration or relocation project to quantify surface water flows and ground water levels. Soil moisture in the vicinity of the relocated stream will be monitored to evaluate success in creating additional habitat for *Spiranthes diluvialis*. Vegetative monitoring at the site will continue for at least 7 to 10 years. *Spiranthes diluvialis* may remain (after germination) in a micorrhizal association for up to 7 to 10 years before developing above-ground parts. Thus, even though successful hydrologic restoration can be demonstrated in a relatively short time frame, assessment of success in a biological sense may require several years.

ACKNOWLEDGEMENTS

Steve Petersburg, Resource Management Specialist at Dinosaur National Monument initiated the riparian restoration project and facilitated this study. Most of the field data presented in this report were collected by the staff (Nate Inouye, George McFarland, and Russ McDaniel) at Dinosaur in addition to their regular duties. Special thanks to Lynn Riedel, who conducted monitoring and data analyses in 1991 and 1992. Her contributions included vegetation identification and monitoring, soil moisture studies, monitor well installation, streamflow gaging, water table measurements, data analysis, and public education and interpretation. Other project participants and advisors include Tamara Naumann, Boulder County (CO) Open Space, Rick Foster and Wayne McAllister, U.S. Soil Conservation Service (SCS), Bill Jackson, National Park Service - Water Resources Division (WRD), and Sherel Goodrich, Larry England, Lucy Jordan, and Jim Coyner (retired), U.S. Fish and Wildlife Service (USFWS). Members of the Chew family (local ranchers) provided much information on the history of grazing and irrigation practices in the area and cooperated throughout the project.

INTRODUCTION

Hog Canyon is a small, deeply incised canyon situated on the south flank of Split Mountain in Dinosaur National Monument (DINO) (see Photos 1 and 2). It contains a small perennial tributary to Cub Creek, which in turn flows into the Green River (Figure 1). Flow in the tributary is sustained by at least two surface springs and possibly additional subsurface springs or seeps. Snowmelt and runoff from precipitation contribute to surface flows intermittently.

Hog Canyon is the site of an early pioneer homestead and is used regularly by DINO for interpretive programs. It has been significantly impacted by man's activities including pasturing of domestic swine (thus the name Hog Canyon), grazing by domestic sheep and cattle, and hiking by monument visitors. The stream channel in the upper part of the canyon has been severely eroded to depths of about 12 feet. That area now shows evidence of stabilization and natural revegetation. In the lower part of the canyon, the stream is incised in a ditch approximately 1 to 2 feet wide and up to 5 to 6 feet deep. This incision is directly related to past ditching efforts by agricultural interests in attempts to divert the flow to other areas for irrigation purposes (Doug Chew, pers. comm. 1990). Hog Canyon flows into Cub Creek approximately 1/4 mile south from the mouth of the canyon. Cub Creek is incised approximately 20 feet below the valley floor, possibly affecting ground water flow patterns in the area. The Cub Creek incision is thought to result from upstream head-cutting following failure of an earthen dam many years ago.

Hog Canyon represents an uncommon type of riparian system in this region: a small canyon supporting both a riparian wetland community along a perennial stream and adjacent wet meadow communities sustained by a high water table. Long-term grazing by domestic livestock has significantly altered both riparian vegetation and stream channel morphology. The revegetation of cutbanks in the upper part of the canyon indicates some recovery, but this same area has been heavily invaded by Russian knapweed. The wet meadow complex in the lower canyon is believed to have been affected by grazing. Possible lowering of the water table by stream channelization may also have had a significant effect on the vegetative community. Although many of the species associated with the historic wet meadow communities are still present, diversity is probably reduced and species distribution and frequency have been altered. The dominant species in the lower canyon is now scouring rush. At least three rare plant species are recorded in the canyon; *Epipactis gigantea* (Giant helleborine), *Cirsium ownbeyi* (Ownbey thistle), and *Spiranthes diluvialis* (Ute ladies'-tresses). *Spiranthes diluvialis* is listed (as of January, 1992) as a threatened species under the federal Endangered Species Act.

In 1989, a small population (about 50) of *Spiranthes diluvialis* was discovered along the incised stream in the lower canyon. Monitoring in 1990 located only four plants. A more concerted effort in 1991 located more than 100 plants in the lower canyon. This perennial orchid is endemic to low elevation mesic or wet meadows along perennial streams and springs. It occupies sandy, upper floodplain sites with moist soils and

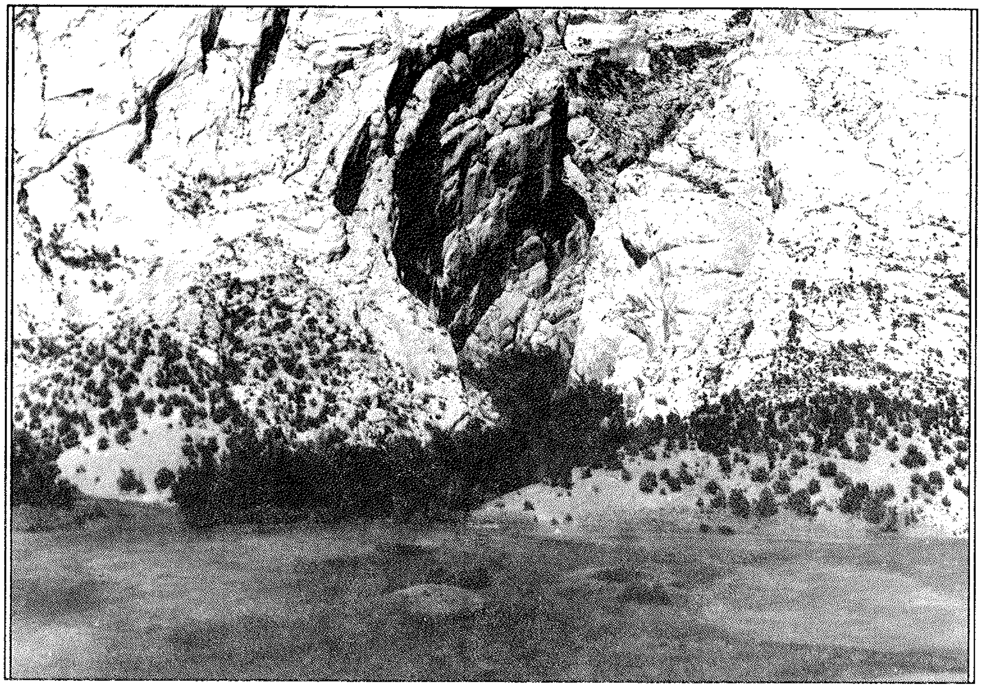
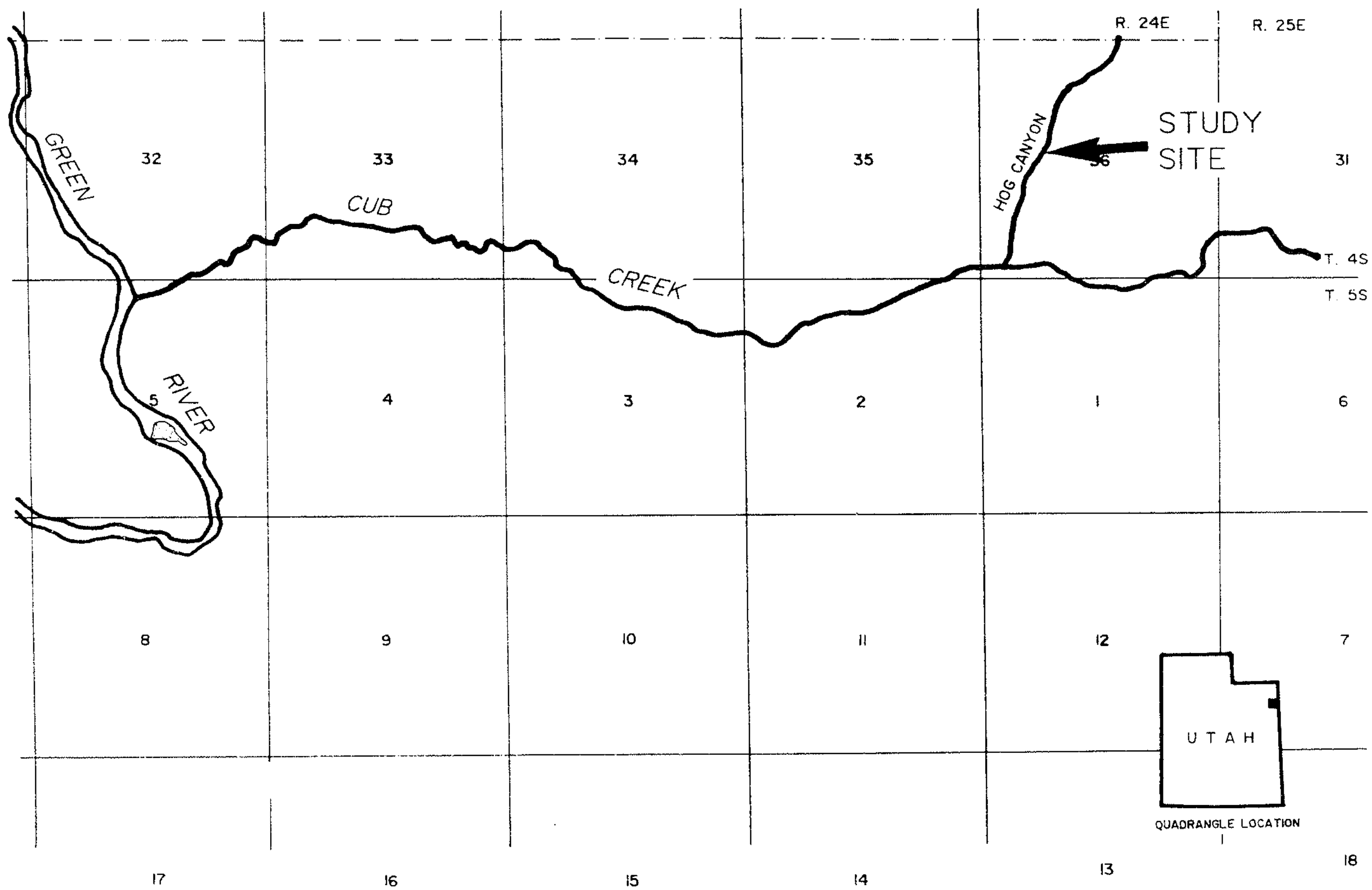


Photo 1. Looking north, towards Split Mountain and Hog Canyon. The alluvial fan and associated wetland areas are in the foreground.

Photo 2. Looking south, in the lower part of Hog Canyon.



Source: U.S.G.S. Split Mountain, Utah (7.5' Quadrangle, 1955).

Figure 1. General site location.

shallow water tables. Little else is known about this plant's specific habitat requirements or the range of acceptable environments.

The riparian ecosystem in the lower part of the canyon appears to have changed significantly with incising of the stream. Surface elevations and anecdotal evidence suggest that the stream originally meandered over the surface of the valley floor. The vegetation appears to have departed substantially from a wet meadow complex as a result of lowering of the water table. Vegetation communities, though distorted in species composition, are thought to be sufficiently intact to permit restoration to near pre-settlement conditions if the hydrologic functions of the ground-surface-water systems are restored to their natural conditions.

OBJECTIVES

In September, 1990, an interdisciplinary team of hydrologists, botanists, soil scientists, and park resource managers met to develop a plan for evaluating riparian conditions and management opportunities for Hog Canyon. At this meeting a set of study objectives was developed to help focus information needs:

Study Objectives

1. Quantify existing conditions (ground water and surface water hydrology, stream channel characteristics, vegetation, soils, orchid populations and habitat).
2. Predict the effects of alternative channel and ground water management approaches on water regimes, including near-stream, riparian-zone soil moisture and alluvial fan ground water.
3. Predict the effects of altered water regimes on vegetation, including woody vegetation and rare plants (*Spiranthes diluvialis*).

These study objectives were intended to aid park managers in accomplishing the following management objectives:

Management Objectives

1. Reestablish the stream in its "natural location" on the canyon floor and alluvial fan and in proper association with its floodplain and riparian zone, with widths, depths, and sinuosities representative of pre-settlement conditions (i.e., correct effects of past ditching and overgrazing practices).
2. Maintain water yields from Hog Canyon to Cub Creek.
3. Maintain or improve habitat conditions for *Spiranthes diluvialis.*
4. Reestablish pre-settlement vegetation conditions.

5. Develop an interpretive program to explain the objectives, design, and progress of riparian rehabilitation to monument visitors.

This report focuses on analysis of hydrologic data collected during the first year of the study. Specifically, the authors discuss seasonal surface and ground water hydrologic conditions, stream channel and ground water relationships, soil moisture conditions, and other aspects of Hog Canyon hydrology relevant to the management objectives stated above. A set of preliminary management/restoration alternatives are also presented as a starting point for continued discussions by the evaluation team.

GENERAL SITE HYDROLOGY AND GEOLOGY

Hog Canyon

The hydrogeology of Hog Canyon consists of an unconsolidated alluvial deposit filling the bottom of the canyon (and forming the canyon floor) and the relatively impermeable bedrock forming the canyon walls and underlying the alluvial valley fill. Ground water discharges from the sandstone bedrock as springs and seeps within the canyon. Some of the springs are visible at land surface at the intersection of the valley floor and the canyon walls. There are probably also underground seeps and springs in the canyon: places where water discharges from the bedrock directly into the alluvial aquifer below land surface.

Springs and seeps are a perennial source of water in the canyon. Surface water runoff occurs only intermittently in direct response to rainfall or snowmelt on the small (approximately 0.5 square miles (mi^2)) drainage basin. Discharge from the springs and seeps is sufficient to maintain baseflow of approximately 0.35 cubic foot per second (ft^3/s) in the creek throughout the year. Additionally, the springs and seeps are an important source of alluvial ground water in the canyon. Depending on the season of the year and the elevation of the water table relative to the elevation of the creek, the ground water system is either being recharged by leakage from the creek, or the alluvial ground water is discharging to the creek. The quantity of ground water flowing from the canyon toward Cub Creek cannot be accurately determined because the hydraulic conductivity and thickness of the saturated sediments are unknown. The authors' estimates of ground water flow from the canyon range from about 1000 to 9000 cubic feet per day (ft^3/day) (0.01 to 0.1 ft^3/s).

Flood Frequency and Magnitudes

Estimates of anticipated flood frequencies and magnitudes were made using regional regression equations as described by Thomas and Lindskov (1983). The watershed area was estimated to be 0.55 mi^2. The mean elevation of the watershed was estimated to be 7224 feet (the mean elevation of 15 randomly chosen points in the watershed was 7224 feet above mean sea level). The approximate boundary of the drainage basin is shown on Figure 2. Regression equations for the northern mountains low elevation sub-region were used to predict flood magnitudes for recurrence intervals shown in Table 1. The variables in the regression equations are elevation and area of the drainage basin. The average standard error of estimate for these regression equations is about 70%.

Table 1. Estimates of peak discharges from Hog Canyon, from regional regression equations.

Recurrence Interval (yr)	Probability of Occurring in any Year	Discharge Ft^3/S
2	50%	6
5	20%	10
10	10%	12
25	4%	15
50	2%	17
100	1%	19

An alternative method of predicting flood events was used to investigate the effects of using a general SCS runoff model applied to site-specific conditions. The purpose of using the alternative runoff model was to use large curve numbers to simulate runoff from the slickrock formations that dominate the drainage basin. Runoff and peak discharge were calculated by the Farmer-Fletcher method (Farmer and Fletcher 1971). Basin characteristics used in the runoff model are:

Average basin slope	40%
Drainage basin area	0.55 mi^2
Longest channel length	5000 feet
Curve number	85

Rainfall frequency for storm durations of 30 minutes to 24 hours were obtained from the *Rainfall Frequency Atlas of the United States* (Hershfield 1963). Simulation of runoff from these storms generally showed that the peak discharge occurred for storms of a 2-hour duration. These peak discharges last for only a short time period, the majority of the flood event probably lasts only 15 to 20 minutes. Shorter duration storms do not yield enough water to produce as large a runoff event. Longer duration storms do not drop significantly larger amounts of water. The rain that does fall is spread out over a longer time period, resulting in lower peak discharge but longer periods of high flow. Peak discharge estimated by this method is shown in Table 2.

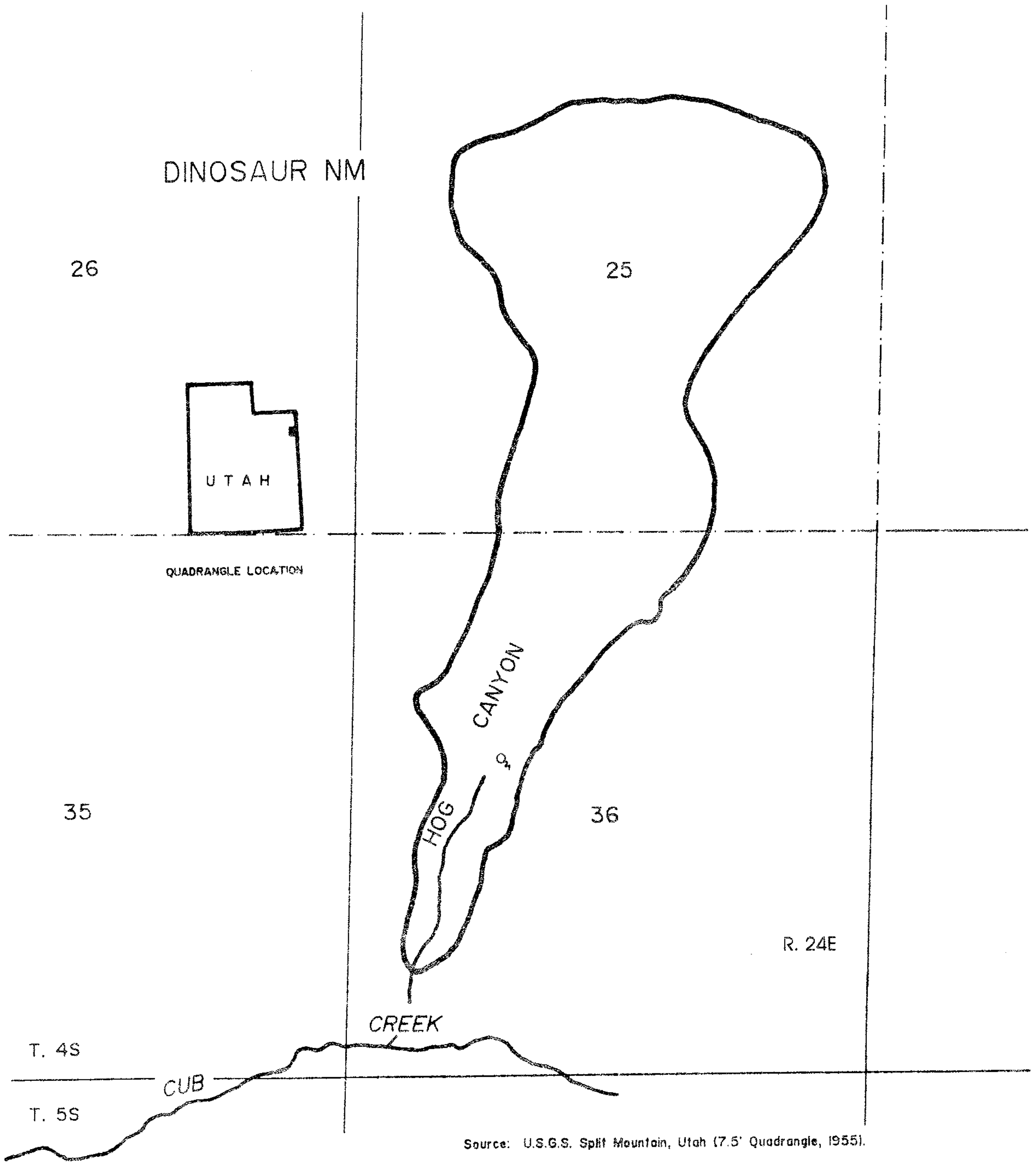


Figure 2. Hog Canyon drainage basin.

Table 2. Estimates of peak discharges from Hog Canyon, from SCS runoff model using curve numbers.

Recurrence Interval (yr)	Probability of Occurring in any Year	Discharge Ft^3/S
2	50%	17
5	20%	56
10	10%	98
25	4%	176
50	2%	205
100	1%	285

Because most of the drainage basin has relatively impermeable slickrock exposed at the surface, runoff from rainfall tends to be very concentrated. Peak discharge is very high, but of short duration. This is a response typical of small drainages having low infiltration capacity and subject to brief, intense rainfall events.

Calculation of flood discharge by the two different methods yields very different results (compare Tables 1 and 2). Neither of the methods were developed to predict large-discharge, short-duration runoff events (flash floods) in small steep canyons of this type. The anticipated flood discharges probably fall somewhere between the two estimates. Local ranchers report anecdotal experiences of short-duration floods (half hour or less) from the canyon having water depths of about 1 foot. Floods of this type could easily have a peak discharge in excess of 100 ft^3/s.

Floods are the main agent responsible for transporting sediment from the canyon and forming the alluvial fan at the mouth of the canyon. In a normal undisturbed situation the creek would be flowing at, or near, land surface throughout the canyon and across the alluvial fan. The effect of the creek entrenchment on sediment transport and deposition are unknown. It appears that one effect of entrenchment is to prevent the creek from meandering and shifting course both within the canyon and to a lesser extent on the upper part of the alluvial fan.

Geomorphology and Alluvial Fan Development

Alluvial fans form when a high-energy, steep-gradient stream leaves a confined valley and enters flatter terrain. Sediment is deposited due to the reduction in stream energy and a fan shaped alluvial deposit forms, radiating from the mouth of the valley. Alluvial fans are formed over long time periods by many distinct flood events. During floods, large volumes of sediment are moved from the canyon and deposited on the alluvial fan. As the elevation of the fan increases from sediment deposition, the creek may suddenly change course and flow across another, lower part of the fan.

Alluvial fans formed in this manner contain a heterogeneous mix of grain sizes, generally ranging from silts to gravel and cobbles. Because the sediments are deposited in stream channels and overbank floods, there is no lateral continuity. When viewed in cross-section, perpendicular to the stream channel, sediments forming alluvial fans will grade vertically, having several sequences alternating from silt through gravel. There is no lateral continuity to the deposits due to their being deposited by running water in and along stream channels.

Hydrogeologically, an alluvial fan is an alternating sequence of discontinuous aquifers and semi-confining beds. Generally there is enough interconnection between the more permeable units for ground water to remain underground rather than being forced to the surface of the fan by an extensive layer of low hydraulic conductivity. If the fan overlies relatively impermeable material, ground water may discharge from near the toe of the fan, where the fan becomes too thin to transmit the volume of ground water flowing through the fan.

Geology

Information about the local geology in the Hog Canyon area was obtained from a USGS map report (Hansen, et al. 1983). An enlargement of that map for the Hog Canyon area is shown in figures 3-3A.

Hog Canyon is cut into the Weber Sandstone Formation. The Weber Sandstone is a massive, thickly-bedded, fine- to very-fine-grained sandstone of eolian origin. The Weber Sandstone is the source of the springs in the upper part of Hog Canyon. Near the mouth of Hog Canyon there may be small exposures of the lower unit of the Park City Formation. The Park City Formation consists of sandstone, dolomite, and limestone. For purposes of this investigation, it is irrelevant whether there is any Park City Formation present. It would be lumped, hydrologically, with the Weber Sandstone.

The valley bottom in Hog Canyon is filled with an unknown thickness (probably ten's of feet) of alluvium. The alluvium spills out of the canyon forming an alluvial fan in the valley of Cub Creek. In the Cub Creek valley, the alluvium is intermixed with alluvium from Cub Creek and older alluvial terraces deposited during the wetter climate of the Pleistocene.

The Moenkopi Formation underlies the alluvium in the Cub Creek valley. The Moenkopi is a shale and siltstone deposit and therefore has a low permeability relative to the overlying alluvium.

The bluff forming the ridge on the south side of the Cub Creek valley is the Garra Member of the Chinle Formation. It is a low permeability unit and dips toward the south. It is of no consequence in this investigation of Hog Canyon.

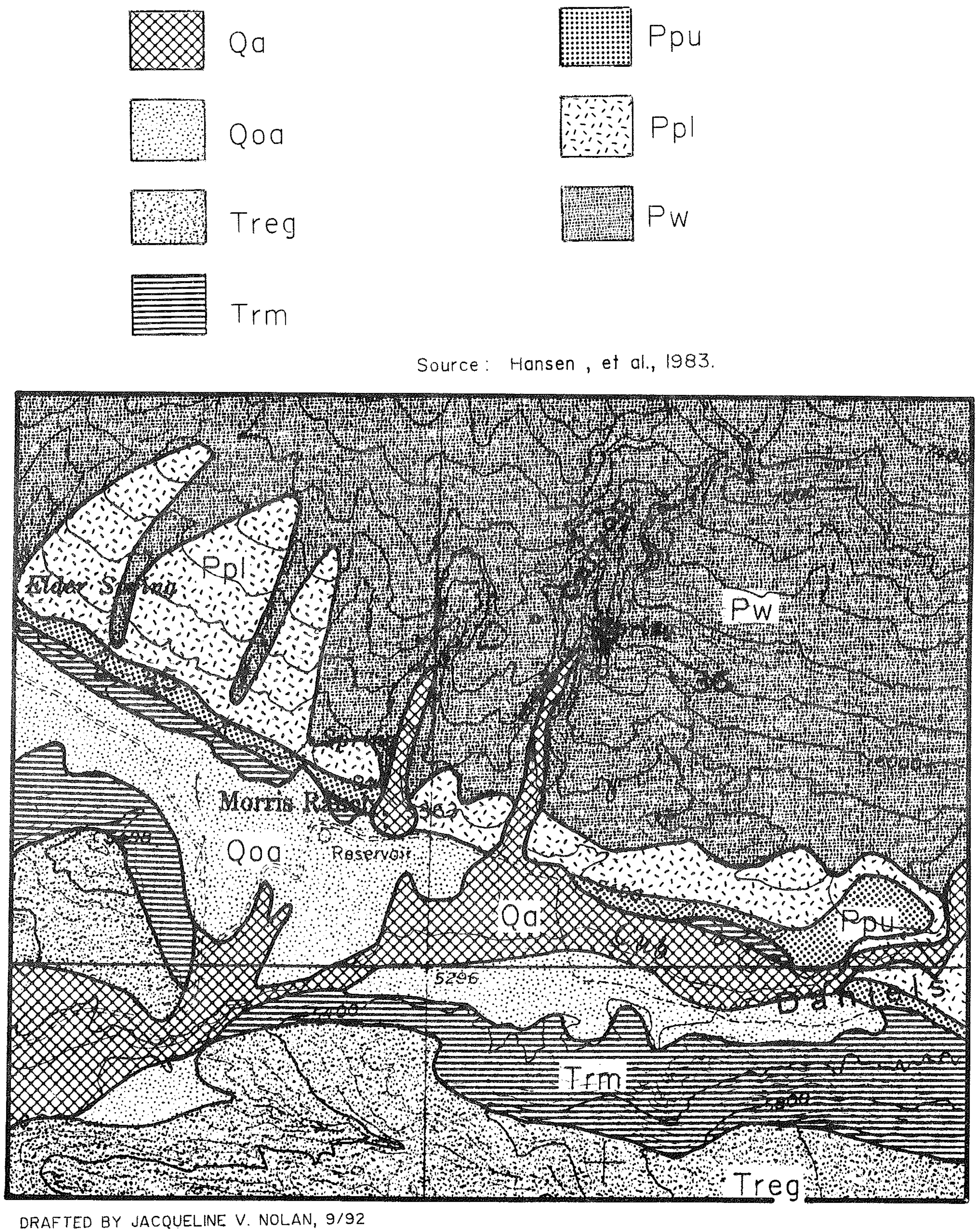


Figure 3. Geologic map of the study area. Explanation of geology on the following page.

