Illinois State Water Survey Division

GROUND-WATER SECTION

SWS Contract Report 480

DEWATERING WELL ASSESSMENT FOR THE HIGHWAY DRAINAGE SYSTEM AT FOUR SITES IN THE EAST ST. LOUIS AREA, ILLINOIS (PHASE 4)

by Steven D. Wilson, Ellis W. Sanderson, and Robert D. Olson

Prepared for the
Illinois Department of Transportation

Champaign, Illinois
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Illinois Department of Energy and Natural Resources

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ABSTRACT

In the East St. Louis vicinity, the Illinois Department of Transportation (IDOT) owns 48 wells that are used to maintain the elevation of the ground-water table below the highway surface in areas where the highway is depressed below the original land surface. The dewatering systems are located at four sites in the alluvial valley of the Mississippi River in an area known as the American Bottoms. At the dewatering sites the alluvial deposits are about 90-115 feet thick and consist of fine sand, silt, and clay in the upper 10-30 feet underlain by medium to coarse sand about 70-100 feet thick.

The condition and efficiency of a number of the dewatering wells became suspect in 1982 on the basis of data collected and reviewed by IDOT staff. Since 1983 a cooperative investigation has been conducted by IDOT and the State Water Survey to more adequately assess the condition of selected individual wells, and to begin an attempt to understand the probable causes of well deterioration. Phase 4 work has established the condition of 12 dewatering wells.

During Phase 1, 14 wells were field-tested by conducting step tests to determine the response of the wells at various rates of pumping. Most of the tested wells were in relatively good condition. Based upon the analysis of the step-test data, four wells were recommended for treatment and one well for replacement. During Phase 2, 12 additional wells were field-tested with step tests. Most of these wells were in relatively good condition. Based upon well losses of 10 to 29 percent of total drawdown, specific capacities of 33 to 44 gallons per minute per foot (gpm/ft) of drawdown, and head differences between the wells and their adjacent piezometers of 10 to 13 feet, four wells were recommended for treatment.

During Phase 3, six wells were step tested. These wells were in good condition, averaging 104.7 gpm/ft, except for 25th Street Well No. 10, which had a specific capacity of 62.8 gpm/ft. The lone I-70 well tested, I-70 Well No. 6, had a specific capacity of 111.1 gpm/ft. Based on drawdown of 9.6 ft at 600 gpm and a specific capacity of 62.87 gpm/ft, 25th Street Well No. 10 was recommended for treatment.

For Phase 4, ten step tests were performed on nine wells. The ten tests showed an average specific capacity of 94.4 gpm/ft. We recommend treatment of I-70 Well No. 12 at this time, based on a specific capacity of 45.1 gpm/ft. I-64 Well No. 3, Venice Well No. 6, and 25th Street Well No. 10 were previously recommended for treatment on the basis of previous step tests and IDOT measurements.

Well rehabilitation was completed on five wells during Phase 4. The average increase in specific capacity was 55%. The treatment results were encouraging.

The construction of I-70 Well No. 14 (7a) was completed with two sizes of gravel pack. Six new piezometers were drilled at the new 9th Street and 42nd Street locations. An inspection of I-70 Well No. 9 revealed that the sand being pumped from the well is coming from the upper 12 to 15 feet of screen. This problem may be linked to the strong horizontal flow gradient caused by the intake at this location. A series of specific capacity tests using the Polysonics Flowmeter were also completed during Phase 4. This is a simple and reliable way to measure discharge, providing that the actual inside pipe diameter is known.

INTRODUCTION

Background

The Illinois Department of Transportation (IDOT) operates 48 high-capacity water wells at four sites in the East St. Louis area. The wells are used to control and maintain ground-water levels at acceptable elevations to prevent depressed sections of interstate and state highways from becoming inundated by ground water. When the interchange of I-70/55 and I-64 was originally designed, ground-water levels were at lower elevations because of large withdrawals of the area's industry. Due to a combination of water conservation, production cutbacks, and conversion from ground water to river water as a source, ground-water withdrawals by industry have decreased about 50% since 1970, and as a result, ground-water levels in many areas have recovered to early development levels. This exacerbates IDOT's need to dewater the areas of depressed highways.

