

WETLANDS OF THE SAN LUIS VALLEY, COLORADO:
AN ECOLOGICAL STUDY AND ANALYSIS OF THE
HYDROLOGIC REGIME, SOIL CHEMISTRY, VEGETATION
AND THE POTENTIAL EFFECTS OF A WATER TABLE DRAWDOWN

Research Performed for:

State of Colorado Division of Wildlife
U.S. Fish and Wildlife Service
Rio Grande Water Conservation District

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INTRODUCTION

The northern San Luis Valley in south-central Colorado is an intermountain basin surrounded by high mountains. Mountains to the west block winter storm tracks, while mountains to the east block spring storm tracks, creating the lowest precipitation region of Colorado. Streams from the San Juan, Sangre de Cristo and Sawatch Mountains flow into the very flat basin, yet no surface outlet occurs creating a closed basin. Throughout the closed basin area the water table is high, in most places it is within 5 to 15 feet of the ground surface. Over many thousands of acres, the water table or surface water occurs at the ground surface in streams, lakes, ponds and wetlands.

This abundant water creates a lush environment for plant growth which creates habitat for many different types of animals. Aquatic insects thrive and birds, such as migratory waterfowl, shorebirds, raptors such as peregrine falcons, passerine birds are abundant. In many areas amphibians, reptiles and small mammals are also abundant. The plants however, are the key factor in determining where animals occur and must be included in any realistic ecological perspective of Colorado's "wild life". The diversity of plant life makes the San Luis valley wetlands among the most productive habitat in Colorado, and habitat of this quality is essential to protect.

The only realistic means of understanding the needs of wildlife associated with wetlands is to understand the wetland hydrologic regime and water and soil chemistry. These physical factors determine the potential of a wetland for supporting plants which form the vegetation. The vegetation provides the food for aquatic insect food chains and habitat for larger animals. Just studying the animals does not lead to an understanding of how to protect their habitat. However, an integrated study of physical and biological factors that create habitat done concurrently with studies of aquatic insects and other animal use will lead to a comprehensive understanding of how a wetland functions.

In the western U.S. competing uses for a limited amount of water have put urban, agricultural and wildlife values in conflict. In the San Luis Valley this problem especially acute because rainfall is so limited. Most land uses rely on surface water that originates in the surrounding mountains or ground water that is either ancient, or is recharged by runoff from the surrounding mountains. Wild animals rely on the surface water and high water tables supported by this runoff as well. Ground water is being pumped by agricultural users for irrigation of seed and tuber crops and for hay. The U.S. Bureau of Reclamation pumps ground water for export to New Mexico and Texas via the Rio Grande River in their Closed Basin Project. The potential of developing ground water for export to urban markets is being explored by the American Water Development, Inc. (AWDI). The effects of AWDI's project on water tables and wildlife in the San Luis valley is a subject of great concern, since the proposed project is very large and ground water table drawdown maps generated by the State of Colorado Engineers Office indicate permanent drawdowns of many feet over large areas of the northern valley.

The effect of AWDI's drawdown was the impetus for initiating a study of wetland ecosystems in the San Luis Valley. These wetlands are supported by surface and ground water. The principle goal of the study reported here was to collect data to develop a large data base on the interrelationships among water table, surface water, soils and vegetation. This study presents this data base, its analyses, conclusions and hypotheses. Our goal is to describe the wetlands occurring in the northern San Luis Valley and develop an understanding of how to maintain these wetlands on the landscape.

Wetlands similar to those occurring in the San Luis valley occur on the prairies of the U.S. (van der Valk and Davis 1976; Kantrud et al. 1989; Dix and Smiens 1967) and Canada (Dodd and Coupland 1966; Walker and Coupland 1968, 1970; Millar 1973; Shay and Shay 1986; van der Valk and Bliss 1971) and in several parts

of the West, especially the Great Salt Lake (Flowers 1934, Smith and Kadlec 1985, Kadlec 1982). Surprisingly very little study of Colorado marshes has occurred, and nothing in the San Luis Valley. In South Park, Colorado two wetland studies of note have been performed which provide helpful reference, Ungar (1974) who studied the salt flat vegetation around Antero Reservoir and Cooper (1990) who studied wetlands of the entire South Park region. However, South Park occurs at higher elevations than the San Luis Valley, has mostly surface as opposed to ground water flows, marsh type wetlands, such as occur in the San Luis Valley, do not occur. Wetlands in South Park include peatlands, wet meadows, and salt flats. Thus, little data for direct comparison with other parts of Colorado exists.

In addition, to the value of this data for understanding the effects of water table changes on wetlands, data on wetland hydrology, chemistry and vegetation also is fundamental for the development of water, vegetation and wildlife management plans that are objective and definitive.

METHODS

This study was conducted in four main areas in the San Luis Valley, Mishak Lakes, Russell Lakes, San Luis Lakes and Villa Grove (Figure 1). The methods of study are similar from area to area. A general outline of the methods used in this study are presented here. Locations of sample stations are presented in following sections.

Selection of transects. Each of the four study areas was studied by field reconnaissance prior to the establishment of this research. We wanted to establish transects which would allow us to study the distribution of plant and soil characteristics along quantifiable hydrologic gradients. Our goal was to establish transects along a topographic gradients which usually correspond to a hill or valley side. A transect runs from valley side to valley side crossing a wetland basin or valley. In most cases transects run perpendicular to topographic contours from the wetland center to the uplands. In the San Luis Valley, zonation of plant communities along the water table gradient is very apparent. Along each transect the plant communities were identified and the boundaries between communities marked with stakes. All observations and data presented in this report are from these transects. A total of 30 transects were established; 3 at Villa Grove, 2 at Mishak, 12 at Russell Lakes and 12 at San Luis Lakes area. The number of stations established along each transect is variable.

Hydrology. The ground water and surface water elevation of study wetlands were studied along transects. Ground water monitoring wells were installed to approximately 3 feet below the water table in April 1991 at the boundary between each community marked by stakes, as described above. Every well was hand augured. The hole was cased using PVC pipe. Each PVC pipe consisted of a bottom cap, 2 or more feet of machine slotted pipe at the hole bottom, a coupler and unslotted pipe to approximately 1 foot above the soil surface. All wells were capped. Wells were not installed in surface water features such as lakes and

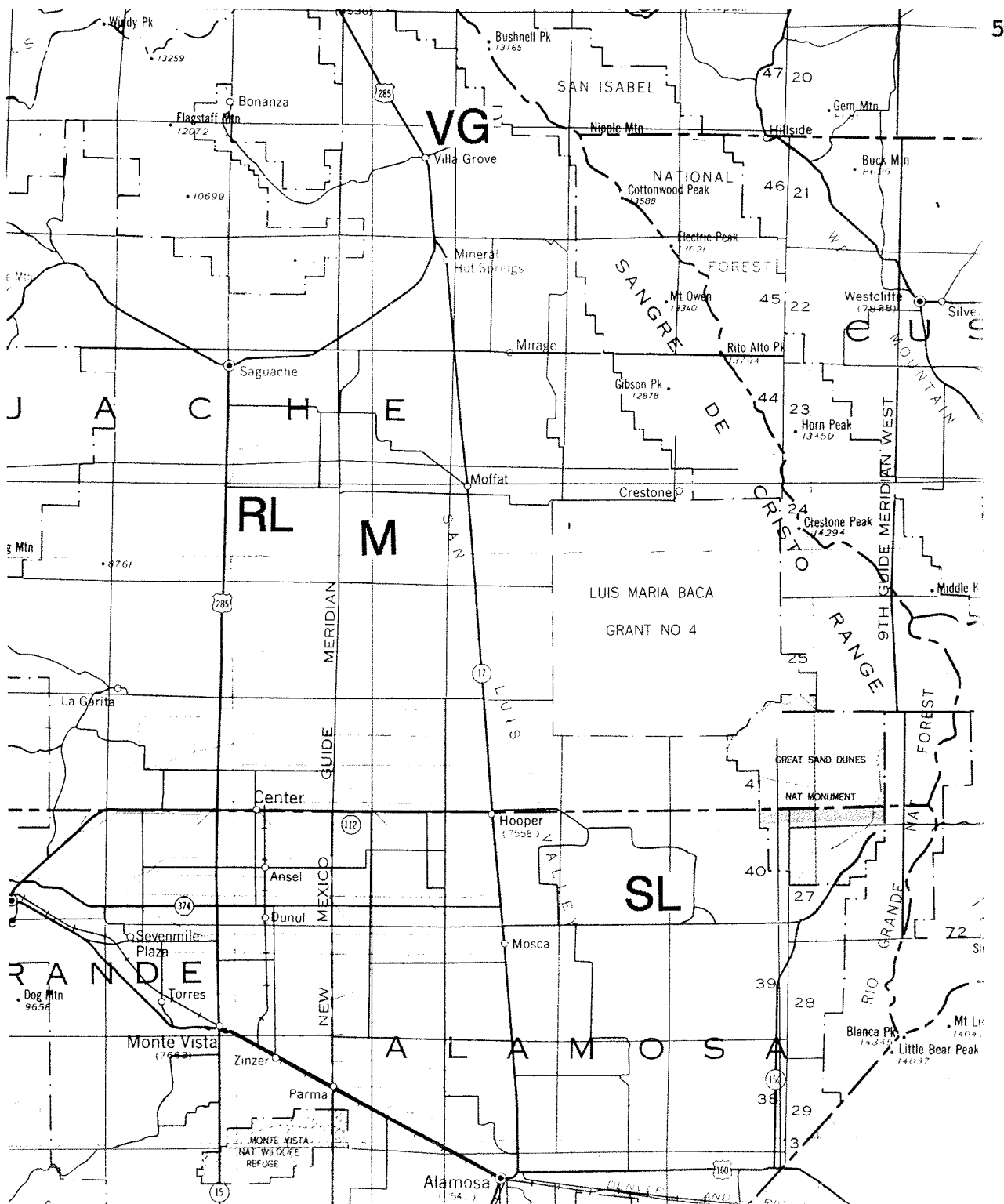


Figure 1. Map showing four study areas in the San Luis Valley. VG is Villa Grove, RL is Russell Lakes, M is Mishak Lakes, and SL is San Luis Lakes. Map scale is 1:500,000.

streams. Instead staff gauges consisting of a metal fence post with a ruler permanently attached were installed.

Weekly measurements of depth to water table from the well casing rim and the water level on staff gauges were made and the data entered in field data books. This data was transferred to the computer spreadsheet software program Quattro Pro 3.0. This program was used for data storage, and many of these analyses. Hydrologic analyses include transect profiles showing the elevation of the water table on different dates and hydrographs for individual or multiple monitoring wells using weekly data and other analyses.

Topographic surveying. All staff gauges and ground water monitoring wells were surveyed using a full station by Davis Engineering, Del Norte, Colorado. Survey information provides latitude, longitude and elevation to the 1/100th of a foot. Its accuracy is exceptional. In all cases except Mishak Lakes, the elevations are calculated from established bench marks and are true elevations. All elevations are in feet.

Water Chemistry. Several times during the season the surface water of streams and lakes and the ground water in monitoring wells was sampled to determine its characteristics for some important chemical variables. Water Ph, conductance and temperature were measured for almost every sample collected in the field seconds after collecting the samples. Monitoring wells were pumped for several minutes where possible to insure that we were sampling ground water unaffected by the well casing environment. For selected stations samples were collected and refrigerated until being filtered through a 0.45 micron filter. The samples were then acidified with nitric acid until a pH of 2.0 was reached. The samples were frozen until analyzed. Water was directly analyzed for the following cations using atomic absorption spectrophotometer; Ca^{++} , Na^+ , Mg^{++} and K^+ .

Soil Chemistry. Soil was collected from the top three to four inches in representative stands between ground water observation wells and topographically above and below the last

well on each transect. Each sample weighted approximately 20 g. Samples were placed in plastic bags, labeled and sealed. Within two weeks they were air dried. In the laboratory samples were weighted on a balance. The sample was the placed into a clean blender and mixed with a volume of distilled water five times the weight of the dry soil. Water and soil were blended and allowed to settle. The water was decanted, filtered, acidified and analyzed using the same methods as described for water samples.

Vegetation. Vegetation between wells and above and below the end wells or staff gauges on transects was quantified. A list of all plant species was made in a 20m² plot and the canopy coverage of each species was estimated. Voucher specimens of plant species were collected, verified by W.A. Weber and are in the University of Colorado, Boulder herbarium. This data was used to develop a vegetation classification and to perform direct gradient analyses for investigating the distribution of plant species to measured environmental gradients. Indirect ordination using Detrended Correnspondence Analysis (Hill 1979) and Canonical Correspondence Analysis (Ter Braak 1987) along with Braun-Blanquet table methods (Westhoff and Maarel 1978) were used to further explore and classify the vegetation. Within each plot a 0.2m² quadrat was randomly placed and the above-ground herbaceous plant material produced during 1991 was clipped at the ground surface. This material was placed into marked bags and dried in an oven. Samples were weighted on a balance.

THE STUDY AREAS

For the purposes of this research four study areas were chosen. These areas were chosen because it contains representative San Luis Valley wetlands. The study areas are Villa Grove, Russell Lakes, San Luis Lakes-Medano Ranch and Mishak Lakes (Figure 2, 3, 4, 5 maps). Each study area is described below and a map presented to show the location of transects and ground water observation holes.

The town of Villa Grove is in the northern most portion of the San Luis Valley. We chose two study areas in this vicinity, both on the eastern side of U.S. highway 285. The northern study area occurs approximately 2 miles north of Villa Grove (Figure 2), along San Luis Creek and includes one transect that spans the entire valley system. The area here is irrigated for hay. It is also grazed by cattle. The second study area is located just east of Villa Grove and occupies the valley bottom along San Luis and Rock Creek. Rock Creek is a groundwater fed stream that originates in this area and flows south to meet San Luis Creek just south of our study area. The area is the most complex hydrologically that we saw in the San Luis Valley. It contains a perennial stream that flows through the valley (San Luis Creek), the spring fed creek that arises here (Rock Creek), ground water inflow from east, west and north, and vertical groundwater discharge that creates a number of springs and quagmires in the valley center. The vegetation is mostly native sedges and grasses and the area is grazed in mid to late summer.

The Mishak Lakes study area occur in the center of the San Luis valley, just north of the agricultural district north of Center, and can be found on the Moffat South U.S. Geological Survey 1:24,000 topographic map and is shown on Figure 3. Mishak Lakes occurs at the confluence of Russell Creek, La Garita Creek and Werner Arroyo, all originating farther west in the Valley. The main water source appears to be Russell Creek, but all creeks can carry surface water. The area is a series of ponds along creeks in an area where groundwater and surface water intersect

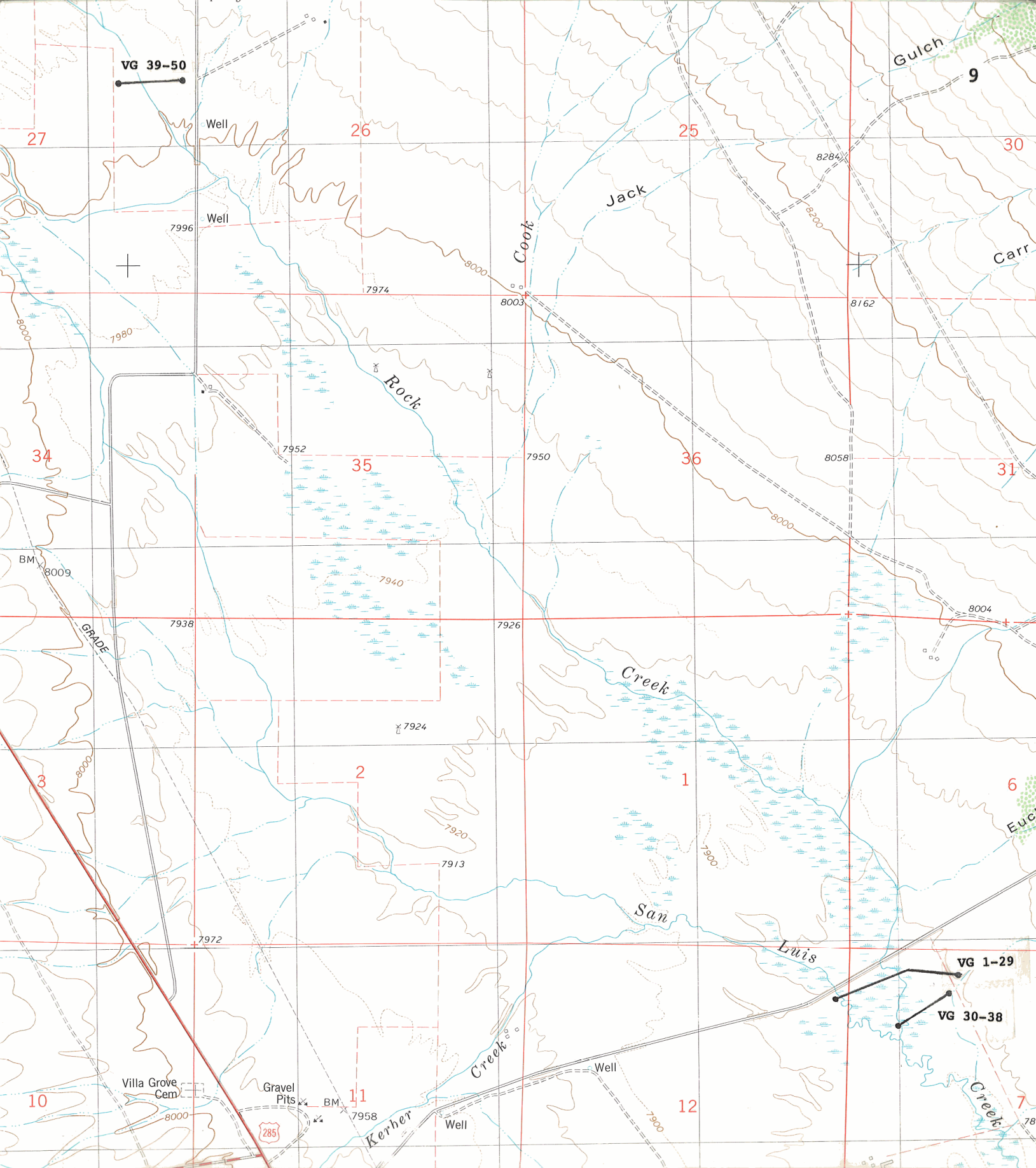
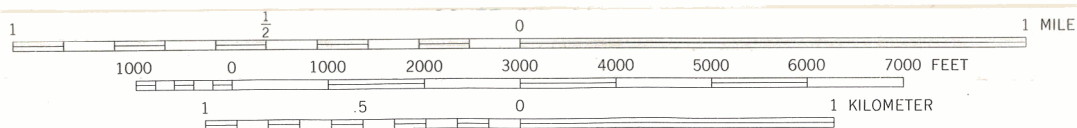


Figure 2. Study area at Villa Grove showing locations of wells.



CONTOUR INTERVAL 40 FEET
 DOTTED LINES REPRESENT 20-FOOT CONTOURS
 NATIONAL GEODETIC VERTICAL DATUM OF 1929

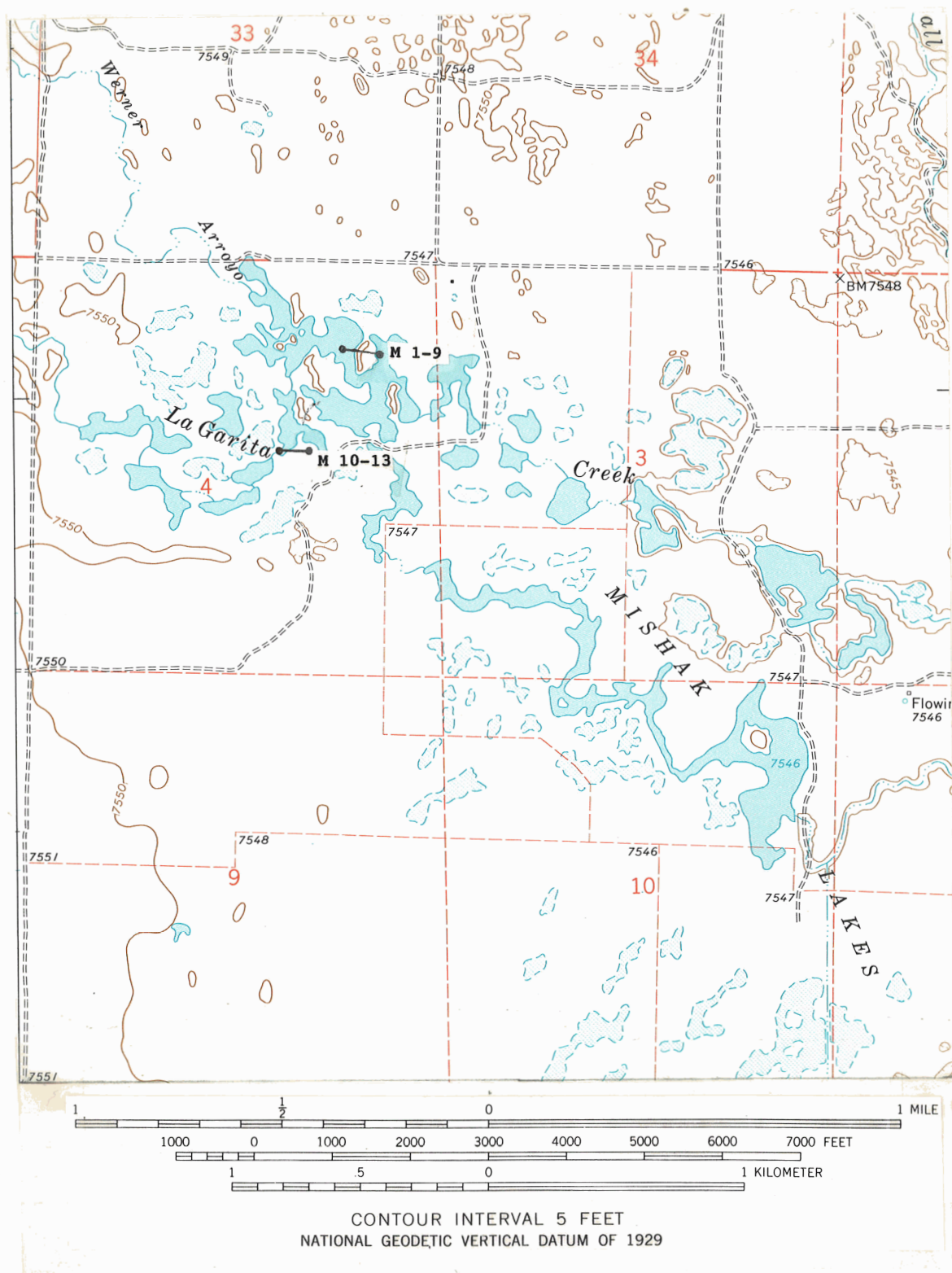


Figure 3. Study area at Mishak Lakes showing locations of wells.

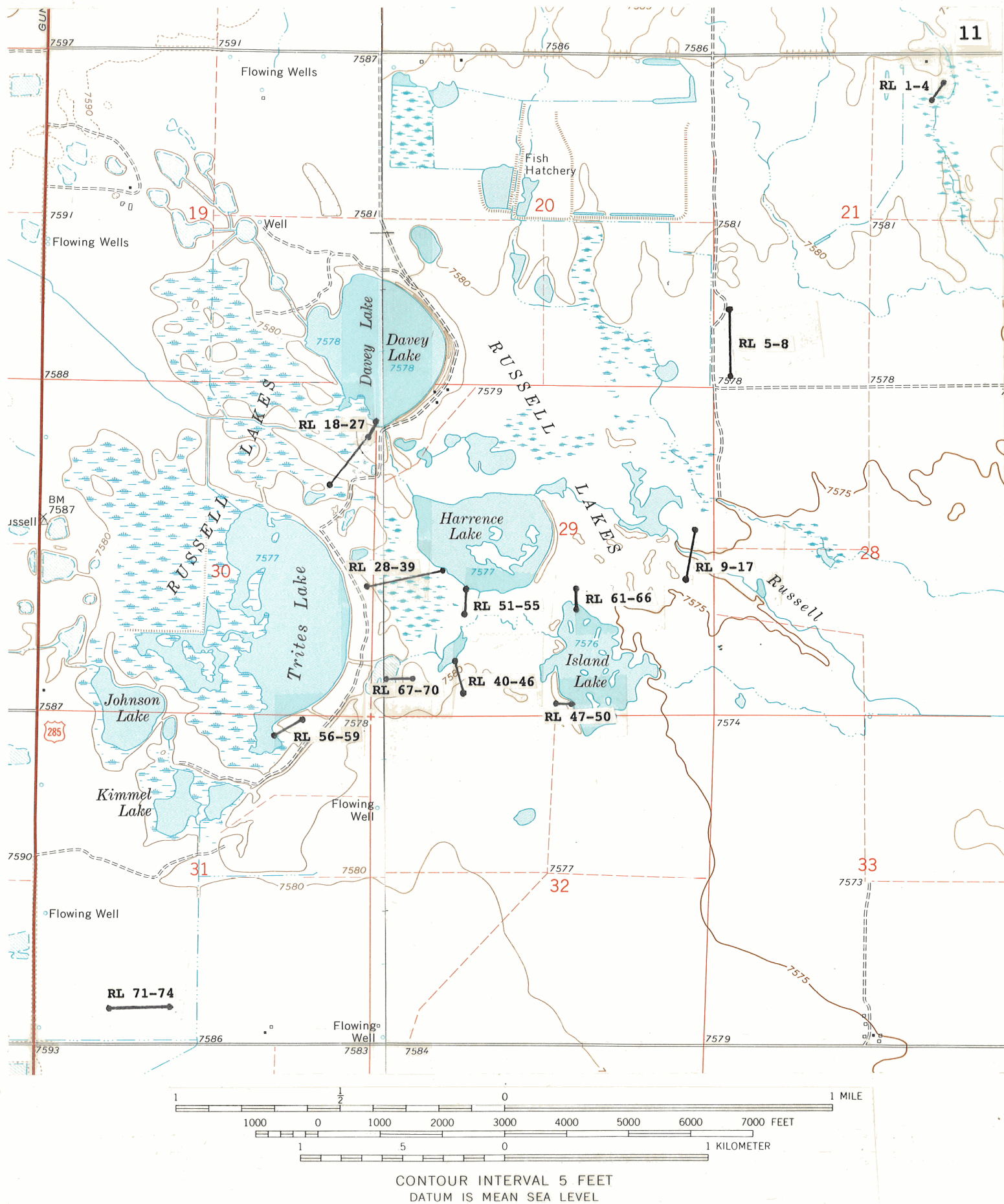


Figure 4. Study area at Russell Lakes showing locations of wells.

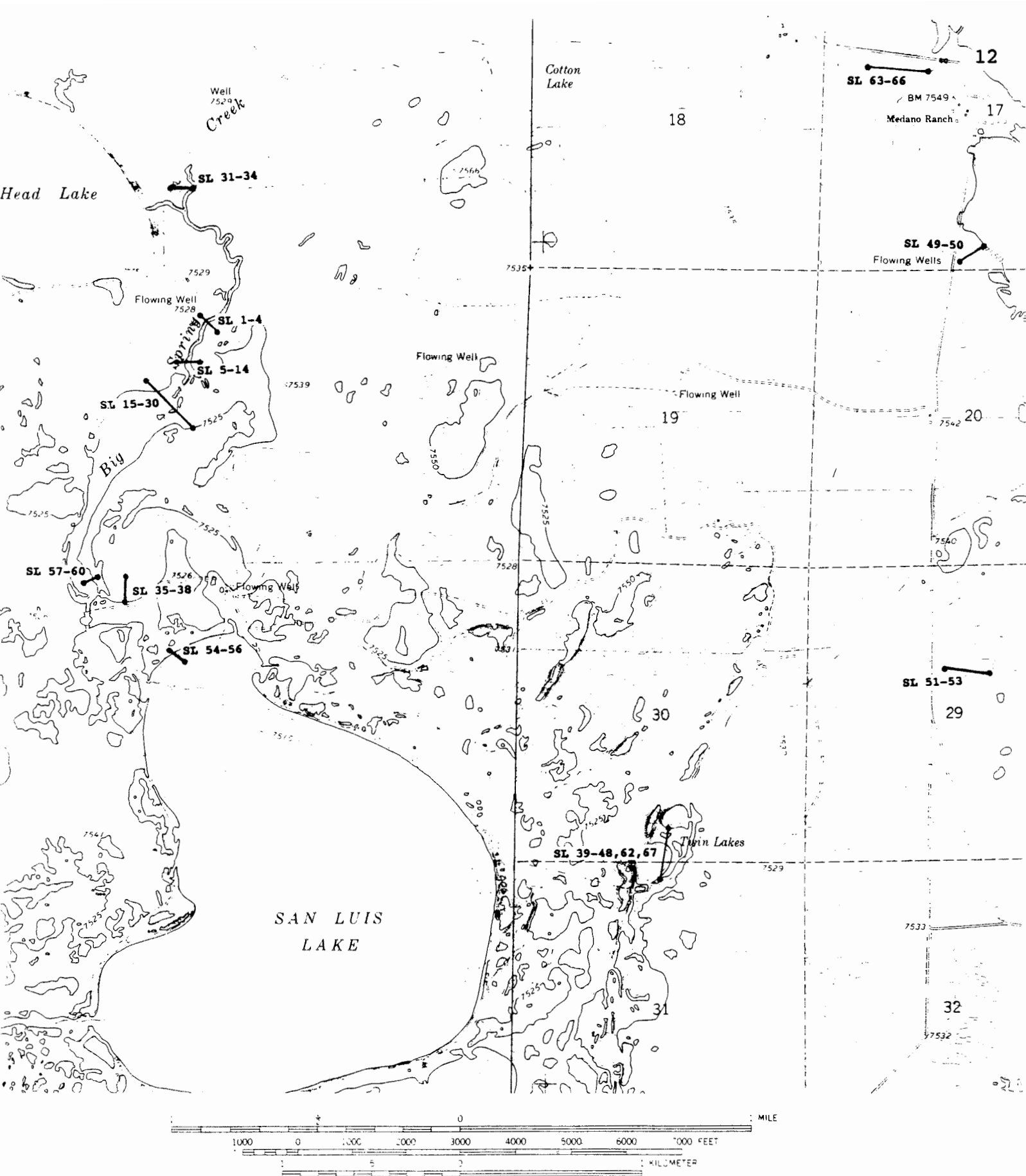


Figure 5. Study area at San Luis Lakes showing locations of wells.

in an area of extremely level topography. Across this area from northwest to southeast, a distance of more than 2 miles, the topography is flat, at 7547 feet elevation. Thus, the confluence of surface water sources into an area of stagnant ground water build local water tables and creates surface water expression as ponds and marshes. We established two transects in this area as is shown in Figure 3.

The Russell Lakes study area is located approximately 9 miles south of Saguache in the northwestern portion of the San Luis Valley and can be seen on U.S. Geological Survey topographic maps (1:24,000 scale series) Swede Corners and Harrence Lake quadrangles. U.S. Highway 285 is on the west side of the area. Several large natural lakes occur here; Trites, Harrence, Davey, Johnson and Kimmel. In addition, Island Lake and several smaller lakes have been created with dikes and surface water. This area is managed by the State of Colorado Division of Wildlife. The area is naturally fed by a very high water table and surface water from Russell Springs. Recently artesian groundwater has been tapped and is used to maintain lake levels and saturate the man-made lakes and marshes. The large lakes all have similar characteristics, being rounded on the east side, with large dunes on the east. The dunes are created by dust and sand blowing from the dry lake bed during dry times. The eastern lake shores are vegetation free, while the western side is choked with dense stands of bulrush. Aquatic vegetation is very limited in these lakes. These lakes are famous for their waterfowl value. Our study transects spanned the entire AREA as is shown in Figure 4, and we established 75 monitoring well and staff gauge locations and 12 transects.

The San Luis Lakes study area is in the eastern portion of the San Luis Valley near the Great Sand Dunes National Monument and can be seen on the U.S. Geological Survey topographic maps (1:24,000 scale series) Medano Ranch quadrangle. The area is complex with large dune fields to the east and salt flats to the south and west. San Luis Creek, an intermittent stream in this

region, enters from the north, while the spring fed Big and Little Spring Creeks enter from the east. In addition, the snowmelt runoff fed Sand (or Arena) Creek enters from the northeast. Two large and several small natural lakes occur in the area; San Luis, Head, Twin, Cotton and Dollar Lakes. San Luis is the largest natural lake in the San Luis Valley, being approximately 1 mile in diameter. It once dried up during droughts and filled during wet periods. Today lake level is maintained by the Bureau of Reclamation. Our study encompassed the area between San Luis and Head Lakes and the western portion of the Medano Ranch. The location of our 11 transects and 67 wells and staff gauges is on Figure 5.

RESULTS

WEATHER AND CLIMATE

The northern San Luis Valley is an interior basin surrounded on the north, west and east by mountains up to 14,000 feet in elevation. The effect of rain shadows is profound and total average annual precipitation in Alamosa is 6.9 inches, the lowest received by any Colorado station. The flat valley floor is at around 7,500 feet elevation. Summer temperatures are not hot, but usually are sunny.

Mean monthly precipitation for the town of Center for the years 1964-1991 is shown in Figure 6. Mean monthly precipitation for the winter months (November through April) is less than 0.5 inch. This is unusual, since western Colorado stations in general receive their maximum precipitation during these months. The influence of rain shadows is pronounced here. Mean monthly precipitation for the spring months (May and June) is also low. June is typically the driest month in western Colorado, while eastern Colorado stations all have precipitation maxima in the spring, peaking in May. The Sangre de Cristo Mountains block the eastern moisture source from reaching the San Luis Valley, while the San Juan Mountains block the western winter storms.

Precipitation in the San Luis Valley is highest in late summer, July, August and September, with August being the month with the highest average precipitation. This moisture source is the Gulf of Mexico and Gulf of California and is derived from monsoonal flow from the desert southwest. This air moves north through Arizona and New Mexico into the Valley where no mountains obstruct the flow. The Valley vegetation is decidedly influenced by this late summer rain which usually occurs as thundershowers. Most annual plants germinate and grow and most perennial plants flower during the late summer.

Total annual precipitation for the years 1964 through 1991 averaged for six stations in the San Luis Valley (Center, Saguache, Crestone, Alamosa, Great Sand Dunes National Monument and Del Norte) are presented in Figure 7. Precipitation for the

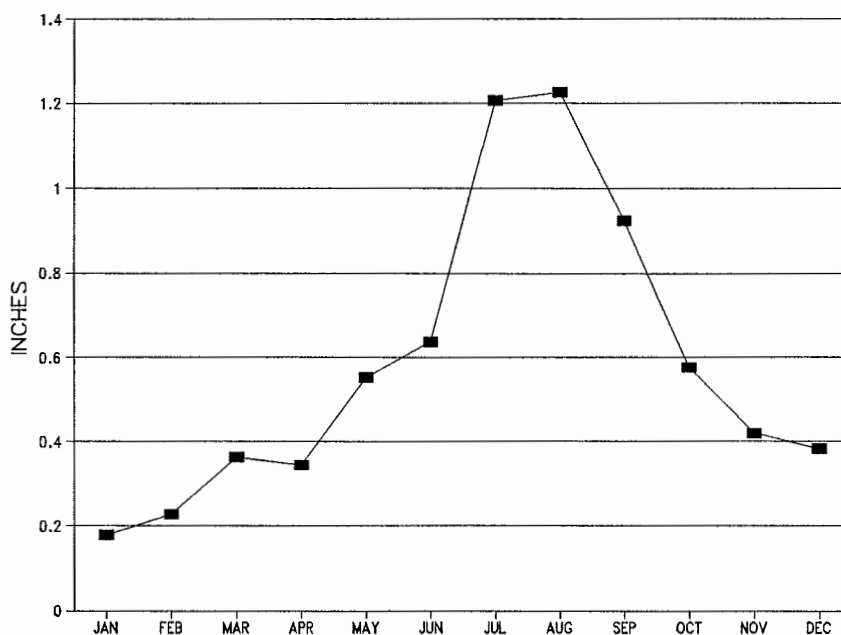


Figure 6. Mean monthly precipitation for the town of Center for the years 1964-1991.

1960's was extremely variable from year to year with alternating highs and lows. From 1970 to 1980 annual precipitation was remarkably constant. Beginning in 1981 and culminating in 1985 and 1986 total annual precipitation was much higher than in the previous decade. From 1987 to the present precipitation in the valley has returned to 1970's levels. The same pattern is seen when the data from Center alone are examined (Figure 8).

Figure 9 is crowded but depicts total annual precipitation for the six stations. The figure shows that most stations are in phase responding to the same climatic variables. In general Crestone, Great Sand Dunes and Del Norte which occur in the foothills have higher annual precipitation totals than Center, Alamosa and Saguache which occur on the Valley floor. This is

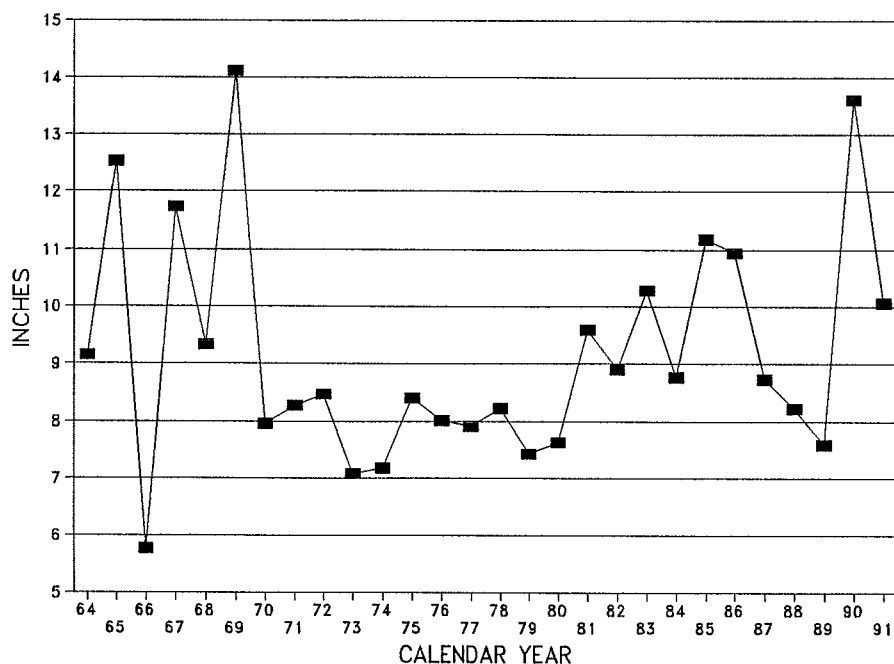


Figure 7. Total annual precipitation for the six stations in the San Luis Valley. Total precipitation for Center, Saguache, Crestone, Alamosa, Great Sand Dunes National Monument and Del Norte.

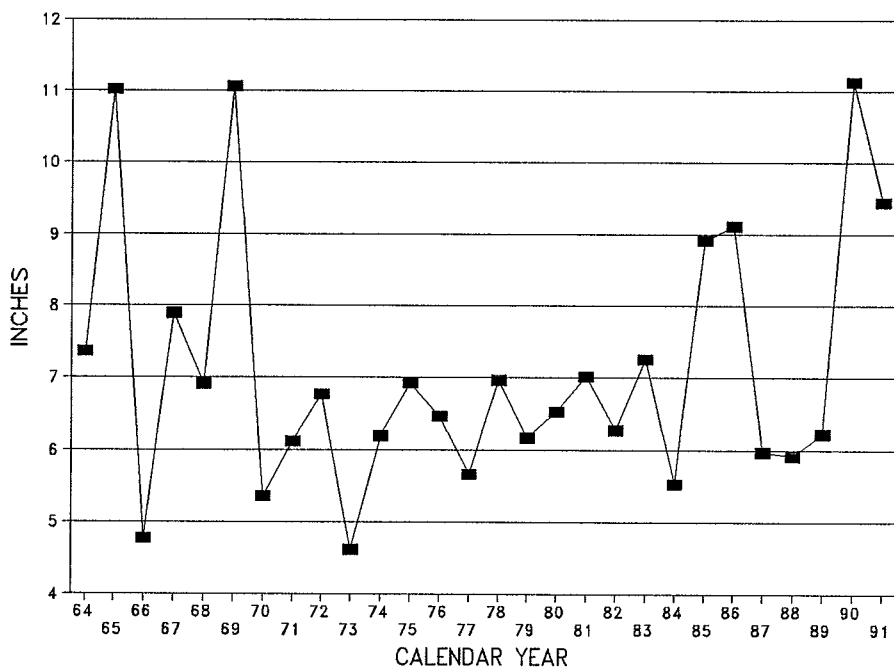
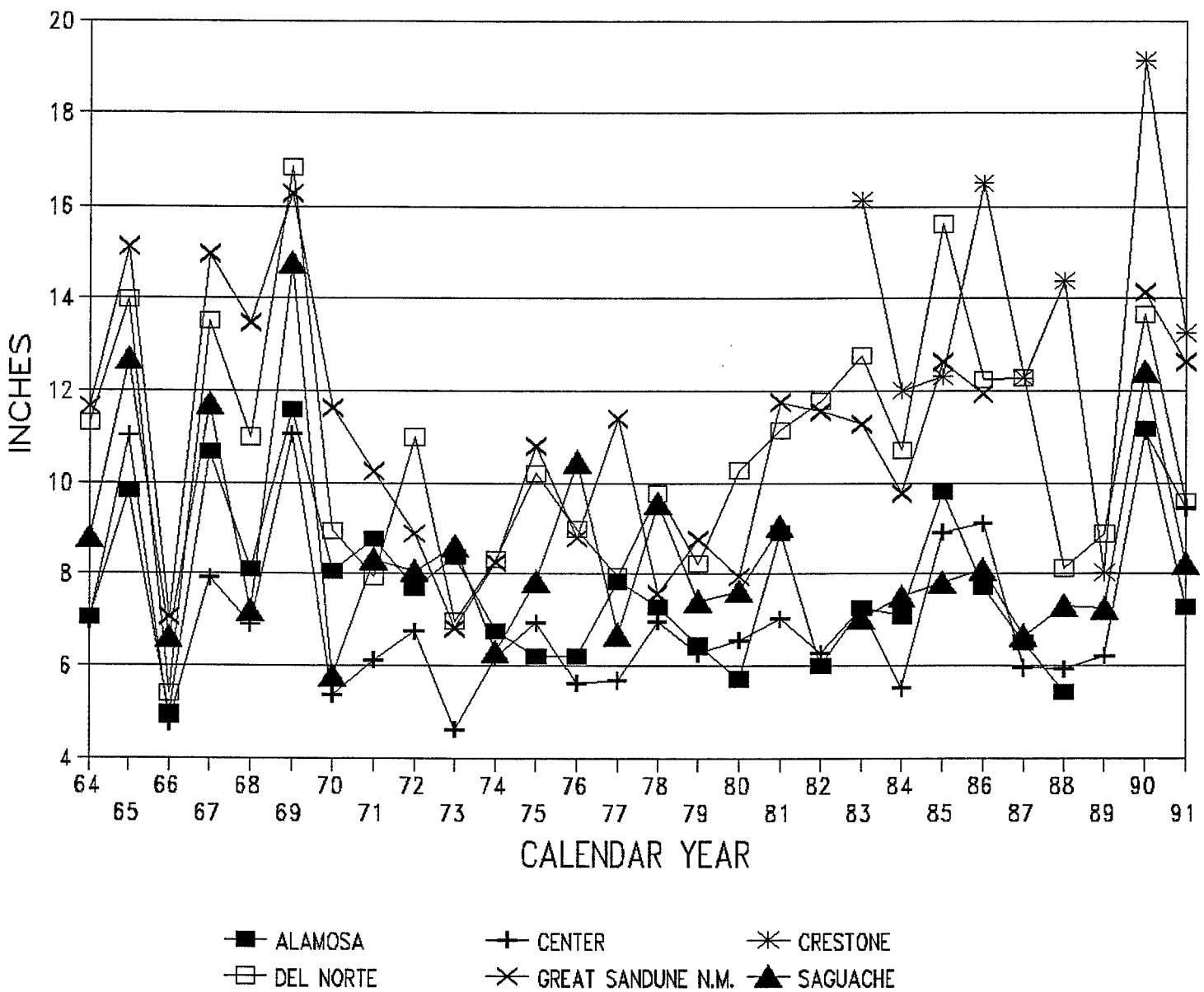


Figure 8. Total annual precipitation for Center, Colorado.

Figure 9. Total annual precipitation for six stations in the San Luis Valley.



particularly obvious in the years 1980 to 1991.

Total annual precipitation for Wolf Creek Pass in the San Juan Mountains southwest of the study area is shown in Figure 10. Annual precipitation totals range from approximately 32 to nearly 70 inches. The highest total was recorded in calendar year 1970 which was a low precipitation year in the Valley (see Figure 7).

Two interesting patterns are apparent in these precipitation data. One is the remarkable constancy of annual precipitation in the Valley during the 1970's compared with the 1960's or 1980's. It should be noted that precipitation above the base amounts received during the 1970's resulted in increased summer water, some of which was available for summer plant growth.

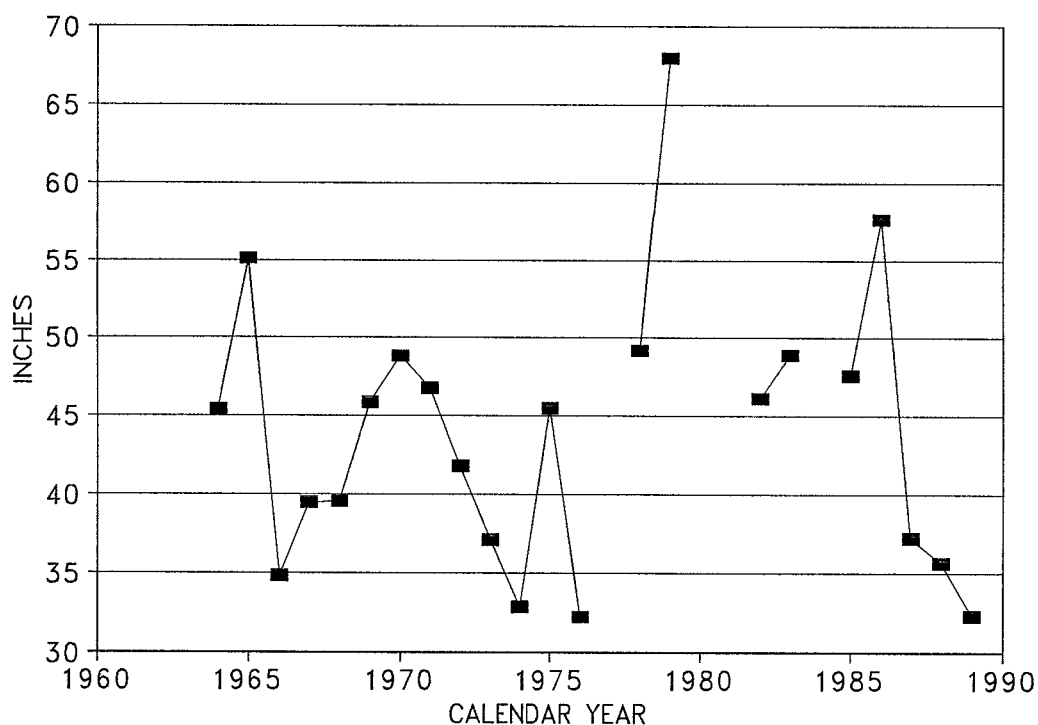


Figure 10. Total annual precipitation for Wolf Creek Pass.