EXPLANATION

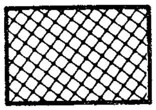
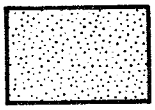
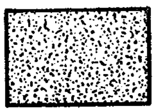
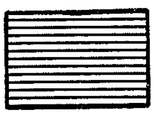
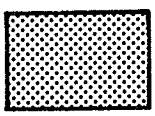
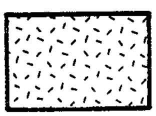
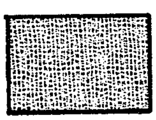
	Qa	Quaternary	Alluvium	(Holocene)
	Qoa	Quaternary	Older Alluvium	(Pleistocene)
	Treg	Triassic	Garra Member of Chinle Fm. - Sandstone	
	Trm	Triassic	Moenkopi Fm. - Siltstone and Shale	
	Ppu	Permian	Upper Unit of Park City Fm. - Limestone, siltstone, sandstone, and dolomite	
	Ppl	Permian	Lower Unit of Park City Fm. - Sandstone, dolomite, and limestone	
	Pw	Pennsylvanian	Weber Sandstone - Sandstone, fine - to - very-fine grained, thickly bedded, eolian deposits	

Figure 3A. Explanation of geology for the study area.

HYDROGEOLOGY

Conceptual Model

Surface runoff occurs only intermittently in direct response to snowmelt or precipitation on the drainage basin of Hog Canyon. Streamflow and the ground water flow system in Hog Canyon are maintained by discharge of springs and seeps issuing from the sandstone bedrock in the upper part of Hog Canyon. Surface water flowing in the creek in Hog Canyon will recharge the alluvial aquifer when the water table drops below the level of the stream, typically in late summer. In the winter months, when evapotranspiration losses are reduced, the water table is higher than the water level in the creek and the alluvial aquifer loses water to the stream. As the creek exits from Hog Canyon and flows across the alluvial fan, it becomes a braided stream, flowing through several small wetland areas, and eventually loses a distinctive channel before flowing into Cub Creek as sheetflow. This suggests that down-cutting on Cub Creek was not responsible for initiating down-cutting on Hog Creek.

Ground water flowing in the alluvium in Hog Canyon will discharge to the creek during periods when the water table is high, typically winter and spring. As trees leaf out and vegetation begins to grow late in the spring, evapotranspiration losses increase and the water table is drawn down below the level of the creek. Water from the creek is then drawn into the alluvial aquifer, helping to maintain a high water table near the creek. As ground water exits from the canyon, it continues to flow through the Hog Canyon alluvial fan and Cub Creek alluvial deposits until it is forced to the surface by thinning of the alluvial aquifer against the underlying impermeable bedrock (Figure 4). Ground water forms seeps and wetlands in several places near the toe of the alluvial fan. Water discharging in these areas continues as sheetflow toward Cub Creek. Some of the water in the alluvial deposits probably remains underground all the way to Cub Creek. The quantity of water remaining underground depends on the thickness of the alluvium, which is unknown.

Hydrologic Monitoring - Ground Water

Lower Hog Canyon -- Transect Analyses

Fifteen shallow monitoring wells were installed (September, 1990) along five east-west transects across the lower part of Hog Canyon to monitor the water table in the area inhabited by *Spiranthes diluvialis* in 1989-90. Well locations are shown in Figure 5. Reference posts were placed in the creek at each transect to provide a known elevation and measuring point for determining the water surface elevation in the creek. Comparison of the water table and creek elevations could then be made to determine ground water/surface water relationships.

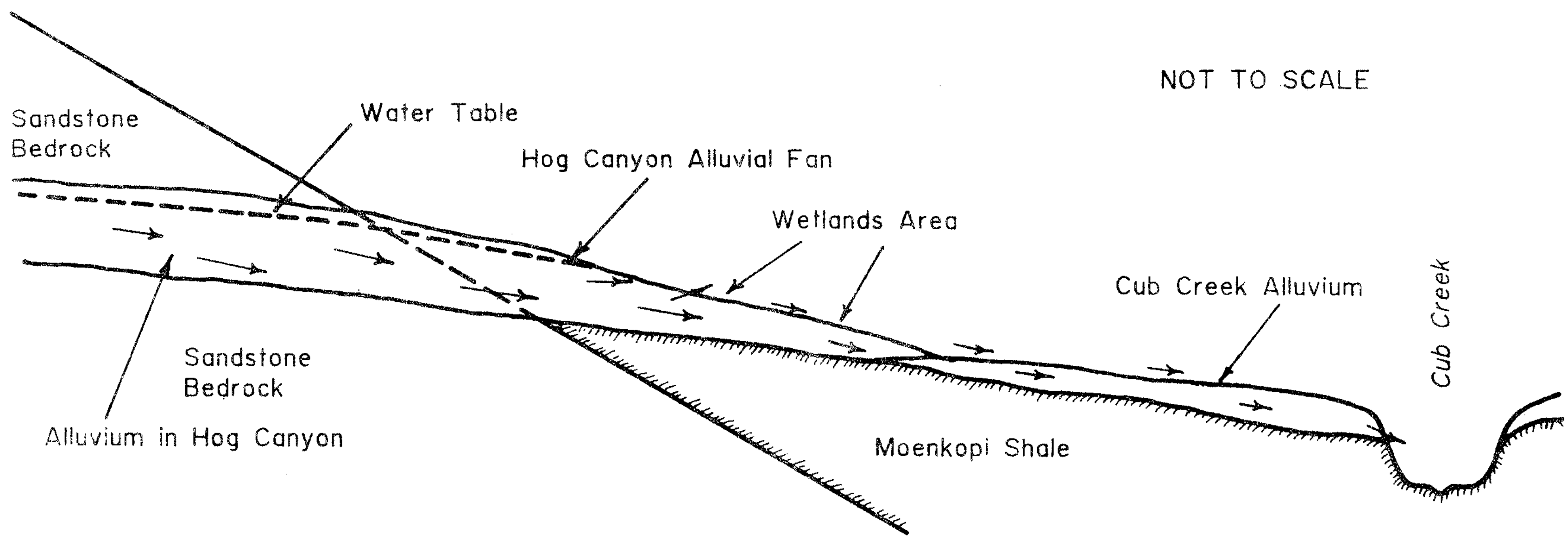


Figure 4. Schematic north-south cross-section through the Hog Canyon alluvial fan, showing geology and probable ground water flow paths (arrows). As the alluvial fan thins, ground water is forced out on the land surface where it continues as sheet-flow, towards Cub Creek. Wetlands occur where sheet-flow is at, or near, land surface.

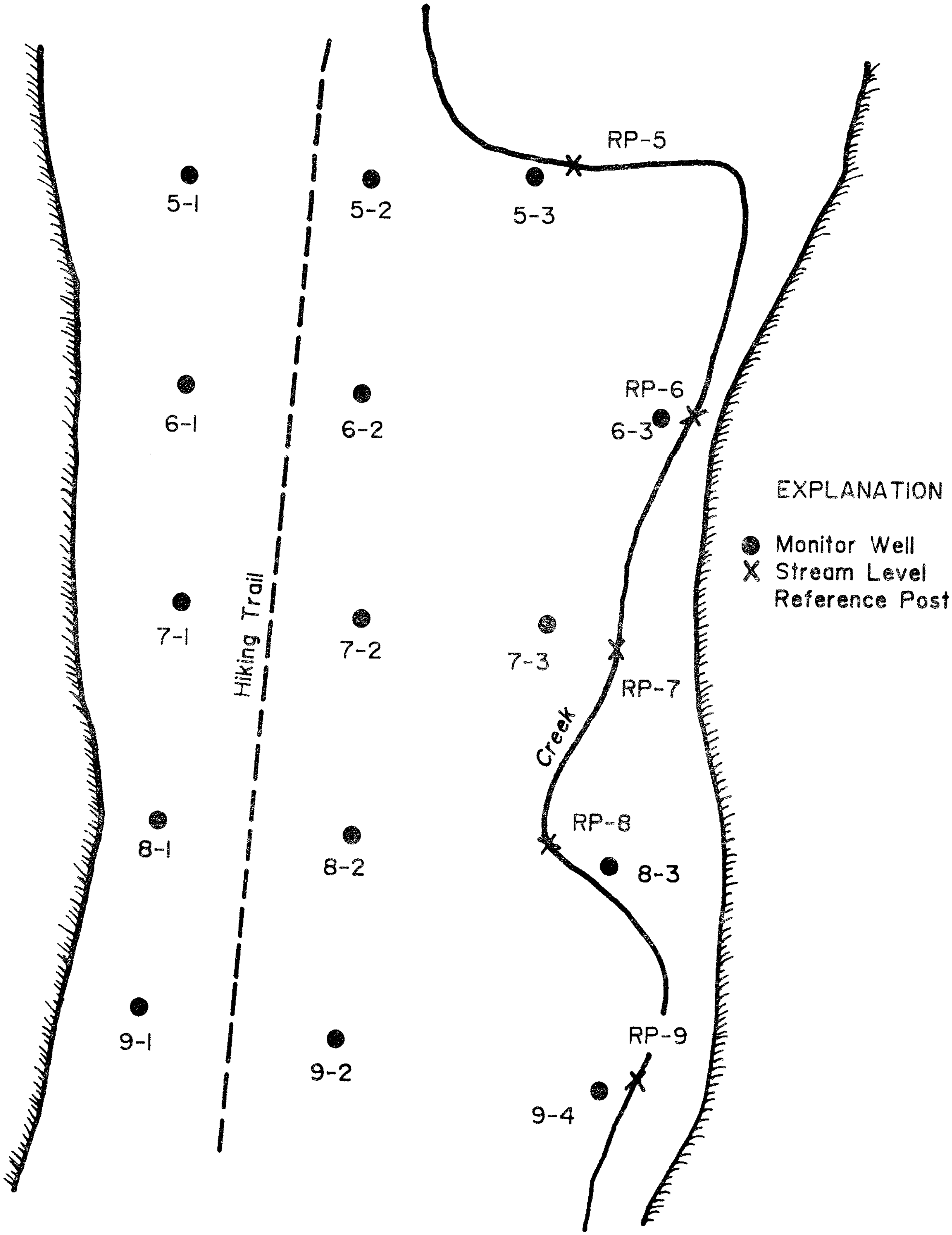


Figure 5. Monitor well locations in Lower Hog Canyon.

At transect 5, monitoring well 5-3 is closest to the creek and showed the least amount of annual water table change, approximately 0.5 feet (Figure 6). The water table elevation in well 5-3 is slightly higher than the creek in the winter, indicating that ground water flow is towards the creek. In the summer, the water table is slightly lower than the creek, indicating that surface water is recharging the aquifer, and that recharge is sufficient to maintain the water table at a relatively constant level near the stream. Monitoring wells 5-2 and 5-1 show increasing seasonal water level variability of approximately 2.0 and 3.4 feet, respectively. Water levels in these wells rise above the creek in winter, probably in response to recharge from further up the canyon. Ground water flow in the winter is towards the creek. In the summer, the water table at these two wells drops 1 to 2 feet below the creek, indicating that evapotranspiration losses exceed the rate of recharge from the creek or from upgradient ground water sources in the canyon.

At transect 6, monitoring well 6-3 is closest to the creek and showed the least amount of annual water table change, approximately 0.5 feet (Figure 7). The water table elevation in well 6-3 is slightly higher than the creek throughout the year, indicating that ground water flow is toward the creek. Ground water in this area is probably recharged from the creek near monitoring well 5-3, where the creek is flowing from west to east; and returns to the stream in the vicinity of monitoring well 6-3. Monitoring wells 6-2 and 6-1 show increasing seasonal water level variability of approximately 2.1 and 3.5 feet, respectively. In the winter, water levels in these wells are 2 to 3 feet higher than the water level in the creek, probably in response to recharge from further up the canyon. Ground water flow in the winter is towards the creek. In the summer, the water table at these two wells drops to about 1 foot below the creek, indicating that evapotranspiration losses exceed the rate of recharge from the creek or ground water sources upgradient in the canyon.

At transect 7, monitoring well 7-3 is closest to the creek and showed the least amount of annual water table change, approximately 1.3 feet (Figure 8). This is more fluctuation than is seen at either monitoring well 5-3 or 6-3 and is probably a result of well 7-3 being a little further from the creek and not influenced by ground water recharge as at the sharp turn in the creek near wells 5-3 and 6-3. The water table elevation in well 7-3 is about 1 to 2 feet higher than the creek throughout the year, indicating that ground water flow is towards the creek. Monitoring wells 7-2 and 7-1 show increasing seasonal water level variability of approximately 2.5 and 3.5 feet respectively. In the winter, water levels in these wells are 2 to 3 feet higher than the water level in the creek, probably in response to recharge from further up the canyon. Ground water flow in the winter is towards the creek. In the summer, the water table at monitoring well 7-1 drops to about 1 foot below the creek, indicating that evapotranspiration losses exceed the rate of recharge from the creek or ground water sources upgradient in the canyon. The water table in monitoring well 7-2 remains slightly higher than the creek, indicating that the quantity of ground water flowing from upgradient in the canyon is sufficient to meet some of the evapotranspiration losses.

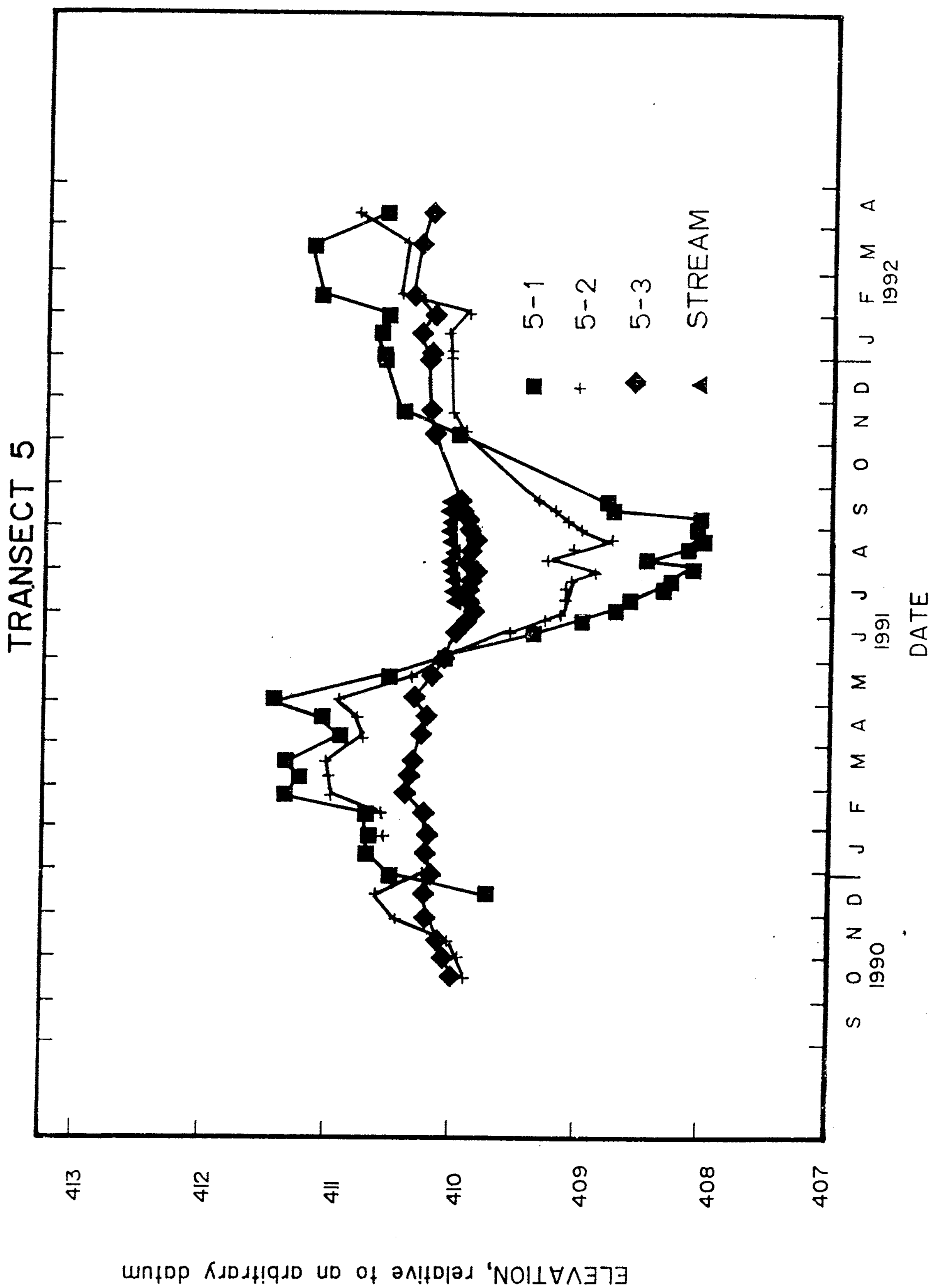


Figure 6. Water table hydrographs at Transect 5.

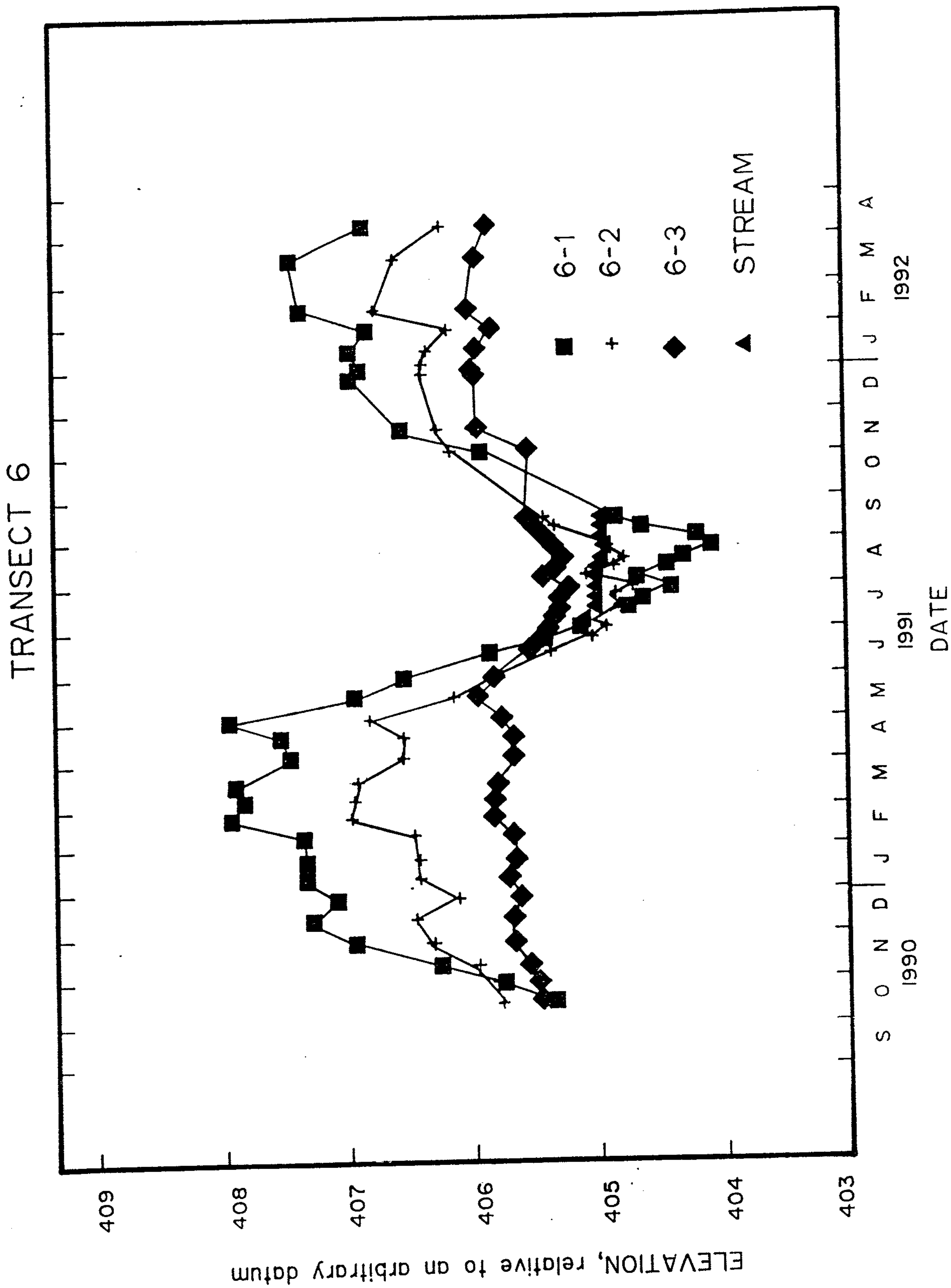


Figure 7. Water table hydrographs at Transect 6.

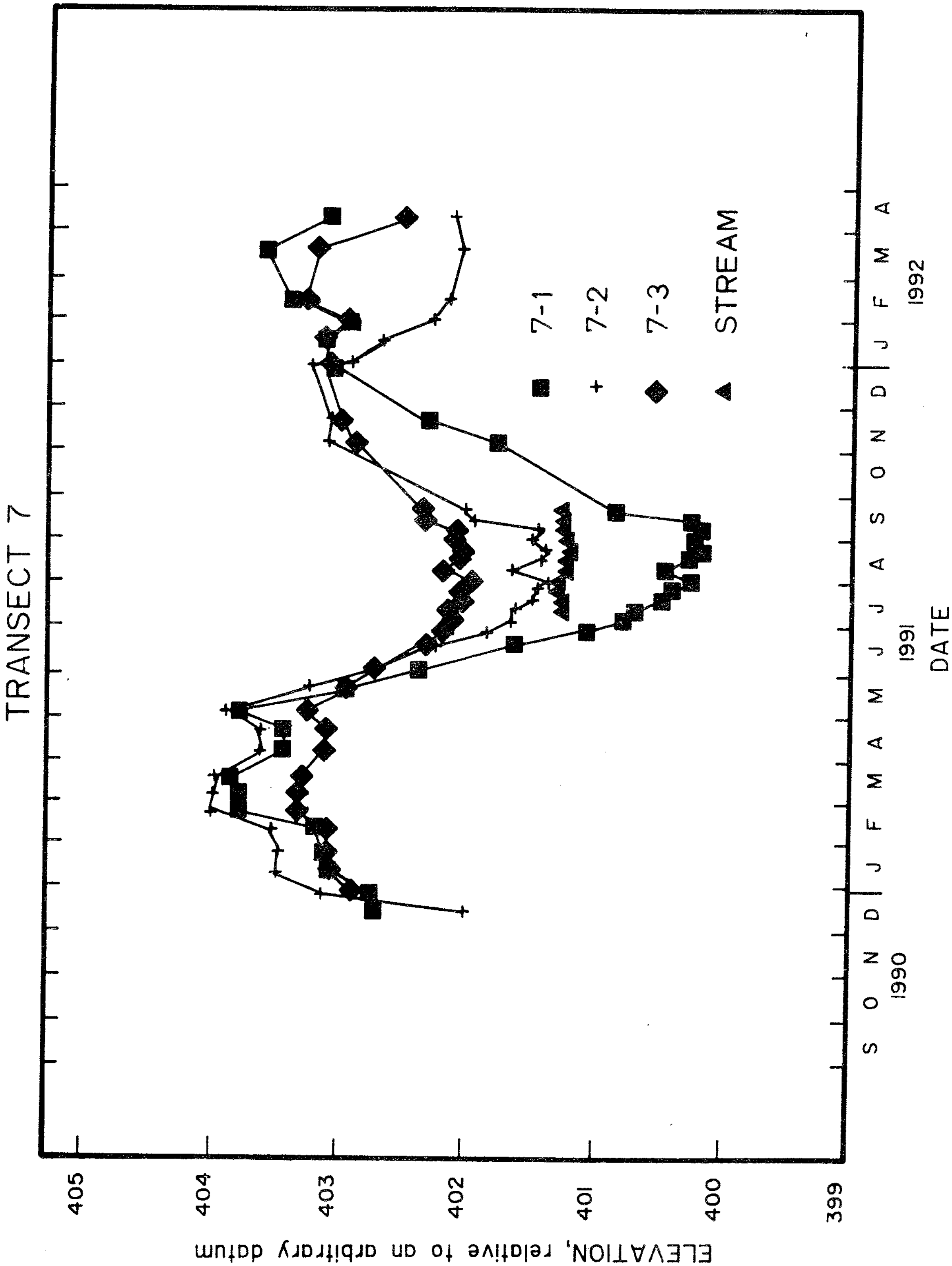


Figure 8. Water table hydrographs at Transect 7.

At transect 8, monitoring well 8-3 is closest to the creek and is located east of the creek, in contrast with the other transects where all of the monitoring wells are on the west side of the creek. Monitoring well 8-3 showed the least amount of annual water table change at this transect, approximately 1 foot (Figure 9). This is more fluctuation than is seen at either monitoring well 5-3 or 6-3 and is probably a result of well 8-3 being a little further from the creek and on the opposite side of the creek from the main local ground water flow path. Also, well 8-3 is in an area with more trees (and therefore higher evapotranspiration losses) than wells 5-3 or 6-3. The water table elevation in well 8-3 is about the same as the creek in the winter months and about 0.5 feet lower than the creek in the summer, indicating that the direction of ground water flow is parallel to the creek in the winter and that water is leaking from the creek to recharge the alluvial aquifer in the summer months. Monitoring wells 8-2 and 8-1 show increasing seasonal water level variability of approximately 2.8 and 3.9 feet, respectively. In the winter, water levels in these wells are slightly higher than the water level in the creek, indicating that the ground water and surface water systems are in equilibrium and ground water flow is parallel to the creek. In the summer, the water table at monitoring well 8-1 drops to about 3 feet lower than the creek, indicating that evapotranspiration losses exceed the rate of recharge from either the creek or ground water sources upgradient in the canyon. The water table at monitoring well 8-2 drops to about 2 feet lower than the creek, indicating that the alluvial aquifer in the midsection of the canyon is also in deficit due to evapotranspiration losses.

