

## DEPARTMENT OF WATER RESOURCES

NORTHERN DISTRICT  
2440 MAIN STREET  
P. O. BOX 607  
RED BLUFF 96080  
(916) 527-6530



August 5, 1987

Mr. Bill Van Orden  
Executive Coordinator  
City of Willits  
111 East Commercial  
Willits, CA 95490

Dear Mr. Van Orden:

This report presents the findings of a one-year cooperative City of Willits-Department of Water Resources ground water study. It discusses Little Lake Valley geology, ground water, and ground water quality conditions. A separate Morris Reservoir limnology and water quality report will be completed in December 1987.

The study concluded that sufficient ground water is available in Little Lake Valley to help meet the City of Willits' water demands well into the Twenty-First Century. It also found that blending the Park well with Morris Reservoir waters would yield sufficient water of acceptable quality to meet the present City of Willits' municipal demands. The mixing of Morris Reservoir and the Park well water would help solve Morris Reservoir's turbidity and other quality problems and the Park well ground mineral quality problems.

The report recommends that the City of Willits should: conduct a profile on the Park well to determine the poor ground water quality source, continue to monitor ground water levels and quality, and study the feasibility of establishing a well field in Little Lake Valley.

Sincerely,

A handwritten signature in cursive script, reading "Wayne S. Gentry".

Wayne S. Gentry, Chief  
Northern District

Enclosure



CONTENTS

	<u>Page</u>
I. INTRODUCTION . . . . .	1
Area of Investigation . . . . .	1
Water Demands and Supply . . . . .	1
Methods of Investigation . . . . .	2
II. SUMMARY AND CONCLUSIONS . . . . .	3
III. RECOMMENDATIONS . . . . .	5
IV. GENERAL GEOLOGY AND HYDROGEOLOGY . . . . .	7
Franciscan Complex . . . . .	7
Continental Basin Deposits . . . . .	7
Holocene Alluvium . . . . .	10
Geologic Structures and Faults . . . . .	11
V. GROUND WATER HYDROLOGY . . . . .	13
Ground Water in Storage . . . . .	15
Water-Level Fluctuations . . . . .	16
VI. AQUIFER TESTS . . . . .	17
Predicted Well Yield . . . . .	20
Radius of Influence of Park Well . . . . .	20
VII. WATER QUALITY . . . . .	27
VIII. REFERENCES . . . . .	29



TABLES

	<u>Page</u>
1 Specific Capacity Compilation . . . . .	10
2 Estimated Storage Capacities of Upper 100 feet of Valley Fill . . .	15
3 Chemical Quality of Ground Water in Little Lake Valley . . . . .	28

FIGURES

1 Geology Map, Well Locations, and Basin Boundary . . . . .	9
2 Availability of Ground Water and Spring 1987 Ground Water Elevation Contours . . . . .	14
3 Water-Level Fluctuations in Wells 18N/13W-18K1, -18K2, and -18L1 Measured During March-April, 1987 Aquifer Test . . .	18
4 NW-SE Geologic Section . . . . .	19
5 Discharge Versus Drawdown for Various Durations of Pumping . . . .	21
6 Cones of Depression Influenced by Boundary Conditions (illustration) . . . . .	22
7 Drawdown Contours After 5, 6, and 30 Days of Continuous Pumping . .	23
8 Radial Influence of Park Well as a Function of Pumping Rate . . . .	24
9 Radial Influence of Park Well as a Function of Time (Duration) . .	26

APPENDICES

- A. Summary of Aquifer Test and Drawdown Graphs
- B. Data Sheets (used for calculations found in text)
- C. Lab Analysis of Park Well



## I. INTRODUCTION

Morris Reservoir is the main source of domestic water for the City of Willits. Ranches and residences outside the city obtain water from individual wells and springs. Historically, the city has experienced water shortages during dry years. It is not known whether sufficient ground water resources are available to supplement or replace existing municipal supplies. Therefore, the City of Willits requested information on the availability, occurrence, quantity and quality of ground water. This investigation was undertaken to enable the city to decide on how to meet present and future water needs.

The Department of Water Resources (DWR), in cooperation with the City of Willits, completed this one-year ground water hydrology study in Little Lake Valley, Mendocino County. DWR and the City of Willits jointly funded this study.

### Area of Investigation

Little Lake Valley is in the central part of Mendocino County, California. The valley has an area of approximately 12.5 square miles and an average elevation of 1,350 feet. The surrounding low hills encompass an additional 5 square miles. Several small streams, including Baechtel, Broaddus, Berry, Davis, Haehl, and Willits Creeks, flow through the valley and drain into a marshy area near the north end of the valley. Outlet Creek, a tributary of the Eel River, drains the marshy area.

### Water Demands and Supply

Kennedy/Jenks Engineers (1985) projected the City of Willits' average annual water demand to be 1,344 acre-feet (AF) in 1985 and 2,930 AF by 2015. Detailed water supply and demand data are included in their 1985 report.

Presently, all the municipal supply, except park irrigation, is from Morris Reservoir. Morris Dam is 51.2 feet high and has an available storage capacity of about 725 AF when 2.5-foot flashboards are installed. Morris Reservoir has a 90-percent safe yield of 1,000 AF or 0.9 million gallons/day (mgd) (Kennedy/Jenks Engineers, 1985).

There is an estimated 60,000 AF of ground water available in Little Lake Valley. Farrar (1986) estimated total ground water pumpage at about 2,000 AF/year.

The Morris Reservoir yield is fixed and can be increased only by raising the dam. There appears to be ample ground water available to help meet Willits future water demands. Coordinated use of Morris Reservoir and Little Lake Valley ground water could solve Willits' water quality and quantity demands well into the twenty-first century.



## Methods of Investigation

An extensive geologic and hydrologic literature search was conducted. Subsurface geology data were obtained from previous studies and well logs. Two studies relating to the hydrogeology of Little Lake Valley were conducted by the U. S. Geological Survey (USGS) in 1965 and 1986. Cardwell (USGS, 1965) described the occurrence, availability, and quality of ground water in seven valley areas in Sonoma and Mendocino Counties. Farrar (USGS, 1986) described the ground water resources in Mendocino County. Some background information in this report is taken from these two studies.

DWR and the City of Willits jointly conducted a survey of water-well owners in the study area. Wells were field located wherever possible and observation wells near the City Park well were then selected. On August 20, 1986, the City Park well was pumped for 4.5 hours to see which wells were affected by the pumpage and what range of drawdowns would be encountered. Both agencies measured water levels in selected wells. During the investigation, three separate aquifer performance tests were conducted: one on September 3-4, 1986, the second on January 26-February 2, 1987, and the third on March 24-April 3, 1987. Each test consisted of pumping the City Park well (18N/13W-18K2) and carefully measuring the drawdown in the pumped well and in observation wells. One shallow observation well (18N/13W-18K1) was equipped with a Stevens Type F continuous water-level recorder during the March-April test. Test data were used to determine ground water basin properties, such as aquifer transmissivity and storage coefficients and well interference at various spacings and pumpage rates, other than those employed during the test itself.

Water quality samples for mineral and metal analysis were collected at the beginning and near the end of the test. Temperature, pH, and electrical conductivity (EC) were monitored for changes throughout the test.



## II. SUMMARY AND CONCLUSIONS

The Department of Water Resources and the City of Willits agreed in 1986 to conduct a cooperative ground water study of the ground water resource and a limnology study of Morris Reservoir. We agreed to complete the ground water study in June 1987 and the Morris Reservoir study in December 1987. This report discusses the ground water study and a separate DWR December 1987 report will cover the limnology study.

The Little Lake Valley ground water basin includes most of the Holocene alluvium with at least 60,000 AF available ground water in storage in the Holocene alluvium. The alluvium consists generally of lenticular beds of unconsolidated gravel, sand, silt, and clay. The aquifers appear to be both free and confined. Semiconsolidated Quaternary continental basin deposits and consolidated Jurassic through Tertiary basement rocks underlie the alluvium. The older rocks contain limited quantities of recoverable ground water and, therefore, are not considered a major source of ground water.

Three separate aquifer tests were conducted on the Park well to determine its yield, influence on adjacent wells, and the quality of water pumped. These tests show that the park well can be pumped continuously 365 days/year at 390 gallons/minute (gpm) with a 53-foot drawdown. Assuming no recharge during a 6-month dry period, the maximum drawdown 2 miles north of the Park well would be about 5 feet.

The chemical quality of the Little Lake Valley ground water in the Holocene alluvium is generally acceptable for domestic, industrial, and agricultural uses. It is a calcium-magnesium-bicarbonate water with chloride and sodium as minor constituents. The dissolved solids range from less than 100 to about 350 milligrams/liter (mg/L). Iron and magnesium concentrations generally exceed EPA secondary drinking standards. Water pumped from the Park well is generally similar except for arsenic levels above EPA standards.

The Park well can be used to supplement the existing supply from Morris Reservoir if it can be treated to reduce the arsenic, iron, and manganese to acceptable levels. Mixing the Park well and Morris Reservoir waters should resolve the quality problems. This will be discussed in the forthcoming DWR December 1987 limnology report.

Additional high-capacity municipal wells could be constructed in Little Lake Valley to provide water as the demand arises. Individual well yields up to 1,000 gpm, capable of producing 1,110 AF/year, are possible.

The projected water demand for the City of Willits is about 3,000 AF/year in 2015. Morris Reservoir provides about 1,000 AF/year. Little Lake Valley ground water basin has about 60,000 AF of available ground water and is producing about 2,000 AF/year. With proper ground water development and treatment, the basin should be capable of producing the additional 2,000 AF/year necessary to meet the 2015 water demands.



### III. RECOMMENDATIONS

- The City should run a vertical water quality profile of the Park well. This could define the poor water quality zone(s) so the City could determine the feasibility of sealing off the zone(s).
- The City should experiment with mixing (diluting) the Park well water with Morris Reservoir water. This could help improve the Morris Reservoir winter turbidity problems and the Park well's iron, manganese, and arsenic problems.
- Standard water quality monitoring should continue at the well in order to detect changes that may occur as the well is put into service.
- Water-level measurements should be made monthly at the Park well and four observation wells around it.
- The City should study the feasibility of establishing a well field in Little Lake Valley.



#### IV. GENERAL GEOLOGY AND HYDROGEOLOGY

Three geologic units occur in the vicinity of Little Lake Valley. They are from oldest to youngest: the Tertiary through Jurassic Franciscan Complex, Quaternary and Tertiary continental basin deposits, and Quaternary-Holocene alluvium. The surface geology of the valley is shown in Figure 1.

##### Franciscan Complex

The Franciscan Complex is a melange of highly sheared graywacke and mudstone enclosing blocks of graywacke, chert, greenstone, serpentinite, blueschist and limestone. These rocks are generally fine-grained or cemented. According to Cardwell (USGS, 1965), a few domestic wells around the margins of Little Lake Valley obtain water from Basement rocks. Well yields vary widely depending on local rock type and degree of fracturing. Many dry holes have been drilled in this unit. Farrar, however, notes that yields of up to 200 gpm have been reported (USGS, 1986).

##### Continental Basin Deposits

Continental basin deposits were deposited directly on basement rock during Late Pliocene to Pleistocene time. The deposits crop out over about 5 square miles along the east, south and the southwestern parts of the valley. The basin deposits extend across most of the valley in the subsurface. Thickness ranges from zero at the valley margin to several hundred feet in the central part and up to 1,500 feet thick in the southwestern part of the valley. These deposits consist of a heterogeneous mixture of compact to semi-consolidated, poorly sorted gravel, sand, silt, and clay. Sand and gravel beds are typically lenticular and interfinger with beds stratigraphically above and below. The beds in the southwestern part of the valley are composed mostly of clay, silt, shale, and mudstone.









## LEGEND

### EXPLANATION FOR FIGURE 1

- Qal**            **Holocene Alluvium** - Unconsolidated gravel, sand, silt, and clay; includes most productive water-bearing formations, high porosity, and permeability.
- QTc**            **Continental Basin Deposits** - Semi-consolidated to unconsolidated gravel, sand, silt, and clay, some mudstone and shale; poorly productive water-bearing formation; high porosity, but low permeability.
- TKJf**            **Franciscan Complex** - (Undifferentiated basement) highly sheared graywacke and mudstone enclosing blocks of chert, graywacke, greenstone, serpentinite, blueschist, and limestone. Poorly productive water-bearing formation; low porosity and permeability except where rock type and fracturing are favorable.
- Maacama Fault Zone** - dashed where approximately, dotted where concealed, and queried where extent unknown.
- Line of geologic section.**
- Well location and number.**
- Ground water basin boundary.**

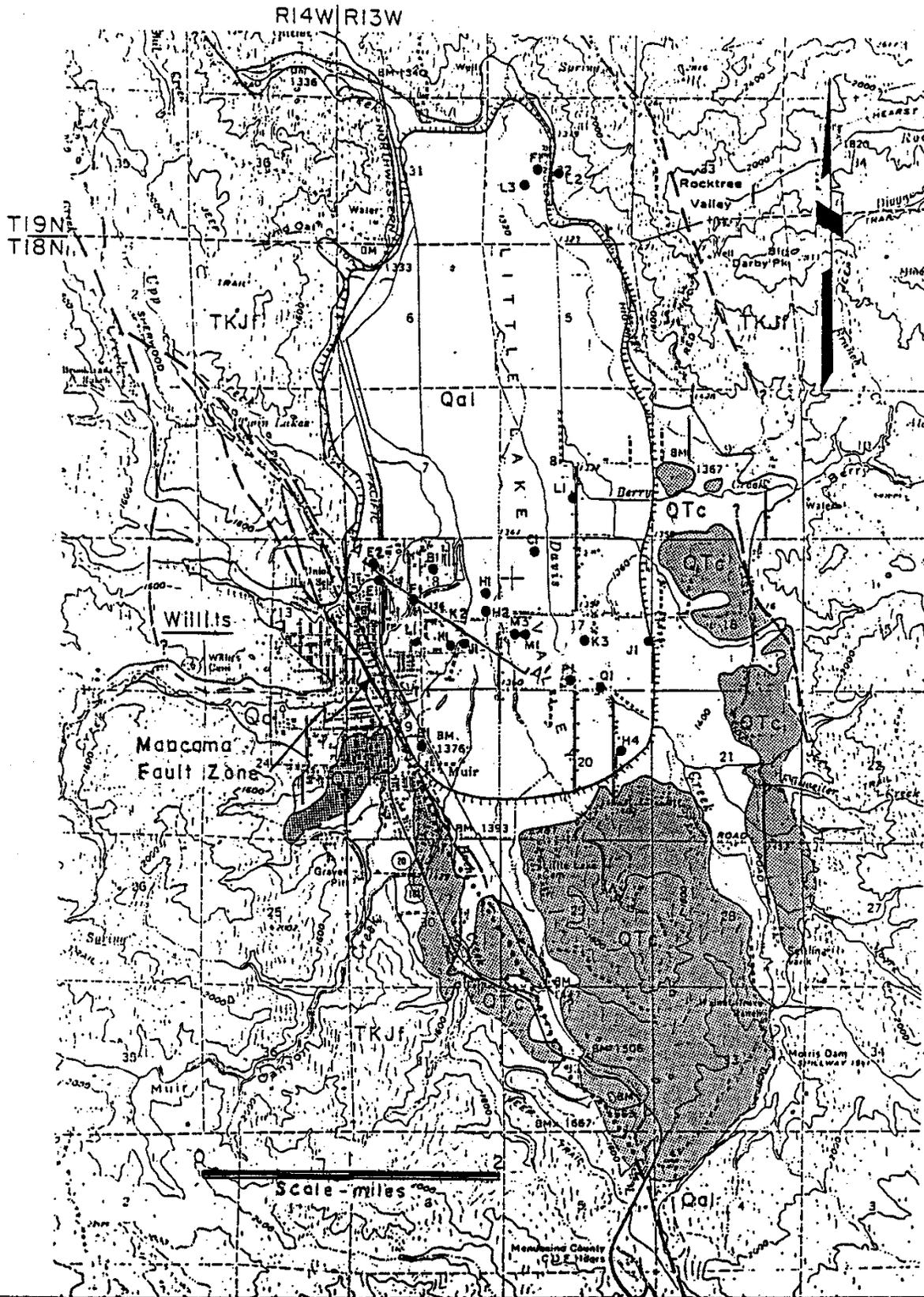


Figure 1. Geology of Little Lake Valley, well locations, and line of geologic section. Geology modified from CDMG (1982), Cardwell (1965), and Farrar (1986).