A second apparent pattern is that while the precipitation peak in the San Luis Valley occurred during 1985 and 1986 the peak in stream hydrographs occurred during 1987. Thus, the water

table rise in the mid 1970's due to Valley precipitation allowed more stream flows to remain as surface waters and not to recharge groundwater aquifers.

HYDROLOGY

HYDROLOGY: STREAM DISCHARGE IN THE NORTHERN SAN LUIS VALLEY

Total discharge recorded at the U.S.G.S. stream gauge on Saguache Creek for the water years (October through September and named for the year that the runoff will be produced) 1978 through 1990 is shown in Figure 11. Total discharge varies tremendously, from a low of nearly 20,000 acre feet in 1981 to over 80,000 acre feet in 1987. Annual discharge for the years 1983 through 1987 is nearly double that of many other years shown. Precipitation in the San Luis Valley floor stations shown in Figure 7 peaked in 1985 and 1986 and is slightly out of phase with the discharge maximum for Saguache Creek which peaked in 1984 and 1987.

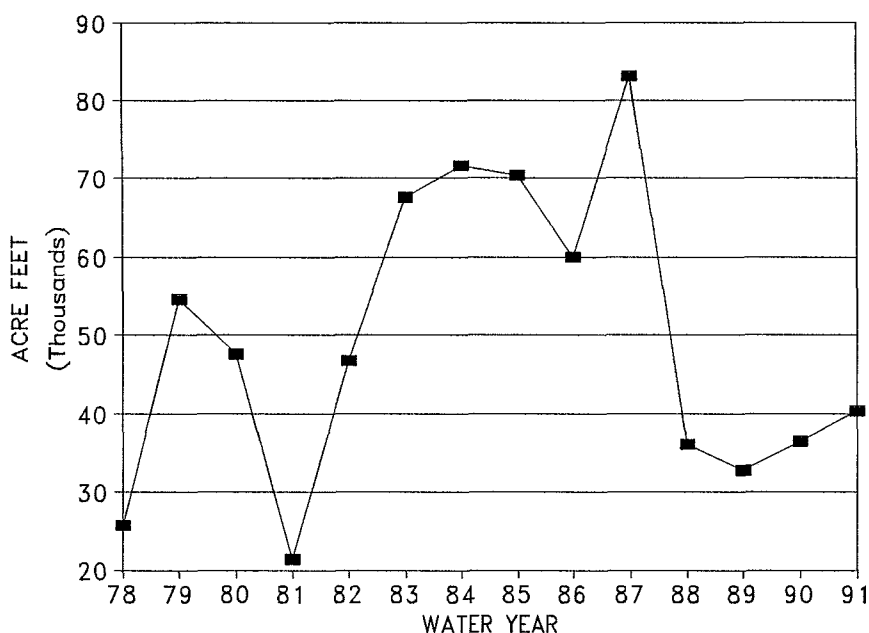


Figure 11. Total annual stream discharge for Saguache Creek, 1978-1990.

Total annual discharge for North Crestone and La Garita Creeks shown in Figure 12 were broadly in phase for the years 1978 through 1990. Discharge highs and lows were the same as described for Saguache Creek. There were big differences in discharge variation recorded for La Garita Creek, ranging from 4,000 acre feet in 1978 and 1981 to over 20,000 acre feet recorded in 1987. Differences between years of over 300%

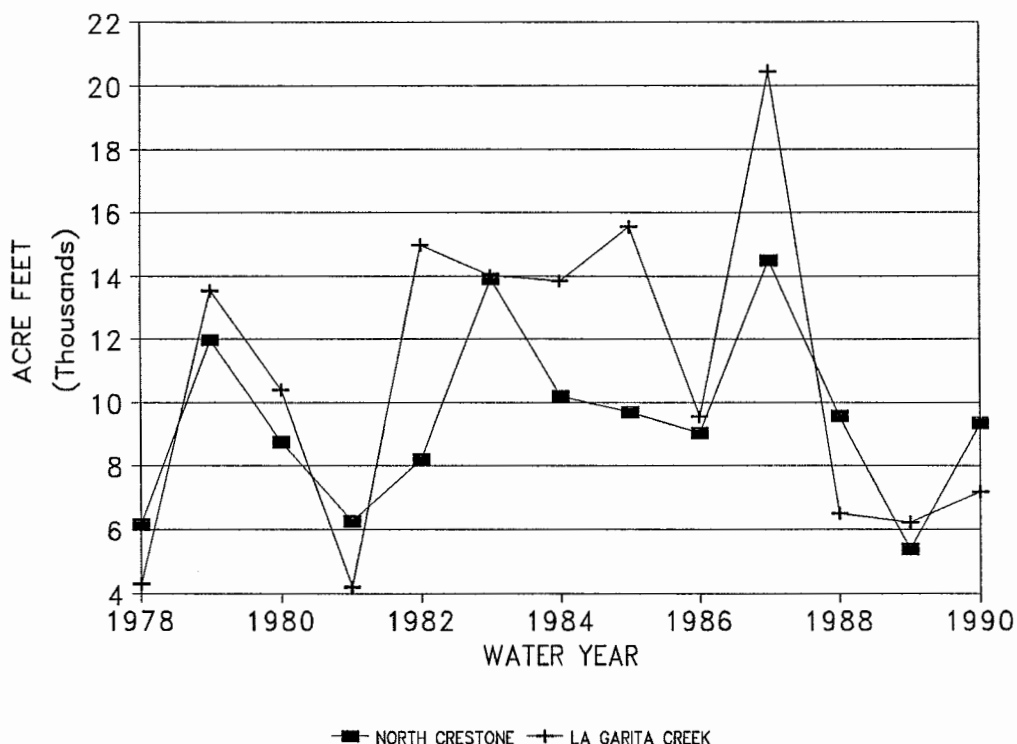


Figure 12. Total annual stream discharge for North Crestone and La Garita Creeks, 1978-1990.

occurred in 1981 to 1982 and 1987 to 1988. Between year differences in discharge for North Crestone Creek were similar to those of Saguache Creek.

HYDROLOGY: HYDROLOGIC REGIMES OF THE FOUR STUDY AREAS

Staff gauges and ground water observation wells installed along transects allowed us to study seasonal changes in the depth to the water table at individual monitoring wells and also allowed us to construct ground water table elevation profiles along our transects. The following sections describe the results of this study.

San Luis Lakes - Medano Ranch Area

The hydrologic regime of the San Luis Lakes - Medano Ranch area is influenced by four main factors:

- 1) The local and regional water table is high (within 10-15 feet of the ground surface) throughout this region.

2) Little Spring, Big Spring and Sand (Arena) Creeks enter the area from the east and northeast bringing very fresh surface water into the area, particularly in the early summer.

3) Much of the study area lies within Phase I of the Closed Basin Project.

4) Portions of the study area on the Medano Ranch are influenced by stream diversion for the purpose of irrigating meadows.

Overall Ground Water Patterns

Figure 13 shows the water table elevation for wells SL14, 35, 44, 50, 51 and 65. It provides an overall perspective on seasonal water table changes during 1991 for this study area. The water elevations are considerably higher in the eastern portion of the region, particularly at well 50 east of the Medano Ranch house and well 65 near Big Spring Creek northwest of the ranch house. Ground water elevations are lower in the southern part of this area at well 51 which is located within 1/4 mile of a Closed Basin pumping well. Ground surface elevation for station 50 is 7,547.58 feet while that of station 51 is 7,540.83 feet, a difference of approximately 7 feet. However, the water table difference for any date ranges from 11 to 14 feet. The water elevation at well 44 located at Twin Lakes is more than 20 feet lower than that at stations 65 and 50. This elevation difference is due to an overall ground surface drop between the Medano Ranch and the San Luis Lake area. The Twin Lakes area is approximately 7,529 feet elevation while the Medano Ranch is at approximately 7,549 feet. The three wells mentioned above have relatively stable water tables, with a general decline of 2 to 3 feet from spring to fall. Wells 65 and 50 both show water table elevation increases in late July, presumably due to large rainstorms at that time.

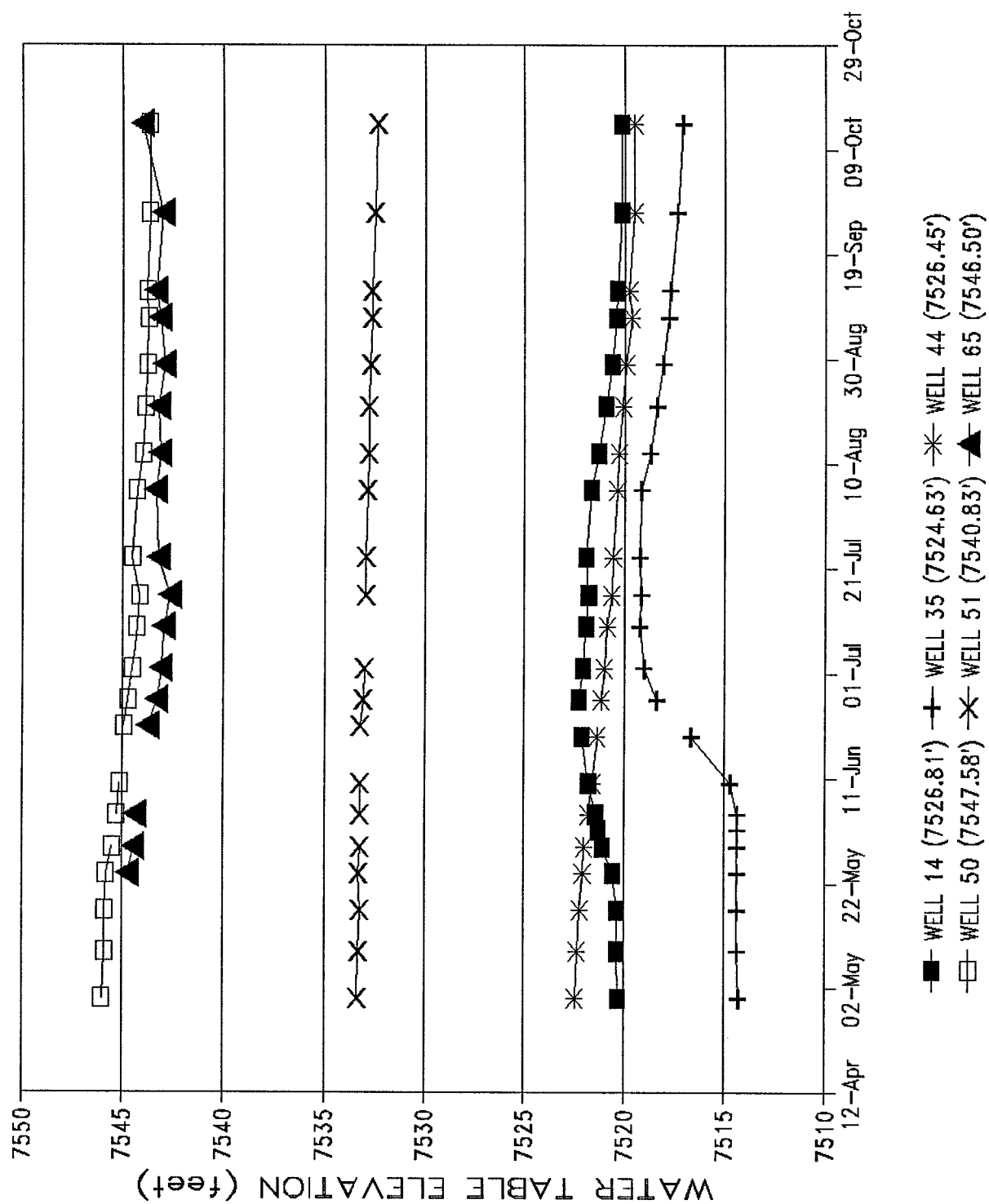


Figure 13. Hydrographs for stations SL-14, 35, 44, 50, 51, and 65 during 1991.

Wells 35 and 14 are located in uplands adjacent to Big Spring Creek in the area between Head and San Luis Lakes. Well 14 shows a water level increase beginning in late May when Big Spring Creek began to bring surface water into this area. Well 35 begins a sudden and large rise in early June when the flow of Big Spring Creek reaches that area which is farther south than well 14. It records a water table rise of nearly 5 feet at that time. Thus, while the entire area has a permanent high water table, certain portions of the area have a water table high in the late winter (wells 44, 50 and 51), others in early summer when Big Spring Creek causes a rise in the water table (wells 35 and 14).

Hydrographs for wells 63 through 65 located near Big Spring Creek northwest of the Medano Ranch house are shown in Figure 14. The elevation of Big Spring Creek at a bridge where it crosses the ranch road is also shown. The creek flowed continuously from mid-June through mid-September. It should be recognized that wells 63 and 66 are located close to Big Spring Creek while wells 64 and 65 are located away from the Creek channel. Ground water levels for wells 65 and 64 were highest in May before the creek carried surface flows. A short period of surface flooding occurred in late June and all wells were high during the period from early July through mid September when the creek was flowing.

Twin Lakes Area Water tables in the Twin Lakes area are shown in Figures 15 and 16. Figure 15 shows hydrographs for wells 39, 44, 45, 48 and staff gauge 67 located in south Twin Lake. All stations show a steady water table decline during the entire period of measurement. A water table rise was measured for certain stations in late July in response to rainfall events. The Lake went dry in late August as is recorded on staff gauge (SG) 67. Surface and ground water levels declined at the same rate although surface water elevations were usually approximately 1 foot above ground water elevations.

Figure 14. Hydrographs for stations SL-63, 64, and 65 on the Medaon Ranch during 1991.

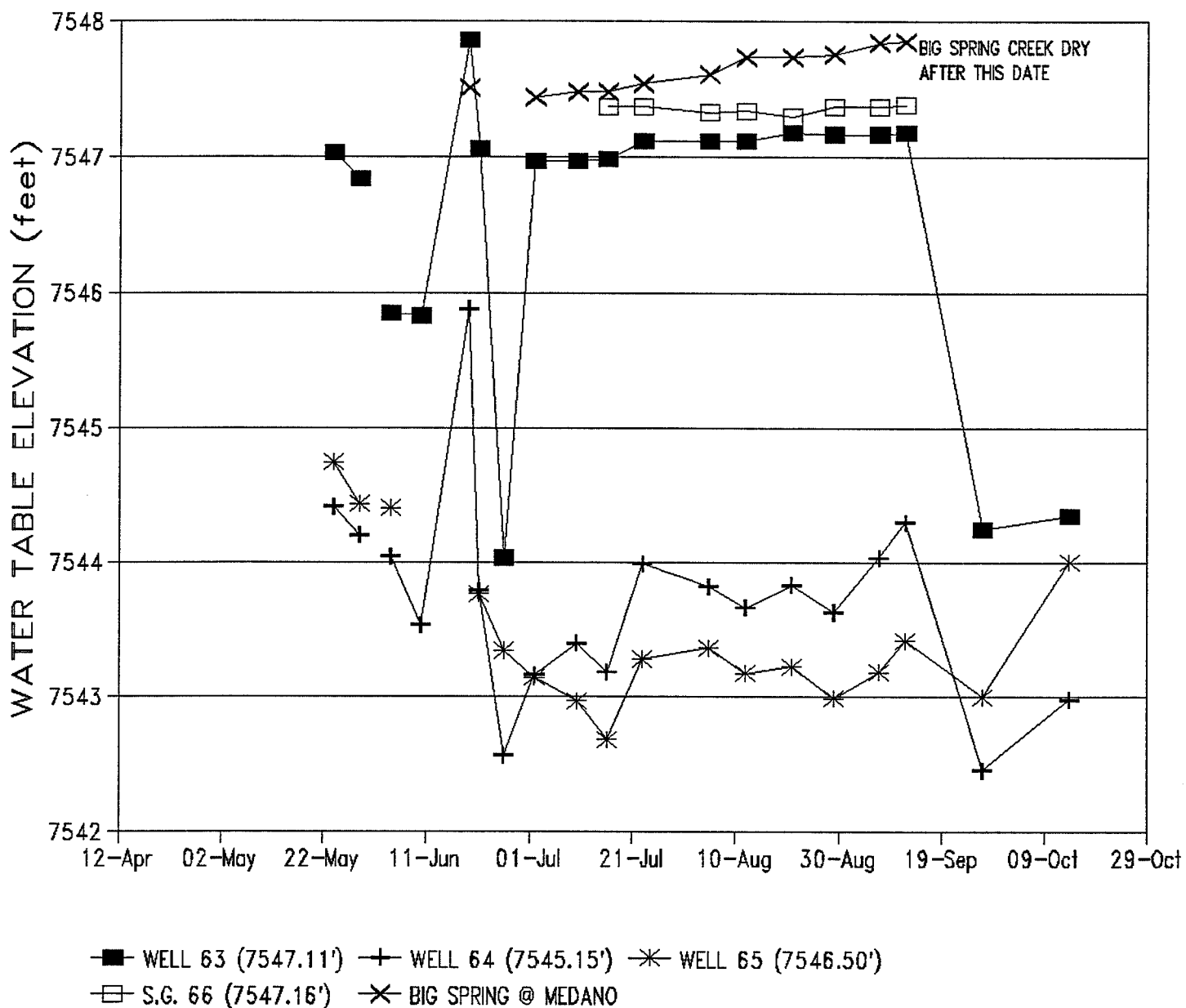
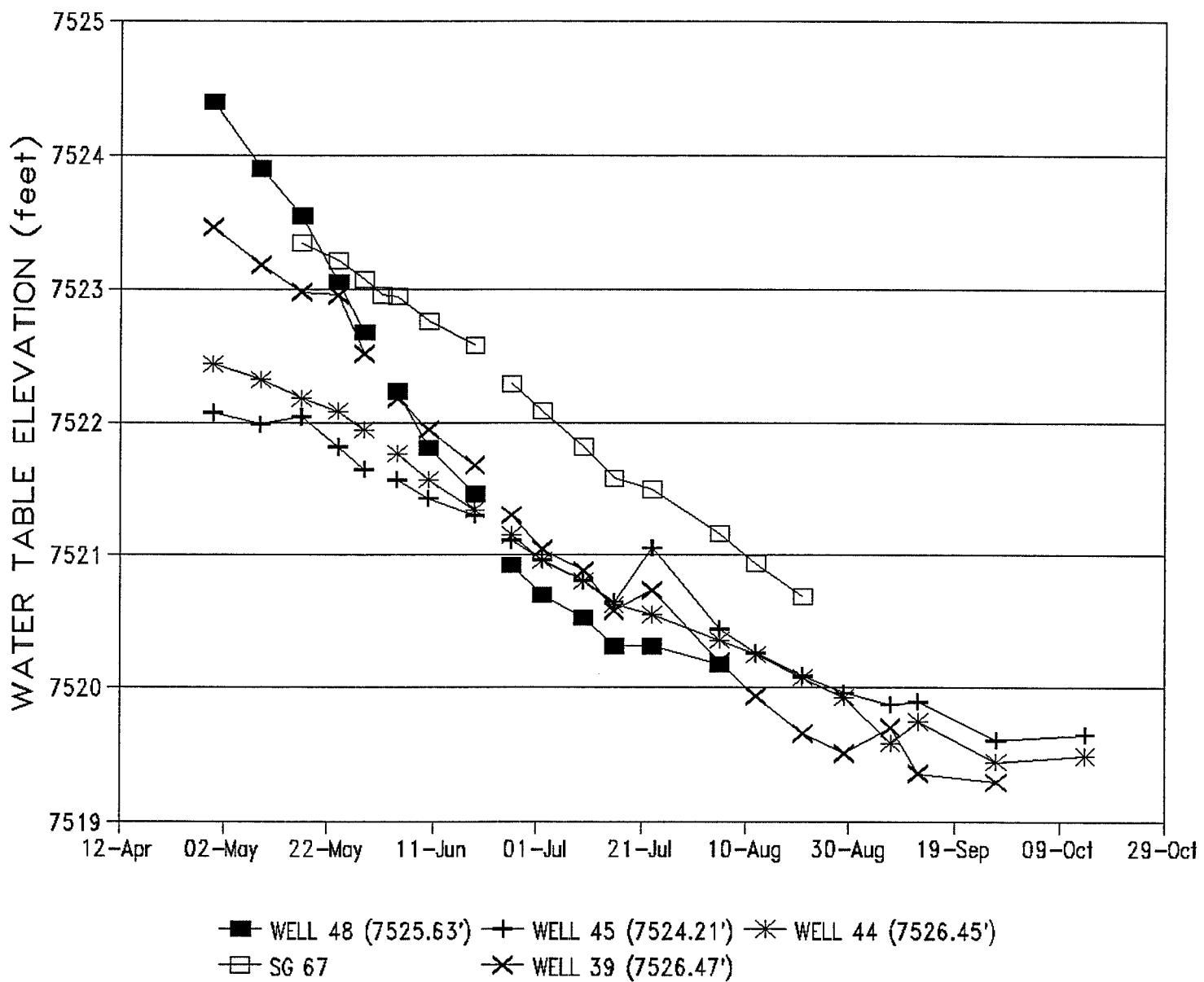


Figure 15. Hydrographs for stations SL-39, 44, 45, and 48 and staff gauge 67 at South Twin Lake on the Medano Ranch during 1991.



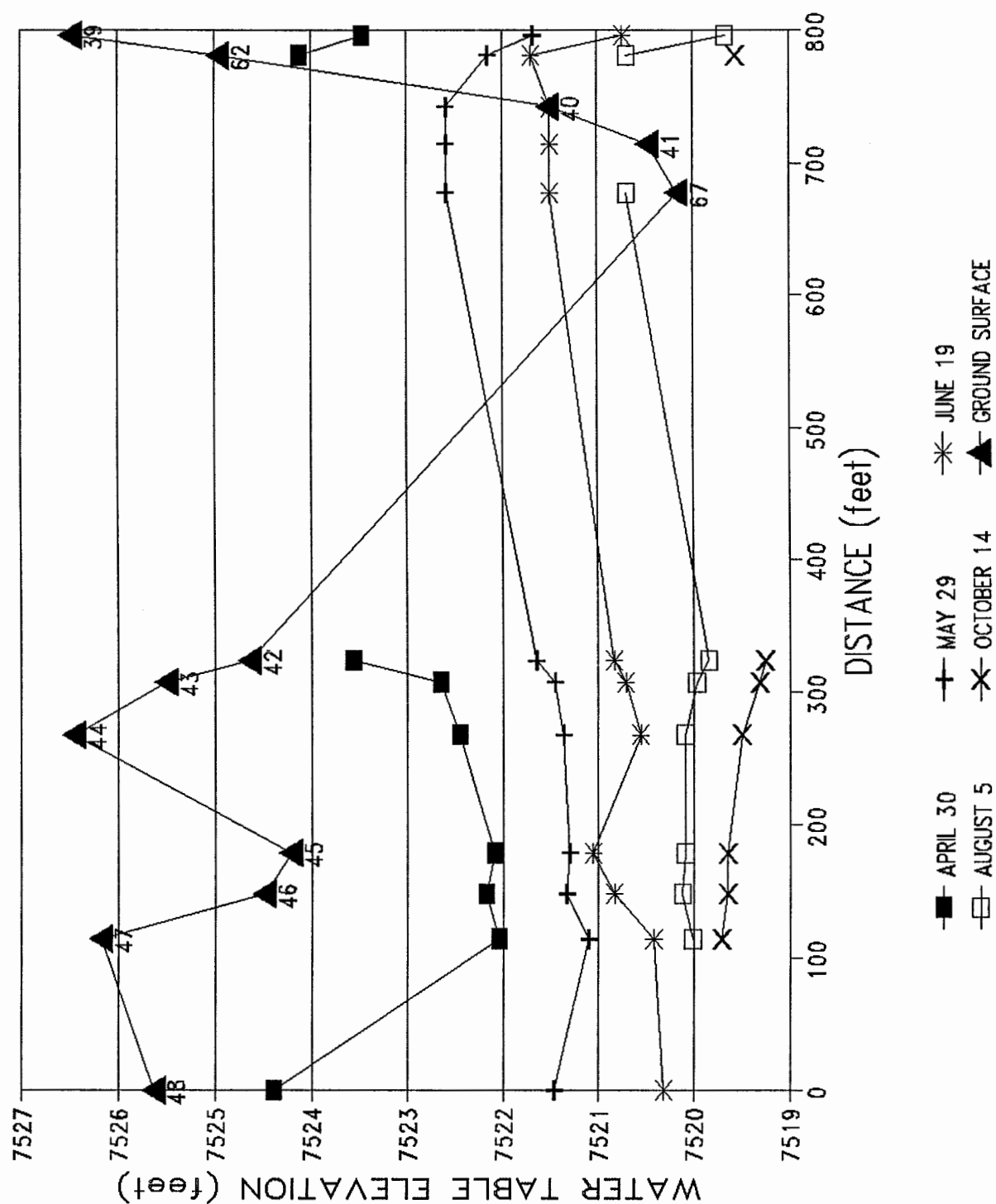


Figure 16. Water table profiles for the Twin Lakes area, Medano Ranch, during 1991.

Water table elevation profiles for the Twin Lakes area are shown in Figure 16. Ground surface is shown with the filled triangles. From right to left (south to north) across the figure well 39 is on a hill top, the lake is indicated by staff gauge 67, well 44 to the north of the lake is on a small hill, a small playa is centered at well 45 and a hill is at well 47. Ground water levels were highest on 30 April. Staff gauge station 67 was not installed on this data, but the lake level was approximately 7,524.5 feet elevation. On 30 April the profile indicates two ground water mounds; one centered on South Twin Lake which is approximately 2.5 feet above well 45, and another mound to the north of well 48 at North Twin Lake. As surface water levels lower during the summer the mounding diminishes and the water table mound at the end of May is approximately 1 foot.

South Twin Lake continued to lower through June. The position of the water table high reversed in late June when well SL-45 (a playa) had the highest water levels on the north side of the transect. Water levels in this area remained high throughout the year as water levels in other areas around the lakes continue to drop. Total water level changes range from approximately 4.5 feet for South Twin Lake and the wells surrounding it to less than 2.5 feet under the playa at well SL-45.

Surface water inflow from Little Spring Creek fill the Twin Lakes creating the ground water mounding in early summer. But as these seasonal water levels drop the regional water table becomes nearly level. Playas that receive runoff from rainfall can recharge groundwater systems, creating localized water table mounding and flow reversals.

The Slough

Our largest study area in the San Luis Lakes regions was an area we called "the slough", located along Big Spring Creek between Head and San Luis Lakes. Big Spring Creek flows from the northeast through the Medano Ranch and into Head Lake. When Head Lake fills it overflows back up Big Spring Creek which splits and flows south toward San Luis Lake through the slough. Large

wetland complexes occur in this area. We established five transects in the slough. Hydrographs for wells 1 through 4 are shown in Figure 17. Overall water table elevations were rising from late April through May, but well 2 located adjacent to the Creek records a very sharp rise of 2.5 feet in late May when the Creek began to flow. Wells such as 1 located away from the Creek did not record this rise for two or more weeks. Hydrographs for stations along transect 2 and 3 located farther south along Big Springs Creek showed similar water table rises corresponding to the surface flows. The profiles for this transect (Figure 18) are simple, showing a flat water table in April, and then a flowing creek in May and June that loses water to both streambanks. Once the creek ceases to flow the water tables drop to April level by late August. Water levels reach their lowest points in October, indicating that ground water levels are highest in spring from winter snowmelt recharge.

Water table hydrographs for wells 5, 7, 9, 10, 12, and 14 shown in Figure 19 overall patterns similar to wells along transect one. Wells closest to the creek show the first and largest water elevation rises. Also, spring water table elevations are approximately 1 foot higher in many wells than fall elevations.

Water table profiles for transect 2, wells 5 through 14 are shown in Figure 20. The April 30 profile shows the water table low to be in the sandy soils at well 11 in the Big Spring Creek channel. By the end of May the water table high was in the vicinity of the Creek channel. This water table high spread during the summer and large areas were flooded in June and July. By early August the Creek had dried up and the water table leveled off. By mid-October there had been a water table elevation reversal and the water table low was again in the vicinity of the Creek channel and the water table highs were under hills to the east and west of the channel. Thus, when the Creek the direction of ground water flow is from the channel toward the east and west, but flow direction reverses in the late

summer and fall when ground water flows from the east and west toward the channel.

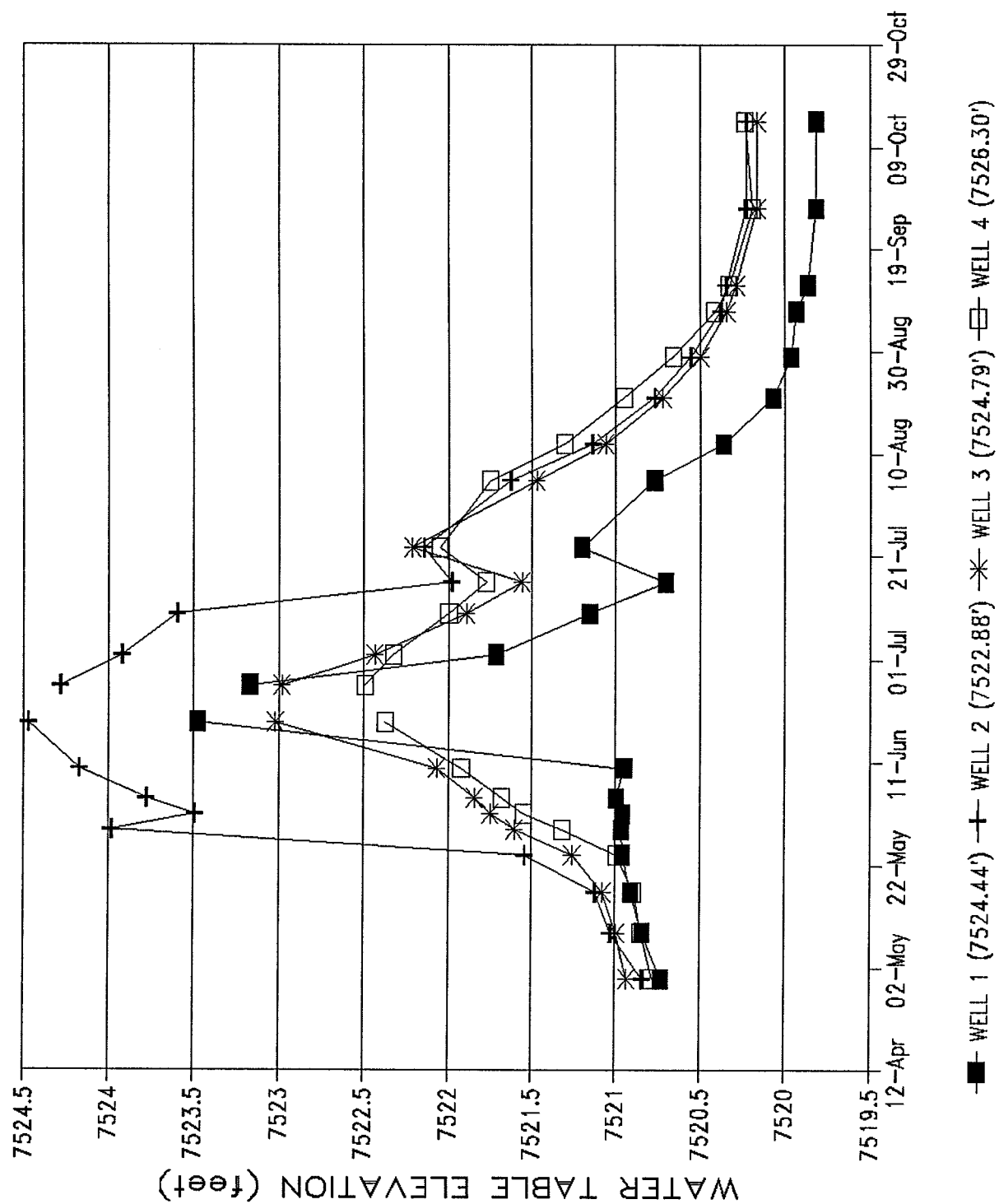


Figure 17. Hydrographs for wells SL-1 through SL-4 at "the slough", during 1991.

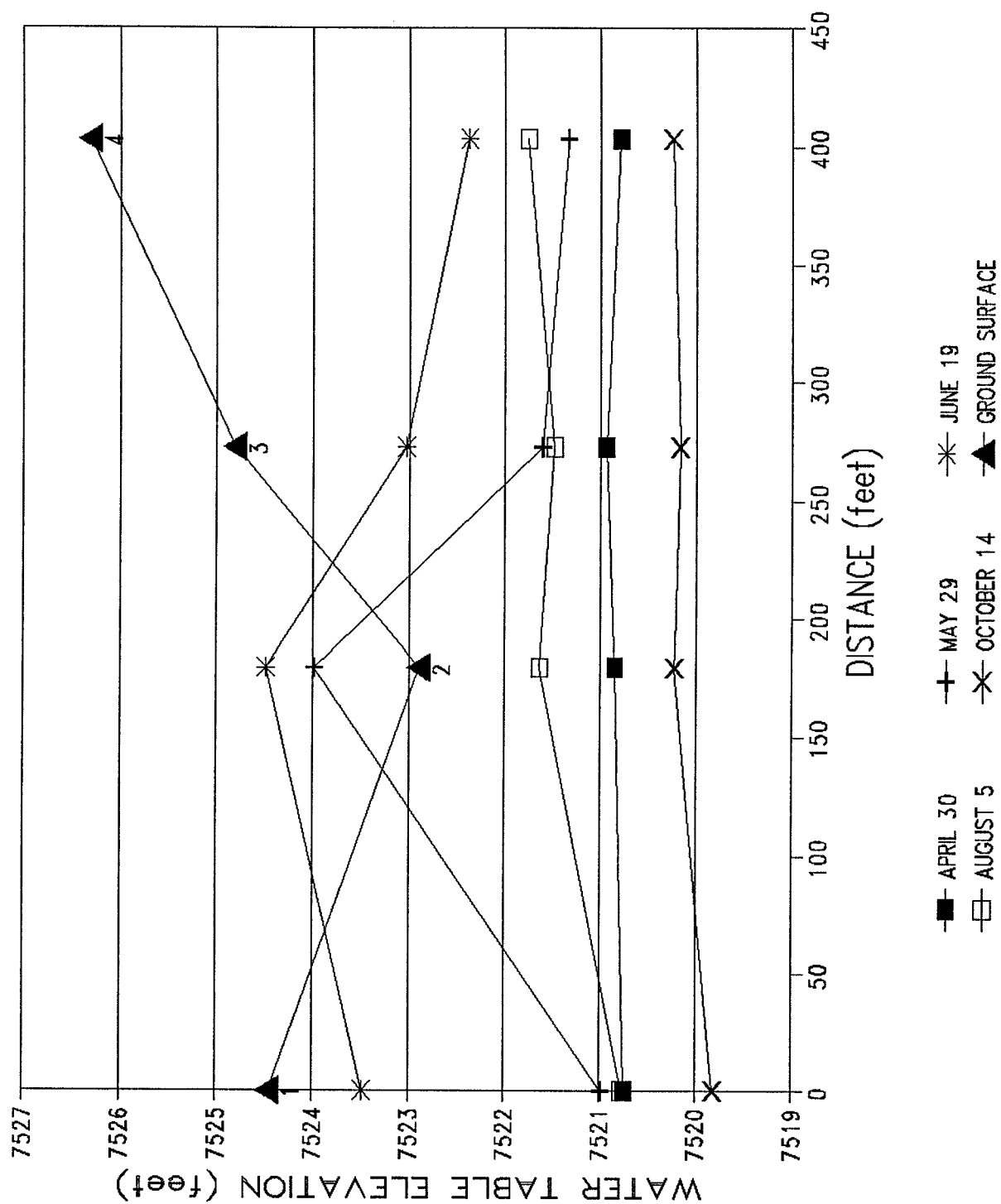
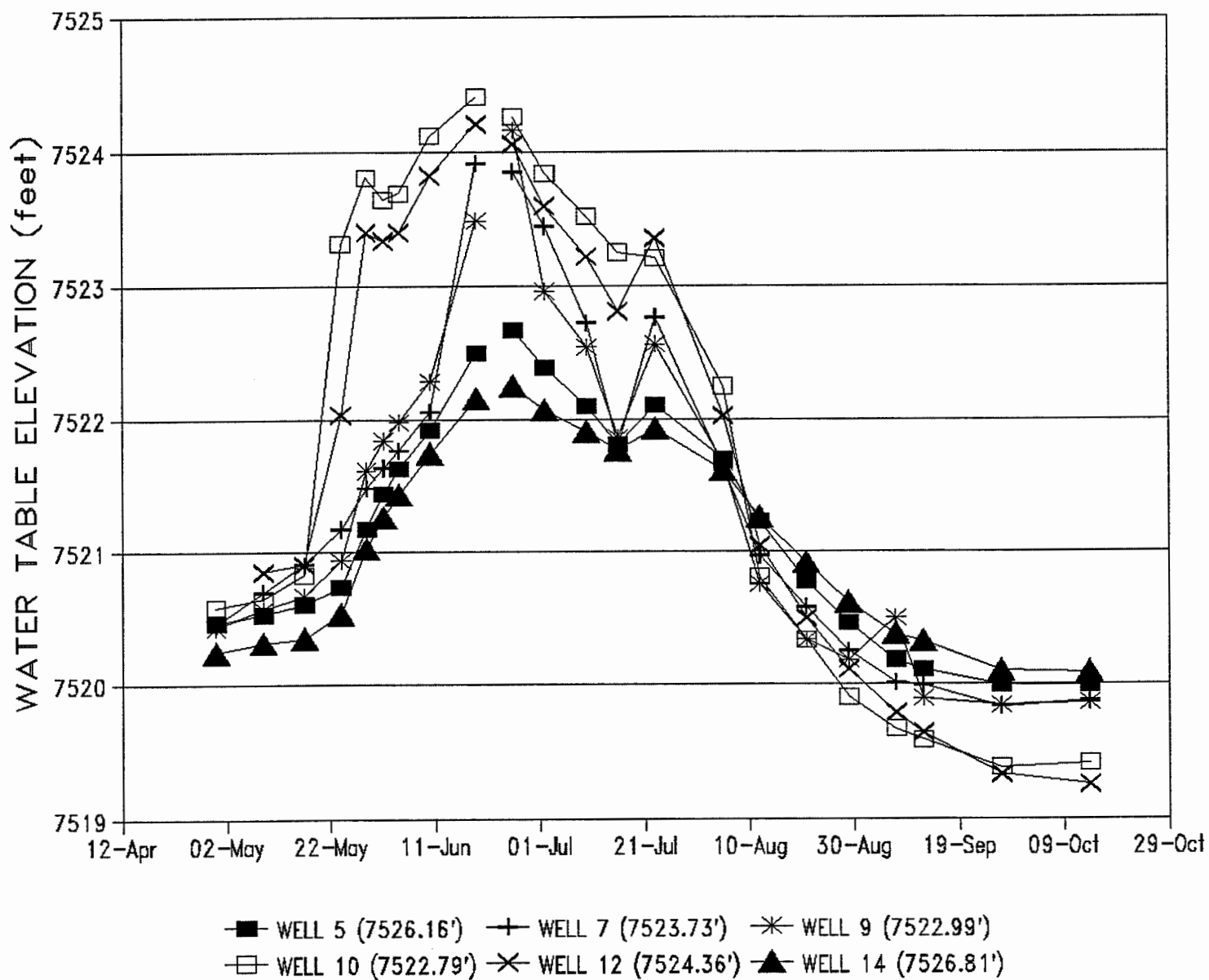


Figure 18. Water table profiles for wells SL-1 through SL-4 at "the slough", during 1991.

Figure 19. Hydrographs for wells SL-5, 7, 9, 19, 12, and 14 at "the slough", during 1991.



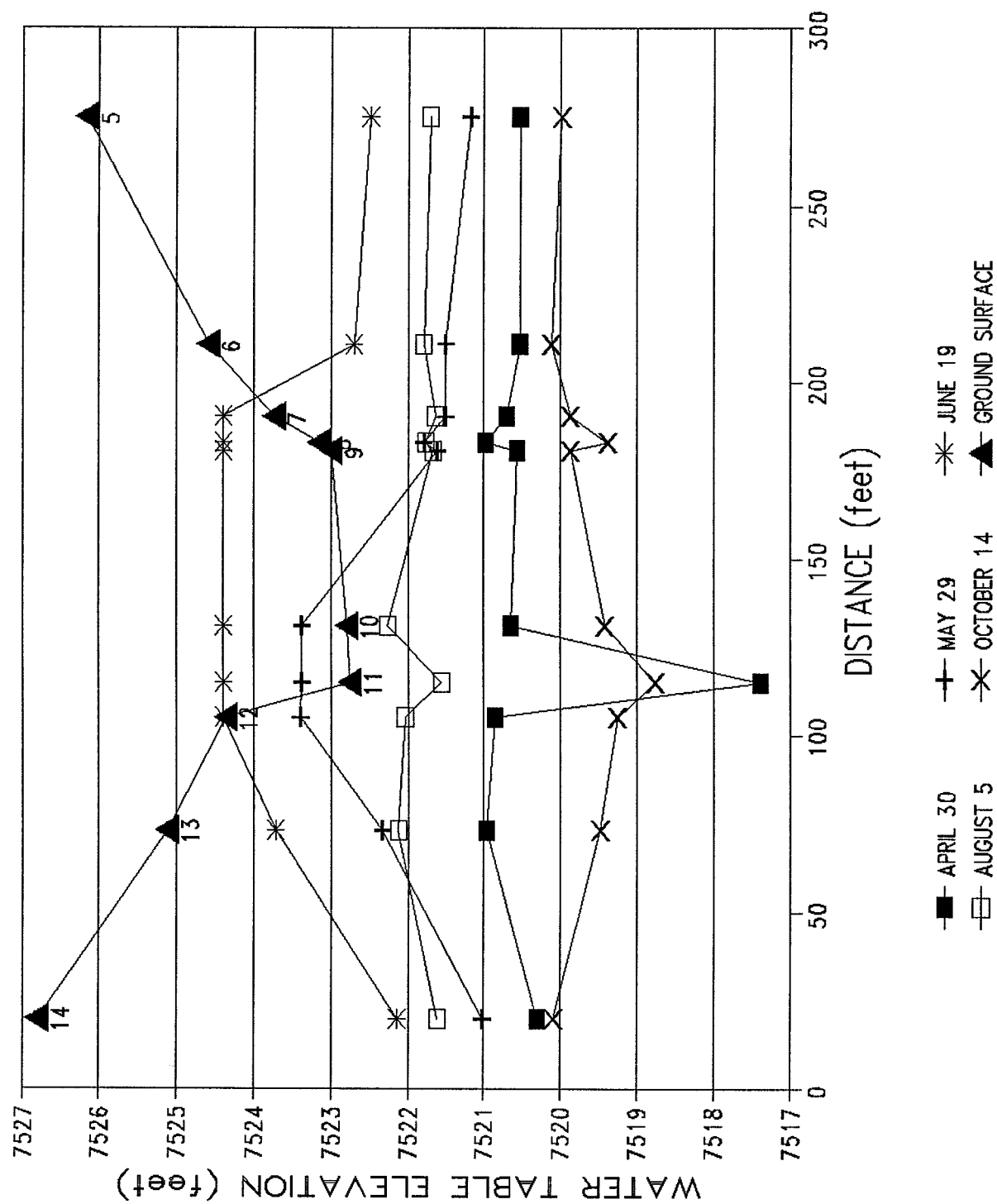


Figure 20. Water table profiles for wells SL-5 through SL-14 at "the slough", during 1991.

The reason for these reversals is due to localized ground water mounding under creeks. The mound spreads laterally causing the rise in ground water elevations under hills at some distance from the mound. When the creek dries up the ground water beneath its sandy channel rapidly drains downstream creating a groundwater concavity. It establishes a ground water gradient from hillsides toward the creek. The response of water tables to surface water flows indicates the direct connection of these water tables to surface water flows. The building of groundwater mounds by Big Spring Creek is an essential process for the saturation of soils in the slough.

The water table elevation profiles show a more complex pattern along transect 3, wells 15 through 30, which runs through the widest part of the slough (Figure 21). Widespread flooding occurred from June through August. What is striking is the similarity of ground water table elevations on 17 May and 7 September for the stations along the western side of the transect (wells 15 through 24). Also, well profiles for this transect in Figure 21 show that the lower upland boundary on the east (well 30) and west (well 15) sides of the transect are at nearly identical elevation and have identical responses to the flow of Big Spring Creek in the area.

Wells 35 through 38 occur as a transect from the center of a large playa that Big Springs Creek flows into, to a hill on the south side of the playa. The playa is part of the Big Spring Creek flow system. Ground water elevations for these four wells were similar in May and all responded to surface flows from Big Spring Creek in early June, approximately two weeks after the Creek began to flow out of Head Lake and down into the slough area (Figure 22). The playa filled by late-June and held water for the remainder of the study period. The water table at well 35 located on a hill to the south of the playa rose approximately 4.5 feet when the playa filled. Water levels here remained approximately 3 to 4 feet below the surface water elevation. Thus, water tables adjacent to the playa were not at the

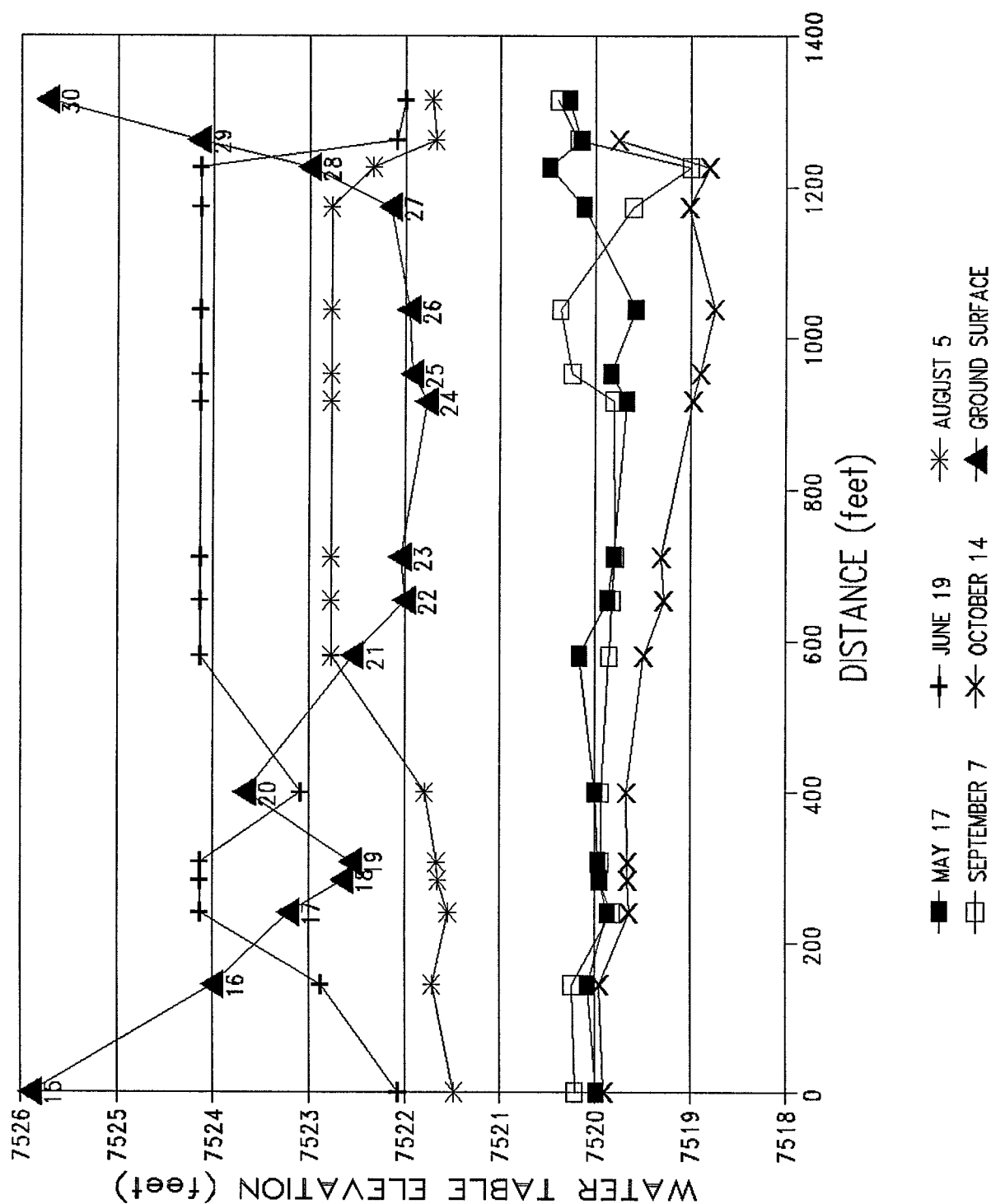


Figure 21. Water table profiles for wells SL-15 through SL-30 at "the slough", during 1991.