At transect 9, monitoring well 9-3 is closest to the creek and showed the least amount of annual water table change, approximately 0.5 feet (Figure 10). The small annual fluctuation is similar to that seen at wells 5-3 and 6-3, in the upper part of the canyon. The hydrologic setting in relation to the creek may also be similar. Immediately upstream from the monitoring well the stream channel is somewhat perpendicular to the slope of the valley floor. There may be more leakage from the stream at the upstream bend, with the ground water returning to the creek downstream from this line of wells. The concept may be thought of as water seeking the shortest path between 2 points. The water table elevation in well 9-3 is slightly below the level of the creek throughout the year, indicating that water from the creek is recharging the alluvial aquifer throughout the year. Monitoring wells 9-2 and 9-1 show increasing seasonal water level variability of approximately 2.7 and 3.3 feet respectively. Water levels in these wells are below the level of the creek throughout the year, ranging from about 1 to 1.5 feet lower than the creek in the winter to 4 to 5 feet lower than the creek in the summer, indicating that the west side of the lower canyon is an area that always has a water deficit relative to the creek.

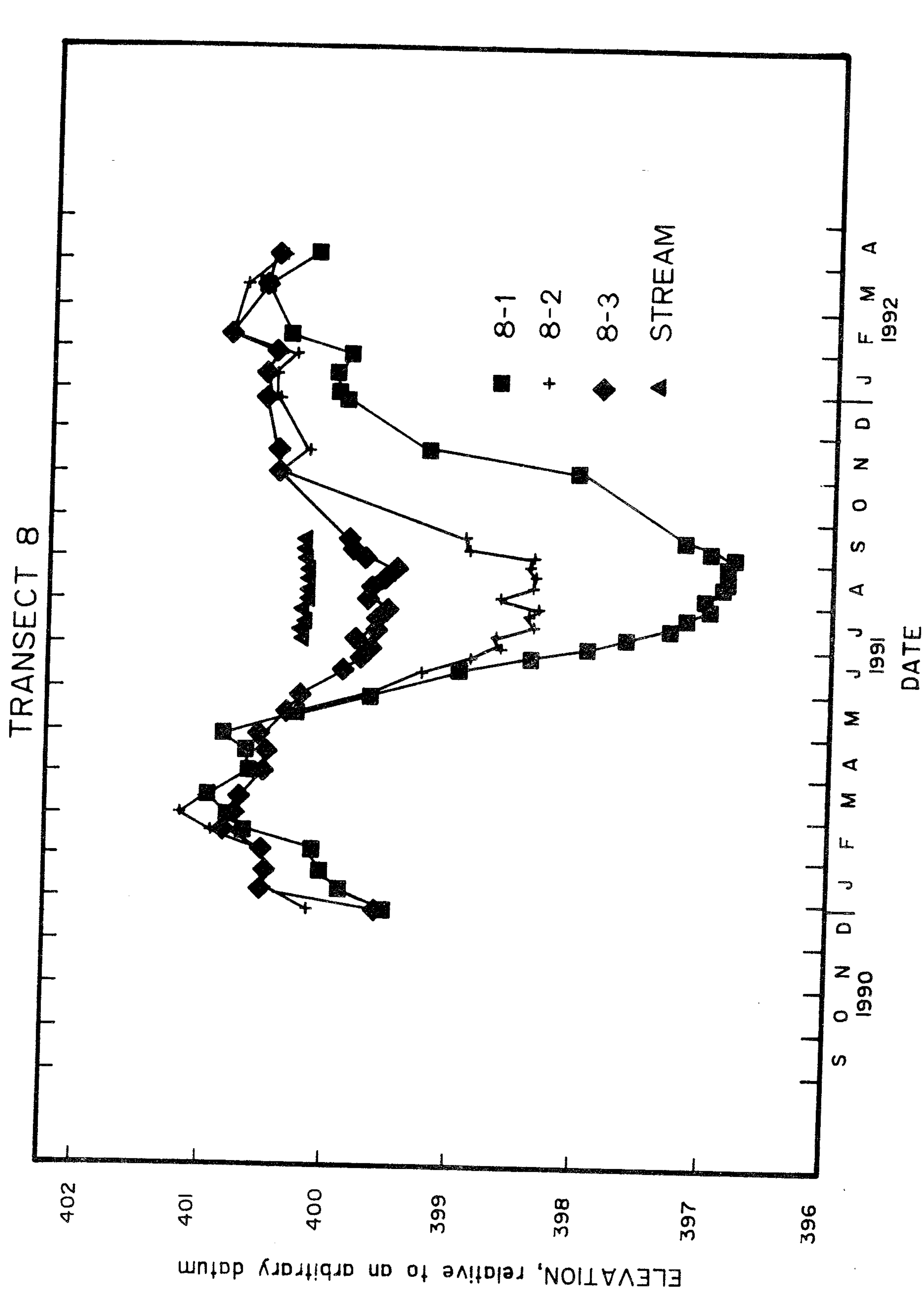


Figure 9. Water table hydrographs at Transect 8.

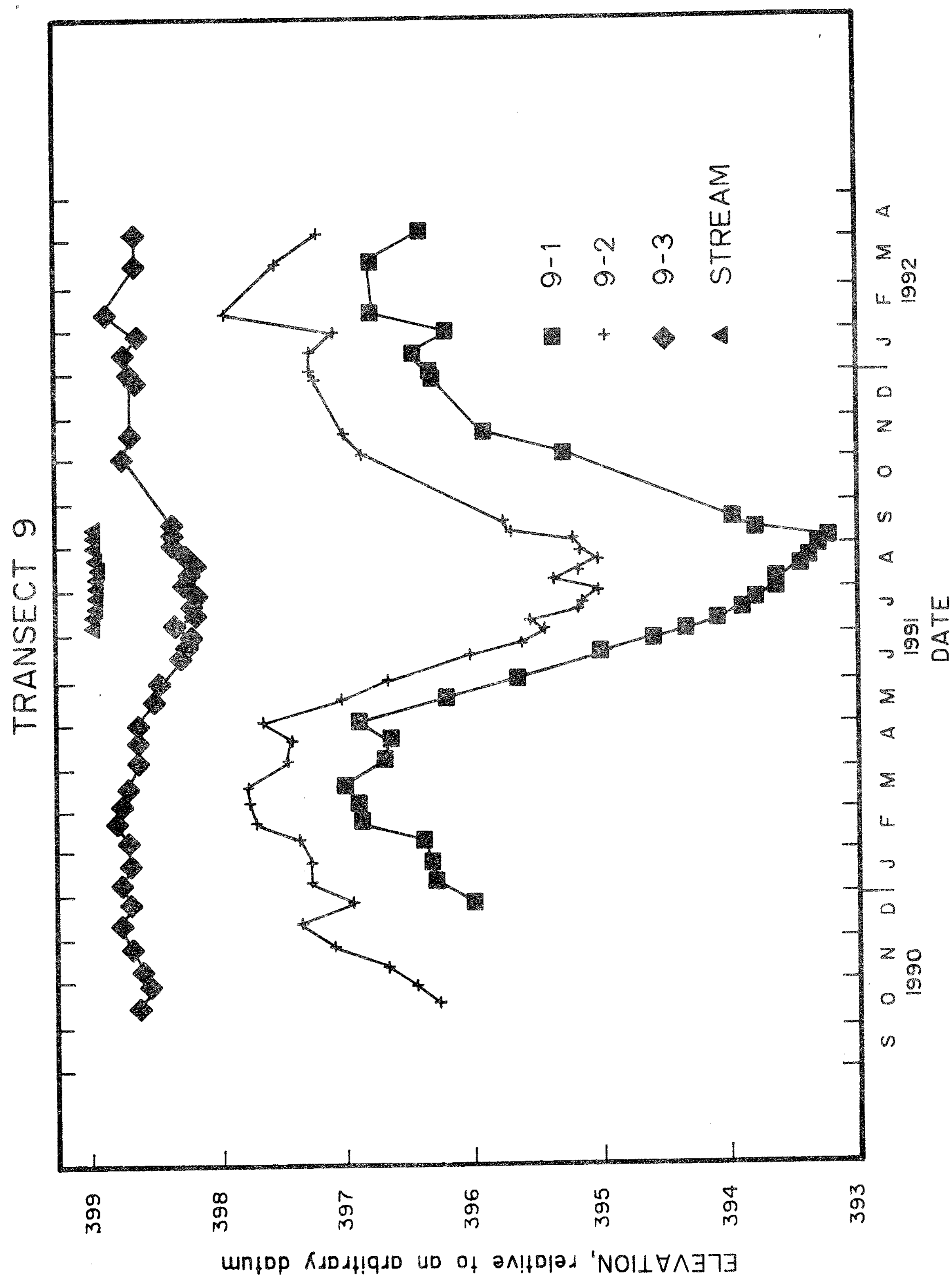


Figure 10. Water table hydrographs at Transect 9.

Lower Hog Canyon -- General Trends

Hydrographs of monitoring wells in the canyon (Figures 6 through 10) show a similar seasonal response. The water table begins to rise late in the fall in response to recharge from precipitation and reduced evaporation and transpiration by plants (evapotranspiration). The water table stabilizes in late-winter and spring as the alluvial aquifer fills and an equilibrium is established between the ground water and surface water systems. The water table begins to drop about May 1 in response to the trees leafing out (increased evapotranspiration). The amount of seasonal water level change varies between wells depending on distance from the creek, because water level changes near the creek are moderated by recharge from the creek.

Figure 11 is a contour map showing the water table on May 2, 1991 (high water table conditions). Ground water flow paths (perpendicular to the contours) are generally toward the creek, indicating that the alluvial aquifer has been filled to the level that ground water is discharging to the creek.

Figure 12 is a contour map of the water table on August 1, 1991 (low water table conditions). Ground water flow paths in the upper part of the canyon are generally parallel and equally spaced, indicating that ground water flow is approximately straight down the canyon. Ground water flow paths in the lower part of the canyon are generally away from the creek, indicating that surface water is recharging the alluvial aquifer in the lower reach of the canyon.

Hydrologic relationships of ground water and surface water for both a gaining and losing section of the creek are shown in Figure 13. Different reaches of the creek change from gaining to losing depending on the seasonal variations of water table elevation.

The water table contour maps show that the creek is perched above the water table, and therefore discharging to the alluvial aquifer along its lower reach (below transect 9) throughout the year. During the summer months, the water table is drawn down and the creek is perched above the water table below transect 7. From observations of the vegetative ecosystems in the upper part of the canyon, above the well locations, it appears that the creek is also probably perched above the water table in this area. The creek intersects the water table, and drains the aquifer, only along a short reach in the vicinity of transects 5, 6, and 7 where it has been incised by ditching for irrigation use. Thus, it would seem that the natural hydrologic condition in the canyon is for the creek to be perched above the water table with the water table receiving recharge via leakage out the bottom of the creek.

Ground water levels near the creek (e.g., monitoring wells 5-3, 6-3, 7-3 in Figures 6, 7, and 8) show relatively little seasonal change, ranging from about 0.5 to 1.0 feet. Seasonal variation in these areas is dampened by recharge from the adjacent perennial stream.

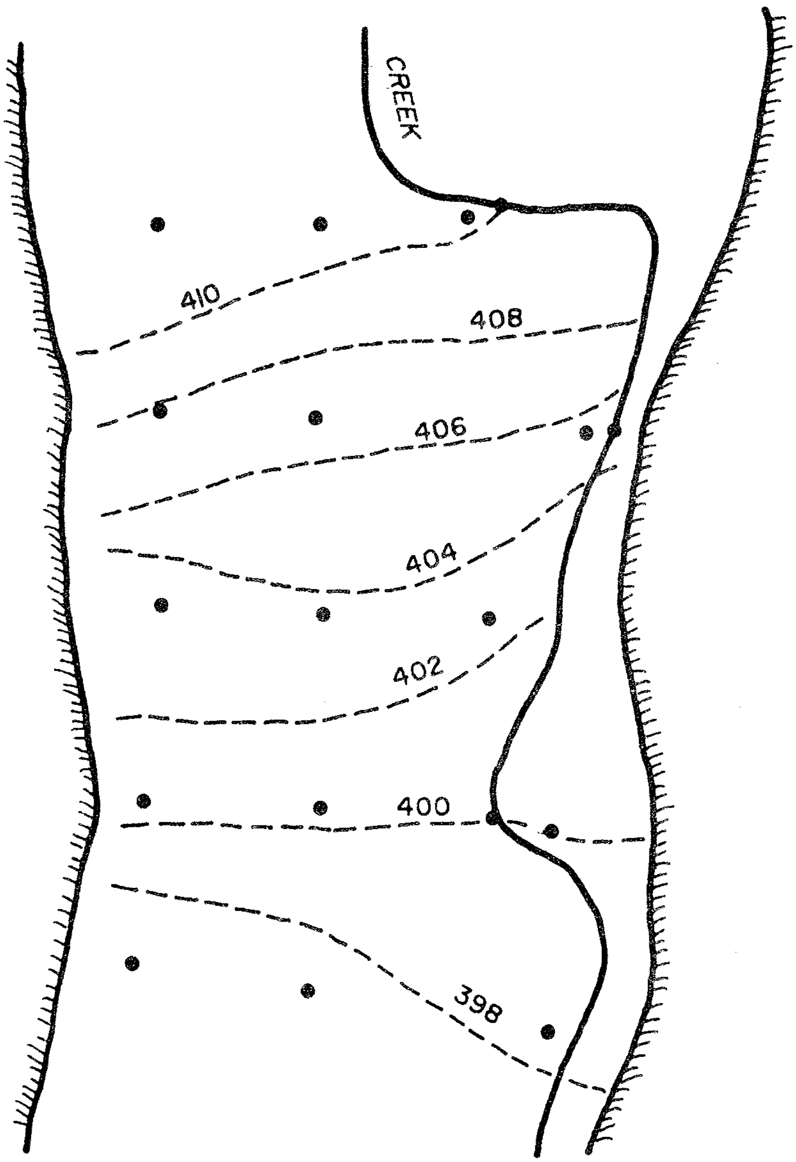


Figure 11. Water table contour map. Lower Hog Canyon, May 2, 1991.

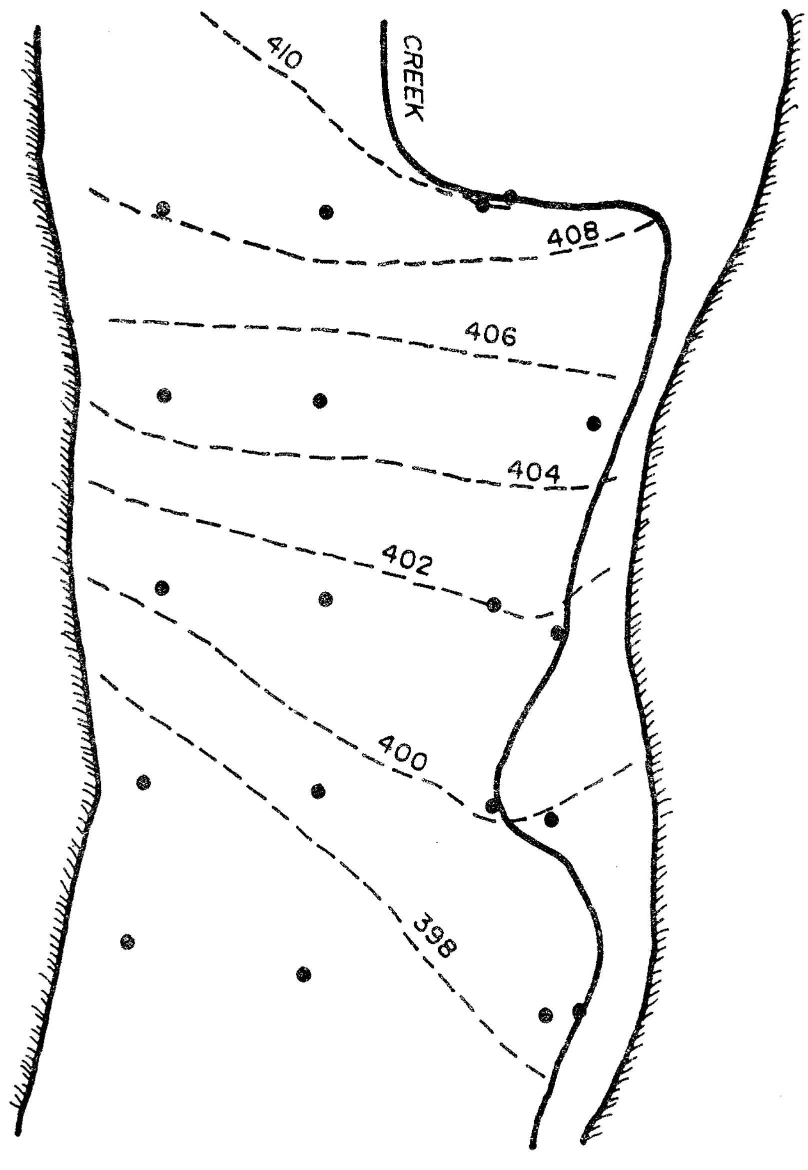
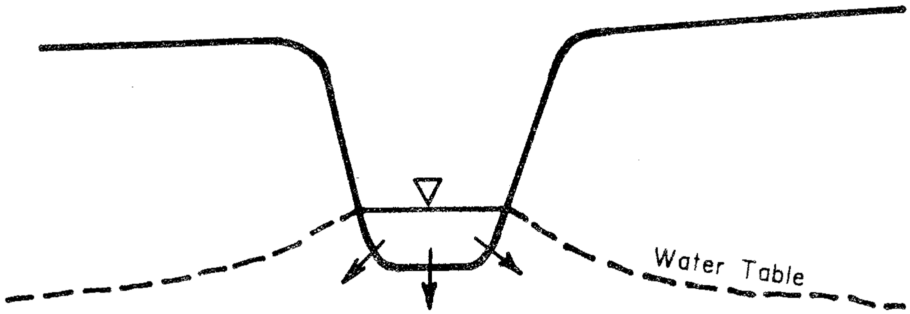
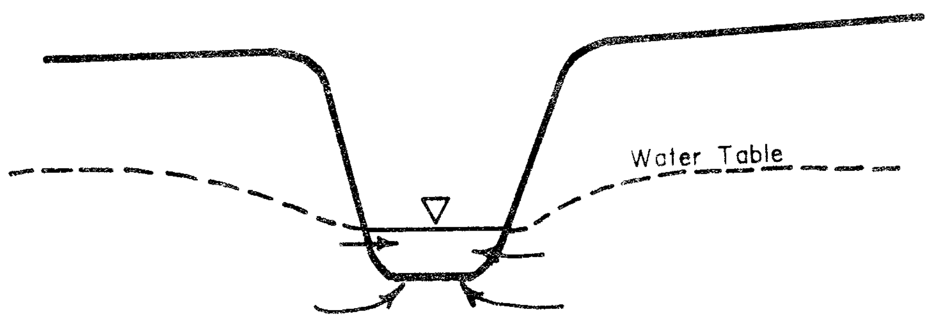


Figure 12. Water table contour map. Lower Hog Canyon, August 1, 1991.



LOSING STREAM



GAINING STREAM

Figure 13. Schematic of ground water/surface water relationships for a gaining and losing stream.

Monitoring wells on the west side of the canyon have the greatest seasonal water level change. This area is too distant from the stream to receive much recharge from the stream throughout the summer months when evapotranspiration is greatest. In winter, water levels in this area rise above the level of the stream. Recharge in this area is from ground water flow from areas upgradient in the canyon.

Alluvial Fan Monitoring

Nine monitoring wells were installed on the alluvial fan downstream from the mouth of Hog Canyon (Figure 14). The wells were placed along three transects across the fan to identify hydrologic variability related to the position of the creek, wetland areas, and sheetflow on the lower part of the fan. Because of the greater distances between wells and the land surface elevations across the fan, it is also instructive to look at plots of depth to water below land surface for the individual wells shown in Figures 15, 16, and 17.

Monitoring wells on transect 12, which were installed in September, 1990, had water table variations similar to that seen along the transects in lower Hog Canyon. Monitoring well 12-3 is located near the east edge of the fan, near the creek. Water levels in this well showed little variability, remaining within 1 foot of land surface throughout the year. Monitoring wells 12-2 and 12-1 had seasonal water level variation of 2.5 and 3.9 feet, respectively. Water levels in winter rose to within about 3.5 feet of the land surface. In summer, the water table was drawn down to about 6 to 8 feet below land surface. The local effects of the creek on ground water levels are seen along this transect. Water levels near the creek are most affected, with effects waning to the west, away from the creek. Recharge from the creek maintains a higher ground water level in the vicinity of the creek, allowing wetland vegetation to flourish in these areas.

Monitoring wells in transects 13 and 14 were installed in July, 1991, and therefore have a much shorter period of record. Wells in both transects show similar hydrologic conditions across the fan. Wells 13-2 and 14-2, in the wetland areas near the toe of the fan, have water levels above or near the land surface. Monitoring wells 13-1 and 14-1, in the drier areas near the west edge of the fan have water levels several (3 to 5) feet below land surface. Wells 13-3 and 14-3, near the east edge of the fan have water levels between 1 and 3 feet below land surface for most of the year. Water levels in this area may be influenced by the nearby creek.

Depth to Ground Water in the Lower Part of the Canyon

The depth to ground water is an important factor in determining the vegetative community in an area. In Hog Canyon, the depth to ground water is controlled in part by the incision of the creek in an artificially constructed ditch on the east side of

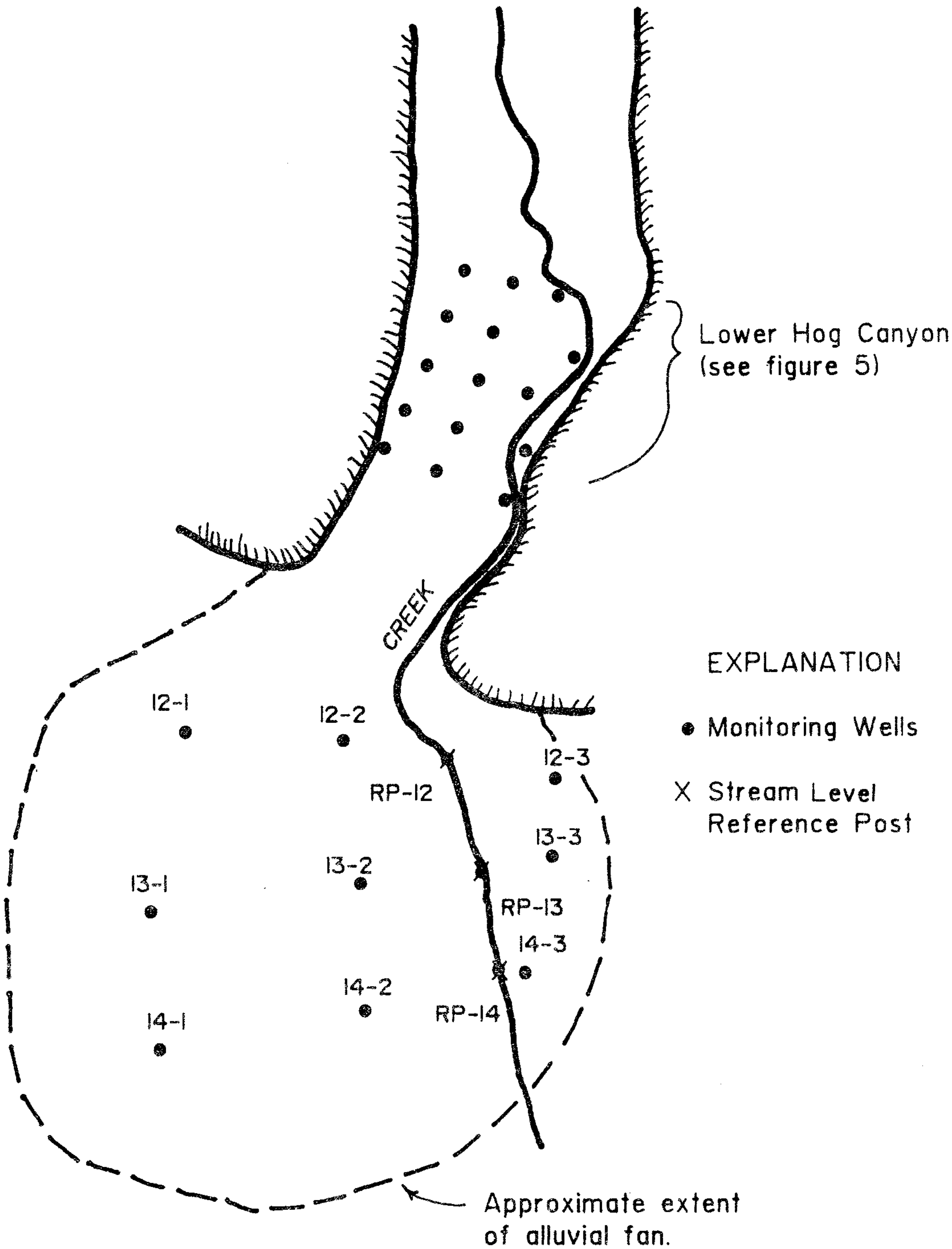


Figure 14. Monitoring locations on the Hog Canyon alluvial fan.

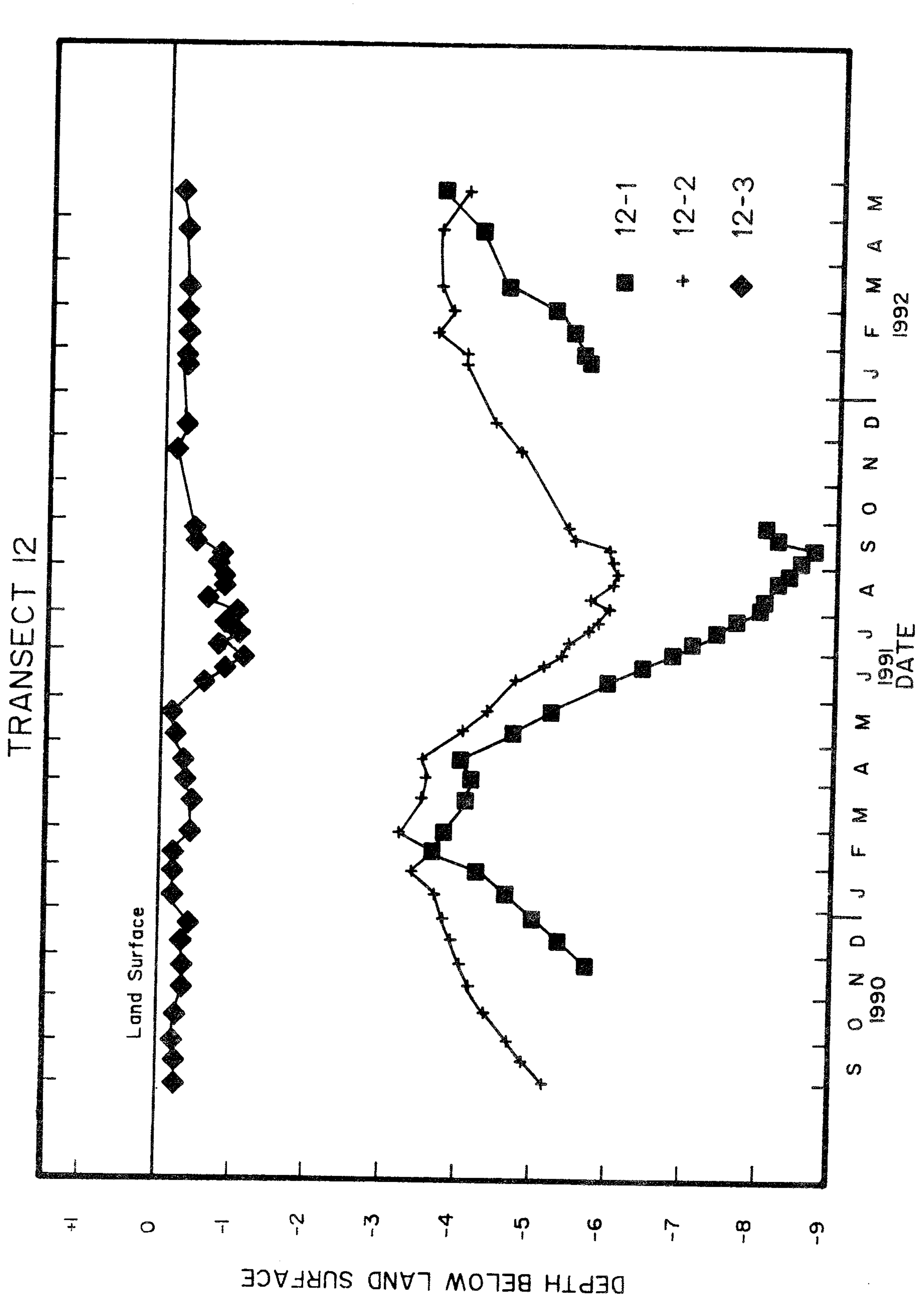


Figure 15. Water table hydrographs at Transect 12.