Scope of Study

The Illinois Department of Transportation first installed 12 dewatering wells in 1973, followed by an additional 30 in 1975. By 1977, the initial 12 wells were showing signs of loss of capacity. As a result, all 42 wells in use at that time were chemically treated to restore capacity. Although good results were obtained on most of the wells, routine monitoring by IDOT showed that deterioration problems were continuing to develop. Chemical treatment of isolated wells was made by IDOT personnel as required. In 1982, six more wells were installed. In October 1982, IDOT asked the Illinois State Water Survey (ISWS) to begin an investigative study of the dewatering wells to learn more about their condition, to determine efficient monitoring and operating procedures, and to determine suitable methods of rehabilitation. The first phase of the work, begun in 1983, included an assessment of the condition of 14 selected wells, a review of IDOT's monitoring program, a model study to outline efficient operating schemes, recommendations on wells to be treated, and recommendations for chemical treatment procedures. The second phase of the work, begun in 1984, included an assessment of the condition of 12 selected wells; testing of a non-invasive, portable flowmeter; and an initial study of the chemistry of the ground water as it moves toward an operating well.

Phase 3, begun in 1985, included an assessment of the condition of six wells; a continued study of the water chemistry; and documentation of the rehabilitation of four dewatering wells.

Phase 4 included ten step tests; documentation of the treatment of five wells; documentation of the construction of I-70 Well No. 14 (7a); investigation of the sand pumpage and buildup problem at I-70 Well No. 9; specific capacity testing using the portable, non-intrusive flowmeter; and installation of piezometers at two sites in East St. Louis.

Future work will measure the effectiveness of rehabilitation by chemical treatment, continue the investigation into the potential causes of well deterioration, and assess the condition of additional wells.

Physical Setting of Study Area

The study area is located in the alluvial valley of the Mississippi River in East St. Louis, Illinois, in an area known as the American Bottoms (see figure 1). The geology of the area consists of alluvial deposits overlying limestone and dolomite of the Mississippian and Pennsylvanian Ages. The alluvium varies in thickness from zero to more than 170 feet, averaging about 120 feet. The region is bounded on the west by the Mississippi River and on the east by upland bluffs. The regional ground-water hydrology of the area is well documented (Bergstrom and Walker, 1956; Schicht, 1965; Collins and Richards, 1986; Ritchey et al., 1984; Kohlhase, 1987). Ground water generally flows from the bluffs toward the river, except where diverted by pumpage or drainage systems.

Detailed locations of the four dewatering sites operated by IDOT are shown in figures 2 and 3. The geology at these sites is consistent with regionally mapped conditions. The land surface lies at about 410-415 feet above mean sea level (ft msl). The alluvial deposits are about 90-115 ft thick, meaning the bedrock surface lies at approximately 300-320 ft msl. The alluvium becomes progressively-coarser with depth. The uppermost 10 to 30 feet consists of extremely fine sand, silt, and clay, underlain by the aquifer, which is about 70-100 feet thick. The elevation of the top of the aquifer is about 390-395 ft msl.

Acknowledgments

This phase of the assessment of the condition of the highway dewatering well systems in the American Bottoms was funded by the Illinois Department of Transportation, John D. Kramer, Secretary. Special thanks are due Frank Opfer, Hydraulic Engineer, and Vic Modeer, Geotechnical Engineer, District 8, who reviewed and coordinated the investigation. The Maintenance Division Pump Crew under the supervision of Stan Gregowicz provided field support during the conduct of step-drawdown tests on the selected wells. State Water Survey Ground-Water Section staff who ably assisted the authors with field data and water sample collection included

