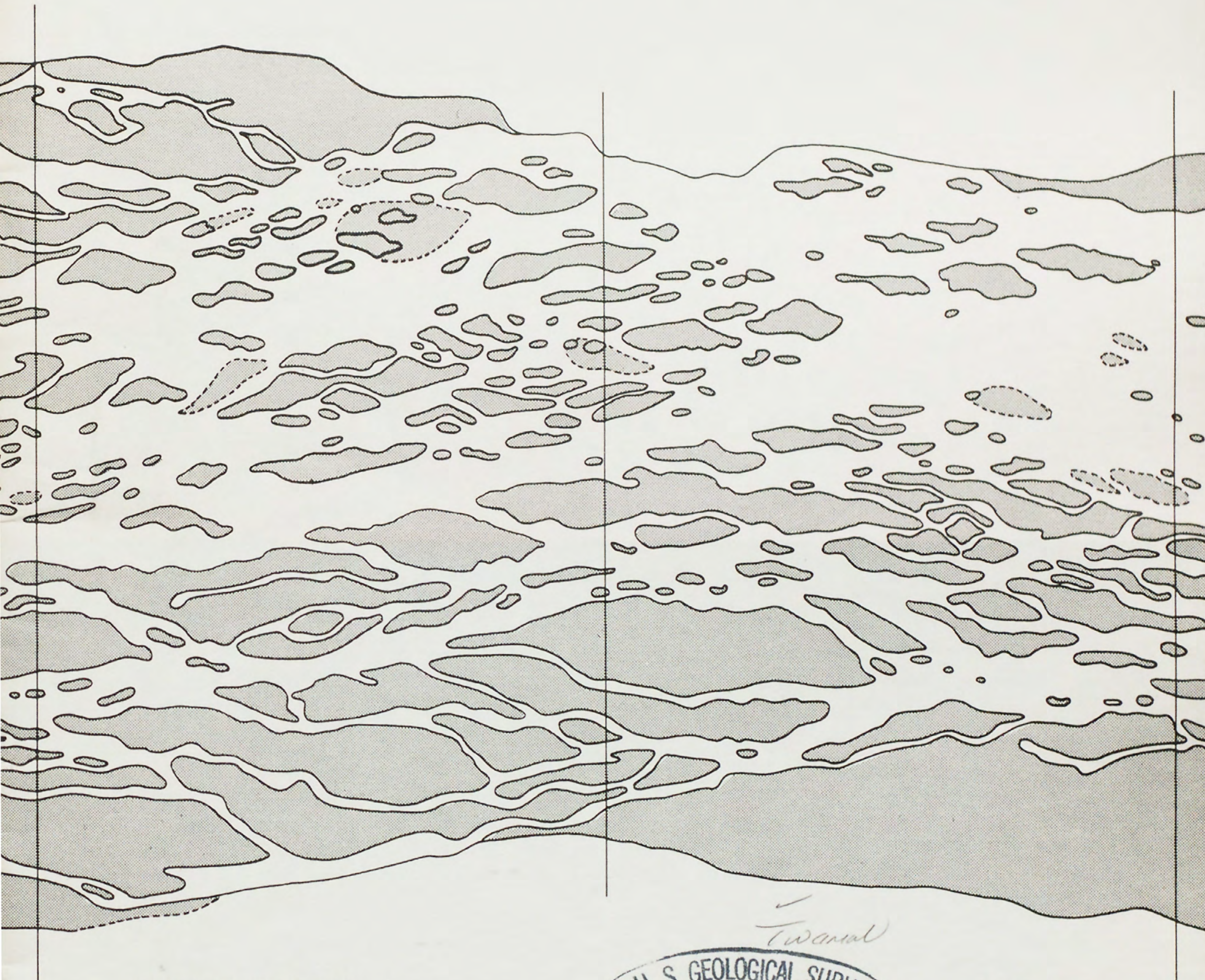
# GROUND-WATER HYDROLOGY OF THE MORMON ISLAND CRANE MEADOWS WILDLIFE AREA, NEAR GRAND ISLAND, HALL COUNTY, NEBRASKA





UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OPEN-FILE REPORT 81-1109

Cover illustration--A 2-km reach of the Platte River channel near Kearney, Nebraska, from an aerial photograph taken in 1957.

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By R. Theodore Hurr

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U.S. GEOLOGICAL SURVEY

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## METRIC CONVERSIONS

Inch-pound units used in this report may be converted to metric units by use of the following conversion factors:

| *Multiply inch-pound unit* | *By* | *To obtain metric unit* |
|---|---|---|
| inch | 25.4 | millimeter |
| foot | 0.3048 | meter |
| mile | 1.609 | kilometer |
| gallon per minute | $6.309 \times 10^{-2}$ | liter per second |
| foot squared per day | $1.075 \times 10^{-6}$ | meter squared per second |

*National Geodetic Vertical Datum of 1929 (NGVD of 1929)*: A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level." NGVD of 1929 is referred to as sea level in this report.

GROUND-WATER HYDROLOGY OF THE MORMON ISLAND CRANE MEADOWS WILDLIFE AREA, NEAR GRAND ISLAND, HALL COUNTY, NEBRASKA

By R. Theodore Hurr

ABSTRACT

The Platte River in south-central Nebraska flows generally eastward in a broad, flat valley. The river banks and many areas adjacent to the river support thick stands of cottonwood, elm, and willow trees. Brush, grass, pasture land, and cultivated fields occupy most of the remaining area. This is the habitat for many types of wildlife that live in the area or stop over in the area during annual migrations. Both sandhill cranes and whooping cranes are part of the annual migrations. There is concern that water-management changes, such as surface-water diversions or ground-water withdrawals for irrigation, may alter the hydrologic environment of the wetland areas in a manner that may be harmful to the wildlife habitat.

In order to determine some of the possible effects changes in water management might have on ground-water levels in the wetland areas, detailed data were collected from Mormon Island Crane Meadows wildlife area, which is on an island in the Platte River, 8½ miles south of Grand Island, Nebr. The island is approximately 10 miles long and 1 mile wide. Ground-water levels and river stage were monitored for a period of 7 months in 1980 to determine the relationships between ground water and surface water for the alluvial aquifer-river system.