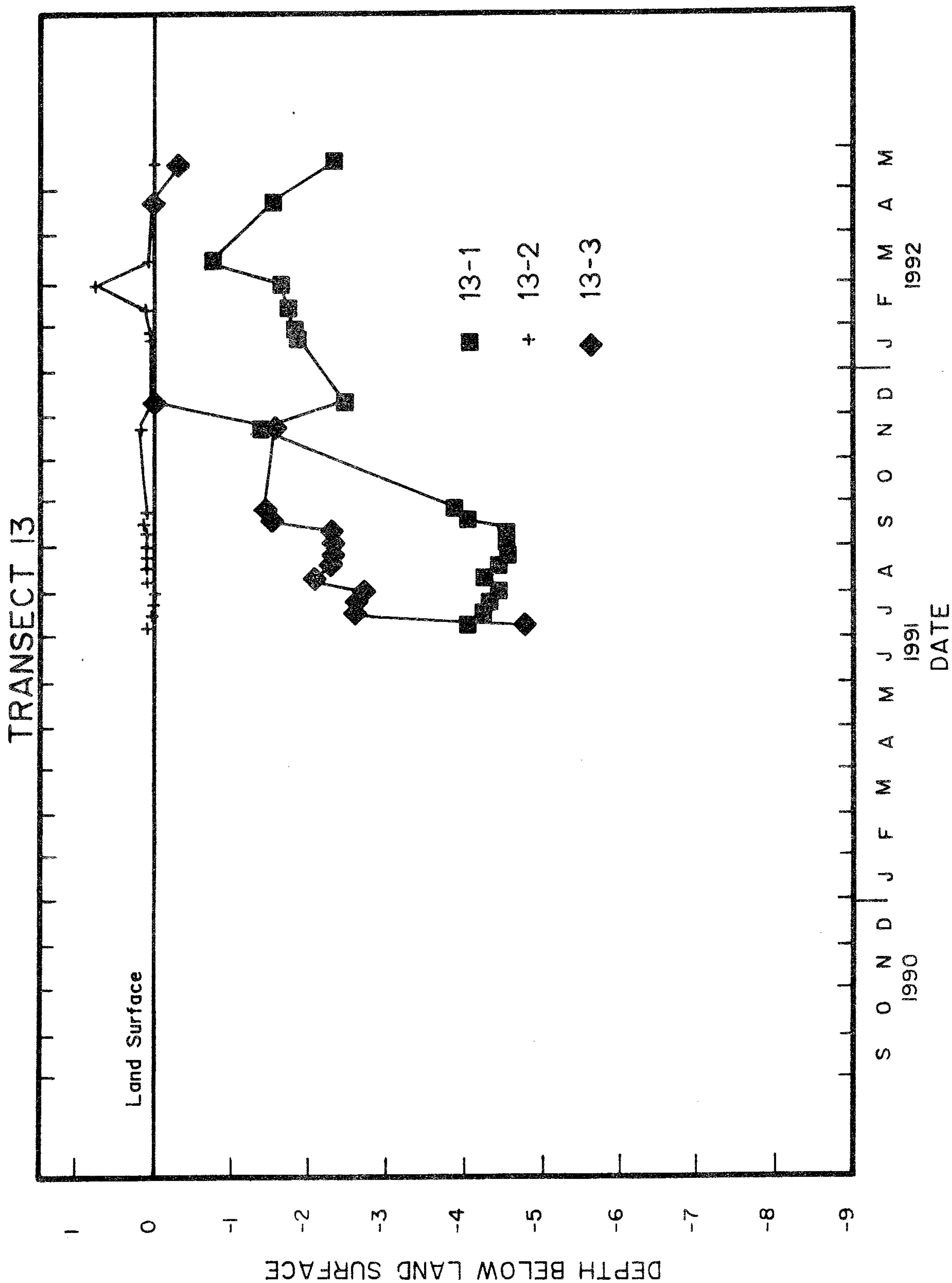


Figure 16. Water table hydrographs at Transect 13.

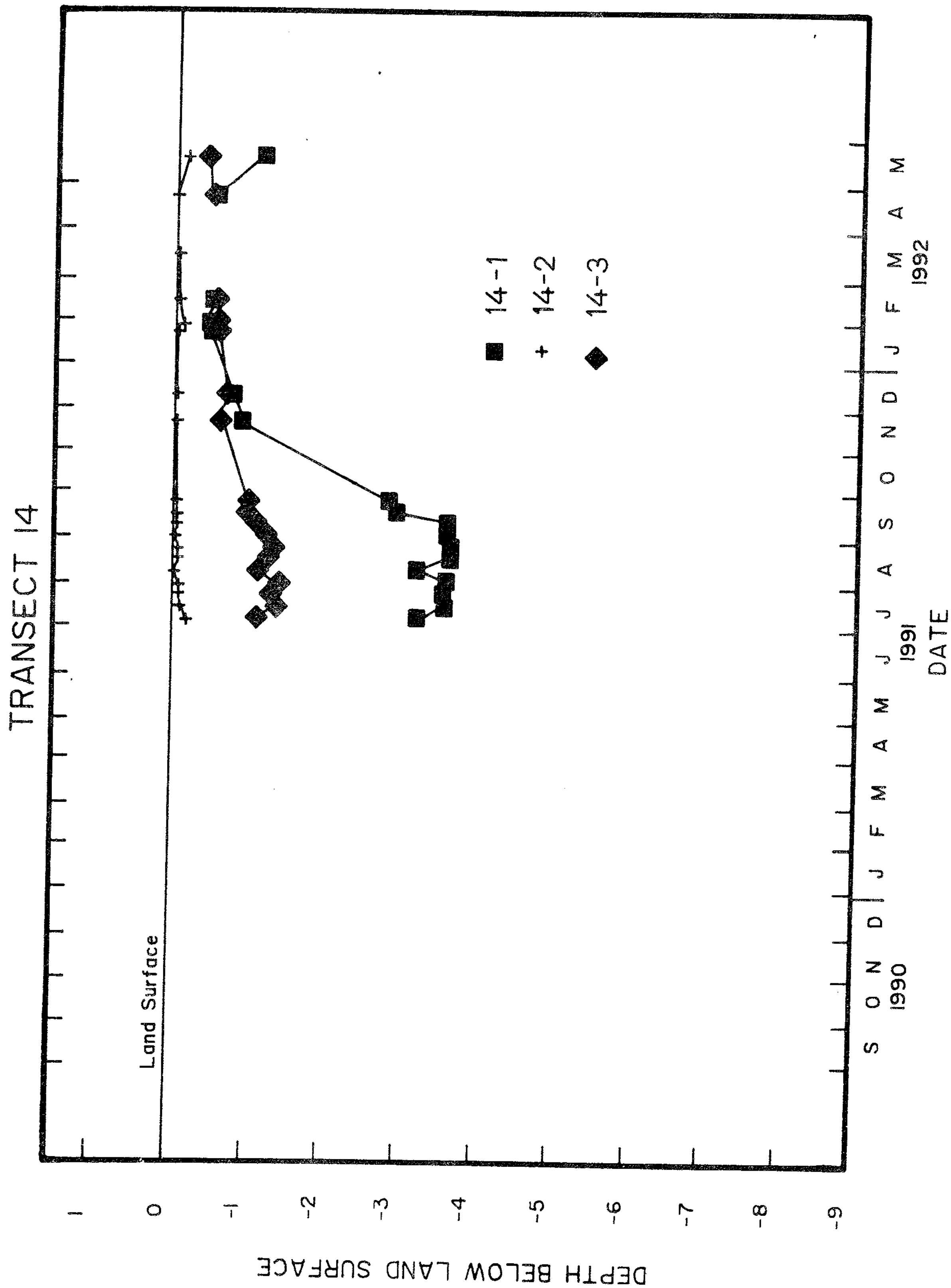


Figure 17. Water table hydrographs at Transect 14.

the lower canyon. Figures 18 and 19 show the depth to ground water on May 2 and August 1, 1991 at monitoring wells in the lower part of Hog Canyon. There is relatively little seasonal variation in the depth to the water table near the creek. The lack of variation is due to interaction of the ground water and surface water systems near the creek. The creek acts as either a constant head source of recharge or a drain for the water table, depending on local hydrologic conditions. In May, when the water table is highest, the water table is generally about 1 to 2 feet below land surface in most of the lower canyon except where it is affected by the creek or the incised channel. In August, when the water table is at its lowest level, the depth to water is more than 5 feet near the west side of the canyon and 3 to 4 feet along the middle profile of the canyon.

Hydrologic Monitoring - Surface Water

A 90-degree V-notch weir was installed on Hog Canyon Creek in the upper part of the canyon, but below all known tributaries, springs, and seeps. Streamflow at the weir remained fairly constant at about 0.35 ft^3/s. A thunderstorm on August 2, 1991 caused a sudden increase in streamflow and eroded the embankment adjacent to the weir. The weir was replaced and no further problems were encountered at the site.

Streamflow monitoring was conducted on Cub Creek upstream and downstream from Hog Canyon to determine the amount of streamflow gain attributable to flow from Hog Canyon. It is not possible to attribute all of the streamflow gain to discharge from Hog Canyon because several other small tributary canyons parallel to Hog Canyon also contribute to the streamflow gain on Cub Creek. Streamflow monitoring data for Cub Creek are presented in Table 3.

Table 3. Streamflow measurements for Cub Creek. Values are Ft^3/S.

Date	Cub Creek Downstream	Cub Creek Upstream	Gain Ft^3/S
1991 September 16	1.83	1.17	0.66
September 17	1.76	1.20	0.56
October 25	1.58	1.06	0.52
November 6	1.53	1.02	0.51
November 22	1.59	0.94	0.65
December 21	1.68	1.25	0.43
1992 January 3	1.33	0.94	0.39
January 17	1.75	1.21	0.54
February 8	1.70	1.14	0.56
February 14	1.61	1.13	0.48
		Average	0.53

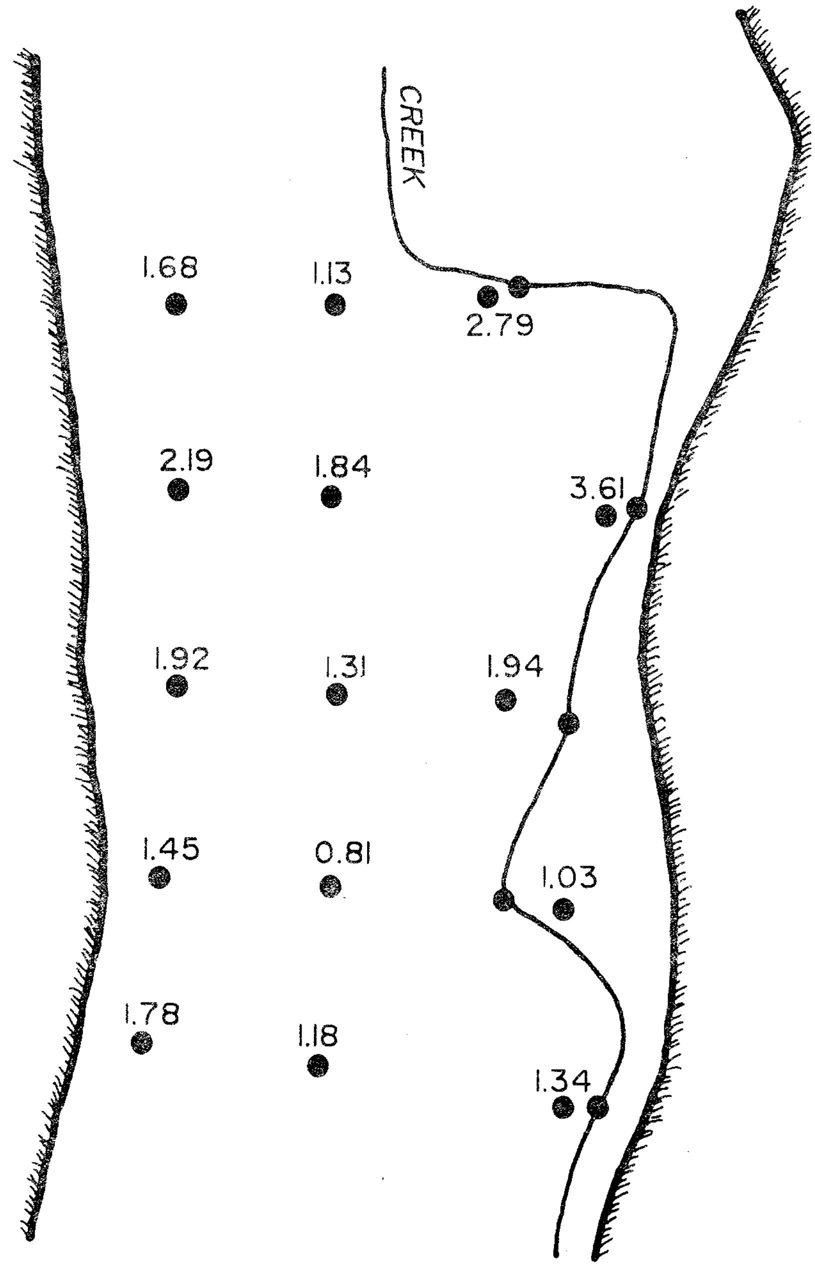


Figure 18. Depth to water (below land surface) in Lower Hog Canyon, May 2, 1991.

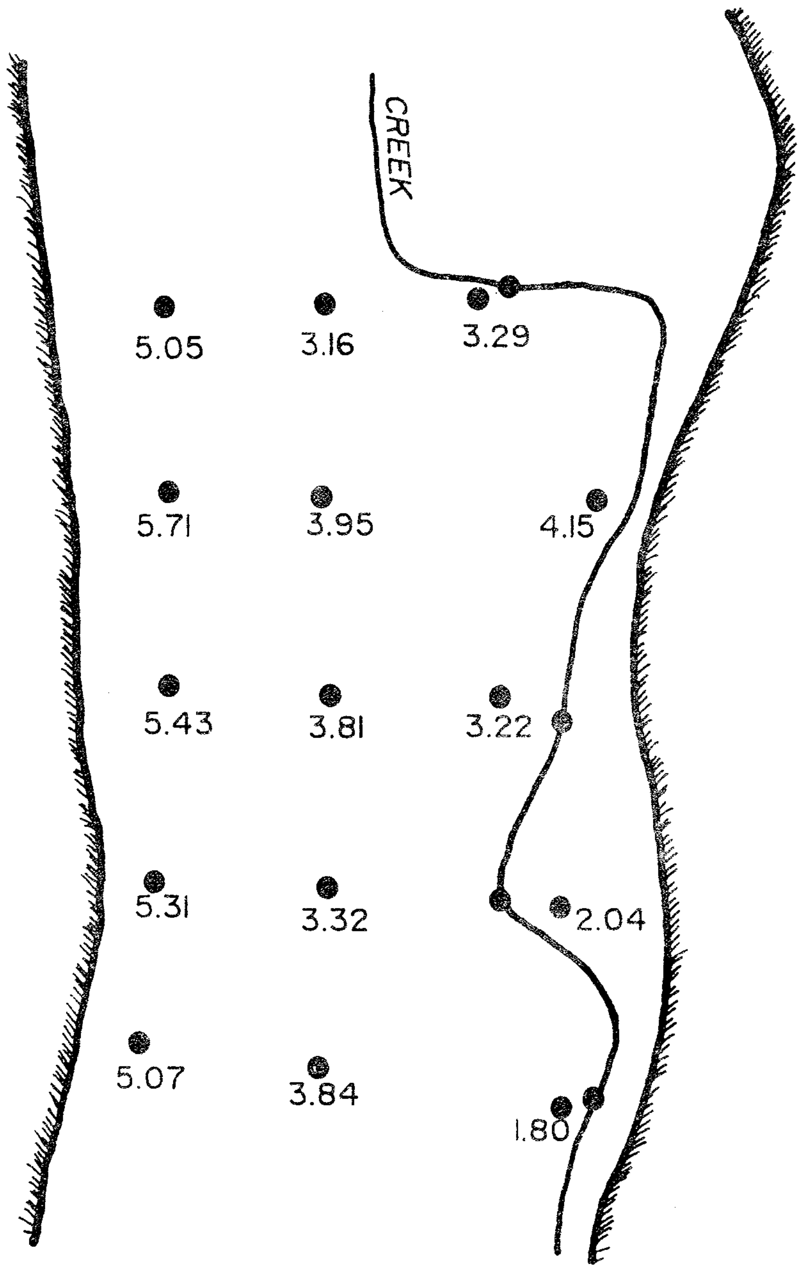


Figure 19. Depth to water (below land surface) in Lower Hog Canyon, August 1, 1991.

Prior to September 16, streamflow monitoring sites on Cub Creek were not far enough upstream or downstream to include all of the gain in the reach of Cub Creek passing Hog Canyon. Monitoring sites on Cub Creek were moved further upstream and further downstream on September 16 to better account for tributary water from Hog Canyon. Data collected after that time show an average streamflow gain of about 0.5 ft^3/s in Cub Creek as it passed the mouth of Hog Canyon. Most, but not all, of the gain can be attributed to outflow from Hog Canyon. Outflow from other small canyons adjacent to Hog Canyon also contribute water to Cub Creek. The amount of water contributed by adjacent canyons is probably relatively small because they do not support perennial streams. Ground water is the only source of outflow from these canyons. The quantity of water flowing from the canyon as ground water is small compared with surface water outflow, as explained in the following section.

Estimate of Ground Water Flow from Hog Canyon

An estimate of the quantity of ground water flowing from Hog Canyon was made for comparison with the quantity of surface water flowing in the creek and to establish a frame of reference regarding the quantities of water that may potentially be affected by a riparian restoration project in Hog Canyon. The reader should remember that the water table in the alluvial aquifer is at a depth of approximately 1 to 2 feet below land surface in the winter and spring, i.e., the aquifer is nearly full. This time period represents the maximum ground water flow contribution from Hog Canyon.

Ground water flow through this part of the canyon was estimated using Darcy's Law:

$$Q = K A \frac{h_1 - h_2}{L}$$

Where:
- Q = discharge
- K = hydraulic conductivity of the sediments
- A = cross sectional area (width x depth)
- $h_1 - h_2$ = head loss
- L = length between head measurements

An average canyon width of 150 feet was determined from survey data at each transect. The average distance between transects 5 and 12 is 200 feet. Data is not available for determining the thickness of the alluvial aquifer. Estimates of discharge are made using thickness ranging from 10 to 30 feet to provide an estimate of discharge for the full range of probable conditions. Hydraulic conductivity is also unknown. Textbook values of the hydraulic conductivity of fine sand range from about 10 to 30 feet/day. Average water table elevations at transects 5 and 12 were computed for both May 2 (high water table) and August 1 (low water table). In May, the average water table elevations were 410.9 and 397.7 feet at transects 5 and 12, respectively. Average head loss between the two transects was 13.2 feet. In August, the average water table elevations were 408.9 and 395.6 feet. Average head loss between the two transects was 13.3 feet. Thus, the slope (h_1 - h_2) of the water table remains approximately the same for both high and low water table conditions.

The only parameter in the equation that varies seasonally is the thickness of the aquifer (water table elevation - elevation of the aquifer bottom). In this case that change is 2 feet. Since the thickness of the aquifer is unknown, it is impossible to judge the effect this change has on ground water discharge from the canyon. If the aquifer is 20 feet thick, lowering the water table 2 feet will reduce the discharge by 10%. If the aquifer is 10 feet thick, lowering the water table 2 feet will reduce discharge by 20%.

In this investigation, the following parameters were used to estimate ground water flow in the lower part of Hog Canyon:

K = 10, 20, or 30 feet/day
Width = 150 feet
Depth = 10 to 30 feet
A = width x depth
h_1 - h_2 = 13.2 feet
L = 200 feet

Estimated ground water discharge from Hog Canyon for the range of conditions described above is given in Table 4. Discharge values given in the table are in ft^3/day (with ft^3/s in parentheses for comparison with streamflow values).

Table 4. Estimated ground water outflow from Hog Canyon. Values are Ft^3/Day and Ft^3/S.

Hydraulic Conductivity	Thickness (feet) 10	20	30
10 ft/day	990 (.01)	1980 (.02)	2970 (.03)
20 ft/day	1980 (.02)	3960 (.05)	5940 (.07)
30 ft/day	2970 (.03)	5940 (.07)	8910 (.10)

Estimates of ground water discharge from Hog Canyon range from less than 0.01 to about 0.1 ft^3/s. Streamflow in Hog Canyon remains fairly constant at about 0.353 ft^3/s. Thus, it should be obvious that ground water is a minor component of total discharge from the canyon. These estimates of ground water discharge assume that the alluvial aquifer in Hog Canyon is nearly full. Moving the stream from its present incised location to another position on the surface of the valley fill will have little appreciable effect on the thickness of the aquifer, and therefore ground water discharge will not change significantly.

Summary of Water Budget

Monitoring has shown that Cub Creek gains about 0.5 ft^3/s of water as it flows past Hog Canyon. Field inspections verify that surface water leaving Hog Canyon flows into Cub Creek. It also appears likely that ground water flowing from Hog Canyon contributes to the gain in Cub Creek. Ground water appears to be forced to the surface on the alluvial fan, but still reaches Cub Creek as sheetflow after passing through wetland areas. Streamflow from Hog Canyon is about 0.35 ft^3/s and ground water outflow is probably about 0.01 to 0.1 ft^3/s; for a total canyon outflow of about 0.35 to 0.45 ft^3/s. Some of the gain in streamflow at Cub Creek may be attributed to ground water outflow from smaller canyons adjacent to Hog Canyon. Within the bounds of measurement error and estimation, the streamflow gain in Cub Creek can be accounted for by outflow from Hog Canyon.

Streamflow gaging data for Cub Creek is only available for September, 1991 to February, 1992. Evapotranspiration losses during this time can be assumed to be negligible. Thus, the authors are able to show close agreement between outflow from Hog Canyon and inflow to Cub Creek. Continued monitoring of the Cub Creek sites could provide data to estimate evapotranspiration losses in Hog Canyon and the alluvial fan during summer months.

SOIL MOISTURE

Introduction and Methods

Soil moisture data were collected in lower Hog Canyon and on the alluvial fan below the canyon mouth during the summer of 1991. The data were intended as "snapshot" observations of soil moisture conditions at key locations in the study area for use in:

1. Helping to determine what factors may be controlling soil moisture in Hog Canyon (e.g., influence of the water table and the stream).

2. Providing initial information relating soil moisture conditions to known orchid locations.

3. Predicting how changes in the location of the stream might affect soil moisture conditions in Hog Canyon.

Twenty-two sampling holes were augered in Hog Canyon and on the alluvial fan (see sample locations in Figures 20 and 21). Five of these sampling sites were in the vicinity of *Spiranthes diluvialis* plants in the lower canyon (sites 1, 1a, 2, 2a, and 3). Three sampling holes were augered in a line perpendicular to the stream near well 5-3 ("site 5"), and a series of 9 holes were augered perpendicular to the stream near well 7-3 ("site 7"). Sites 5 and 7 were sampled primarily to look at the relationships between soil moisture, the water table, and the stream. Soil samples were also taken during installation of 5 monitoring wells on the alluvial fan (sites 13-1, 13-2, 13-3, 14-1, and 14-3). These samples were taken to look at relationships between soil moisture and the water table on the alluvial fan.

Methods used to extract, store, dry, and weigh soil samples were consistent throughout the data collection effort (see full discussion of methods in Riedel 1992). At each site, samples were taken at 6-inch intervals over the first 2 feet of depth, and at 12-inch intervals below 2 feet to a total depth of 60 inches (less at some sites where the water table was encountered near the surface). Sample cans were marked with the site locations and filled approximately 50 to 75% with soil. Lids were taped on the sample cans to minimize moisture loss. The wet weights of the samples were obtained as soon as possible (2 to 6 hours) after collection. Samples were dried for 24 hours at 85°C. Dry weights were then recorded, and tare weights were obtained by weighing the cleaned, dried cans. The percent moisture for the samples were calculated using the formula:

$$\%\ \text{moisture} = \frac{\text{wet weight - dry weight}}{\text{dry weight - tare weight}} \times 100$$

That is, it was determined what percentage of the mass of each soil sample was water.

Availability of soil moisture to plants is related to soil texture. For example, at the same percent moisture, the water in a sandy loam (relatively coarse-textured soil) is more available to plants than in a finer-textured medium such as a clay soil. Therefore, it is necessary to know specific characteristics of the soils at the sample sites in order to interpret the soil moisture data.