The widespread basin deposits have high porosity but low permeability, which limits well yields. Farrar inventoried 12 wells that obtain water solely from the basin deposits and found that specific capacities (yield to wells per foot of drawdown) range from less than 1 to 2.5 gpm/foot (ft). Specific capacities of seven wells range from 0.7 to 2.5 gpm/ft; five wells were less than 0.7 gpm/ft. A compilation of specific capacities from Farrar's (1986) study and from review of 19 additional drillers' well logs is shown in Table 1.

Table 1. Specific Capacity Compilation (gpm/ft)

	Number of Wells <u>Tested</u>			<u>Range</u>	<u>Average</u>	
		<u>5 Wells</u>	<u>7 Wells</u>			
Specific capacity from basin deposits (Farrar, 1986)	12	<u>&lt;0.7</u>	<u>0.7-2.5</u>	<u>&lt;0.7-2.5</u>	<u>1.5</u>	
Specific capacity from Holocene alluvium (Farrar, 1986)	19	<u>&lt;0.1</u>	<u>&gt;11</u>	<u>0.3-83</u>	<u>2.8</u>	
Specific capacities from 19 additional wells in alluvium and basin deposits (DWR, this study)	19	<u>&lt;2.5</u>	<u>&gt;9</u>	<u>0.06-15</u>	<u>1.7</u>	<u>0.6</u>

#### Holocene Alluvium

Holocene alluvium overlies continental basin deposits over most of the valley floor. The outcrop area is about 12 square miles. Thickness ranges from a few feet to 250 feet south and east of central Willits. Well logs indicate that the alluvium consists of gravel, sand silt, and clay. The coarse material was deposited in lenticular bodies on alluvial fans and stream channels and is locally very thick. The contact between alluvium and underlying continental basin deposits cannot be determined precisely because of the similarities in the drill-cutting descriptions.

The coarse-grained, unconsolidated alluvium is high in porosity and permeability. Around the margins of the valley where alluvium is thin, these deposits may be dry in late summer and early autumn (Farrar, 1986). Cardwell (1965) found that the alluvium yields several hundred gallons per minute to properly constructed wells throughout the valley except near the valley perimeter. Farrar found that specific capacities for 19 wells in Holocene alluvium ranged from 0.3 to 83 gpm/ft. The mean specific capacity, excluding the high value of 83 gpm/ft, is 2.8 gpm/ft.



Nineteen water well drillers' reports were reviewed for this study, in addition to those reviewed by Farrar (1986). These wells penetrate various depths and water-bearing strata and have an average well depth of 98 feet. The average specific capacity of these wells is 1.7 gpm/ft. If the two wells with specific capacities of 9 and 15 gpm/ft are excluded, the average specific capacity is 0.6 gpm/ft. This lowers the overall average for the 38 wells to 2.2 gpm/ft and is probably more representative of average specific capacities in the basin.

### Geologic Structures and Faults

Major geologic structures in Mendocino County have a predominant northwest to north-northwest trend. The long axis of Little Lake Valley is aligned along this trend. The active Maacama Fault trends northwest through the central part of the county and bounds the southwestern edge of the valley (Figure 1). The Maacama Fault is a zone of parallel to subparallel en echelon breaks with right lateral displacement.

Little Lake Valley is a down-dropped fault block (graben) that was created by oblique extension and normal faulting along two parallel fault zones (McLaughlin and Nilson, 1982). Sedimentation began in-filling at the onset of basin formation and continued concurrent with further down dropping of the graben. As a result, in excess of 450 feet of valley fill has accumulated in Little Lake Valley.

Geologic faults and other subsurface barriers can impede the movement of ground water and act as impervious boundaries. The Maacama Fault zone is an impervious boundary along the southwestern margin of the valley, as identified from aquifer test analyses.



## V. GROUND WATER HYDROLOGY

Geologic formations can be divided into water-yielding and nonwater-yielding. Water-yielding formations (or aquifers) readily absorb, transmit, and yield usable quantities of ground water to wells. Materials considered water-yielding are unconsolidated sand and gravel deposits of the Holocene alluvium. Clay and consolidated rocks are usually considered low to nonwater-yielding.

The Little Lake Valley ground water basin is filled with alluvium. These deposits contain both unconfined and confined ground water. The relatively shallow unconfined aquifer is recharged mostly from direct infiltration of precipitation and surface runoff. Water levels in shallow wells that tap this aquifer reflect the free water table. The deeper, confined aquifer is overlain by a relatively impervious layer. It cannot receive direct recharge from the surface; rather, recharge occurs upslope of the confining (impervious) layer. Water moves under hydraulic pressure in confined aquifers. Ground water will rise in a well to a level called the potentiometric level. Water levels in two nearby wells can vary greatly if the wells tap different aquifers.

Ground water occurrence, availability, movement, and fluctuations can be determined by analyzing well logs and water-level data. Ground water in the basin has been classified by Farrar (1986) into four type-areas (Figure 2):

Type I - This 7.5-square-mile area coincides with the valley floor and is underlain by thick valley fill including the thickest Holocene alluvium. Ground water is generally abundant, and production rates and supply are sufficient for agriculture, industrial, municipal, and domestic uses.

Type II - This 3-square-mile area forms a concentric band around the Type I area, but extends wider and further from the flat valley floor along creek channels that drain into the valley. Type II area is underlain by thin Holocene alluvium. Some ground water generally is available year-round for domestic use and may be adequate for irrigation or industrial use.

Type III - This area includes about 7 square miles around the southern margin and low hills of the valley. Type III area is underlain by continental basin deposits. Ground water is generally sufficient for domestic use, but production rates are low or seasonally limited.

Type IV - This area occupies the mountainous terrain surrounding the valley. Type IV area is underlain by the Franciscan Complex basement which is generally considered nonwater-producing. Ground water occurrence is restricted to local areas that are lithologically or structurally favorable. These areas may provide adequate supply for livestock or domestic use.



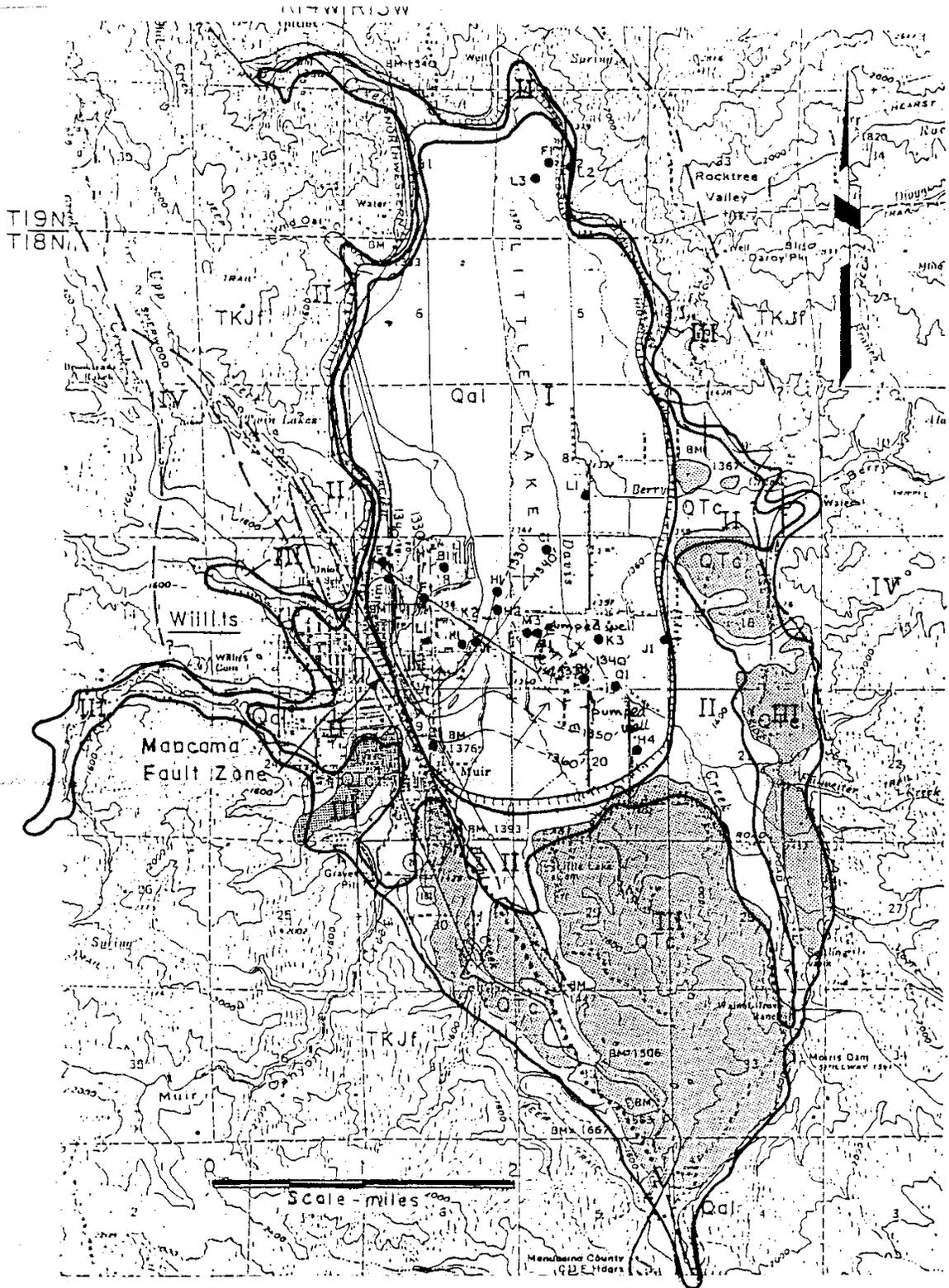


Figure 2. Availability of ground water (after Farrar, 1986); and spring 1987 ground water elevation contours. Arrows indicate direction of ground water movement. Note depression caused by pumped wells.



Most of the available ground water for municipal and industrial use is in the Holocene alluvium in Type I area. Types II, III, and IV areas are underlain by strata that have some available ground water in storage but have marginal capacities to yield water to wells. Therefore, the boundary of the ground water basin that the Park well draws from includes only the Type I area.

Recharge to Little Lake Valley includes precipitation, surface-water infiltration, and domestic and agricultural return flows. Some recharge may occur from upward flow of ground water along faults or fracture zones. Surface water recharges the aquifers by infiltration along creek channels draining into the valley. Downward percolation of surface water from livestock or irrigation ponds may also recharge ground water. Return flows from sewage-disposal facilities, septic tanks, and excess irrigation water are minor sources of recharge.

Discharge of ground water from the valley includes well pumpage, vegetative evapotranspiration (ET), and discharge to streams. Ground water moves generally from the valley sides toward the center and from south to north (Figure 2). Water-level measurements were made in wells of differing depths that penetrate different aquifers. Water-level contours in Figure 2 show the approximate elevations of a composite ground water system representing both the unconfined and confined aquifers.

#### Ground Water in Storage

Most of the ground water in storage is in the valley fill of Type I area. To estimate the amount of storage in Type I material, an average specific yield<sup>1/</sup> of 8 to 10 percent was used. The specific yield was estimated from the nature of the materials recorded in water well drillers' reports of wells tapping alluvium and from field observations of outcrops. Cardwell (1965) and Farrar (1986) have estimated ground water storage capacities, which are shown in Table 2.

Table 2. Estimated Storage Capacities of  
Upper 100 feet of Valley Fill

	<u>Type I Area</u>	<u>Type II Area</u>
Cardwell (1965)	50,000 AF	No estimate.
Farrar (1986)	35,000 AF	9,000 AF

<sup>1/</sup> Specific yield is defined as the ratio of the volume of water that will drain by gravity from a saturated sample of material to the total volume of the sample, expressed as a percentage.



### Water-Level Fluctuations

Ground water levels fluctuate annually in response to pumpage, evapotranspiration, springs, base flow to streams, and recharges from sub-surface inflow and precipitation. Long-term fluctuations occur when recharge is above or below discharge. Four long-term hydrographs spanning 15 years or more through 1983 were made by Farrar and extended to spring 1987 during this study. If precipitation is 75 percent or more of normal during the preceding rainfall season, ground water levels recover completely in the spring (Farrar, 1986). Water levels are usually highest in the winter and spring and lowest in the fall. Since 1980, DWR has measured 12 wells semi-annually in the basin. Seasonal water levels fluctuate between 8 feet and 18 feet. The average fluctuation is 12 feet.



## VI. AQUIFER TESTS

Aquifer test results are used to predict yield, drawdown in a pumping well and its interference on neighboring wells. Test results, tables, and calculations are presented in Appendix A.

Three separate aquifer tests were conducted on the City Park well: September 3-4, 1986, January 26 to February 2, 1987, and March 24 to April 3, 1987. The aquifer tests were to determine:

- the yield from the City Park well;
- the influence on adjacent wells;
- the quality of water pumped.

A Stevens continuous recorder, installed on a shallow 41-foot well (18K1), recorded water levels during the March-April, 1987 aquifer test. Water levels were also measured at the pumped well and in twelve observation wells. (See Figure 1 for well locations.) Figure 3 shows water-level fluctuations at three of the wells during pumping and recovery. Data from the continuous recorder showed no change in the free water table due to pumping from the confined system. The record shows a constant decline in water level in response to regional ground water decline following a storm. This indicates that there is no hydraulic connection between the upper-unconfined and lower-confined aquifers at this point. Water levels in the observation wells (18N/13W-17M1, -18F1, and -18L1) did respond to pumping from the confined system. Therefore, these wells tap an aquifer that is hydraulically connected to the deeper confined aquifer system. Once pumping ceased, water levels began to recover almost immediately .

Figure 4 is a geologic section showing well locations and relative depths to upper and lower aquifers. The two aquifers--one unconfined extending to a depth of about 40 feet; the other confined from depths of 80 feet to about 250 feet--are separated by a confining 35- to 40-foot-thick clay layer. It is not known if the clay layer is a continuous stratum. Time-drawdown measurements from observation well 18F1 indicate that the lower aquifer might be partially confined. Some surface recharge may also be occurring from Broadus Creek. This suggests that the clay layer is either discontinuous or leaky at this point.