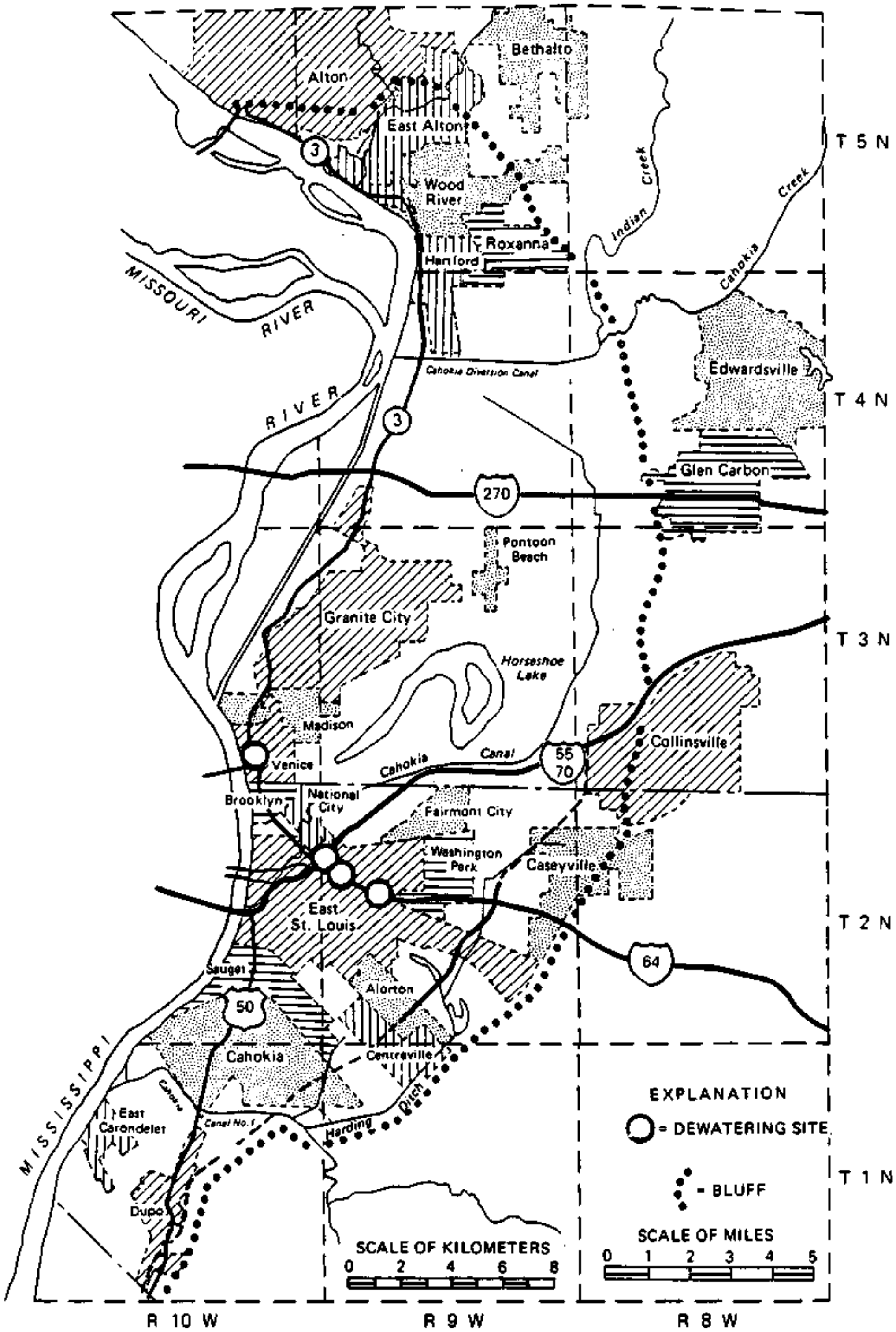


Figure 1. Location of the East St. Louis area

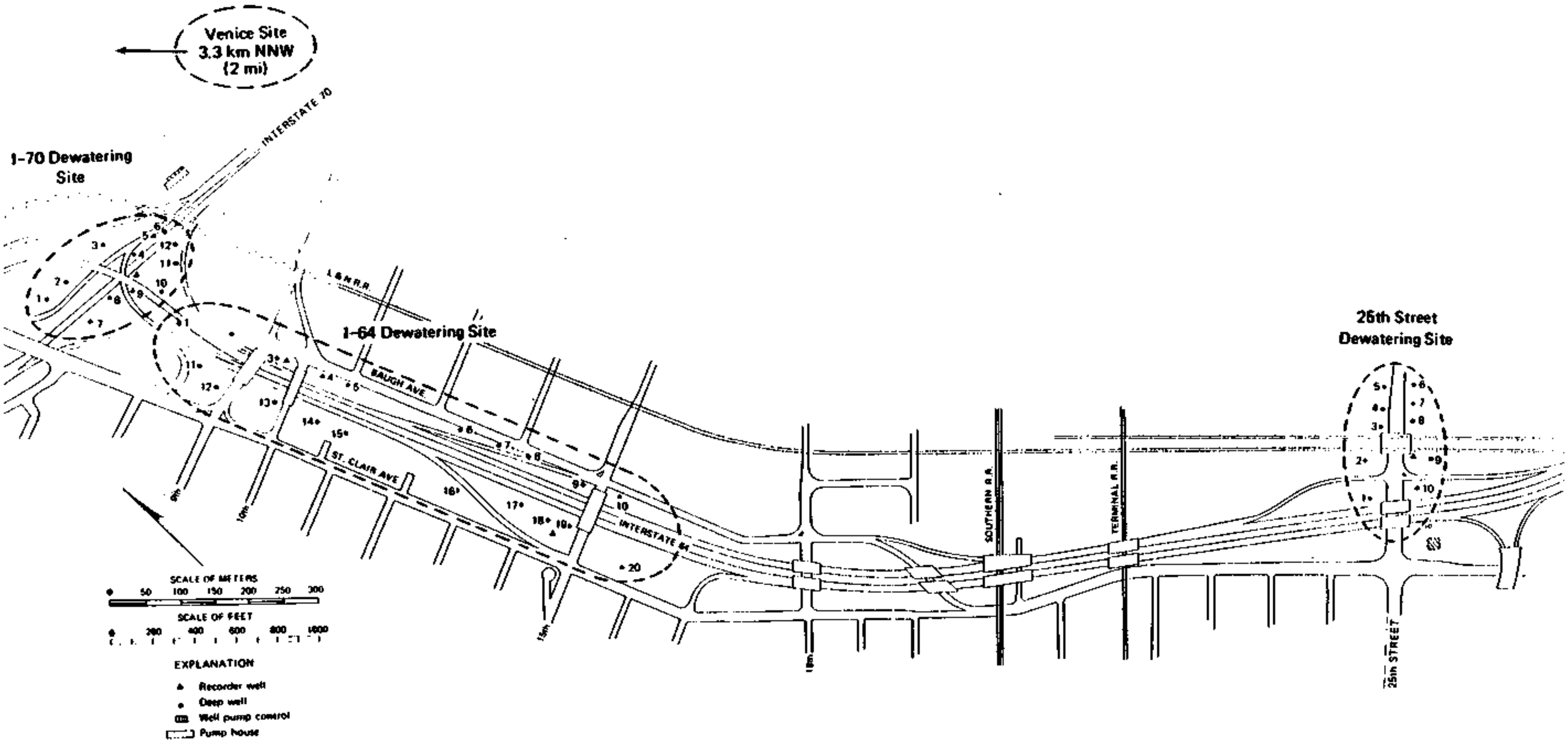


Figure 2. Locations of dewatering wells at the I-70 Tri-Level Bridge, I-64, and 25th Street