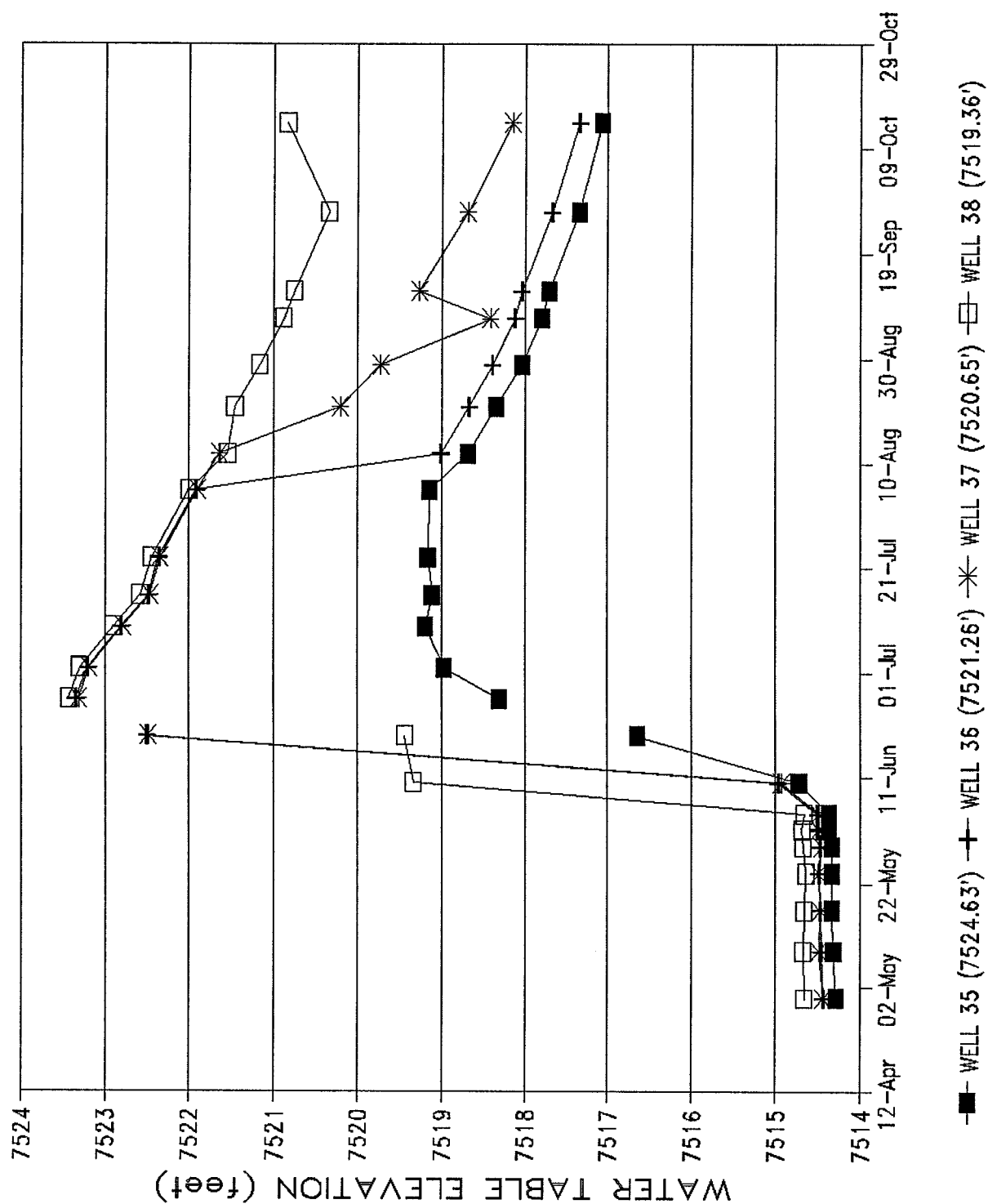


Figure 22. Hydrographs for wells SL-35 through SL-38 near San Luis Lake, during 1991.

elevation of surface water in the playa, but were controlled by the elevation of water in the playa. For example, well 36 located in a stand of hard-stem bulrush on the playa margin was flooded during June and July but when surface water retreated in early August and the well was no longer flooded water tables more than 2 feet below the ground surface were recorded.

San Luis Lakes - Medano Ranch Area Summary

The regional water table in the San Luis Lakes - Medano Ranch area is highest in the late winter and spring and has a seasonal amplitude of approximately 2 to 3 feet. Localized surface water flows provided by Sand, Big Spring and Little Spring Creeks create surface flooding and build seasonal ground water mounds that fill lakes, sloughs and create wetlands. These creeks are vital for the persistence of wetlands in this area.

Another factor to consider in this area is the effect of the Closed Basin Project on regional water tables. This effect has not been adequately addressed by the present study. However, examination of monthly water elevation records for the time period September 1974 through October 1991, for Rio Grande Water Conservation District ground water monitoring well number 42, shown in Figure 23, located on the Medano Ranch road show important patterns. The well indicates both seasonal flux and longer-term flux. A water table high occurs in the late 1970's through the mid-1980's. However, from 1989 through 1991 a drop of several feet is recorded and the water table is now approximately 2 to 3 feet below historic levels. This drop is most likely due to the pumping wells of the Closed Basin project. We are unsure if this 2 to 3 feet of water table lowering has occurred throughout the study area, but we have no reason to doubt that it has. Most wetland areas in the slough have water tables 2 to 3 feet below the soil surface in April indicating that prior to Closed Basin they may have had saturation to the soil surface prior to the arrival of Big Springs Creek water later in the season. Now, because soil saturation to the surface does not occur in spring, wetlands can only exist with the

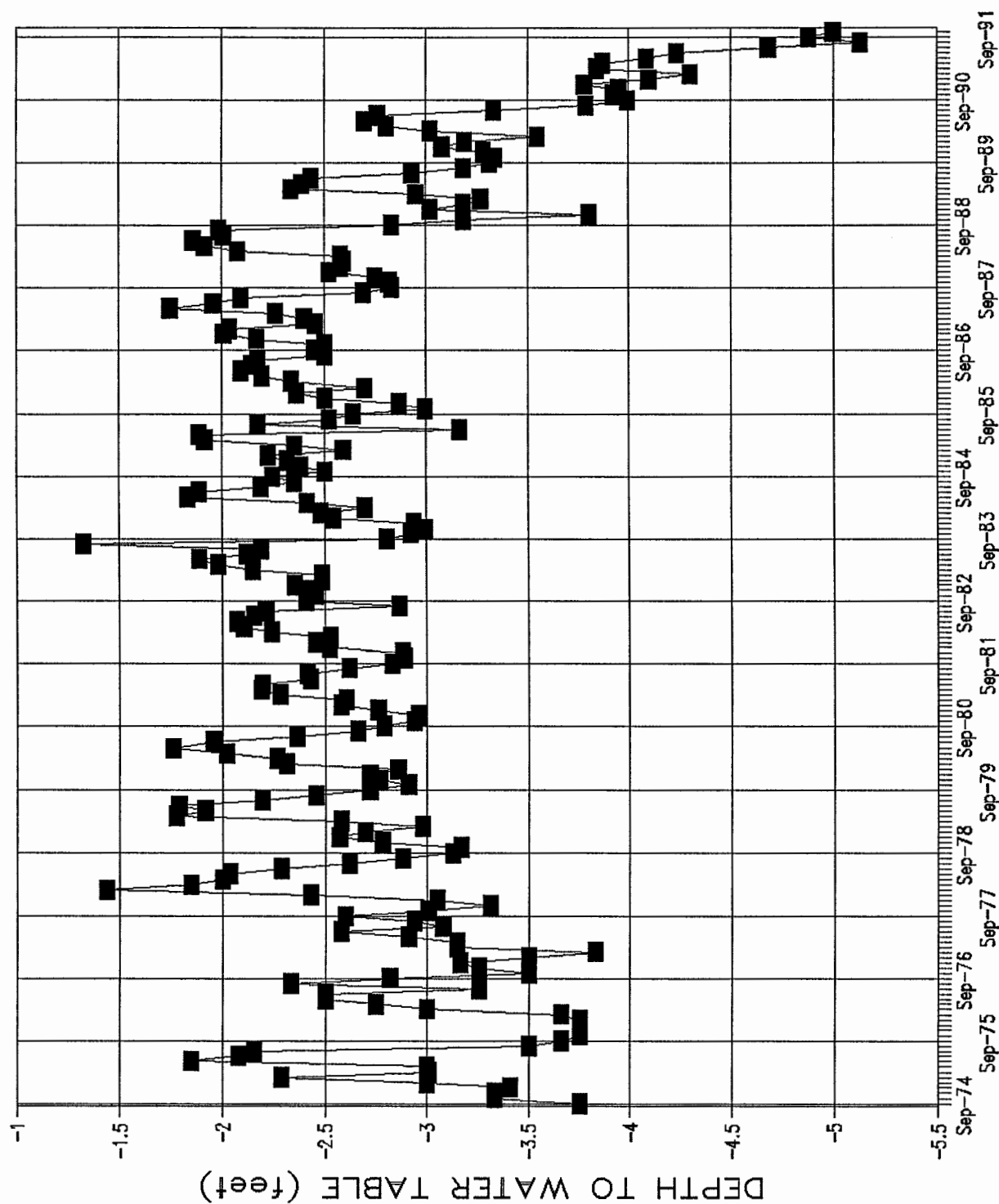


Figure 23. Hydrograph of Rio Grande Water Conservation District well 42. Monthly data for September 1974 through October 1991.

development of ground water mounds adjacent to surface water flows.

What effects Closed Basin pumping will have on the development and maintenance of ground water mounds in the vicinity of creeks and lakes is not known. During normal or above normal precipitation and runoff years the effect may be small. However, in dry years when little surface water will arrive at the slough there may not be any water for wetlands and severe drought conditions will occur.

Mishak Lakes Area Hydrology

The Mishak Lakes occur at the confluence of Russell and La Garita Creeks and Werner Arroyo. The stream that flows east from this area is called La Garita Creek. These stream systems bring water into the Mishak Lakes area and, similar to the hydrologic processes in the San Luis Lakes area, build seasonal ground water mounds on the permanent high water table. These water table mounds are expressed as playas; temporary lakes filled from April through July. During wet years these lakes could be filled for the entire summer, in dry years they might be filled for a shorter time.

Rio Grande Water Conservation District ground water monitoring well number 10, shown in Figure 24, which is located northwest of the Mishak Lakes gives a good long-term perspective of regional water tables. Monthly data collected from September 1974 through October 1991 show water table changes on two scales; decade long patterns of water table highs and lows, and annual seasonal changes. The long-term patterns show water table highs in the early 1970's and again in the mid 1980's. The low for the period of record was in 1980-1981. Seasonal water table lows occur in September and October and in the 17 year period of record are within 0.5 foot of 7574 feet elevation. Thus, relatively little overall difference occurs with regard to this water table characteristic.

However, much larger differences in the long-term patterns of seasonal water table highs. For example, the water table high in 1981 was approximately 7,574.5 feet elevation, while in 1987 it was 7,577.2, a difference of nearly three feet.

Annual water levels change of approximately 2.0 feet occur on most years, with the magnitude of change being less in a dry year such as 1981 (1.5 feet of difference) and greater in a wet year, such as 1987 (2.5 feet of difference). These patterns indicate great regional stability in the water table which each winter is within 0.5 feet of 7.574 feet elevation, yet with great differences in the summer high which usually occurs in May. A

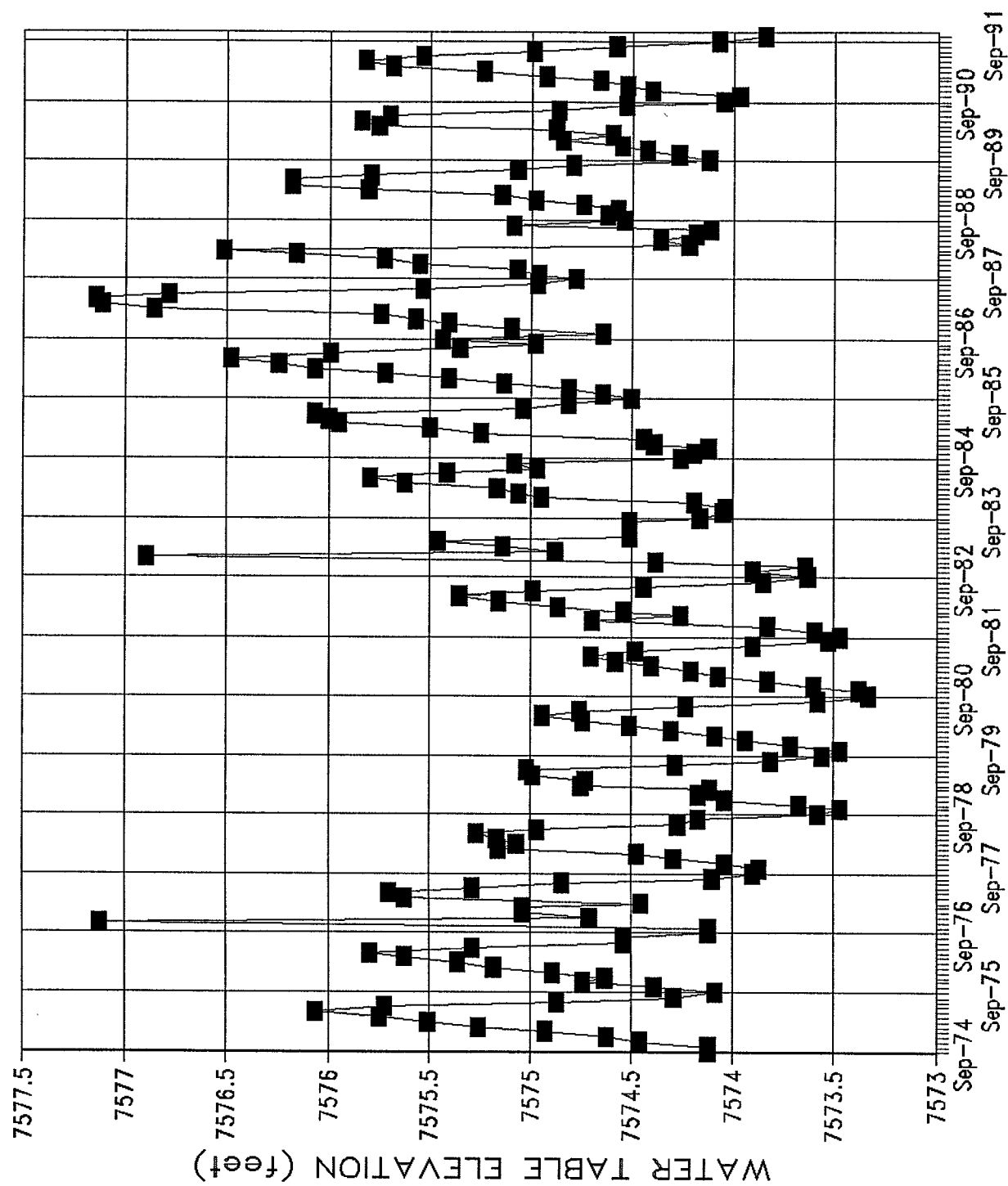


Figure 24. Hydrograph of Rio Grande Water Conservation District well 10. Monthly data for September 1974 through October 1991.

high water year may have water tables 2.5 feet above those of low water years and 1.0 to 1.5 feet above more average years. These high water years are most likely extremely important for determining the distribution of plants in wetland basins in the San Luis Valley, particularly plants, such as greasewood that are intolerant of flooding.

Only two transects were established in the Mishak Lakes area because we relied on erroneous information that the region had been dried up. We did not know that the area was vital until early June 1991. Transect one includes wells M-1 through M-9. It spans a hill with each end of the transect in different portions of the same lake. The approximate 1991 surface water high was determined from an organic drift line above the water levels seen during the summer. The water table elevation profile along this transect for several dates during 1991 is shown in Figure 25. In June the lakes are mounded above the water table which is lowest under the hill at wells 6 and 1. A water table gradient from west to east flowing from pond segment to pond segment under the hill is apparent and extends from well M-8 to M-1. The pond dried up in late August and recharge of the groundwater ceased. After that time the water table under the ponds dropped quickly and the water table was highest under the hills. Thus, a reversal in groundwater flow gradient occurred and well 6 had the highest water table elevation, as it did on 17 October.

The rate of decline in surface and ground water is very similar as can be seen from the hydrographs for wells 1 through 5 (Figure 26) and 6 through 9 (Figure 27). There is only a very slight response of the groundwater to the large rain events of around 21 July.

Wells 10 through 13 are along La Garita Creek which has a sand bed. Water table profiles for several 1991 dates along this transect are shown in Figure 28. The Creek, at well 13, is high in June, but when the creek dries up in early August, the ground water mound disappears and the water table profile becomes

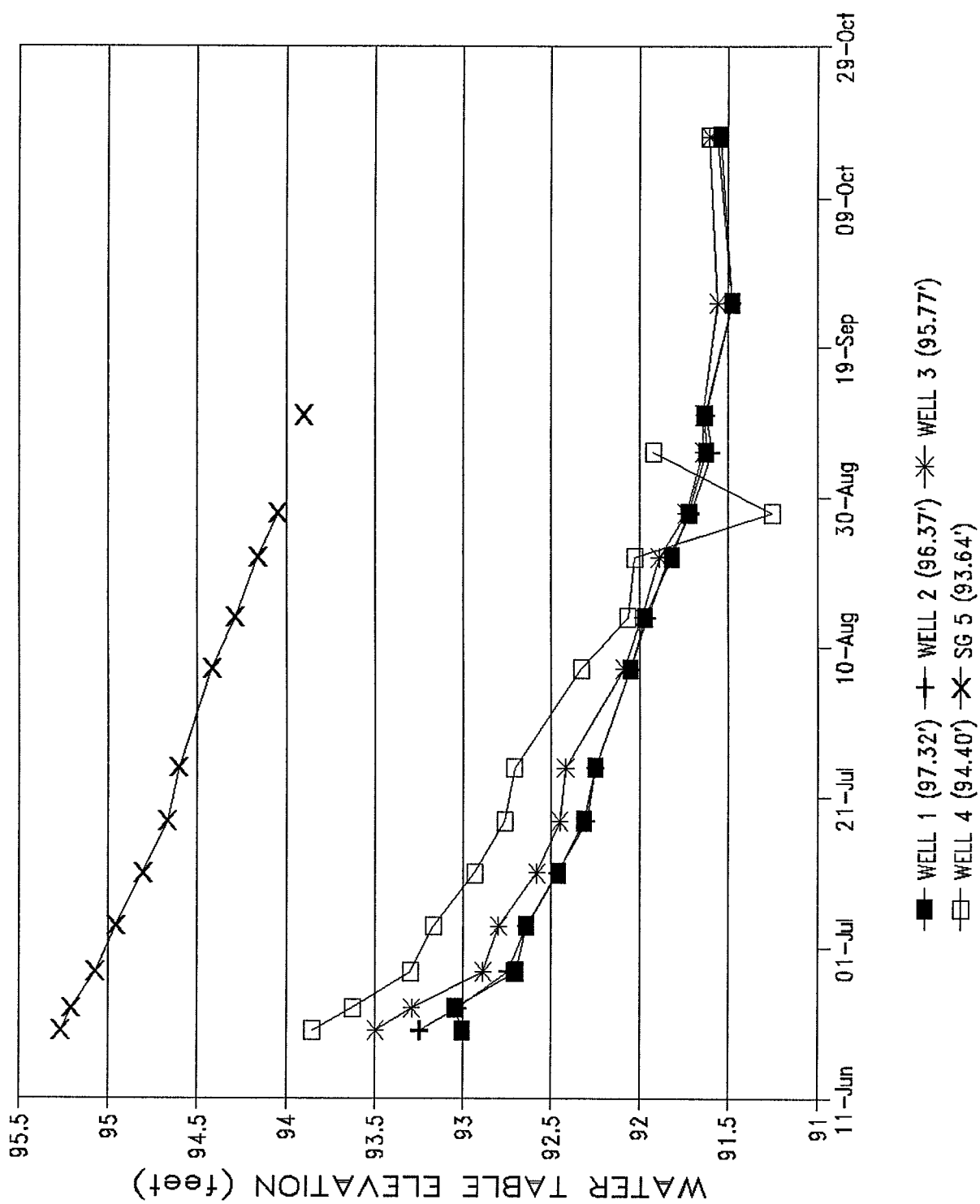


Figure 26. Hydrograph of wells M-1 through M-5 at Mishak Lakes, during 1991.

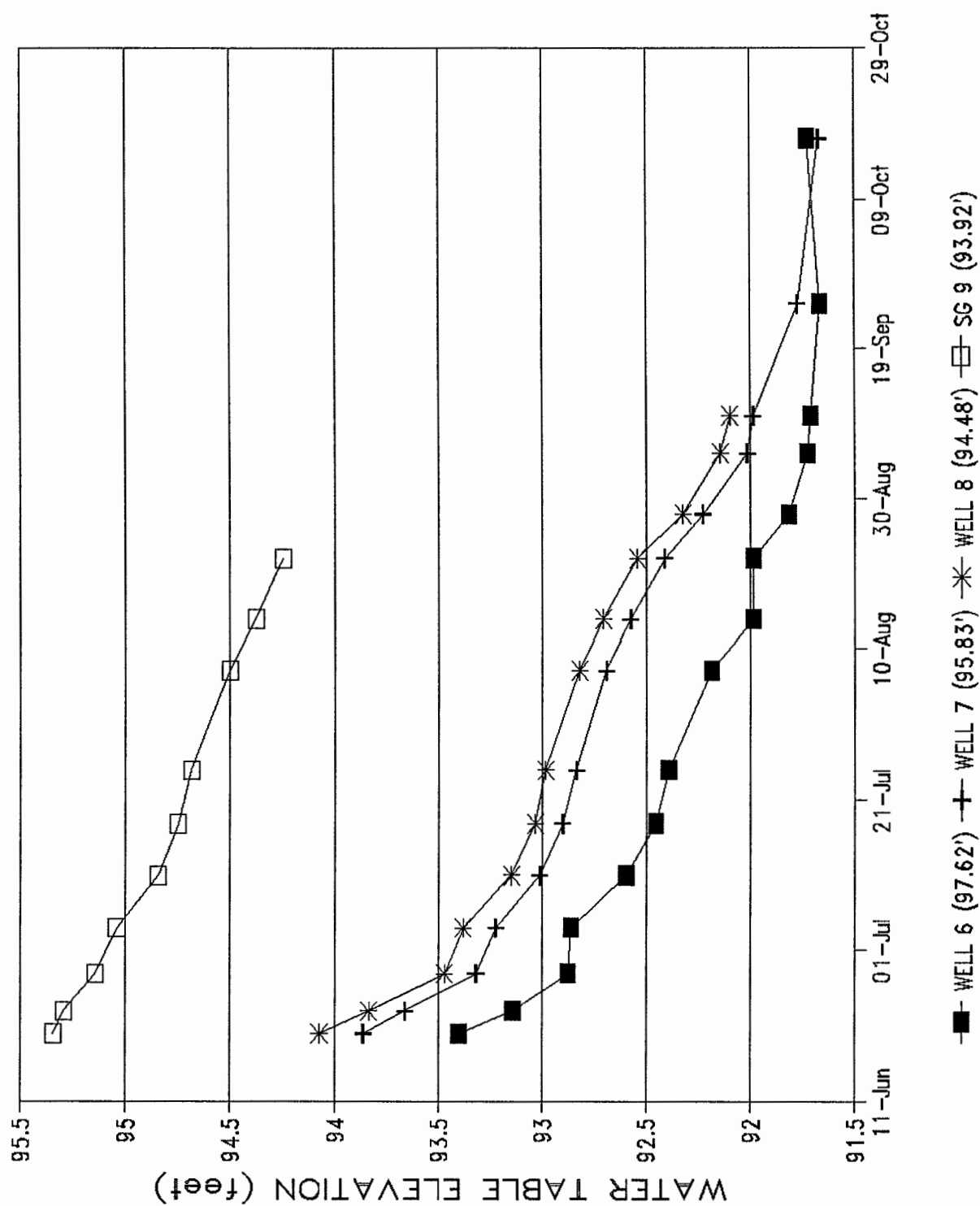


Figure 27. Hydrograph of wells M-6 through M-9 at Mishak Lakes, during 1991.

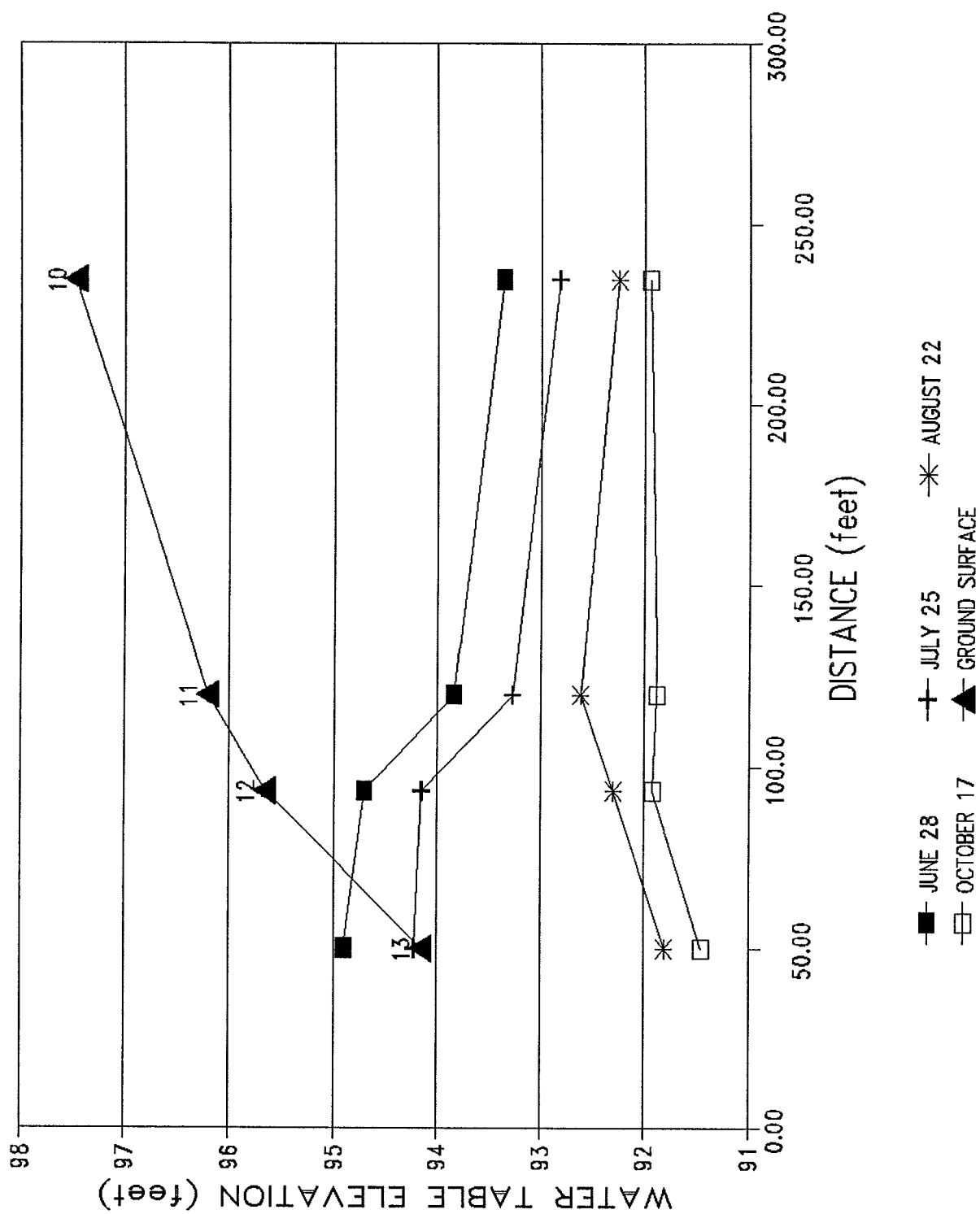


Figure 28. Water table profiles for well M-10 through M-13 at Mishak Lakes, during 1991.

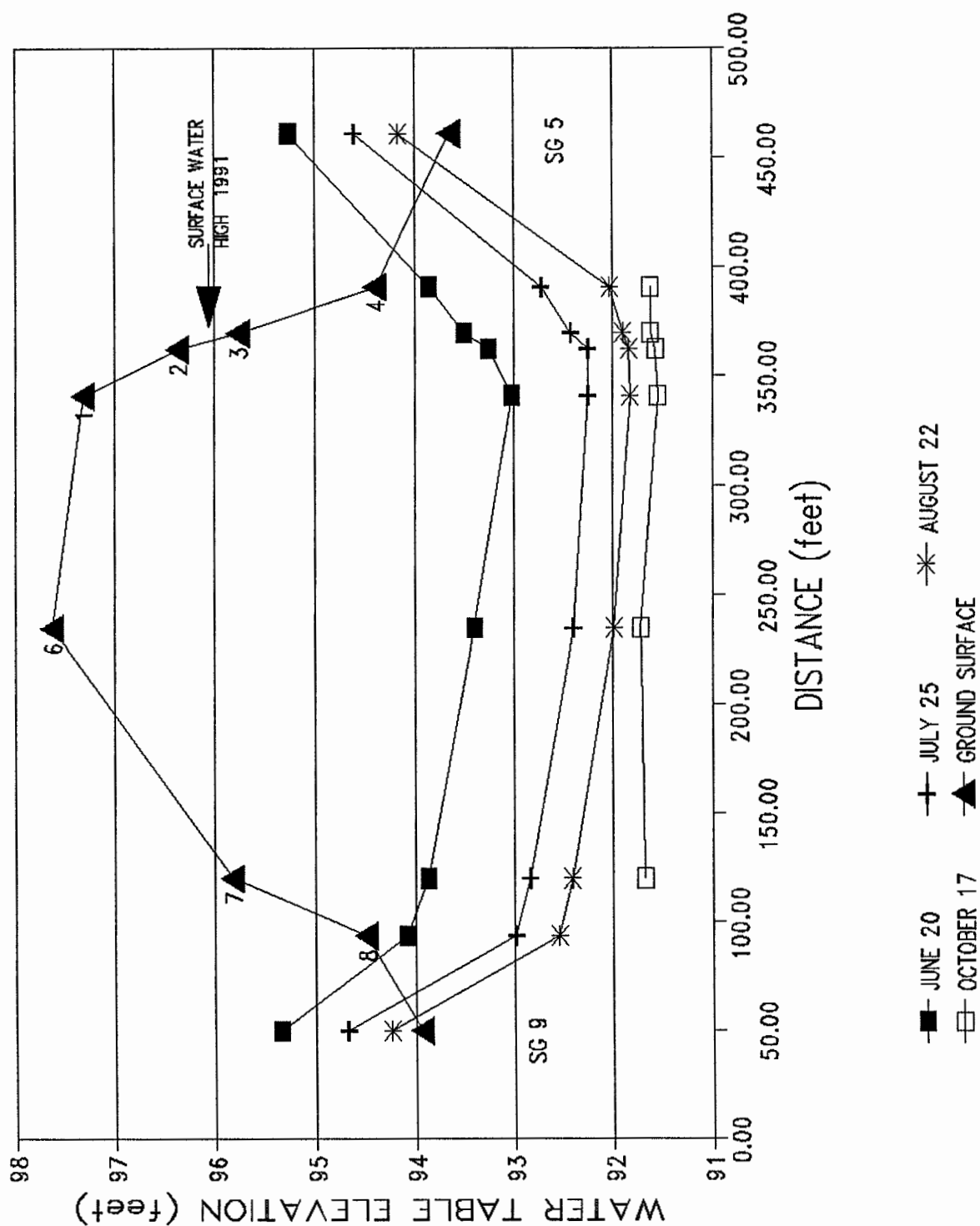


Figure 25. Water table profile for wells M-1 through M-9 at Mishak Lakes study area during 1991.

concave. The water table under wells 10 and 11 are more stable. Well 11 is receiving water from La Garita Creek in summer, yet losing water to the Creek area in late summer. Again, the local reversal of groundwater flow gradient. Hydrographs for these stations shown in Figure 29, indicate little response to summer rainstorms. The hydrographs also clearly show that areas with the highest spring water levels become the stations with the lowest late summer water levels. Also station with the lowest spring water levels become the stations with the highest autumn water levels.

Russell Lakes Area Hydrology

The Russell Lakes area is a very complex landscape with several large permanent lakes, numerous small lakes and innumerable playas. The entire region has a high water table and certain areas to the south of the lakes region are irrigated. Surface water in the lakes are augmented by artesian wells.

Figure 30 shows the water elevations for the four largest lakes in the area; Trites, Davey, Harrence and Island Lakes. Trites, Harrence and Davey are natural lakes while Island is man-made. Water levels in Trites, Davey and Island Lakes were quite stable during 1991, in general changing less than 0.5 feet in elevation. The levels in Harrence Lake however, increased during the later part of the summer and ending at a season high in late October. In general lake water levels show similar patterns until late July. Note the water level rise in late June, drop in mid July and rise again in early August. However, then patterns change somewhat. It is hard to tell how water management has affected these patterns.

Hydrographs for two stations in the irrigated lands are shown in Figure 31. Well 73 is located in sandy soils of an old stream channel which respond very quickly to the application or removal of irrigation water. The site is flooded in May and June, goes dry in July and is flooded again in early August. Well 71 is not flooded during the summer, but has a water table within three feet of the soil surface throughout the period of

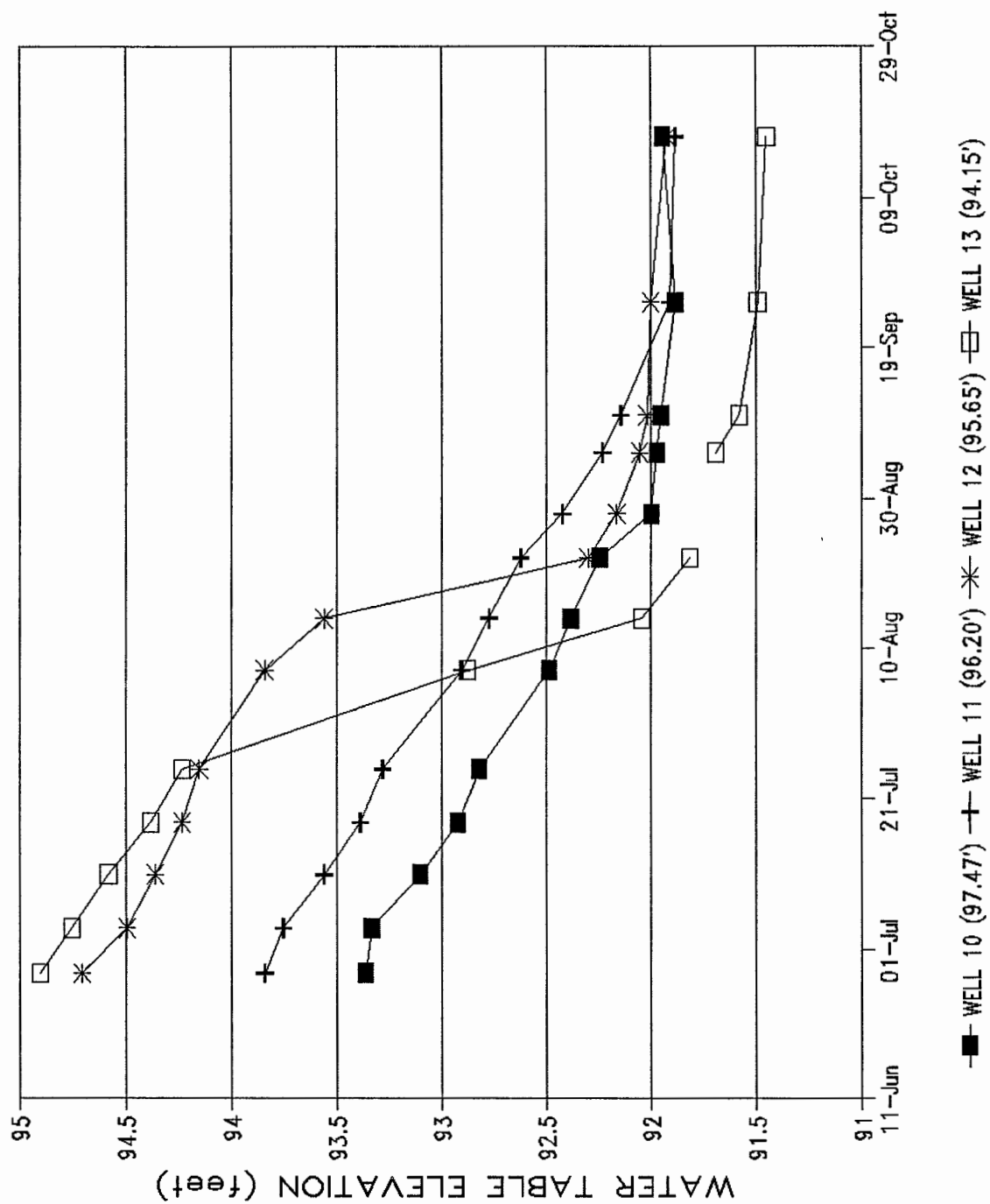


Figure Figure 29. Hydrograph of wells M-10 through M-13 at Mishak Lakes, during 1991.

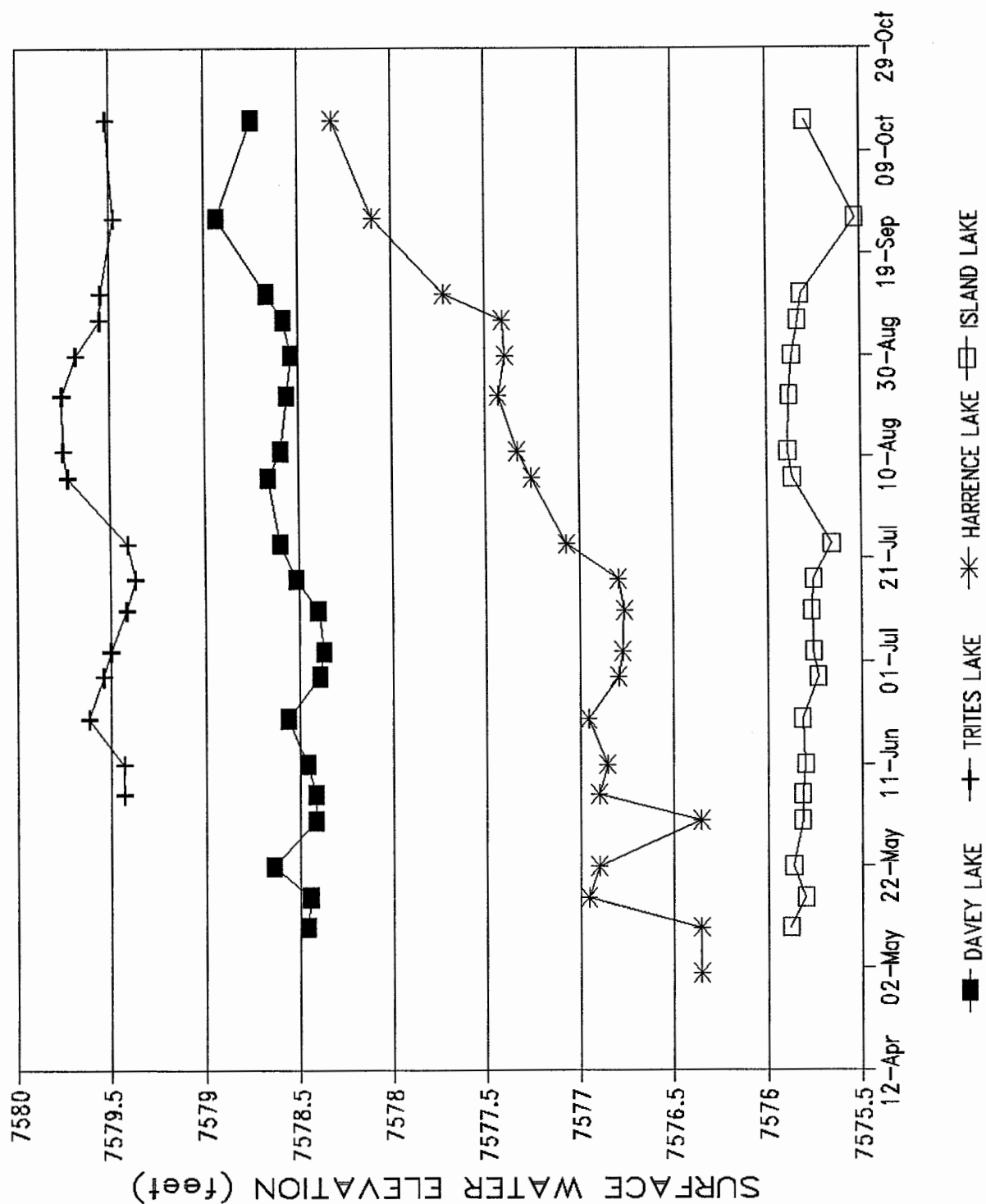


Figure 30. Surface water elevations of Trites, Davey, Harrence, and Island Laeks, Russell Lakes area, during 1991.

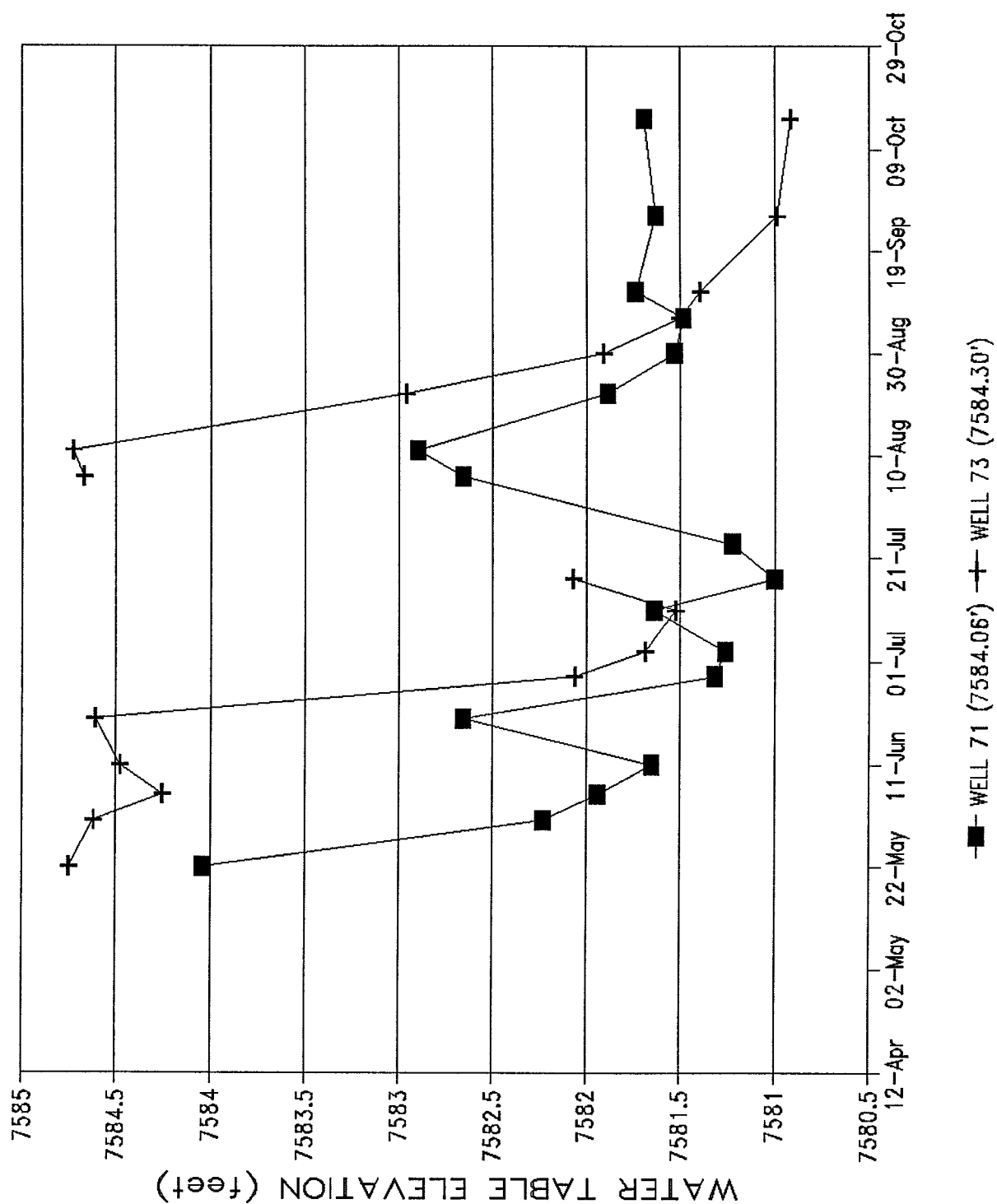


Figure 31. Hydrograph for wells RL-71 and RL-73, Russell Lakes area, during 1991. These wells occur in irrigated pasture.

record. It occurs on a loamy soil. The May-June and early-August irrigation periods caused water tables responses creating local water table highs under the irrigated pasture. It should be clear however, that because these soils respond to drainage quickly, a regional water table decline of 1 to 3 feet would make it impossible for the available volume of water to support these wetlands.