Ground-water levels beneath the island respond to changes in river stage, to recharge from snowmelt and precipitation, and to evapotranspiration by riparian vegetation and from areas where the water table is close to the land surface. The data for the island show that ground-water levels in the general area along the Platte River respond rapidly to changes in river stage--usually within 24 hours for distances up to 2,500 feet from the edge of the river. Thus, temporary changes in river stage due to changes in surface-water diversions will have an almost immediate effect on ground-water levels, and the change in ground-water level will be maintained as long as the change in river stage exists. There will be no long-term residual effect on ground-water levels if the river is returned to its original stage.

Changes in ground-water withdrawals will have the simultaneous effects of (1) directly changing ground-water levels due to water-level declines beneath habitat areas and (2) indirectly changing ground-water levels due to changes in river stage caused by the depletion of streamflow. Due to the aquifer characteristics and the distance of withdrawals from the habitat areas, the effects of the withdrawals will develop slowly and be long lasting, perhaps weeks or months. If most of the changes in withdrawal occur farther than 2,500 feet from the river, however, the resulting change in ground-water levels within 2,500 feet of the river will probably average less than 1 or 2 feet. These changes could be modified on a short-term basis by controlling the river stage through controlling diversions and reservoir releases.

# INTRODUCTION

## Purpose and Scope

The Platte River in south-central Nebraska flows generally eastward in a broad, flat valley. Braiding of the river channel creates numerous islands of various sizes. The river banks and many areas adjacent to the river support thick stands of cottonwood, elm, and willow trees. Brush, grass, pasture land, and cultivated fields occupy most of the remaining area. This is the habitat for many types of wildlife that live in the area or stop over in the area during annual migrations. Both sandhill cranes and whooping cranes are part of the annual migrations which include ducks, geese, and other, nongame birds. There is concern that water-management changes, such as increases or decreases in surface-water diversions or ground-water withdrawals for irrigation, may affect the hydrologic environment of the wetland areas in a manner that would be harmful to the wildlife habitat. It is the purpose of this study to quantitatively describe some of the possible effects that management changes would have on the ground-water system of the habitat area. Rather than study the entire valley, the U.S. Geological Survey selected a typical area, the Mormon Island Crane Meadows wildlife area on an island in the Platte River near Grand Island, Nebr., for detailed study (fig. 1). Although the study area takes its name from Mormon Island, it is not actually on Mormon Island.

The objectives of the study were to determine the relationship between ground water and surface water so that the effects of any potential increases or decreases in surface-water diversions or ground-water withdrawals that change river flow and the resulting river stage or ground-water levels directly can be used to predict the changes in ground-water level in habitat areas. These predictions of changes in ground-water levels can then be used by botanists and wildlife biologists to determine the effects on the habitat in terms of depth, area, and duration of standing water and in the assemblage and vigor of plant communities. It is beyond the scope of this report to discuss or evaluate particular management plans or the effects any given plan might have on ground-water levels or river flow.

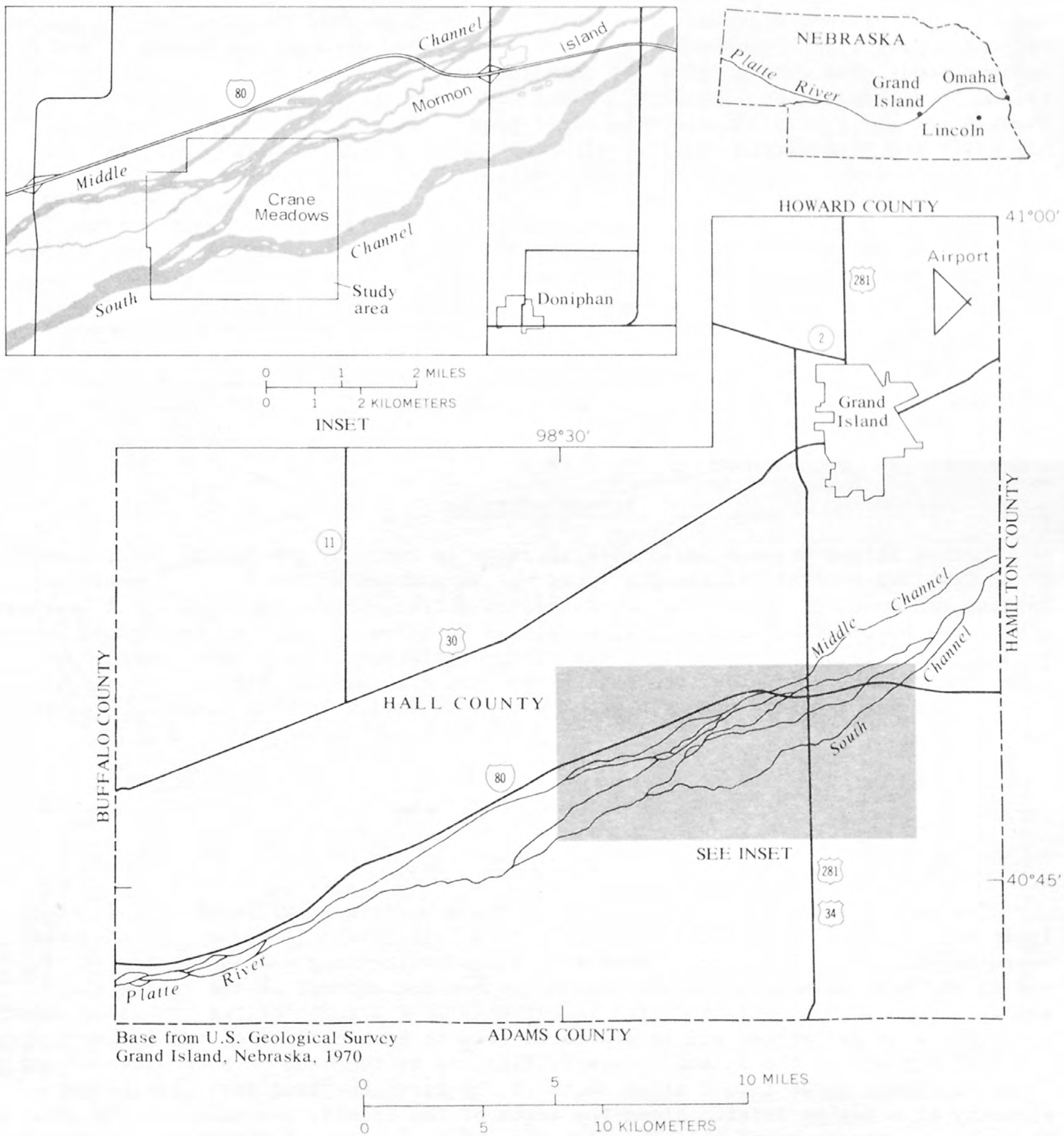


Figure 1.--Location of Mormon Island Crane Meadows study area.