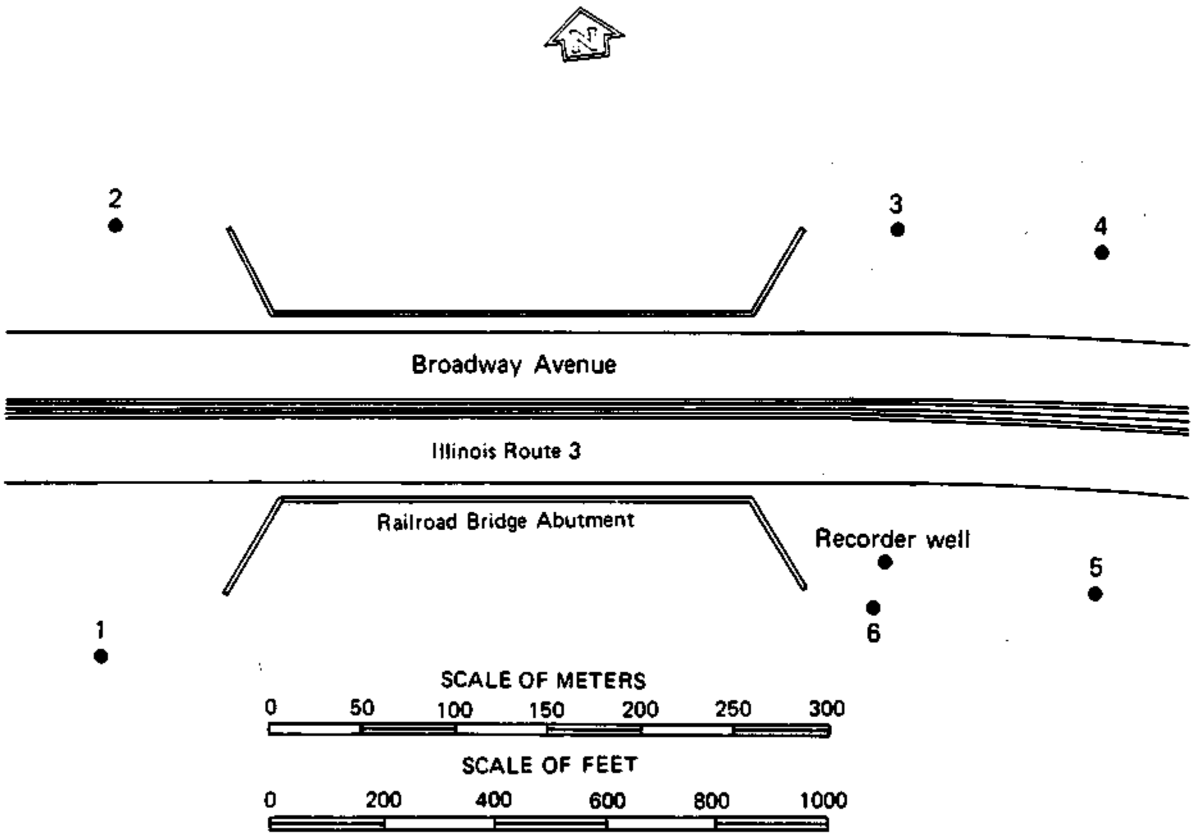


Figure 3. Locations of dewatering wells at the Venice Subway (Illinois Route 3)

Robert Kohlhase, Adrian Visocky, Jeff Stollhans, Doug Kelly, Bridget Cartwright, John Nealon, Rachael Hammen, Brian Kaiser, and Kenni James.

Manuscript editing was done by Gail Taylor, and the illustrations were prepared by John Brother, Jr., and Linda Riggin. The manuscript was typed by Pamela Lovett, Ground-Water Section secretary.

HISTORICAL SUMMARY OF DEWATERING DEVELOPMENT

The eastbound lanes of Interstate 70 (I-70) below the Tri-Level Bridge between St. Clair and Bowman Avenues in East St. Louis dip down to elevation 383.5, or approximately 32 feet below natural ground surface. At the time of highway design in 1958, the ground-water levels were near an elevation of 390, or about 6.5 feet above the planned highway (McClelland Engineers, Inc., 1971)..

Horizontal Drain System

A horizontal French drain system was designed for controlling the ground-water levels along an 800-foot reach of depressed highway. For highway construction, the excavation area was dewatered by pumping from seven wells 100 feet deep and 16 inches in diameter. The wells were equipped with 1800-gallons-per-minute (gpm) turbine pumps. The construction dewatering system was designed to maintain the ground-water level at the site near elevation 370.

The French drain system failed shortly after the construction dewatering system was turned off in the fall of 1962. The failure was attributed to the fact that the filter sand around the perforated diagonal drains and collector pipes was too fine for the 1/4-inch holes in the drain pipes. A sieve analysis on the filter sand showed that 98.5% of the filter sand was finer than the 1/4-inch perforations in the drain pipes. As a result, when the construction dewatering system was turned off and ground-water levels rose above the drains, filter sand migrated through the holes into the drain pipes. After the filter sand migrated into the drain, the very fine "sugar" sand used as the pavement foundation was free to move downward to the drains, resulting in development of potholes above the drains. Further migration of sand into the French drainage system was halted by operating the construction dewatering system to lower the ground-water table. Since it was very likely that the foundation sands had piped from beneath the pavement, the diagonal drains beneath the pavement were cement-grouted to prevent any further loss of support beneath the pavement (McClelland Engineers, Inc., 1971).