# Willits Aquifer Test, March 24-April 3, 1987

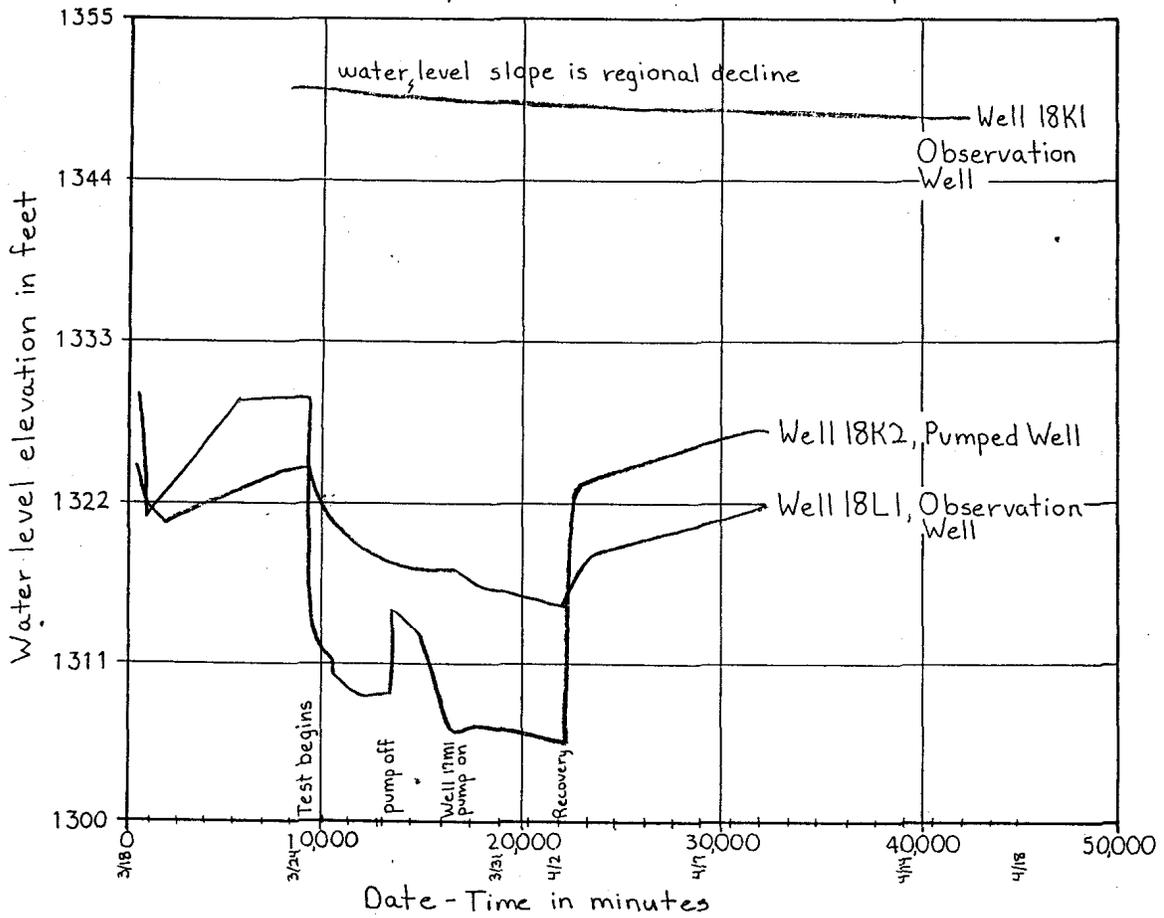


Figure 3. Water-level fluctuations in wells 18N/13-W-18K1, -18K2, and -18L1. Well 18K1 was equipped with a continuous recorder.







### Predicted Well Yield

Well yield can be defined as the maximum pumping rate that can be supplied by a well without lowering the water level in the well below the pump intake (Cherry and Freeze, 1979). To maximize well yield, it is important that pumping levels do not drop below the first screened interval. Water levels below this interval can cause cascading water in the well and reduce well yield.

Figure 5 shows a graph of discharge versus drawdown for various durations of pumping between 10 and 365 days. The graph indicates that as the well is pumped, the water-level continues to drop. The pumping-level is dependent on time and discharge. For example, after 10 days of pumping at 200 gpm, the drawdown is 10.6 feet; at 400 gpm, the drawdown is 21.2 feet. By doubling the discharge, the drawdown is also doubled.

To calculate the pumping rate when water levels are lowest, use Figure 5 and example cases below. First, calculate specific capacity (discharge/feet of drawdown) for a given pumping duration. Second, determine available drawdown. To find this, predicted pumping levels based on seasonal changes and drawdowns from neighboring well interferences are summarized. In addition, to keep the pumping level above first screen interval, assume a safety factor of 10 feet. For example:

Observed static level (highest point) . . . . .	23.0 feet
Drop in seasonal level including interference from neighboring wells . . . . .	20.0 feet
Safety factor . . . . .	10.0 feet
Sum of the net lowest anticipated static-level. . . .	53.0 feet
Maximum pumping-level (top of first screen) . . . . .	80.0 feet
Available drawdown is the maximum pumping-level minus the lowest anticipated static level:	
	80.0 feet - 53.0 feet = 27.0 feet

Assuming 27.0 feet is a good estimate, Figure 5 shows that 390 gpm can be pumped continuously from the Park well for 365 days (equals 628 AF annually).

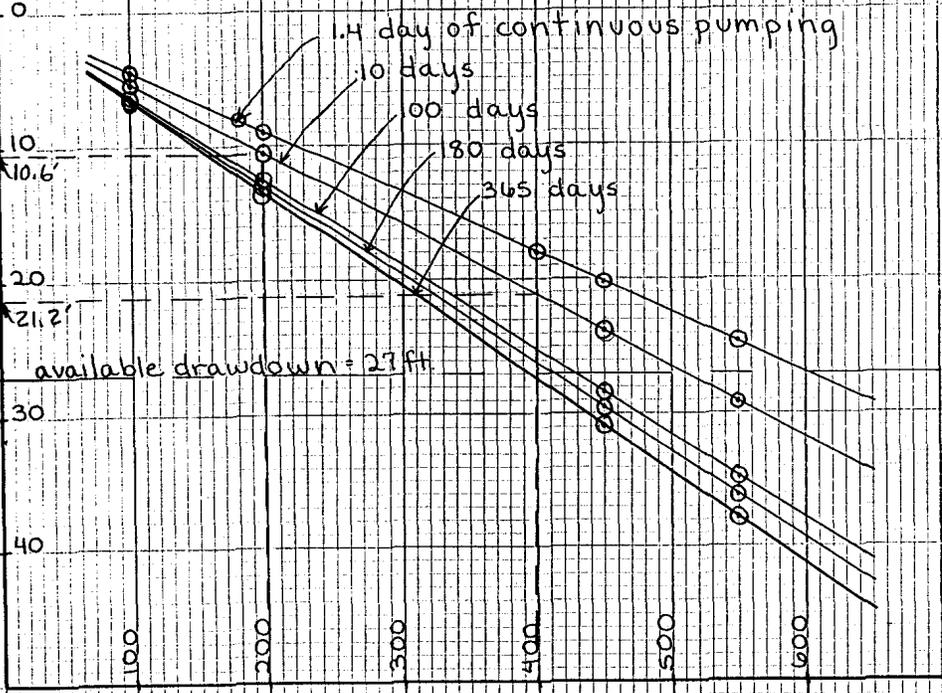
### Radius of Influence of Park Well

When pumping of ground water lowers the potentiometric surface, a cone of depression (or drawdown curve) is created in the immediate vicinity of the well. As the well is pumped, the cone expands and deepens at a decreasing rate with time. Figure 6 shows two cones of depression. Cone (a) will continue to enlarge until aquifer recharge equals pumpage. If the expanding cone of depression encounters an impervious boundary on one side of the well, it can expand no further in that direction. As a result, cone (b) must expand and deepen more rapidly in all other directions to maintain the yield of the well.



# Projected Pumping Level - Park Well 18N/13W-18K2

Drawdown in feet



Discharge in gallons per minute

Figure 5. Discharge versus drawdown graph; Data in Appendix B.

CROSS SECTION - 10 SQUARES TO INCH



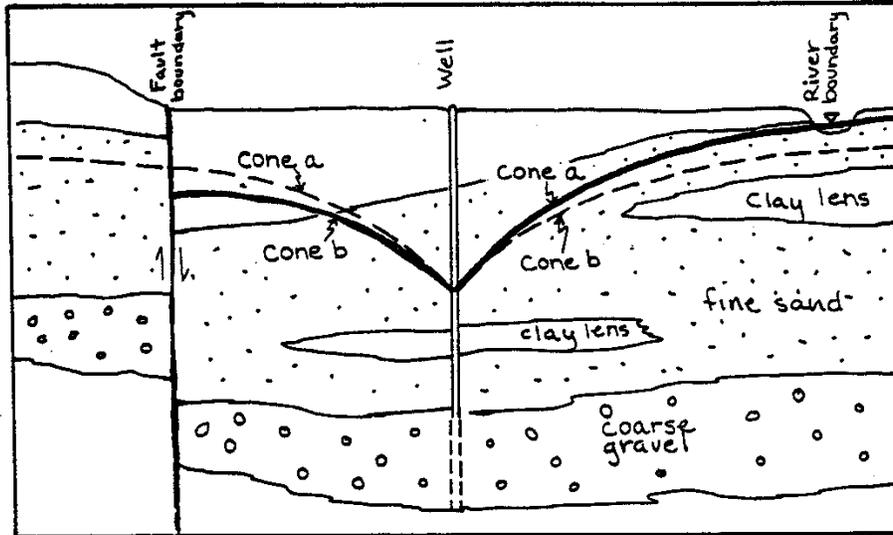


Figure 6. A) Cone of depression receiving recharge from river and unaffected by an impervious boundary.

B) Cone of depression affected by an impervious boundary. In this case, the boundary is a fault.

— drawdown curve as a result of both recharge and discharge boundaries.

-- -- drawdown curve unaffected by boundary conditions.

Analysis of the 27-hour September test did not indicate a boundary condition because the cone of depression did not expand to the boundary for the test duration. Analysis of the 9-day March to April drawdown test did, however, reveal the existence of an impervious boundary, probably the Maacama Fault zone. An impervious boundary causes the slope on time-drawdown graphs to steepen. Observation wells closest to the boundary show evidence of the boundary before wells further away do. Time-drawdown graphs from well 18L1 shows a steepening slope earlier than does well 18F1 or well 17M1 (Appendix I, Figures 13-15).

After 4 days of pumping, the cone expanded the distance to the impervious boundary. As a result, drawdowns around the pumped well are asymmetrical. Drawdown is greater near the boundary. Drawdown contours after 5, 6, and 30 days of pumping are shown in Figure 7.

Figure 8 shows the radial influence of pumped well (18K1) as a function of time, distance from the well, and pumping rate. Note that the maximum distance of influence (or interference) is related to duration of pumping and to pumping rate. For example, there would be 5.5 feet of drawdown at a well 1,000 feet away after 1.4 days of pumping at 450 gpm. The maximum radius of influence at the end of 1.4 days is about 2 miles. Doubling the pumping rate does not extend the distance of influence. It does, however, double the drawdown interference within the radius of influence.







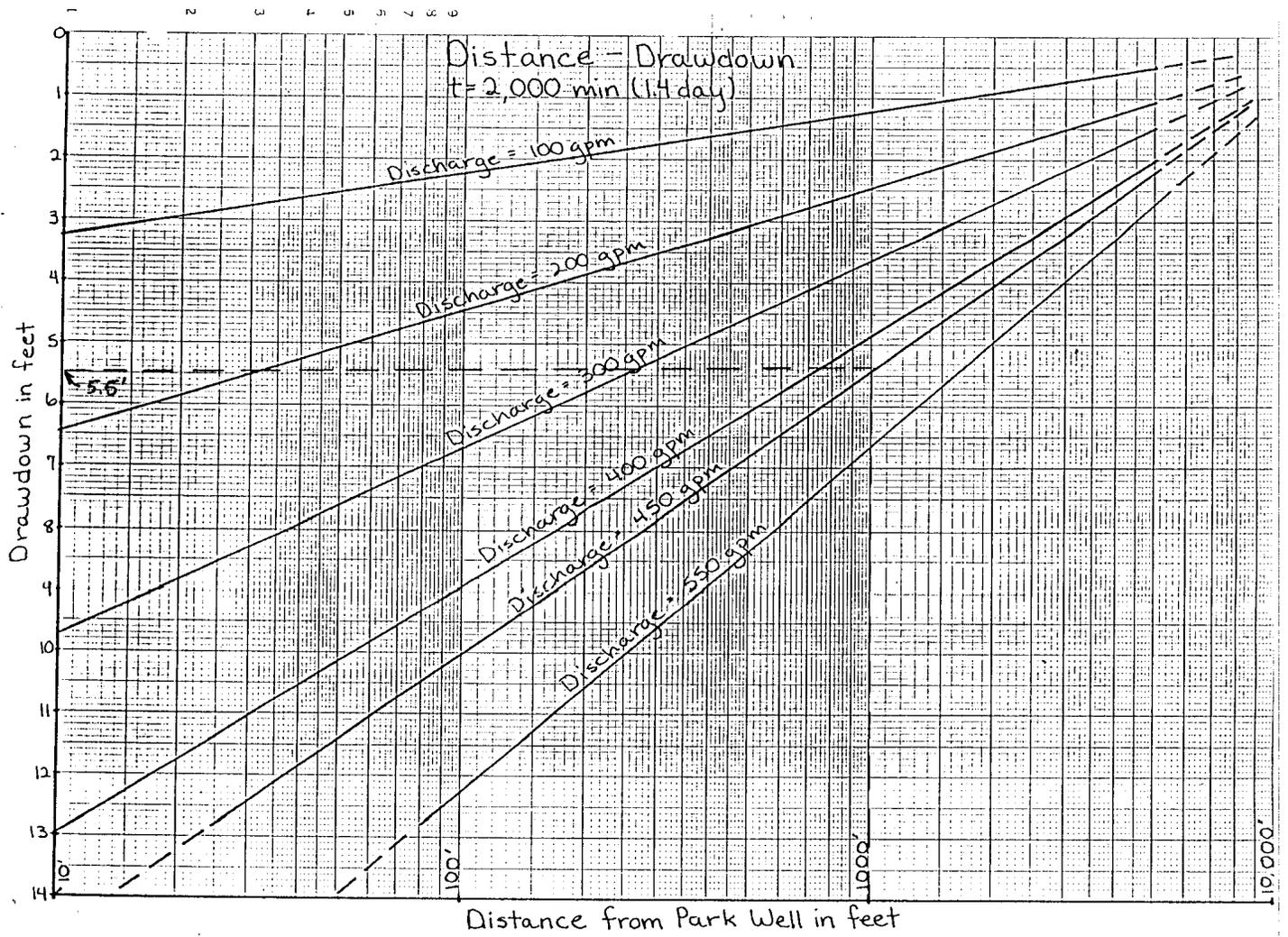


Figure 8. Radial influence of Park well as a function of pumping rate. Data calculated from observation well 18N/13W-181.1.



Water levels can be predicted from the time-drawdown graph after long periods of continuous pumping. If the City Park well was pumped continuously at 450 gpm for 15 or 180 days, the maximum radius of influence would extend beyond 2.3 miles. Figure 9 is another type of a distance-drawdown graph. Discharge from well 18K1 is constant while time is variable. After 180 days of pumping, a well 1,000 feet from the Park well will have a drawdown of about 15 feet.