The effect of lakes on groundwater table elevations is seen in the transect from Trites Lake to Harrence Lake along wells 28 through 39 shown in Figure 32a. Station 59 is a staff gauge in Trites Lake while station 39 is a staff gauge in Harrence Lake. Groundwater elevations were highest along the western portion of the transect in June. Groundwater levels adjacent to Harrence Lake at well 38 were considerably lower than lake water elevations. These water levels dropped through the summer. When Harrence Lake began to fill in September there was recharge to the groundwater table adjacent to the lake and we measured a water table rise in stations 36, 37 and 38. As the lake water rose from September 9 through October 15 the water table as far West as well 32 was seen to rise and a large groundwater table rise at stations 36-38 was measured (Figure 32b). This indicates that the elevation of lakes can be used to manage groundwater table elevations in the Russell Lakes area, a point that wildlife management specialists could focus on.

Well hydrographs for this transect shown in Figure 33 indicate that wells 28 and 32 and even 34 are broadly in phase with water levels in Trites Lake, most easily seen during July through October. Groundwater elevations at these wells rise in late July and decline in late August and September even though Harrence Lake is rising. Thus, the upgradient Trites Lake could be managed to influence the groundwater levels on the western end of the transect while Harrence Lake could be managed to influence the groundwater levels just west of the Lake.

Wells 9 through 17 are installed in a string across a tributary of Russell Creek and profiles are shown in Figure 34.

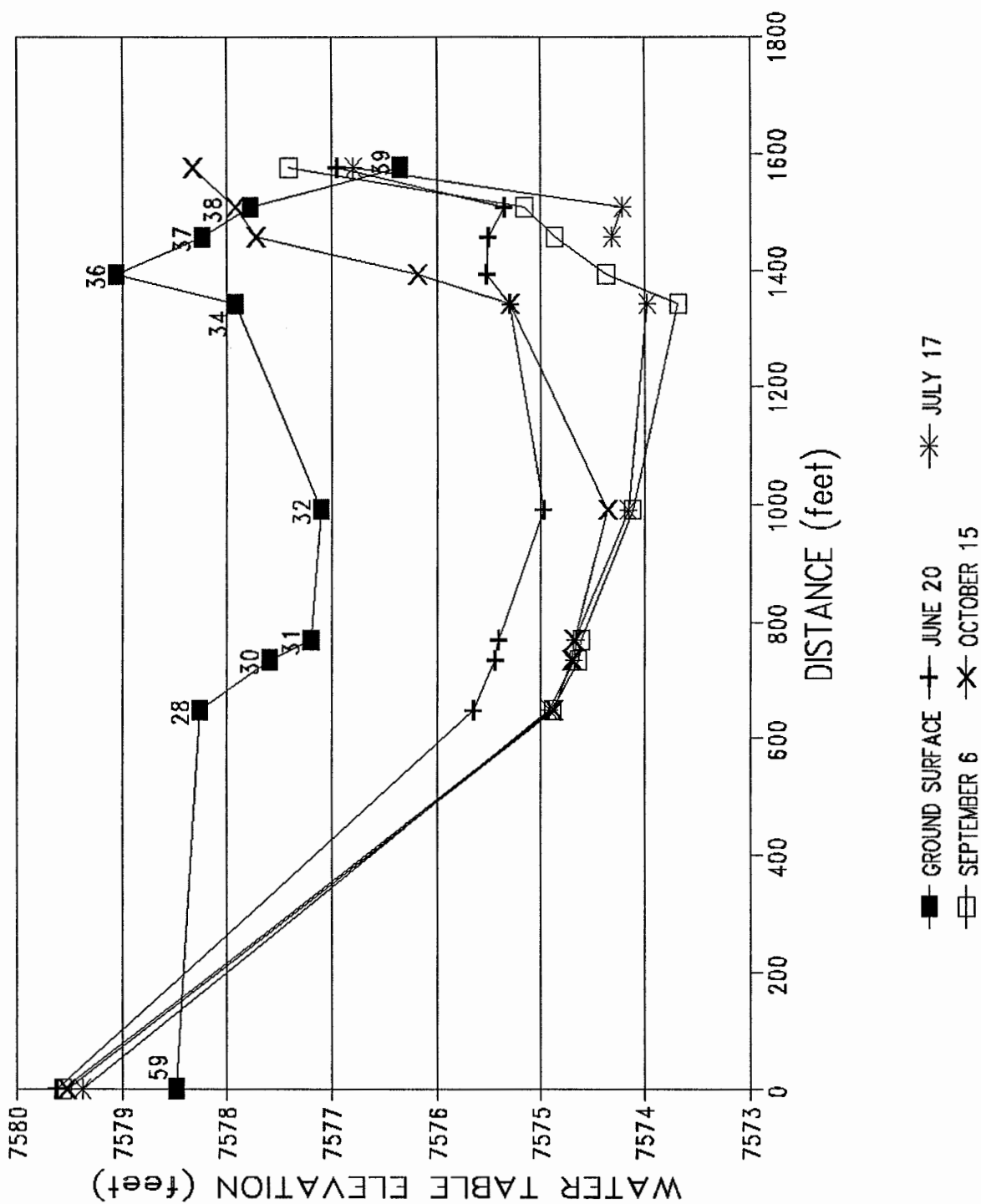
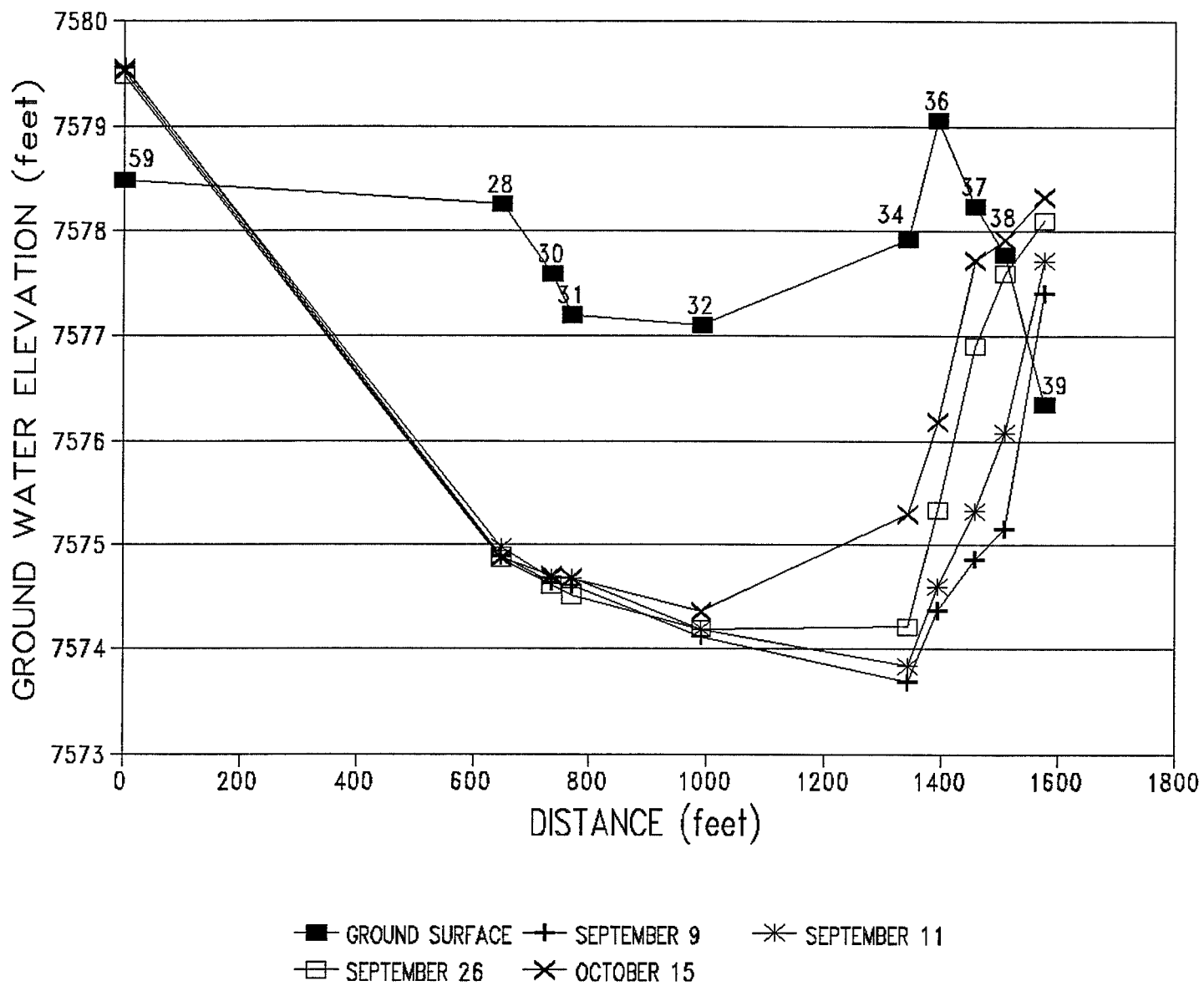


Figure 32a. Water table profile for wells RL-28 through RL-39, Russell Lakes area, during 1991.

Figure 32b. Late summer water table profiles for wells RL-28 through RL-39, Russell Lakes area, during 1991.



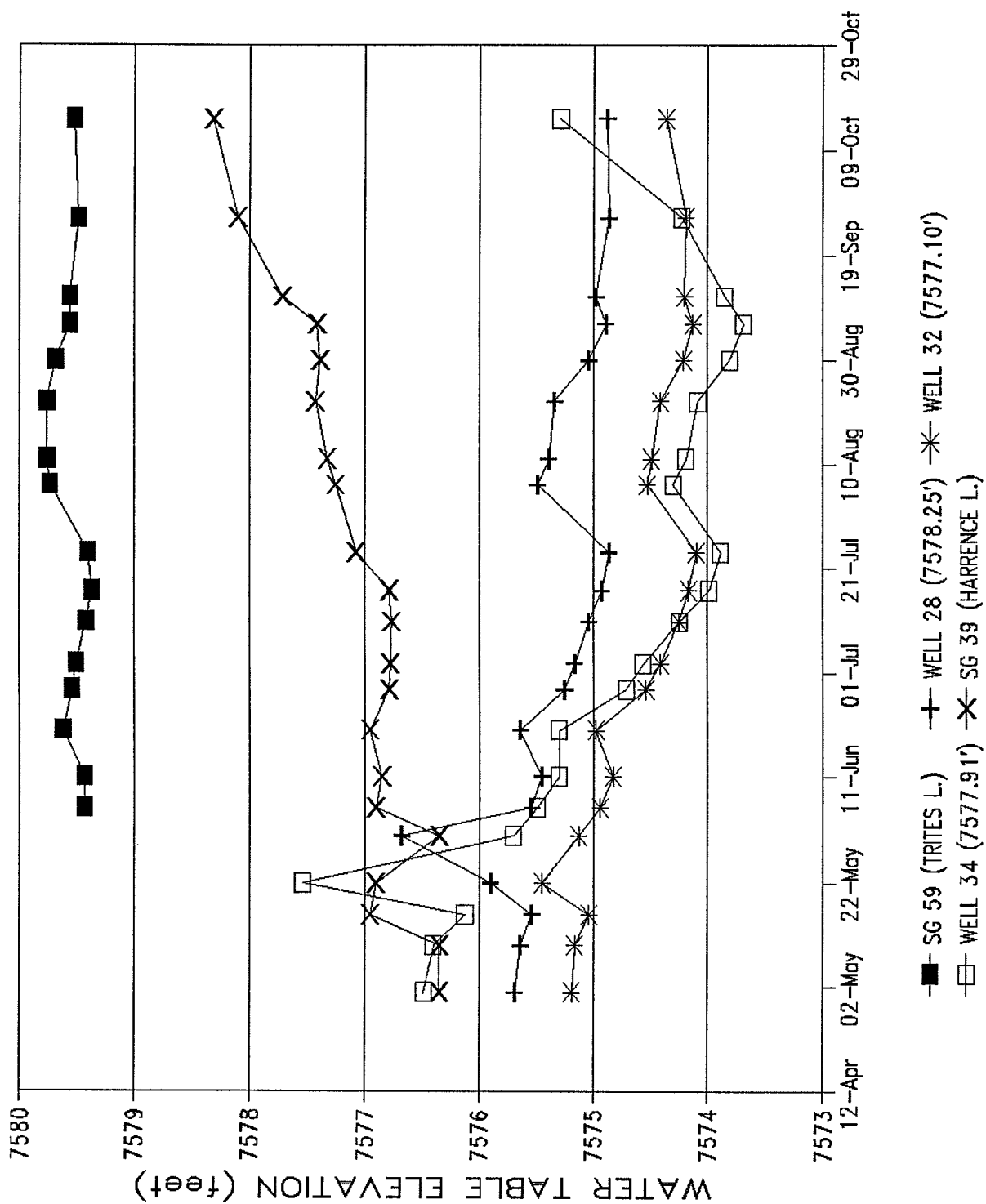


Figure 33. Hydrograph of wells RL-28, 32, 34, and staff gauges 59 and 39, Russell Lakes area, during 1991.

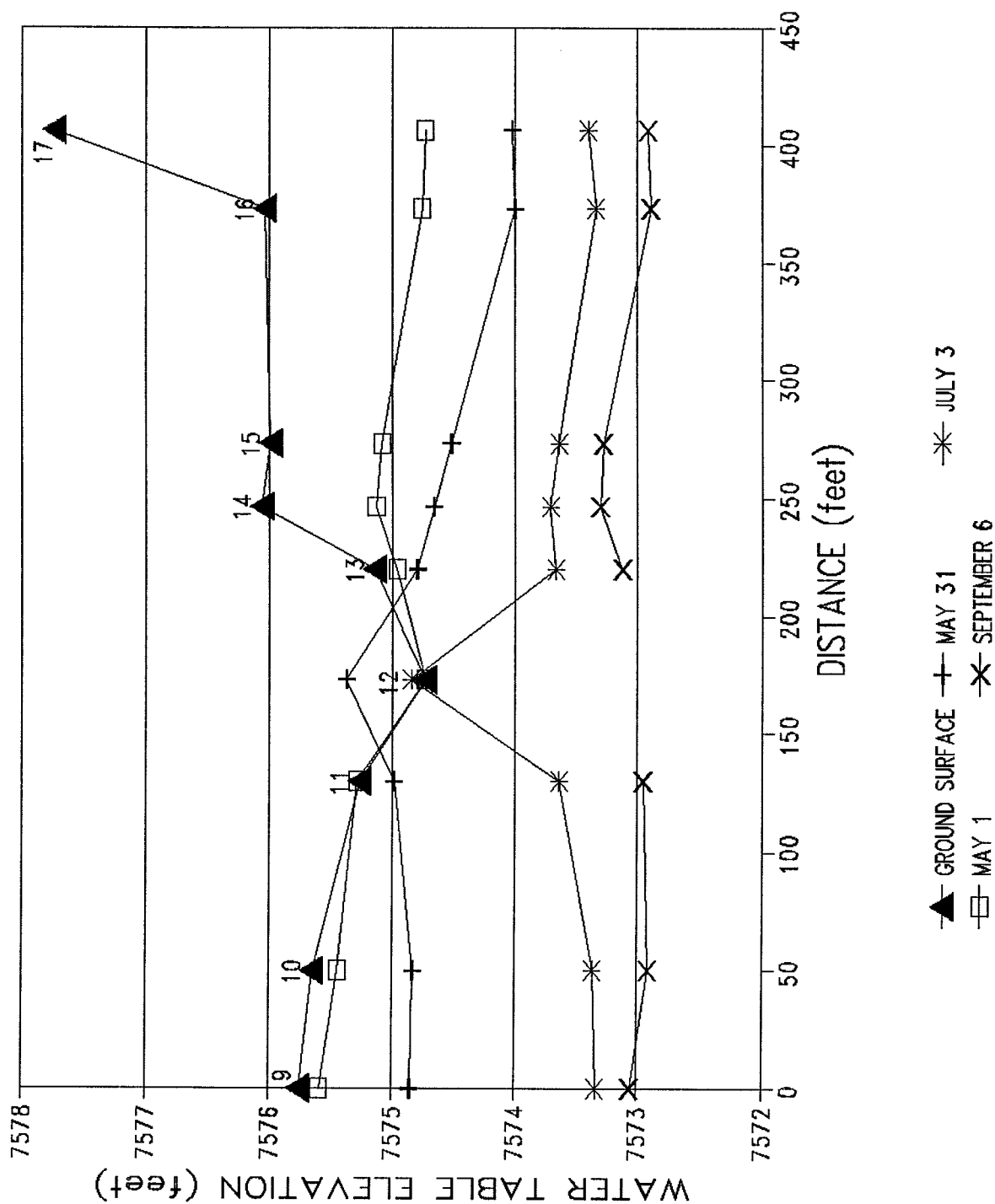


Figure 34. Water table profile for wells RL-9 through RL-17, Russell Lakes area, during 1991.

Water tables were highest on 1 May when the creek had a very low flow. At this time groundwater was recharging the Creek. By 31 May the Creek was flowing at its seasonal peak and it was higher than the water table under the surrounding wetlands. At this time and for the remainder of the time that it flowed, it was recharging the surrounding water tables creating a local water table mound. The creek was dry later in the summer and the water table mound disappeared. Very small scale water table highs can be found, for example on 6 September at well 14. Hydrographs for wells 9 north of the Creek, and 14 and 16 south of the Creek along with the water levels recorded at well 12 located in the Creek are shown in Figure 35. Small changes in the elevation of the Creek (well 12) causes changes in the water table in these three wells. The drop in stream levels in late June caused an immediate and precipitous drop in the groundwater levels in these wells. When the Creek began to flow in mid-August and again in mid-September after dry periods water tables responded with rises.

A transect spanning what we call "Yucca Hill" (because it is the only area supporting Yucca glauca in the Russell Lakes area) shows the relationships between a surface water source and water tables extending horizontally toward uplands and salt flats. Well 46 is located on the upper edge of a small backwater pond supporting hardstem bulrush. Well 42 is near the top of Yucca Hill on the lower edge of a bluegrama grass community. Well 40 is located in a greasewood-salt flat community. The profile of this transect in Figure 36 shows strikingly the magnitude of water table elevation change (changes of three feet or more) for wells 43 through 46 located close to the surface water source. Stations 40, 41 and 42 however have a seasonal water level change of approximately 1 foot. While groundwater tables at well 42 remain relatively stable, water tables in the wetland pond area change from a groundwater high to a groundwater depression. This same phenomenon occurs throughout the San Luis Valley and illustrates how critical fresh surface water is to most wetlands.

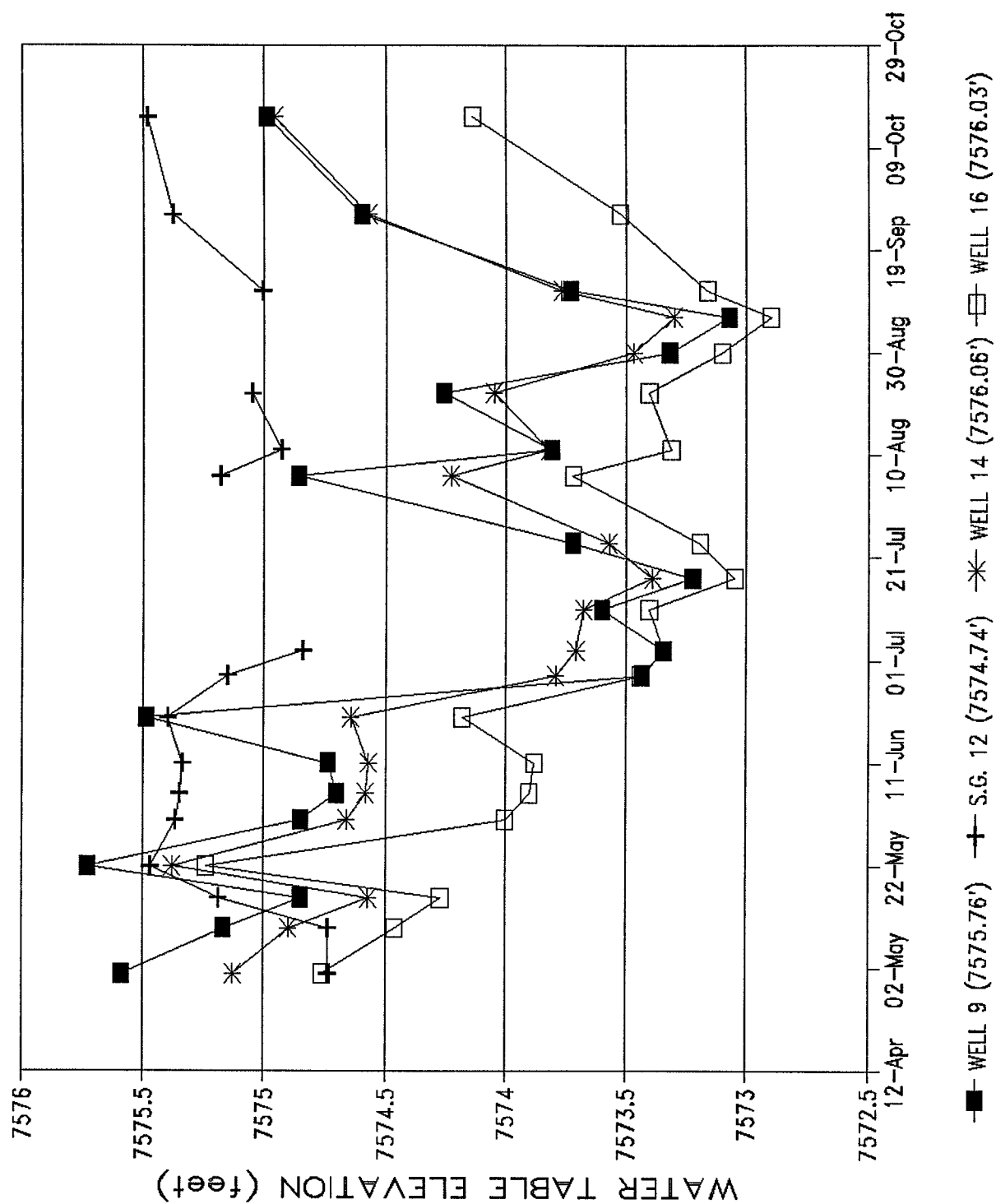


Figure 35. Hydrographs for wells RL-9 through RL-17, Russell Lakes area, during 1991.

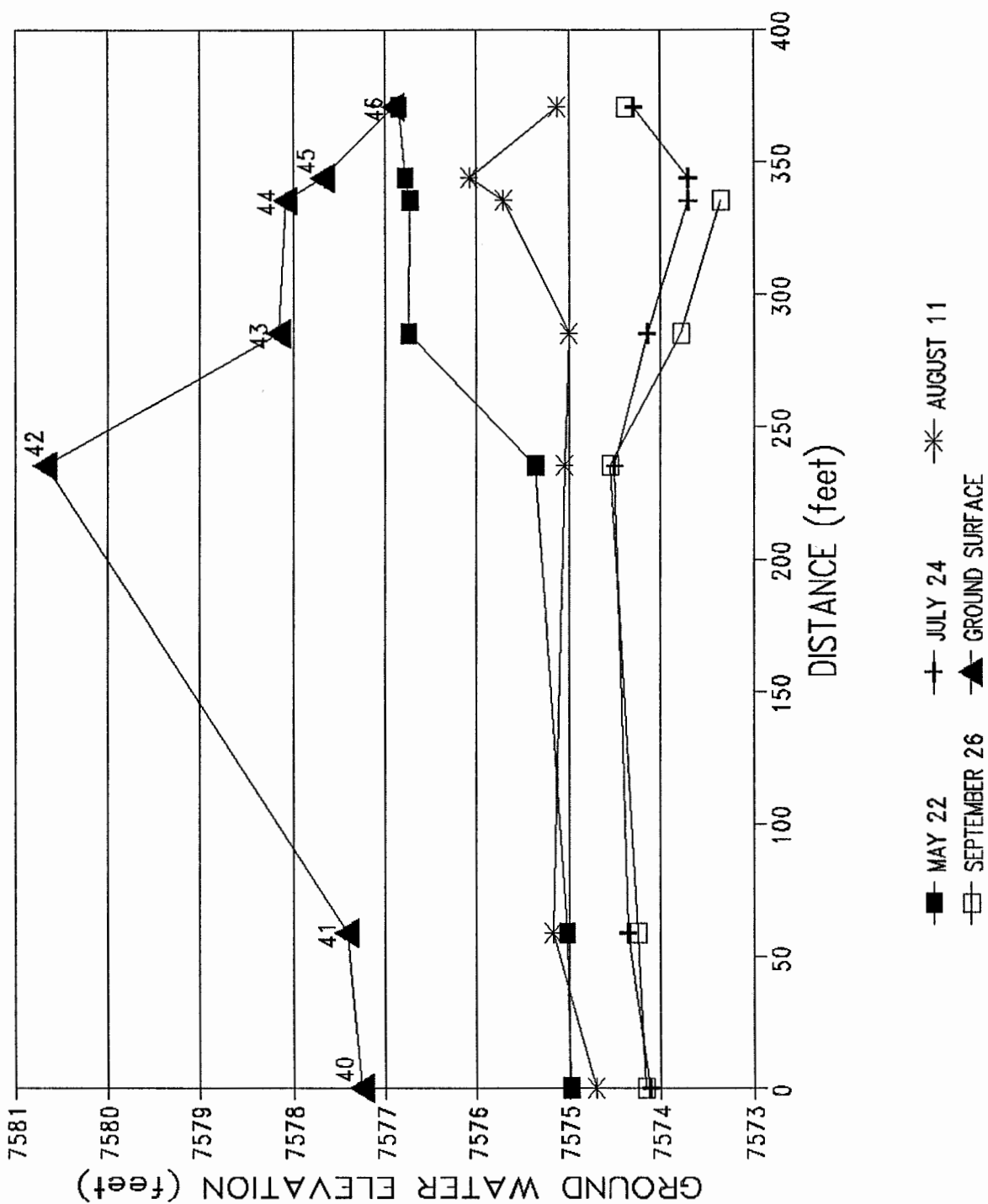


Figure 36. Water table profiles for wells RL-40 through RL-46, Russell Lakes area, during 1991.

Hydrographs for selected wells along this transect shown in Figure 37 indicate a general water table decline from late May through mid-July. Large rains in late July and early August led to a water table rise at all stations followed by a drop in water levels in the Autumn. Well 44 is located in an area of sandy soils that responded very rapidly to hydrologic forces.

Villa Grove Area Hydrology

The hydrologic regime in the Villa Grove study area, particularly the southern portion, is unique in the northern San Luis Valley. San Luis Creek flows south through a valley that is approximately one mile wide. Large alluvial fans extend from the Sangre de Cristo Mountains down to the eastern side of the valley floor. Large alluvial deposits also occur to the west. These alluvial fans contain ground water flow systems that intrude on the San Luis Creek valley resulting in gaining valley bottom ground and surface water flow systems. Kerber Creek enters the valley here from the west as well. Large perennial springs erupt throughout the valley bottom on both the east and west sides of San Luis Creek. Many of these springs take the form of quagmires, supporting floating mats of vegetation. Peat soils occur adjacent to all springs and indicate great temporal stability in the groundwater flow system. In fact, much of the entire valley bottom east of the town of Villa Grove has peat soils indicating that large areas are actually receiving discharged ground water.

Peat accumulation rates in Colorado range from 6 to 12 inches per 1,000 years (Cooper 1990). Peat thicknesses of over 3 feet are common here indicating antiquity of these ecosystems. The peat and fine-textured silt and clay soils in many areas created very different situations for groundwater monitoring than we encountered elsewhere in the San Luis Valley. When the surface soils are pierced by an auger for the placement of a monitoring well, the hydrologic pressure forces water up the well to a level equaling the hydrologic head. Thus, many of our wells

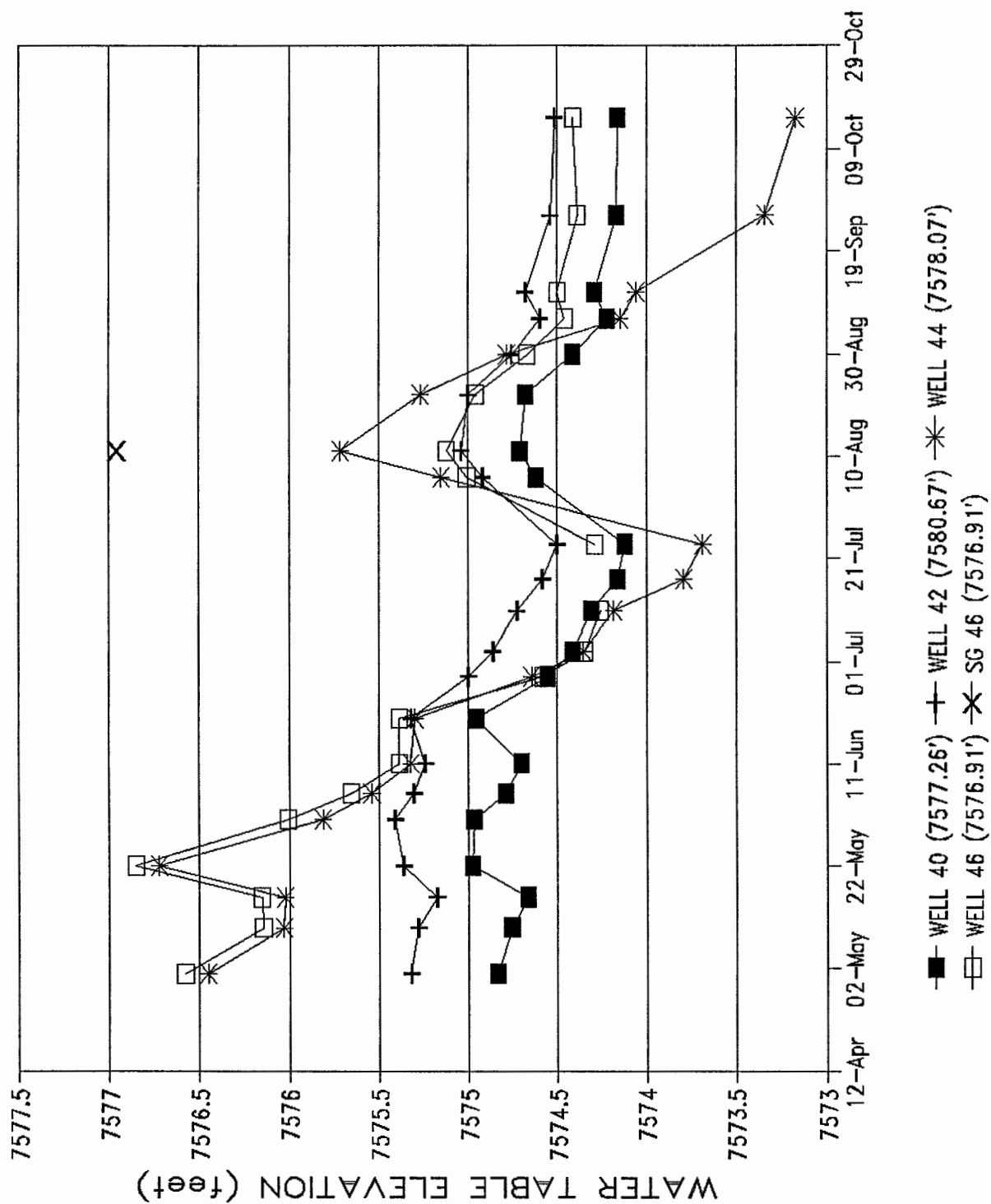


Figure 37. Hydrographs for selected wells along transect from wells RL-40 to RL-46, Russell Lakes area, during 1991.

are indicating aquifer head, not static water table elevations. Interpretation of this data cannot be the same as in the sandy soil areas farther south where our well indicate water table elevations.

Water elevation data for Rio Grande Water Conservation District well 1, located in this area, is shown in Figure 38. Data for the period July 1979 through 1991 show that seasonal water level highs have been quite stable through the period of record. Water level highs for all years, except 1982, were within one foot of each other. Water level highs for 1991 were very similar to those for the larger water years of the mid 1980's. However, seasonal lows are very different ranging from 6 feet below the soil surface during the drier years of the early 1980's to 2.5 feet below the soil surface in wetter years. Water table highs are usually recorded in May and water table lows in September of each year.

Two creeks flow through the study area, San Luis Creek and Rock Creek. San Luis Creek has its headwaters farther north in the valley than our study area. However, Rock Creek originates in the area just north of the study area and derives all of its flow from groundwater discharge in this area east of Villa Grove. Both are gaining streams as they flow south.

Figure 39 shows hydrographs of wells 1 through 5 and water levels in San Luis Creek. All these wells are located near the Creek. They show a high water level in late May in response to a rainy period which brought water levels to near the ground surface at all wells. Water levels at all stations, including San Luis Creek, dropped through the month of June and leveled off during July. The beginning of a rainy period in late July brought ground water levels up, but did not affect San Luis Creek levels which remained nearly constant for the rest of the study period.

Figure 40 presents hydrographs for San Luis Creek, Rock Creek, well 5 located west of San Luis Creek, wells 21 and 19 located between the two creeks and well 31 located east of Rock

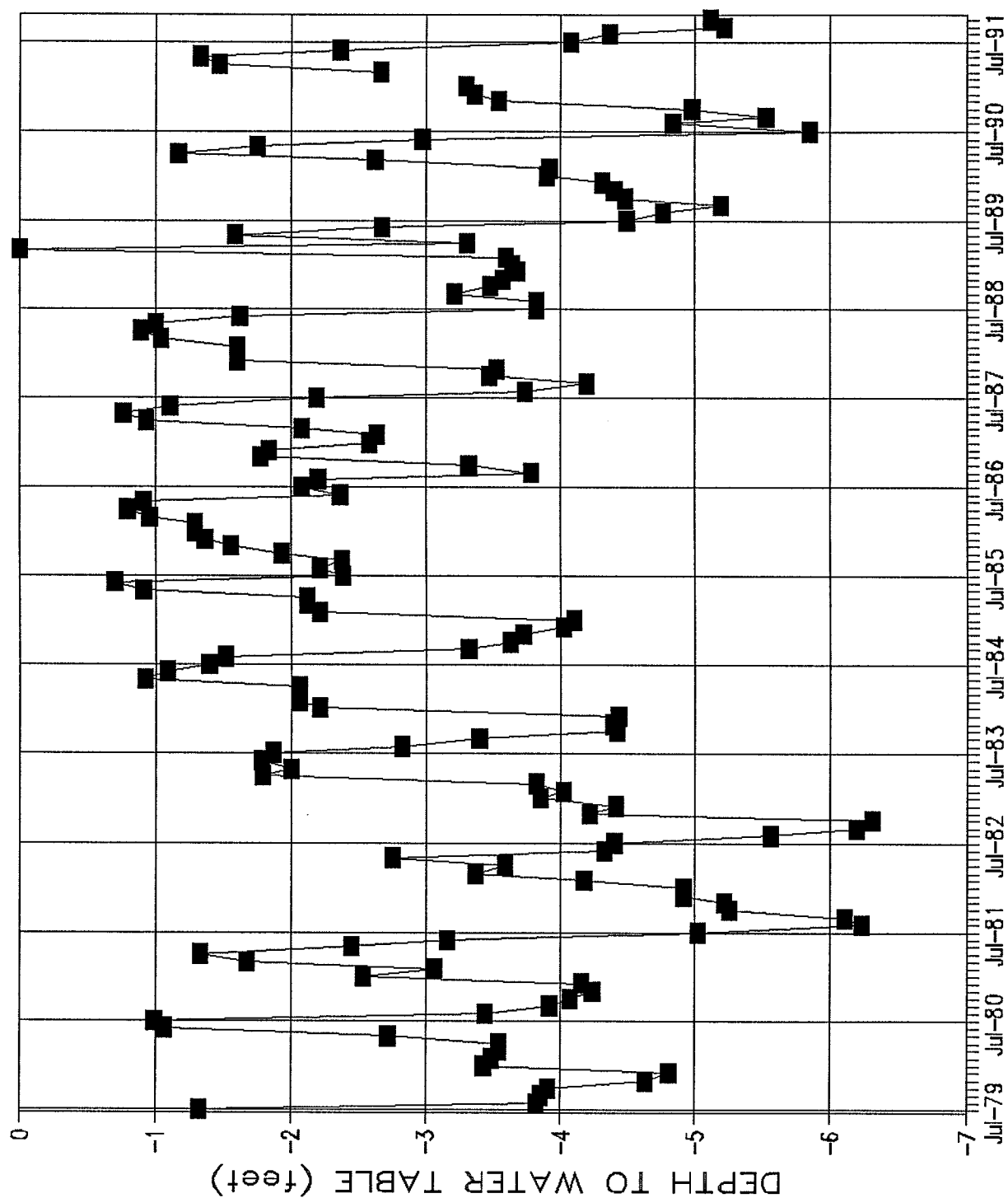


Figure 38. Hydrograph for Rio Grande Water Conservation District well 1, for the period July 1979 to October 1991, Villa Grove area.

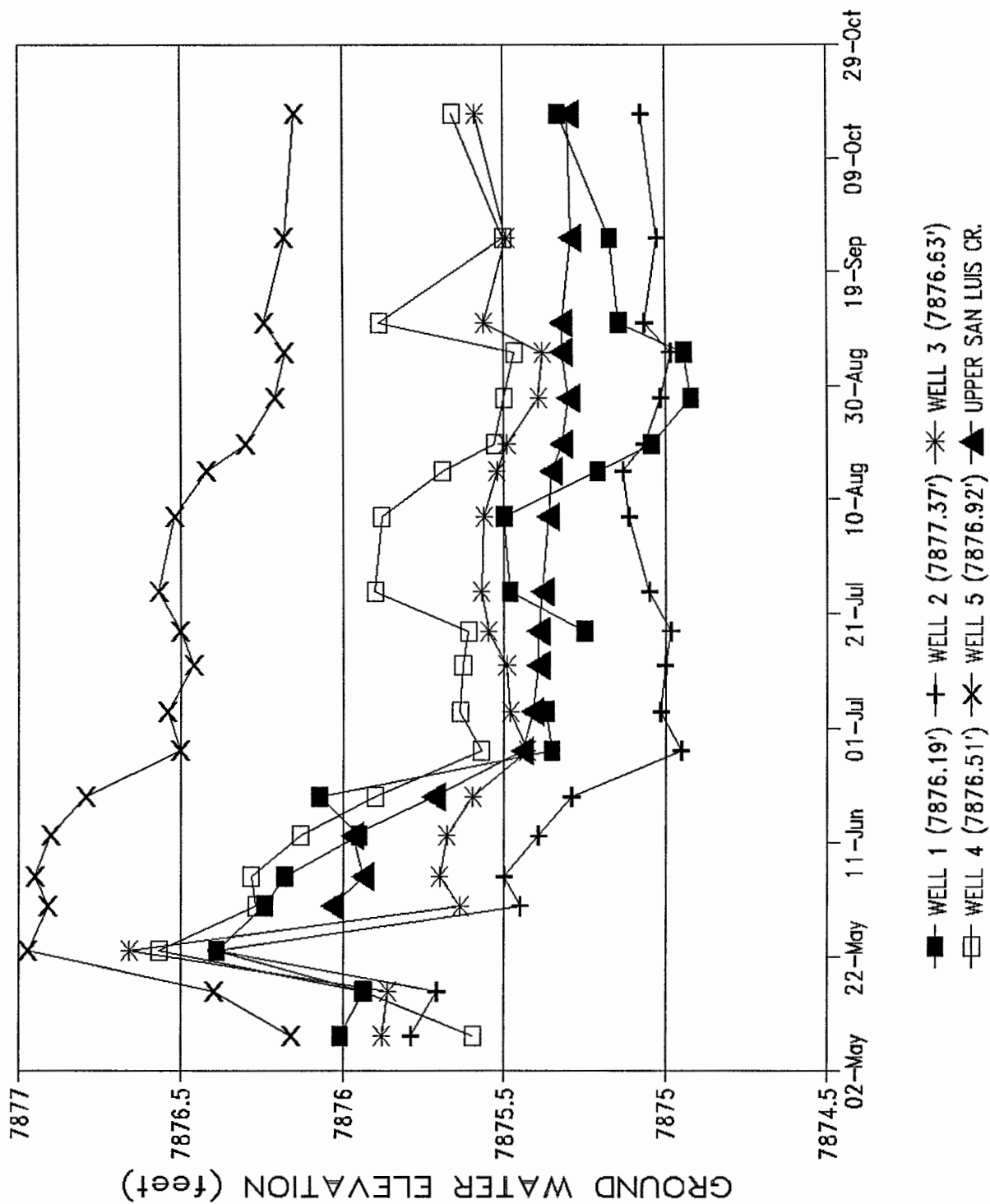
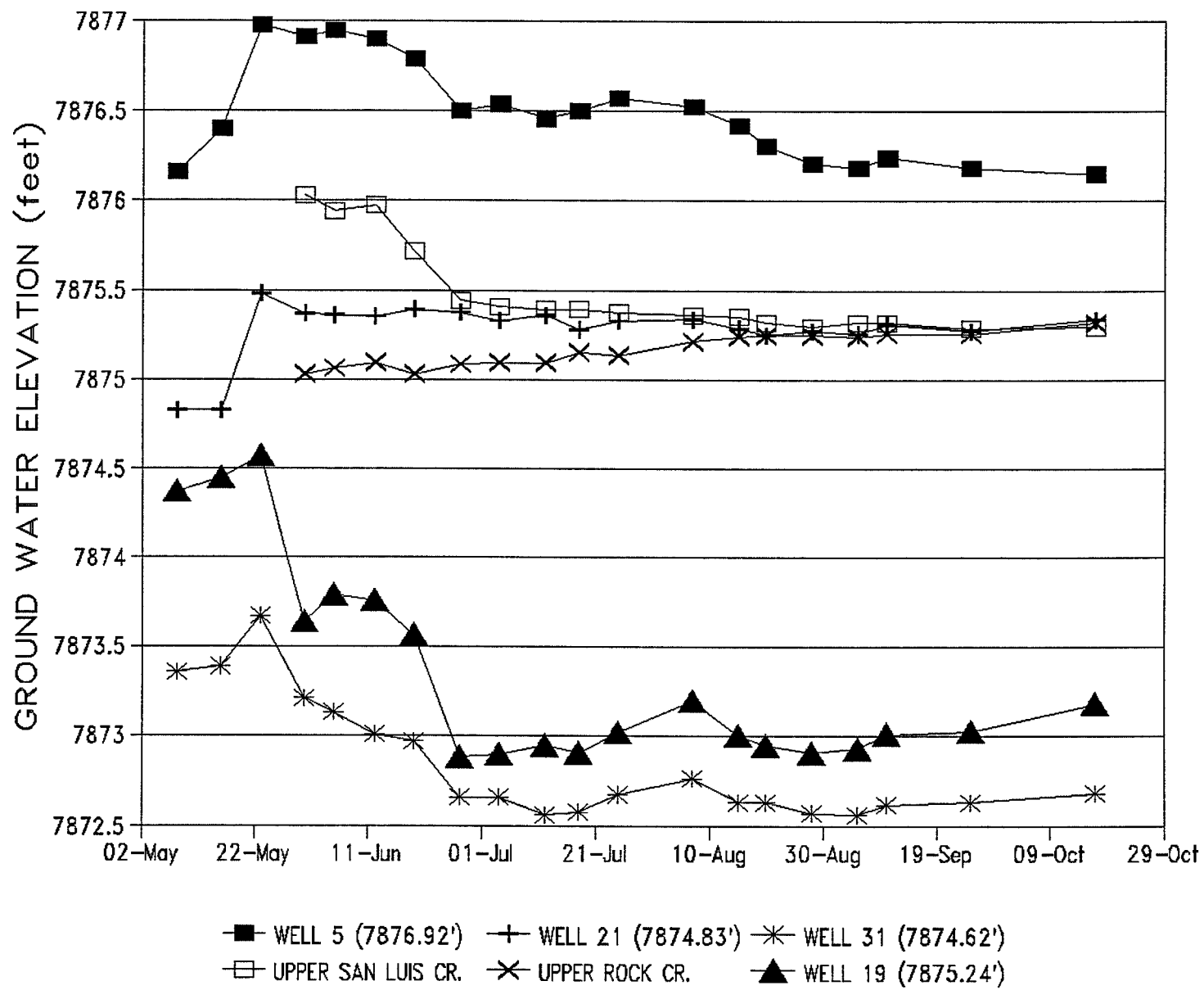


Figure 39. Hydrographs for wells VG-1 through VG-5, Villa Grove area, during 1991.

Figure 40. Hydrographs for San Luis and Rock Creeks and VG-5, 21, 19, and 31, during 1991.



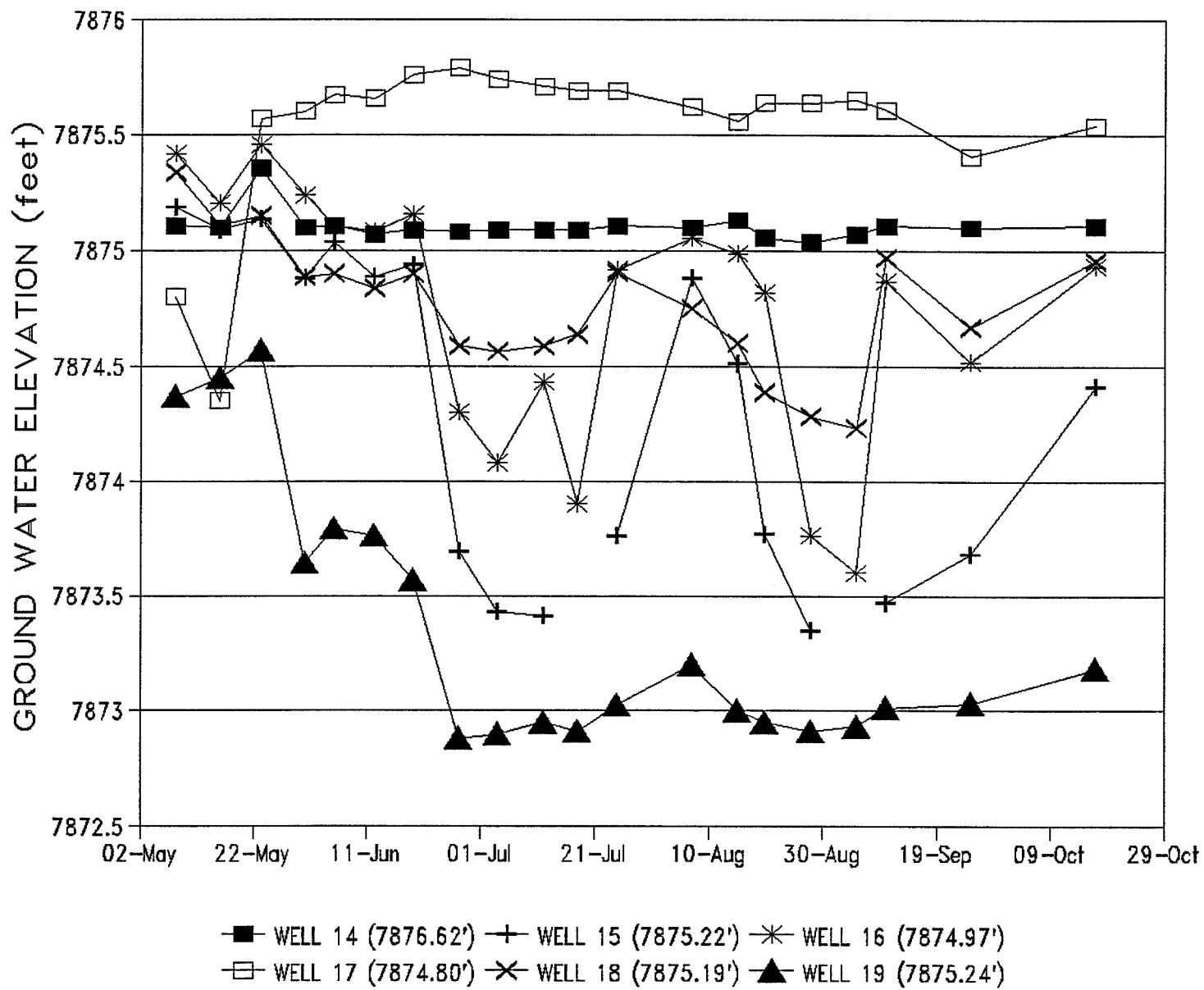
Creek. Hydrographs for well 5 and San Luis Creek early in the summer were very similar to those of 19 and 31. All of these stations occur in mineral soils. Water levels in well 21 located in a quagmire with floating peat mat was extremely constant for the period of record. A striking aspect of this figure is the convergence of San Luis and Rock Creek to the exact elevation of well 21 later in the summer. This indicates that hydrologic head under this entire area maintains water levels at the elevation of this head; 7875.3 feet. Groundwater tables at stations with mineral soils (eg. 5, 19 and 31) throughout the area have similar responses to snow melt and rain events. Early in the year these events affect San Luis Creek. However, later in the year the very strong vertical component of groundwater discharge seen at 21 dominates the flow patterns in San Luis and Rock Creek.