During soil moisture sampling, Rick Foster of the SCS, in Vernal, Utah, identified soil types for the study site. The soils in lower Hog Canyon and across much of the alluvial fan are predominantly Green River loam, with typical profiles consisting of loam, sandy loam, and loamy sand to 60 inches or more in depth. Field capacity for

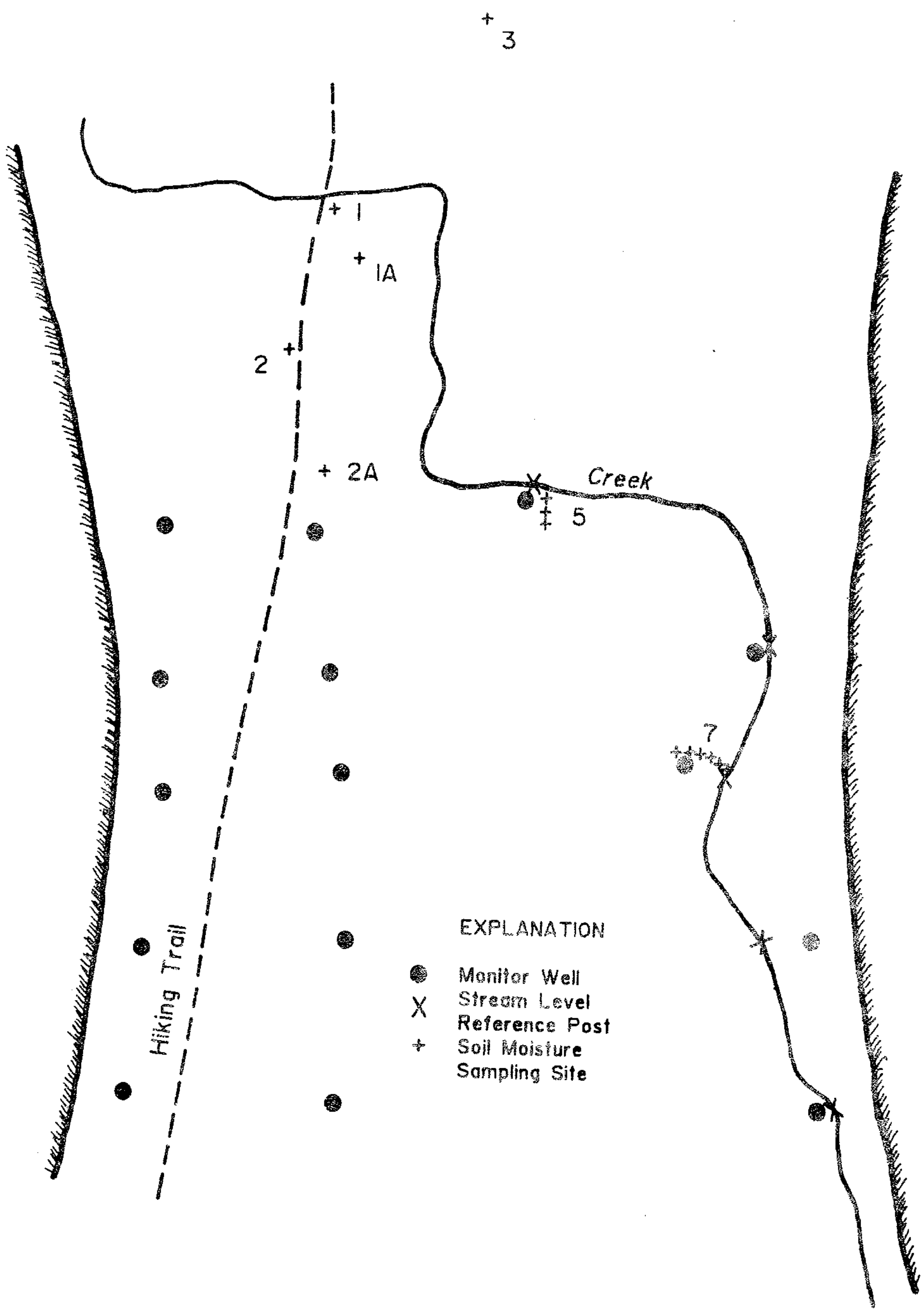


Figure 20. Location of soil moisture sampling sites, Lower Hog Canyon.

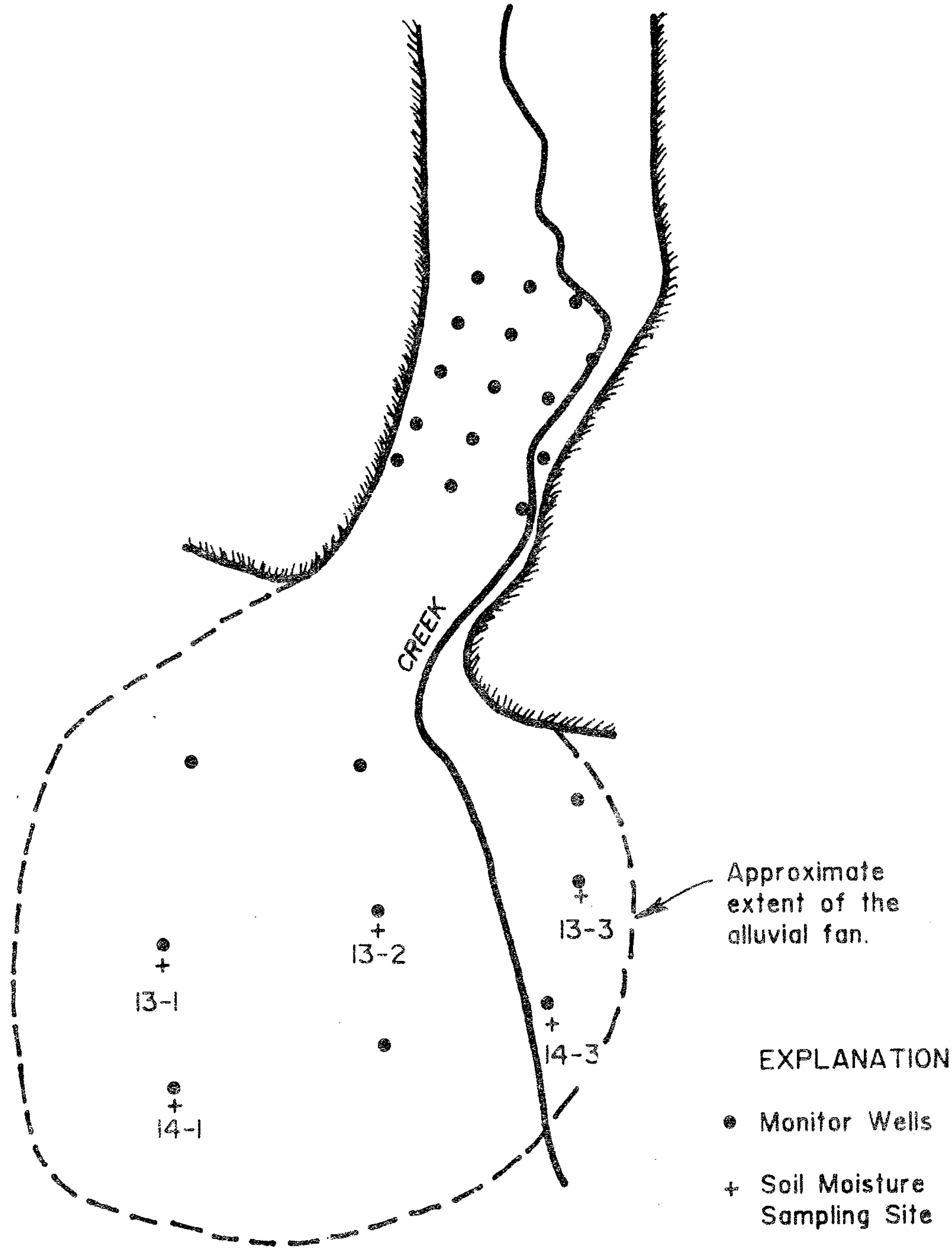


Figure 21. Location of soil moisture sampling sites on the alluvial fan.

this soil is approximately 18% soil moisture, with a permanent wilting point of about 8% (Rick Foster, pers. comm., SCS). However, these values will vary from site to site depending upon local variation in texture. Within this range, soil moisture is available to a relatively wide variety of plants. But as values rise well above 18% and approach saturation during the growing season, hydrophytic plants will tend to dominate.

The other soil series noted in the study area along the wetter margins of the alluvial fan is the Poganeab series. These soils, which are common to wet meadow/floodplain environments in this region, are typically silty clay loams that are frequently stratified with layers of sand or sandy loam. These soils also exhibit a peat layer near the surface in sites along the margin of the fan where the soil is saturated to the surface for extended periods during the growing season. Field capacities and wilting points are quite variable in this soil type because of texture variability and stratification. Representative values are about 25% to 30% for field capacity and about 15% for permanent wilting point (Rick Foster, pers. comm., SCS).

Sources of Soil Moisture in Lower Hog Canyon

Rainfall

During significant rainfall events, Hog Canyon soils can become temporarily saturated. Once gravity has drained excess soil water to the point of field capacity, evaporation and plant transpiration draw soil moisture down toward the permanent wilting point (unless the supply of soil moisture is replenished). Rainfall is not expected to play a significant role in maintaining high soil moisture near the ground surface in this arid environment, with the possible exception of site 3 as explained in the "Results and Interpretation" section below.

Capillary Zone Above a High Water Table

Capillary water rises through the pore spaces in the soil above the water table to a height at which gravity counterbalances the forces of adhesion and cohesion in soil water. Normally this rise is inversely proportional to the size of the pore spaces in the soil, so a relatively coarse-textured soil such as the Green River loam in Hog Canyon has less capillary rise above the water table than would a finer-textured soil. Estimated capillary rise above the water table in Hog Canyon soils is in the range of 18 to 24 inches (derived from Figure 5.5 in Brady 1990, and from Rick Foster, pers. comm., SCS). Therefore, when the water table is within about 2 feet of the ground surface in Hog Canyon, soil moisture in the root zone for most herbaceous vegetation should, in theory, be constantly replenished through capillary rise above the water table. The longer the high water table in these areas is sustained, the longer soil moisture can be replenished near the surface and create potential orchid habitat.

Moist Streamside Zones

In addition to vertical capillary water movement above the water table, capillary movement occurs horizontally in soils away from surface water sources such as streams or irrigation ditches. Figure 22 illustrates both the downward flow of irrigation water (primarily through gravity) as well as the lateral and upward movement away from the water source via capillary action. Part (a) of this figure indicates that even for a relatively coarse sandy loam such as that found in Hog Canyon, a moist streamside zone of perhaps 1 to 2 feet or more is created on either side of the stream. Clearly, this process would create more potential orchid habitat when the stream is flowing on the surface than along the nearly vertical, deeply incised channel banks in the ditched portions of the stream.

Results and Interpretation

Figures 23 through 27 show results of the soil moisture sampling conducted during the summer of 1991 in Hog Canyon. Site numbers refer to the soil sampling locations shown in Figures 20 and 21. Values shown in these figures are percent soil moisture calculated by the methods discussed above. Water levels and other hydrologic data are included in these figures where pertinent to the following discussions.

Sites 1, 1a, 2, and 2a

These soil sample sites were located within the zone where ninety-six *Spiranthes diluvialis* plants were found during monitoring in 1991 (Figure 20). Figure 23 shows that all four of these sites showed percent soil moisture well above the estimated field capacity for the Green River loam at or near the ground surface. Water level at well 5-2 is shown with the data from sample site 2a, to illustrate the relationship between water table elevation, capillary rise above the water table, and soil moisture. The rapid decrease in soil moisture between the 6-inch depth sample and the 12-inch depth sample coincides well with the estimated capillary rise of about 18 to 24 inches in the Green River loam. These data also provide some evidence of a correlation between high soil moisture and presence of orchids.

It appears that several processes are contributing to high soil moisture conditions in this area. This reach of the perennial stream is not incised and, therefore, the stream constantly replenishes moisture in a relatively broad streamside zone at the surface. Because of the sinuosity of the stream in this area, more streamside zone exists than if the channel followed a course straight down the canyon. Stream sinuosity also allows for more aquifer recharge in this zone than if the stream was straight down the canyon. Finally, the water table is not drained locally by an incised channel as is the case

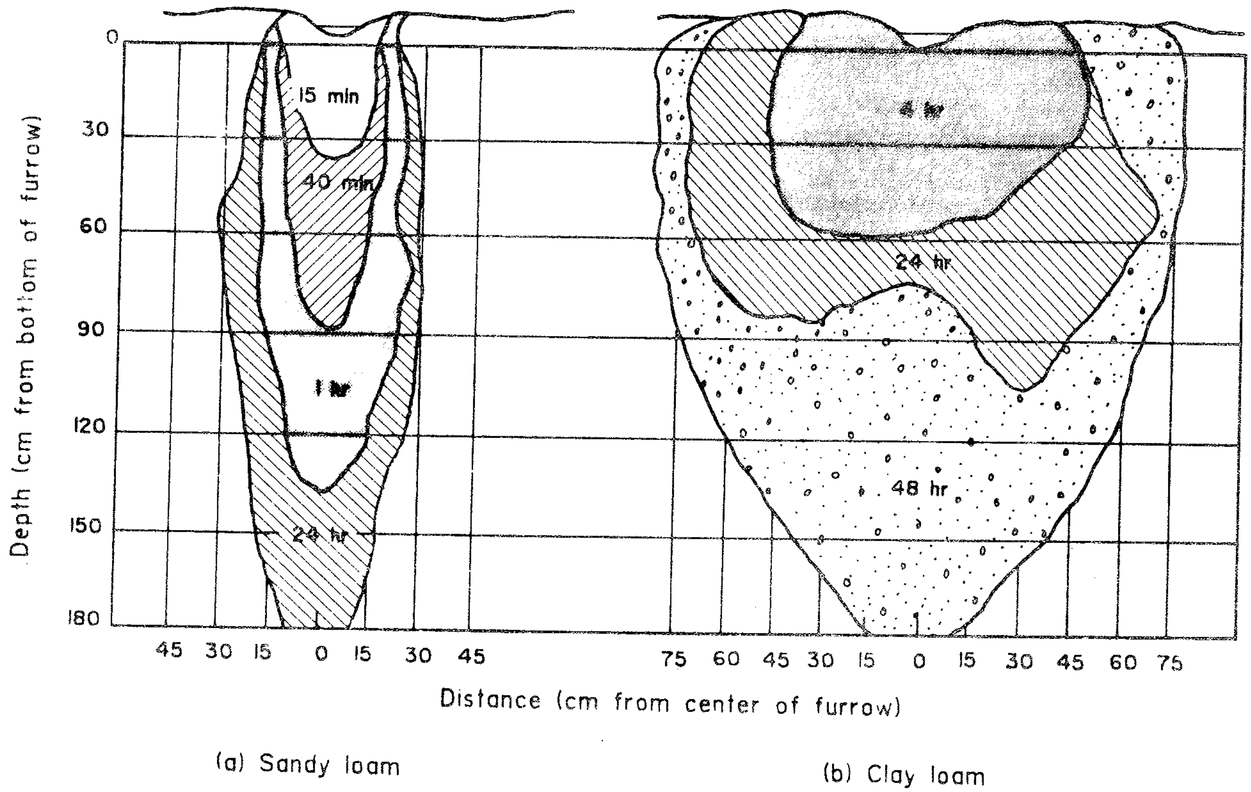


Figure 22. Comparative rates of irrigation water movement into a sandy loam and a clay loam. Note the significantly more rapid rate of movement in the sandy loam, especially in a downward direction. [Redrawn from Brady (1990)].

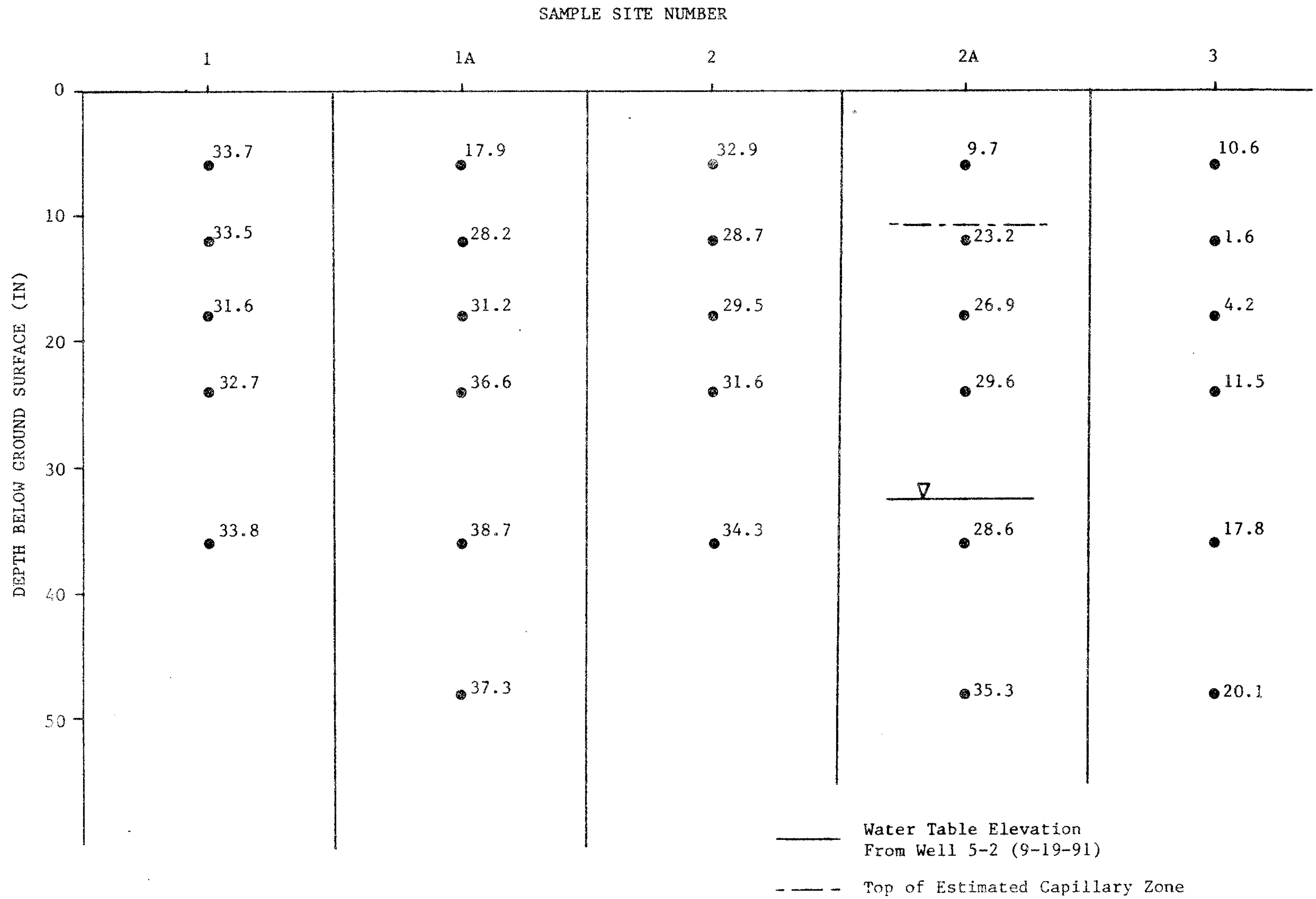


Figure 23. Hog Canyon soil moisture content -- sites 1, 2, 3, (8/6/91) and 1A, 2A (9/18/91).

further down the canyon. The result is an area with a sustained high water table where capillary rise can maintain high soil moisture near the ground surface even in one of the driest periods of the year (August and September).

Site 3

Figure 23 shows results of soil sampling in August of 1991 at site 3. This site is located in a small, ephemerally wet pocket near the east canyon wall (see "J" in Figure 4 of Riedel, 1992) where two *Spiranthes diluvialis* plants were located in 1991. The soil moisture data at this site indicate much drier conditions in August, 1991 than at sites 1, 1a, 2, and 2a, with moisture near or below the wilting point for these soils.

Although no water level information is available for the site, it is assumed that soil moisture is not influenced by the perennial stream or the water table aquifer in the canyon due to the site's elevation and distance from the stream. Possible explanations for the presence of *Spiranthes diluvialis,* as well as other hydrophytic plant species e.g., *Dodecatheon pulchellum* (Shooting Star), *Carex nebrascensis* (Nebraska Sedge), include presence of an ephemeral underground water source or a small "perched" water table that fills with spring runoff but dries as the summer progresses.

Site 5

This site is a transect of three sample holes arranged perpendicular to the stream near well 5-3 (Figure 20). The site was chosen to observe the relationship between the stream, the water table, and soil moisture in an incised segment of the stream. No orchids have been found at this site.

Figure 24 shows the results of the soil moisture sampling on this transect. Water level data from well 5-3 and a 24-inch zone representing the estimated capillary fringe above the water table for the Green River loam are indicated to help illustrate the relationship between water table elevation, capillary rise above the water table, and soil moisture. The high soil moisture values found above the water table are quite consistent with the theoretical capillary zone of 18 to 24 inches described previously. However, soil moisture above this capillary zone drops rapidly, with moisture conditions in the upper 12 inches of the soil (root zone of *Spiranthes diluvialis* and other herbaceous vegetation) much drier than those found at sites 1, 1a, 2, and 2a.

Incision of the stream channel may be an important factor in the absence of orchids near this site. First, the stream drains the aquifer during the winter and spring, helping to prematurely draw the water table below the point where it can replenish soil moisture near the surface. Second, the position of the stream in the narrow, deep channel precludes development of a moist streamside zone, further limiting potential habitat for *Spiranthes diluvialis.*

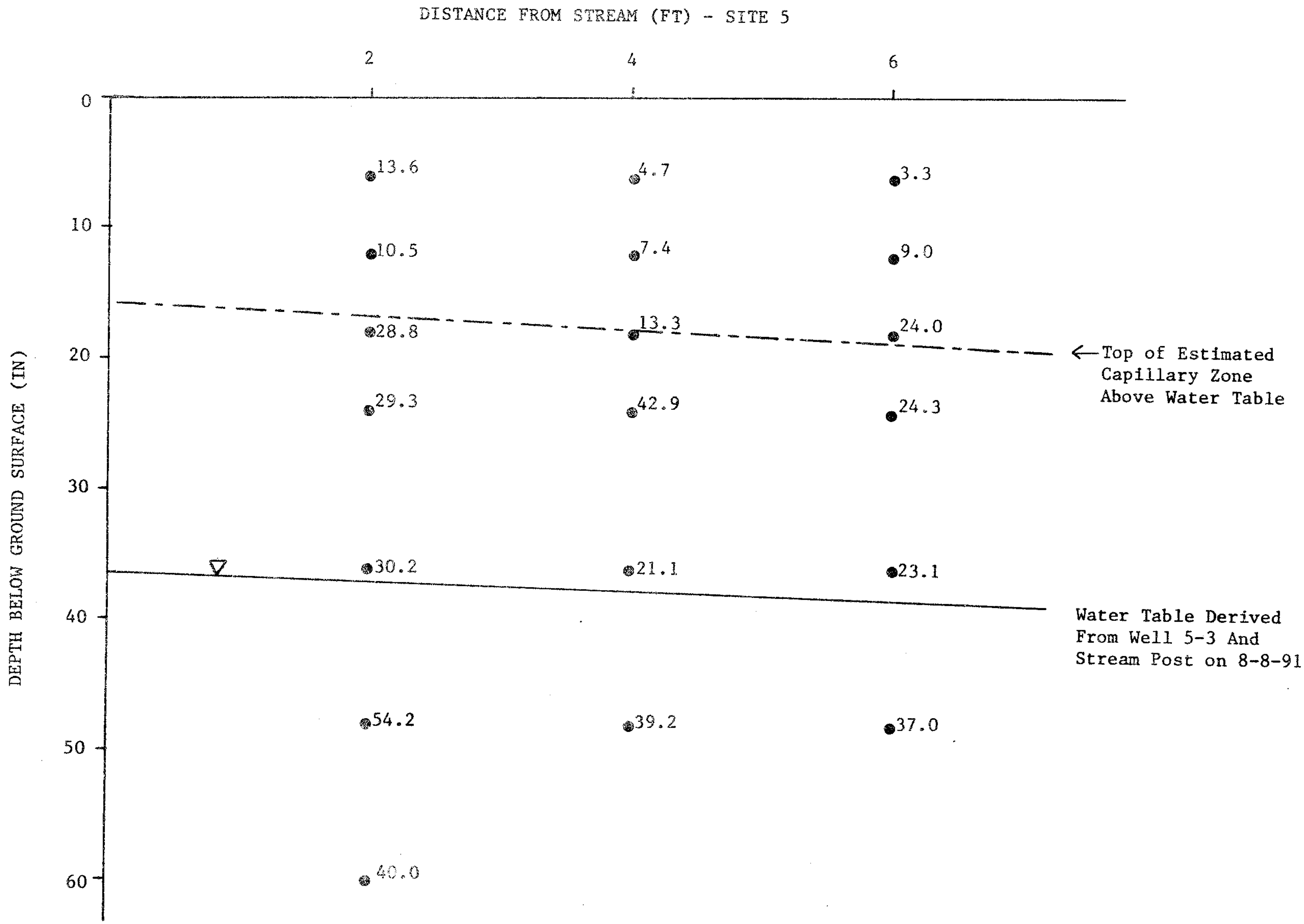


Figure 24. Hog Canyon soil moisture content – site 5 (8/6/91).

Site 7

This site is a transect of nine sample holes arranged perpendicular to the stream near well 7-3 (Figure 20). Like site 5, this site was chosen to observe the relationships between the stream, the water table, and soil moisture in an incised segment of the stream. Figure 25 shows the results of soil moisture sampling on this transect. Water level data from well 7-3 and a 24-inch zone representing the theoretical capillary fringe above the water table for the Green River loam are indicated to help illustrate water table/soil moisture relationships. Between 8 and 22 feet from the stream, there is evidence of a pattern similar to that for site 5, where soil moisture is very high within an approximately 2-foot capillary zone above the water table, but then drops off rather quickly near the surface. But from 2 to 6 feet from the stream that pattern is not seen; rather, a zone of very moist soil extends from the water table all the way to the surface (as much as 40 inches above the water table).

Despite the high soil moisture near the surface within 6 feet of the stream at this site, no orchids have been found within that zone. Our very limited observations cannot explain the source of this moisture or document the time period over which this high soil moisture is sustained. Additional investigations would be necessary to explain the anomalous soil moisture results and provide possible reasons why *Spiranthes diluvialis* is not found in what appears to be potential habitat. Several orchids (four plants in 1991) *have* been found on the opposite side of the stream from soil moisture site 7 (Figure 20). These plants are approximately 18 to 24 inches above the level of the stream at a site where slumping has created a sloped bank rather than the vertically incised banks found immediately upstream (Lynn Riedel, pers. comm. 1992). The plants at this site are apparently within the capillary zone above the water table, as discussed previously.

Sites 13-1, 13-2, 13-3, 14-1, and 14-3

Soil moisture was sampled during the process of augering holes for installation of water level monitoring wells at these five locations (Figure 21). The primary reason for the soil moisture sampling at these sites was to observe relationships between water levels and soil moisture on the lower fan.