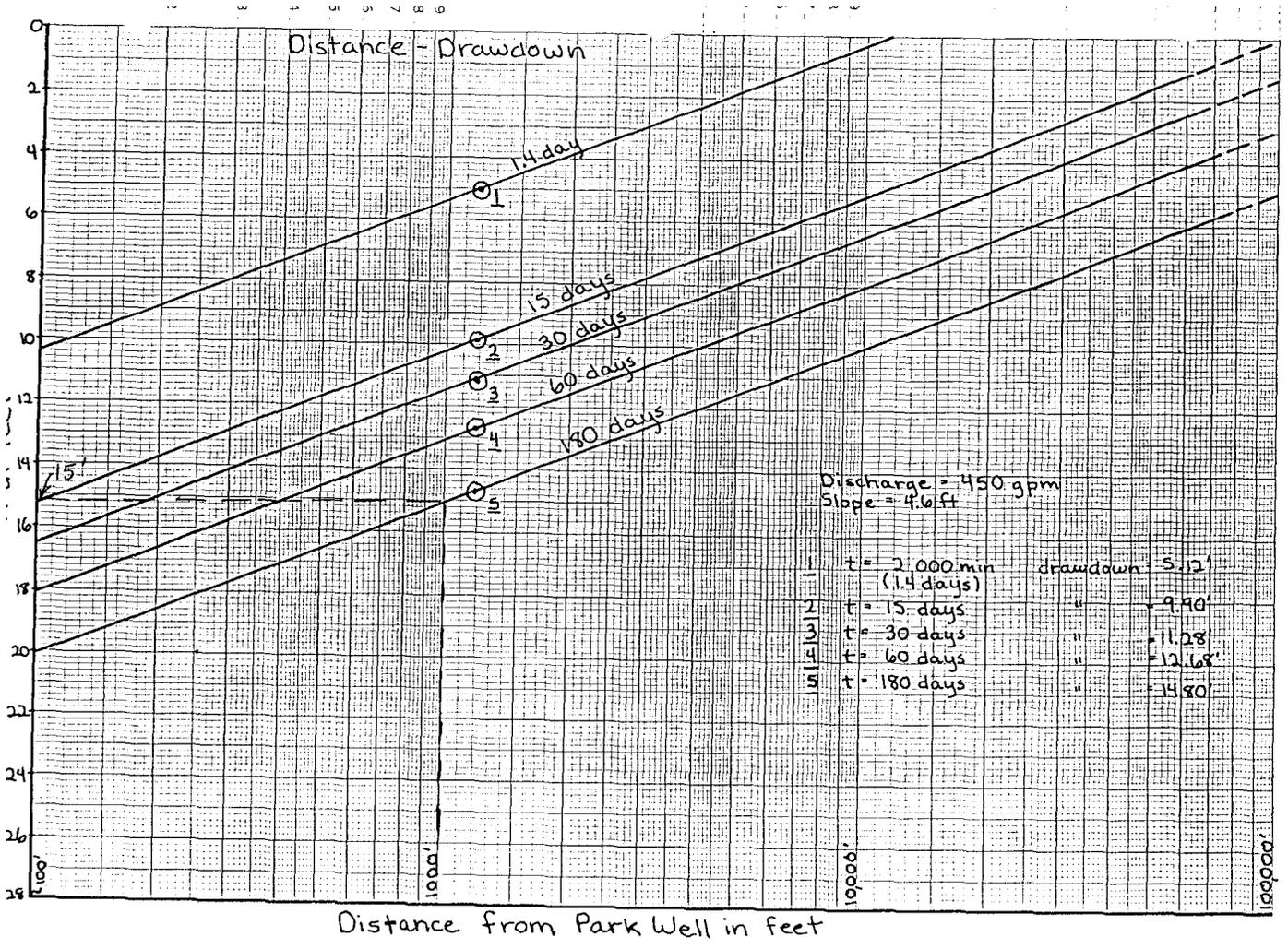


Figure 9. Radial influence of Park well as a function of time (duration). Data calculated from observation well



## VII. WATER QUALITY

Samples were taken at beginning and end of each aquifer test to determine Park well water quality after prolonged pumping. During the tests, pH, temperature, and EC were monitored for changes. Laboratory analyses of Park well water collected in September are complete for both standard and minor elements (refer to Appendix B). During the March-April test, water samples were also collected from 12 wells throughout the valley. Unfortunately, all the sample analyses have not been completed at this time.

The USGS (1986) collected and analyzed 20 samples from 17 wells in Little Lake Valley. Two distinct water types were identified from the data: (1) water in which calcium-magnesium bicarbonate is *predominant and sodium and chloride* are minor, and (2) water in which sodium and chloride are predominant and total dissolved solids are high relative to the first type. Mean concentrations of iron and manganese from both water types exceed Environmental Protection Agency (EPA) standards<sup>1/</sup>.

Park well water analysis is similar to the first water type, in which calcium-magnesium is predominant and sodium and chloride are minor. Arsenic (0.12 mg/L), iron (1.1 mg/L), and manganese (3.2 mg/L) concentrations all exceed EPA standards. Table 3 lists chemical quality of ground water in the valley (Farrar, 1986) relative to Park well water concentrations and EPA standards.

Temperature, pH, and turbidity did not change during either aquifer tests. Analysis of Park well water, field EC and pH measurements, and USGS water quality analyses, show there are no aquifers or zones that can be identified. The water quality from the Park well represents the quality that will be supplied to the municipal system during normal pumping operations.

Water extracted from the Park well may be drawn from several aquifers which have differing qualities. Refer to Figure 4 for well construction and perforation intervals. The well is sealed against pollution to a depth of 50 feet. The first perforation interval occurs at a depth of 80 feet. At this depth, the water is confined and is not locally hydraulically connected to the upper unconfined aquifer. Therefore, samples collected from the Park well do not reflect water quality of the unconfined aquifer.

Water samples should be obtained from various perforation intervals. This may identify aquifers or zone from which high concentrations of arsenic, iron, and manganese are found.

---

<sup>1/</sup> EPA Standard: National Interim Primary Drinking Water Regulation, U. S. Environmental Protection Agency, 1975; and National Secondary Drinking Water Regulations, U. S. Environmental Protection Agency, 1977.



Table 3. Chemical Quality of Ground Water in Little Lake Valley

	<u>Number of</u> <u>Analyses</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Mean</u>	<u>Park</u> <u>Well</u>	<u>EPA</u> <u>Standard</u>
<u>Major Constituents, in milligrams per liter</u>						
Alkalinity as CaCO <sub>3</sub>	17	380	67	170	344	-
Calcium	17	89	11	37	56	-
Chloride	17	770	2.9	80	8	250
Fluoride	17	3.4	.1	.35	-	1.8
Magnesium	17	39	4.9	17	41	-
Nitrogen NO <sub>2</sub> +NO <sub>3</sub> as N	17	7.2	-	0.7	-	10
Potassium	17	2.9	0.5	1.2	0.7	-
Silica	17	57	11	28	-	-
Sodium	17	510	6.0	58	26	-
Sulfate	17	24	5.0	7.5	4	250
Sum of dissolved constituents	16	1,710	97	340	-	-
<u>Minor Constituents, in micrograms per liter</u>						
Aluminum	8	<100	<100	<100	-	-
Arsenic	8	16	1.0	4.1	122	50
Barium	8	500	40	185	-	1,000
Boron	20	127,000	20	8,600	200	-
Cadmium	8	<30	<1.0	<5.6	-	10
Chromium	8	<10	<10	<10	-	50
Copper	8	40	<10	<24	-	1,000
Iron	18	16,000	<10	<2,250	1,100	300
Lead	8	<100	-	<88	-	50
Manganese	17	1,700	3.0	528	3,200	50
Mercury	8	1.8	<.1	<.58	-	2
Nickel	8	<100	<100	<100	-	-
Zinc	8	150	5.0	37	-	5,000



## VIII. REFERENCES

- California Division of Mines and Geology. 1982. Special Studies Zones: Willits NE, 1:62,500.
- Cardwell, G. T. 1965. "Geology and Ground Water in Russian River Valley Areas and in Round, Laytonville, and Little Lake Valleys, Sonoma and Mendocino Counties, California". U. S. Geological Survey, Water-Supply Paper 1548. 154 pp.
- Farrar, C. D. 1986. "Ground Water-Resources inn Mendocino County, California". U. S. Geological Survey, Water-Resources Investigations Report 85-4258. 81 pp.
- Kennedy/Jenks Engineers 1985. "Final Report Water System Master Plan, City of Willits, California".
- McLaughlin, R. J., and Nilsen, T. H. 1982. "Neogene Nonmarine Sedimentation and Tectonics in Small Pull-Apart Basins of San Andreas Fault System, Sonoma County, California: Sedimentology". V. 29, No. 6, p. 685-876.



## APPENDICES

- A. Summary of Aquifer Test and Drawdown Graphs
- B. Data Sheets (used for calculations found in text)
- C. Lab Analysis of Park Well



## APPENDIX A. Summary of Aquifer Test and Drawdown Graphs

Three separate aquifer tests were conducted. Each test consisted of pumping the City Park well (18K2) at a constant rate. DWR conducted the first test for 1,248 minutes (<1 day) on September 3-4, 1986. The test duration was insufficient for a thorough analysis of data. It was necessary to extend the duration of the aquifer test. To do this, the City of Willits pumped the Park well continuously for 8,650 minutes (6 days) and measured static level and drawdown after one day of pumping. For a number of reasons, extending these data onto the first test data proved inconclusive. DWR conducted the third test for 10 days from March 24 through April 3, 1987. During this test, drawdown and recovery measurements were made in the pumped well and in three observation wells: 18L1, 18F1, and 17M1. A Stevens Type F continuous recorder was placed on a shallow well (18K1) to measure any influence from pumpage of well 18K2.

After 3 days of pumping, the pump was off about 6 hours. This was quickly remedied and the test resumed. Periodic pumping from neighboring wells and in well 17M1 influenced drawdown measurements in observation well 17M1. However, this did not significantly influence drawdown measurements in the other wells.

After 4 days of continuous pumping, the cone of depression from the Park well expanded to an impervious Maacama fault boundary. A steepening change in slope on time-drawdown graphs indicates a fault boundary. Wells closer to the boundary showed a boundary effect earlier in the test than wells farther away.

Early and late test data were used to calculate aquifer coefficients. All drawdown and some recovery are plotted against time in fractions of minutes. Coefficients of transmissivity (T) and storativity (S) are tabulated below. Results of aquifer coefficients are based on three types of analyses: Theils, Nonequilibrium, Artesian Method, Cooper-Jacob Method, and Hantusch Leaky Artesian Method. Values of T and S that best represent aquifer characteristics in vicinity of Park well are 24,000 gpd/ft and  $7.5 \times 10^{-4}$ .



Results of Aquifer Tests: Coefficients of Transmissivity and Storativity

Well No.	Date	Aquifer Coefficients		
		T (gpd/ft)	S	
18N/13W-18L1	9/3-4/86	59,900 (a)	$6.4 \times 10^{-5}$ (a)	
		58,000 (a)	$5.7 \times 10^{-4}$ (a)	
		e - 45,200 (b)	e - $3.9 \times 10^{-4}$ (b)	
		l - 39,800 (b)	l - $5.3 \times 10^{-4}$ (b)	
		57,300 (c)	$2.2 \times 10^{-4}$ (c)	
	1/26-2/2/87	l - 19,900 (b)	l - $9.8 \times 10^{-4}$ (b)	
	3/24-4/3/87	e - 39,700 (a)	e - $4.3 \times 10^{-5}$ (a)	
		l - 26,200 (a)	l - $6.9 \times 10^{-4}$ (a)	
		e - 34,900 (b)	e - $5.1 \times 10^{-4}$ (b)	
		l - 23,800 (b)	l - $7.5 \times 10^{-4}$ (b)	
	18N/13W-18F1	3/24-4/2/87	e - 38,200 (a)	e - $2.3 \times 10^{-3}$ (a)
			l - 32,600 (a)	l - $2.1 \times 10^{-4}$ (a)
e - 29,200 (b)			e - $1.7 \times 10^{-3}$ (b)	
l - 17,600 (b)			l - $3.6 \times 10^{-3}$ (b)	
18N/13W-17M1	3/24-4/2/87	28,400 (a)	$2.0 \times 10^{-4}$ (a)	
		e - 35,500 (b)	e - $1.6 \times 10^{-4}$ (b)	
		l - 21,600 (b)	l - $3.6 \times 10^{-4}$ (b)	
18N/13W-18K2	9/3-4/86	32,700	N/A	
	3/24-4/2/87	27,000	N/A	
Averages		35,200	$7.8 \times 10^{-4}$	
Average Early Time		37,100	$8.5 \times 10^{-4}$	
Average Late Time		25,900	$1.0 \times 10^{-3}$	

Notes: (a) - Theis Nonequilibrium Method      e - Results from early-time data  
 (b) - Cooper-Jacob Method                    l - Results from late-time data  
 (c) - Hantusch Leaky Artesian Method



Willits Aquifer Test  
3/24-3/31/87-drawdown

Theis Nonequilibrium Artesian Method

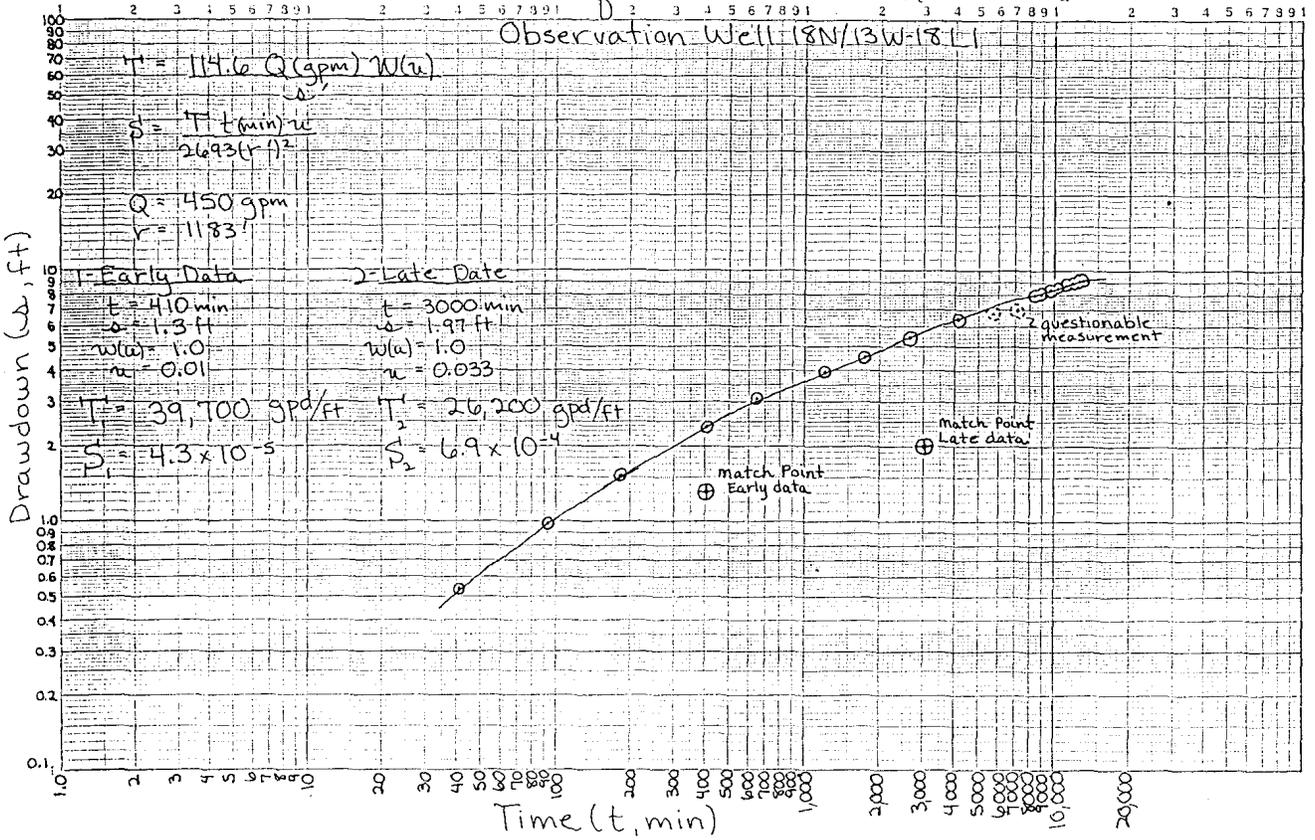
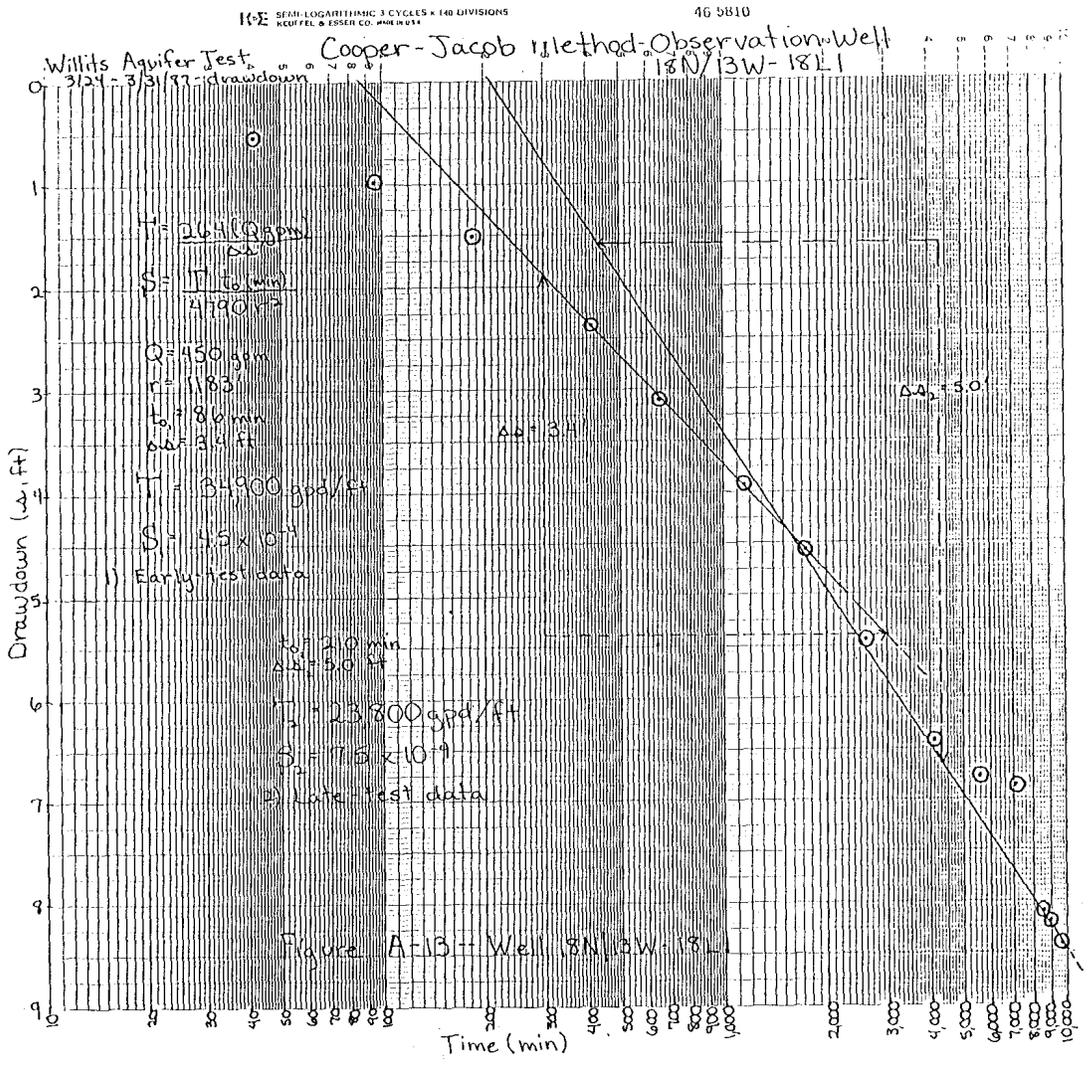