Figure 41 shows six wells in the center of the study area between the two Creeks. Wells 14 and 17 are located in or adjacent to peatlands and their wells indicated strong and very stable groundwater discharge patterns. Station 19 reflects the mineral soil San Luis Creek hydrograph while wells 15, 16 and 18 fluctuate sharply with late July-early August rains.

Figure 42 illustrates wells near Rock Creek. Wells 26, 20 and 21 all have very stable hydrographs reflecting strong groundwater discharge systems. Wells 19 west of the Creek and 25 east of the Creek show the spring high, summer low of many wells in mineral soil.

The hydrographs for wells in this study area indicate to us that there are at least two or three different groundwater flow systems supporting wetlands in this area. One system enters from the west and support San Luis Creek early in the summer. Another flow system enters from the east and supports mineral soil stations on the east. Another system has a vertical component deriving its water from much deeper and more stable groundwater sources feeding the large spring systems throughout the center of the study area. This deep groundwater ultimately determines the lower limits of the water table in many wells and in the Creeks.

Figure 41. Hydrograph for wells VG-14 through VG-19, Villa Grove area, during 1991.



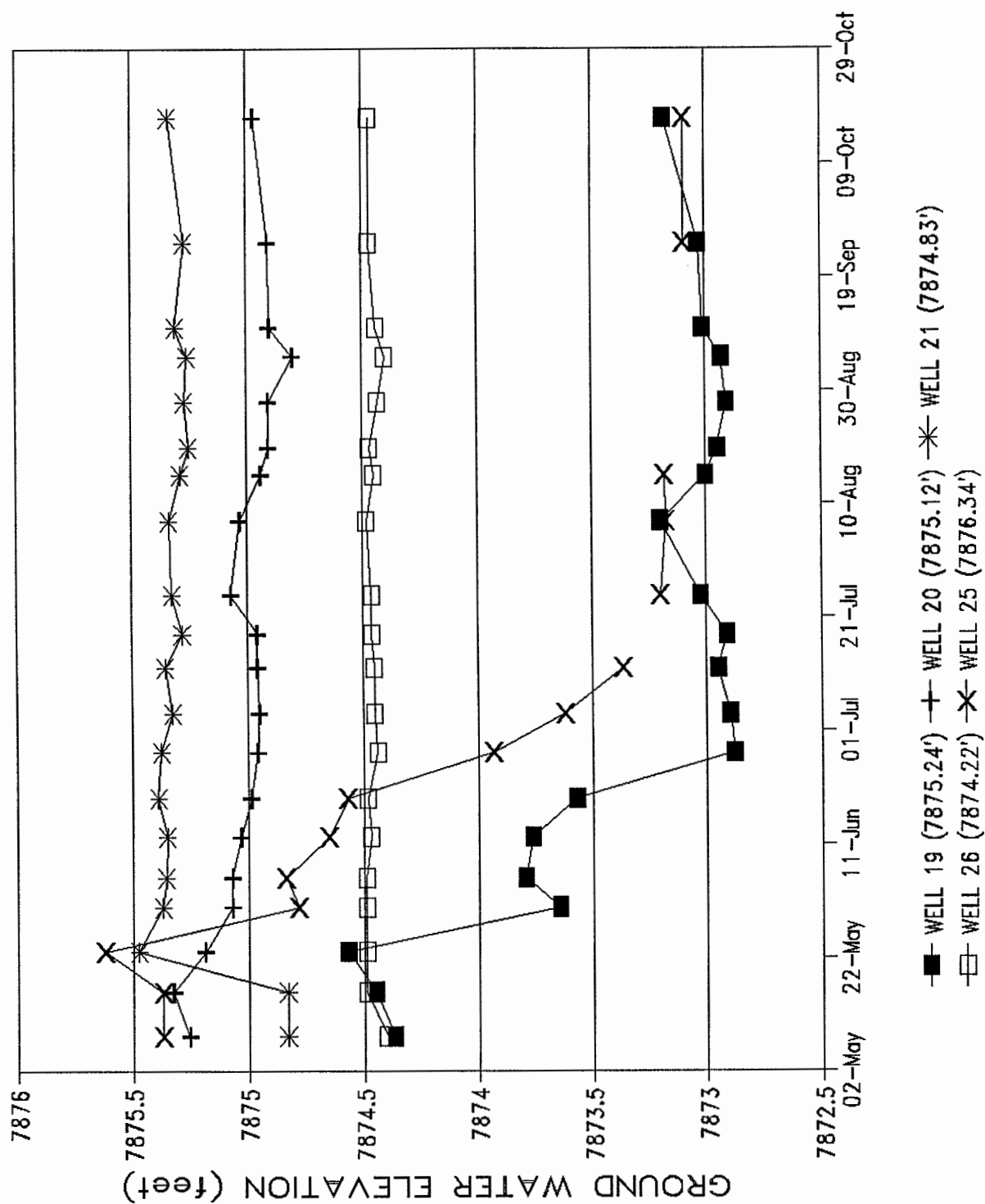
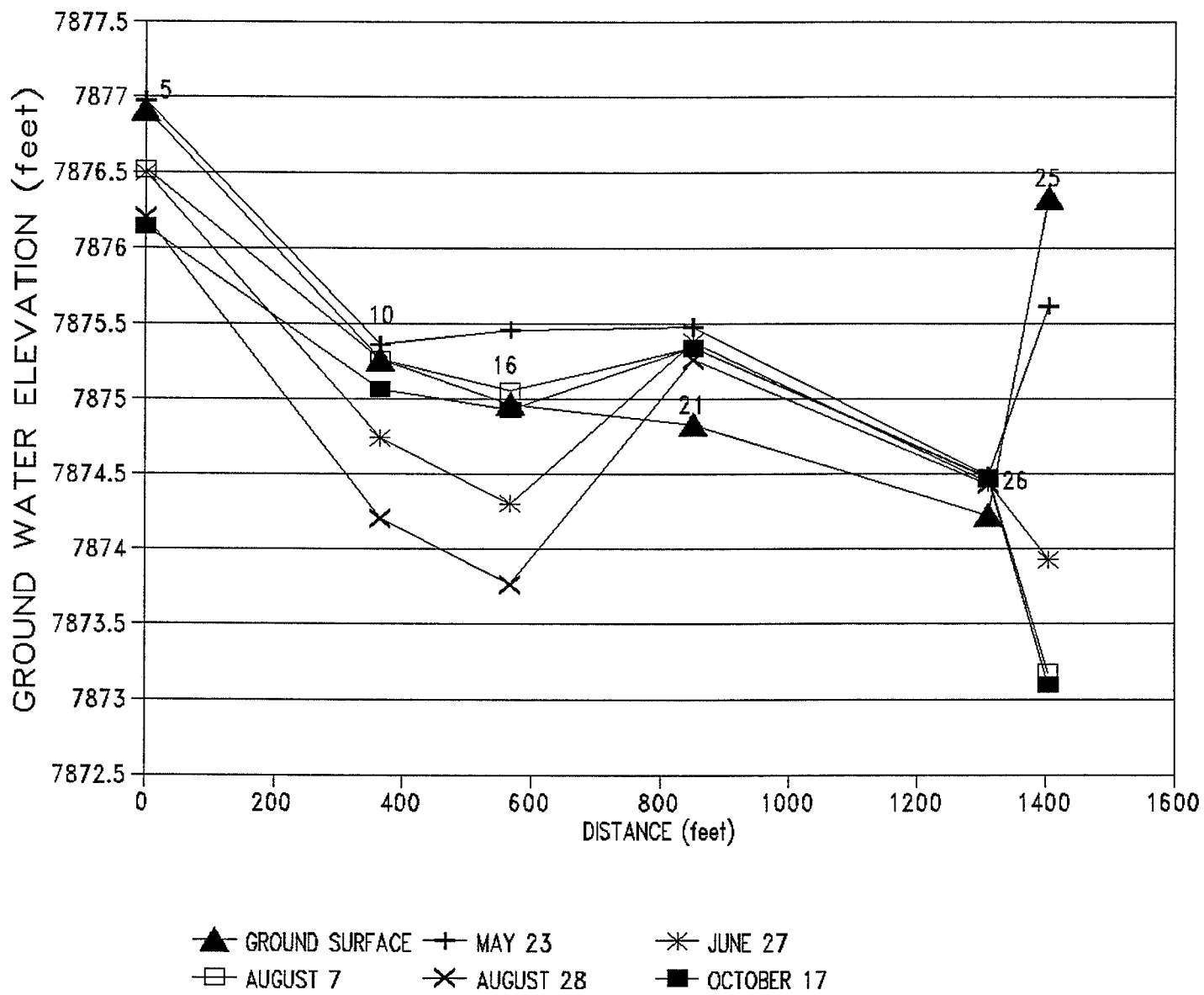


Figure 42. Hydrograph for wells VG-19, 20, 21, 25, and 26, Villa Grove area, during 1991.

However, water input from the east and west and in San Luis Creek can overlay this deep groundwater discharge.

A profile across the main study area shown in Figure 43 illustrates some of this complexity. West is to the left. Station 5, located just west of San Luis Creek, has higher elevation water tables than any other station supported by water flowing from the direction of Kerber Creek. Station 25 on the east supported by water flowing within alluvial fans has water levels higher than the Creeks early in the summer but lower than any other area after early August. Wells located between the two creeks have water levels above the ground early in the summer, but only 21 maintains this level of head. Thus, a very complex picture of perennial groundwater discharge on the west, intermittent groundwater discharge on the east, groundwater mounds at strong discharge sites such as well 21, and seasonal fluctuations at other stations which may actually be discharge areas at some times and recharge areas at others.

Figure 43. Water table profiles across the main Villa Grove study area, showing water levels for selected dates during 1991.



WATER CHEMISTRY

Water chemistry patterns for the study area are investigated in a cursory manner in this report. Additional work is suggested.

San Luis Lakes. Water in the San Luis Lakes area is very variable. It was sampled in streams, lakes and groundwater wells. Big Spring Creek had the freshest water found in the study area. Surface water Ph ranged from low 7's early in the summer to low 8's later in the summer. Conductance was very low, around 100 umhos/cm² in early summer and ranging up to 150-200 umhos/cm² later in the summer. This pure water flowed from the area north of the Medano Ranch all the way to San Luis Lake. Conductance of ground water in the areas remote from the influence of this surface water source, such as well SL-53 located in the eastern portion of the study area were ten times as high, eg. 1,727 umhos/cm² measured in August.

The influence of surface water on groundwater conductance is seen along a study transect at the lower end of the "Slough" between Head and San Luis Lakes. The transect is a string of wells from well SL-57 on the waters edge up to SL-60 in the uplands. Water at well SL-57 had a conductance of 169 umhos/cm² on 13 August. At this same time water in well SL-58 located uphill at the lower limit of the wire grass community had conductance of 775 umhos/cm² while water in well SL-60 at the lower upland edge was 1,158 umhos/cm². Thus, the surface water sources that create groundwater mounds mix their fresh, low conductance water with higher conductance groundwater under and adjacent to the mound.

The highest pH and conductance (15,130 umhos/cm²) groundwater in the San Luis Lakes study area was found under a small playa at well SL-45 between the two Twin Lakes. It indicated to us that small isolated groundwater systems are scattered within the matrix pattern of groundwater and surface water flow associated with the creeks. The creeks create appear to maintain regional groundwater flow systems of moderate

conductance and also support surface water influenced streams, lakes and groundwater mounding areas which have very low conductance.

These water chemistry patterns and the complexity they create is only partially detectable in the surface vegetation patterns. Playas that have salt crusts prior to the monsoon season have local groundwater flow systems that are very saline. When this water and its salt reaches the surface it creates extremely saline soils prohibiting the growth of plants in many areas and limiting to all but halophytes (salt plants) where soils are somewhat less saline. Streams and seasonal groundwater mound areas have clean water as evidenced by the presence of "glykophytes" (sweet plants), plants intolerant of high salt concentrations in the soil and water. Examples of these glykophytes are cattail, giant burreed, and sedges.

Mishak Lakes. Conductances are relatively similar for all stations during the time of sampling, ranging from 700 to 800 umhos/cm². Groundwater pH is very similar across the transect and as would be expected surface water pH's are high due to carbon dioxide removal by aquatic plants. Values above pH 10.0 were measured in late June surface water while ground water had pH's between 7.4 and 7.5.

Seasonally conductance increased in groundwater from 700-800 umhos/cm² in late June to greater than double this in August. Groundwater temperature increased by approximately two degrees centigrade during the summer.

Russell Lakes. Surface water pH in the Russell Lakes area was between 9.0 and 10.0 for most water bodies at most times during the summer. Ground water was much more variable ranging from the low 7's at station RL-32 near the shore of Harrence Lake, RL-25 near the outlet of Davey Lake and RL-28 near Trites Lake. Pockets of high pH groundwater also occur, indicating local groundwater flow systems that are unaffected by surface water flows in the area. For example at stations RL-42 and RL-70 located under "Yucca Hill" south of Harrence Lake.

Conductance of surface and groundwater was very variable spatially. Several artesian wells produced water of very low conductance and this water sampled in Davey Lake, Harrence Lake, station RL-4 in the northeast portion of the study area, and a small stand of cattail located near Davey Lake. For these stations conductance never exceeded 200 to 400 umhos/cm² and most measurements were less than 300 umhos/cm². Most groundwater systems had much higher conductances. For example, the "Yucca Hill" area groundwater at well RL-70 was nearly 100 times the conductance of the cleanest water found, up to 15,920 umhos/cm². More moderate conductances ranging from 600 to 3,000 umhos/cm² occur at the other wells that are influenced by fresh surface water.

Villa Grove. Figure 44 shows conductance of groundwater on 17 October. A few patterns are clearly illustrated indicating strong support for the observations put forth in the hydrologic description of this area. San Luis Creek flows across the left side of this graph from left center to lower left. Rock Creek flows from top center to lower right of center. Both Creeks in general flow from northwest to southeast. Water conductances on the western (left) side of the valley range from 330 to 574 umhos/cm². On the eastern side of the valley measurements have a similar range. Some measurements are higher in both areas. The area of Rock Creek, however, is very different. The Creek has a conductance of 157 umhos/cm² where it enters the study area and 163 umhos/cm² where it leaves. Springs feeding the creek forming a northwest-southeast line up the valley have conductances ranging from 100 to 120 umhos/cm². Thus, Rock Creek is the result of a line of springs occurring in the valley and its water chemistry supports this hypothesis.

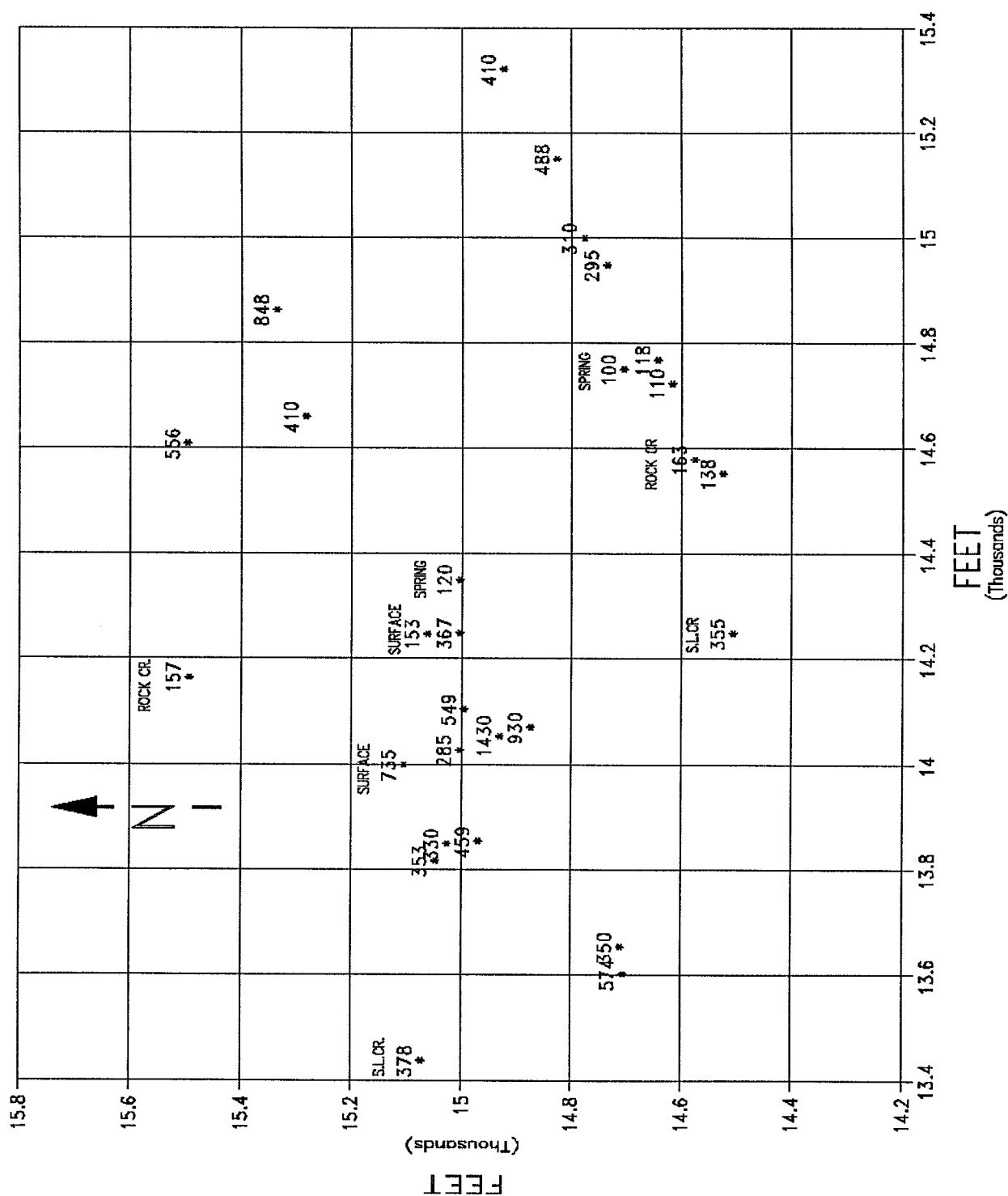


Figure 44. Conductivity (umhos/cm²) of water in wells and surface waters on 17 October 1991 for the main Villa Grove study area.

SOIL CHEMISTRY

Soil chemistry in the study area was investigated only from the standpoint of measuring the conductivity of soil extracts as an indirect measure of soil salinity. This was done to determine the growing conditions for plants. Soil samples were taken in May and again in September from every station. Some stations were also sampled in summer. The conductance of soil water extract gives a reliable and repeatable picture of total dissolved solids in soil. This data can be used to compare stands.

It was our hypothesis that salts in soils near the water table are similar to the concentrations in the water. We also felt that soils located above the water table where the capillary fringe reaches the soil surface seasonally would have the highest concentrations of salts. We further proposed that soils located well above the capillary fringe would have the most salt free soils because salts were leached downward by rain and snowmelt to the water table and are not replaced by capillary fringe evaporation. Our soil analyses support these hypotheses. However, we were not expecting the tremendous differences between water table, capillary fringe and above capillary fringe areas. Soils that were flooded or had a water table to the soil surface each year had soil extract conductances of from 200 to 1,000 umhos/cm², with very few measurements above 800. The lowest measurements in this class were from streamside and lake side emergent communities dominated by Carex lanuginosa and Sparganium eurycarpum. Aquatic and bulrush communities had higher concentrations of salts, particularly where they dry up seasonally and salt concentrates on the soil surface. The highest salt concentrations were at sites where the water table never reached the soil surface during 1991 as is shown in Figure 45. All but a few sites that had maximum soil conductivities greater than 1,000 umhos/cm² during 1991 had water tables between the soil surface and 4 feet below the soil surface.

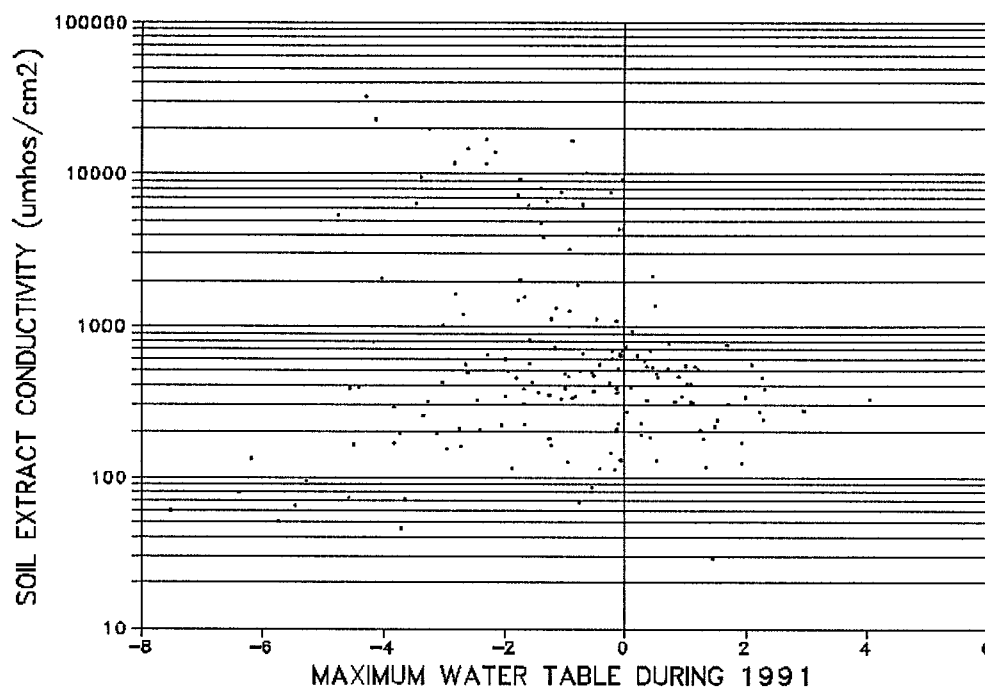


Figure 45. Scattergram of soil conductivity vs. maximum water table at wells during 1991.

Figure 46 shows the mean water table during the 1991 growing season vs. maximum soil conductivity. The highest conductances occurred where the water table averaged between -1 and -5 below the soil surface. It should be made clear that not all feetsites with a mean water table between -1 and -5 feet had high concentrations of salts in their soils. Proximity to surface water sources that would allow a site to flood or have seasonal maximum water tables near the soil surface would have low conductivities. However, sites with similar water table characteristics but that are never influenced by fresh surface water can have much more saline soils. Sites in the mean water table range mentioned above with low conductivity soils are dominated by wet meadow species such as arctic rush, but those sites not influenced by fresh water are dominated by alkali cordgrass, saltgrass and greasewood.

It should also be noted that almost all sites with soil

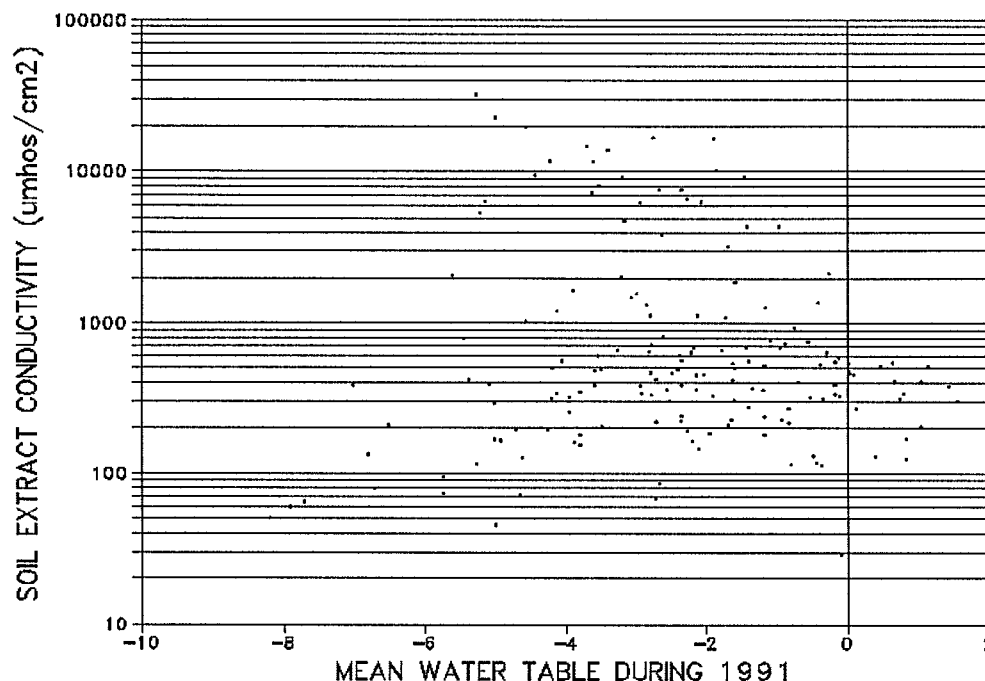


Figure 46. Scattergram of soil conductivity vs. mean water table at wells during 1991.

conductances less than 100 umhos/cm² occurred where depth to water table was greatest or in areas adjacent to the freshest streams, such as Big Springs Creek. When proceeding upgradient from an aquatic zone to a bluegrama grass upland, soil conductivities change from 200 to 800 umhos/cm² in areas affected by the water table, to 1,000 to over 30,000 umhos/cm² in soils where the capillary fringe reaches the soil surface resulting in salt accumulation, to 40 to 150 umhos/cm² in higher elevation sites where salts are leached downward. Three zones can then be defined; 1) water table influenced; 2) salt accumulation; and 3) salt leached. It should also be noted that this entire soil salinity change occurs over an elevation change of as little as 5 to 8 feet. There is also a notable seasonal change in salinity in the upper soil horizons. We observed this but do not have sufficient data to describe it quantitatively. The San Luis Valley receives little precipitation during the winter and spring. Water tables rise from regional aquifer recharge, and

water evaporates from the soil during this time leaving thick salt deposits on the soil surface. When monsoonal circulation develops in July rains commence and soluble salts are temporarily washed down into the soils, or where runoff occurs, downslope to playas.

We observed during 1991 that many herbaceous plants in the San Luis Valley flowered and grew very late in the summer, July and August. It should be remembered that the growing season began in May. The germination of annual plants and the growth and flowering of perennial plants appears to be timed to the beginning of monsoon season in the late summer! During this "wet season" root zone soil water is at its season high and simultaneously soil salinity is at its seasonal low. The soil water solution that plants utilize for growth has its lowest salt concentration at the time when plants most need it. Indeed, this area support the latest blooming flora of any place I have seen in Colorado.

VEGETATION ANALYSIS

VEGETATION ANALYSIS: INTRODUCTION

Vegetation occurring along study transects was analyzed using a number of different methods. Numerical analyses using multivariate techniques of direct and indirect gradient analysis were used in the exploration of the main variables controlling the distribution of species and communities. This data analysis is used to understand species interactions and distributions in relation to physical environment variables and to develop a hierarchical classification for the study area vegetation. The classification uses Braun-Blanquet floristic-sociological methods (Westhoff and Maarel 1978) as is commonly used in Eurasia and many other parts of the world. The classification is hierarchical allowing land managers to investigate the vegetation at any level in the hierarchy they wish. This classification is hierarchical and build on the work of Cooper and Cottrell (1989 and in prep) and Cooper (1990).

Direct gradient analysis was used to explore relationships between stand hydrologic regime and soil conductivity and stand primary production, canopy coverage of different plant species, species richness, and percent bare soil in stands.

Ordination is a multivariate technique that produce two dimensional graphs in which stands are represented by points in the ordination space. The most similar stands are positioned closest to each other and the more dissimilar ones are positioned farthest away (Jongman et al. 1987). Floristic similarity and dissimilarity between stands accounts for the position of stands along the axes. The first axis usually accounts for much of the variation in the data. The result of ordination is a graphical depiction of relationships between stands. This depiction is a valuable means of exploring relationships between stands and the contribution of different plant species to the variation seen. Interpretation of the graph is usually done by correlating axes with environmental variables, but even without correlation the graph is extremely valuable for illustrating floristic

similarities between stands.

Ordination is appropriate for vegetation data because standard statistical methods, such as regression analysis, can only be used for single species. Because vegetation is composed of many species it is most desirable to analyze the entire floristic composition of stands. Species also have unimodal, as opposed to linear, response curves to environmental variable. Thus, stand statistical methods can often fail to produce meaningful analyses of this data.

Two ordination techniques were used on the San Luis Valley data. Detrended correspondence analysis, DECORANA, (Hill 1979; Hill and Gauch 1980) analyzes the species data to produce ordinations of species and stands. Canonical correspondence analysis, CCA, (Ter Braak 1986) is used to analyze the species data and environmental data on hydrology and soil conductance simultaneously. Thus, it produces ordinations based on species abundance and environmental variables.

VEGETATION ANALYSIS: ORDINATION

Figure 47 is a DECORANA ordination of all 149 stands from the Russell Lakes, San Luis Lakes and Mishak Lakes study areas. The ordination Axis 1 can be correlated with a moisture gradient with the driest stands on the left and wettest on the right. What is interesting is that the driest stands are clumped together near -40 on the x axis and +10 on the y axis. Most of the ordination space is taken up by the various wetland stands. This indicates that the hydrologic regime is the major factor determining the distribution of species in the study area, which is not surprising. Most species occupy a fairly to very limited range along this hydrologic regime and stands have little floristic relationship to each other. However, at the drier end of the range, stand floristic composition is much more closely related to each other. This is surprising since soil salinity varies tremendously in this drier end, ranging from the most saline to the least saline stands. However, apparently the

species that occupy the most salty stands, such as Distichlis spicata and Spartina gracilis, also grow in the least salty stands that are characterized by Bouteloua gracilis. Thus, salt flat and upland grasslands are more closely related to each other floristically than they are to the wetland stands.

Figure 48 is a species ordination using the same analysis as Figure 47. It clearly indicates which species are creating the patterns shown in the stand ordination. Bulrush (Schoenoplectus lacustris ssp. acutus) is in the upper right and aquatics (Potamogeton, Hippuris, and Persicaria amphibia) are in the lower right. In the center of the diagram are species like three square (Schoenoplectus pungens) and wiregrass (Juncus arcticus) which occupy wet meadows. These stands have some floristic similarity to both wetter and drier stands.

When stands scores for Axis 1 are plotted against the maximum water table height for stands during 1991 (Figure 49) a more clear understanding of the wet to dry gradient is revealed. Stands on the right have the highest seasonal water tables with flooded conditions, while stands in the center have either flooding or high water tables (thus most stands are flooded periodically but not annually), and stands on the left have a seasonal high water table several feet below the soil surface. Clearly the first axis, and most of the floristic variability in the data set is controlled by stand hydrologic regimes. Annual or regular flooding is a major selection factor, and only a few of the species (located to the right of 0 on the x axis) are adapted for prolonged periods of seasonal flooding.

When percent coverage of plant species in all stands is plotted against DECORANA axis 1 ordination stand scores the ecological amplitude of species in the ordination space can be seen (Figures 50a and 50b). Species abundances in stands are what is driving the ordination and as described earlier the stands are arranged from wettest to driest. The areas where species overlap occurs is in the center of the ordination space where the wetland emergent species spikerush (Eleocharis

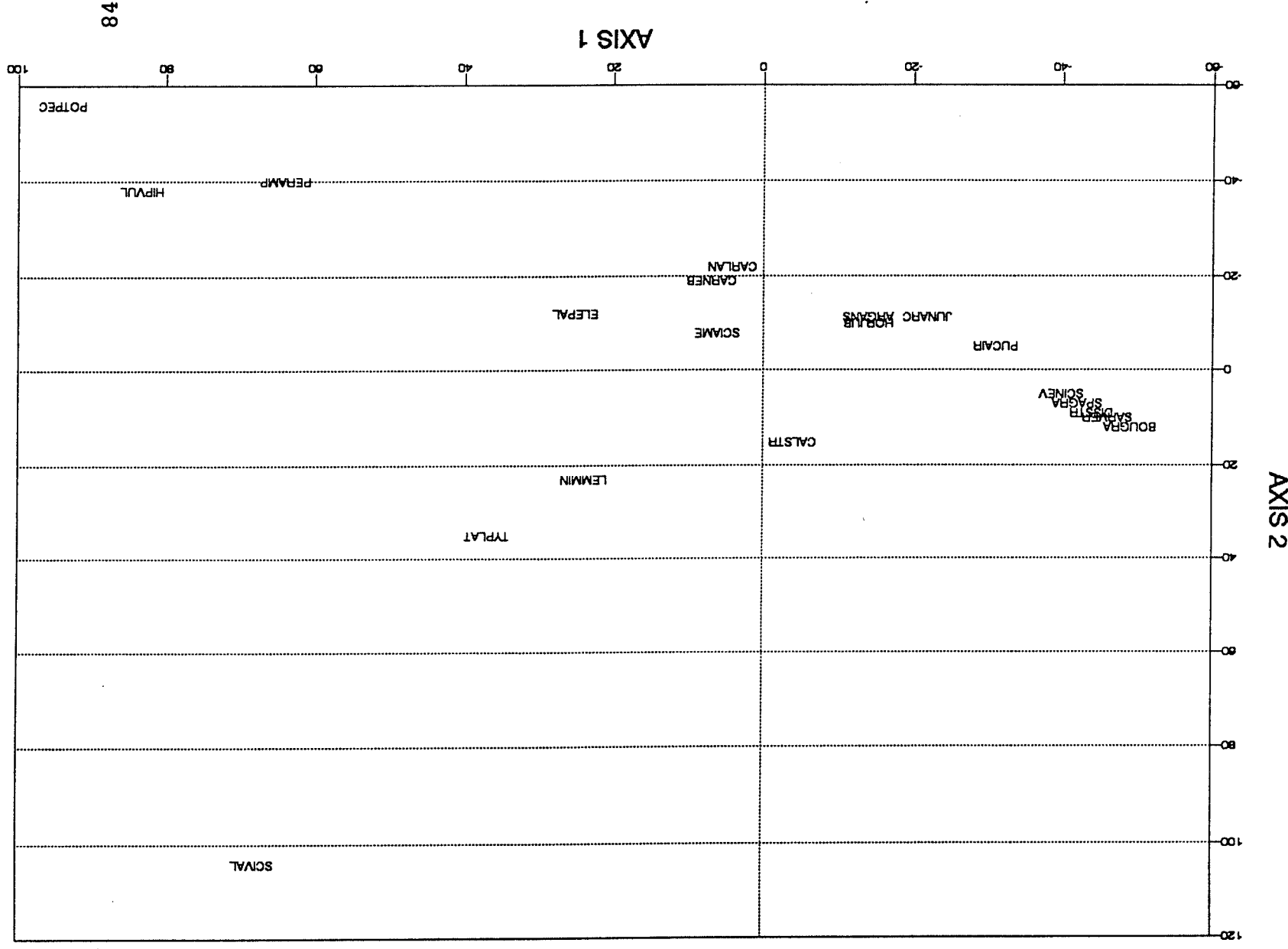


Figure 48. DECORANA ordination of species data from the 149 stands in the San Luis, Mishak and Russell Lakes Study areas. Plant species that are important for creating the positions in the ordination are shown on the graphic.

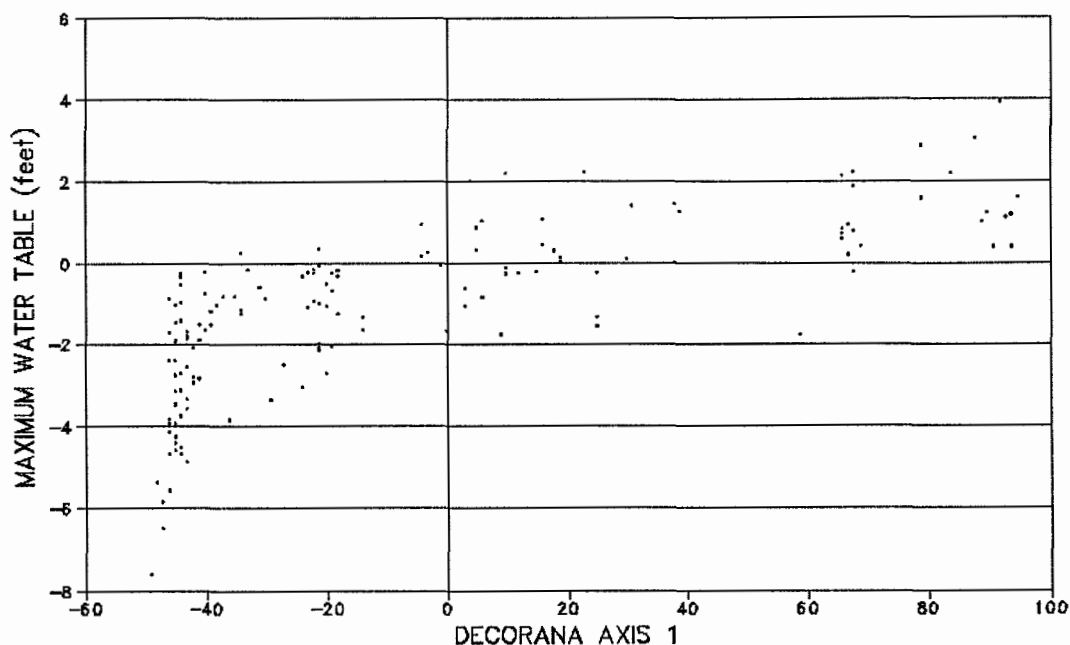


Figure 49.

palustris), hairy sedge (Carex lanuginosa) and three square (Schoenoplectus pungens) occur. These species occupy similar hydrologic positions in the wet to dry gradient, each tolerating some early season flooding. However, the duration of flooding and the salt tolerance of these species is different as will be seen later in this discussion.

Another area of overlap is on the left side of the ordination diagram where bluegrama grass (Bouteloua gracilis), salt grass (Distichlis spicata), greasewood (Sarcobatus vermiculatus) and alkali cordgrass (Spartina gracilis) are shown. What is most interesting about this latter overlap is that these are the most salt tolerant species overlapping with bluegrama grass, the most salt intolerant species. It indicates the tremendously broad tolerance of saltgrass, greasewood and alkali cordgrass for soil salinity. These species are, however, relatively or totally intolerant of flooding.

Canonical correspondance analysis (CCA) was used to analyze this same species data set along with environmental variables for

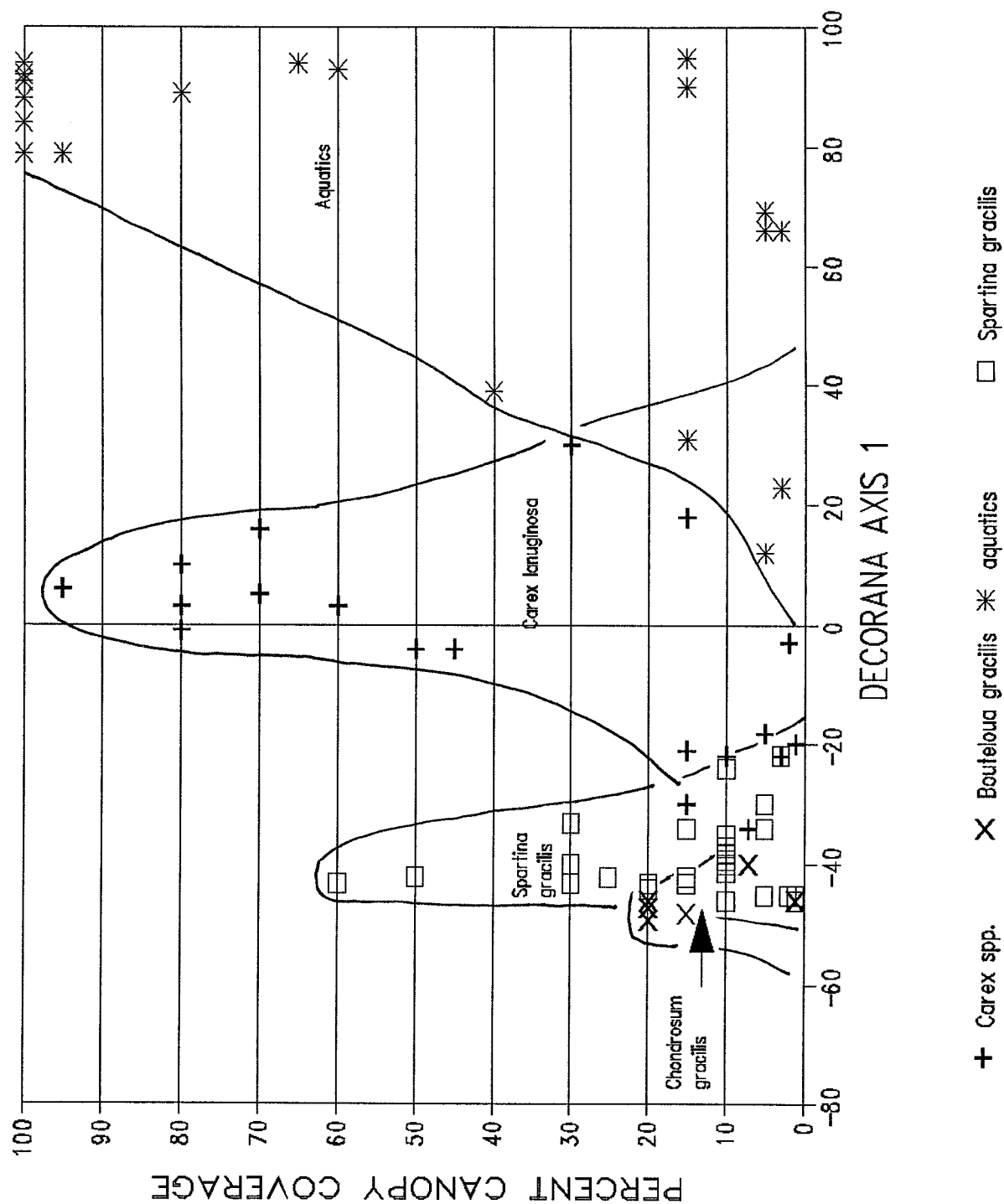
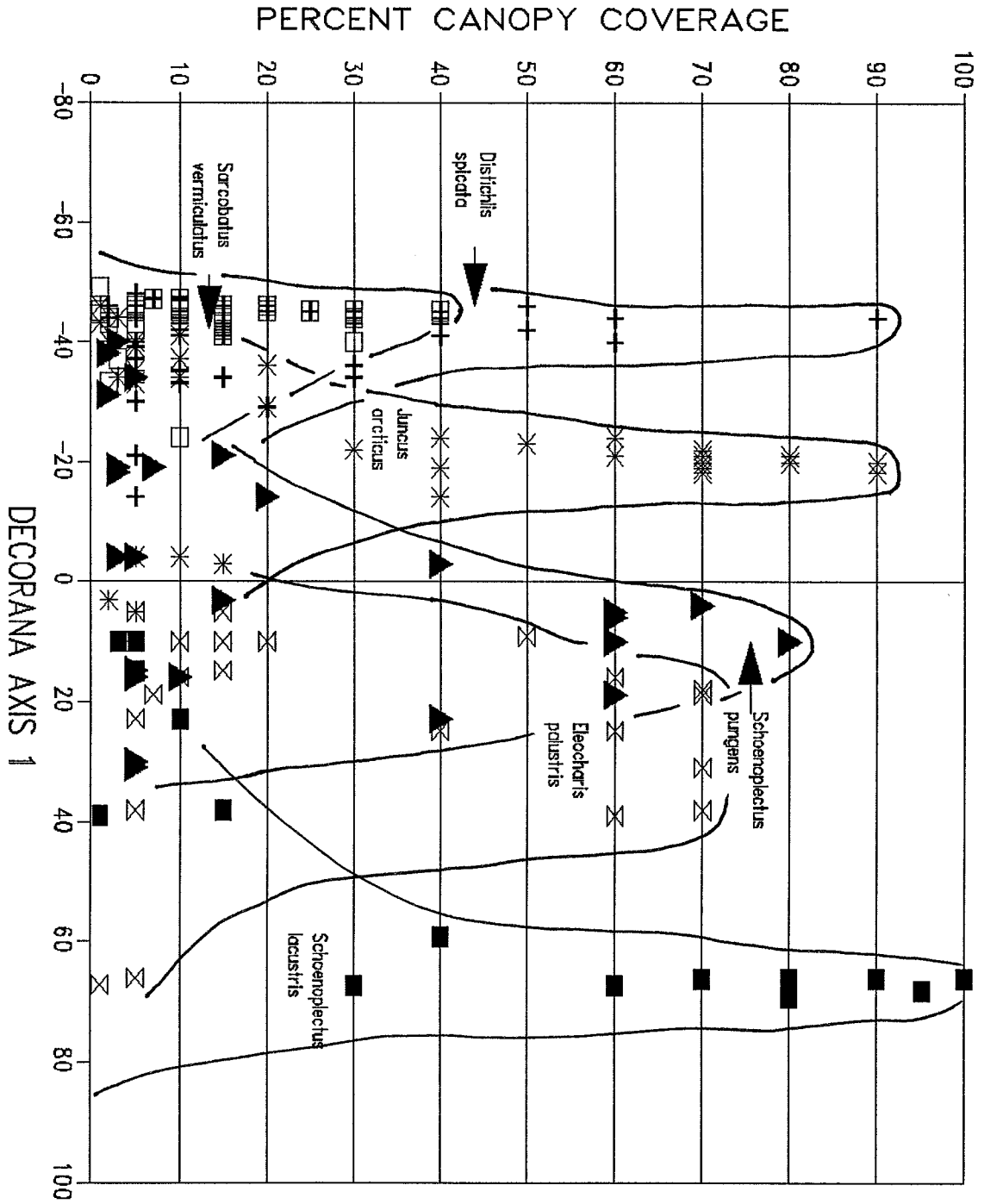


Figure 50a. Plant species coverage plotted against DECORANA axis 1 stand scores. Shown are Chondrosium gracilis, Spartina gracilis, Carex spp., and aquatics. Lines are drawn around the distribution of all species points.