Soil moisture monitoring results at these sites are shown in Figures 26 and 27. These results show a much different pattern than the sites within the canyon. Soil moisture is very high all the way to the surface at all sites and, unlike almost all of the sampling sites in the canyon, seems to be unrelated to the position of the water table. Several factors may be influencing these results. First, the Poganeab series soils found on much of the lower fan are generally finer-textured than the canyon soils, and therefore tend to hold more moisture. Second, layering of fine- and coarse-textured deposits on the alluvial fan can result in lenses of higher soil moisture (or saturation) above drier strata in these soils. Third, sampling error can be introduced in these soils if a wet layer is

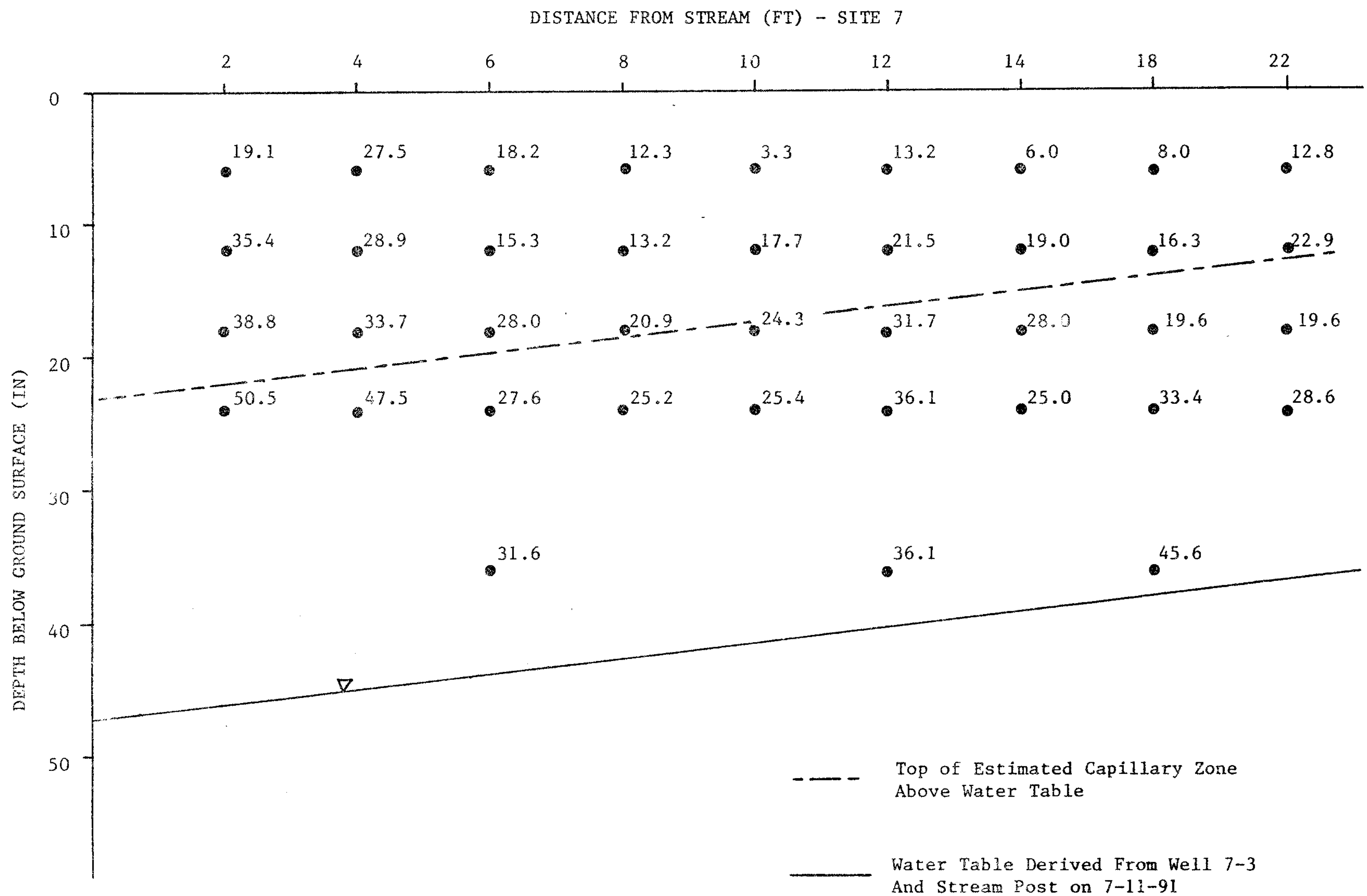


Figure 25. Hog Canyon soil moisture content – site 7 (7/11/91).

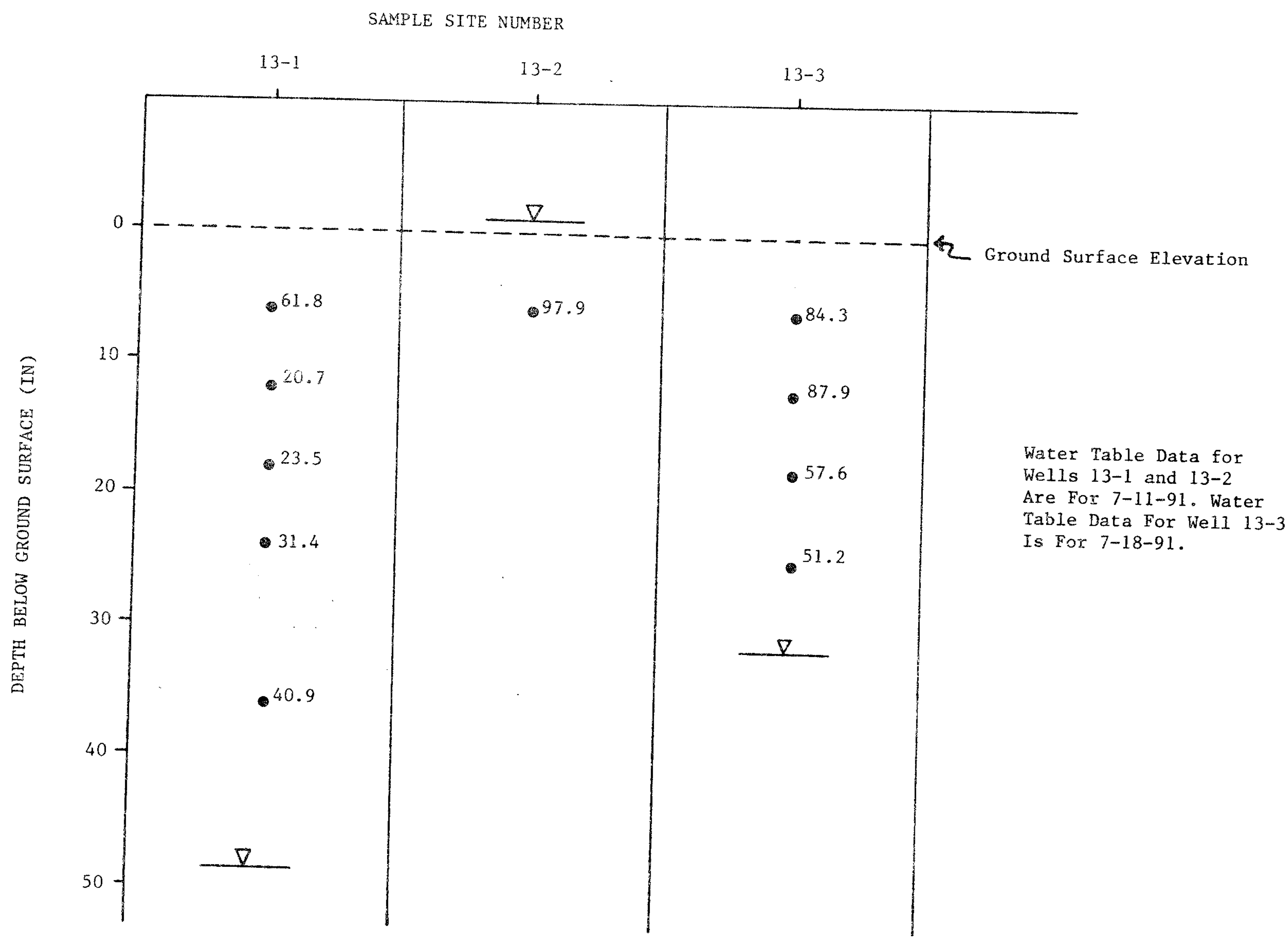


Figure 26. Hog Canyon soil moisture content – Transect 13 (7/8/91).

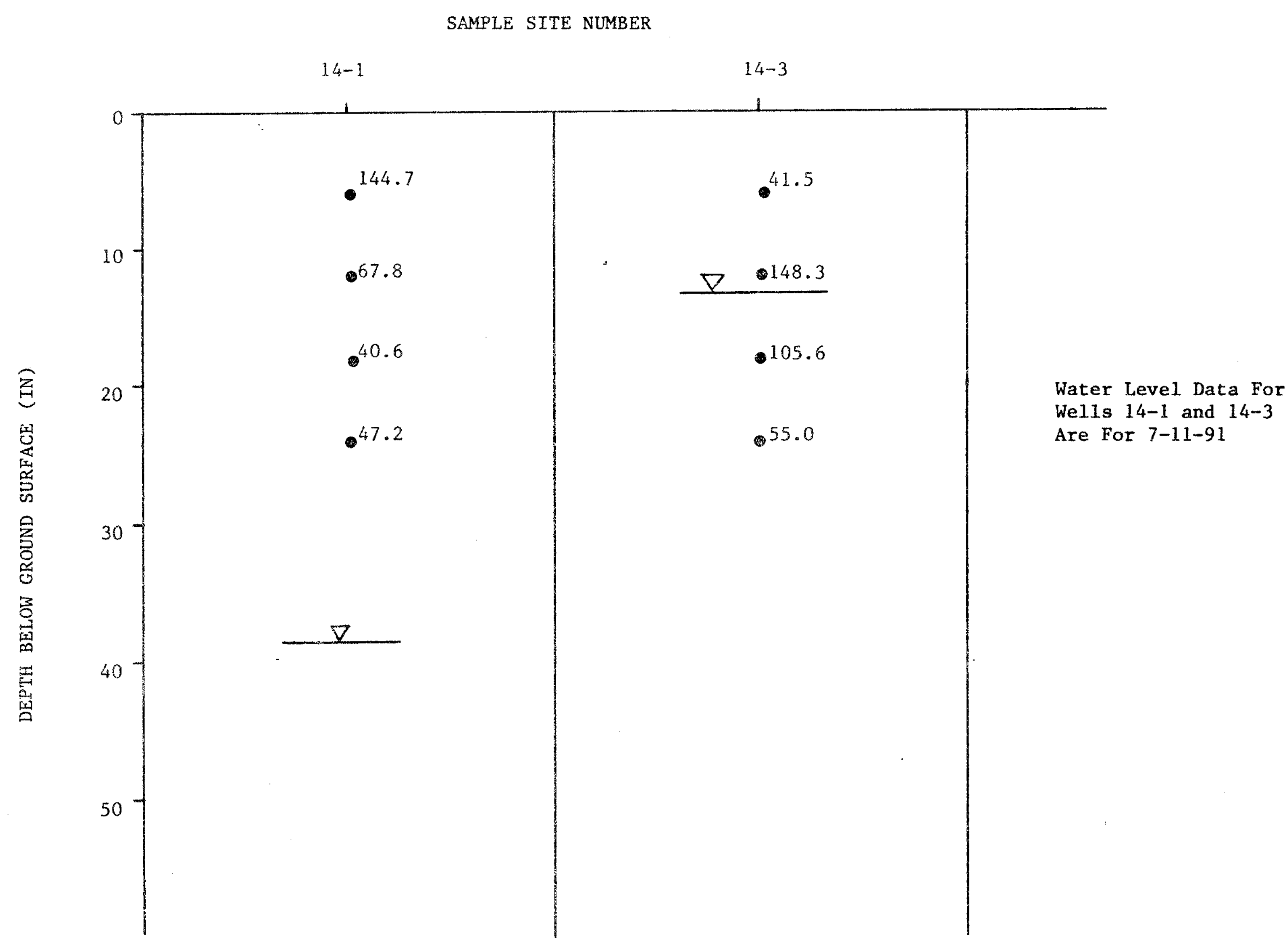


Figure 27. Hog Canyon soil moisture content -- Transect 14 (7/8/91)

encountered during augering, thereby contaminating samples from drier underlying strata. Thus, it is concluded that generalizations can not be made about soil moisture/water table relationships at the alluvial fan sites from these very limited data.

Summary and Conclusions Regarding Soil Moisture

1. Soil moisture sampling in Hog Canyon during the summer of 1991 provided evidence of a correlation between high soil moisture values and presence of *Spiranthes diluvialis.* Root zone soil moisture values at all four sites (1, 1a, 2, 2a) within the area where ninety-six orchids were found in 1991 were well above estimated field capacity for the Green River loam. Site 3 did not show high soil moisture near the surface at the time of sampling, but presence of other hydrophytic plant species such as *Dodecatheon pulchellum* and *Carex nebrascensis* at this site indicate that the soil is very wet near the surface for a significant period during the growing season. Site 5 and most of site 7 had low soil moisture values in the root zone, and neither site appears to support orchids. High soil moisture values near the ground surface seen between 2 to 6 feet from the stream at site 7 could not be explained by this limited monitoring effort.

2. Several hydrologic processes interact to sustain high soil moisture conditions in portions of Hog Canyon. The most important of these is capillary rise above the high water table and creation of a zone of moist soil along the edges of the perennial stream. A third process, direct rainfall and runoff trapped in a perched water table, may be occurring in the ephemerally wet pocket near the east canyon wall (site 3).

3. Field data generally support the theoretical capillary rise of 18 to 24 inches above the water table for the Green River loam. The authors conclude that high soil moisture can be maintained in the root zone in areas where the water table can be held within approximately 2 feet of the ground surface. Elimination of the incised stream channel should increase the duration of high water tables in lower Hog Canyon by eliminating artificial drainage and by increasing contributions to the aquifer from the perennial stream, resulting in increased potential orchid habitat.

4. The "moist streamside zone" along the perennial stream appears to be important orchid habitat in Hog Canyon. Therefore, the longer the stream channel (i.e., a sinuous channel rather than a straight ditch), the more potential streamside orchid habitat. When the stream is at or near the surface, this zone may extend 1 to 2 feet or more on either side of the stream in the Green River loam. When the stream flows through the deep, narrow channels with essentially vertical walls, development of the moist streamside zone is very limited. The

authors conclude that additional potential streamside orchid habitat would be created by eliminating the straight ditch and returning the stream to a sinuous channel in its more natural position on the surface of the alluvium.

SUMMARY OF HYDROLOGY AND IMPLICATIONS FOR RIPARIAN RESTORATION

A major concern of park management relative to a riparian restoration project in the lower part of Hog Canyon is the impact that such a project might have on habitat for the threatened orchid species *Spiranthes diluvialis*. Hydrogeologic data collected in this investigation show that in the area of concern, there is close interconnection between the ground water and surface water systems. The alluvial aquifer fills nearly to the ground surface during the winter and spring when evapotranspiration losses are minimal. The primary sources of water filling the aquifer are leakage from the creek and seepage from the bedrock underlying the alluvial fill. Infiltration from precipitation is an intermittent and probably minor component of recharge. The alluvial aquifer discharges water to the creek in places where the creek has been artificially incised below the water table. This deep incision likely has resulted in lowering the water table in the lower canyon, causing the vegetative ecosystem to change from a wet meadow complex to a more xeric community.

Presently, the water table in the lower part of the canyon is drawn down by two factors. Evapotranspiration losses during the growing season exceeds the rate of recharge from the creek and other sources, and the water table is lowered in some areas as much as several feet. Evapotranspiration losses from the alluvial aquifer are exacerbated by drainage of the water table toward the artificially incised stream channel. Recharge of the aquifer from the creek under some conditions and drainage toward the creek under other conditions maintains the water table in the vicinity of the creek at relatively constant levels throughout the year.

The water table in lower Hog Canyon will always fluctuate in response to seasonal changes in evapotranspiration demands. However, restoring the creek to flow in its natural position on the surface of the valley floor and filling the incised irrigation ditch should eliminate the unnatural drain on the water table.

Some orchid habitat may be lost along the incised ditch if the creek is diverted back to its "natural" position on the valley floor, but more habitat should be created along the riparian area of the relocated stream. Under present conditions, orchid habitat along the incised stream is limited to a narrow band immediately adjacent to the stream where there is sufficient soil moisture to support orchids. Through much of the incised reach, the stream is incised 2 to 3 feet or more, creating a drain for the water table and resulting in low soil moisture conditions that will not allow orchid growth. Restoring the stream to flow on the surface in a broader, shallow, sinuous channel (similar to the upper canyon) should result in a wider band of moist soil on both sides of the restored channel suitable for orchid growth.

Relocating the creek to a position on top of the alluvium (rather than incised below the valley floor) will probably result in a stream that is perched above the water table for a greater portion of the year (possibly throughout the year). Drainage of the water table to the stream will be greatly diminished or eliminated. Instead, there will be an increase in recharge to the alluvial aquifer from streamflow leakage. The stream reach that will be most affected is the incised reach in the lower canyon, downstream from where the hiking trail crosses the creek. This reach of stream is about 300 to 400 feet long. Water leaking from the stream to the ground water system will either be consumed by evapotranspiration or continue flowing down the canyon as ground water, discharging on the alluvial fan or directly into Cub Creek. Water lost to evapotranspiration is a natural process, the quantity consumed should be no greater than occurred under natural conditions prior to ditching the creek. The total quantity of water flowing from the canyon, surface and ground water, should be the same as under natural, predisturbance conditions.

Moving the creek from the incised channel to the surface in lower Hog Canyon may also result in relocation of streamflow on the alluvial fan. In addition, the entire stream system may continue to shift courses and flow across different areas of the lower canyon and alluvial fan, particularly during flood events. This is a natural consequence of geomorphic processes in alluvial systems.

The major concerns that have been expressed relative to the proposed riparian restoration project are maintaining the yield of water from Hog Canyon to Cub Creek and maintaining or enhancing habitat for *Spiranthes diluvialis*. The total yield of water from Hog Canyon is not expected to change measurably. Monitoring will continue throughout any relocation or restoration efforts to determine if this is the case. The timing of water flowing from the canyon may change slightly. Some of the surface runoff that presently flows downstream very quickly will infiltrate to the ground water aquifer in the canyon and be released over a much longer time period. The net effect will be to dampen the peaks from the stream hydrograph and increase baseflow in the stream. These changes are expected to be so small as to be immeasurable. It is anticipated that additional *Spiranthes diluvialis* habitat will be created in the riparian zone and that existing habitat will be enhanced by restoring the stream channel to its natural position. Monitoring for *Spiranthes diluvialis* viability and reproduction will continue throughout any restoration project and for a period of several (7 to 10) years following stream relocation.

ALTERNATIVE ACTIONS

1. Do nothing.

If this alternative is adopted, it assumes the loss of not even one orchid is willing to be risked during a restoration effort. Nothing is done to restore the site to more natural conditions because restoration activities may eliminate some existing orchid habitat in an area. There would be no opportunity to create additional orchid habitat in the riparian area of the relocated stream. The vegetative ecosystems in the lower part of the canyon would continue their progression from a wet meadow complex to a more xeric ecosystem. Orchids will probably continue to exist in areas having required growing conditions. Doing nothing to restore the stream may result in further loss of orchid habitat if the stream continues head-cutting upstream from the wet meadow area that presently has many orchids.

2. Experimental stream relocation.

The stream would be temporarily relocated to its natural position on the valley floor along the west side of the canyon. A new stream channel would need to be constructed near where the hiking trail crosses the creek or possibly further downstream. A very detailed survey would be required to determine where the relocated stream would flow and to insure that adequate measures are taken to protect the hiking trail from becoming a conduit for streamflow. Additional monitoring wells would be installed to determine the impact of stream relocation on the water table and soil moisture. This would provide information about possible creation of additional orchid habitat in the riparian areas of the relocated stream. The temporary relocation could be conducted at a time of the year when orchids along the incised channel would be least likely to be impacted. Sufficient data to evaluate the effects of stream relocation could probably be obtained in about 2 weeks. A temporary relocation of 2 weeks would be sufficient time to evaluate the effects of relocation on the hydrologic regime of Hog Canyon, but not long enough to allow evaluation of effects on Cub Creek. The stream would then be returned to its present location while the data are evaluated and subsequent management recommendations are made and evaluated. Stream relocation, even temporary, will require some amount of surface disturbance. A new channel will need to be constructed to bring the water to the head of the natural channel and a dam will be needed in the present stream channel to force water to flow in the new channel.

3. Further study.

Under this alternative, it is assumed that sufficient unanswered questions and data gaps remain to justify delay of any restoration activities at this time. Restoration might proceed if additional data show that restoration will either increase orchid habitat or will not threaten present orchid populations. If this option is chosen, a concerted effort should be made to identify all problems that remain unresolved, and a field study should be designed to provide all data needed to make a final management decision. Additional required data can probably be divided between habitat/hydrologic information and orchid biology information.

4. Full restoration based on known information.

Under this alternative, all interested parties agree that there is enough information to justify proceeding with full restoration of the lower canyon area. Additional surveying work will be needed to design the channel between the existing stream location and its "correct" position. The hiking path will need to be removed and restored to prevent it from becoming an artificial channel. The incised channel should be filled to prevent the stream from returning at some future time. Park management should be aware that the stream's natural function is to move and meander about on the valley floor and alluvial fan. The stream channel is not a static entity. Sudden, and apparently devastating changes are likely to occur, particularly during flood events. These changes may eliminate previously healthy habitat locations, but new habitat will be formed to replace it.

5. Temporary splitting of streamflow.

Under this alternative, a structure would be put in place that would allow splitting the streamflow between the existing incised channel and a new channel on the surface of the valley floor. This alternative would allow evaluation of relocating the stream to the surface of the valley floor while maintaining some of the existing flow across the alluvial fan to Cub Creek. This alternative may result in hydrologic conditions that do not represent a relocated stream and do not maintain existing conditions.

6. Longer-term temporary relocation.

This alternative would be essentially the same as Alternative 2, except that the relocation would be permitted to continue for several months to allow longer period of data collection and evaluation. If the results are favorable, the temporary relocation could become permanent. A long-term temporary relocation would probably be started in November, when impacts on vegetation and downstream water users would be minimal. The stream could be returned to the incised channel after 2 to 3 months if there is concern that the relocation has had an impact on either the orchid habitat or downstream delivery of water to Cub Creek.

PREFERRED ALTERNATIVE

The preferred alternative for riparian restoration in Hog Canyon is Number 6, longer-term temporary relocation of the stream to its natural position on the valley floor.

The relocation will be conducted in the winter months to avoid any possible interference with downstream irrigation supplies and minimize any possible impacts on the orchids. This will also permit the relocation to continue for several months and allow a longer period for the relocated stream to reach hydrologic equilibrium with its surroundings. If the results appear favorable after the initial 2 to 3 months of relocation, and if all parties agree, the relocation could be continued through the spring and summer to assess effects of relocation for a longer time period. The stream relocation will be conducted in a manner that will allow returning the stream to its present incised channel if there is concern about negative impacts at any time during the project.

The relocated stream will exit the canyon at approximately the same place as the present incised channel. It is not expected to affect hydrologic functions in the alluvial fan below Hog Canyon or water delivery to Cub Creek. Monitoring will be conducted to test these hypotheses.

A new stream channel will need to be constructed approximately 20 to 30 feet downstream from where the hiking trail crosses the creek (downstream from the main population of orchids). A very detailed survey will be made to determine where the relocated stream will flow and to insure that adequate measures are taken to protect the hiking trail from becoming a conduit for streamflow. Additional monitoring wells will be installed to determine the impact of stream relocation on the water table and soil moisture. This will provide information about possible creation of additional orchid habitat in the riparian areas of the relocated stream.

Stream relocation, even temporary, will require some amount of surface disturbance. A new channel will need to be constructed to bring the water to the head of the natural channel and a dam will be needed in the present stream channel to force water to flow in the new channel.

The project will be successful, hydrologically, if it can be shown that stream relocation has not significantly affected the quantity of water flowing from Hog Canyon, that the water table has been raised sufficiently to support reestablishment of a wet meadow vegetation complex (the water table is no longer being drained by the incised ditch), and that additional riparian areas have been created having sufficient soil moisture to support *Spiranthes diluvialis* and other riparian vegetation. Successful restoration from a vegetative standpoint will be determined by maintenance of wetland areas on the alluvial fan below Hog Canyon, reestablishment of a riparian and wet meadow vegetation complex in the lower part of Hog Canyon, survival of *Spiranthes diluvialis* in existing areas, and colonization of *Spiranthes diluvialis* in new areas along the relocated stream. It may take several years to assess vegetative success of the project due to the relatively long time required for establishment of vegetation in response to changes in soil moisture and hydrologic conditions. In particular, *Spiranthes diluvialis* may remain (after germination) in a micorrhizal association for up to 7 to 10 years before developing above ground parts. Thus, even though success may be demonstrated in a hydrologic sense within a relatively short period of time (months), assessment of success in a biological sense may require several years.