Figure A-10-- Well 18N/13W-18L1

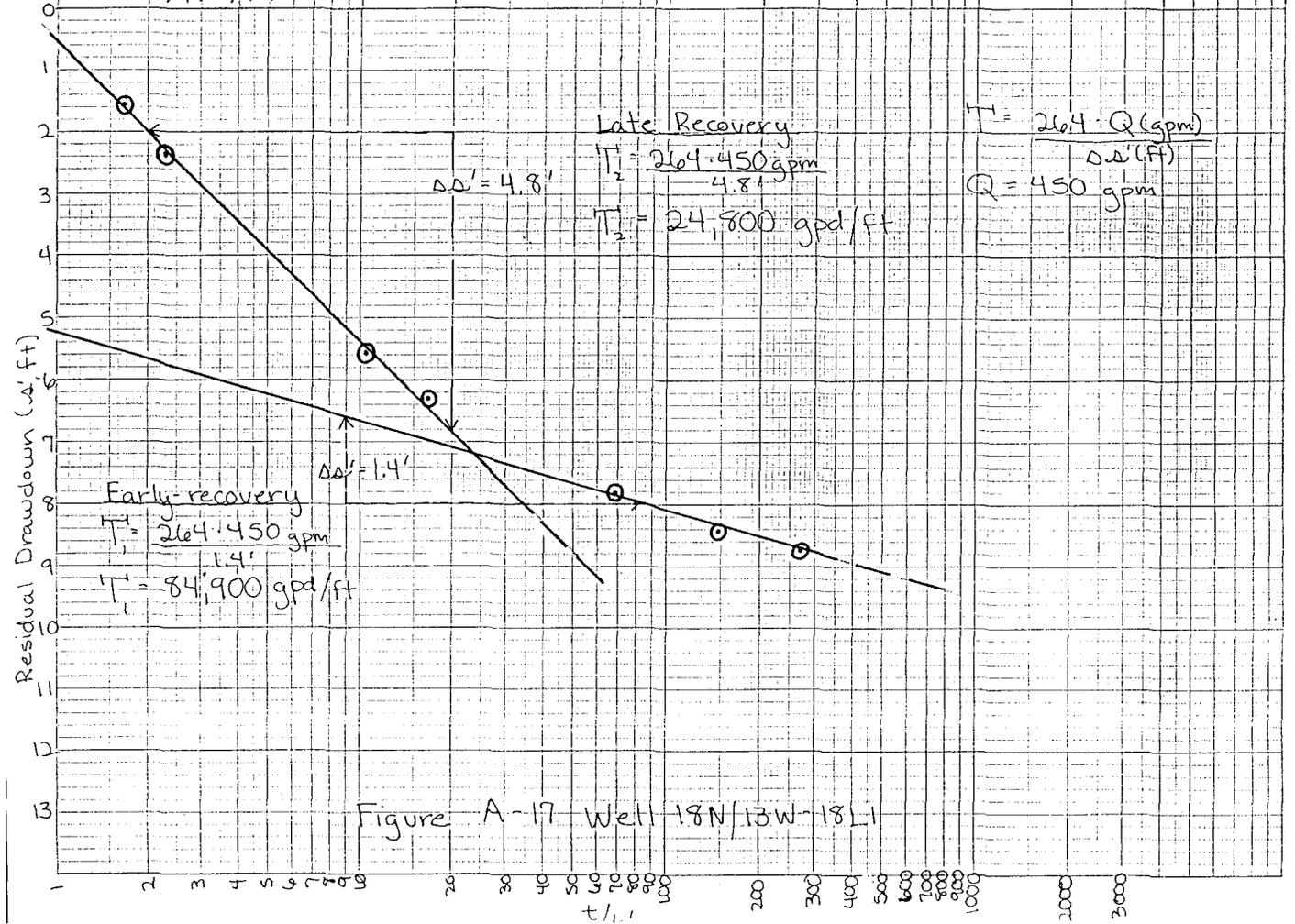






Willits Aquifer Test  
 4/2-3/87, 4/1/87, 4/15/87

# Recovery - Well 18N/13W-18L1





Willetts Aquifer Test  
3/24-3/31/87 - drawdown

Theis Nonequilibrium Artesian Method

Observation Well 18N/13W-18F1

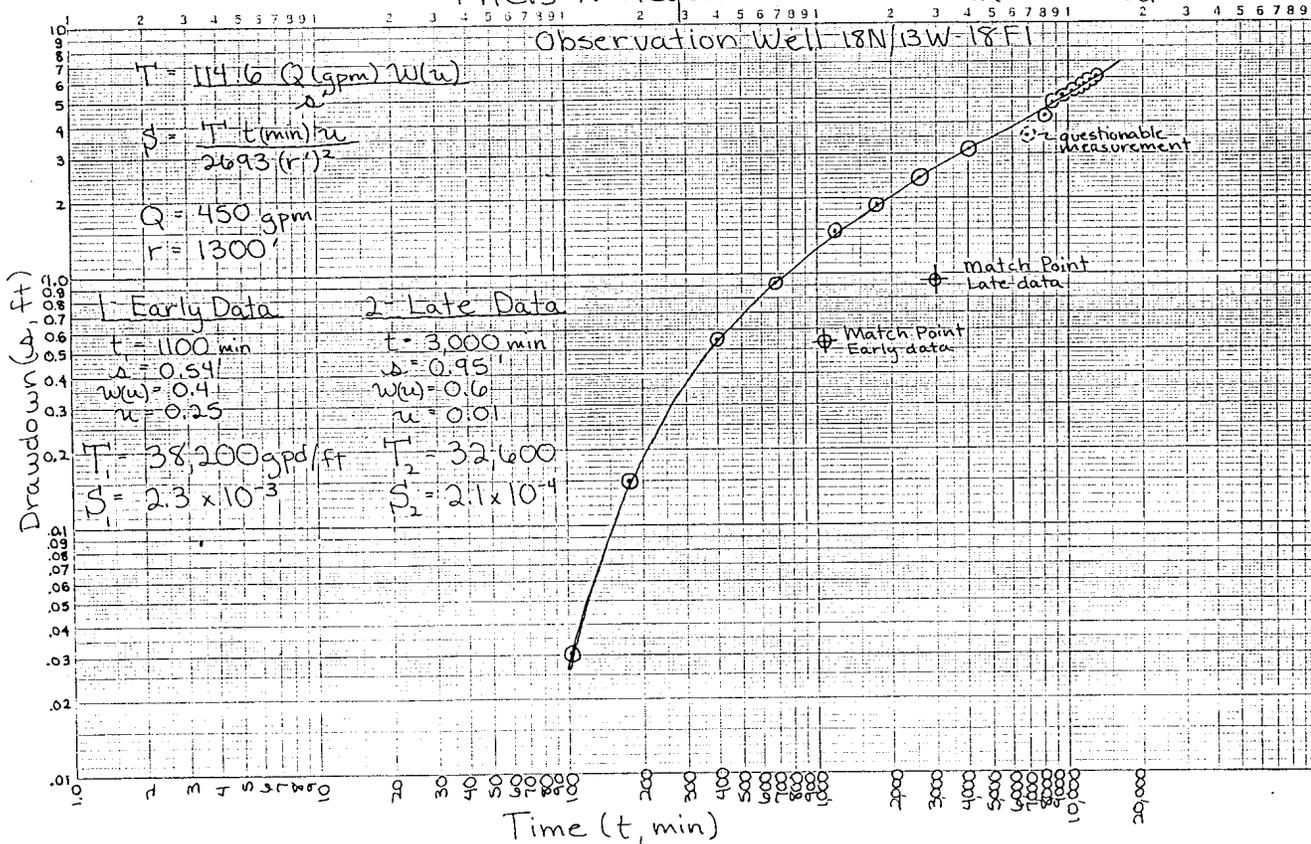


Figure A-11-- Well 18N/13W-18F1



Willetts, quifer Test  
 3/24 to 3/31/87 - drawdown = Cooper-Jacob Method; observation Well 18N/13W-18F1