## Methods of Investigation

Previously published reports by the U.S. Geological Survey and the Conservation and Survey Division, University of Nebraska, have been used to determine the geological and hydrological framework of the area. Detailed data on the Mormon Island Crane Meadows study area were obtained by drilling 60 test holes into the alluvium of the island to determine the lithology. These test holes were cased and used as either observation wells or piezometers in order to monitor water levels. Three of the six wells and piezometers equipped with continuous water-level recorders provided useful water-level records. Fifty-four wells and piezometers were measured manually on a weekly basis (fig. 2). Two river-stage recorders were installed--one on either side of the island (fig. 2). Ground-water levels and river stage were monitored for a period of approximately 7 months, beginning in April and ending in November 1981.

The data were analyzed to quantitatively determine the relationship between river stage and ground-water levels. The analysis was done by comparing observed ground-water level fluctuations with observed river-stage fluctuations, and by comparing calculated with observed ground-water level fluctuations. Calculation of ground-water level fluctuations was done both analytically and by digital-model simulation.

## Acknowledgments

Mormon Island Crane Meadows wildlife area is owned by the Platte River Whooping Crane Critical Habitat Maintenance Trust and is managed by The Nature Conservancy. Farming and ranching operations are leased to Quirk Land and Cattle Co., of Hastings, Nebr. The cooperation of these organizations in allowing the U.S. Geological Survey to drill test holes and to collect data is appreciated. Weekly water-level measurements were made under contract by Mr. and Mrs. Russ Hettinger, who manage the farming and ranching operations. Their contribution to this study is greatly appreciated.

# DESCRIPTION OF STUDY AREA

## Geography

The island on which the Mormon Island Crane Meadows wildlife area is located is in the Platte River $8\frac{1}{2}$ miles south of Grand Island in Hall County, south-central Nebraska (fig. 1). The island, approximately 10 miles long and $1\frac{1}{4}$ miles wide, is one of the many permanent islands within the braided channel of the Platte River and is unnamed. Mormon Island lies immediately to the north of the island on which the study area is located and is separated from it by a channel of the Platte River. The land surface of the island is nearly flat, as is the land on both sides of the river, although about 1 to 2 miles south of the river the land does rise rather abruptly to a higher level. Along the edges of the island, the banks of the river channels are nearly vertical. The elevation of the center of the island is several feet lower than the margins of the island.

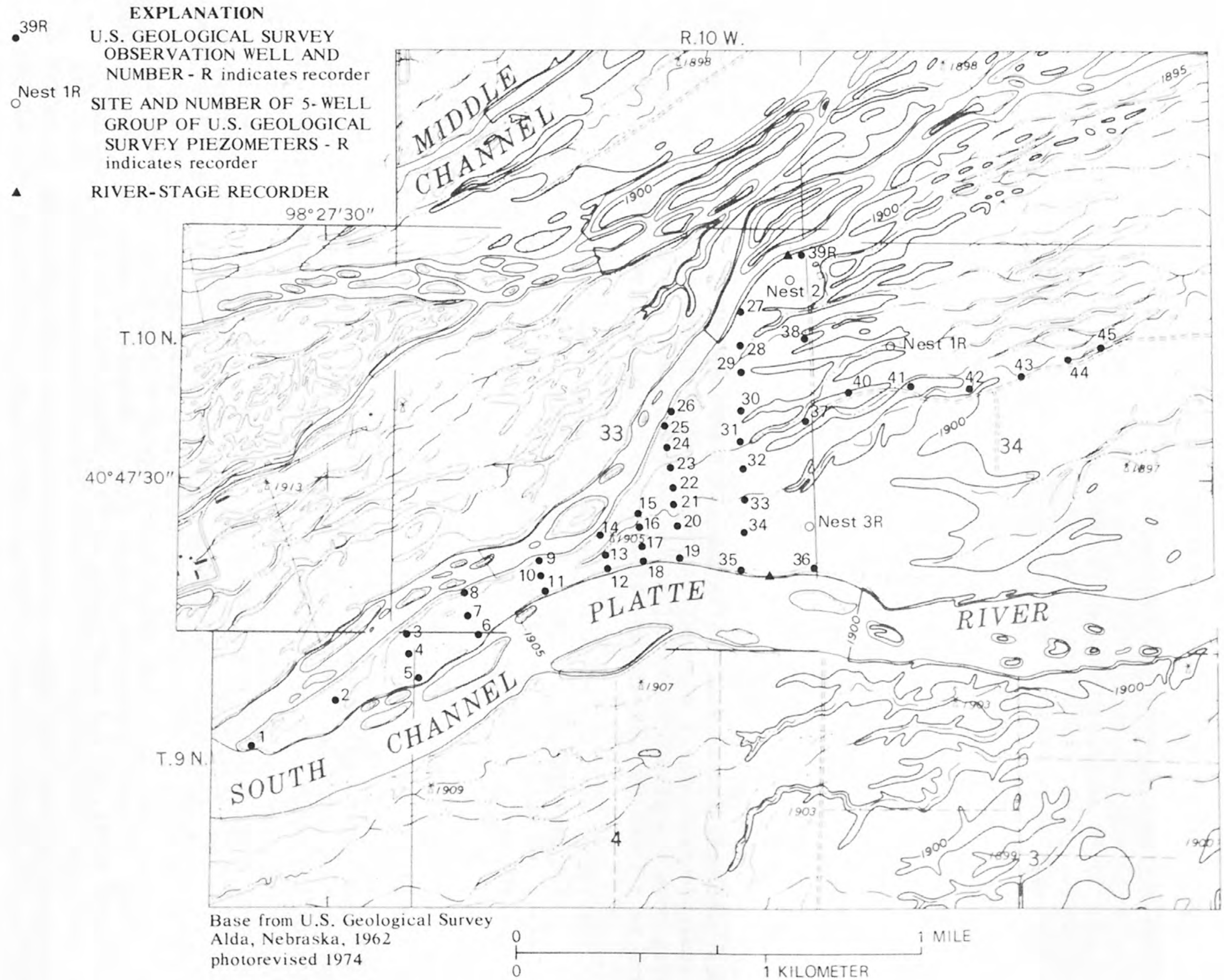


Figure 2.--Location of observation wells, including recorder wells, and river-stage recorders, Mormon Island Crane Meadows study area.