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APPENDIX

HYDROLOGIC MONITORING DATA

October 1990 - April 1992

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 5-1

Date YYMMDD	Measured Depth (from top of casing)	Case Elev.	Ground Elev.	Case Height	Depth to water (below land surface)	Water Table Elevation
901215	4.21	413.92	413.11	0.81	3.40	409.71
901228	3.43	413.92	413.11	0.81	2.62	410.49
910112	3.24	413.92	413.11	0.81	2.43	410.68
910125	3.25	413.92	413.11	0.81	2.44	410.67
910209	3.23	413.92	413.11	0.81	2.42	410.69
910223	2.59	413.92	413.11	0.81	1.78	411.33
910307	2.70	413.92	413.11	0.81	1.89	411.22
910319	2.59	413.92	413.11	0.81	1.78	411.33
910406	3.02	413.92	413.11	0.81	2.21	410.90
910420	2.88	413.92	413.11	0.81	2.07	411.04
910502	2.49	413.92	413.11	0.81	1.68	411.43
910518	3.41	413.92	413.11	0.81	2.60	410.51
910531	3.86	413.92	413.11	0.81	3.05	410.06
910618	4.58	413.92	413.11	0.81	3.77	409.34
910627	4.96	413.92	413.11	0.81	4.15	408.96
910704	5.23	413.92	413.11	0.81	4.42	408.69
910711	5.33	413.92	413.11	0.81	4.52	408.59
910718	5.60	413.92	413.11	0.81	4.79	408.32
910725	5.67	413.92	413.11	0.81	4.86	408.25
910801	5.86	413.92	413.11	0.81	5.05	408.06
910808	5.48	413.92	413.11	0.81	4.67	408.44
910816	5.81	413.92	413.11	0.81	5.00	408.11
910822	5.93	413.92	413.11	0.81	5.12	407.99
910830	5.88	413.92	413.11	0.81	5.07	408.04
910906	5.90	413.92	413.11	0.81	5.09	408.02
910912	5.19	413.92	413.11	0.81	4.38	408.73
910919	5.14	413.92	413.11	0.81	4.33	408.78
911106	3.95	413.92	413.11	0.81	3.14	409.97
911122	3.49	413.92	413.11	0.81	2.68	410.43
911229	3.33	413.92	413.11	0.81	2.52	410.59
920103	3.34	413.92	413.11	0.81	2.53	410.58
920117	3.31	413.92	413.11	0.81	2.50	410.61
920131	3.36	413.92	413.11	0.81	2.55	410.56
920214	2.82	413.92	413.11	0.81	2.01	411.10
920320	2.75	413.92	413.11	0.81	1.94	411.17
920412	3.35	413.92	413.11	0.81	2.54	410.57

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 5-2

Date YYMMDD	Measured Depth (from top of casing)	Case Elev.	Ground Elev.	Case Height	Depth to water (below land surface)	Water Table Elevation
901017	3.63	413.51	412.04	1.47	2.16	409.88
901031	3.58	413.51	412.04	1.47	2.11	409.93
901112	3.50	413.51	412.04	1.47	2.03	410.01
901128	3.06	413.51	412.04	1.47	1.59	410.45
901215	2.91	413.51	412.04	1.47	1.44	410.60
901228	3.28	413.51	412.04	1.47	1.81	410.23
910125	2.97	413.51	412.04	1.47	1.50	410.54
910209	2.96	413.51	412.04	1.47	1.49	410.55
910223	2.53	413.51	412.04	1.47	1.06	410.98
910307	2.51	413.51	412.04	1.47	1.04	411.00
910319	2.49	413.51	412.04	1.47	1.02	411.02
910406	2.78	413.51	412.04	1.47	1.31	410.73
910420	2.73	413.51	412.04	1.47	1.26	410.78
910502	2.60	413.51	412.04	1.47	1.13	410.91
910518	3.18	413.51	412.04	1.47	1.71	410.33
910531	3.38	413.51	412.04	1.47	1.91	410.13
910618	3.96	413.51	412.04	1.47	2.49	409.55
910627	4.23	413.51	412.04	1.47	2.76	409.28
910704	4.39	413.51	412.04	1.47	2.92	409.12
910711	4.41	413.51	412.04	1.47	2.94	409.10
910718	4.42	413.51	412.04	1.47	2.95	409.09
910725	4.45	413.51	412.04	1.47	2.98	409.06
910801	4.63	413.51	412.04	1.47	3.16	408.88
910808	4.27	413.51	412.04	1.47	2.80	409.24
910816	4.47	413.51	412.04	1.47	3.00	409.04
910822	4.77	413.51	412.04	1.47	3.30	408.74
910830	4.51	413.51	412.04	1.47	3.04	409.00
910906	4.41	413.51	412.04	1.47	2.94	409.10
910912	4.31	413.51	412.04	1.47	2.84	409.20
910919	4.17	413.51	412.04	1.47	2.70	409.34
911106	3.57	413.51	412.04	1.47	2.10	409.94
911122	3.50	413.51	412.04	1.47	2.03	410.01
911229	3.47	413.51	412.04	1.47	2.00	410.04
920103	3.46	413.51	412.04	1.47	1.99	410.05
920117	3.44	413.51	412.04	1.47	1.97	410.07
920131	3.60	413.51	412.04	1.47	2.13	409.91
920214	3.06	413.51	412.04	1.47	1.59	410.45
920320	3.10	413.51	412.04	1.47	1.63	410.41
920412	2.69	413.51	412.04	1.47	1.22	410.82

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 5-3

Date YYMMDD	Measured Depth (from top of casing)	Case Elev.	Ground Elev.	Case Height	Depth to water (below land surface)	Water Table Elevation
901017	3.63	413.62	413.10	0.52	3.11	409.99
901031	3.58	413.62	413.10	0.52	3.06	410.04
901112	3.53	413.62	413.10	0.52	3.01	410.09
901128	3.43	413.62	413.10	0.52	2.91	410.19
901215	3.41	413.62	413.10	0.52	2.89	410.21
901228	3.46	413.62	413.10	0.52	2.94	410.16
910112	3.42	413.62	413.10	0.52	2.90	410.20
910125	3.43	413.62	413.10	0.52	2.91	410.19
910209	3.41	413.62	413.10	0.52	2.89	410.21
910223	3.25	413.62	413.10	0.52	2.73	410.37
910307	3.28	413.62	413.10	0.52	2.76	410.34
910319	3.30	413.62	413.10	0.52	2.78	410.32
910406	3.37	413.62	413.10	0.52	2.85	410.25
910420	3.41	413.62	413.10	0.52	2.89	410.21
910502	3.31	413.62	413.10	0.52	2.79	410.31
910518	3.45	413.62	413.10	0.52	2.93	410.17
910531	3.53	413.62	413.10	0.52	3.01	410.09
910618	3.64	413.62	413.10	0.52	3.12	409.98
910627	3.72	413.62	413.10	0.52	3.20	409.90
910704	3.79	413.62	413.10	0.52	3.27	409.83
910711	3.72	413.62	413.10	0.52	3.20	409.90
910718	3.76	413.62	413.10	0.52	3.24	409.86
910725	3.76	413.62	413.10	0.52	3.24	409.86
910801	3.81	413.62	413.10	0.52	3.29	409.81
910808	3.71	413.62	413.10	0.52	3.19	409.91
910816	3.75	413.62	413.10	0.52	3.23	409.87
910822	3.81	413.62	413.10	0.52	3.29	409.81
910830	3.75	413.62	413.10	0.52	3.23	409.87
910906	3.75	413.62	413.10	0.52	3.23	409.87
910912	3.69	413.62	413.10	0.52	3.17	409.93
910919	3.68	413.62	413.10	0.52	3.16	409.94
911106	3.45	413.62	413.10	0.52	2.93	410.17
911122	3.41	413.62	413.10	0.52	2.89	410.21
911229	3.40	413.62	413.10	0.52	2.88	410.22
920103	3.42	413.62	413.10	0.52	2.90	410.20
920117	3.32	413.62	413.10	0.52	2.80	410.30
920131	3.43	413.62	413.10	0.52	2.91	410.19
920214	3.27	413.62	413.10	0.52	2.75	410.35
920320	3.33	413.62	413.10	0.52	2.81	410.29
920412	3.40	413.62	413.10	0.52	2.88	410.22

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 - Stream Level Reference Post 5

Date YYMMDD	Post Top To Stream Surface	Post Elev. (Top)	Stream Surface Elev.
910711	3.69	413.70	410.01
910718	3.68	413.70	410.02
910725	3.68	413.70	410.02
910801	3.66	413.70	410.04
910808	3.65	413.70	410.05
910816	3.68	413.70	410.02
910822	3.67	413.70	410.03
910830	3.65	413.70	410.05
910906	3.65	413.70	410.05
910912	3.64	413.70	410.06
910919	3.65	413.70	410.05

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 6-1

Date YYMMDD	Measured Depth (from top of casing)	Case Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901017	5.23	410.58	410.14	0.44	4.79	405.35
901031	4.82	410.58	410.14	0.44	4.38	405.76
901112	4.32	410.58	410.14	0.44	3.88	406.26
901128	3.63	410.58	410.14	0.44	3.19	406.95
901215	3.28	410.58	410.14	0.44	2.84	407.30
901228	3.49	410.58	410.14	0.44	3.05	407.09
910112	3.24	410.58	410.14	0.44	2.80	407.34
910125	3.24	410.58	410.14	0.44	2.80	407.34
910209	3.22	410.58	410.14	0.44	2.78	407.36
910223	2.65	410.58	410.14	0.44	2.21	407.93
910307	2.74	410.58	410.14	0.44	2.30	407.84
910319	2.68	410.58	410.14	0.44	2.24	407.90
910406	3.11	410.58	410.14	0.44	2.67	407.47
910420	3.04	410.58	410.14	0.44	2.60	407.54
910502	2.63	410.58	410.14	0.44	2.19	407.95
910518	3.62	410.58	410.14	0.44	3.18	406.96
910531	4.02	410.58	410.14	0.44	3.58	406.56
910618	4.72	410.58	410.14	0.44	4.28	405.86
910627	5.18	410.58	410.14	0.44	4.74	405.40
910704	5.44	410.58	410.14	0.44	5.00	405.14
910711	5.56	410.58	410.14	0.44	5.12	405.02
910718	5.83	410.58	410.14	0.44	5.39	404.75
910725	5.94	410.58	410.14	0.44	5.50	404.64
910801	6.15	410.58	410.14	0.44	5.71	404.43
910808	5.89	410.58	410.14	0.44	5.45	404.69
910816	6.13	410.58	410.14	0.44	5.69	404.45
910822	6.27	410.58	410.14	0.44	5.83	404.31
910830	6.50	410.58	410.14	0.44	6.06	404.08
910906	6.38	410.58	410.14	0.44	5.94	404.20
910912	5.93	410.58	410.14	0.44	5.49	404.65
910919	5.73	410.58	410.14	0.44	5.29	404.85
911106	4.65	410.58	410.14	0.44	4.21	405.93
911122	3.99	410.58	410.14	0.44	3.55	406.59
911229	3.60	410.58	410.14	0.44	3.16	406.98
920103	3.65	410.58	410.14	0.44	3.21	406.93
920117	3.60	410.58	410.14	0.44	3.16	406.98
920131	3.73	410.58	410.14	0.44	3.29	406.85
920214	3.21	410.58	410.14	0.44	2.77	407.37
920320	3.12	410.58	410.14	0.44	2.68	407.46
920412	3.70	410.58	410.14	0.44	3.26	406.88

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 6-2

Date YYMMDD	Measured Depth (from top of casing)	Case Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901017	3.33	409.11	408.67	0.44	2.89	405.78
901031	3.29	409.11	408.67	0.44	2.85	405.82
901112	3.13	409.11	408.67	0.44	2.69	405.98
901128	2.78	409.11	408.67	0.44	2.34	406.33
901215	2.63	409.11	408.67	0.44	2.19	406.48
901228	2.97	409.11	408.67	0.44	2.53	406.14
910112	2.67	409.11	408.67	0.44	2.23	406.44
910125	2.65	409.11	408.67	0.44	2.21	406.46
910209	2.63	409.11	408.67	0.44	2.19	406.48
910223	2.13	409.11	408.67	0.44	1.69	406.98
910307	2.15	409.11	408.67	0.44	1.71	406.96
910319	2.16	409.11	408.67	0.44	1.72	406.95
910406	2.54	409.11	408.67	0.44	2.10	406.57
910420	2.55	409.11	408.67	0.44	2.11	406.56
910502	2.28	409.11	408.67	0.44	1.84	406.83
910518	2.95	409.11	408.67	0.44	2.51	406.16
910531	3.25	409.11	408.67	0.44	2.81	405.86
910618	3.75	409.11	408.67	0.44	3.31	405.36
910627	4.08	409.11	408.67	0.44	3.64	405.03
910704	4.18	409.11	408.67	0.44	3.74	404.93
910711	4.12	409.11	408.67	0.44	3.68	404.99
910718	4.28	409.11	408.67	0.44	3.84	404.83
910725	4.25	409.11	408.67	0.44	3.81	404.86
910801	4.39	409.11	408.67	0.44	3.95	404.72
910808	4.02	409.11	408.67	0.44	3.58	405.09
910816	4.23	409.11	408.67	0.44	3.79	404.88
910822	4.32	409.11	408.67	0.44	3.88	404.79
910830	4.18	409.11	408.67	0.44	3.74	404.93
910906	4.14	409.11	408.67	0.44	3.70	404.97
910912	3.78	409.11	408.67	0.44	3.34	405.33
910919	3.66	409.11	408.67	0.44	3.22	405.45
911106	2.94	409.11	408.67	0.44	2.5	406.17
911122	2.81	409.11	408.67	0.44	2.37	406.30
911229	2.69	409.11	408.67	0.44	2.25	406.42
920103	2.69	409.11	408.67	0.44	2.25	406.42
920117	2.73	409.11	408.67	0.44	2.29	406.38
920131	2.91	409.11	408.67	0.44	2.47	406.20
920214	2.31	409.11	408.67	0.44	1.87	406.80
920320	2.46	409.11	408.67	0.44	2.02	406.65
920412	2.86	409.11	408.67	0.44	2.42	406.25

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 6-3

Date YYMMDD	Measured Depth (from top of casing)	Case Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901017	4.75	410.21	409.38	0.83	3.92	405.46
901031	4.73	410.21	409.38	0.83	3.90	405.48
901112	4.65	410.21	409.38	0.83	3.82	405.56
901128	4.53	410.21	409.38	0.83	3.70	405.68
901215	4.51	410.21	409.38	0.83	3.68	405.70
901228	4.58	410.21	409.38	0.83	3.75	405.63
910112	4.49	410.21	409.38	0.83	3.66	405.72
910125	4.53	410.21	409.38	0.83	3.70	405.68
910209	4.53	410.21	409.38	0.83	3.70	405.68
910223	4.36	410.21	409.38	0.83	3.53	405.85
910307	4.38	410.21	409.38	0.83	3.55	405.83
910319	4.39	410.21	409.38	0.83	3.56	405.82
910406	4.53	410.21	409.38	0.83	3.70	405.68
910420	4.55	410.21	409.38	0.83	3.72	405.66
910502	4.44	410.21	409.38	0.83	3.61	405.77
910518	4.23	410.21	409.38	0.83	3.40	405.98
910531	4.38	410.21	409.38	0.83	3.55	405.83
910618	4.65	410.21	409.38	0.83	3.82	405.56
910627	4.77	410.21	409.38	0.83	3.94	405.44
910704	4.83	410.21	409.38	0.83	4.00	405.38
910711	4.87	410.21	409.38	0.83	4.04	405.34
910718	4.92	410.21	409.38	0.83	4.09	405.29
910725	4.90	410.21	409.38	0.83	4.07	405.31
910801	4.98	410.21	409.38	0.83	4.15	405.23
910808	4.77	410.21	409.38	0.83	3.94	405.44
910816	4.87	410.21	409.38	0.83	4.04	405.34
910822	4.93	410.21	409.38	0.83	4.10	405.28
910830	4.85	410.21	409.38	0.83	4.02	405.36
910906	4.80	410.21	409.38	0.83	3.97	405.41
910912	4.69	410.21	409.38	0.83	3.86	405.52
910919	4.64	410.21	409.38	0.83	3.81	405.57
911106	4.66	410.21	409.38	0.83	3.83	405.55
911122	4.24	410.21	409.38	0.83	3.41	405.97
911229	4.23	410.21	409.38	0.83	3.4	405.98
920103	4.21	410.21	409.38	0.83	3.38	406.00
920117	4.25	410.21	409.38	0.83	3.42	405.96
920131	4.37	410.21	409.38	0.83	3.54	405.84
920214	4.17	410.21	409.38	0.83	3.34	406.04
920320	4.23	410.21	409.38	0.83	3.4	405.98
920412	4.35	410.21	409.38	0.83	3.52	405.86

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 - Stream Level Reference Post 6

Date	Post Top To Stream Surface	Post Elev. (Top)	Stream Surface Elev.
910711	3.24	408.32	405.08
910718	3.30	408.32	405.02
910725	3.30	408.32	405.02
910801	3.30	408.32	405.02
910808	3.31	408.32	405.01
910816	3.32	408.32	405.00
910822	3.36	408.32	404.96
910830	3.37	408.32	404.95
910906	3.35	408.32	404.97
910912	3.36	408.32	404.96
910919	3.36	408.32	404.96

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 7-1

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901215	3.55	406.28	405.72	0.56	2.99	402.73
901228	3.53	406.28	405.72	0.56	2.97	402.75
910112	3.18	406.28	405.72	0.56	2.62	403.10
910125	3.16	406.28	405.72	0.56	2.60	403.12
910209	3.07	406.28	405.72	0.56	2.51	403.21
910223	2.49	406.28	405.72	0.56	1.93	403.79
910307	2.49	406.28	405.72	0.56	1.93	403.79
910319	2.41	406.28	405.72	0.56	1.85	403.87
910406	2.82	406.28	405.72	0.56	2.26	403.46
910420	2.83	406.28	405.72	0.56	2.27	403.45
910502	2.48	406.28	405.72	0.56	1.92	403.80
910518	3.28	406.28	405.72	0.56	2.72	403.00
910531	3.89	406.28	405.72	0.56	3.33	402.39
910618	4.62	406.28	405.72	0.56	4.06	401.66
910627	5.18	406.28	405.72	0.56	4.62	401.10
910704	5.47	406.28	405.72	0.56	4.91	400.81
910711	5.56	406.28	405.72	0.56	5.00	400.72
910718	5.76	406.28	405.72	0.56	5.20	400.52
910725	5.84	406.28	405.72	0.56	5.28	400.44
910801	5.99	406.28	405.72	0.56	5.43	400.29
910808	5.78	406.28	405.72	0.56	5.22	400.50
910816	5.97	406.28	405.72	0.56	5.41	400.31
910822	6.08	406.28	405.72	0.56	5.52	400.20
910830	6.01	406.28	405.72	0.56	5.45	400.27
910906	6.07	406.28	405.72	0.56	5.51	400.21
910912	5.98	406.28	405.72	0.56	5.42	400.30
910919	5.40	406.28	405.72	0.56	4.84	400.88
911106	4.46	406.28	405.72	0.56	3.90	401.82
911122	3.91	406.28	405.72	0.56	3.35	402.37
911229	3.18	406.28	405.72	0.56	2.62	403.10
920103	3.14	406.28	405.72	0.56	2.58	403.14
920117	3.11	406.28	405.72	0.56	2.55	403.17
920131	3.28	406.28	405.72	0.56	2.72	403.00
920214	2.84	406.28	405.72	0.56	2.28	403.44
920320	2.63	406.28	405.72	0.56	2.07	403.65
920412	3.13	406.28	405.72	0.56	2.57	403.15

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 7-2

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901215	4.16	406.19	405.22	0.97	3.19	402.03
901228	3.07	406.19	405.22	0.97	2.10	403.12
910112	2.69	406.19	405.22	0.97	1.72	403.50
910125	2.71	406.19	405.22	0.97	1.74	403.48
910209	2.65	406.19	405.22	0.97	1.68	403.54
910223	2.17	406.19	405.22	0.97	1.20	404.02
910307	2.18	406.19	405.22	0.97	1.21	404.01
910319	2.19	406.19	405.22	0.97	1.22	404.00
910406	2.57	406.19	405.22	0.97	1.60	403.62
910420	2.55	406.19	405.22	0.97	1.58	403.64
910502	2.28	406.19	405.22	0.97	1.31	403.91
910518	2.91	406.19	405.22	0.97	1.94	403.28
910531	3.44	406.19	405.22	0.97	2.47	402.75
910618	3.93	406.19	405.22	0.97	2.96	402.26
910627	4.32	406.19	405.22	0.97	3.35	401.87
910704	4.49	406.19	405.22	0.97	3.52	401.70
910711	4.53	406.19	405.22	0.97	3.56	401.66
910718	4.66	406.19	405.22	0.97	3.69	401.53
910725	4.68	406.19	405.22	0.97	3.71	401.51
910801	4.78	406.19	405.22	0.97	3.81	401.41
910808	4.50	406.19	405.22	0.97	3.53	401.69
910816	4.73	406.19	405.22	0.97	3.76	401.46
910822	4.75	406.19	405.22	0.97	3.78	401.44
910830	4.66	406.19	405.22	0.97	3.69	401.53
910906	4.71	406.19	405.22	0.97	3.74	401.48
910912	4.19	406.19	405.22	0.97	3.22	402.00
910919	4.13	406.19	405.22	0.97	3.16	402.06
911106	3.20	406.19	405.22	0.97	2.23	402.99
911122	2.92	406.19	405.22	0.97	1.95	403.27
911229	2.67	406.19	405.22	0.97	1.70	403.52
920103	2.68	406.19	405.22	0.97	1.71	403.51
920117	2.70	406.19	405.22	0.97	1.73	403.49
920131	2.89	406.19	405.22	0.97	1.92	403.30
920214	2.38	406.19	405.22	0.97	1.41	403.81
920320	2.44	406.19	405.22	0.97	1.47	403.75
920412	2.86	406.19	405.22	0.97	1.89	403.33

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 7-3

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901228	3.42	406.32	405.22	1.10	2.32	402.90
910112	3.25	406.32	405.22	1.10	2.15	403.07
910125	3.22	406.32	405.22	1.10	2.12	403.10
910209	3.22	406.32	405.22	1.10	2.12	403.10
910223	2.98	406.32	405.22	1.10	1.88	403.34
910307	3.00	406.32	405.22	1.10	1.90	403.32
910319	3.01	406.32	405.22	1.10	1.91	403.31
910406	3.18	406.32	405.22	1.10	2.08	403.14
910420	3.20	406.32	405.22	1.10	2.10	403.12
910502	3.04	406.32	405.22	1.10	1.94	403.28
910518	3.35	406.32	405.22	1.10	2.25	402.97
910531	3.58	406.32	405.22	1.10	2.48	402.74
910618	3.98	406.32	405.22	1.10	2.88	402.34
910627	4.09	406.32	405.22	1.10	2.99	402.23
910704	4.19	406.32	405.22	1.10	3.09	402.13
910711	4.14	406.32	405.22	1.10	3.04	402.18
910718	4.25	406.32	405.22	1.10	3.15	402.07
910725	4.23	406.32	405.22	1.10	3.13	402.09
910801	4.32	406.32	405.22	1.10	3.22	402.00
910808	4.10	406.32	405.22	1.10	3.00	402.22
910816	4.23	406.32	405.22	1.10	3.13	402.09
910822	4.25	406.32	405.22	1.10	3.15	402.07
910830	4.20	406.32	405.22	1.10	3.10	402.12
910906	4.21	406.32	405.22	1.10	3.11	402.11
910912	3.95	406.32	405.22	1.10	2.85	402.37
910919	3.93	406.32	405.22	1.10	2.83	402.39
911106	3.39	406.32	405.22	1.10	2.29	402.93
911122	3.28	406.32	405.22	1.10	2.18	403.04
911229	3.15	406.32	405.22	1.10	2.05	403.17
920103	3.15	406.32	405.22	1.10	2.05	403.17
920117	3.16	406.32	405.22	1.10	2.06	403.16
920131	3.29	406.32	405.22	1.10	2.19	403.03
920214	2.99	406.32	405.22	1.10	1.89	403.33
920320	3.09	406.32	405.22	1.10	1.99	403.23
920412	3.76	406.32	405.22	1.10	2.66	402.56

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 - Stream Level Reference Post 7

Date	Post Top To Stream Surface	Post Elev. (Top)	Stream Surface Elev.
910711	3.92	405.22	401.30
910718	3.93	405.22	401.29
910725	3.90	405.22	401.32
910801	3.89	405.22	401.33
910808	3.96	405.22	401.26
910816	3.96	405.22	401.26
910822	3.98	405.22	401.24
910830	3.96	405.22	401.26
910906	3.93	405.22	401.29
910912	3.92	405.22	401.30
910919	3.91	405.22	401.31

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 8-1

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901228	3.30	402.84	402.31	0.53	2.77	399.54
910112	2.94	402.84	402.31	0.53	2.41	399.90
910125	2.78	402.84	402.31	0.53	2.25	400.06
910209	2.71	402.84	402.31	0.53	2.18	400.13
910223	2.17	402.84	402.31	0.53	1.64	400.67
910307	2.03	402.84	402.31	0.53	1.50	400.81
910319	1.87	402.84	402.31	0.53	1.34	400.97
910406	2.19	402.84	402.31	0.53	1.66	400.65
910420	2.17	402.84	402.31	0.53	1.64	400.67
910502	1.98	402.84	402.31	0.53	1.45	400.86
910518	2.58	402.84	402.31	0.53	2.05	400.26
910531	3.16	402.84	402.31	0.53	2.63	399.68
910618	3.86	402.84	402.31	0.53	3.33	398.98
910627	4.44	402.84	402.31	0.53	3.91	398.40
910704	4.89	402.84	402.31	0.53	4.36	397.95
910711	5.19	402.84	402.31	0.53	4.66	397.65
910718	5.52	402.84	402.31	0.53	4.99	397.32
910725	5.66	402.84	402.31	0.53	5.13	397.18
910801	5.84	402.84	402.31	0.53	5.31	397.00
910808	5.81	402.84	402.31	0.53	5.28	397.03
910816	5.94	402.84	402.31	0.53	5.41	396.90
910822	5.97	402.84	402.31	0.53	5.44	396.87
910830	5.98	402.84	402.31	0.53	5.45	396.86
910906	6.03	402.84	402.31	0.53	5.50	396.81
910912	5.84	402.84	402.31	0.53	5.31	397.00
910919	5.62	402.84	402.31	0.53	5.09	397.22
911106	4.78	402.84	402.31	0.53	4.25	398.06
911122	3.57	402.84	402.31	0.53	3.04	399.27
911229	2.91	402.84	402.31	0.53	2.38	399.93
920103	2.84	402.84	402.31	0.53	2.31	400.00
920117	2.83	402.84	402.31	0.53	2.30	400.01
920131	2.94	402.84	402.31	0.53	2.41	399.90
920214	2.45	402.84	402.31	0.53	1.92	400.39
920320	2.26	402.84	402.31	0.53	1.73	400.58
920412	2.65	402.84	402.31	0.53	2.12	400.19

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 8-2

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901228	2.53	402.68	401.67	1.01	1.52	400.15
910112	2.19	402.68	401.67	1.01	1.18	400.49
910125	2.20	402.68	401.67	1.01	1.19	400.48
910209	2.11	402.68	401.67	1.01	1.10	400.57
910223	1.75	402.68	401.67	1.01	0.74	400.93
910307	1.51	402.68	401.67	1.01	0.50	401.17
910319	1.68	402.68	401.67	1.01	0.67	401.00
910406	2.03	402.68	401.67	1.01	1.02	400.65
910420	2.05	402.68	401.67	1.01	1.04	400.63
910502	1.82	402.68	401.67	1.01	0.81	400.86
910518	2.44	402.68	401.67	1.01	1.43	400.24
910531	2.93	402.68	401.67	1.01	1.92	399.75
910618	3.41	402.68	401.67	1.01	2.40	399.27
910627	3.80	402.68	401.67	1.01	2.79	398.88
910704	4.01	402.68	401.67	1.01	3.00	398.67
910711	3.97	402.68	401.67	1.01	2.96	398.71
910718	4.29	402.68	401.67	1.01	3.28	398.39
910725	4.23	402.68	401.67	1.01	3.22	398.45
910801	4.33	402.68	401.67	1.01	3.32	398.35
910808	4.01	402.68	401.67	1.01	3.00	398.67
910816	4.26	402.68	401.67	1.01	3.25	398.42
910822	4.30	402.68	401.67	1.01	3.29	398.38
910830	4.24	402.68	401.67	1.01	3.23	398.44
910906	4.28	402.68	401.67	1.01	3.27	398.40
910912	3.75	402.68	401.67	1.01	2.74	398.93
910919	3.72	402.68	401.67	1.01	2.71	398.96
911106	2.23	402.68	401.67	1.01	1.22	400.45
911122	2.45	402.68	401.67	1.01	1.44	400.23
911229	2.20	402.68	401.67	1.01	1.19	400.48
920103	2.13	402.68	401.67	1.01	1.12	400.55
920117	2.17	402.68	401.67	1.01	1.16	400.51
920131	2.35	402.68	401.67	1.01	1.34	400.33
920214	1.83	402.68	401.67	1.01	0.82	400.85
920320	1.94	402.68	401.67	1.01	0.93	400.74
920412	2.24	402.68	401.67	1.01	1.23	400.44

