U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS and the
U.S. SOIL CONSERVATION SERVICE

WATER-RESOURCES INVESTIGATIONS
REPORT 91-4109 (SHEET 1 OF 7)

INTRODUCTION

The construction of Lock and Dam 1, in November 1984, on the Red River near Vick, Louisiana, affected river stages upstream to the site of Lock and Dam 2 near Poland, Louisiana. Changes in river stages affected water levels and ground-water flow in the Red River alluvial aquifer. In an effort to gain additional knowledge of the relation between river stage and ground-water levels in the Red River waterway area, the altitudes of water levels and flow in the alluvial aquifer were investigated by the U.S. Geological Survey as part of a cooperative program with the U.S. Army Corps of Engineers, Vicksburg District, Vicksburg, Mississippi, and the U.S. Soil Conservation Service, Alexandria, Louisiana.

This map report contains six potentiometric surface (water level) maps which show water-level altitudes in the Red River alluvial and terrace aquifers under low- and high-flow conditions in the Red River before and after the construction of Lock and Dam 1. Comparison of these maps indicates the effect of the construction of Lock and Dam 1 on water levels in the aquifers. Three of the maps show water levels during low- and high-flow conditions prior to construction of the structure (sheets 2, 4, and 5), and three of the maps show water levels after construction (sheets 3, 6, and 7). Hydrographs of water levels in seven observation wells that were completed in the alluvial aquifer show water-level fluctuations for the period 1968-89 (fig. 1 on this sheet). Water levels in some wells completed in the terrace aquifer were used to help define the potentiometric surface where the terrace and alluvial aquifers were in direct hydraulic connection.

The pool 1 area is primarily within the Red River Valley from the confluence of the Black and Red Rivers near Delhoste, in eastern Louisiana, upvalley westward to near Poland in Rapides Parish. Normal design operating conditions for Lock and Dam 1 call for an upstream pool altitude of 40 ft and a downstream river altitude of about 4 ft.

HYDROGEOLOGY

Within the study area, the Red River flows through a valley about 10 to 20 mi wide. The present valley is eroded into deposits of Tertiary age. Subsequent deposition has partly refilled the valley with alluvial sediments, and the flood plain is characterized by low relief, meandering old and present-day river courses, and oxbow lakes. Natural levees along abandoned and present-day river courses form the topographic highs. Backswamps away from the river form the topographic lows (Ludwig and Terry, 1980). The alluvial deposits of Quaternary age in the valley can be divided into two parts: A lower aquifer composed of medium to very coarse sand (SP)[1] and gravel (GP)[1], grading upward to fine sand (SM)[1], and an upper confining unit composed of clay (CL and CH)[1], silt (ML)[1], and fine sand. The aquifer in the area ranges from 40 to 170 ft thick and averages about 90 ft (Ludwig, 1979, p. 4). The upper confining unit thickness ranges from a few feet to as much as 140 ft.

[1] Unified Soil Classification Systems abbreviations (U.S. Department of Defense, 1968).

Sediments of Pliocene and Miocene age underlie the alluvial deposits and crop out along the valley walls and are composed primarily of clay. Terrace deposits of Pleistocene age, which are remnants of older flood plains, overlie the Tertiary deposits and are composed of sands, gravels, silts, and clays. The terrace aquifers may be in direct hydraulic connection with the alluvial aquifer and locally may be the source of relatively large quantities of water (Ludwig and Terry, 1980, p. 12).

Downward percolation of rainfall is the primary source of recharge to the alluvial aquifer. Other sources of recharge include flow from adjacent or underlying aquifers, primarily the terrace aquifers, and flow from rivers and bayous during periods of high river stage (Rogers, 1983, p. 8). Within the study area and throughout the Red River Valley, the Red River and its major tributaries cut through the upper confining unit and are in hydraulic connection with the alluvial aquifer to varying degrees. Except during high-flow conditions in the river, water in the alluvial aquifer generally moves laterally and downvalley until it discharges upward into the Red River or a tributary.