Figure 50b. Coverage vs. DECORANA axis 1 stand scores for *Distichlis spicata*, *Juncus arcticus*, *Schoenoplectus pungens*, *Eleocharis palustris*, *Schoenoplectus lacustris*.



maximum, mean and minimum water tables during 1991 and maximum soil conductance. The graphic output is shown in Figure 51. The stand groups are more clearly separated than in the DECORANA ordination. The salt free bluegrama grass stands are on the right and are separated more from the greasewood and saltgrass dominated stands. The variability in the species data set is tempered somewhat by the environmental data which is more discontinuous than the species data set. The CCA ordination is very useful for making decisions about vegetation classification that are employed later in this report. However, some of the same overlap issues still occur, particularly with the emergent species spikerush, three square and sedge.

VEGETATION ANALYSIS: ZONATION OF PLANT SPECIES AND COMMUNITIES IN THE SAN LUIS VALLEY

Most wetlands in the study areas have very distinct bands or zones around them, each dominated by one or a few species. It gives the impression that distinct communities occur each with some species that also have discontinuous distributions along the wet to dry soil moisture gradient.

Zonation of plant species along the wet to dry soil moisture gradient results from competition between plant species that have different potential niches. A species' potential niche is the total habitat that it could occupy. Potential niches are rarely what is seen in nature because the real world of species on the landscape is in competition with other species. The area actually occupied by a species is its realized niche. Several species are so abundant and dominant in their realized niches and uncommon outside of that niche that what appear to be very distinct zones occur and are repeatedly found throughout the valley. The most prominent species or species groups creating the zonation are; 1) aquatics, 2) hardstem bulrush, 3) spikerush, 4) three square, 5) arctic rush, 6) saltgrass, 7) cordgrass, 8) bluegrama grass. However, the zonation is not identical for every wetland. The gradient is truncated in wetlands that do not have standing water. More importantly, the duration of standing water and the proximity to fresh water cause differences in the emergent zones. This complexity is summarized in Figure 52.

Where a wetland has standing water for some or all of the growing season the aquatic zone is always present in topographically lowest position. However, major differences can occur above this position. Where short duration flooding of only 1-3 months occurs in most years, the hardstem bulrush zone is absent. Playas without adjacent perennial streams or lakes do not have soils flushed with fresh water and soils can be quite saline. In these situations the emergent zone is dominated by spikerush (Eleocharis palustris) which is a facultative halophyte and the aquatic zone may have an abundance of horned pondweed

(Zanichellia palustris) which is an aquatic halophyte. The wet meadow zones can be quite small and poorly developed where the gradient is steep. This type of zonation occurs at the Mishak Lakes study area.

Where there is short duration flooding yet the wetland is adjacent to a stream or lake that provides abundant fresh water for flushing salts from soils, the emergent zone is dominated by hairy sedge (Carex lanuginosa), not spike rush. This is the case at Harrence Lake.

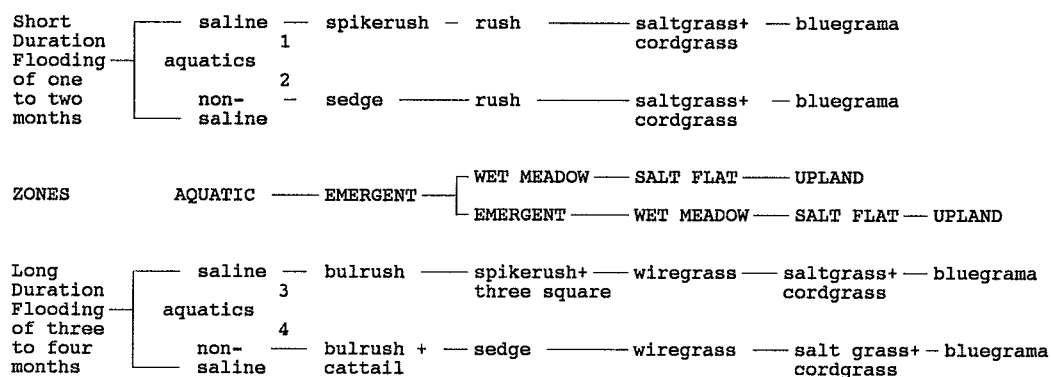
Where longer duration flooding of 3 to 4 months occurs, the aquatic zone and bulrush zone are always present. In many areas two emergent zones are present. However, in many perennial lakes, the aquatic vegetation is poorly developed. This most likely is due to water depths greater than 1 meter which limit light to the lake bottom, and high organic matter content of lake sediments which inhibits plant growth. Where the lake draws down each summer the soils can become quite saline. Again, horned pondweed can dominate the aquatic zone and bulrush dominates the emergent zone. However, cattails (Typha) are absent. Outside the bulrush zone may be a zone dominated by spikerush and/or a zone dominated by three square (Schoenoplectus pungens). The wet meadow, salt flat and upland zones are all usually well developed. This is the situation at South Twin Lake and at the slough between Head and San Luis Lakes.

Where longer duration flooding occurs along a stream or a nearly permanent lake, salts are flushed from the soils. Here the aquatic and bulrush zones occur, yet cattail can replace bulrush. This is present in a few sites at the Russell Lakes study area. In a few situations along streams giant burreed or giant manna grass can replace cattail or bulrush as occurs along Big Spring Creek. The emergent zone outside bulrush or cattail is usually dominated by sedges. The rush, salt flat and upland zones are also well developed here. This is the situation on the south shore of Davey Lake.

The patterns and causes of zonation are essential to

understand in the San Luis Valley. This knowledge can help the planning of hydrologic regimes for wetland construction, enhancement and management programs. For example, this information could be used to interpret why the Mishak Lakes wetlands lack hardstem bulrush stands, and what could be done to create habitat suitable for bulrush. It also helps understand why sedge occurs in certain areas instead of spikerush in the zonation sequence.

Figure 52. Zonation of plant species in the San Luis Valley under four different hydrological scenarios. Scenario one includes short duration flooding and saline soil conditions. Scenario two includes short duration flooding and fresh water and non-saline soil conditions. Scenario three includes long duration flooding and saline soils. Scenario four includes long duration flooding and non-saline soils.



VEGETATION ANALYSIS: CLASSIFICATION

The vegetation classification has been developed using ordination and Braun-Blanquet methods. The ordination was helpful for understanding the main relationships between stands, while the raw stand and species data helped determine dominant and also character species for associations. Character species have narrow niches and are relatively good indicators of certain ecological habitats. The classification contains four levels; class, order, alliance and association. This classification is similar to species taxonomy, with order, family, genus, and species. Genera link similar species just as alliances link similar associations. This classification can be used at any level that a land manager would like. For example, you may wish to talk about salt flats as a class, but within that class you could also recognize many different types of salt flat vegetation. The same is true for emergent vegetation, aquatics and peatlands. Classes are the major habitats, while subordinate units are divided based on floristic composition. First a summary overview of the classification is presented in Table 1, and then a description of the units is provided.

Table 1. Summary of the Vegetation Classification.

Class Potamogeton pectinatus-Zanichellia palustris (aquatic vegetation)	
Order Potamogeton pectinatus-Zanichellia palustris (submergent aquatics)	
Alliance Potamogeton pectinatus-Zanichellia palustris	
Association	
1. Potamogeton pusillus - Zanichellia palustris	
Order Hippuris vulgaris	
Alliance Hippuris vulgaris	
Association	
2. Hippuris vulgaris	
Order Persicaria amphibia (floating leaved aquatics)	
Alliance Persicaria amphibia (floating leaved aquatics)	
Association	
3. Persicaria amphibia	
Class Chara sp. (lakebed algal vegetation)	
Order Chara sp.	
Alliance Chara sp.	
Association	
4. Chara sp. (lakebed algal community)	
Class Schoenoplectus lacustris - Sagittaria cuneata (reed swamps and emergents)	
Order Schoenoplectus lacustris - Sagittaria cuneata	
Alliance Schoenoplectus lacustris - Sagittaria cuneata	
Associations	
5. Schoenoplectus lacustris ssp. acutus (hardstem bulrush)	
6. Typha latifolia - Sagittaria (cattail marsh)	
7. Eleocharis palustris (spike rush marsh)	
8. Sparganium eurycarpum (burreed marsh)	
9. Glyceria maxima ssp. grandis (giant manna grass)	
Alliance Carex utriculata (large sedge swamps)	
Associations	
10. Carex utriculata (beaked sedge)	
11. Carex vesicaria	
Alliance Schoenoplectus pungens (three square alkaline marshes)	
12. Schoenoplectus pungens (three-square)	
Class Carex aquatilis - Pedicularis groenlandica (small sedge minerotrophic peatlands)	
Order Carex aquatilis - Pedicularis groenlandica	
Alliance Carex aquatilis - Pedicularis groenlandica	
Associations	
13. Carex aquatilis (water sedge fens)	
14. Carex simulata (floating fens)	
Class Juncus arcticus - Deschampsia cespitosa (wiregrass and hairgrass wet meadows)	
Order Juncus arcticus - Deschampsia cespitosa (wiregrass and hairgrass wet meadows)	
Alliance Juncus arcticus - Deschampsia cespitosa (wiregrass wet meadows)	
Associations	
15. Juncus arcticus - Argentina anserina (wiregrass meadows)	
16. Deschampsia cespitosa (hairgrass meadows)	
17. Agrostis gigantea (redtop meadows)	
Alliance Carex nebraskensis (nebraska sedge meadows)	
18. Carex nebraskensis (nebraska sedge meadows)	
19. Carex lanuginosa - Calamagrostis stricta (hairy sedge meadows)	
Class Puccinellia airoides - Triglochin maritimum (inland salt meadows and flats)	
Order Puccinellia airoides - Triglochin maritimum (inland salt meadows and flats)	
Alliance Puccinellia airoides - Triglochin maritimum (inland salt meadows)	
Associations	
20. Distichlis stricta (saltgrass flats)	
21. Spartina gracilis - Scirpus nevadensis (alkali cordgrass flats)	
22. Glaux maritima - Plantago eriopoda (seaside milkwort flats)	
Order Sarcobatus vermiculatus	
Alliance Sarcobatus vermiculatus (greasewood flats)	
Association	
23. Sarcobatus vermiculatus -bare. (greasewood flats)	
Class Chenopodium glaucum-rubrum (drawdown vegetation of annual plants in playas)	
Order Chenopodium glaucum-rubrum	
Alliance Chenopodium glaucum-rubrum	
Association	
24. Chenopodium glaucum (drawdown community)	
Class Bouteloua gracilis - Stipa comata (upland grasslands)	
Order Bouteloua gracilis - Stipa comata	
Alliance Bouteloua gracilis - Stipa comata	
Associations	
25. Bouteloua gracilis (bluegrama grass grassland)	
Alliance Calamovilfa longifolia - Andropogon hallii (sand prairie grasslands)	
26. Oryzopsis hymenoides (sand dune grasslands)	
Alliance Sporobolus airoides (alkali sacaton grasslands)	
Association	
27. Sporobolus airoides (alkali sacaton grasslands)	

VEGETATION ANALYSIS: DESCRIPTION OF THE VEGETATION UNITS

Class *Potamogeton pectinatus* - *Zanichellia palustris* (aquatics). This class includes the submergent vegetation of ponds and slow moving streams. In the study area these communities occur where there is seasonal or permanent standing water. The best developed communities all occur in small to medium sized ponds. Larger lakes, which have permanent pools do not support dense stands of submergent vegetation. This is most likely due to wind erosion of the aquatic beds and the accumulation of organic matter in anaerobic sediments. These sediments are not conducive to the growth and propagation of aquatic plants. Temporary ponds draw down annually or periodically allowing the decomposition of organic matter maintaining mineral sediments that provide greater nutrient availability and greater aerobic rooting environment. Species that can only survive as submerged in water occur here, including; *Potamogeton* spp., *Zanichellia palustris*, aquatic species of *Batrachium*, along with species that have floating leaves, such as *Persicaria amphibia* and species that can be either totally submerged or partially emergent, such as *Hippuris vulgaris*.

Order *Potamogeton pectinatus* - *Zanichellia palustris*. This order includes the submergent vegetation of ponds and slow streams as described above.

Alliance *Potamogeton pectinatus* - *Zanichellia palustris*. This order includes the submergent vegetation of ponds and slow streams as described above.

Associations

1. *Potamogeton pusillus* - *Zanichellia palustris*. This is the most common aquatic community occurring in the San Luis Valley. It dominates the deepest water of all ponds in the Mishak Lakes area, along with Twin Lakes and the slough in the San Luis Lakes area, and the center of small ponds and protected bays in the Russell Lakes area. This community provides the primary feeding areas for waterfowl, some shorebirds, fish and fish eating birds such as herons. It occurs in areas with

standing water for most of the growing season, and the water depth usually ranges from 1 to 3 feet.

Order Hippuris vulgaris. This order includes the rank submergent and emergent vegetation dominated by mare's tail (*Hippuris vulgaris*). This species occurs only at Island Lake and the slough south of Head Lake.

Alliance Hippuris vulgaris.

Association

2. *Hippuris vulgaris*. Communities dominated by *Hippuris vulgaris* occur in two portions of the study area; the slough at San Luis Lakes and the northern part of Island Lake in the Russell Lakes area. It is a very productive aquatic community.

Order Persicaria amphibia. This order includes the rank floating leaved aquatic communities dominated by water smartweed (*Persicaria amphibia*).

Alliance Persicaria amphibia.

Association

3. *Persicaria amphibia*. Communities dominated by this floating-leaf species occur in the Slough area of the San Luis Lakes region. The floating leaves of *Persicaria amphibia* are the primary habitat for the larvae of an aquatic beetle (sp) and tremendous populations of these invertebrates were observed. This is an extremely productive community that frequently mixes with *Potamogeton pectinatus* - *Zanichellia palustris*.

4. *Chara* sp. Lakes that have severe wind erosion, and organic sediments have a very open aquatic community occupied solely by the alga *Chara* sp. It is usually the only species present and it is usually not very productive.

Class Schoenoplectus lacustris ssp. acutus - Sagittaria cuneata (emergents). This provisional class includes the tall and medium height emergent vegetation of pond margins and slow moving streams. The communities of this class provide the highest primary production of any community in the San Luis Valley;

particularly the hardstem bulrush and cattail communities. These communities usually occur where there is seasonal standing water up to 1.5 feet in depth. When the water persists for most of the summer bulrush stands form dense reed swamps with stems up to 8 feet tall. Where the water is of shorter duration, such as at Mishak Lakes, the community in shallow water outside aquatic communities is dominated by spike rush and bulrush will be absent. Cattail-dominated stands are uncommon in the San Luis Valley because they are intolerant of high salinity in water and soil. They are absent throughout the Valley where the conductance of surface water is greater than 200-300 umhos/cm². Small cattail stands are present along Big Spring Creek in the San Luis Lakes area and around artesian wells in the Russell Lakes area. Giant burreed and manna grass are present in several areas in the San Luis Lakes area in the pure water of Big Spring Creek. These communities also occur around artesian wells throughout the Valley.

Order Schoenoplectus lacustris - Sagittaria cuneata. Same as the class.

Alliance Schoenoplectus lacustris - Sagittaria cuneata. Same as the class.

Associations

5. Schoenoplectus lacustris ssp. acutus (hardstem bulrush). This community usually is a monoculture yet has the highest primary production of any community in the study area. The dense and tall stems provide the only nesting habitat for many bird species, including marsh wren, eared grebe and white-face ibis. Many other birds use this community as habitat. As described above, hardstem bulrush is moderately tolerant of oligosaline water which has a conductance greater than 800 umhos/cm² (Cowardin et al. 1979). It should be remembered that this conductance does not have to occur at all times, it could be the annual or periodic maximum which is enough to exclude species intolerant of anything but fresh water, conductance less than 800 umhos/cm². In some stands duckweed

(Lemna minor), bladderwort (Utricularia ochroleuca) and other aquatic plants can occur.

6. Typha latifolia - Sagittaria cuneata. Reed swamps dominated by cattail are uncommon in the San Luis valley because most surface waters are periodically or continuously oligosaline. This is enough to keep cattail from invading or persisting.

7. Eleocharis palustris (spike rush). Spikerush stands occur on the margins of ponds where the seasonal water depth is less than 1.0 feet. Stands can occur landward of taller reed swamps dominated by bulrush, or they can be the only emergent stands present. In the Mishak Lakes area this is the primary emergent community on pond edges. This is due to the short-duration flooding in that area.

8. Sparganium eurycarpum (giant burreed). Giant burreed communities, which superficially look like cattail communities, occur in the freshest moving water areas in the San Luis Valley. In our study areas this community only occur in the Big Spring Creek channel between Head and San Luis Lakes. The stands are small, usually less than 400 m², and scattered.

9. Glyceria maxima ssp. grandis. A few small stands dominated by giant manna grass occur along Big Spring Creek on the Medano Ranch. The stands occur in the creek channel and impinge on the flow. Plants are up to four feet tall. Giant manna grass is indicative of disturbed environments (Shay and Shay 1988) and the disturbance is probably a combination of cattle grazing and periodic flooding.

Alliance Carex utriculata (large sedge swamps). Large sedge swamps occur in cold soils with shallow standing water for long duration during the growing season. Soils can be peat. In Colorado beaked sedge (Carex utriculata) is the dominant species in these swamps.

Associations

10. Carex utriculata (beaked sedge). In the San Luis Valley beaked sedge communities were seen only at

groundwater discharge sites in the Villa Grove study area. Seasonally there was 10-30 cm of standing water which apparently is enough to keep other sedges from invading the sites. This very large and productive sedge forms peat soils. Snipe frequently nest in and around these communities, particularly on hummocks.

11. Carex vesicaria. One stand which was a monoculture of Carex vesicaria was seen in the study area, along Big Spring Creek at transect 1 in the San Luis Lakes area. This is a large sedge, similar to Carex utriculata.

Alliance Schoenoplectus pungens (three-square).

Association

12. Schoenoplectus pungens (three-square). Stands dominated by three-square occur on the edges of ponds and streams. The stands are inundated early in the growing season. They usually occur on the landward side of stands dominated by spikerush and bulrush, but lower in elevation than those dominated by wiregrass (Juncus arcticus). The stands are tolerant of relatively high salt concentrations in soil. Stands along the edges of freshwater lakes that have non-saline soils are dominated by Carex lanuginosa instead of three square.

Class Carex aquatilis - Pedicularis groenlandica (peatlands). Peatlands ecosystems have waterlogged and anaerobic soils for most of the summer. Waterlogging inhibits the decomposition of root, leaf and shoot litter which accumulates and becomes a dominant component of the soil. Peatlands in Colorado occur where groundwater is discharged by a strong and constant aquifer that keeps soils saturated. In the northern San Luis Valley floor peatlands were only observed in the Villa Grove area. Peatlands are more common higher in the mountains. San Luis Valley peatlands are rich fens, meaning that they are fed by groundwater with relatively high concentrations of calcium and other salts. The two San Luis Valley communities in this class are dominated by Carex aquatilis and Carex simulata. Carex

simulata-dominated stands occur only in quagmires (floating peat mats in areas with very strong upward groundwater discharge). Where breaks in the peat turf occur and water spills to the surface small populations of Epilobium ciliatum and Mentha arvensis occur along with Nasturtium officinale. Carex aquatilis dominated stands occur in areas without deep standing water, but in areas that are not quagmire.

Order Carex aquatilis - Pedicularis groenlandica (rich fens). Same as class.

Alliance Carex aquatilis - Pedicularis groenlandica (rich fens). Same as class.

Associations

13. Carex aquatilis - Drepanocladus aduncus.

Small stands of Carex aquatilis occur in the southern study area at Villa Grove. The stands occupy constantly wet sites that do not have greater than 10 cm of standing water during the growing season (sites with greater than 10 cm of water are occupied by Carex utriculata), and do not occur in quagmires (these sites are occupied by Carex simulata), or strongly minerotrophic springs (these sites are occupied by Carex nebraskensis). Carex aquatilis forms a near monoculture, but small populations of moss occur in the ground layer.

14. Carex simulata. A large number of small stands dominated by a dense floating turf of Carex simulata occur in the southern Villa Grove study area. The mats can support a man's weight but are quagmires, and remind us of a water bed. These stands are usually monocultures, although small populations of Carex nebraskensis can also occur.

Class Juncus arcticus - Deschampsia cespitosa (wiregrass and hairgrass wet meadows). Wet meadows are abundant in the northern San Luis valley occurring on level plains or the margins of lakes and streams where the water table is near the surface for at least the early part of the summer. These communities occupy more area than all other wetland types occurring in the San Luis

Valley combined. Many of these stands are used for agricultural purposes. Some are provided with supplemental irrigation water and some are mowed for hay production. Most have a large number of plant species occurring in the stands. These communities provide nesting habitat for waterfowl and grazing for native ungulates.

Order Juncus arcticus - Deschampsia cespitosa (wiregrass and hairgrass wet meadows). Characteristics are the same as class.

Alliance Juncus arcticus - Deschampsia cespitosa (wiregrass and hair grass wet meadows).

Characteristics are the same as class.

Associations

15. Juncus arcticus - Argentina anserina. Stands dominated by wiregrass (Juncus arcticus) are abundant in the San Luis Valley. This is probably the most abundant community in the region. It occurs where the water table reaches to near the soil surface for much of the early part of the growing season, although it can be dry later on. Soils are generally low in salt concentration, but Juncus plants can also occur in quite salty and dry sites.

16. Deschampsia cespitosa (hairgrass wet meadows). A few stands dominated by hairgrass occur in the Villa Grove area. They are closely related to wet meadows dominated by Juncus arcticus and Agrostis gigantea.

17. Agrostis gigantea (redtop wet meadows). Redtop is a pasture grass introduced into North America from Eurasia and is widely cultivated as hay. This species escapes cultivation and can be found in many wet meadows in the western U.S. including those that are no longer cultivated or have never been cultivated.

Alliance Carex nebraskensis (nebraska sedge meadows)

18. Carex nebraskensis (nebraska sedge). Nebraska sedge is common in certain portions of the San Luis Valley, particularly in the Villa Grove area. It occupies springs and

other sites that have a water table near the soil surface for most of the growing season. It can occupy seasonally flooded sites and can tolerate moderate salinity.

19. Carex lanuginosa - Calamagrostis stricta (hairy sedge meadows). This is the most widespread sedge meadow in the San Luis valley typically occurring on lake and water course shores where there is early season flooding and a high water table for most of the growing season. Soils are quite salt free.

Class Puccinellia airoides - Triglochin maritimum (inland salt meadows and salt flats). Inland salt meadows and salt flats are abundant in the San Luis Valley. They develop in areas where the capillary fringe reaches the soil surface for portions of growing season. As the ground water evaporates, salt accumulates in the upper soil horizons. Soil salinities, as determined by soil extract conductivity, can be 100 to 500 times higher than sites where the capillary fringe does not intersect the soil surface and the water table also does not reach the soil surface. Only a few species are adapted for these high salt, and periodically wet conditions. They are: Distichlis stricta, Spartina gracilis, Scirpus nevadensis, Sarcobatus vermiculatus, Glaux maritima, Puccinellia airoides, and Triglochin maritimum.

Order Puccinellia airoides - Triglochin maritimum (inland salt meadows and salt flats)

Alliance Puccinellia airoides - Triglochin maritimum (inland salt meadows and salt flats)

Associations

20. Distichlis stricta. Nearly pure stands of inland salt grass occur throughout the San Luis Valley. They occur in many of the saltiest areas in the valley and in the saltiest portions of the wetland to upland gradient.

21. Spartina gracilis - Amphiscirpus nevadensis (alkali cordgrass - nevada bulrush salt flats). Stands dominated by alkali cordgrass and/or nevada bulrush occur above the zone

dominated by Juncus arcticus along the wet to dry gradient. The species can tolerate soils that are periodically saturated to the surface. Salinity is usually not as high as in stands dominated by Distichlis stricta. This is a very widespread community in the San Luis Valley. Plants are usually scattered and production is low.

22. Glaux maritimum - Plantago eriopoda. This community occurs on salt flats on the eastern side of the valley at Villa Grove. Salts are precipitated at the soil surface and the water table is usually within 2-3 feet of the soil surface at some time during the growing season.

Order Sarcobatus vermiculatus

Alliance Sarcobatus vermiculatus

Associations

23. Sarcobatus vermiculatus - bare. Greasewood dominated flats are abundant in the San Luis Valley. The communities lumped here are what we call "Chico con nada". They are pure stands of greasewood with little or no understory. They occur in areas where the water table is close to the soil surface for much of the growing season and have very high soil salinities. The greasewood forms a very open canopy, usually only 10 to 15 percent canopy coverage. Soils will have a hard crust and in the dry season can have a deposit of free salts on the surface.

Class Chenopodium glaucum-rubrum (Drawdown communities of annual plants). Playas that periodically fill and dry up during the summer support communities of annual plants that flourish for the short periods of times following drawdown. These communities are populated by species that can tolerate both dry conditions and periodically flooded conditions. They all germinate readily following drawdown, grow, flower and set seed in a few weeks. The seeds remain dormant through the wet phase of playa filling and germinate once the playa dries. Species indicative of this class are: Chenopodium glaucum, Chenopodium rubrum, Atriplex

rosea, Plagiobothrys scouleri and Suaeda calicioliformis.

Order Chenopodium glaucum-rubrum Same as the class.

Alliance Chenopodium glaucum-rubrum. Same as class.

Association

24. Chenopodium glaucum. This association occurs on drying playa floors. It consists totally of annual, salt tolerant, drought and flooding tolerant fast growing species. Many are considered weeds.

Class Bouteloua gracilis - Stipa comata (short grass prairie and sand prairie). Communities dominated by non-hydrophyte grasses occur in stands where the water table never reaches within a few feet of the soil surface. Many species, such as bluegrama grass, are intolerant of salty soils. These communities are dominated by bluegrama grass in stable relatively salt free soils, by indian rice grass in sandy and loose soils, and by alkali sacaton in salty soils. The bluegrama stands are species rich (for the San Luis Valley), containing many herbaceous and woody plants.

Order Bouteloua gracilis - Stipa comata. Same as class.

Alliance Bouteloua gracilis - Stipa comata. This alliance includes the relatively salt-free stands dominated by bluegrama grass, needle and thread grass and indian rice grass.

Associations

25. Bouteloua gracilis - Opuntia compressa.

Bluegrama grass communities occur in the most salt-free and dry sites in the San Luis Valley. Soils are well drained and at least 2-3 feet above the seasonal high water table. The well-drained soils allow leaching of all salts to the water table leaving salt-free soils. The soils are loose and single grain in many soils. Shrubs such as greasewood, rabbitbrush (Chrysothamnus nauseosus) and Senecio spartioides occur in the stands. Prickly pear cactus (Opuntia compressa) are also common as are yucca (Yucca glauca).

Alliance Calamovilfa longifolia - Andropogon hallii (sand prairie grasslands).

26. Oryzopsis hymenoides - Muhlenbergia pungens (sand dune grasslands). This association occurs on loose sand deposits and is dominated by species that are colonizers and stabilizers of sand. This community is particularly common in the eastern portion of the San Luis Valley where dunes are abundant.

Alliance Sporobolus airoides. Alkali sacaton grasslands.

27. Sporobolus airoides (alkali sacaton grasslands). Alkali sacaton dominated grasslands occur throughout the San Luis Valley. The grass forms a scattered understory to greasewood. Species diversity is low and the stands usually occur in locations where the capillary fringe can periodically reach the soil surface and create conditions too salty for the bluegrama grass and other non-halophytes.

VEGETATION ANALYSIS: DIRECT GRADIENT ANALYSIS OF THE MAJOR PLANT COMMUNITIES

Direct gradient analysis is utilized to illustrate the habitat occupied by the most important plant communities in the study area. Habitat is simply defined here as the physical environment where the community occurs. The environmental variables of hydrologic regime and soil chemistry have been measured and determined to be the most important physical factors. These factors are used to analyze where species occur on the landscape.

Figure 53 is a diagram synthesizing the realized niches of 9 important plant communities in the San Luis Valley along two environmental gradients; maximum soil conductivity and the 1991 water table maximum. Several communities are largely monocultures, dominated by one species; eg. bulrush and spikerush. Dominance by one species is common in high water table and high salt concentration ecosystems. It gives the distinct impression that there is definite community zonation in bands around a marsh. However, Johnson et al (1987) have shown

that in several South Dakota prairies, the species formed a virtual continuum and the only discontinuity occurred along lake shores due to wave exposure and ice. However, in the San Luis Valley the discontinuity of dominant plant species is apparent and vegetation composition differences are easily detected while moving uphill from a marsh center. The portion of this two dimensional gradient occupied by each community is outlined to include all stands of each community. It was predictable that the principle gradient would be the water table and that communities in the figure would be ordered from top to bottom along this gradient. Aquatics and emergents are at the top of the figure and wet meadows, salt flats and upland grassland occur farther toward the bottom.

The soil conductivity (salinity) gradient however, brings to light some other important features of the vegetation. Communities such as salt flats and wet meadows span a much greater range than do communities at the wettest or driest end of the moisture gradient. Aquatic, bulrush and sedge communities occupy very small ranges in the salinity gradient. However, communities dominated by alkali cordgrass, saltgrass or greasewood occupy very broad ranges along the salinity gradient, extending from the most salt free to the most saline soils in the study area. The wettest communities are tolerant of flooding, but intolerant of saline soils. Wet meadow communities are tolerant of short periods of flooding and moderate salinity. Salt flat communities are intolerant of flooding, but are tolerant of a wide range of soil environments, both salt free and high salinity. Bluegrama grass communities are intolerant of both soil saturation and salinity.

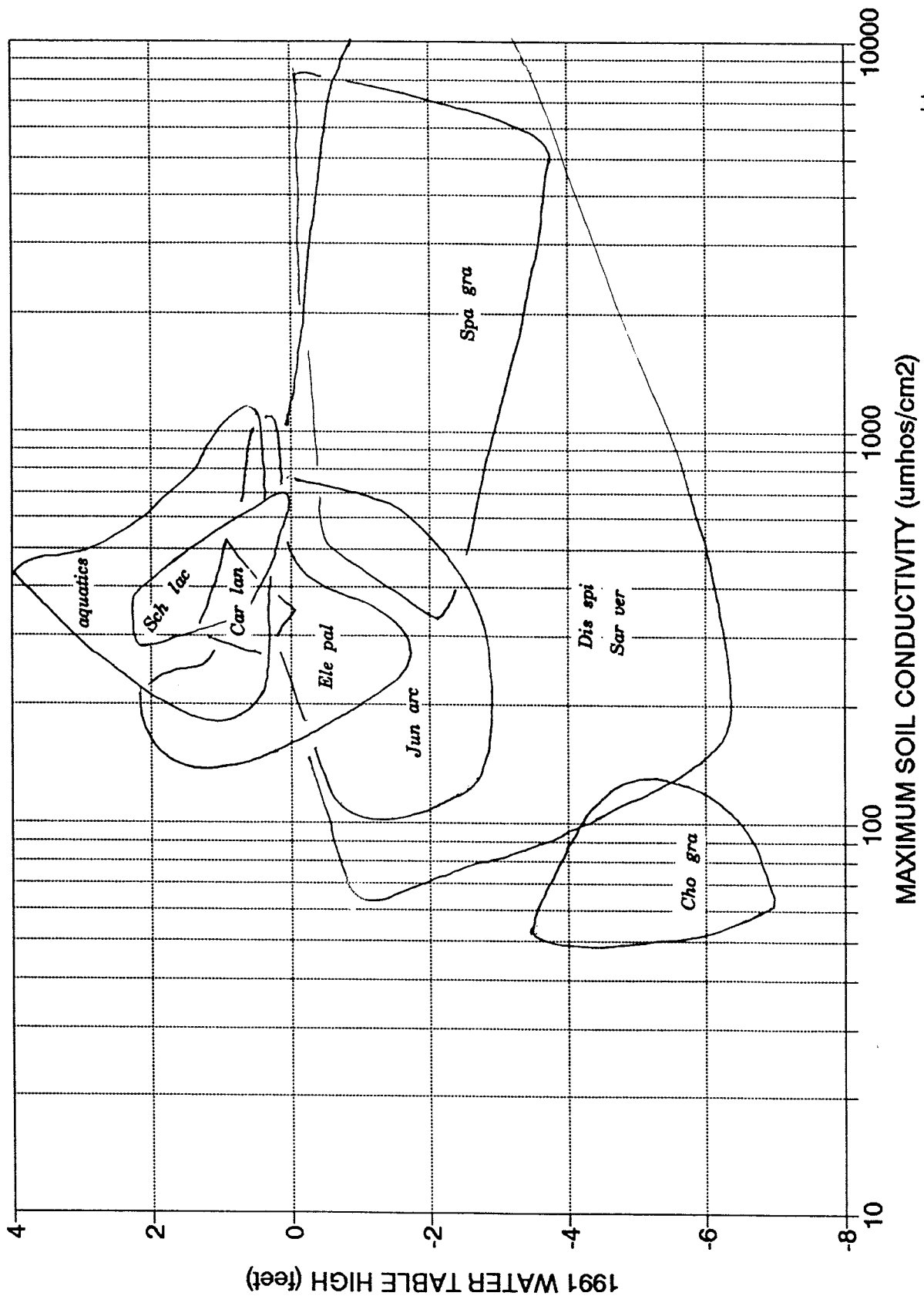


Figure 53. Graphic of direct gradient analysis of stand maximum water table and maximum soil conductivity during 1991 showing area occupied by stands dominated by the species shown.

VEGETATION ANALYSIS: PRIMARY PRODUCTION

NET HERBACEOUS PRODUCTION

Net herbaceous production is the total above ground dry weight of leaf and stem produced by living plants during 1991. To determine this weight for a community, plants in randomly selected plots within study stands were clipped, placed in bags, dried and weighted as described in the methods section. Total net herbaceous production is an extremely important measurement when comparing plant communities in the San Luis Valley because most natural communities have very low production, but a few have high or very high production. Production is an important feature of wetlands because this organic matter provides habitat structure for bird nesting and cover for all animals. Plant organic matter is the primary food for aquatic and terrestrial insect larvae. Thus, food chains begin with plant production. Plant production can be used as an indirect measure of the potential of a community for supporting certain wildlife species.

We have measured net above ground primary production; plants use a proportion of the carbon fixing during photosynthesis for their own respiration. We measured carbon that plants allocate to above ground growth.

We hypothesized that the same two environmental factors that control the distribution of plant communities would also control most of the variability in plant community production; soil salinity (estimated here as conductivity of soil extract) and water table. High soil salinity and lower water tables would result in lower plant production.

Production by Community Type

Standing crop (production) data for the major community types in the study area were pooled and means and standard deviations developed. This data is provided in Table 1. The community types used in this analysis are listed below:

- 1) aquatic communities pooled together;
- 2) Typha latifolia - Sagittaria cuneata;
- 3) Schoenoplectus lacustris;
- 4) Carex lanuginosa - Calamagrostis stricta;
- 5) Schoenoplectus pungens -;
- 6) Carex nebraskensis;
- 7) Eleocharis palustris;
- 8) Juncus arcticus - Argentina anserina;
- 9) Chenopodium glaucum - rubrum (playa);
- 10) Spartina gracilis - Amphiscirpus nevadensis;
- 11) Distichlis stricta;
- 12) Sporobolus airoides;
- 13) Sarcobatus vermiculatus;
- 14) Bouteloua gracilis - Opuntia compressa and Oryzopsis hymenoides - Muhlenbergia pungens (pooled)

Production data in Table 2 show great variability for San Luis Valley study area communities ranging from 1781 g/m² for bulrush communities, to less than 200 g/m² for salt flat, playa and upland grass dominated communities. Within community variability is also high, with standard deviations almost as large as means for many communities and broad ranges. Community three, bulrush (Schoenoplectus lacustris ssp. acutus) has an extremely wide range, from 123 to 1,781 g/m². This variability is a function of water table, with the most productive stands occurring in the wetter sites as is shown in Figure 54. Clearly stands with a mean water table at the soil surface or below the soil surface during 1991 had production that was only 10% to 20% as high as stands that were flooded for longer periods of time and had a mean water table above the soil surface. This information could be used to develop management plans for bulrush communities on wildlife areas in the study area.

Table 2. Net standing crop (primary production) for 14 major community types in the study area. Community types numbers are listed above. Number of stands sampled is listed under n. Mean production and standard deviation (sd) are also shown.

Community	n	mean prod	sd	range
1	7	316.6	229.4	136-794
2	1	2213.0	-	2213
3	11	791.2	587.2	123-1781
4	6	501.6	402.7	197-1293
5	9	461.7	339.4	116-1237
6	2	541.0	285.0	
7	8	352.2	218.1	107-686
8	20	387.0	131.0	143-636
9	2	9.3	13.1	20-203
10	16	138.5	102.5	29-428
11	14	159.2	117.8	27-395
12	4	133.6	95.7	46-266
13	12	84.3	68.5	20-204
14	6	35.9	12.9	29-56

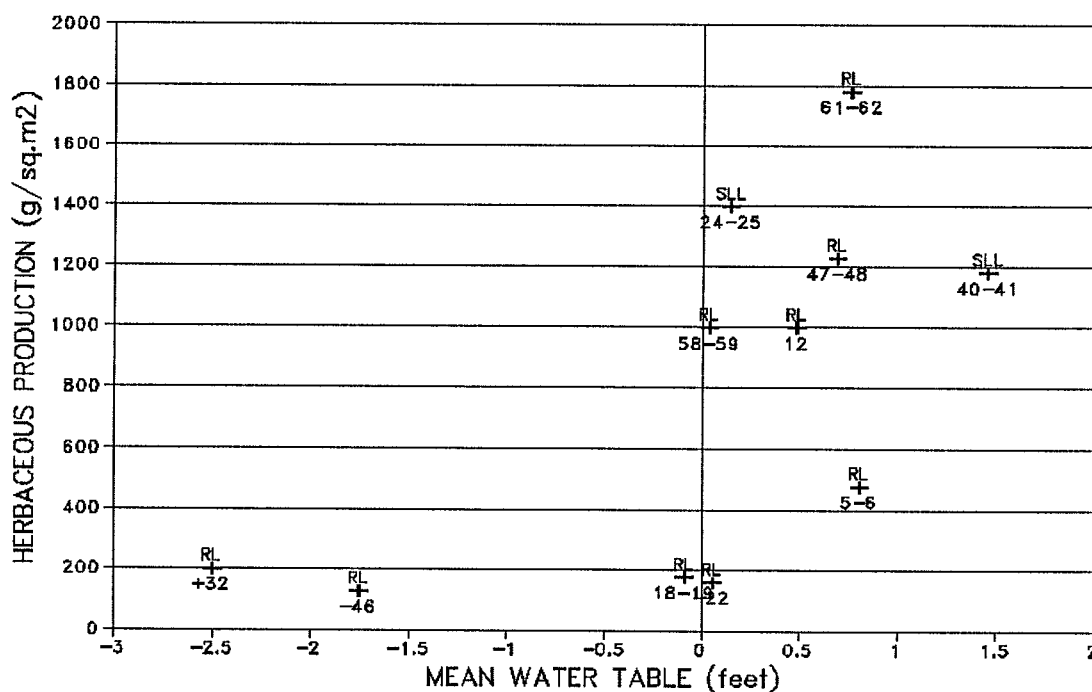


Figure 54. Primary production (g/m^2) for bulrush stands during 1991 plotted vs. mean water table for stands.

Table 3 provides data for comparing the production of San Luis Valley wetlands with similar wetland communities in other parts of the western U.S. Community 1, aquatics, shows that the San Luis Valley communities have high primary production. Particularly the dense stands dominated by Potamogeton pusillus, Zanichellia palustris and Hippuris vulgaris. Stands dominated by Hippuris can be nearly as productive as emergent communities dominated by bulrush! Only one cattail stand, community 2, occurs along the study area transects, and it was the only one sampled for production. Production was quite high, nearly as high as the most productive stands found at Great Salt Lake, Utah. Bulrush stands, community 3, were very variable, as mentioned above. However, the most productive stands were the most productive bulrush stands found in the literature, while the least productive stands were among the lowest. Community 4, sedge (Carex lanuginosa) stands had production close to that reported for sedge stands in Iowa marshes. The most productive sedge stand along our study transects was along Big Spring Creek on the Medano Ranch. Its production was similar to an emergent community. Community 7, spikerush, production was similar to the only data reported in the literature.

This literature review indicates that some San Luis Valley wetland communities have production similar to other marsh wetlands reported for the northern prairies of the U.S. and Canada and for marshes around Great Salt Lake, Utah. Thus, where properly managed very productive marshes can be maintained in the study area.

Table 3. Comparison of standing crop of San Luis Valley wetland communities with similar wetland communities in the U.S. All values are in g/m².

Community	SLV		Iowa(1)	Alta(2)	Manit(3)	Utah(4)
	mean	range				
1	316.6	136-794	156-225	30-297		
2	2213			322	1750	521-2532
3	791.2	123-1781	511-541		94-570	915-1559
4	501.6	197-1293	541-792	116-368		
5	461.7	116-1237				
7	352.2			341-447		

Data Sources

- 1 = van der Valk and Davis 1976
- 2 = van der Valk and Bliss 1971
- 3 = Shay and Shay 1986
- 4 = Smith and Kadlec 1985

Production vs. Soil Conductivity

Using the vegetation classification described above, environmental data for the 14 community types were pooled and mean soil conductivities developed. Figure 55 shows the relationship, by community type, between mean production and maximum soil conductivity during 1991. Four rather distinct groups of communities are seen on this diagram. The first group includes Typha (cattail and similar emergents) and Schoenoplectus lacustris ssp. acutus (bulrush) communities that have the highest mean production in the study area. These communities occur in shallow seasonal or permanent standing water. The second group, the bluegrama grass dominated and related communities, had the lowest conductivity and very low production. These stands occupy nearly salt free stand and they also have deep water tables, well below the root zone of plants. The dry conditions cause low production. The third group includes the wet meadows and aquatic vegetation types dominated by Carex nebraskensis, Carex lanuginosa, Schoenoplectus pungens, Juncus arcticus, Eleocharis palustris and Potamogeton pusillus. These communities occur where the water table is close to the surface of the soil at some time during the summer or the site is flooded with deep water for long periods of time. Mean soil conductivity is less than 1000

umhos/cm² for these communities. The fourth group are the salt flat communities occurring near the capillary fringe and affected by high concentrations of salt accumulation in soils. These communities have low production and high soil salts. They are dominated by Distichlis stricta, Spartina gracilis, Sporobolus airoides and Sarcobatus vermiculatus. Playas, with little plant growth, are also included in this category.

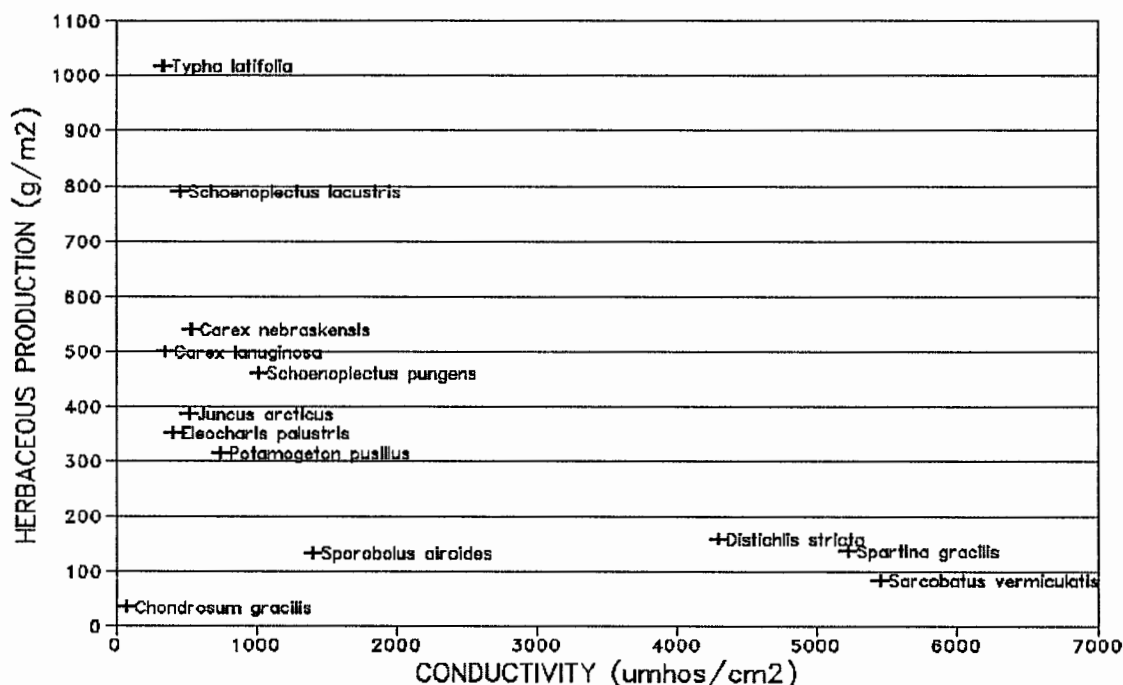


Figure 55. Mean primary production for 13 community types vs. mean maximum conductivity for each community during 1991.

The pattern obvious in this simple plot of community means is that communities with mean net production greater than 200 g/m² have mean soil conductances less than 800-1,000 umhos/cm², and most have means less than 500 umhos/cm². Communities that have mean net production less than 200 g/m² have the least or most salty soils. Obviously the distribution of salt is controlled by water table factors that will be discussed later in this section.

Another view of the overall patterns of production to soil conductivity is shown in Figure 56, which is a scatter diagram of raw stand data. Conductivity is plotted on a log scale. The

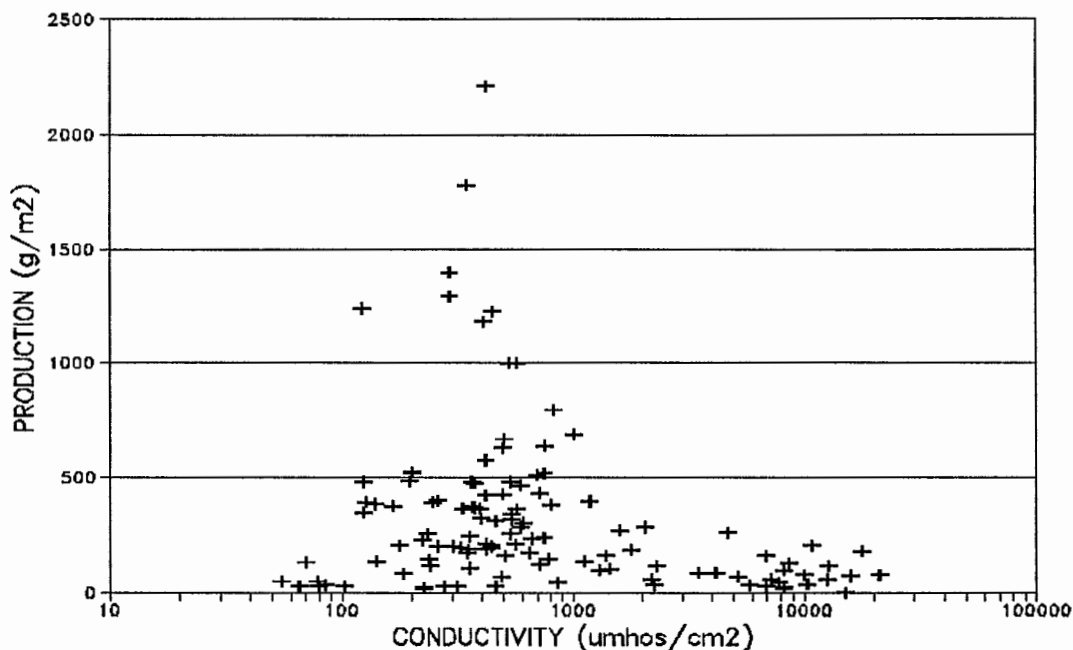


Figure 56. Scattergram of stand primary production vs. maximum stand soil conductivity during 1991.

figure produces a near normal distribution of values indicating that the production response curve is log-normal, and skewed far to the left.