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 8-3

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901228	2.83	402.45	401.60	0.85	1.98	399.62
910112	1.92	402.45	401.60	0.85	1.07	400.53
910125	1.96	402.45	401.60	0.85	1.11	400.49
910209	1.94	402.45	401.60	0.85	1.09	400.51
910223	1.62	402.45	401.60	0.85	0.77	400.83
910307	1.70	402.45	401.60	0.85	0.85	400.75
910319	1.73	402.45	401.60	0.85	0.88	400.72
910406	1.91	402.45	401.60	0.85	1.06	400.54
910420	1.94	402.45	401.60	0.85	1.09	400.51
910502	1.88	402.45	401.60	0.85	1.03	400.57
910518	2.09	402.45	401.60	0.85	1.24	400.36
910531	2.20	402.45	401.60	0.85	1.35	400.25
910618	2.54	402.45	401.60	0.85	1.69	399.91
910627	2.68	402.45	401.60	0.85	1.83	399.77
910704	2.75	402.45	401.60	0.85	1.90	399.70
910711	2.62	402.45	401.60	0.85	1.77	399.83
910718	2.80	402.45	401.60	0.85	1.95	399.65
910725	2.80	402.45	401.60	0.85	1.95	399.65
910801	2.89	402.45	401.60	0.85	2.04	399.56
910808	2.72	402.45	401.60	0.85	1.87	399.73
910816	2.75	402.45	401.60	0.85	1.90	399.70
910822	2.86	402.45	401.60	0.85	2.01	399.59
910830	2.95	402.45	401.60	0.85	2.10	399.50
910906	2.69	402.45	401.60	0.85	1.84	399.76
910913	2.59	402.45	401.60	0.85	1.74	399.86
910919	2.55	402.45	401.60	0.85	1.70	399.90
911106	1.99	402.45	401.60	0.85	1.14	400.46
911122	1.98	402.45	401.60	0.85	1.13	400.47
911229	1.88	402.45	401.60	0.85	1.03	400.57
920103	1.89	402.45	401.60	0.85	1.04	400.56
920117	1.88	402.45	401.60	0.85	1.03	400.57
920131	1.94	402.45	401.60	0.85	1.09	400.51
920214	1.59	402.45	401.60	0.85	0.74	400.86
920320	1.86	402.45	401.60	0.85	1.01	400.59
920412	1.95	402.45	401.60	0.85	1.10	400.50

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 - Stream Level Reference Post 8

Date	Post Top To Stream Surface	Post Elev. (Top)	Stream Surface Elev.
910711	3.74	403.99	400.25
910718	3.73	403.99	400.26
910725	3.76	403.99	400.23
910801	3.75	403.99	400.24
910808	3.77	403.99	400.22
910816	3.78	403.99	400.21
910822	3.78	403.99	400.21
910830	3.78	403.99	400.21
910906	3.77	403.99	400.22
910912	3.76	403.99	400.23
910919	3.75	403.99	400.24

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 9-1

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901228	3.72	399.71	398.70	1.01	2.71	395.99
910112	3.41	399.71	398.70	1.01	2.40	396.30
910125	3.38	399.71	398.70	1.01	2.37	396.33
910209	3.31	399.71	398.70	1.01	2.30	396.40
910223	2.81	399.71	398.70	1.01	1.80	396.90
910307	2.78	399.71	398.70	1.01	1.77	396.93
910319	2.68	399.71	398.70	1.01	1.67	397.03
910406	3.00	399.71	398.70	1.01	1.99	396.71
910420	3.04	399.71	398.70	1.01	2.03	396.67
910502	2.79	399.71	398.70	1.01	1.78	396.92
910518	3.49	399.71	398.70	1.01	2.48	396.22
910531	4.06	399.71	398.70	1.01	3.05	395.65
910618	4.71	399.71	398.70	1.01	3.70	395.00
910627	5.12	399.71	398.70	1.01	4.11	394.59
910704	5.39	399.71	398.70	1.01	4.38	394.32
910711	5.62	399.71	398.70	1.01	4.61	394.09
910718	5.82	399.71	398.70	1.01	4.81	393.89
910725	5.93	399.71	398.70	1.01	4.92	393.78
910801	6.08	399.71	398.70	1.01	5.07	393.63
910808	6.08	399.71	398.70	1.01	5.07	393.63
910816	6.27	399.71	398.70	1.01	5.26	393.44
910822	6.35	399.71	398.70	1.01	5.34	393.36
910830	6.41	399.71	398.70	1.01	5.40	393.30
910906	6.50	399.71	398.70	1.01	5.49	393.21
910913	5.92	399.71	398.70	1.01	4.91	393.79
910919	5.76	399.71	398.70	1.01	4.75	393.95
911106	4.43	399.71	398.70	1.01	3.42	395.28
911122	3.79	399.71	398.70	1.01	2.78	395.92
911229	3.38	399.71	398.70	1.01	2.37	396.33
920103	3.37	399.71	398.70	1.01	2.36	396.34
920117	3.24	399.71	398.70	1.01	2.23	396.47
920131	3.51	399.71	398.70	1.01	2.50	396.20
920214	2.92	399.71	398.70	1.01	1.91	396.79
920320	2.90	399.71	398.70	1.01	1.89	396.81
920412	3.29	399.71	398.70	1.01	2.28	396.42

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 9-2

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901017	3.13	399.41	398.85	0.56	2.57	396.28
901031	2.94	399.41	398.85	0.56	2.38	396.47
901112	2.73	399.41	398.85	0.56	2.17	396.68
901128	2.30	399.41	398.85	0.56	1.74	397.11
901215	2.04	399.41	398.85	0.56	1.48	397.37
901228	2.47	399.41	398.85	0.56	1.91	396.94
910112	2.13	399.41	398.85	0.56	1.57	397.28
910125	2.13	399.41	398.85	0.56	1.57	397.28
910209	2.01	399.41	398.85	0.56	1.45	397.40
910223	1.68	399.41	398.85	0.56	1.12	397.73
910307	1.63	399.41	398.85	0.56	1.07	397.78
910319	1.62	399.41	398.85	0.56	1.06	397.79
910406	1.92	399.41	398.85	0.56	1.36	397.49
910420	1.95	399.41	398.85	0.56	1.39	397.46
910502	1.74	399.41	398.85	0.56	1.18	397.67
910518	2.36	399.41	398.85	0.56	1.80	397.05
910531	2.73	399.41	398.85	0.56	2.17	396.68
910618	3.40	399.41	398.85	0.56	2.84	396.01
910627	3.79	399.41	398.85	0.56	3.23	395.62
910704	3.98	399.41	398.85	0.56	3.42	395.43
910711	3.86	399.41	398.85	0.56	3.30	395.55
910718	4.23	399.41	398.85	0.56	3.67	395.18
910725	4.26	399.41	398.85	0.56	3.70	395.15
910801	4.40	399.41	398.85	0.56	3.84	395.01
910808	4.04	399.41	398.85	0.56	3.48	395.37
910816	4.24	399.41	398.85	0.56	3.68	395.17
910822	4.39	399.41	398.85	0.56	3.83	395.02
910830	4.26	399.41	398.85	0.56	3.70	395.15
910906	4.19	399.41	398.85	0.56	3.63	395.22
910913	3.72	399.41	398.85	0.56	3.16	395.69
910919	3.66	399.41	398.85	0.56	3.10	395.75
911106	2.54	399.41	398.85	0.56	1.98	396.87
911122	2.38	399.41	398.85	0.56	1.82	397.03
911229	2.14	399.41	398.85	0.56	1.58	397.27
920103	2.11	399.41	398.85	0.56	1.55	397.30
920117	2.11	399.41	398.85	0.56	1.55	397.30
920131	2.31	399.41	398.85	0.56	1.75	397.10
920214	1.43	399.41	398.85	0.56	0.87	397.98
920320	1.83	399.41	398.85	0.56	1.27	397.58
920412	2.16	399.41	398.85	0.56	1.60	397.25

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 9-3

Date YYMMDD	Measured Depth from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901017	1.98	400.60	399.98	0.62	1.36	398.62
901031	2.05	400.60	399.98	0.62	1.43	398.55
901112	2.00	400.60	399.98	0.62	1.38	398.60
901128	1.91	400.60	399.98	0.62	1.29	398.69
901215	1.83	400.60	399.98	0.62	1.21	398.77
901228	1.90	400.60	399.98	0.62	1.28	398.70
910112	1.83	400.60	399.98	0.62	1.21	398.77
910125	1.90	400.60	399.98	0.62	1.28	398.70
910209	1.89	400.60	399.98	0.62	1.27	398.71
910223	1.79	400.60	399.98	0.62	1.17	398.81
910307	1.84	400.60	399.98	0.62	1.22	398.76
910319	1.88	400.60	399.98	0.62	1.26	398.72
910406	1.96	400.60	399.98	0.62	1.34	398.64
910420	1.96	400.60	399.98	0.62	1.34	398.64
910502	1.96	400.60	399.98	0.62	1.34	398.64
910518	2.08	400.60	399.98	0.62	1.46	398.52
910531	2.13	400.60	399.98	0.62	1.51	398.47
910618	2.30	400.60	399.98	0.62	1.68	398.30
910627	2.34	400.60	399.98	0.62	1.72	398.26
910704	2.37	400.60	399.98	0.62	1.75	398.23
910711	2.24	400.60	399.98	0.62	1.62	398.36
910718	2.41	400.60	399.98	0.62	1.79	398.19
910725	2.38	400.60	399.98	0.62	1.76	398.22
910801	2.42	400.60	399.98	0.62	1.80	398.18
910808	2.31	400.60	399.98	0.62	1.69	398.29
910816	2.35	400.60	399.98	0.62	1.73	398.25
910822	2.40	400.60	399.98	0.62	1.78	398.20
910830	2.33	400.60	399.98	0.62	1.71	398.27
910906	2.22	400.60	399.98	0.62	1.60	398.38
910913	2.23	400.60	399.98	0.62	1.61	398.37
910919	2.23	400.60	399.98	0.62	1.61	398.37
911106	1.83	400.60	399.98	0.62	1.21	398.77
911122	1.90	400.60	399.98	0.62	1.28	398.70
911229	1.93	400.60	399.98	0.62	1.31	398.67
920103	1.90	400.60	399.98	0.62	1.28	398.70
920117	1.85	400.60	399.98	0.62	1.23	398.75
920131	1.96	400.60	399.98	0.62	1.34	398.64
920214	1.71	400.60	399.98	0.62	1.09	398.89
920320	1.93	400.60	399.98	0.62	1.31	398.67
920412	1.95	400.60	399.98	0.62	1.33	398.65

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 - Stream Level Reference Post 9

Date	Post Top To Stream Surface	Post Elev. (Top)	Stream Surface Elev.
910711	3.82	402.81	398.99
910718	3.82	402.81	398.99
910725	3.84	402.81	398.97
910801	3.84	402.81	398.97
910808	3.85	402.81	398.96
910816	3.86	402.81	398.95
910822	3.86	402.81	398.95
910830	3.84	402.81	398.97
910906	3.83	402.81	398.98
910912	3.82	402.81	398.99
910919	3.82	402.81	398.99

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 12-1

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901228	6.13	379.67	379.26	0.41	5.72	373.54
910112	5.75	379.67	379.26	0.41	5.34	373.92
910125	5.42	379.67	379.26	0.41	5.01	374.25
910209	5.07	379.67	379.26	0.41	4.66	374.60
910223	4.68	379.67	379.26	0.41	4.27	374.99
910307	4.08	379.67	379.26	0.41	3.67	375.59
910319	4.23	379.67	379.26	0.41	3.82	375.44
910406	4.50	379.67	379.26	0.41	4.09	375.17
910420	4.57	379.67	379.26	0.41	4.16	375.10
910502	4.43	379.67	379.26	0.41	4.02	375.24
910518	5.11	379.67	379.26	0.41	4.70	374.56
910531	5.60	379.67	379.26	0.41	5.19	374.07
910618	6.34	379.67	379.26	0.41	5.93	373.33
910627	6.81	379.67	379.26	0.41	6.40	372.86
910704	7.20	379.67	379.26	0.41	6.79	372.47
910711	7.48	379.67	379.26	0.41	7.07	372.19
910718	7.80	379.67	379.26	0.41	7.39	371.87
910725	8.05	379.67	379.26	0.41	7.64	371.62
910801	8.34	379.67	379.26	0.41	7.93	371.33
910808	8.40	379.67	379.26	0.41	7.99	371.27
910816	8.59	379.67	379.26	0.41	8.18	371.08
910822	8.75	379.67	379.26	0.41	8.34	370.92
910830	8.89	379.67	379.26	0.41	8.48	370.78
910906	9.02	379.67	379.26	0.41	8.61	370.65
910912	8.56	379.67	379.26	0.41	8.15	371.11
910919	8.42	379.67	379.26	0.41	8.01	371.25
911106		379.67	379.26	0.41		
911122		379.67	379.26	0.41		
911229	6.06	379.67	379.26	0.41	5.65	373.61
920103	5.98	379.67	379.26	0.41	5.57	373.69
920117	5.82	379.67	379.26	0.41	5.41	373.85
920131	5.58	379.67	379.26	0.41	5.17	374.09
920214	4.98	379.67	379.26	0.41	4.57	374.69
920320	4.60	379.67	379.26	0.41	4.19	375.07
920412	4.11	379.67	379.26	0.41	3.70	375.56

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 12-2

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901017	6.00	382.18	381.37	0.81	5.19	376.18
901031	5.70	382.18	381.37	0.81	4.89	376.48
901112	5.48	382.18	381.37	0.81	4.67	376.70
901128	5.17	382.18	381.37	0.81	4.36	377.01
901215	4.97	382.18	381.37	0.81	4.16	377.21
901228	4.87	382.18	381.37	0.81	4.06	377.31
910112	4.73	382.18	381.37	0.81	3.92	377.45
910125	4.61	382.18	381.37	0.81	3.80	377.57
910209	4.55	382.18	381.37	0.81	3.74	377.63
910223	4.19	382.18	381.37	0.81	3.38	377.99
910307	4.45	382.18	381.37	0.81	3.64	377.73
910319	4.03	382.18	381.37	0.81	3.22	378.15
910406	4.33	382.18	381.37	0.81	3.52	377.85
910420	4.38	382.18	381.37	0.81	3.57	377.80
910502	4.28	382.18	381.37	0.81	3.47	377.90
910518	4.84	382.18	381.37	0.81	4.03	377.34
910531	5.17	382.18	381.37	0.81	4.36	377.01
910618	5.56	382.18	381.37	0.81	4.75	376.62
910627	5.92	382.18	381.37	0.81	5.11	376.26
910704	6.15	382.18	381.37	0.81	5.34	376.03
910711	6.22	382.18	381.37	0.81	5.41	375.96
910718	6.49	382.18	381.37	0.81	5.68	375.69
910725	6.61	382.18	381.37	0.81	5.80	375.57
910801	6.75	382.18	381.37	0.81	5.94	375.43
910808	6.52	382.18	381.37	0.81	5.71	375.66
910816	6.83	382.18	381.37	0.81	6.02	375.35
910822	6.88	382.18	381.37	0.81	6.07	375.30
910830	6.79	382.18	381.37	0.81	5.98	375.39
910906	6.76	382.18	381.37	0.81	5.95	375.42
910912	6.30	382.18	381.37	0.81	5.49	375.88
910919	6.21	382.18	381.37	0.81	5.40	375.97
911106	5.55	382.18	381.37	0.81	4.74	376.63
911122	5.23	382.18	381.37	0.81	4.42	376.95
911229	4.83	382.18	381.37	0.81	4.02	377.35
920103	4.84	382.18	381.37	0.81	4.03	377.34
920117	4.44	382.18	381.37	0.81	3.63	377.74
920131	4.64	382.18	381.37	0.81	3.83	377.54
920214	4.47	382.18	381.37	0.81	3.66	377.71
920320	4.45	382.18	381.37	0.81	3.64	377.73
920412	4.81	382.18	381.37	0.81	4.00	377.37

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 12-3

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
901017	1.85	377.26	375.67	1.59	0.26	375.41
901031	1.84	377.26	375.67	1.59	0.25	375.42
901112	1.83	377.26	375.67	1.59	0.24	375.43
901128	1.86	377.26	375.67	1.59	0.27	375.40
901215	1.94	377.26	375.67	1.59	0.35	375.32
901228	1.94	377.26	375.67	1.59	0.35	375.32
910112	1.92	377.26	375.67	1.59	0.33	375.34
910125	2.01	377.26	375.67	1.59	0.42	375.25
910209	1.71	377.26	375.67	1.59	0.12	375.55
910223	1.69	377.26	375.67	1.59	0.10	375.57
910307	1.70	377.26	375.67	1.59	0.11	375.56
910319	2.01	377.26	375.67	1.59	0.42	375.25
910406	2.05	377.26	375.67	1.59	0.46	375.21
910420	1.93	377.26	375.67	1.59	0.34	375.33
910502	1.92	377.26	375.67	1.59	0.33	375.34
910518	1.80	377.26	375.67	1.59	0.21	375.46
910531	1.75	377.26	375.67	1.59	0.16	375.51
910618	2.19	377.26	375.67	1.59	0.60	375.07
910627	2.46	377.26	375.67	1.59	0.87	374.80
910704	2.70	377.26	375.67	1.59	1.11	374.56
910711	2.37	377.26	375.67	1.59	0.78	374.89
910718	2.65	377.26	375.67	1.59	1.06	374.61
910725	2.44	377.26	375.67	1.59	0.85	374.82
910801	2.61	377.26	375.67	1.59	1.02	374.65
910808	2.22	377.26	375.67	1.59	0.63	375.04
910816	2.44	377.26	375.67	1.59	0.85	374.82
910822	2.44	377.26	375.67	1.59	0.85	374.82
910830	2.37	377.26	375.67	1.59	0.78	374.89
910906	2.40	377.26	375.67	1.59	0.81	374.86
910912	2.04	377.26	375.67	1.59	0.45	375.22
910919	2.03	377.26	375.67	1.59	0.44	375.23
911106	1.78	377.26	375.67	1.59	0.19	375.48
911122	1.89	377.26	375.67	1.59	0.30	375.37
911229	1.88	377.26	375.67	1.59	0.29	375.38
920103	1.89	377.26	375.67	1.59	0.30	375.37
920117	1.90	377.26	375.67	1.59	0.31	375.36
920131	1.89	377.26	375.67	1.59	0.30	375.37
920214	1.89	377.26	375.67	1.59	0.30	375.37
920320	1.87	377.26	375.67	1.59	0.28	375.39
920412	1.80	377.26	375.67	1.59	0.21	375.46

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Stream Level Reference Post 12

Date	Post Top To Stream Surface	Post Elev. (Top)	Stream Surface Elev.
910711	3.89	381.84	377.95
910718	3.91	381.84	377.93
910725	3.92	381.84	377.92
910801	3.92	381.84	377.92
910808	3.96	381.84	377.88
910816	3.97	381.84	377.87
910822	3.98	381.84	377.86
910830	3.97	381.84	377.87
910906	3.93	381.84	377.91
910912	3.98	381.84	377.86
910919	3.98	381.84	377.86

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 13-1

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
910711	4.36	367.40	367.08	0.32	4.04	363.04
910718	4.56	367.40	367.08	0.32	4.24	362.84
910725	4.64	367.40	367.08	0.32	4.32	362.76
910801	4.77	367.40	367.08	0.32	4.45	362.63
910808	4.59	367.40	367.08	0.32	4.27	362.81
910816	4.75	367.40	367.08	0.32	4.43	362.65
910822	4.88	367.40	367.08	0.32	4.56	362.52
910830	4.86	367.40	367.08	0.32	4.54	362.54
910906	4.86	367.40	367.08	0.32	4.54	362.54
910912	4.37	367.40	367.08	0.32	4.05	363.03
910919	4.19	367.40	367.08	0.32	3.87	363.21
911106	1.69	367.40	367.08	0.32	1.37	365.71
911122	2.79	367.40	367.08	0.32	2.47	364.61
911229	2.19	367.40	367.08	0.32	1.87	365.21
920103	2.15	367.40	367.08	0.32	1.83	365.25
920117	2.05	367.40	367.08	0.32	1.73	365.35
920131	1.97	367.40	367.08	0.32	1.65	365.43
920214	1.06	367.40	367.08	0.32	0.74	366.34
920320	1.86	367.40	367.08	0.32	1.54	365.54
920412	2.67	367.40	367.08	0.32	2.35	364.73

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 13-2

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
910711	1.89	373.68	371.71	1.97	-0.08	371.79
910718	1.94	373.68	371.71	1.97	-0.03	371.74
910725	1.96	373.68	371.71	1.97	-0.01	371.72
910801	1.98	373.68	371.71	1.97	0.01	371.70
910808	1.88	373.68	371.71	1.97	-0.09	371.80
910816	1.89	373.68	371.71	1.97	-0.08	371.79
910822	1.88	373.68	371.71	1.97	-0.09	371.80
910830	1.86	373.68	371.71	1.97	-0.11	371.82
910906	1.86	373.68	371.71	1.97	-0.11	371.82
910912	1.81	373.68	371.71	1.97	-0.16	371.87
910919	1.87	373.68	371.71	1.97	-0.10	371.81
911106	1.80	373.68	371.71	1.97	-0.17	371.88
911122	1.93	373.68	371.71	1.97	-0.04	371.75
911229	1.91	373.68	371.71	1.97	-0.06	371.77
920103	1.94	373.68	371.71	1.97	-0.03	371.74
920117	1.86	373.68	371.71	1.97	-0.11	371.82
920131	1.19	373.68	371.71	1.97	-0.78	372.49
920214	1.90	373.68	371.71	1.97	-0.07	371.78
920320	1.96	373.68	371.71	1.97	-0.01	371.72
920412	1.95	373.68	371.71	1.97	-0.02	371.73

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 13-3

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface)	Water Table Elevation
910711	6.56	373.41	371.63	1.78	4.78	366.85
910718	4.40	373.41	371.63	1.78	2.62	369.01
910725	4.41	373.41	371.63	1.78	2.63	369.00
910801	4.51	373.41	371.63	1.78	2.73	368.90
910808	3.87	373.41	371.63	1.78	2.09	369.54
910816	4.10	373.41	371.63	1.78	2.32	369.31
910822	4.12	373.41	371.63	1.78	2.34	369.29
910830	4.11	373.41	371.63	1.78	2.33	369.30
910906	4.07	373.41	371.63	1.78	2.29	369.34
910912	3.34	373.41	371.63	1.78	1.56	370.07
910919	3.23	373.41	371.63	1.78	1.45	370.18
911106	3.35	373.41	371.63	1.78	1.57	370.06
911122	1.84	373.41	371.63	1.78	0.06	371.57
911229						
920103						
920117						
920131						
920214						
920320	1.77	373.41	371.63	1.78	-0.01	371.64
920412	2.08	373.41	371.63	1.78	0.30	371.33

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 - Stream Level Reference Post 13

Date	Post Top To Stream Surface	Post Elev. (Top)	Stream Surface Elev.
910711	4.86	375.84	370.98
910718	4.90	375.84	370.94
910725	4.90	375.84	370.94
910801	4.89	375.84	370.95
910808	4.90	375.84	370.94
910816	4.91	375.84	370.93
910822	4.92	375.84	370.92
910830	4.92	375.84	370.92
910906	4.93	375.84	370.91
910912	4.90	375.84	370.94
910919	4.92	375.84	370.92

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 14-1

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface	Water Table Elevation
910711	4.82	360.64	359.02	1.62	3.20	355.82
910718	5.17	360.64	359.02	1.62	3.55	355.47
910725	5.17	360.64	359.02	1.62	3.55	355.47
910801	5.22	360.64	359.02	1.62	3.60	355.42
910808	4.81	360.64	359.02	1.62	3.19	355.83
910816	5.24	360.64	359.02	1.62	3.62	355.40
910822	5.26	360.64	359.02	1.62	3.64	355.38
910830	5.20	360.64	359.02	1.62	3.58	355.44
910906	5.20	360.64	359.02	1.62	3.58	355.44
910912	4.55	360.64	359.02	1.62	2.93	356.09
910919	4.42	360.64	359.02	1.62	2.80	356.22
911106	2.49	360.64	359.02	1.62	0.87	358.15
911122	2.36	360.64	359.02	1.62	0.74	358.28
911229	2.09	360.64	359.02	1.62	0.47	358.55
920103	2.05	360.64	359.02	1.62	0.43	358.59
920117	2.09	360.64	359.02	1.62	0.47	358.55
920131						
920214						
920320	2.15	360.64	359.02	1.62	0.53	358.49
920412	2.73	360.64	359.02	1.62	1.11	357.91

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 14-2

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface	Water Table Elevation
910711	1.22	364.20	363.13	1.07	0.15	362.98
910718	1.16	364.20	363.13	1.07	0.09	363.04
910725	1.14	364.20	363.13	1.07	0.07	363.06
910801	1.14	364.20	363.13	1.07	0.07	363.06
910808	1.10	364.20	363.13	1.07	0.03	363.10
910816	1.12	364.20	363.13	1.07	0.05	363.08
910822	1.12	364.20	363.13	1.07	0.05	363.08
910830	1.08	364.20	363.13	1.07	0.01	363.12
910906	1.10	364.20	363.13	1.07	0.03	363.10
910912	1.09	364.20	363.13	1.07	0.02	363.11
910919	1.10	364.20	363.13	1.07	0.03	363.10
911106	1.08	364.20	363.13	1.07	0.01	363.12
911122	1.08	364.20	363.13	1.07	0.01	363.12
911229	1.09	364.20	363.13	1.07	0.02	363.11
920103	1.16	364.20	363.13	1.07	0.09	363.04
920117	1.11	364.20	363.13	1.07	0.04	363.09
920131						
920214	1.08	364.20	363.13	1.07	0.01	363.12
920320	1.04	364.20	363.13	1.07	-0.03	363.16
920412	1.17	364.20	363.13	1.07	0.10	363.03

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 -- Well Number 14-3

Date YYMMDD	Measured Depth (from top of casing)	Casing Elev.	Ground Elev.	Casing Height	Depth to Water (below land surface	Water Table Elevation
910711	3.21	368.25	366.14	2.11	1.10	365.04
910718	3.46	368.25	366.14	2.11	1.35	364.79
910725	3.41	368.25	366.14	2.11	1.30	364.84
910801	3.49	368.25	366.14	2.11	1.38	364.76
910808	3.21	368.25	366.14	2.11	1.10	365.04
910816	3.35	368.25	366.14	2.11	1.24	364.90
910822	3.40	368.25	366.14	2.11	1.29	364.85
910830	3.33	368.25	366.14	2.11	1.22	364.92
910906	3.19	368.25	366.14	2.11	1.08	365.06
910912	3.07	368.25	366.14	2.11	0.96	365.18
910919	3.07	368.25	366.14	2.11	0.96	365.18
911106	2.70	368.25	366.14	2.11	0.59	365.55
911122	2.78	368.25	366.14	2.11	0.67	365.47
911229	2.68	368.25	366.14	2.11	0.57	365.57
920103	2.69	368.25	366.14	2.11	0.58	365.56
920117	2.66	368.25	366.14	2.11	0.55	365.59
920131						
920214						
920320	2.56	368.25	366.14	2.11	0.45	365.69
920412	2.51	368.25	366.14	2.11	0.40	365.74

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

SPIRANTHES DILUVIALIS HABITAT AND RIPARIAN RESTORATION STUDY
Hog Canyon, Dinosaur National Monument
Groundwater Monitoring Data 1990-92 - Stream Level Reference Post 14

Date	Post Top To Stream Surface	Post Elev. (Top)	Stream Surface Elev.
910711	4.04	364.28	360.24
910718	4.05	364.28	360.23
910725	4.05	364.28	360.23
910801	4.05	364.28	360.23
910808	4.02	364.28	360.26
910816	4.03	364.28	360.25
910822	4.04	364.28	360.24
910830	4.02	364.28	360.26
910906	4.04	364.28	360.24
910912	4.13	364.28	360.15
910919	4.14	364.28	360.14

All elevations are relative to an arbitrary benchmark that was established on a large rock at the upper end of the canyon. This benchmark was assigned a value of 500 feet and corresponds to about 5500 feet msl.

As the nation's principal conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental an cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D - 87 October 1992