Water levels in most of the wells completed in the alluvial aquifer within the study area are above the base of the upper confining unit, indicating that the aquifer is primarily under artesian conditions. Water levels in the alluvial aquifer, under natural conditions, generally are highest in the winter and early spring and lowest in September and October (Rogers, 1983, p. 10). High water levels in the alluvial aquifer occur when rainfall is high, stages in the Red River and tributaries are high, and evapotranspiration rates are low.

POTENTIOMETRIC SURFACES

The potentiometric surface of the Red River alluvial aquifer under low-flow conditions prior to construction of Lock and Dam 1 is shown on sheet 2. The map is based on water levels measured on or about October 5, 1971. The Red River at Alexandria, Louisiana, 62 river miles upstream from Lock and Dam 1, had a stage of 43.1 ft above sea level. The Black River at Acme, Louisiana, 8 river miles downstream from the structure, had a stage of 10.7 ft above sea level. Because the direction of ground-water flow is perpendicular to the potentiometric contours, the map shows that flow in the alluvial aquifer was primarily toward the Red River across the flanks of the valley in October 1971. Ground-water gradients ranged from 2 ft/mi at distances of 5 to 8 mi from the Red River to about 8 ft/mi near the river.

The potentiometric surface under similar low-flow conditions after construction of the structure is shown on sheet 3. The map is based on water levels measured October 6-14, 1987. The Red River at Alexandria and the Black River at Acme had stages of 45.7 ft and 8.1 ft above sea level. The stage immediately downstream of the dam was approximately 9 ft above sea level.

Comparison of the preconstruction and postconstruction potentiometric surfaces shows that water levels have risen as much as 15 ft adjacent to the river immediately upstream from the structure. Differences in water levels decrease upvalley and with an increase in distance from the Red River. Differences between the potentiometric surfaces decreased from 15 ft about 2 mi upriver from the structure (postconstruction water level), to about 10 ft at Vick (14 mi upriver), to about 4 ft at Echo (23 mi upriver), to less than 1 ft near Poland (31 mi upriver). Water levels increased only about 4 ft at a point less than 1 mi south of the river and approximately 2 mi upriver from the structure. Differences in preconstruction and postconstruction water levels at distances greater than 2 mi south of the river were small.

Postconstruction ground-water gradients are similar to preconstruction gradients in most of the area. However, construction of the lock and dam reversed the ground-water gradients just upstream from the structure, resulting in flow from the river to the aquifer. Postconstruction potentiometric surface contours indicate that water from the river moves into the aquifer and around the structure and then discharges back into the river a short distance downstream.

Potentiometric surfaces of the Red River alluvial aquifer under high-flow conditions prior to construction are shown on sheets 4 and 5. The potentiometric surface shown on sheet 4 was based on water levels measured January 8-18, 1973, under high-flow conditions at a stage of 60.7 ft above sea level on the Red River at Alexandria and a stage of 45.0 ft above sea level on the Black River at Acme. The potentiometric surface shown on sheet 5 was based on water levels measured on or about April 6, 1973, under flood conditions. The stages of the Red River at Alexandria and the Black River at Acme on April 6, 1973, were 74.1 and 51.9 ft above sea level. Water levels were not available from all wells at this time due to flooding. Water levels were estimated at wells that could not be measured by adjusting water levels measured in March by the amount of water-level change that occurred in nearby wells where measurements were available. These maps show that in January 1973 flow generally was from the river to the alluvial aquifer in the eastern part of the area, and during April 1973 flow was from the river to the aquifer throughout the area. Upstream from Echo, flow was toward the Red River during January 1973.

Ground-water gradients during January 1973 ranged from less than 2 ft/mi in areas at distances of 5 to 8 mi from the river to a maximum of about 9 ft/mi south of the river at Moncla. Gradients during April 1973 were similar to those of January 1973 at distances of 5 to 8 mi from the river but were as high as about 12 ft/mi just south of the river near Moncla. During January 1973, flow in Avoyelles Parish in the area just north of the Red River generally was downvalley toward Larto Lake. Just north of the river in Catahoula Parish, the closely spaced contour lines indicate a relatively steep gradient northward away from the river toward Larto Lake. South of the site of Lock and Dam 1 in Avoyelles Parish, flow generally was southward toward Little River and Lake Long. In the southwestern part of the area, in Rapides Parish, flow was primarily in an easterly direction paralleling the Red River, but the potentiometric contours indicate that the flow diverged, with part of the flow moving toward the Red River and part toward Chatlin Lake Canal. Ground-water flow patterns during the April 1973 flood were similar except that flow was away from the Red River throughout the area and gradients were steeper near the river.