Much of the bottomland near and adjacent to the river is covered with cottonwood and willow trees as well as smaller scrub vegetation and brush. Some of the area, including most of the Crane Meadows study area is pastureland with various types of grasses. Some land is cultivated and planted with row crops, such as corn.

The habitat generally includes the river itself, wetland or wet meadows on the islands or areas adjacent to the river, and dry pastures and cultivated fields. Although some birds such as the sandhill crane may feed in fields considerably distant from the river, the habitat area that can be influenced by water-management changes generally is restricted to within about a half mile on either side of the river.

## Geology

The Platte River in south-central Nebraska is underlain by alluvial clay, silt, sand, and gravel of Quaternary age deposited in a series of broad troughs cut into the underlying shales and limestones of Cretaceous age and clay, silt, sand, and gravel of Tertiary age. The Cretaceous rocks are the Niobrara Formation and the Pierre Shale. The Tertiary formation is the Ogallala Formation.

The Niobrara Formation is predominantly gray to orange, argillaceous chalk and limestone with some interbedded chalky shale. The Pierre Shale is a gray to black marine shale, which locally contains very thin layers of bentonite. Within the study area both the Niobrara Formation and the Pierre Shale have low permeability and serve as a lower boundary to the flow system of the shallow alluvial aquifer.

The Ogallala Formation consists of interfingering beds of clay, silt, sand, and gravel. The material in the sand and gravel beds is fine to medium grained, poorly sorted, and arkosic. The lithology can vary laterally and vertically over very short distances. Sandstone beds are common. Calcium carbonate cement forms widespread distinctive "mortar beds," and locally, secondary silica has cemented the sand into quartzite (Dreeszen and others, 1973). Sand, gravel, and some sandstones in the Ogallala Formation are both porous and permeable, and transmit water and supply water to wells.

The Quaternary alluvium contains the principal aquifer in the area and consists of interfingering lenses and beds of unconsolidated clay, silt, sand, and gravel. The lower half of this unit is predominantly clay or silt and the upper half is predominantly sand and gravel with some beds of clay or silt.

Beneath the study area both the Ogallala Formation and the Pierre Shale were removed by erosion prior to the deposition of the Quaternary alluvium. The Niobrara Formation is the base of the shallow hydrologic system in this area (Keech and Dreeszen, 1964). The Quaternary alluvium is approximately 270 to 275 feet thick, of which the lower 120 to 150 feet is clay or silt. This lower part, although probably saturated with water, is not considered to be a significant part of the aquifer system. The upper part is 120 to 155 feet thick and consists of interfingering beds and lenses of sand and gravel with some clay and silt. The sand is medium to very coarse, and subrounded. The gravel is very fine to medium, and subrounded.

The grains of the sand and gravel are mostly quartz with some feldspar and granitic fragments. In the study area this material is saturated to within a few feet of the land surface and supplies water to wells, including irrigation wells. The aquifer, which is part of this alluvium, is in hydraulic connection with the Platte River when water is present in one or more of the channels.

## Hydrology

Recharge to the aquifer in the Crane Meadows study area is from rainfall, snowmelt, and seepage from the Platte River. Precipitation in Hall County averages about 24 inches per year, most of which occurs in the spring and summer. The average annual snowfall is 25 inches, most of which falls during February and March (Keech and Dreeszen, 1964). Recharge occurs from both rainfall and snowmelt.

The island on which the study area is located is bounded on the south by South Channel Platte River, which is the main channel of the river, and is bounded on the north by interconnecting channels between South Channel and Middle Channel Platte River. Middle Channel is ¼ to ½ mile north of the study area. The flow of the river usually is highest in the spring due to snowmelt and rainfall runoff. The flow decreases during the summer due to diversions for irrigation and decreasing runoff. Frequently, the flow of Middle Channel and the interconnecting channels ceases altogether. Occasionally, even South Channel goes dry. In the fall when irrigation diversions stop altogether, the flow of the river increases and remains approximately steady or decreases only slightly through the winter to the next spring.

Ground water in the alluvium is in direct hydraulic connection with the river when water is present in the river. The ground-water level is controlled by the presence and altitude of the river as it passes by the island. The direction of ground-water movement beneath the island, as inferred from the water-table contours, is to the northeast (fig. 3), parallel to the principal direction of flow of the river. North and south of the river, the ground water has a slight component of flow away from the river as water from the river recharges the aquifer.

Changes in river stage will alter the direction of ground-water flow locally. When the river stage is high, the direction of flow of ground water immediately adjacent to the river will tend to become more perpendicular to the river's edge as water flows from the river into the aquifer. When the river stage is low, the direction of ground-water flow will tend to become more parallel to the river's edge, although flow still continues to be from the river into the aquifer. In general the ground-water level beneath the island and beneath the land adjacent to the river in the vicinity of the island is always lower than the level of water in the river. This is due mostly to evapotranspiration by riparian vegetation and from areas where the water table is close to land surface. North and south of the river it is also due to (1) natural flow away from the Platte River to other, lower river systems, such as the Wood River and the Blue River systems (Freethey, 1973), and (2) to ground-water withdrawals by wells in areas adjacent to the river.

The aquifer beneath the island on which the study area is located supplies water to one irrigation well, two domestic wells, and several stock wells. The irrigation well is seldom used. No water is diverted from the river for irrigation in this area.