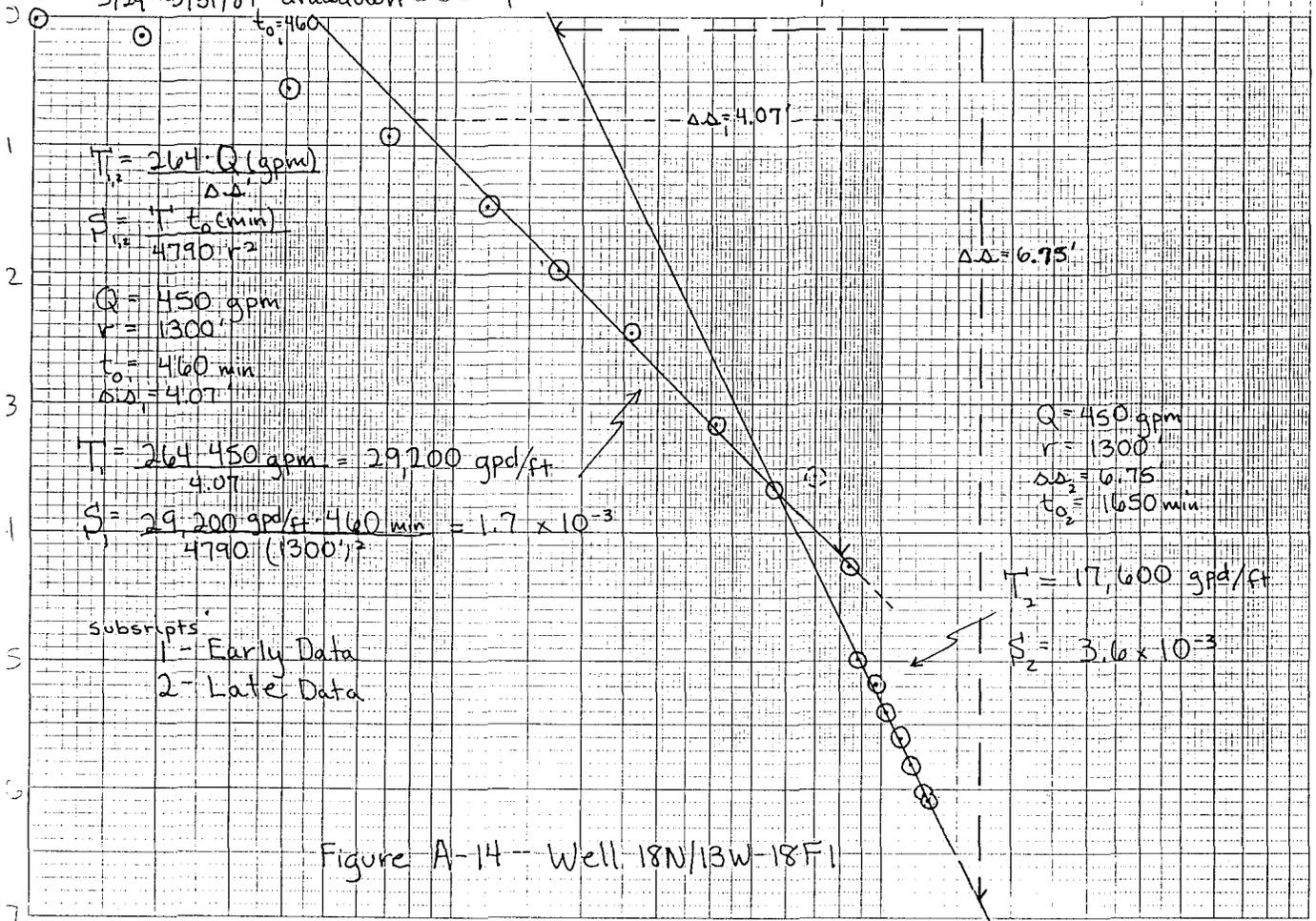


Figure A-14 -- Well 18N/13W-18F1



Willeys Aquifer Test  
3/24 - 3/31/87 - drawdown

Theis Nonequilibrium Artesian Method

Observation Well 18N/13W-17M1

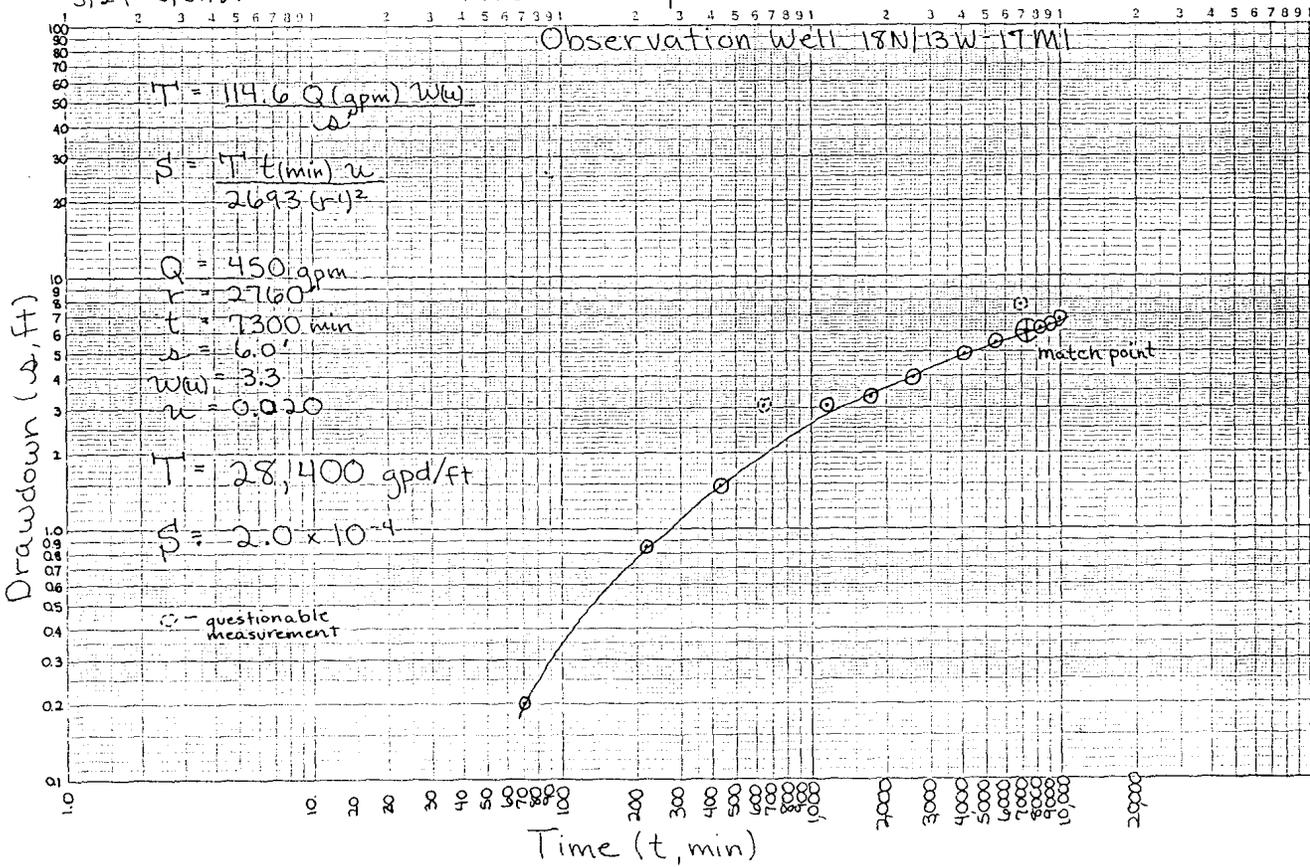
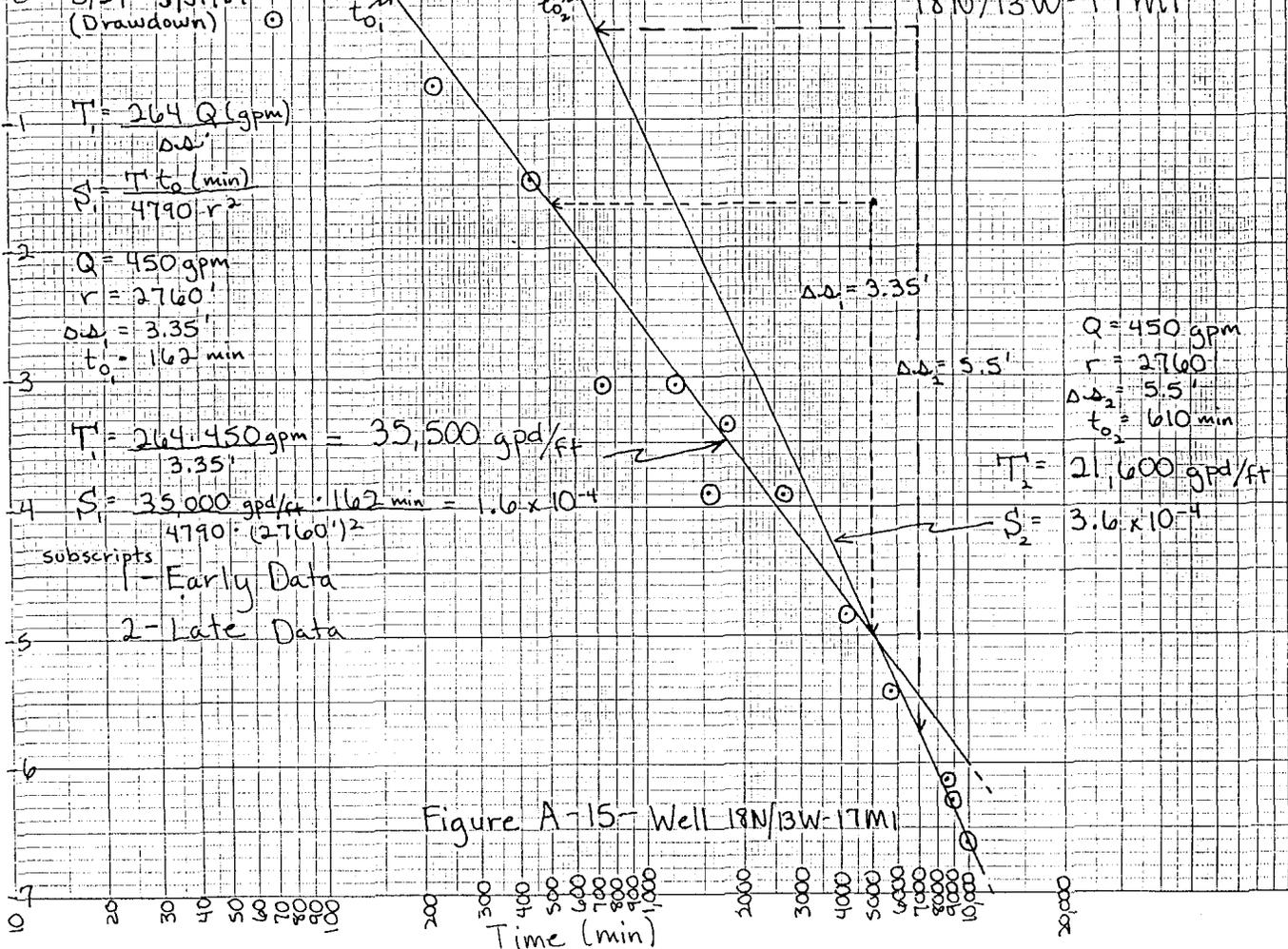


Figure A-12 Well 18N/13W-17M1



Willits Aquifer Test  
3/24 5/31/87  
(Drawdown)

Cooper-Jacob straight line method, Observation Well





18N/13W-18K2

Willits Pump Test  
 3/27 - 3/31/87

City Park Well - Pumped Well

Cooper-Jacob Method

$$T = \frac{2.64 Q (\text{gpm})}{\Delta s} (\text{gpd/ft})$$

$$T = \frac{2.64 (450 \text{ gpm})}{4.4 \text{ ft}} = 27,000 \text{ gpd/ft}$$

Q = 450 gpm  
 $\Delta s = 4.4 \text{ ft}$

(-) questionable measurement

$\Delta s = 4.4 \text{ ft}$

Drawdown (Δ ft)

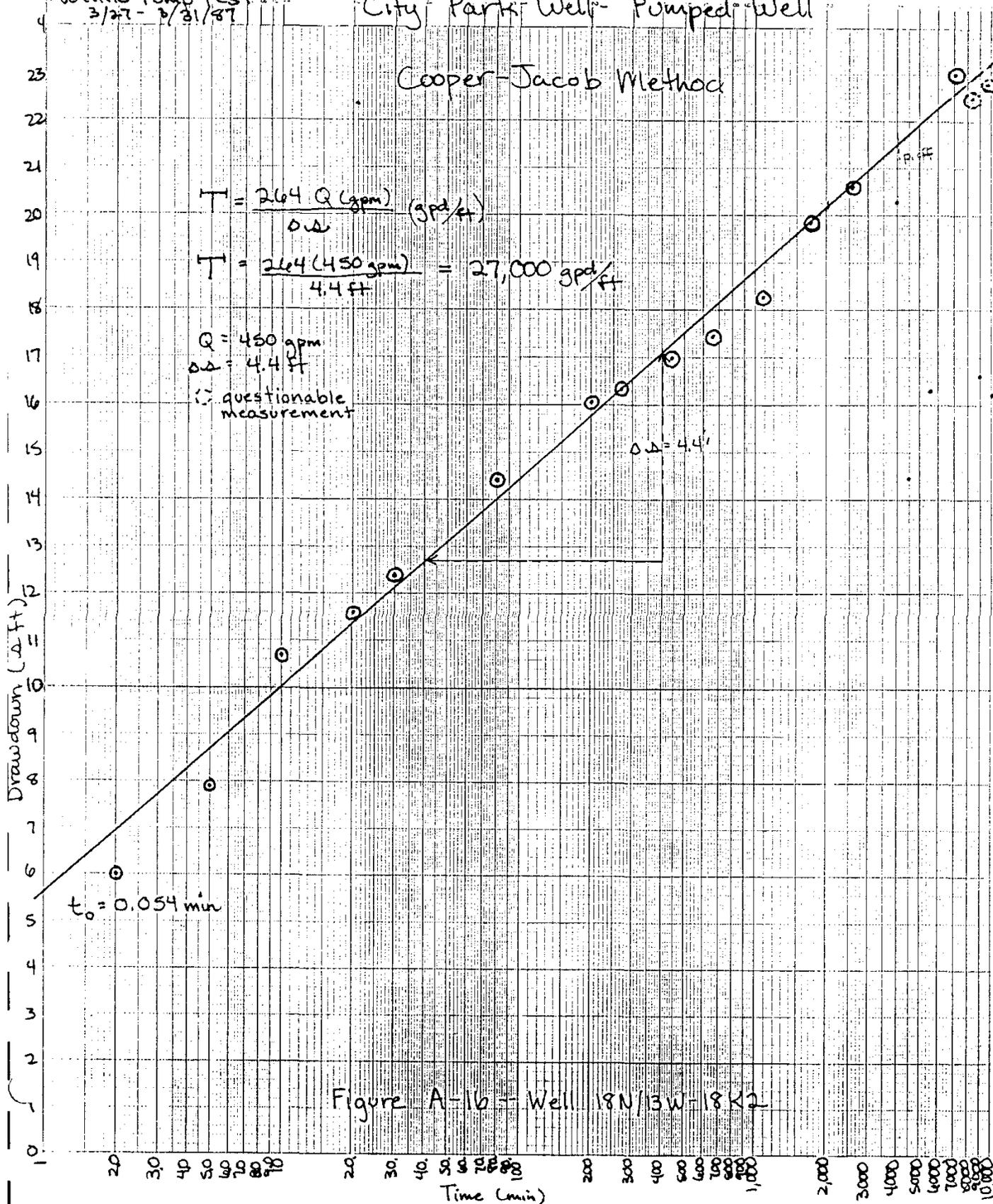
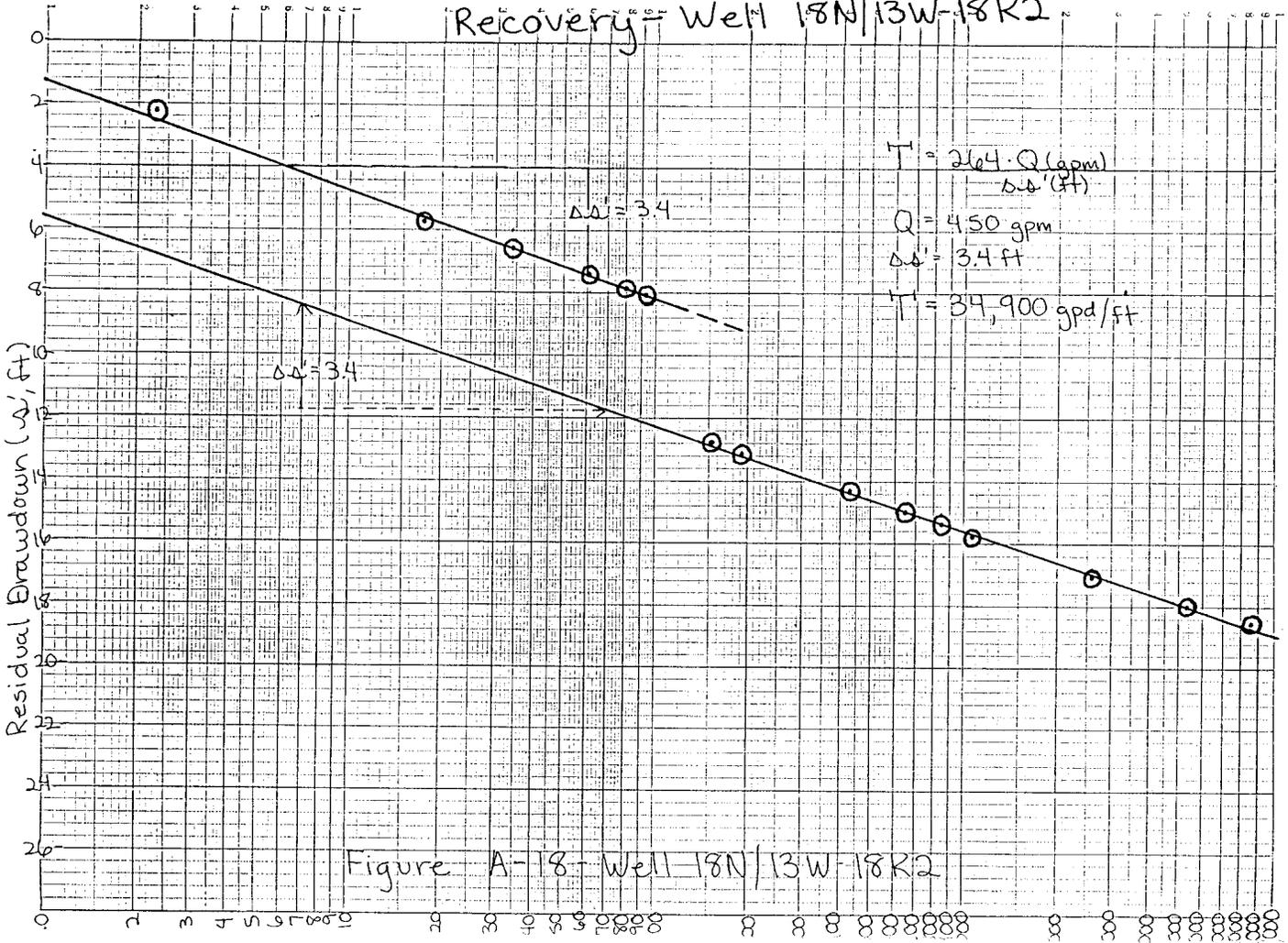


Figure A-16 - Well 18N/13W-18K2



# Recovery - Well 18N/13W-18K2





---

APPENDIX B. Data Sheets

---



# Discharge (Q) - Drawdown (s) City Park Well, 18N/13W-18K2

Time = 4 day

Q (gpm)	s (ft)
100	4.5
200	9.0
400	18.0
450	20.2
550	24.7

Time = 365 day = 824,000 min

Q (gpm)	s (ft)
100	6.9
200	13.8
450	31.0
550	37.9

Time = 10 days

Q (gpm)	s (ft)
100	5.3
200	10.6
450	23.9
550	29.2

Time = 100 days

Q (gpm)	s (ft)
100	6.3
200	12.6
450	28.4
550	34.7

Time = 180 days

Q (gpm)	s (ft)
100	6.6
200	13.1
450	29.5
550	36.1

Data calculated from Cooper-Jacob Plot;  
data used in Figure 5.