The potentiometric surface of the Red River alluvial aquifer under high-flow conditions after construction is shown on sheet 6. The map on this sheet is based on water levels measured April 7-8, 1987. On April 7, stages were 59.9 and 35.0 ft above sea level on the Red River at Alexandria and the Black River at Acme. The stage at Lock and Dam 1 pool was 40 ft above sea level with a tailwater of 37.4 ft above sea level. Although stages of the Red River at Alexandria were approximately the same in January 1973 and April 1987, the stage of the Black River at Acme was 10 ft lower in April 1987 than in January 1973. Ground-water gradients in April 1987 ranged from about 0.5 ft/mi south of the Red River to about 6 ft/mi north of the river in Avoyelles Parish. A ground-water divide existed north of Vick in the central part of the area. This divide was the result of recharge from the terrace aquifer to the west of Vick on the north side of the valley. Eastward flow from this recharge source moved southward toward the Red River and northward away from the river. In Catahoula Psrish, flow generally was downvalley paralleling the river. These flow patterns were similar to those prior to construction (sheet 4) except that gradients during April 1987 were flatter.

Comparison of tne January 1973 preconstruction and the April 1987 postconstruction potentiometric maps (sheets 4 and 6) shows that the potentiometric surfaces were similar in the vicinity of the structure. Along the Avoyelles-Rapides Parish line, the postconstruction surface was approximately 3 ft higher near the Red River. The difference between preconstruction and postconstruction water levels decreases upriver and with increasing distance from the river. The postconstruction potentiometric surface was about 2 ft higher than the preconstruction surface at a distance of 5 mi west of the Avoyelles-Rapides Parish line and 5 mi south of the river.

Comparison of the April 1973 preconstruction and the April 1987 postconstruction potentiometric surfaces (sheets 5 and 6) indicates that near the Red River preconstruction water levels generally were 8 to 12 ft higher in Avoyelles and Catahoula Parishes. These relatively large differences in water levels can be attributed to the extremely high preconstruction water levels caused by flood conditions on the Red River. Near Poland, preconstruction water levels along the Red River in April 1973 were approximately 8 ft higher than postconstruction levels, but the difference decreased to less than 1 ft higher at a distance of 5 mi from the river.

A potentiometric surface map of the Red River alluvial aquifer based on average water levels after construction of the lock and dam structure is shown on sheet 7. This map was based on water levels measured January 1985 through December 1987, a period of normal flows on the Red and Black Rivers. This postconstruction average potentiometric map was drawn to compare with preconstruction and predicted postconstruction average potentiometric maps prepared by Ludwig (1979, pls. 1 and 2). The predicted postconstruction and average potentiometric maps matched closely over most of the area. Differences were less than about 4 ft over most of the area near the structure. In a small area west of the structure, measured water levels (sheet 7) were as much as 10 ft lower than Ludwig's (1979, pl. 2) predicted water levels. In this area, Ludwig predicted flow to the river including the pool upstream of the structure from the west, whereas the average potentiometric surface based on measured water levels indicates flow out of the pool to the aquifer. In some areas upstream from the structure, average water-level altitudes shown on sheet 7 are slightly lower than those shown by Ludwig (1979). The maps drawn by Ludwig (1979, pls. 1 and 2) were based on computed water levels derived from a digital model simulation of projected conditions. Limitations of the model may be responsible for some of the differences. The lateral discretization of the model affects water-level computations, making precise comparison with measured water levels difficult. Another factor that may have contributed to differences between the maps was the lack of measured water-level data in some areas and uncertainties in the potentiometric contours shown on sheet 7. These differences are not significant in the comparison of preconstruction and postconstruction average water-level maps used to determine the affect of the construction of Lock and Dam 1.