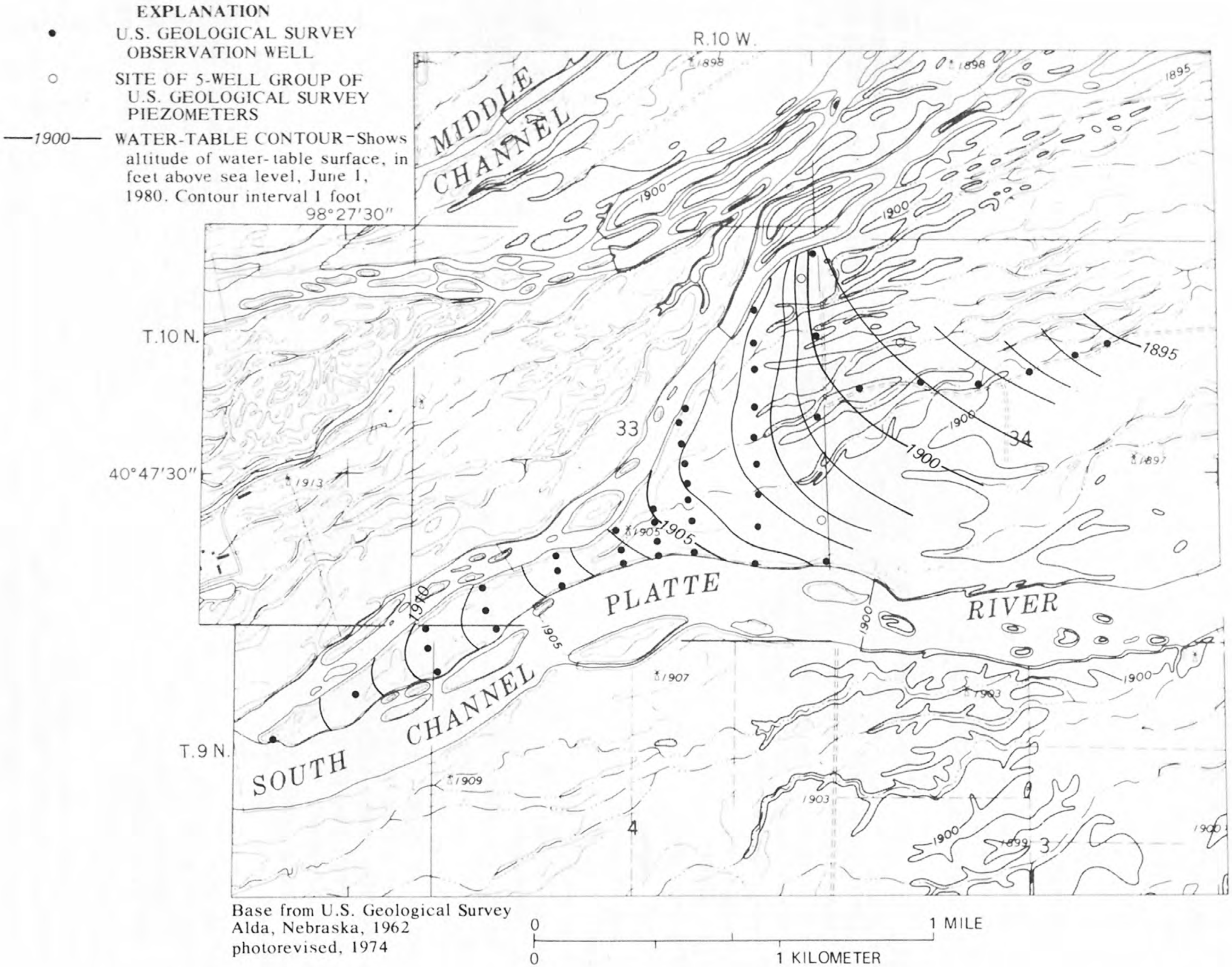


Figure 3.--Water-table configuration beneath the Mormon Island Crane Meadows study area, June 1, 1980.

GROUND-WATER HYDROLOGY

## Water Levels

Water levels in the aquifer beneath Mormon Island Crane Meadows wildlife area range from land surface to approximately 7½ feet below land surface, depending on the location and the time of year. Water levels are highest in the late spring to early summer. During this time, when there is water in the channels on both sides of the island, recharge from the river enters the ground-water system along the edges of the island and flows toward the center of the island, curving northeastward along the downstream trend of the island (fig. 3). Most of this water never returns to the river. It either is consumed by evapotranspiration or flows back to the north after the channel on the north side of the island goes dry during mid- to late summer. The water-table configuration of the area in August 1980 when the channel on the north side of the island was dry is shown in figure 4. Recharge from the river was still occurring along the south side of the island. Along the north side of the island, the channel had dried up, recharge had stopped, ground-water levels were below the bottom of the channel, and the direction of ground-water flow was northward and eastward in response to more regional flow conditions.

The altitude of the Platte River at the stage recorder on South Channel (fig. 2) is shown in figure 5. The altitudes of ground-water levels at three sites across the width of the island (see fig. 2 for location) are shown in figures 6, 7, and 8. Comparisons between these hydrographs show rises in ground-water levels attributed to recharge from snowmelt (fig. 6, April 1-3, 1980) and rainfall (figs. 6 and 7, May 16 and May 31, 1980), with little or no change in river stage; general rises and declines in ground-water levels that are in direct response to changes in river stage; and diurnal fluctuations in ground-water levels that are caused by diurnal changes in the rate of evapotranspiration.

At three sites on the island (fig. 2), groups of piezometers were installed to monitor the hydraulic head at different depths within the aquifer. Each group or nest consisted of five piezometers drilled within a 25-foot radius area. The piezometers were set at five different depths, approximately 30 feet apart, starting at a depth of 25 feet. Piezometers are different from observation wells in that piezometers are only open to the aquifer at a specific depth and provide a measure of the pressure or hydraulic head of that specific depth.

Water levels in these nested piezometers showed only a slight difference in hydraulic head from the top of the aquifer to the bottom. The maximum difference in hydraulic head was less than 0.2 foot higher near the top of the aquifer than near the bottom. This difference occurred during the period of maximum water-level stage (May 31 to June 1, 1980).

## Analysis of Observations

The response of ground-water levels to changes in river stage is rapid. Observed changes of water levels in the piezometers at nest 1, about 2,500 feet from the nearest channel of the river, occur within 24 hours of a change in river stage.