CROSS SECTION - 10 SQUARES TO INCH Distance - Drawdown Data

	18N-13W-18L1	18N-13W-18F1	18N-13W-17M1
Distance from Park Well (feet)	1183 ft	1300 ft	2760'
<u>Discharge = 100</u> (gpm)			
Drawdown (s'ft)	1.14 ft	0.49 ft	0.80 ft
$\Delta s' / \log \text{ cycle}$	1.02 ft	0.72 ft	0.93 ft
<u>Discharge = 200</u> (gpm)			
Drawdown (s'ft)	2.28 ft	0.98 ft	1.60 ft
$\Delta s' / \log \text{ cycle}$	2.04 ft	1.44 ft	1.86 ft
<u>Discharge = 300</u> (gpm)			
Drawdown (s'ft)	3.41 ft	1.47 ft	2.40 ft
$\Delta s' / \log \text{ cycle}$	3.07 ft	2.17 ft	2.79 ft
<u>Discharge = 400</u> (gpm)			
Drawdown (s'ft)	4.55 ft	1.96 ft	3.20 ft
$\Delta s' / \log \text{ cycle}$	4.09 ft	2.89 ft	3.72 ft
<u>Discharge = 450</u> (gpm)			
Drawdown (s'ft)	5.12 ft	2.20 ft	3.60 ft
$\Delta s' / \log \text{ cycle}$	4.60 ft	3.25 ft	4.18 ft
<u>Discharge = 550</u> (gpm)			
Drawdown (s'ft)	6.26 ft	2.69 ft	3.40 ft
$\Delta s' / \log \text{ cycle}$	5.62 ft	3.97 ft	5.11 ft

Data obtained from Cooper-Jacob plots; data used for figures 8 and 9.



3/24-4/2/87

Table 2 - Aquifer Test  
Aquifer Coefficients

	18N/13W18 F1	-17 L1	-17 M1	-17 K2
Distance (r)	1300'	1183'	2760'	0
Depth	100	91	67	240
Transmissivity Coefficient, $T'$ (gpd/ft)	38,200 (a)	39,700 (a)	28,400 (a)	24,100 (a)
	29,200 (b)	34,900 (b)	35,500 (b)	27,000 (b)
Storativity Coefficient, $S$ (dimensionless)	$2.3 \times 10^{-3}$ (a)	$4.3 \times 10^{-4}$ (a)	$2.0 \times 10^{-4}$ (a)	N/A
	$1.7 \times 10^{-3}$ (b)	$5.1 \times 10^{-4}$ (b)	$1.6 \times 10^{-4}$ (b)	N/A

Average  $T'$  = 32,900 (gpd/ft)  
 Average  $S$  =  $8.9 \times 10^{-4}$

- (a) Theis Type Non-equilibrium method
- (b) Cooper-Jacob straight-line method

% diff  
30%

Coefficients influenced by impermeable boundary:

	18F80	17L80 1 day	17M80 3.2 day	Park
$T'$ (gpd/ft)	22,850	23,800	21,600	N/A
$S$	$4.7 \times 10^{-3}$	$7.5 \times 10^{-4}$	$3.6 \times 10^{-4}$	N/A

Average  $T'$  = 22,800 (gpd/ft)  
 Average  $S$  =  $1.9 \times 10^{-3}$

(Determined after 3.2 days of pumping by Cooper-Jacob straight-line method.)



# Well Interference Calculations

$$T = \frac{114.6 Q (\text{gpm}) w(u)}{s (\text{ft})} \Rightarrow u = \frac{114.6 \cdot Q \cdot w(u)}{T}$$

$$S = \frac{T (\text{gpd/ft}) u t (\text{min})}{2693 (r(\text{ft}))^2} \Rightarrow u = \frac{S \cdot 2693 \cdot r^2}{T \cdot t}$$

Aquifer constants:  $T = 32,900 (\text{gpd/ft})$

$$S = 8.9 \times 10^{-4}$$

$$\therefore Q/T = 1.37 \times 10^{-2}$$

$$\therefore S/T = 2.7 \times 10^{-8}$$

$$s(\text{ft}) = 1.16 (w(u)) \quad u = \frac{7.3 \times 10^{-5} (r(\text{ft}))^2}{t(\text{min})}$$

Conditions:  $t = 7200 \text{ min} = 5 \text{ day.}$   
 $Q = 450 \text{ gpm}$

$r(\text{ft})$	$u$	$w(u)$	$s(\text{ft})$
200	0.00041	7.1	11.4
400	0.0016	5.9	9.4
600	0.0037	5.0	8.0
1000	0.010	4.0	6.4
1500	0.023	3.2	5.1
2000	0.041	2.6	4.2
3000	0.091	1.8	2.9
4000	0.16	1.5	2.4
5000	0.25	1.0	1.4
6000	0.37	0.75	1.2
7000	0.50	0.54	0.86
8500	0.73	0.35	0.56
10000	1.0	0.23	0.37

$t = 8640 \text{ min} = 6 \text{ day}$

200	0.00034	7.2	11.5
400	0.0014	6.0	9.6
600	0.0030	5.2	8.3
1000	0.0084	4.3	6.9
2000	0.033	2.8	4.5
3000	0.076	2.0	3.2
4000	0.14	1.6	2.6
5000	0.21	1.2	1.9
6000	0.30	0.88	1.4
7000	0.41	0.68	1.1
8500	0.61	0.44	0.70
10000	0.84	0.28	0.45



$$T = 32,900 \text{ (gpd./ft)} \quad t = 30 \text{ day}$$

$$S = 8.9 \times 10^{-4} \quad t = 43,200$$

$$u = 1.6 (w(u)) \quad u = \frac{7.3 \times 10^{-5} r^2}{43,200}$$

$$u = 1.6 (w(u)) \quad u = 1.69 \times 10^{-9} (r)^2$$

r (ft)	u	w(u)	s (ft)
200	$6.8 \times 10^{-5}$	9.0	14.4
400	$2.7 \times 10^{-4}$	7.7	12.2
600	$6.1 \times 10^{-4}$	6.75	10.6
1000	$1.7 \times 10^{-3}$	5.8	9.0
1500	$3.8 \times 10^{-3}$	5.0	7.8
2000	$6.8 \times 10^{-3}$	4.4	6.7
3000	$1.5 \times 10^{-2}$	3.7	5.7
4000	$2.7 \times 10^{-2}$	3.0	4.7
5000	$4.2 \times 10^{-2}$	2.7	4.1
6000	$6.1 \times 10^{-2}$	2.2	3.4
7000	$8.3 \times 10^{-2}$	1.9	2.9
8500	0.12	1.7	2.6
10000	0.17	1.4	2.2
15000	0.38	0.72	1.1
20000	0.68	0.38	0.6
11000	0.20	1.2	1.8
12000	0.24	1.05	1.6
13000	0.29	0.9	1.4

$$t = 526,000 \text{ min} = 365 \text{ days}$$

$$Q = 390 \text{ gpm}$$

$$T = 32,900 \text{ (gpd./ft)}$$

$$S = 8.9 \times 10^{-4}$$

r (ft)	u	w(u)	s (ft)
10,560 (2 miles)	$1.54 \times 10^{-2}$	3.7	5.0



Willits Aquifer Test 3/24/87 - 4/2/87

Drawdown Data - Well 18N/13W-18K2

Date/Time	Time Elapse (min)	Static Water Level	Drawdown (ft)
3/24/87 11:25am	0.0	25.9 ft	0.0
	2		6.0
	5		7.9
	10		10.7
	20		11.6
	30		12.4
	80		14.4
	202		16.05
	270		16.35
	445		17.00
	725		17.45
	1240		18.28
	1525		19.10
	1799		19.85
	2665		20.62
	4185		20.33
	4550		14.45
	5795		16.30
	7205		23.00
	8485		22.50
	8985		16.16
	9846		22.80
	10,157		16.23
4/2/87 End of drawdown	12,960		27.35



Willits Aquifer Test 3/24-4/2/87  
 Drawdown Data- Well 18N/13W-18L1

Date/Time	Time Elapse (min)	Static Water Level	Drawdown (ft.)
3/24/87 11:25 AM	0.0	28.32 ft	0.0
	42		0.53
	95		0.96
	185		1.50
	412		2.36
	645		3.10
	1,210		3.93
	1,771		4.59
	2,628		5.45
	4,150		6.43
	5,670		6.78
	7,155		6.88
	8,460		8.01
	8,944		8.18
	9,829		8.40
	10,400		8.63
	11,263		8.88
	11,980		8.98
	12,730		9.24
	12,935		9.28
4/2/87 End of drawdown	12,960		9.28



Willits Aquifer Test - 3/24/87 - 4/2/87  
 Drawdown Data - Well 18N/13W-18F1

Date/Time	Time Elapsed (min)	Static Water Level	Drawdown (ft)
3/24/87 11:25am	0.0	28.58 ft	0.0
	37		0.0
	103		0.03
	180		0.15
	404		0.55
	697		0.92
	1205		1.49
	1765		1.92
	2622		2.47
	4140		3.17
	5645		3.67
	7145		3.57
	8445		4.27
	8940		4.91
	9823		5.18
	10,390		5.42
	11,255		5.62
	11,915		5.82
	12,765		6.05
	12,917		6.09
	12,935		6.09
4/2/87 End of drawdown	12,960		6.09



Willits Aquifer Test 3/24-4/2/87  
 Drawdown Data - Well 18N/13W-17M1

Date/Time	Time Elapse (min)	Static Water Level	Drawdown (ft)
3/24/87 11:25 AM	0.0	21.9 ft	0.0
	70		0.2
	218		0.84
	435		1.48
	725		3.07
	1220		3.08
	1455		3.90
	1780		3.38
	2645		3.93
	4160		4.86
	5675		5.45
	7175		7.65
	8470		6.16
	8975		6.31
	9837		6.63
	10,408		6.93
	11,900		8.80
	12,695		9.58
	12,900		7.55
4/2/87 End of drawdown	12,960		7.55



Recovery, 4/2-3/87

pg 1 of 2

Residual Drawdown

$t'$	$t$	$t/t'$	18N/13W-18K2	-18L1
4/2/87 11:25	12960.0	0	27.35	9.28
1.5	12961.5	8641	18.5	—
2.5	12962.5	5185	18	—
5.0	12965	2593	17.1	—
12.0	12972	1081	15.8	—
15.0	12975	865	15.45	—
20.0	12980	649	15.0	—
30.0	12990	433	14.35	—
43.0	13003	302	—	—
48.0	13008	271	—	8.78
60.0	13020	217	—	—
68.0	13028	192	13.2	—
85.0	13045	153	12.8	—
90.0	13050	145	—	—
95.0	13055	137	—	8.42
125.0	13085	105	—	—
140.0	13100	94	8.08	—
165.0	13125	80	7.87	—
215.0	13175	61	7.47	—
224.0	13184	59	—	7.81
240.0	13200	55	—	—
253.0	13213	52	—	—
395.0	13355	34	6.62	—

4/3/87

779	13739	18	—	—
785	13745	17.5	5.67	—



Recovery, 4/2-3/87

Pg 1 of 2

Residual Drawdown

$t'$	$t$	$t/t'$	18N/13W-18K2	-18L1
4/2/87 11:25	12960.0	0	27.35	9.28
1.5	12961.5	8641	18.5	—
2.5	12962.5	5185	18	—
5.0	12965	2593	17.1	—
12.0	12972	1081	15.8	—
15.0	12975	865	15.45	—
20.0	12980	649	15.0	—
30.0	12990	433	14.35	—
43.0	13003	302	—	—
48.0	13008	271	—	8.78
60.0	13020	217	—	—
68.0	13028	192	13.2	—
85.0	13045	153	12.8	—
90.0	13050	145	—	—
95.0	13055	137	—	8.42
125.0	13085	105	—	—
140.0	13100	94	8.08	—
165.0	13125	80	7.87	—
215.0	13175	61	7.47	—
224.0	13184	59	—	7.81
240.0	13200	55	—	—
253.0	13213	52	—	—
395.0	13355	34	6.62	—
- 4/3/87				
779	13739	18	—	—
785	13745	17.5	5.67	—



$t'$	$t$	$t/t'$	18K2	18L1
795	13,755	17.3	—	—
815	13,775	16.9	—	6.31
1260	14,220	11.3	—	—
1365	14,325	10.49	—	—
1370	14,330	10.5	—	5.58

4/9/87

10175	23,135	2.3	- 2.2	2.38
-------	--------	-----	-------	------

4/15/87

18,720	31,680	1.69	-19.1 pumping?	1.58
--------	--------	------	-------------------	------



Project WILLITS AQUIFER TEST

Sheet 1 of 3

Feature W.G. meas

Designed

Date 3/24/87

Item DRAWDOWN

Checked

well elev - 1355

Date

date	time	elapse time (min)	City Park well	Munson	Fish	Giese	Remarks
4	11:15	STATIC WL =	25.9	28.32	21.9/1.7	28.58	
	11:25	start pump					hour meter = 496.45
	11:27	+2	31.9				cf = 7607
	11:30	+5	33.8				Q = 375 gpm
	11:35	+10	36.6				set Q @ 450 gpm
	11:45	+20	37.5				
	11:55	+30	38.3				
	12:02	+37	-			28.58	
	12:07	+42	-	28.85			
	12:35	+70	-		22.1/1.75		
	12:45	+80	40.3				
	13:00	+95	-	29.28			
	13:08	+103	-			28.61	
	14:25	180	-			28.73	
	14:30	185	-	29.82			Q = 450
	14:47	202	41.95				cf = 77,320
	15:03	218	-		22.74/1.75		
	15:55	270	42.25				
	18:09	404				29.13	
	18:17	412		30.68			
	18:40	435			23.38/1.78		
	18:50	445	42.90				
	23:02	697				29.5	
	23:10	705		31.42			
	23:20	715			24.97/1.75		Q = 450
	23:30	725	43.35				30,454 cf
11	07:30	1205				30.07	
	07:35	1210		32.25			
	07:54	1220			24.98/1.65		Q = 450
	08:05	1240	44.13				33,451 cf



Project Willits Aquifer Test 3/24-4/2/87 Sheet 2 of 3

Feature Drawdown Designed \_\_\_\_\_ Date \_\_\_\_\_

Item 910-527-6530

Stn	Time	Well No.	18N/13W-18F1		18N/13W-18L1		Checked 18N/13W-17M1		18N/13W-18K2		Date	Remarks	
			Giese	Munson	Fish	City well							
	0730	1205	30.07										
5	0735	1210		32.25									
	0754	1229				24.98	1.65						
	0805	1240						44.13			036810	(+50)	
	1650	1765	30.50										
	1656	1771		32.91									
	1705	1780				25.28	1.88						
	1724	1799						45.75					
	0707	2622	31.05										
6	0713	2628		33.77		25.83	1.89						
	0730	2645											
	0750	2665						46.52			092180	(+50)	
7	0825	4140	31.75										
	0835	4150		34.75									
	0845	4160				26.78	1.78						
	0910	4185						46.23			100958	(450)	
	1515	4550	Found pump not running power surge at about 11:00 am pos. shut down pump						40.35				
28	0930	5645	32.25										
	0955	5670		35.1								probe line probably cut but not severed	
	1000	5675				27.35	1.80					⊙ This is ? reading	
29	1020	5795						42.2			108738	450	
	1030	7145	32.15								117093		
	1040	7155		35.2									
	11:00	7175				29.55	2.2					(lost probe end??)	
	11:30	7205						48.9				(63.42)	
	8:10	8445	33.3					SPRINKLERS					
	8:25	8460		36.33									
	8:35	8470				29.06	2.45						
	8:50	8485						48.4			125507	(450)	