Horizontal and Vertical Well Drainage System

A new drainage system was designed and installed in early 1963. It consisted of 20 vertical wells and 10-inch- to 12-inch-diameter horizontal drain pipes. The 20 wells (10 wells on each side of the highway) were spaced about 75 feet apart. They were 6 inches in diameter, about 50 feet deep, and equipped with 32 feet of stainless steel well screen (Doerr) with 0.010-inch slots. The horizontal drains were sized for a flow of about 1 gpm per foot of drain, were perforated with 3/8-inch-diameter holes on 3-inch centers, and were surrounded with 6 inches of gravel and sand filter. A total of six 2-inch-diameter piezometers were installed for ground-water level measurements.

Tests immediately after the installation indicated that the new system was performing satisfactorily with a discharge of about 1200 to 2000 gpm compared to a computed design flow of 4500 gpm. Ground-water levels were lowered to elevation 375.5±, about 2 feet below the design ground-water elevation of 377.5, or about 8 feet below the top of the concrete pavement.

The system performed efficiently until March 1965, when a gradual rise in ground-water levels was detected. By July 1967 a rise of 1 foot had occurred, and from July 1967 to April 1969 an additional 4-foot rise was observed. No additional rise was observed between August 1969 and August 1970.

Visual inspection during the late 1960s revealed some sinking of the asphalt shoulders and areas around the storm drainage inlets. Several breaks and/or blockages of the horizontal transit drain pipes were noted on both sides of the pavement, and a break in the steel tee in Well No. 17 was also observed. Depressions in the earth slopes immediately adjacent to the curb and gutter section were noticed. Loss of foundation sands through the transit pipe breaks appeared to be the cause of these depressions. One manhole had settled a total of 15 inches. The attempt to correct this condition was suspended with the detection of a shift in the bottom of this manhole.

A thorough field investigation was begun to correct the damages to the underground system or to replace it if necessary. During the cleaning process of the collector pipes (using a hydrojet at the rate of 100 gpm under a pressure of about 800 pounds per square inch), a significant amount of scale was removed from inside the mild steel pipes, indicating serious corrosion. Nearly all the transit drain pipes also showed signs of stress. Some drains were broken and filled with sand. Attempts to clean or restore the drain pipes were abandoned in favor of a complete replacement of the system.

The field investigation also showed that the tees in the manholes, the collector pipes, and the aluminum rods on the check valves were badly corroded. Sinks, potholes, and general settlement of the shoulders indicated a distressed condition requiring immediate attention. Television inspection of the vertical wells showed no damage to the stainless steel well screens.

Excessive corrosion of the mild steel tees, well risers, and collector pipes was one of the major causes or contributors to the overall failure of the drainage system. The investigations concluded that the corrosion was caused primarily by galvanic action between the stainless steel (cathode) and mild steel (anode) components of the drainage system, with anaerobic bacteria and carbonic acid attack from the carbon dioxide

(CO_2) dissolved in the well water. Galvanic action was magnified by the lack of oxygen and the high chloride content. A chemical analysis showed the extremely corrosive quality of the ground water as evidenced by:

- Extremely high concentration of dissolved carbon dioxide, 160 to 240 parts per million (ppm)
- Complete lack of oxygen, 0 ppm
- High chloride, 54 to 128 ppm; sulfates, 294 to 515 ppm; and iron concentration, 12 ppm
- Biological activity

The field investigators recommended that 304 stainless steel pipes should be used throughout any replacement system to withstand the possibility of severe corrosion caused by the chemical contents of ground water and to prevent galvanic action between different metals (McClelland Engineers, Inc., 1971).