Comparison of the average postconstruction water levels (sheet 7) with the average preconstruction water levels by Ludwig (1979, pl. 1) indicates that ground-water flow is similar prior to and after construction of Lock and Dam 1 for most of the study area. However, the postconstruction map indicates that near the structure flow is from the river to the aquifer, reversing the preconstruction gradient. In the area south of the Red River in Avoyelles Parish, from about 4 mi above the structure to about 2 mi east of the Avoyelles-Rapides Parish line, preconstruction gradients have been reversed and the general direction of postconstruction ground-water flow is away from the Red River and downvalley. The average postconstruction water level (sheet 7) was about 8 ft higher than the preconstruction water level 3 mi upriver from the structure. The increase in water levels as a result of the structure diminished with distance from the river. Two miles south of the river at this point the postconstruction increase was about 2 ft, and 5 mi south of the river the increase was approximately 1 ft. Three miles north of the river at this point, the postconstruction average water level was about 7 ft higher. Increases in water levels as a result of the construction of the lock and dam also decreased with distance upriver from the structure. Near the river at the Avoyelles-Rapides Parish line, the average postconstruction water level was approximately 4 ft higher than preconstruction levels, whereas near the river at Poland the average postconstruction water level was only about 2 ft higher.

Hydrographs of water levels in seven observation wells that were completed in the Red River alluvial aquifer show water-level fluctuations at specific sites in the area for the period 1968-89 (fig. 1 on this sheet). Observation well locations are shown on each map (sheets 2-7). Two uncommon hydrologic events occurred during the period of water-level record affecting flow in the alluvial aquifer: (1) high river stages in the Red River and its tributaries from April to June 1973 caused high water levels in the alluvial aquifer; and (2) pumpage from dewatering wells from September 1978 to November 1984 during construction of Lock and Dam 1 caused water levels to be lowered within about a 5 mi radius of the site. Water levels measured during these two periods were not considered in the evaluation of the effects of the lock and dam structure on water-level fluctuations. The water-level record for the period 1968-72 was considered as representative of preconstruction conditions and is compared to the postconstruction period of record, 1985-88, in the following discussion.

The hydrograph of well Ct-81 in Catahoula Parish, located near the lock and dam structure, shows that postconstruction water levels in the Red River alluvial aquifer during high-flow conditions in the Red River were 1 to 5 ft higher than preconstruction water levels. Postconstruction water levels were 3 to 6 ft higher during low-flow conditions. The hydrograph of well Av-334 in Avoyelles Parish, located about 2 mi upriver from the structure, shows that the preconstruction and postconstruction water levels during high-flow conditions were about the same, whereas postconstruction water levels were about 10 ft higher during low-flow conditions. The hydrographs of wells Ct-75, Ct-80, and Av-339 in Catahoula and Avoyelles Parishes, which are from 4 to 8 mi from the structure, show that the postconstruction water levels during low- and high-flow conditions were about the same to 3 ft lower than preconstruction water levels. The hydrograph of well Av-338, located about 6 mi south of the structure, shows that preconstruction and postconstruction water levels during high-flow conditions were approximately the same. During low-flow conditions postconstruction water levels were 1 to 2 ft higher. The hydrograph of well Av-326, in Avoyelles Parish about 0.5 mi north of the Red River near Vick, shows that during high-flow conditions, postconstruction water levels were about the same to 3 ft lower than preconstruction levels, whereas during low-flow conditions, postconstruction water levels were 8 to 10 ft higher.

SUMMARY AND CONCLUSIONS

Lock and Dam 1, completed in November 1984, on the Red River near Vick, Louisiana, has raised water levels in the Red River alluvial aquifer as much as 15 ft under low-flow conditions. The largest water-level increase is adjacent to the river in an area immediately upstream from the structure. Postconstruction ground-water gradients in this area indicate that flow is from the river to the aquifer, reversing the preconstruction flow from the aquifer to the river. Differences between preconstruction and postconstruction water levels decrease upvalley and with distance from the Red River.