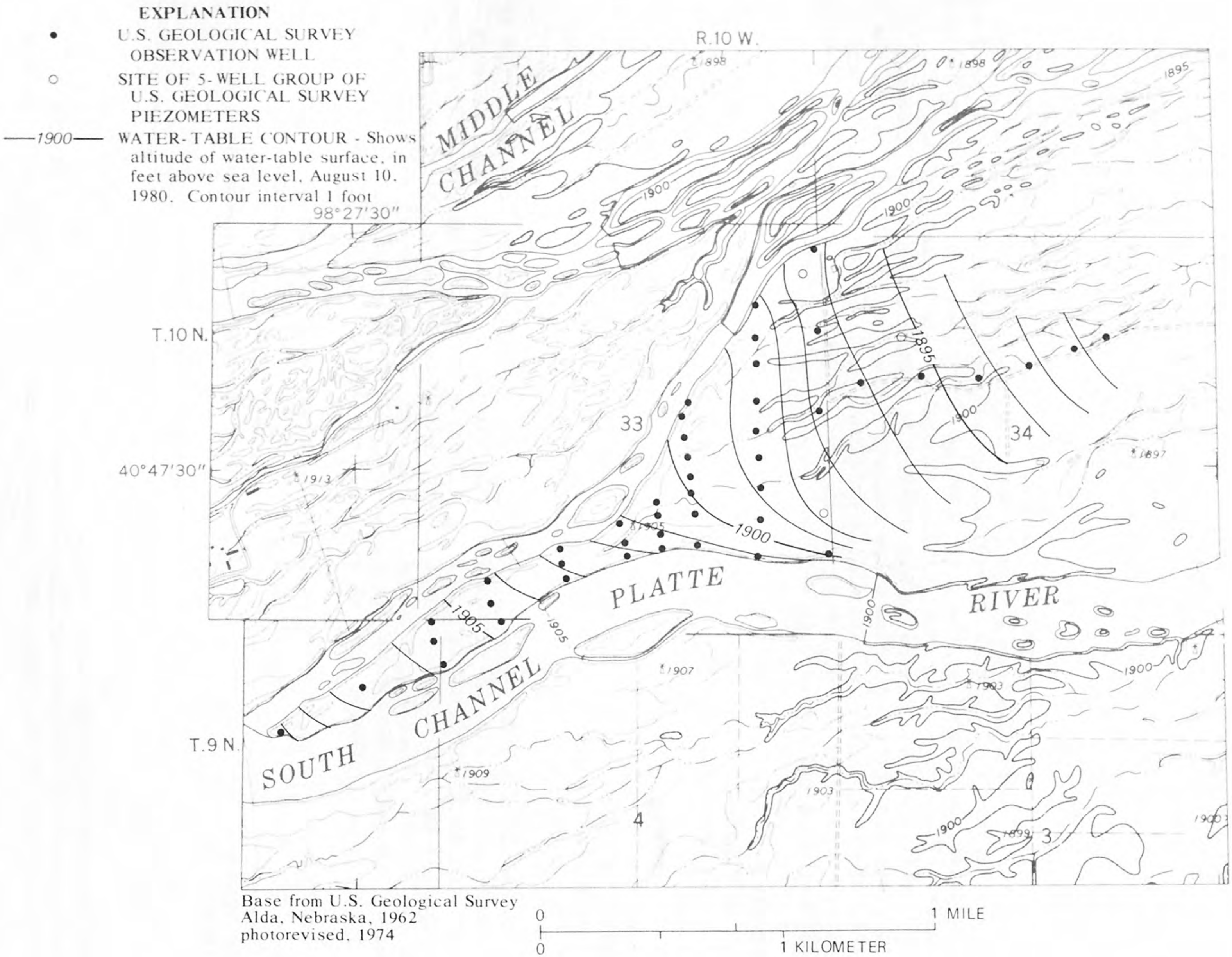


Figure 4.--Water-table configuration beneath the Mormon Island Crane Meadows study area, August 10, 1980.

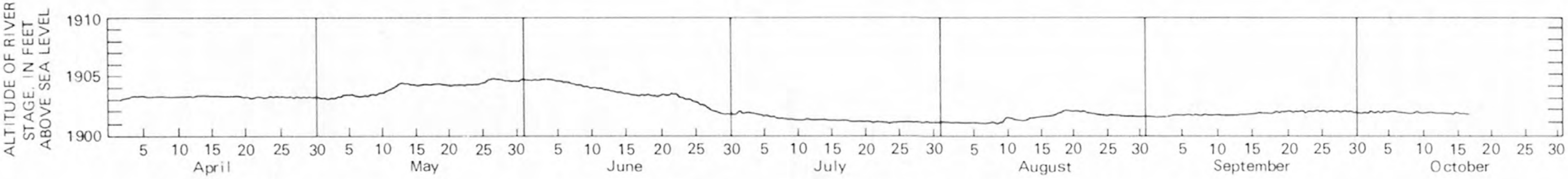


Figure 5.--Hydrograph showing river stage, South Channel of Platte River, Mormon Island Crane Meadows study area.

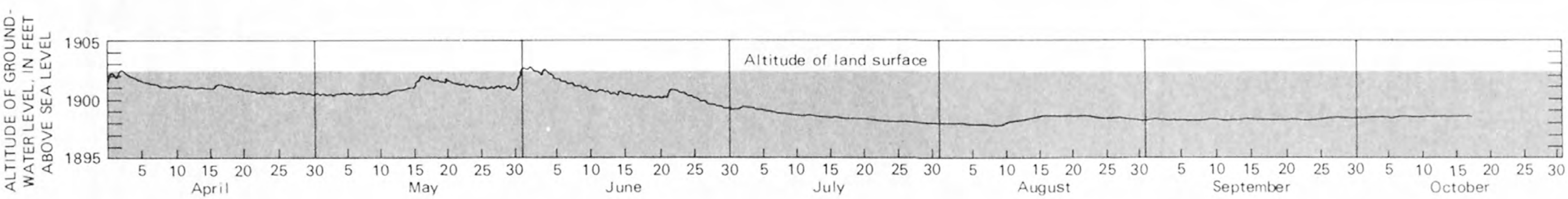


Figure 6.--Hydrograph showing ground-water levels in well 5, nest 3, Mormon Island Crane Meadows study area.



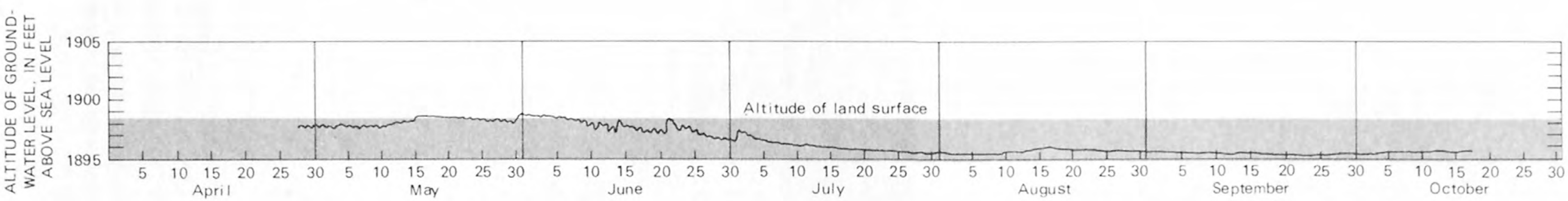


Figure 7.--Hydrograph showing ground-water levels in well 5, nest 1, Mormon Island Crane Meadows study area.