Project WILLITS DRAWDOWN TEST

Sheet \_\_\_\_\_

Feature March - April 87

Designed \_\_\_\_\_

Date \_\_\_\_\_

Item \_\_\_\_\_

Checked \_\_\_\_\_

-3.75

Date \_\_\_\_\_

Je	TIME	Giese	Munson	Fish	City well	Readings
0	1625	8940	33.49			
	1629	8944		36.50		
	1643	8944				29.50, willits Ready mix Gravel Plant well
	1700	8975		28.21	2.66	cut probe line reading
	1710	8985				42.06 EC=70.5 PH=7.0 Temp=62
1	0708	9823	33.76			
	0714	9829		36.72		
	0722	9837		28.53	2.80	probe error
	0731	9846				found 3.75' cut off elec probe from function in well
						EC=700 PH=7.1 Temp=60 good 48.75 133692 (450)
	1242	10,157				probe line is now broken 45.88 42.13 cut probe reading
	1600	10,355	11.13	Ready mix	45.00	Notho Pump kicked on - using all day
	1635	10,390	34.00			
	1645	10,400		36.95		will use well for 2-3 HRS. Tonight
	1653	10,408			28.64	2.85
	1704	10,419				52.5 - 3.75 = 48.82 137106 (450)
1	0700	11,255	34.22			
	0708	11,263		37.20		
	0723	11,278		28.83	2.99	elec. probe water stuck
	0742	11,297				problem getting this!
						52.78 - 3.75 = 49.03
	1715	11,870				52.87 - 3.75 = 49.12 145774 (450)
	1725	11,880		39.1		37.3
	1745	11,900			30.7	3.03
						sprinklers on all sites
	1800	11,915		35.4		34.4
12	0700	12,695			31.48	3.10
	0735	12,730		37.56		
	0740	12,735	34.63			
	0810	12,765			8.5	3.75
						49.45 151106 (450)
	1025	12,900			29.45	3.13
	1045	12,920		37.60		
	11:00	12935				49.50 152160 450



Project WILLOTS RECOVERY TEST

Sheet \_\_\_\_\_

Feature \_\_\_\_\_

Designed \_\_\_\_\_

Date \_\_\_\_\_

Item \_\_\_\_\_

4/2/87 - 4/3/87

49.50

Checked \_\_\_\_\_

Date \_\_\_\_\_

DATE	TIME	min	CITY WELL	Munson	Fish	Grese		
11/2	11:25	00	53.25	37.60	29.15/3.13	34.67		hr meter = 769.0 152300 cf
	11:26:30	+1.5	44.4					
	11:27:30	+2.5	43.9					
	11:30	5	43.0					
	11:37	12	41.7					
	11:40	15	41.35					
	11:45	20	40.90					
	11:55	30	40.25					began to rain
	12:08	43				34.66		}
	12:13	48		37.10				
	12:25	60			30.5/3.14 sprinkler on			}
	12:33	68	39.1					
	12:50	85	38.7					ptly correct
	12:55	90				34.64		
	13:00	95		36.74				
	13:30	125			29.24/3.13			Fish stopped sprinklers will run every other nite
	13:45	140	33.98 37.90 sandy					} begin meas w/ tape - re-calculated probe difference
	14:10	165	33.77					
	15:00	215	33.37					
	15:09	224		36.13				
	15:25	240			28.67/3.12			
	15:38	253				34.44		
	18:00	395	32.52					
13	00:24	779	1			33.94		
	00:30	785	31.57					
16	:40	795	1		27.32/3.13			
	01:00	815		34.63				
	08:25	1260			26.77/3.15			
	10:10	1365				33.48		
	10:40	1395		33.90				

pumping for WQ test



(Original) reduced 12%

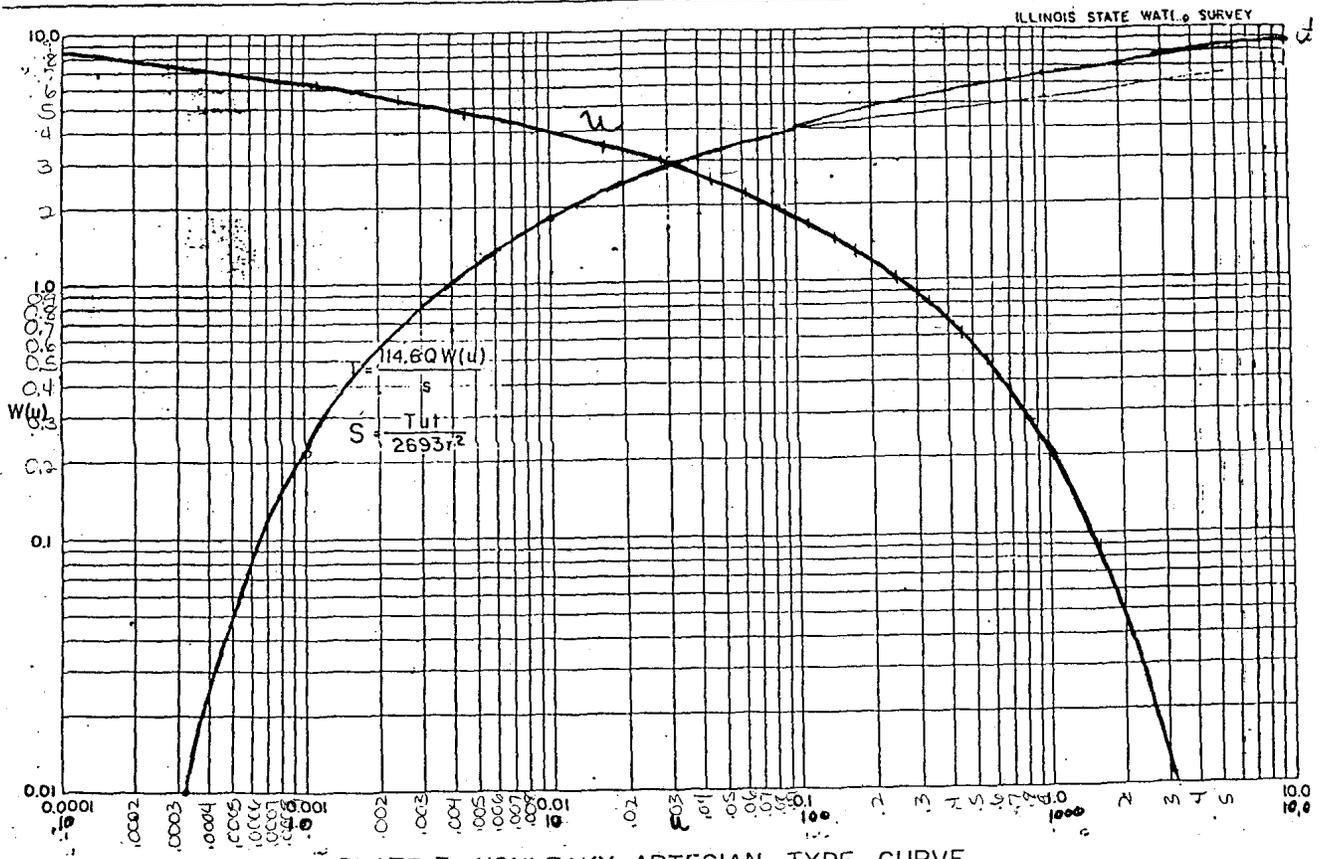


PLATE 3. NONLEAKY ARTESIAN TYPE CURVE



---

APPENDIX C. Lab Analysis of Park Well

---



5 6 N.O. 5.80.7  
1 2 3 3

WATER ANALYSIS (MINERAL)

WATER ANALYSIS (MINERAL) header section with fields for Basin, State Well No./Station No., Yr. (8, 6), Mo. (09), Day (04), Time (PST) (1,00,0), CO., Field Temp., Field EC, Field pH, DO, Discharge (CFS), G.H. (FT.), Depth (FT.), Sampler (5,0,5,0), LK Card Code (1,4).

CARD - 2: TYPE OF ANALYSIS: 1. W.O. 1210-0671. DISSOLVED HARDNESS: 3.08 mg/L. DISSOLVED CALCIUM: 55.5 mg/L. DISSOLVED MAGNESIUM: 41.3 mg/L. DISSOLVED SODIUM: 26.3 mg/L. DISSOLVED POTASSIUM: 0.7 mg/L.

CARD - 2 (continued): DISSOLVED TOTAL ALKALINITY: 17.88 mg CaCO3/L. DISSOLVED SULFATE: 4.4 mg/L. DISSOLVED CHLORIDE: 8.9 mg/L. DISSOLVED NITRATE: 3.0 mg/L. pH: 8.4.

CARD - 3: DISSOLVED FLUORIDE: F mg/L. DISSOLVED BORON: 0.22 mg/L. CALC. DIS. SOLIDS: 345 mg/L. DISSOLVED SOLIDS: 379 mg/L. SPECIFIC CONDUCTANCE: 609 micromhos/cm.

CARD - 3 (continued): DISSOLVED SILICA: SiO2 mg/L. OWNER: Willits Park Well. DETAILED LOCATION: Post Pump Test. DATE TO LAB: SEP 20 1986. DATE COMPLETED: FEB 16 1987. CHEMIST: Ted Meyers.



5 6 N.O.5.8.0.7

WATER ANALYSIS (MINOR ELEMENTS)

BASIN \_\_\_\_\_ STATE WELL NO. STATION NO. \_\_\_\_\_

NO. \_\_\_\_\_ MC. \_\_\_\_\_ DAY \_\_\_\_\_ TIME (GMT) \_\_\_\_\_

FIELD EC \_\_\_\_\_ FIELD PH \_\_\_\_\_ DO \_\_\_\_\_ DISCHARGE (CFS) \_\_\_\_\_ G.H. (FT.) \_\_\_\_\_

DEPTH (FT.) \_\_\_\_\_ SAMPLER \_\_\_\_\_ LK. CARD CODE \_\_\_\_\_

5.0.5.0

TYPE OF ANALYSIS: Total 11, 13, 15, 16, 17, 19, 20, 21, 23, 25 W.G. 1210-0671

ARSENIC ( $\frac{10}{100}$ ) 25 ml BARIUM \_\_\_\_\_ ml CADMIUM  $\frac{BLO.0}{100}$  ml CHROMIUM (all)  $\frac{BLO.0}{100}$  ml

A \_\_\_\_\_ C \_\_\_\_\_ A \_\_\_\_\_ C \_\_\_\_\_ A  $\frac{1.001(15.2.15.2) c}{250}$  1.0 A  $\frac{1.001(15.2.15.2) c}{250}$  1.0

Factor \_\_\_\_\_ Factor \_\_\_\_\_ Factor \_\_\_\_\_ Factor \_\_\_\_\_

A(sam) 23.4 → 43.7 A(sam) \_\_\_\_\_ A(sam)  $\frac{9.00 - 1.00}{25}$  0.4

$43.7 \times 0.25 \times 10 \rightarrow$   $\frac{As}{1000} \text{ mg/L}$  D/T  $\frac{Ba}{17} \text{ mg/L}$  D/T  $\frac{Cd}{25} \text{ mg/L}$  D/T  $\frac{Cr}{25} \text{ mg/L}$  D/T

0.1, 2.2 0.00 0.00 0.00

CHROMIUM (tr6) \_\_\_\_\_ ml COPPER  $\frac{BLO.0}{25}$  ml IRON  $\frac{BLO.0}{25}$  ml LEAD  $\frac{BLO.0}{25}$  ml

A \_\_\_\_\_ C \_\_\_\_\_ A  $\frac{2.5(15.2.15.2) c}{250}$  2.5 A  $\frac{2.5(15.2.15.2) c}{250}$  2.5 A  $\frac{2.5(15.2.15.2) c}{250}$  2.5

Factor \_\_\_\_\_ Factor \_\_\_\_\_ Factor \_\_\_\_\_ Factor \_\_\_\_\_

A(sam) \_\_\_\_\_ A(sam) 0.05 0.04 A(sam) 1.99 1.69 A(sam)  $\frac{-0.08 - 0.10}{25}$

$\frac{Cr}{41} \text{ mg/L}$  D/T  $\frac{Cu}{25} \text{ mg/L}$  D/T  $\frac{Fe}{25} \text{ mg/L}$  D/T  $\frac{Pb}{25} \text{ mg/L}$  D/T

0.00 0.00 1.1 0.00

MANGANESE  $\frac{BLO.0}{25}$  ml MERCURY NOV \_\_\_\_\_ ml SELENIUM 25 ml SILVER \_\_\_\_\_ ml

A  $\frac{2.5(15.2.15.2) c}{250}$  2.5 A  $\frac{BLO.0 \text{ std } 17.6 c}{250}$  0.001 A \_\_\_\_\_ C \_\_\_\_\_ A \_\_\_\_\_ C \_\_\_\_\_

Factor \_\_\_\_\_ Factor  $\frac{0.000568}{25}$  Factor NOV 19 1986 Factor \_\_\_\_\_

A(sam)  $\frac{2.165 - 2.17}{250} \times \frac{4}{12} \times \frac{57}{110} = 3.21$  A(sam) \_\_\_\_\_ A(sam) 0.0 → 0.0 A(sam) \_\_\_\_\_

$\frac{Mn}{9} \text{ mg/L}$  D/T  $\frac{Hg}{17} \text{ mg/L}$  D/T  $\frac{Se}{25} \text{ mg/L}$  D/T  $\frac{Ag}{33} \text{ mg/L}$  D/T

3.2 0.00 0.0 0.0

AX

OWNER \_\_\_\_\_ NAME \_\_\_\_\_ ADDRESS \_\_\_\_\_

CITY \_\_\_\_\_ ZIP CODE \_\_\_\_\_ COPY TO OWNER

DETAILED LOCATION Willits Park Well

Post Pump Test

POINT OF COLLECTION \_\_\_\_\_ PPG \_\_\_\_\_

REF. POINT \_\_\_\_\_ CI RESID. \_\_\_\_\_ COLOR \_\_\_\_\_

DEPTH TO WATER \_\_\_\_\_ FT. SECCHI \_\_\_\_\_ M ODOR \_\_\_\_\_

DEPTH OF WELL \_\_\_\_\_ FT. WIND \_\_\_\_\_ FOAM \_\_\_\_\_

USE \_\_\_\_\_ % CLOUD COVER \_\_\_\_\_

PERF. INTER. \_\_\_\_\_ ALGAE \_\_\_\_\_ TURBID. \_\_\_\_\_

REMARKS \_\_\_\_\_

SAMPLER \_\_\_\_\_ OF \_\_\_\_\_

ZINC  $\frac{BLO.0}{25}$  ml

A  $\frac{1.001(15.2.15.2) c}{250}$  1.0

Factor \_\_\_\_\_ Factor \_\_\_\_\_

A(sam)  $\frac{0.15 - 0.15}{25}$

$\frac{Zn}{25} \text{ mg/L}$  D/T

0.2

DATE TO LAB SEP 26 1986

DATE STARTED NOV \_\_\_\_\_

DATE COMPLETED NOV 1 \_\_\_\_\_

CHEMIST \_\_\_\_\_

CHECKED ML