The relationship of production to soil conductivity is not linear; in fact it is unimodal. Very low production occurs on sites with the most salt-free soils (*Bouteloua gracilis* stands), the highest production in communities with low salt concentrations and low production in communities with the highest salt concentrations.

Production vs. Water Table

Mean 1991 water table highs for the 14 communities described above are plotted against mean production in Figure 57. This Figure shows that communities with a mean season high water table within 1 foot of the soil surface have the highest overall production. Communities with some seasonal shallow standing water, up to one foot, have the highest production. At maximum water depths greater than 1 foot, production decreases.

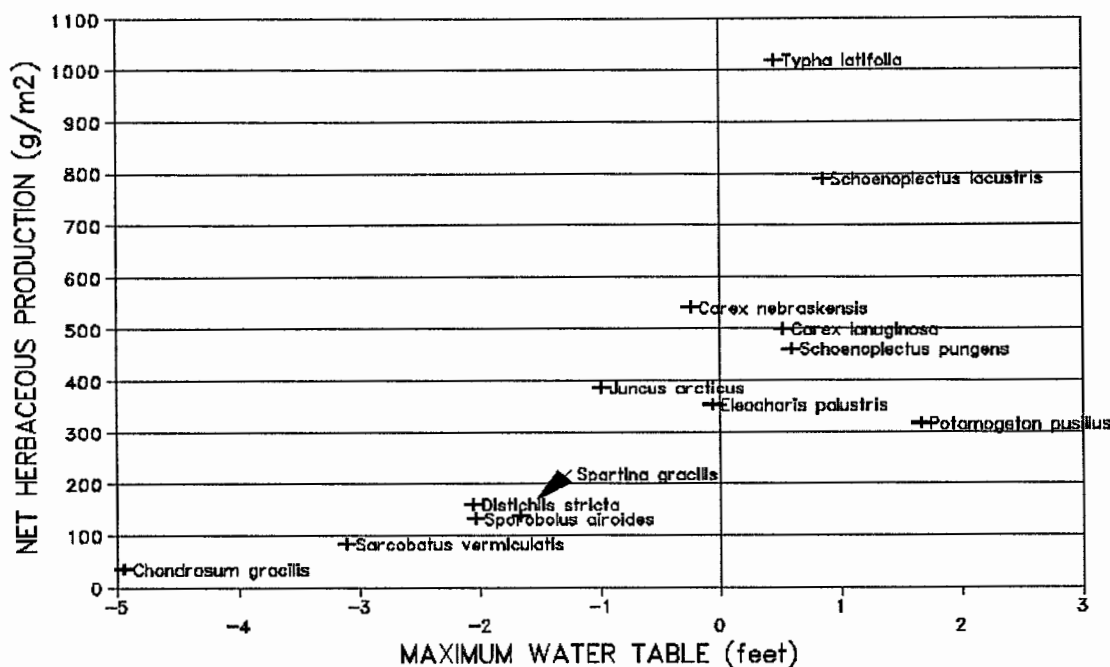


Figure 57. Mean primary production for 13 community types vs. maximum water tables for 1991.

A scattergram of raw stand data of maximum water table vs. production is shown in Figure 58. The response is clearly a parabola, not a straight line, being highest where water tables reach near or above the soil surface. Lower production occurs in stands with the deepest standing water and where the water table did not reach within 2 feet of the soil surface.

Summary of Production

Primary production obviously relates very closely to both water table and soil conductance. However, it should be remembered that water table controls soil conductance. Figure 59 shows the relationship of 1991 maximum water table depths to both soil conductance and production. The data plotted are mean production and mean soil conductance vs. mean seasonal water table high for the 14 communities described above.

Soil conductance (scale on the right y axis) is highest where the water table does not reach to within 1 foot of the soil surface. Simultaneously production is highest in communities

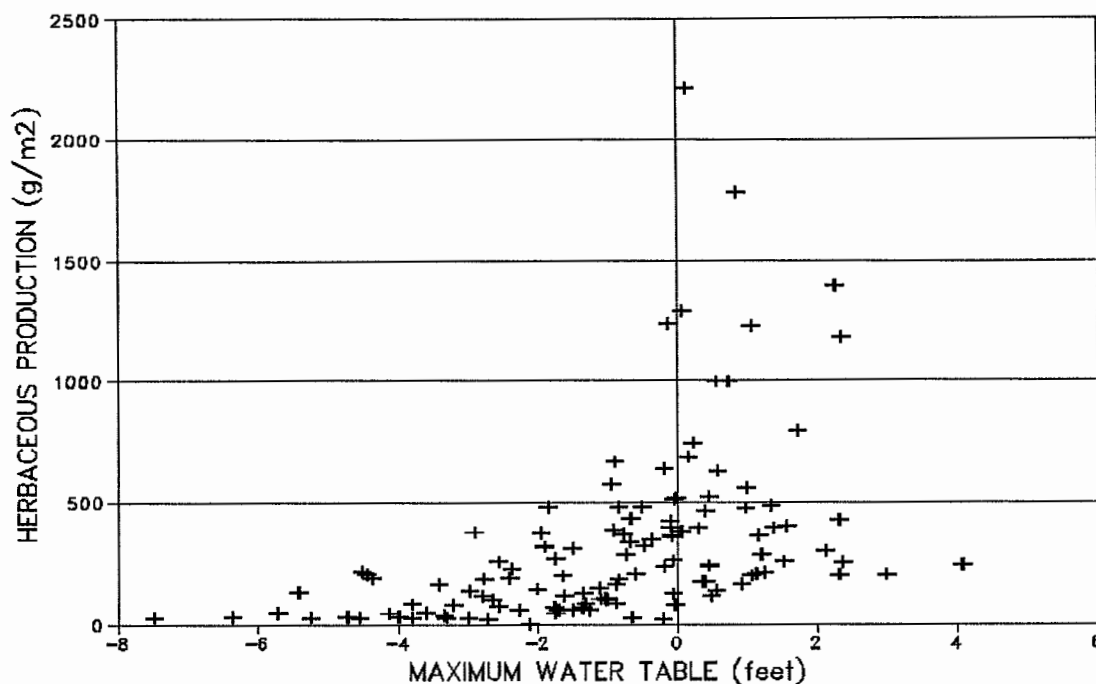


Figure 58. Scattergram of stand primary production vs. stand maximum water tables for 1991.

with a mean seasonal water table high within 1 foot of the soil surface. Thus, the combination of abundant water for growth and to remove excess soil salts occurs on sites with a water table within 1 foot of the soil surface creating the most productive sites.

During high water years, such as 1987, season high water tables in the region were approximately one foot higher than during 1991. Thus, sites where the 1991 water table was one foot from the soil surface would have had a water table at the soil surface during 1987.

We feel that San Luis Valley wetland sites are affected by the hydrologic regime of these high water years. High water years may flush salts from soils and allow greater production during normal or lower water years. The "magic" water table characteristic which can be used to characterize more saline and less productive vs. less saline and more productive stands appears to be a seasonal water table high approximately 1 foot

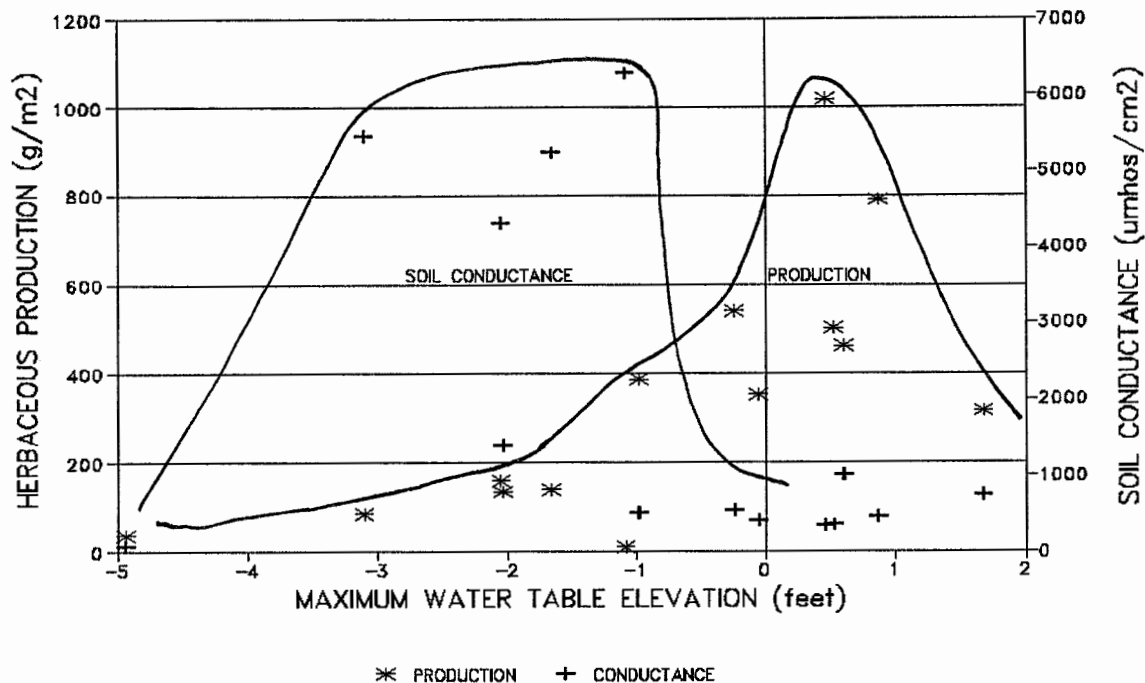


Figure 59. Mean primary production for 14 community types vs. maximum water table height and mean soil conductivity for the same 14 community types for 1991.

below the soil surface during 1991. This number must be kept in mind when evaluating management objectives and plans, and the potential effects of a water table lowering on wetland function.

VEGETATION ANALYSIS: PERCENT BARE GROUND IN STANDS

The large amount of soil or ground exposed in most parts of the San Luis Valley is striking to even the most casual observer. Ground is bare due to low plant cover and production. Low plant production, as we discussed above, is a function of either or both dry soils and high soil salt concentrations. Bare ground can also be caused by erosion on lake shores, highly fluctuating water levels as in playas and other factors.

Percent Bare Ground vs. Water Table Maximum

The water table provides both water for plant growth and a flushing action to remove salts from soils. Figure 60 is a scatter diagram showing percent bare ground vs. the 1991 water

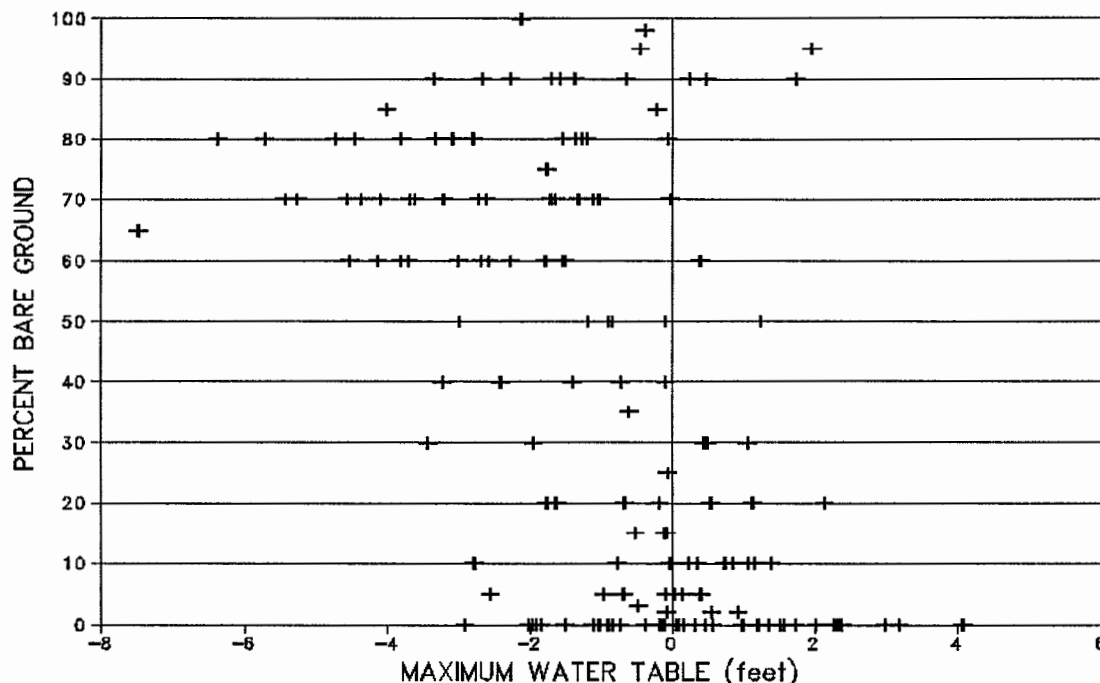


Figure 60. Scattergram plotting percent bare ground in stands vs. maximum water table in stands during 1991.

table maximum for stands in the study area. Most stands with low percentages of bare ground occur close to the water table, while stands with higher percentages of bare ground, particularly above 50%, occur where the water table never reaches closer to the soil surface than 1 foot. The graph is complicated because some sites on lake shores with considerable erosion, or with deep standing water can have both high water tables and high percentages of bare ground. The data were analyzed using linear regression, and there is a 0.000% probability that the trend in the data are due to chance, but a straight line explains only 31% of the variation in the data.

Figure 61 shows the mean percent bare ground for the 14 communities described above plotted against mean maximum water table during 1991 for these communities. Two groups of communities can be distinguished. One includes the wet meadows, emergents and aquatic communities which have a water table within one foot of the soil surface and low (<30%) bare ground. The

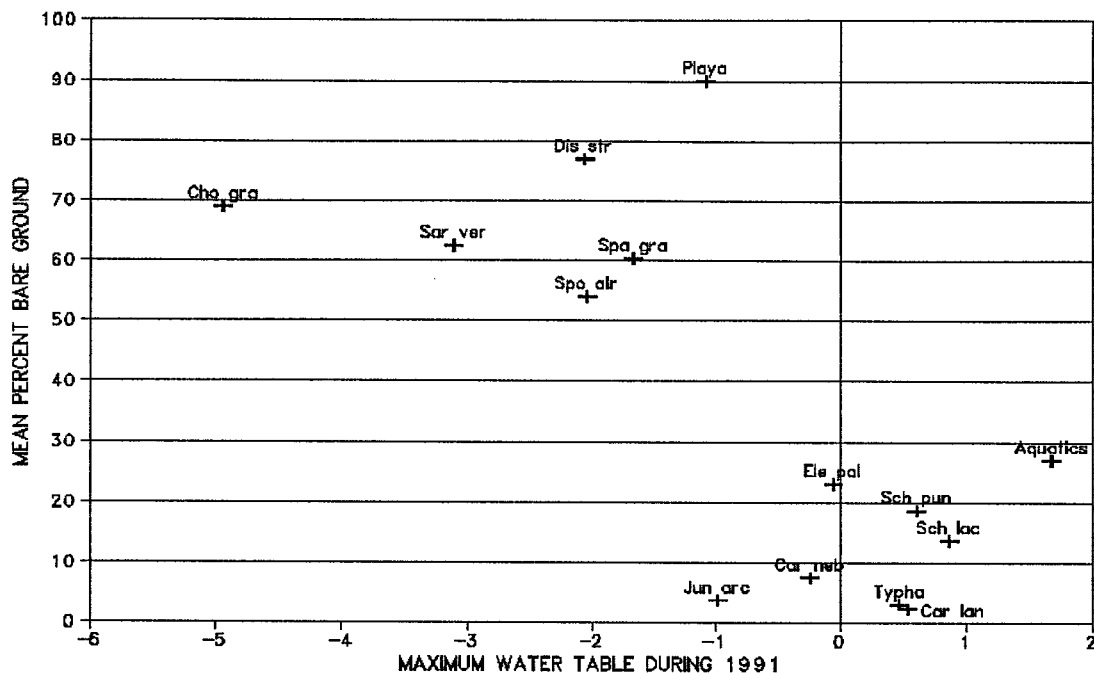


Figure 61. Mean percent bare ground vs. mean water table maximum for 14 community types.

second group are the communities of drier sites, all of which have a mean of greater than 50% bare ground.

Percent Bare Ground vs. Soil Conductivity

Soil conductivity for all stands is plotted against percent bare ground in Figure 62. This figure shows that all but a few sites with less than 50% bare ground occur in sites with a conductivity of less than 1,000 to 2,000 umhos/cm². Sites with greater than 50% bare ground occur on a variety of sites with both low and high conductivity. Again, this graph is complicated because erosion and other physical disturbance, can create bare soil no matter what the soil chemistry is.

Figure 63 plots mean percent bare ground for the 14 communities again maximum soil conductivity. Three groups of communities are seen. Group one are the low bare ground and low soil conductivity wetland communities. Group two are the low conductivity and high bare ground upland grass communities dominated by bluegrama grass and alkali sacaton. Group three are

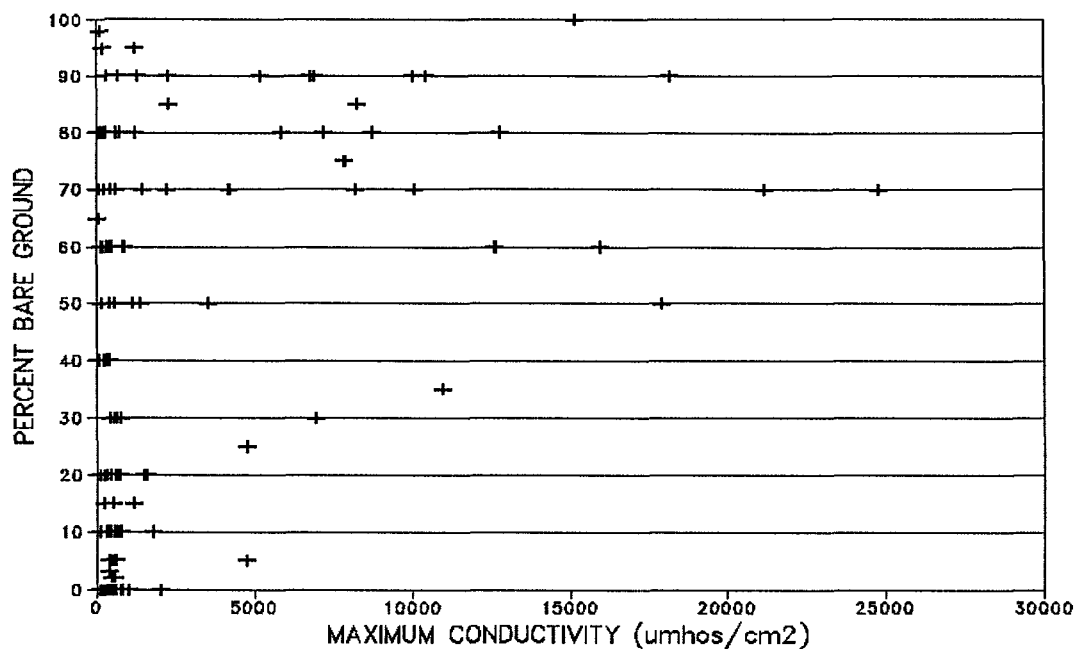


Figure 62. Scattergram plotting percent bare ground in stands vs. maximum stand soil conductivity during 1991.

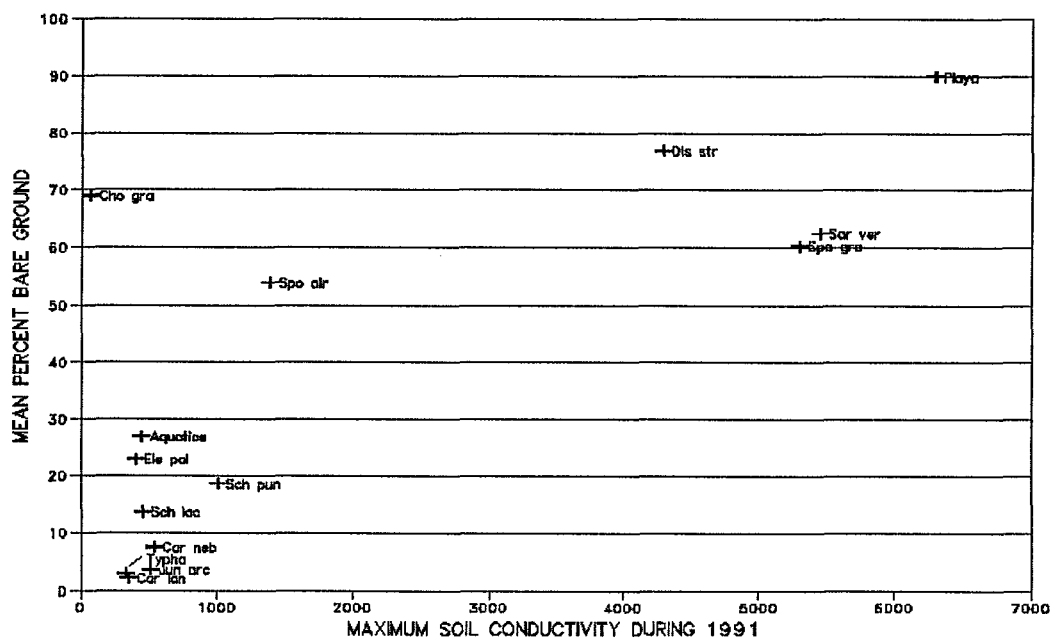


Figure 63. Mean percent bare ground in 14 community types vs. maximum soil conductivity in these communities during 1991.

the high conductivity and high bare ground salt flat communities dominated by saltgrass, alkali cordgrass and greasewood.

VEGETATION ANALYSIS: NUMBER OF SPECIES IN STANDS

Species richness (number of species occurring in a stand) is a useful measure of a sites potential to support a number of species with different adaptations. In general, sites with one or more environmental variables at an extreme are less likely to support high numbers of species.

Number of Species vs. Water Table

Figure 64 is a scattergram of all stands showing number of species plotted against maximum water table height during 1991. Stands that at some time during 1991 had standing water of more than a few inches supported 4 or less species. Stands with season high water tables between 0 and 2 feet below the soil surface supported 4 to 10 species, while sites with water tables 3 to 6 feet below the surface supported 2 to 8 species. Most stands with maximum water tables deeper than 6 feet generally supported more than 8 species. Stands that supported more than 10 species occurred on a wide variety of water table depths, but not in stands with standing water.

Figure 65 plots mean numbers of species in the 14 community types against mean maximum water table height during 1991. This figure shows a very interesting sigmoid (S-shaped) relationship. Low numbers of species occur in deep water. A species richness high is reached in the wet meadow zone communities dominated by Carex nebraskensis, C. lanuginosa and Juncus arcticus. Another species richness low occurs in the salt flats. The highest number of species is reached in the well-drained bluegrama grass stands. As has been discussed earlier water level and soil salinity act in concert here. High water level limit the number of species because few species are adapted for flooded conditions. High species numbers are reached in the low salt and seasonally saturated wet meadow zone in area that are never flooded, or are seasonally flooded. As depth to water table increases salt concentration in surface soils also increases. The combination of seasonally dry and saline soils makes it impossible for all

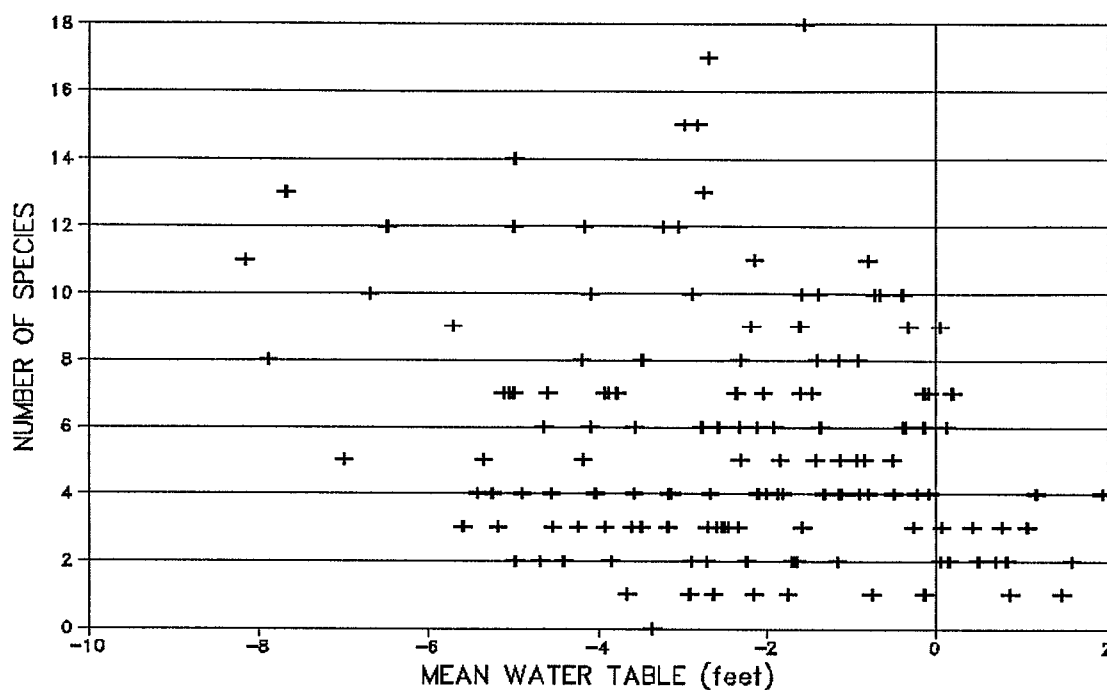


Figure 64. Scattergram plotting number of species in stands vs. mean water table during 1991.

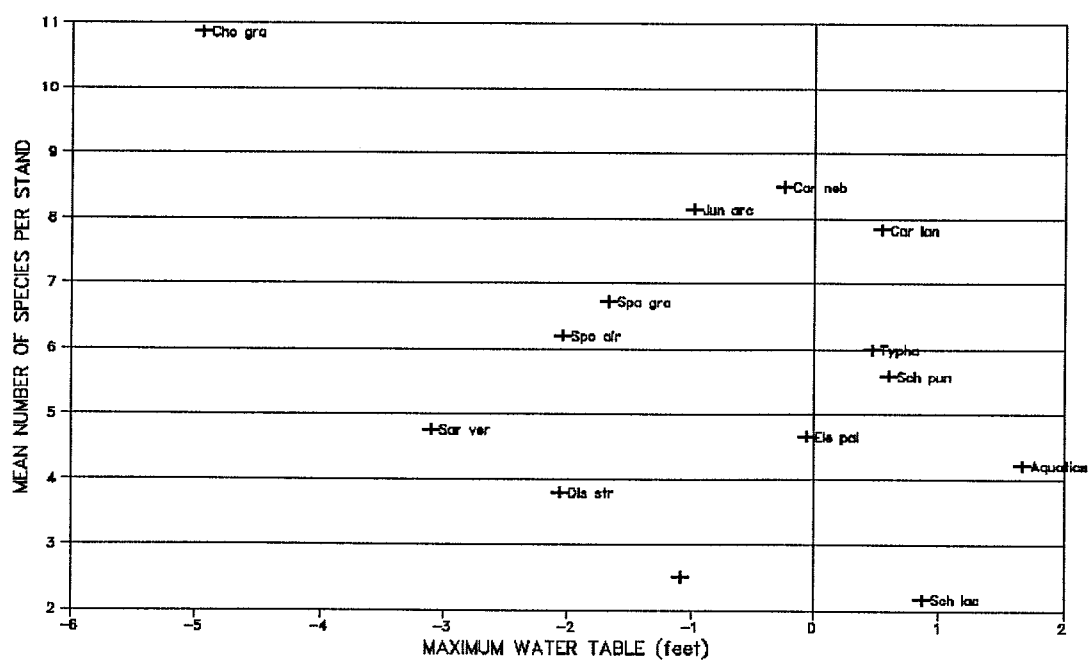


Figure 65. Mean number of plant species per stand in 13 community types vs. maximum water table heights during 1991.

but halophytes to occur. Soils that are well drained and salt-free support the highest species numbers. Even though they are seasonally very dry, these soils do not have seasonal flooding, nor do they have appreciable salt concentrations. Plants need be neither hydrophyte nor halophyte to occur in these upland sites.

Number of Species vs. Soil Conductivity

Only general relationships can be drawn from the scatter diagram (Figure 66) showing number of species in stands plotted against soil conductivity. In general, soils with conductance greater than 1,000 umhos/cm² supported 1 to 6 species. Stands with 10 or more species occurred on soils with conductivities less than 1,000 umhos/cm². Low number of species does not

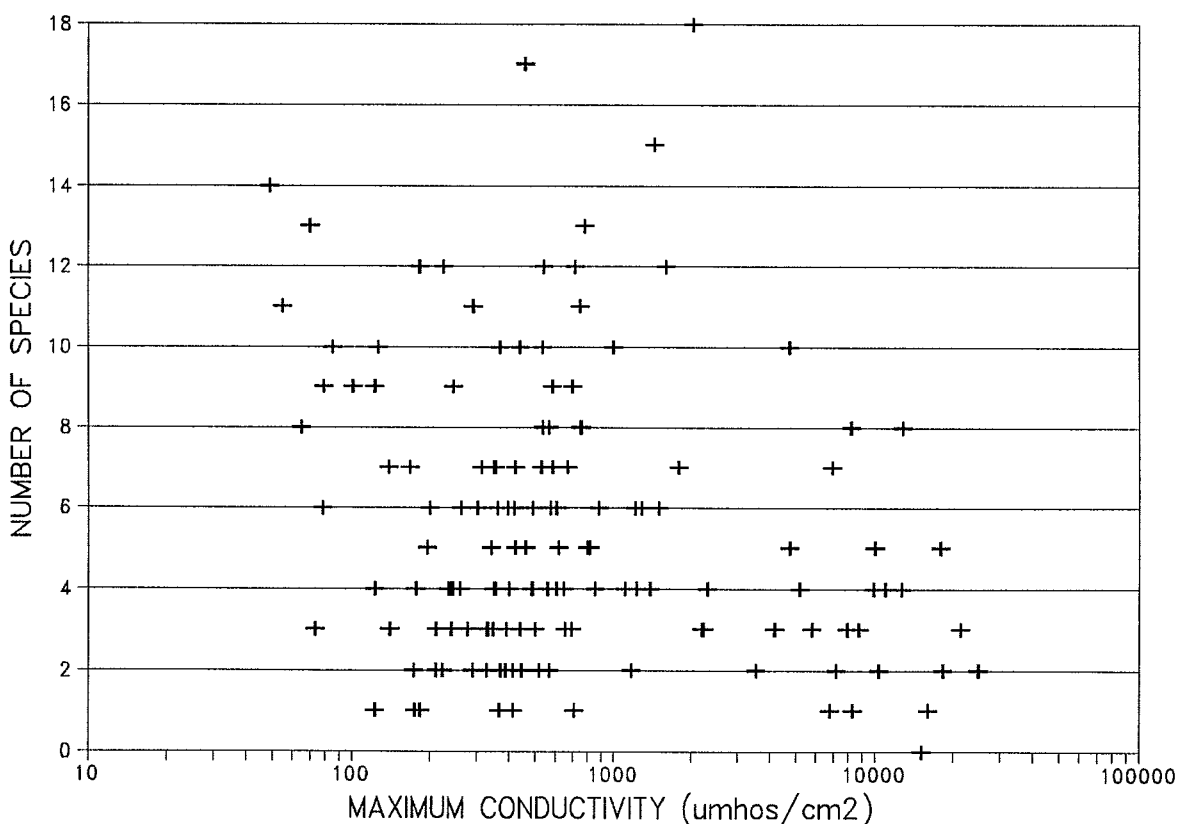


Figure 66. Scattergram plotting number of plant species in stands vs. maximum stand soil conductivity for 1991. Conductivity is plotted on a log scale.

indicate saline soils and conversely, relatively high numbers of species (greater than 6) does not indicate non-saline soils.

Synthesis of Number of Species

Simple linear relationships between number of species in stands and water table and soil conductivity do not occur as was shown in Figure 65. Statistically the relationships are not due to chance, but straight lines do not fit the data. It thus appears that there are relatively few species adapted to flooded soils and saline soils, but there are many which can occur in seasonally wet and salt free and in upland salt free soils.

ANALYSIS OF THE MAJOR PLANT SPECIES: DISTRIBUTION OF PLANT SPECIES ALONG WATER TABLE AND SOIL SALINITY GRADIENTS

Figure 67 is produced using direct gradient analysis to illustrate the realized niches of plant species along the stand maximum water table gradient. The species coenclines (sensu Gauch and Whittaker 1972) include the entire portion of the gradient occupied by each species. Each curve is unimodal, with a high more or less in the middle part of its water table range. The following lists the species discussed in order of the habitat they occupy from wet to dry:

1. Aquatics
2. Schoenoplectus (Scirpus) lacustris ssp. acutus
3. Schoenoplectus (Scirpus) pungens
4. Eleocharis palustris
5. Carex lanuginosa
6. Juncus arcticus
7. Distichlis stricta
8. Spartina gracilis
9. Sarcobatus vermiculatus
10. Chondrosium (Bouteloua) gracilis

The species on the wetter end of the water table gradient occupy a narrower portion of the gradient than species on the drier end. For example, hairy sedge and spike rush both have their abundance peaks where the 1991 maximum water table height was approximately 1 foot above to one foot below the soil surface while arctic rush and salt grass are at their maximum abundance over a much wider segments of the gradient. Canopy cover values for most species are much higher at the wetter end of the gradient as well, which results in greater primary production and less bare ground.

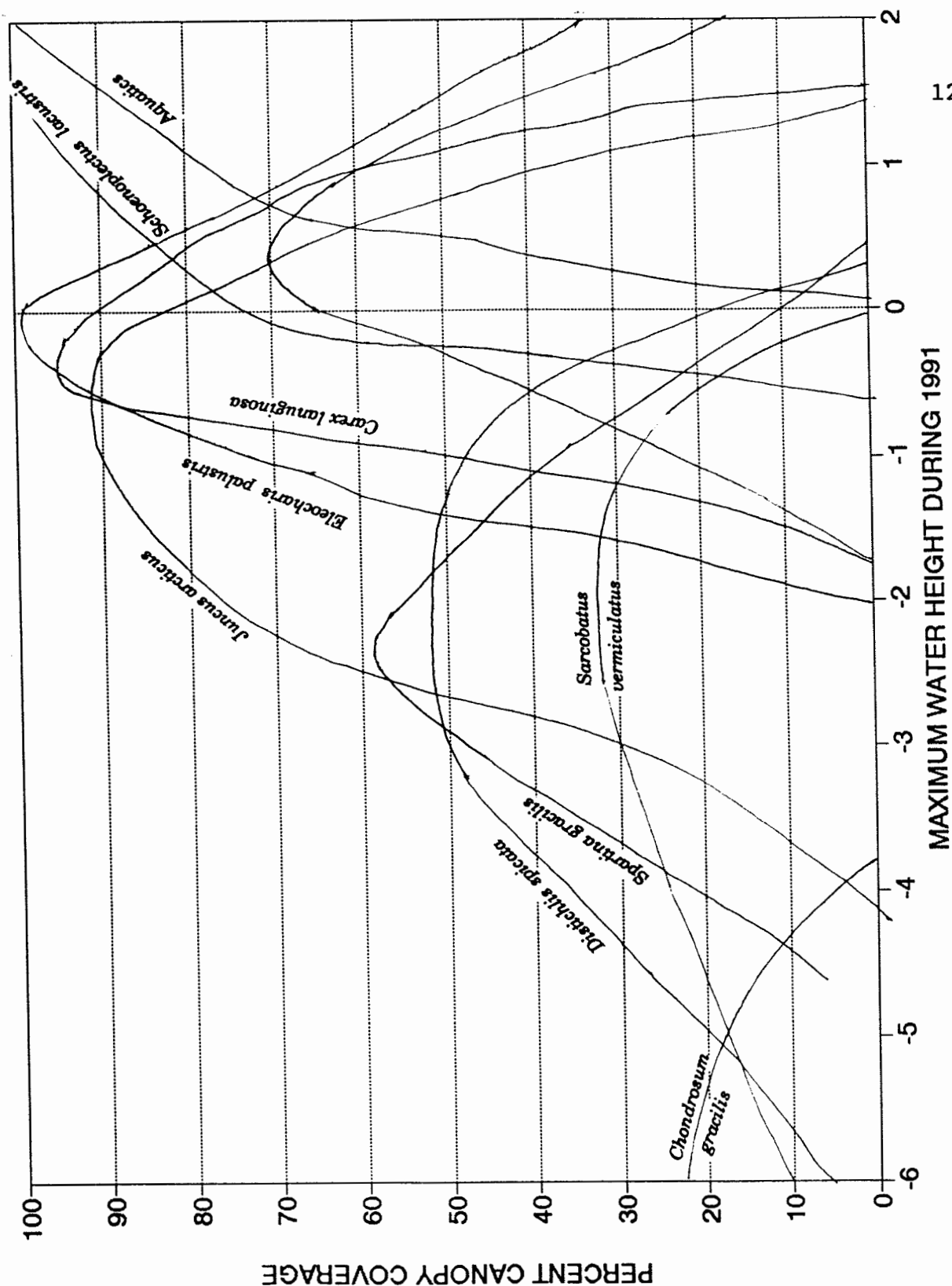


Figure 67. Direct gradient analysis graphic showing the realized niche of 10 important plant species in the San Luis Valley. The gradient analysis shows species abundance along the maximum water table height during 199.

ANALYSIS OF THE MAJOR PLANT SPECIES:

DIRECT GRADIENT ANALYSIS AND DISCUSSION OF EACH PLANT SPECIES

Carex lanuginosa (hairy sedge). Hairy sedge is an amphibious plant species that tolerates short periods of annual or periodic inundation. Carex lasiocarpa and other sedges dominate the wet meadow zones on the northern prairie of the U.S. and Canada (Dix and Smiens 1967; Johnson et al. 1987), but sedges dominated a very restricted set of habitats in the study area. Carex lanuginosa appears to be relatively salt intolerant in the San Luis Valley and occurs only along the shores of large lakes and along streams that supply fresh water. The fresh surface water that periodically inundates and flushes salts from the soils appears to be an important ecological factor. The soils are the most salt-free of any wetland type in the study area (see Figure 68). Stands dominated by this species can have high primary production and support aquatic insect populations when inundated. It provides important nesting habitat and cover for waterfowl.

As a wet meadow community type it has a relatively limited distribution in the valley occurring only adjacent to the cleanest surface water sources and is an excellent indicator species. Water management plans should focus on enhancing communities dominated by this species. This could be done by providing water to inundate shorelines for a short period of time in the spring then drawing the water level down. Figure 68 plots the percent coverage of Carex lanuginosa, C. nebraskensis and C. vesicaria for all stands in which these species occur in the southern three study areas (not Villa Grove). The position of each stand is based on the two directly measured gradients. The figure shows that stands with greater than 40% coverage by a Carex spp. occur close to the water table and many were inundated at some time during 1991. The stands also occur where soil salinity ranges from 200 to 600 umhos/cm², indicating fresh water influencing the stands.

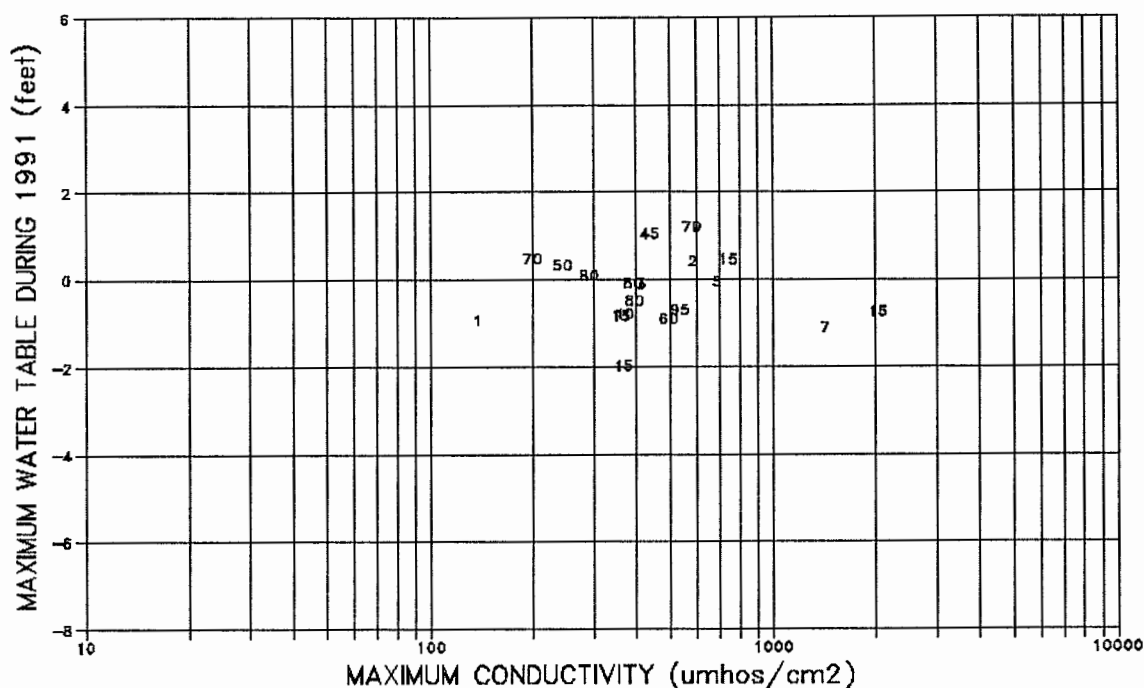


Figure 68. Realized niche of Carex lanuginosa in the study area. The diagram plots cover of Carex on the maximum soil conductivity and maximum water table height gradients.

Chondrosom gracilis (bluegrama grass). Bluegrama grass is an excellent upland salt-free soil indicator in the San Luis Valley. It occurs where the soils have conductivities less than 100 umhos/cm² and where the maximum water table is greater than 4 feet below the soil surface as is shown in Figure 69. It can occur in sandy, but usually not loose and unstable soils. It usually occurs with many other grasses, herbaceous and woody plant species which are the most species rich in the study area.

Distichlis stricta (saltgrass). Saltgrass is a widespread and abundant species in the San Luis Valley. It shows remarkable tolerance for a broad range of water table and soil salinities. Figure 70 shows that it can grow in sites that are seasonally flooded and in sites that are 6 feet or more above the seasonal water table high. It can occupy sites with the most salt free soils in the study area, where it grows with bluegrama grass, and also sites with the saltiest soils as long as they are not playas that are frequently flooded. We have shown that saltgrass is not

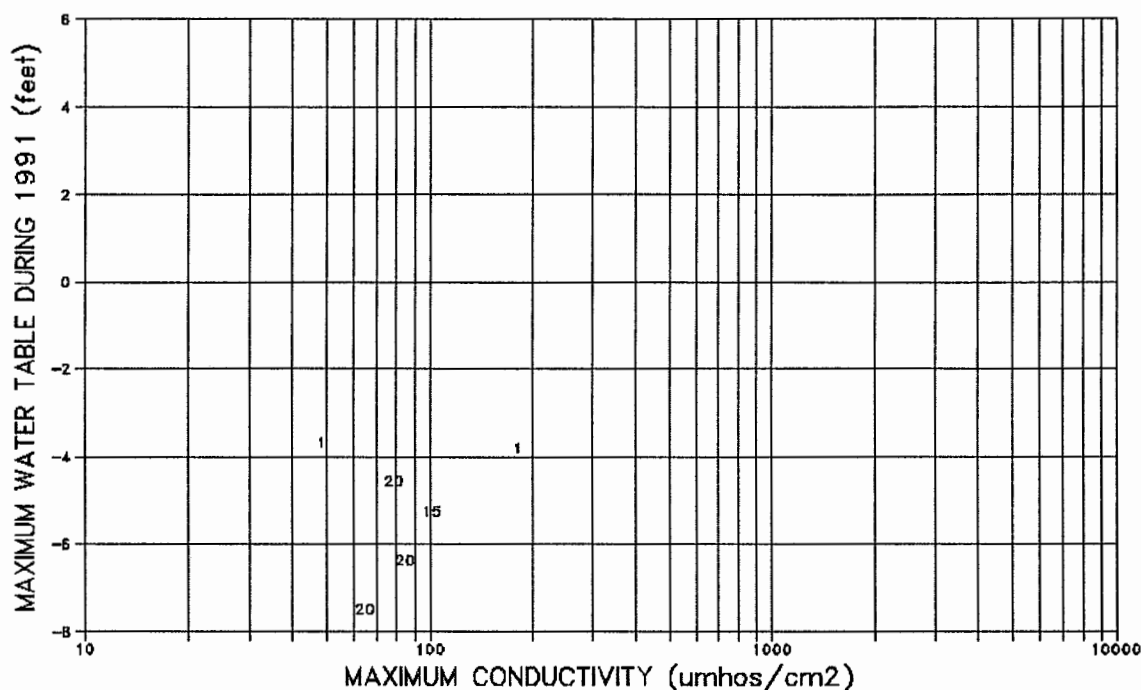


Figure 69. Realized niche of Chondrosum gracilis in the study area. The diagram plots cover of Chondrosum on the maximum soil conductivity and maximum water table height gradients.

an obligate halophyte in the study area and this has been demonstrated by Ungar (1966) for Kansas and Oklahoma.