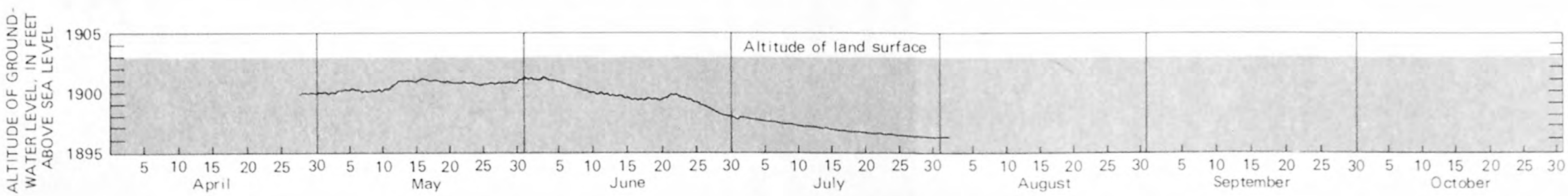


Figure 8.--Hydrograph showing ground-water levels in well 39, Mormon Island Crane Meadows study area.

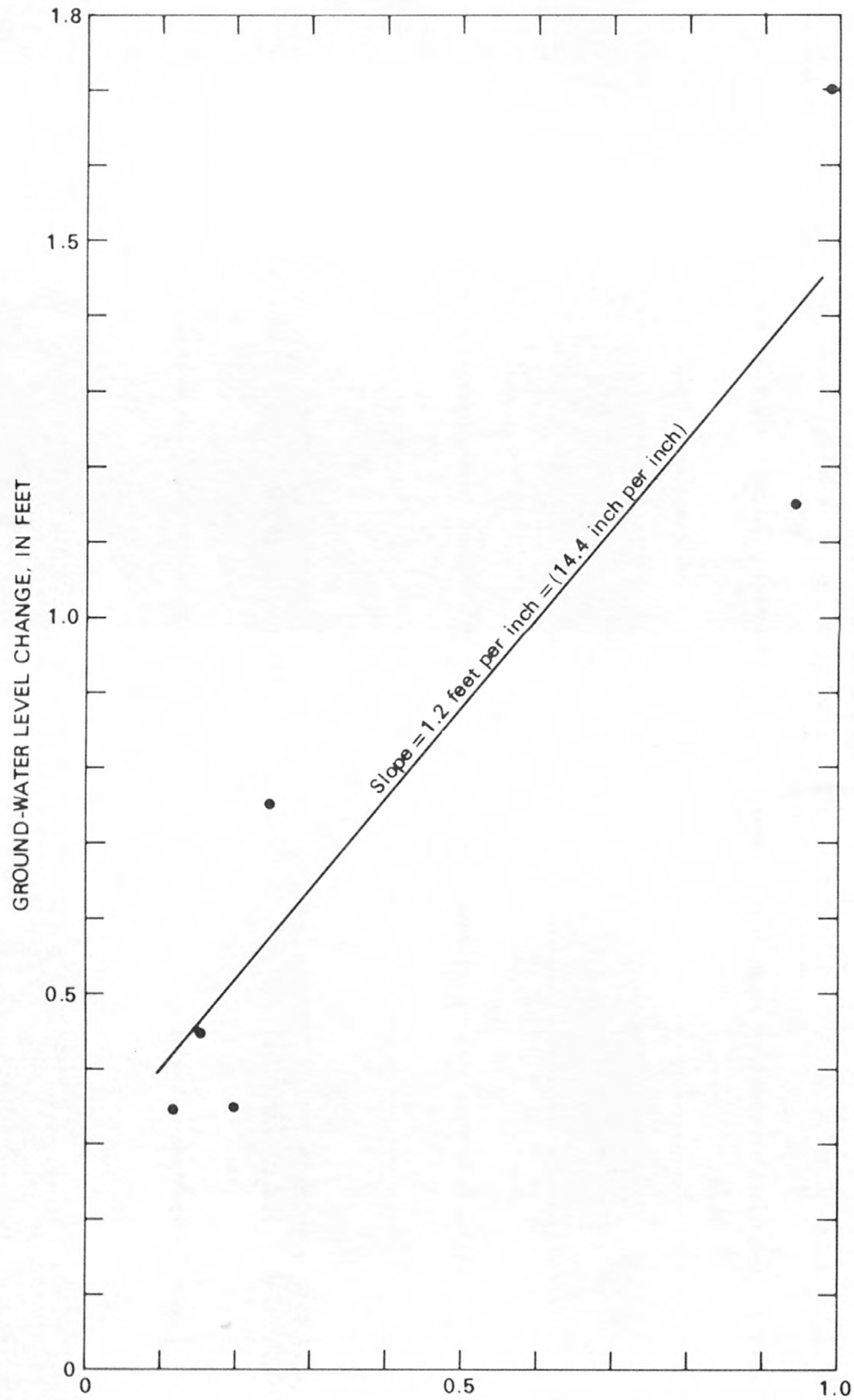


Figure 9.-- Relationship between rainfall and change in ground-water level, Mormon Island Crane Meadows study area.

Trial-and-error comparison of observed ground-water changes with calculated changes indicated a hydraulic diffusivity for the aquifer (transmissivity divided by specific yield) of approximately 200,000 feet squared per day. The calculated changes were obtained by using estimated values of transmissivity and specific yield in the analytical drain formula (Stallman, 1962) and by using a cross-sectional ground-water flow model.

It was not possible to calculate changes in ground-water levels that exactly duplicated the observed change because of some complicating influences. Much of the land surface in the interior of the island is below the elevation of the river, even at low stage. Consequently, the ground-water level can rise only so high--just until the water table intersects and rises slightly above land surface--before ground water begins to run off as surface-water flow in the topographic lows and sloughs which drain the interior of the island. Also, the response of ground-water levels to changes in river stage is mitigated by changes in the rate of evapotranspiration as the depth to water below land surface changes.

Evapotranspiration causes diurnal fluctuations in the ground-water level which range from zero to approximately 0.3 foot, depending on weather conditions, time of the year, and the depth to water below land surface. A 0.3-foot change and an estimated daily evapotranspiration of 0.03 foot (F. J. Otradovsky, U.S. Bureau of Reclamation, oral commun., 1981) would indicate the specific yield for the upper few feet of the aquifer to be 0.10.