Under high-flow conditions, differences between preconstruction and postconstruction water levels, in general, are negligible in the vicinity of the structure, but postconstruction water levels are approximately 3 ft higher along the Avoyelles-Rapides Parish line. Preconstruction water levels measured during flood conditions were 8 to 12 ft higher than postconstruction levels measured in Avoyelles and Catahoula Parishes. Comparison of an average postconstruction potentiometric surface map based on water levels measured January 1985 through December 1987 with a map based on model-predicted water levels (from a digital flow model in a previous study) indicated reasonably good agreement over most of the area. The results obtained with the model for Lock and Dam 1 indicate that other models presently available may be useful for assessing the potential effects of the construction of locks and dams on ground-water levels.

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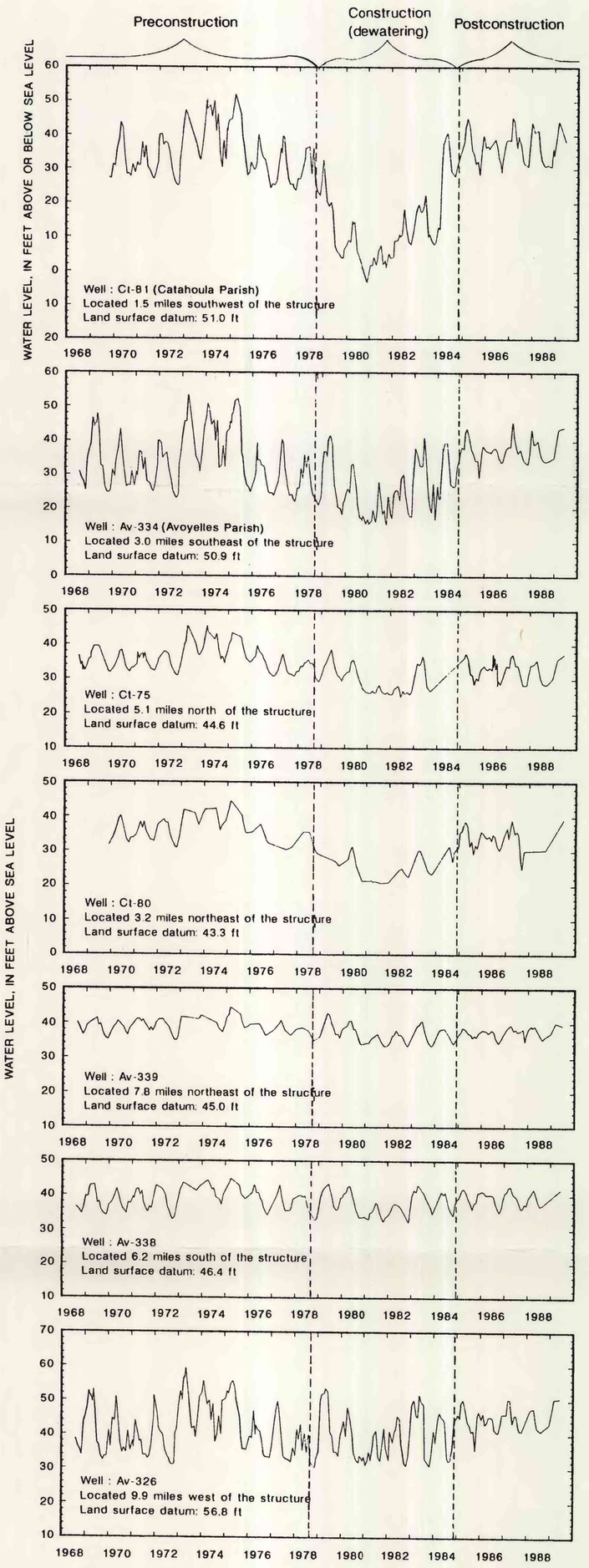

Figure 1.--Water levels in wells in Catahoula and Avoyelles Parishes.

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer

Sea level: In this report "sea level" refers to the 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 Sea Level Datum of 1929.

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GENERALIZED POTENTIOMETRIC SURFACES OF THE RED RIVER ALLUVIAL AQUIFER, POOL 1, RED RIVER WATERWAY AREA, CENTRAL LOUISIANA

By Charles W. Smoot and Angel Martin, Jr.

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