Figure 70 also shows an interesting relationship between the water table and salinity of sites where this species occurs. In relatively salt-free stands the species occurs in stands where the seasonally high water table is 2 or more feet from the soil surface. However, in sites where soils have conductivities greater than 1000 umhos/cm² it can occur in sites that are seasonally wet. It indicates that saltgrass is eliminated by competition with the tall, dense and aggressive wet meadow species Juncus arcticus and Carex lanuginosa in high water table salt-free sites. However, in sites with similar hydrologic regimes but with saltier soils where Juncus and Carex do not grow saltgrass is abundant. High water table and high salinity sites occur in areas that do not receive pulses of fresh water to flush the soils; eg. not on lake or stream shorelines. The species response curve for saltgrass along the two directly measured

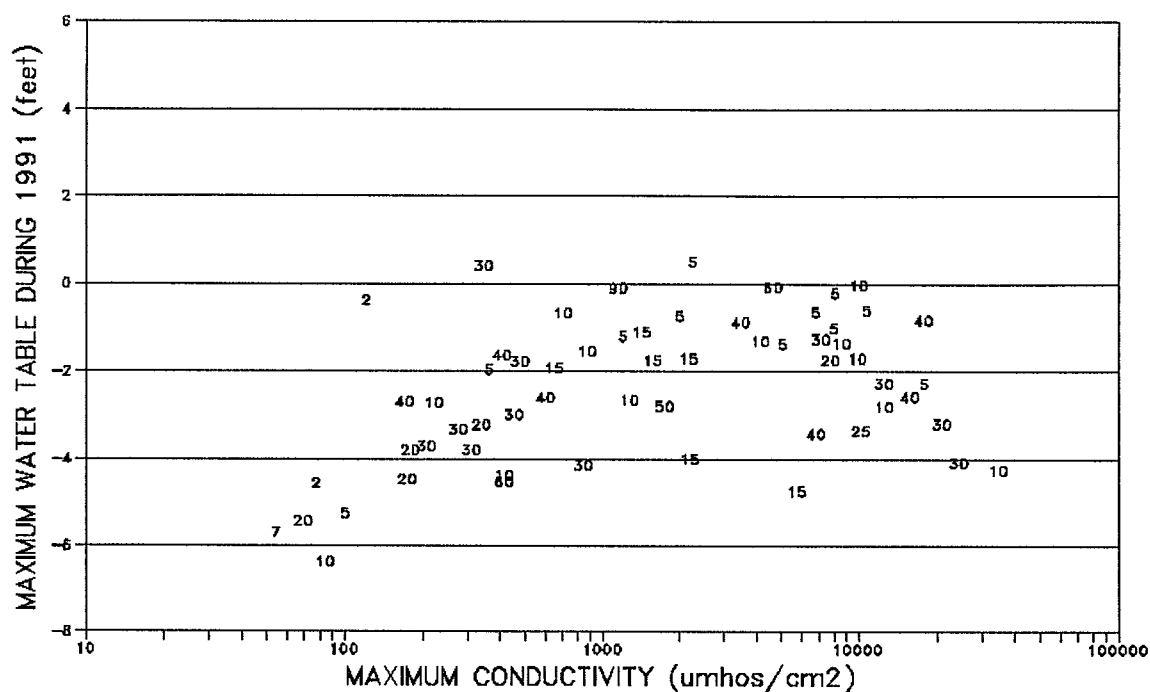


Figure 70. Realized niche of Distichlis spicata in the study area. The diagram plots cover of Distichlis on the maximum soil conductivity and maximum water table height gradients.

gradients is unimodal; it reaches its maximum canopy coverage or abundance at sites on both the salt-free and saline ends of the gradient.

Eleocharis palustris (spikerush). Spikerush is a facultative halophyte and an amphibious species that occurs on the margins of ponds, usually where seasonally standing water occurs. It typically occurs just uphill from stands dominated by bulrush as was shown in the chapter on zonation earlier in this report. However, in marshes with short periods of flooding, such as at Mishak Lakes, bulrush is absent and spikerush occupies the entire emergent zone from aquatics to Juncus arcticus. It's production varies greatly in relation to available water. This species is reported to die out of marshes when flooded with over 15 inches of water for more than 1 year (Harris and Marshall 1963). Figure 71 shows that during 1991 stands occurred in a broad range of hydrologic regimes. Also, most stands occurred where soils were relatively salt free.

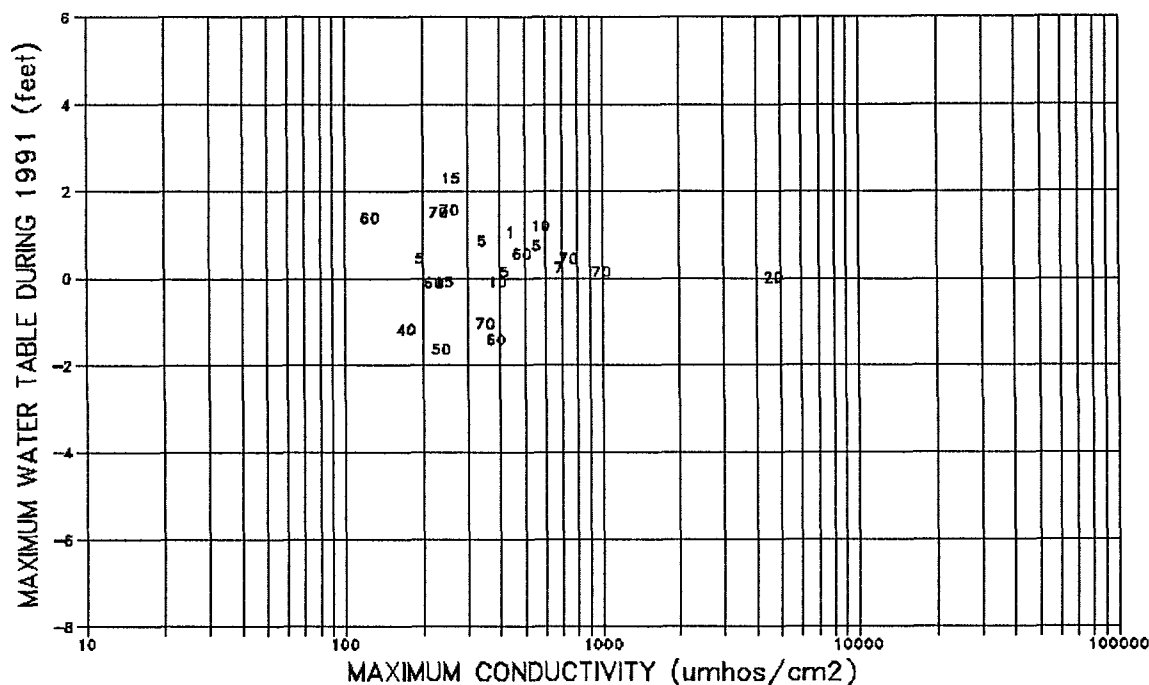


Figure 71. Realized niche of Eleocharis palustris in the study area. The diagram plots cover of Eleocharis on the maximum soil conductivity and maximum water table height gradients.

Juncus arcticus (arctic rush). Arctic rush is the most common wetland plant species in the San Luis Valley. It occupies wet meadows and it is the only plant species that is present along all study transects. It is tolerant of a wide range of water regime and salinity conditions as can be seen in Figure 72. It is tolerant of periodic flooding and can also grow several feet above the seasonal high water table. It can occur in low salinity soils, and it can also grow with alkali cordgrass and saltgrass in saline soils. Shay and Shay (1986) indicate that it has normal growth in fresh ($<2,000$ umhos/cm²) and moderately saline (2,000 to 15,000 umhos/cm²) soils, and has subnormal growth in saline (15,000 to 45,000 umhos/cm²) soils. It is an aggressive and densely growing rhizomatous species with high primary productivity in good habitats. It serves as important habitat for waterfowl nesting and all duck nests seen during 1991 were in communities dominated by this species. It does not appear to support many aquatic insects since it is rarely

flooded. However, stands most likely support insects of other types. Seasonal saturation to the soil surface and later dry soils are the optimal conditions for this species in the San Luis Valley. This species appears to be much more abundant in the San Luis Valley than in wetlands of the northern prairies of the U.S. and Canada, where most wet meadow zones are occupied by Carex spp. The abundance of Juncus in Colorado wet meadows may be due to the relatively high salinity of many meadows.

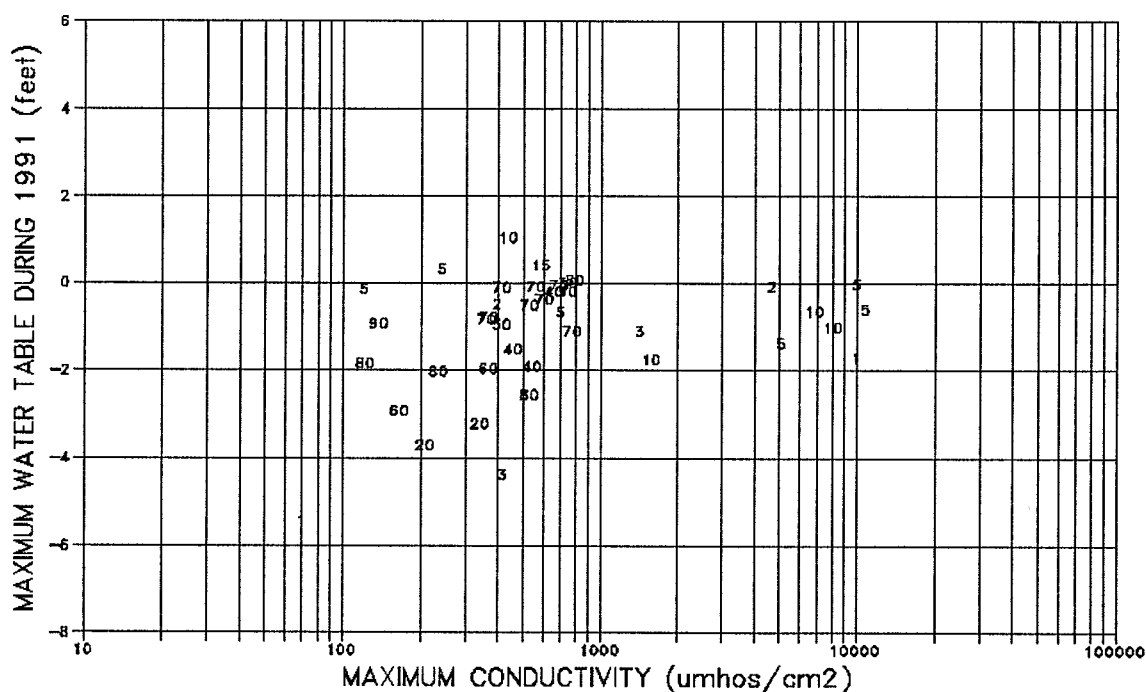


Figure 72. Realized niche of Juncus arcticus in the study area. The diagram plots cover of Juncus on the maximum soil conductivity and maximum water table height gradients.

Potamogeton pusillus (pondweed). Pondweeds is among the most abundant and characteristic aquatic plant species in interior North America. The San Luis species have linear leaves, are entirely submerged during the summer and the leaves have no cuticle. A cuticle is a waxy coating that reduces evaporation from the leaf and allows plants to survive in terrestrial environments where it is necessary to reduce evapotranspiration. Aquatic plants need no cuticle, but the lack of cuticle

necessitates an aquatic habitat. Figure 73 shows that stands dominated by aquatic plant species in the study area occurred in sites with up to 4 feet of standing water during the summer. Soil conductivity varied, but it should be remembered that the conductivity of the water is more important to the growing tissues, and the water in all cases was fresh. However, following drawdown aquatic zone soils can be moderately saline, however plants are dormant at that time.

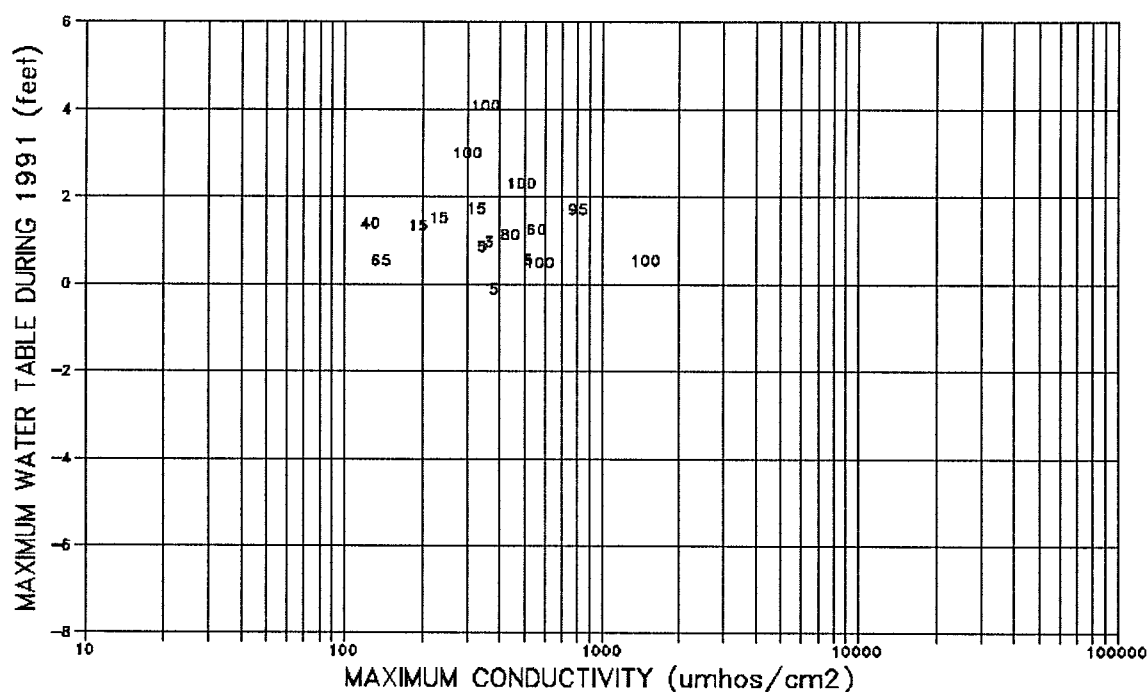


Figure 73. Realized niche of aquatic plant species in the study area. The diagram plots cover of aquatics on the maximum soil conductivity and the maximum water table height gradients.

An analysis of the distribution and production of sago pondweed (*Potamogeton pectinatus*) in the Delta Marsh area of Manitoba by Anderson (1978) showed this species does not grow in water deeper than 120 cm (50 inches or 4.16 feet). It will grow in a variety of soil types including peat through sand. It's primary production was greatest at water depths from 40 to 60 cm and there is a linear decrease in production from 60 to 100 cm! Thus, water levels of approximately 60 cm to less than 100 cm

should be maintained (2 to 3 feet in depth). It has its highest production on fine sandy loam soils and is least productive on peats. It does not occur in lake areas with maximum exposure to wind. Decreasing light intensity appears to keep this species from growing in deeper water. This is especially critical in the early summer when shoots are just sprouting from rhizomes and all leaves are at the pond bottom. This species can become light deprived quickly. Thus, if windy periods during the spring create murky water, this species can be eliminated.

Sarcobatus vermiculatus (greasewood). Greasewood is by far the most abundant woody plant in the study area. Figure 74 indicates that, like saltgrass, it grows in areas that are close to the summer high water table in saline areas, but it grows in areas where the water table is deeper in salt-free and saline environments. It can grow with bluegrama grass more than 6 feet above the water table. It is intolerant of flooding and evidence that thousands of greasewood plants in low lying areas were killed by flooding during 1987 is apparent throughout the area. It is widely tolerant of soil salinity growing in the most salt free and the most saline environments in our study area.

It is widely reported to be a "phreatophyte" (Robinson 1958), but clearly it is not an obligate phreatophyte. This species was not deleteriously affected by experimental water table drawdowns in the Owens Valley, California (Sorenson et al. 1989) indicating that it survives on water derived from precipitation alone. In fact, these researchers report that growth of greasewood improved following drawdowns, perhaps because of improved aeration in the root zone. During its seedling stage and the early years of its life, before it grows deep roots, it is definitely a xerophyte, living only on soil water provided by precipitation. In certain areas it can root to the water table, but root abundance decreases exponentially with depth below 1 m (Sorenson et al. 1989). Root densities were greatest in the upper 0.4 m in the Owens Valley (Groeneveld 1986).

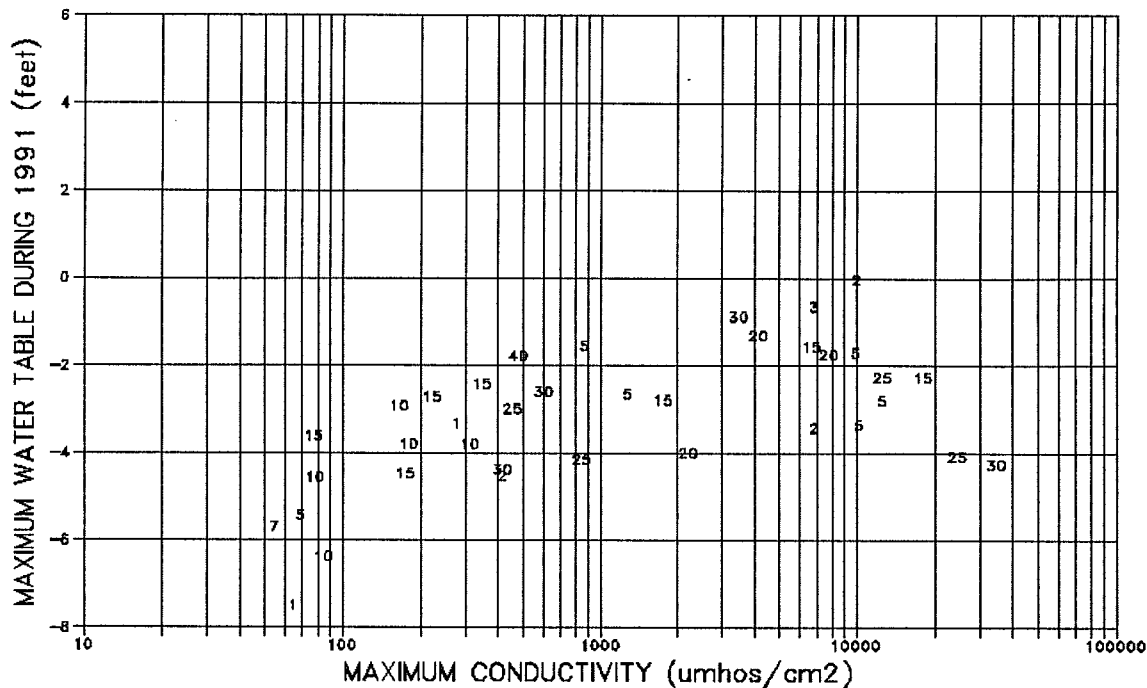


Figure 74. Realized niche of *Sarcobatus vermiculatus* in the study area. The diagram plots *Sarcobatus* on the maximum soil conductivity and the maximum water table height gradients.

Trenches dug in the San Luis Lakes and Moffat areas of the San Luis Valley during this research showed us that few greasewood plants reach the water table and in fact most only reach to the upper part of the capillary fringe. Greasewood roots die in an anaerobic environment, therefore it is not reasonable to expect to see roots in the water table, but only root that would reach to the seasonal capillary fringe high. This upper capillary fringe usually occurs during April, well before the growing season starts. Thus, the time of the year when air temperature is highest, June through August, and evapotranspiration demands are highest, is the time when little water is available to these deep roots. Thus, it appears that greasewood in the San Luis Valley derives almost all of its water from soil storage of winter snow melt, and summer monsoon precipitation.

In many parts of the study area greasewood occurs on small dune-like mounds. These mounds have very high root densities and

surprisingly high concentrations of organic matter. Thus, it appeared to us that these mounds were sponge-like features that would hold rain water above the salty soils and function as water holding storage.

Schoenoplectus lacustris ssp. acutus (hardstem bulrush).

Hardstem bulrush is the only tall bulrush occurring in the San Luis Valley. It is the dominant emergent marsh plant species on pond and slough edges or centers where standing water persists for much of the summer. It grows in swards that could be described as tule, bulrush or reed swamps where conditions are appropriate. These conditions include; seasonal standing fresh water that persists for much of the summer and where shoreline erosion is minimal. Where ponds dry up during the summer, such as occurs in the Mishak Lakes area, bulrush is absent. Where ponds dry down to a small puddle in the middle in many years, bulrush may occupy the pond center while aquatics, spikerushes, and rushes occur in more shallow water, such as occurs at Harrence Lake and the slough north of San Luis Lake.

The plant does not grow in water that seasonally is more than 2 feet deep for long periods of time (Figure 75). Harris and Marshall (1963) and Sharp (1951) have shown that this species dies out of marshes if water is over 15 inches deep for more than 1 year. The maximum water depth for bulrush is a key depth to recognize and integrate into water management efforts in the San Luis Valley because bulrush is one of the most important vegetation types in the study area for wildlife habitat. Some recent water management efforts in the San Luis Valley have created water depths greater than 15 inches in some of the most productive bulrush areas in the San Luis Valley (eg. the slough south of Head Lake). Net herbaceous production measured in g/m²/year for this species varies from stand to stand and appears to be related to stand hydrologic regime. The wetter stands have greatly increase production while dry stands, such as many of those at Russell Lakes have low production and are not particularly valuable habitat.

Schoenoplectus pungens(three-square). Three square is a thin stemmed amphibious bulrush that grows in seasonally standing shallow water and in wet meadows. It is not consistently present along study area transects, but where it occurs it is usually

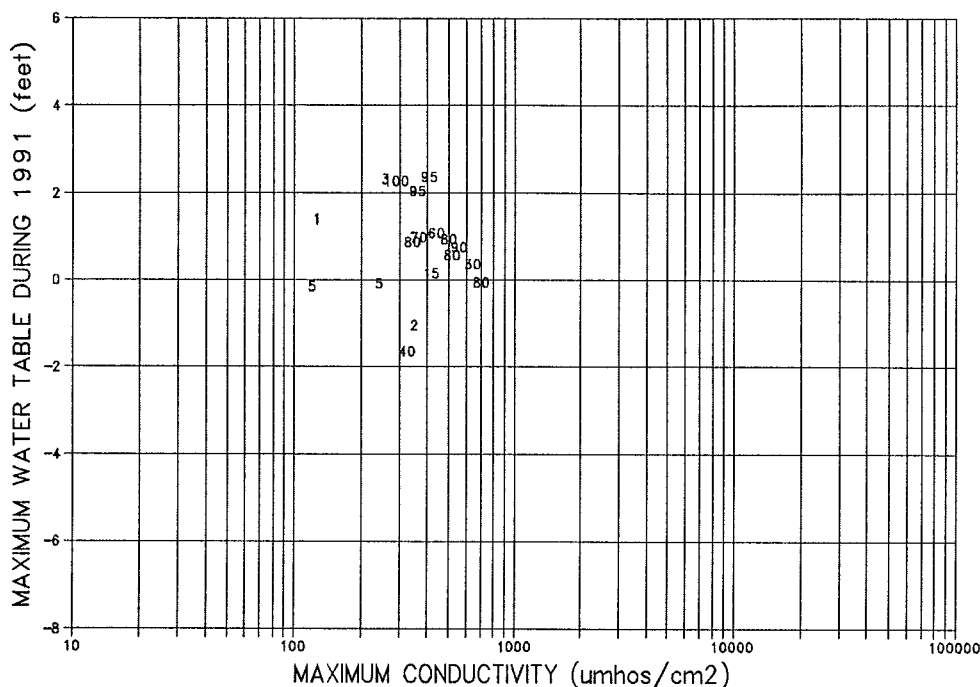


Figure 75. Realized niche of Schoenoplectus lacustris ssp. acutus in the study area. The diagram plots cover of S. lacustris on the maximum soil conductivity and maximum water table height gradients.

present above or in place of the spikerush zone and below the Juncus arcticus zone. It tolerates high salt concentrations in the soil and is common in drying ponds as is shown in Figure 76 and tolerates a wide variety of water regimes. It is most abundant where the water table is at the soil surface or there is seasonal standing water.

Spartina gracilis (alkali cordgrass). Salt marshes throughout the world are dominated by species of Spartina. Therefore, it is fitting that one of the most abundant halophytes in the San Luis Valley is Spartina gracilis. It appeared to grow most rapidly and flower in mid-summer during the monsoon season most likely in response to the reduction in soil salt concentration caused by rains. Alkali cordgrass can tolerate a wide variety of hydrologic conditions as is shown in (Figure 77). It is a "hydrohalophyte", able to tolerate both waterlogged and saline soils. However, it is not an obligate hydrophyte, nor an

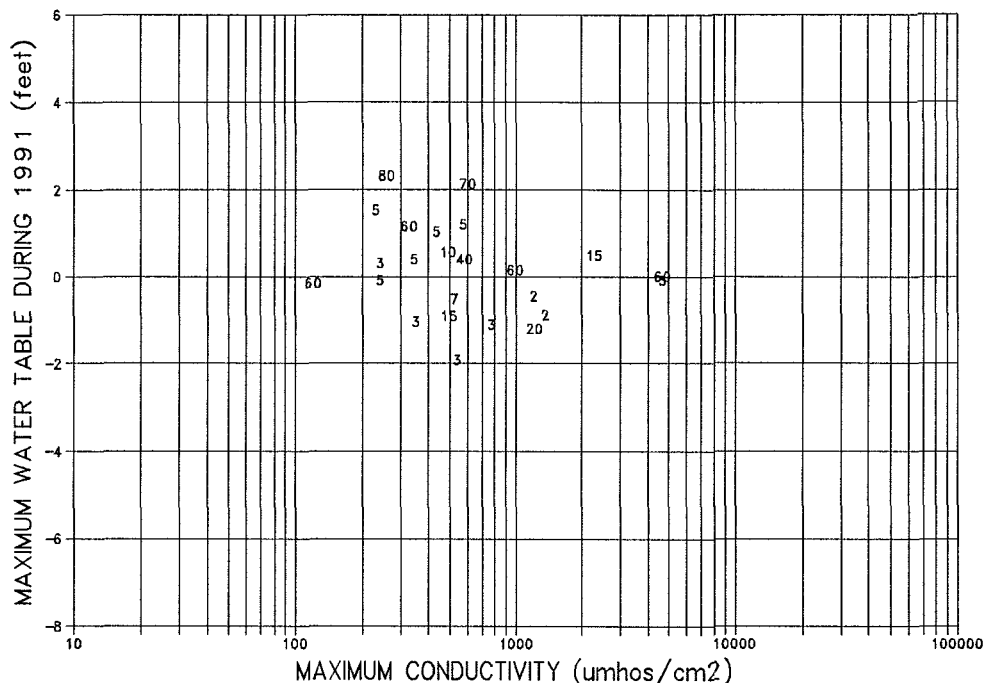


Figure 76. Realized niche of Schoenoplectus pungens in the study area. The diagram plots cover of Schoenoplectus on the maximum soil conductivity and maximum water table height gradients.

obligate halophyte. It can grow very well in dry and salt free environments with bluegrama grass. It most likely could grow very well in areas where it currently is limited by competition as has been shown for other halophytes (Ungar 1979). We believe that this species could occupy the Juncus arcticus and even the Carex lanuginosa zones around marshes but is kept out by these very aggressive competitors. Alkali cordgrass dominated-stands have low canopy coverage and production in the study area. The stands are most likely limited by both high salinity and soil drought.

Typha latifolia (broad-leaf cattail). Cattails are absent from all but the freshest waters in the San Luis Valley. Oligosaline water (conductance greater than 800 umhos/cm²) occurs at least seasonally in most lake and marsh systems in the Valley as they draw down in the late summer. Perennial fresh water (which has a conductance of less than 800 umhos/cm²) occurs in a

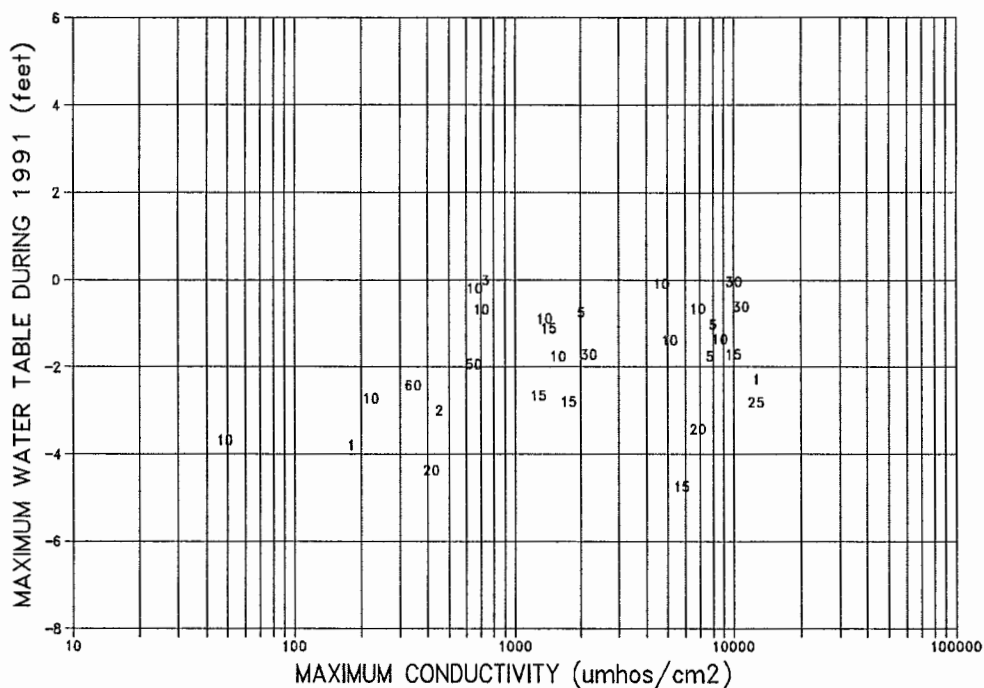


Figure 77. Realized niche of *Spartina gracilis* in the study area. The diagram plots cover of *Spartina* on the maximum soil conductivity and maximum water table height gradients.

few sites; along Big Spring Creek and at artesian wells in the Valley and cattails are found in most of these fresh water wetland areas. *Typha angustifolia* is more tolerant of saline habitats than *T. latifolia* (Grace and Harrison 1986) but it is uncommon in the San Luis Valley. *Typha latifolia* does not survive in water depths of greater than 1 m for more than 2 years (Shay and Shay 1986). Thus, during periods of flooding it can be eliminated.

POTENTIAL IMPACTS TO SAN LUIS VALLEY WETLANDS FROM WATER TABLE DRAWDOWNS

Proposed water table drawdowns in the San Luis Valley can occur from any project that will pump large volumes of groundwater for surface use or export from the Valley. A number of different existing and proposed projects could produce water table drawdowns, including the proposed AWDI project, the Closed Basin project, and various agricultural ground water pumping projects. These projects all can lower local and regional ground water tables. Another potential wetland impact is the reduction of surface water flows into lakes and streams. As discussed in the hydrology section of this report, many study area wetlands occur where they are seasonally saturated or inundated by ground water mounds built by surface water flows. These surface water sources are the surrounding mountains in most instances or large spring systems. The ground water mounds are elongated (the length of the river) and convex, almost snake-like and ephemeral features of these landscapes. They occur in early summer and along with the high regional water table is are essential features of the regional hydrologic regime that naturally supports wetlands in the San Luis Valley.

The discussion of ground water withdrawal must be focused on the ecological impacts of these actions. Interactions of ground and surface water at the landscape scale (the entire San Luis Valley) are involved and changes in these patterns and processes will cause changes in local and regional hydrologic patterns and soil chemistry. The synthesis of data collected over a large area is most appropriate. Impacts can have a number of different effects and these will be discussed separately.

1. Reduction the acreage of flooded or inundated ecosystems. Several different types of vegetation classes (from the vegetation classification presented earlier) occur in areas that are flooded annually or periodically for some period of time. These are: (a) Class *Potamogeton pectinatus-Zanichellia palustris*

(aquatic vegetation); (b) Class *Chara* sp. (lakebed algal vegetation); (c) Class *Schoenoplectus lacustris* - *Sagittaria cuneata* (reed swamps and emergents); (d) Class *Juncus arcticus* - *Deschampsia cespitosa* (wiregrass and hairgrass wet meadows).

Aquatic vegetation requires standing water to grow. It usually grows where water depth is greater than 1 foot but less than 120 cm, and where water persists for at least 3-4 months. Aquatic species require flooding and only *Hippuris vulgaris* can survive as an emergent. Lakebed algal vegetation dominated by species of *Chara* occurs only in deep and saline lake beds. Since aquatic vegetation has its highest production in sites with approximately 60 cm of standing water during the growing season, mitigation of these types of impacts with one or a few large lakes or ponds which have deep water is not possible.

Reed swamps and emergent communities occur on lake and stream shores where they are seasonally inundated with shallow water, up to 2 feet in depth. Several communities in the wet meadow class are periodically or seasonally flooded for short periods of time. The communities mentioned require some period of standing water to function. They also provide almost all of the habitat for waterfowl loafing, feeding and nesting. They provide all of the living and detrital material that becomes food and habitat for aquatic insects. The value of these ecosystems for almost all birds that migrate through, nest or otherwise use the San Luis Valley cannot be overemphasized. In addition, small mammals such as voles use the wet meadows almost exclusively.

Reduction in standing water areas would mean a direct reduction in aquatic vegetation of all types. This effect cannot be reduced. Elimination of standing water for emergent community types such as bulrush can cause a reduction in primary production of up to 90%. This reduction eliminates habitat for many birds. It also reduces the amount of organic matter put into the aquatic food chain.

2. Reduction in the duration of standing water in aquatic and emergent ecosystems. As was shown in the discussion of

vegetation zonation earlier in this report, not all wetland communities occur in all wetlands. Wetlands with short-duration (2 months or less on an average year) flooding can support an aquatic zone, but do not support an emergent zone with bulrush. Thus, the most important habitat type for many species and the ecosystem with the highest primary production in the San Luis Valley does not occur. As was discussed above, when standing water no longer occurs primary production in this community type is greatly reduced. Shorter duration flooding would also limit open water habitat for waterfowl, shorebirds and wading birds, particularly for young animals that need open water to escape predators.

3. Changes in the depth to water table. The overall high water table in the study area is a constant environmental factor, although seasonal and decade long changes in the water table elevation occur. These changes are slight and cyclical. The local and regional water table provides water directly to plants, and it is also necessary for surface water to remain as surface water that can create groundwater mounds which saturates soils and support most wetlands. The groundwater mounds should be envisioned as elongated ribbons with convex cross sections. If the groundwater table is drawn down, surface water would have to fill the additional soil and sediment volume with water before the water table can reach the surface. This is particularly important in the San Luis Lakes area where Big Spring, Little Spring and Sand Creeks flow through sand dune country. They must fill the soil volume above the water table with water in order to maintain a surface flow. Thus, for Sand Creek to carry surface water from the Sangre de Cristo Mountains to the Head Lake area it must fill the sediment in a band from the mountain front to the Head Lake area with water. If the water table is dropped a few feet the volume of water necessary to fill to maintain a surface flow would increase greatly.

Plant species and plant communities are distributed along the water table gradient, as has been shown in this report. Any

directional changes in the depth to water table will change the distribution of plants on the landscape. These changes could occur rapidly if a drawdown beyond the ecological amplitude (niche) of species were to occur in a few years. This situation could result in the death of species populations'. New plants would then have to colonize these area at a later date. Where the water table changes were gradual, a shift in where species occur on the landscape would occur. Species would shift downhill following the retreating water table. For species occupying the center of any wetland basin, there is nowhere to shift to and they must die. The ability of species to migrate is unknown. The ability of new plants to establish is also unknown.

4. Changes in the pattern of salt accumulation on the landscape. As water moves up from the water table by capillary action to form a capillary fringe, salts are transported with the groundwater. As the water evaporates the salt is left in the soil. Where the capillary fringe reaches into the root zone of plants or intersects the soil surface, salts can accumulate creating salt concentrations up to 500 times as high as those in fresh water influenced sites. Most wetland species in the study area have some salt tolerance, but few occur where soil conductivities of greater than 800 to 1000 $\mu\text{mhos}/\text{cm}^2$ were recorded during 1991. Instead, where salt accumulates different ecosystems occur. These include communities in the following two classes: (a) Class *Puccinellia airoides* - *Triglochin maritimum* (inland salt meadows and flats); and (b) Class *Chenopodium glaucum-rubrum* (drawdown vegetation of annual plants in playas). A water table drawdown in a wetland basin would result in areas no longer being flooded and the capillary fringe reaching the soil surface in wet meadow and even emergent community types. Thus, salt will accumulate there to levels that would kill the plants. Halophytic species, such as salt grass and alkali cordgrass, are tolerant of a wide variety of water table regimes and soil salinities and would be able to occupy all sites formerly dominated by non-halophytic species that are not

affected by increased soil salinity. This however, would result in a tremendous loss of biological productivity.

These four items discussed above are only a brief foray into the types of impacts that could occur. The figures presented elsewhere in this report, particularly Figures 53 and 67 can be used to understand the direct impact of any water level change on plant species. For example, in Figure 67, bulrush (Schoenoplectus lacustris) and aquatic plants occur in abundance only where surface flooding occurs. The loss of surface flooding will cause the loss of these species. Sedge (Carex lanuginosa) and spikerush (Eleocharis palustris) both occur in abundance only where there is either some flooding or where the water table is within one foot of the soil surface. If water tables in a particular area will be lowered so that no sites with these hydrologic regimes occur, then these species will no longer persist in an area, nor can they be reintroduced and expected to grow.

The development of a mitigation plan for wetland losses in a complex landscape like the San Luis Valley is a problematic task. Most wetlands are small, and therein lies the value. Many small wetlands in a complex provide much greater wildlife values than one or a few large wetlands. The problem with larger wetlands lies not in that they are large, but that to create large wetlands you must create a huge pool of water. This creates large areas with a water depth greater than 2 to 3 feet. These areas are not wetlands. Thus, much of the area of a large "wetland" is actually not functioning as a wetland. Thus, the value is greatly diminished. Also, mitigation should only be attempted where there has not been a water table drawdown. Because wetlands in the San Luis Valley occur in these groundwater mounds that are built on top of regional high water tables, where the regional water table is significantly lowered, wetland creation will not be possible.

MANAGEMENT IMPLICATIONS OF THIS RESEARCH

The San Luis Valley contains some of the richest waterfowl and shorebird habitats in the Rocky Mountain West. A primary goal of wetland research in the Valley should be aimed at developing an understanding of how important wetland ecosystems function and to use this knowledge to protect, restore and enhance habitat for shorebirds, waterfowl and fishing birds along with other animal species in managed areas.

Our perspective has been developed during the course of study at our Russell Lakes, Mishak Lakes and San Luis Lake study areas during 1991. We feel that waterfowl nesting in managed areas is limited because there is insufficient food base and insufficient nesting habitat to support many pairs.

The following discussion provides several avenues of thought regarding why the habitat is limited and provides ideas for future research to develop information for making better management decisions than can currently be made.

1. Aquatic insect production is one key for understanding the distribution of nesting water birds because most birds consume large number of insects, particularly before and during the nesting period. Insect production in San Luis Valley wetlands is greatest in bulrush and aquatic vegetation types. However, Davey, Trites, San Luis, Head and Harrence Lakes support very little aquatic vegetation. Also, only portions of Davey, Trites and San Luis Lake support extensive bulrush stands. The other lakes support little emergent vegetation on the shorelines. Harrence Lake has no emergent vegetation on the shoreline and almost no aquatic vegetation. Thus, most of the major water bodies in the San Luis Valley are productive only for loafing and resting habitat. Few areas are productive for feeding and nesting and therefore they are not important for supporting the desired populations of breeding waterfowl. Several questions can be developed with regard to these problems and could be addressed by appropriate research initiatives. Answers to these questions could lead to important water management solutions.

There is extensive published literature on the effect of organic matter buildup in lake soils inhibiting the growth of submergent plants (eg. Barko and Smart 1983). Lake soils should be investigated to determine the relationship of organic matter composition to aquatic vegetation. It would then be possible to manage the lakes' water levels to allow decomposition of this organic matter. The only dense beds of submergent vegetation in our San Luis Valley study areas were in the slough between Head and San Luis Lakes, in the Mishak Lakes, and at Island Lake. Mishak and the slough are playas that are dry in the late summer allowing organic matter to decompose. Island Lake is a relatively new lake and there is little organic matter accumulated. This seems to support published research and indicate that there may be another water management scheme for lakes that would be more productive for waterfowl. Since much of the water at Russell and San Luis Lakes goes toward the maintenance of water levels in the large lakes it may be worthwhile to modify the management approach for vegetation enhancement. Perhaps more water could be used to develop seasonal marshes and ponds that could have much higher plant and insect production and therefore be more attractive to the desirable animals.

It should be determined whether changes in lake hydrologic regimes could be used to change lake sediment characteristics and enhance aquatic plant production in lakes. We know that aquatic vegetation provides the most productive insect and plant habitat for waterfowl and shorebirds.

(2) The soil seed bank of the permanent lakes and numerous playas may hold viable propagules of aquatic and emergent plant species. Soil seed banks have been extensively researched in waterfowl areas of the northern Great Plains with stunning improvements in the knowledge and understanding both of how to manage these areas and of how these ecosystems naturally function (eg. R.L. Pederson and A. van der Valk 1984). These propagules could be used in situ to help establish desired vegetation and

habitat if appropriate water level management plans were developed.

(3) Water levels in permanent lakes should be managed to maximize submergent and emergent vegetation production which will lead to maximum insect production. At present water levels are not being managed with an eye toward the optimum levels required by the plants living there. For example, dikes built in the San Luis Lakes area this past summer were not constructed using data on plant requirements to maximize plant production and therefore aquatic food chains. I feel that if water levels are maintained at inappropriate levels the habitat will degrade, not improve. Water level management plans must be developed based on a knowledge of plant requirements. Maximum plant and wildlife production probably is not synonymous with year round maximum water levels. In fact it might be most advantageous to have very high spring and early summer water levels and low or dry late summer and winter levels. Water drawdowns are a proven effective means of management that could be used in the San Luis Valley (for reference see, C.H. Welling et al. 1988). Appropriately timed drawdowns could be used to stimulate the germination and establishment of bulrush populations in areas where they are not present found (for reference see, Kadlec 1962). Bulrushes are tremendously productive for many insect groups which are important food for birds. The bulrush also provide nesting habitat for many birds including marsh wren, eared grebes and white-faced ibis. This habitat could be greatly enhanced in many areas where bulrush does not presently occur, but could with proper water management.

Drawdowns in the San Luis Lake slough area could be timed with the arrival of fall birds such as San Hill Cranes. There is abundant production of large smartweed (Persicaria amphibia), burreed (Sparganium eurycarpum) and other aquatic and emergent plant seeds in the slough, but because water levels are high in the fall this seed is unavailable.

(4) Ground water and lake elevation data collected during

1991 indicate that the elevations of large permanent lakes control water table elevations in surrounding areas. Lake elevations are higher than surrounding water table elevations and the lakes lose water creating ground water mounds in adjacent areas. This is easily seen in the area between Trites and Harrence Lakes in the Russell Lakes area. When Harrence Lake was filled in late summer of 1991 the effect of this rising water level resulted in rising ground water table elevations even in the area west of the lake which is uphill. Water levels in Trites Lake also control water tables in this area between Trites and Harrence Lake. I focus on this area between Trites and Harrence Lakes because it contains numerous playa basins which were dry for most of 1991. A few basins held water for a few days or weeks following rains in August. At this time insect life in the filled playas was fantastic, but the emergent vegetation surrounding these lake basins remained dormant.

(5) The Russell Lakes area has tremendously salty soils and ground water in many areas. Water management techniques could be used to reduce salinity in many areas and to build groundwater mounds using the very fresh water available on site.

SUMMARY

The San Luis Valley study area contains a wide variety of wetland types ranging from aquatic vegetation of seasonal or permanent ponds and lakes to emergent marshes and wet meadows on pond edges and other high water table areas. In addition, salt flats occur as well as upland grass communities. The distribution of plant species and plant communities is determined by species tolerance of flooding, soil salinity, and soil drought. Detailed investigations and analyses provided in this report describe a hierarchical classification of vegetation types, analyze the vegetation along water table and soil salinity gradients.

Species niches are described using direct gradient analysis techniques. In general aquatic, emergent and wet meadow communities occupy rather narrow niches. They are intolerant of saline soils and most likely of soil drought. Species occurring in salt flats, such as saltgrass and alkali cordgrass, have broad niches and are more tolerant of soil salinity. They occur in the most saline and the least saline soils in the study area. Most species are intolerant of flooding, but many are hydrophytes and halophytes, able to tolerate saturated soils and saline soils. Upland species such as bluegrama grass are intolerant of both soil saturation and high or even moderate soil salinities.

The hydrologic regimes of the four study areas are explored and described in detail. The Villa Grove area is unique with large amounts of ground water discharged to the surface. This supports peat soils. The other three study areas are more similar. They have permanent high regional water table upon which seasonal ground water mounds build, fed by fresh surface waters. In these groundwater mound influenced sites most productive wetlands occur. Maintenance of these water table mounds is essential requiring the protection of the regional water table and of surface water deliveries.

Potential wetland impacts from a large scale ground water withdrawal would be enormous because almost all wetlands depend

either directly on the high regional water tables, or upon the seasonal groundwater mounds which can only occur on top of the high regional water tables. If the water table is lowered, the mounds would not influence the surface soils and plants.

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APPENDIX 1: PLANT SPECIES LIST
San Luis Lakes, Mishak and Russell Lakes Areas
(nomenclature follows Weber 1990)

Alisma plantago-aquatica
Alopecurus aequalis
Amphiscirpus nevadensis
Argentina anserina
Artemisia annual
Aster canescens
Aster junciformis
Aster occidentalis
Aster pauciflorus
Astragalus bodinii
Atriplex canescens
Atriplex rosea
Batrachium trichophyllum
Beckmannia syzgachne
Bidens cernua
Bouteloua gracilis
Calamagrostis stricta
Carex lanuginosa
Carex nebraskensis
Carex praegracilis
Carex simulata
Carex vesicaria
Chara sp.
Chenopodium glaucum
Chrysothamnus nauseosus
Cicuta douglasii
Cirsium arvense
Cleome multicaulis
Cleome serrulata
Crepis runcinata
Critesion (Hordeum) brachyantherum
Critesion (Hordeum) jubatum
Deschampsia cespitosa
Descurania ramosissima
Distichlis stricta
Eleocharis acicularis
Eleocharis palustris
Eleocharis parvula
Elymus (Agropyron) trachycaulus
Epilobium ciliatum
Equisetum hyemale
Erigeron elongatus
Eriogonum cernuum
Euphorbia sp.
Glaux maritima
Glyceria grandis
Gutierrezia sarothae
Helianthus nuttallii

Heliotropium curvassavicum ssp. *oculatum*
Hippuris vulgaris
Ipomopsis longifolia
Iris missouriensis
Juncus arcticus
Kochia sp.
Lactuca tatarica
Lemna minor
Lepidium montanum
Lycopus asper
Lygodesmia sp.
Mentha arvensis
Muhlenbergia asperifolia
Muhlenbergia pungens
Muhlenbergia richardsonis
Myriophyllum spicatum
Nuttallia (*Mentzelia*) *multiflora*
Opuntia compressa
Opuntia polyacantha
Oreocarya suffruticosa
Orthocarpus luteus
Oryzopsis hymenoides
Pascopyrum (*Agropyron*) *smithii*
Pedicularis crenulata
Persicaria amphibia
Persicaria lapathifolia
Phalaris arundinacea
Plagiobothrys scouleri
Plantago eriopoda
Poa juncifolia
Poa palustris
Poa pratensis
Polygonum aviculare
Potamogeton pusillus
Psoralea sp.
Puccinellia airoides
Pyrrocoma lanceolata
Ranunculus cymbalaria
Rorippa palustris
Rumex salicifolius
Sagittaria cuneata
Salix exigua
Sarcobatus vermiculatis
Schoenoplectus lacustris
Schoenoplectus pungens
Senecio spartioides
Sidalcea neomexicana
Sisyrinchium montanum
Sisyrinchium pallidum
Sparganium eurycarpum
Spartina gracilis
Sporobolus airoides

Sporobolus cryptandrus
Stipa comata
Suaeda calceoliformis
Triglochin maritimum
Typha latifolia
Utricularia ochroleuca
Veronica anagallis-aquatica
Virgulus (Aster) falcatus
Yucca glauca
Zanichellia palustris