The river-stage hydrograph for South Channel (fig. 5) also shows diurnal fluctuations. The magnitude of these fluctuations is smaller than the magnitude of the fluctuations in ground-water levels, indicating that the river is not the cause of the ground-water fluctuations. In fact, the reverse is probably the case: the river-stage fluctuations are the combined result of direct evaporation from the water surface of the river and the loss of streamflow to the ground-water system to satisfy the evapotranspiration of water from the aquifer.

Direct recharge to the aquifer from precipitation is shown by the hydrograph of ground-water levels in figure 6. Sharp rises in ground-water levels on May 16, 18, 20, and 31, and June 2 and 22 correspond to smaller rises in river stage. Rainfall measured at the Grand Island Airport for these dates plotted against the change in ground-water levels is shown in figure 9. If the same amount of rain fell on the island as was measured at the airport and all of the rainfall was recharge to the aquifer and distributed uniformly over the aquifer, the rise would indicate a specific yield of 0.07.

The transmissivity of the aquifer in the vicinity of the island is approximately 20,000 feet squared per day based on the diffusivity and specific-yield value of 0.10. This is the transmissivity for the upper part of the alluvial aquifer beneath the island. A test hole showed this part to be 135 feet thick. Below this the formation became much finer grained, mostly silt and clay. This lower, fine-grained part of the aquifer does not contribute to the short-term ground-water responses observed in the upper part of the aquifer.

# EFFECTS OF WATER-MANAGEMENT CHANGES

Ground-water levels affect the wet-meadows environment in two ways. The first way is by directly controlling the depth and areal extent of standing and slow-moving water where the water table intersects and stands above the land surface. The second way is the effect that the water level has on plant communities where the water level is below land surface. The depth to water, and therefore the water available to the root systems, is a factor in determining the types and varieties of plants in the community and the vigor with which they can grow.

Any change in water-management practices that affects the flow of the river, and consequently the river stage, will have a rapid and almost direct effect on the ground-water level beneath Mormon Island Crane Meadows study area and adjacent areas. The change of ground-water level will occur within approximately 24 hours for distances up to ½ mile from the river's edge. A rise in river stage will produce a rise in ground-water levels that is somewhat reduced in magnitude, due to an increase in the rate of evapotranspiration from the water table that is closer to the land surface. A decline in river stage will produce a decline in ground-water levels that is smaller in magnitude due to a decreased rate of evapotranspiration.

These changes in ground-water levels will last only as long as the change in river stage is maintained. There would be no long-term effects on the ground-water levels if the river were to be returned to its original stage.

Changes in water-management practices that involve increases or decreases in net ground-water withdrawals would have the additional effect of increasing or decreasing depth to water in the aquifer because of increased or decreased drawdown due to the change in rate of net withdrawal. In general, however, this effect would only occur in areas adjacent to the main river channels, and not in areas or islands between the channels, where there is very little ground-water withdrawal by wells. The areas or islands between channels would be affected only by the rise or fall in river stage caused by the increased or decreased river flow resulting from the decrease or increase in ground-water withdrawal.

Ground-water withdrawn by wells is derived from change of storage within the aquifer, salvage of water from evapotranspiration, and depletion of streamflow. Since most of the ground-water pumpage along the Platte River is at distances greater than 2,500 feet from the river, the greatest drawdowns and changes in ground-water storage due to increases in net ground-water withdrawals will occur beyond that distance from the river. These changes in water levels will have little effect on any habitat because there is not much habitat farther than this distance from the river that is affected by depth to water. The effect of these increases in net ground-water withdrawals at distances closer to the river than 2,500 feet will be to salvage evapotranspiration by lowering the water table and to increase streamflow depletion by increasing the gradient away from the river. Estimates and calculations of these quantities indicate that an average change in water level of not more than 1 or 2 feet should provide enough water from these sources to satisfy anticipated increases in net ground-water withdrawals for irrigation. Depletion of streamflow also would change the stage of the river, which would have the same effect on ground-water levels as previously discussed for changes in surface-water management.

Increases or decreases in ground-water withdrawals would have effects on water levels and river flow that develop more slowly and last longer than the effects caused by increases or decreases in surface-water diversions. The magnitude, occurrence, and duration of the effect from changes in ground-water withdrawals would depend on the magnitude of the change, the distance from the river, and the properties of the aquifer. The rise or decline of ground-water levels adjacent to the river could be reduced on a short-term basis by upstream control of diversions and reservoir releases.

## SUMMARY AND CONCLUSIONS

Ground-water levels in the alluvial aquifer beneath the island and areas adjacent to the Platte River are controlled by the presence and stage of the Platte River in its various channels, by evapotranspiration by vegetation and from areas of shallow depth to water, by regional effects of pumpage and recharge, and by ground-water flow to lower river systems. Changes in the stage of the river rapidly affect ground-water levels. Ground-water responses to changes in river stage occur within 24 hours for distances up to about 2,500 feet. These water-level changes will exist as long as the change in river stage is maintained. Once the river is returned to its original stage, the ground-water level will quickly return to its original level. The only permanent effects may be on the plant communities if water levels are changed for prolonged periods of time.

Increases or decreases in the rate of net ground-water withdrawal from the aquifer in areas adjacent to the Platte River will have two simultaneous effects on the ground-water levels adjacent to the river. First, ground-water levels will decline or rise due to increased or decreased net withdrawal itself. Due to the aquifer characteristics and the distance of withdrawals from the habitat areas, the effects of the withdrawals will develop slowly and be long lasting, perhaps weeks or months. If most of the increase or decrease in withdrawal occurs farther than 2,500 feet from the river, the average ground-water level change within 2,500 feet of the river will be less than about 1 or 2 feet. Ground-water levels beneath islands and areas between flowing river channels will not be affected directly, unless of course, the withdrawals are on the islands themselves. Second, ground-water levels will respond to the changes in river stage as the flow of the river increases or decreases due to changes in ground-water pumpage. This change in river stage will affect ground-water levels adjacent to the river as well as beneath islands and between channels. Some of these rises or declines in ground-water levels will be reduced by accompanying increases or decreases in rates of evapotranspiration as the depth to ground water below land surface decreases or increases. Some water-level changes can be reduced by controlling the stage of the river on a short-term basis.

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