Individual Deep Well Systems

Experience during highway construction in 1961-1962 and during the 1963 drainage system replacement showed that individual deep wells were effective in temporarily maintaining ground-water levels at desired elevations. This alternative as a permanent system, therefore, was given further study. A 1972 consultant's report (Layne-Western Company, Inc., 1972) showed that water levels at the I-70 Tri-Level Bridge site could be maintained at desired elevations with ten deep wells equipped with 600-gpm pumps. An additional two wells were included to permit well rotation and maintenance. These 12 wells were constructed in 1973 and the new system placed in service in April 1974. The wells are 16-inch gravel-packed (42-inch borehole) wells averaging about 96 feet deep and are equipped with 60 feet of Layne stainless steel well screen. The pumps are 600-gpm capacity with 6-inch-diameter stainless steel (flanged coupling) column pipe.

A recorder well was included in the well dewatering system to monitor ground-water levels near the critical elevation of the highway. The well is 8 inches in diameter and is constructed of stainless steel casing and screen. A Leupold-Stevens Type F recorder is in use. Additionally, 2-inch-diameter piezometers with 3-foot-long screens were placed about 5 feet from each dewatering well to depths corresponding to the upper third point of each dewatering well screen. The purpose of these piezometers is to provide information on ground-water levels and to monitor the performance of individual wells by measuring water-level differences between the wells and the piezometers.

The western terminal of Interstate 64 joins Interstate 70 at the Tri-Level Bridge site. A 2200-foot stretch of this highway also is depressed below original land surface as it approaches the Tri-Level Bridge site. To maintain ground-water levels along I-64, a series of 20 wells was added to the dewatering system. The wells were built in 1975 and are essentially identical to those constructed for the Tri-Level Bridge site.

About 6,200 feet southeast of the Tri-Level Bridge, at the East St. Louis 25th Street interchange with I-64, the street was designed to pass below the highway and adjacent railroad tracks. As a result, the 25th Street pavement would be about 3.5 feet below ground-water levels. Ten wells were installed at this site to control ground-water levels. These wells also are identical in design to the I-70 wells. The pumps installed in the wells along I-64 and at 25th Street have nominal pumping capacities of 600 gpm. Two 8-inch observation wells, located near each end of the I-64 depressed section, are used to monitor ground-water levels. An 8-inch observation well also is installed near the critical location at the 25th Street underpass. As at the I-70 wells, each dewatering well for I-64 and 25th Street has a piezometer located approximately 5 feet away for monitoring the performance of each individual installation.

Approximately 2¼ miles north of the I-70 Tri-Level Bridge, Illinois Highway 3 passes beneath the N and W, ICG, and Conrail railroad tracks. When the highway was constructed, ground-water levels were controlled with a horizontal drain system placed 3 feet below the pavement. Problems with the pavement and drainage system were noted in May 1979 and were attributed to the above-normal ground-water levels resulting from three to four months of continuous flood stage in the Mississippi River (about 2,000 feet west). Subsequent investigation showed deterioration of the drainage system, and the consultants recommended installation of six wells to control ground-water levels at the site (Johnson, Depp, and Quisenberry, 1980). The wells were installed in 1982 and are 16 inches in diameter with 50 feet of well screen. They range in depth from 78 to 89 feet below grade and are equipped with submersible turbine pumps with nominal capacities of 600 gpm. One recorder well for the site and piezometers at each dewatering well were constructed to monitor system performance.

Thus at present the highway dewatering operation in the American Bottoms consists of 48 individual dewatering wells fully penetrating the water-bearing sand and gravel aquifer. The wells are distributed at four sites as follows:

I-70 (Tri-Level Bridge)	- 12 wells
I-64	- 20 wells
25th Street	- 10 wells
Venice (Route 3)	- 6 wells

The wells are of similar construction, with 16-inch-diameter stainless steel casing and screen, and 6-inch-diameter stainless steel column pipe (figure 4). Each well is equipped with a 600-gpm submersible pump with bronze impellers, bowls, and jacket motors. The early experience with severe corrosion problems showed that corrosion-resistant materials are required to maximize service life. A total of five 8-inch recorder wells are available to monitor ground-water elevations near critical locations at the four sites. Each of the 48 wells has a 2-inch-diameter piezometer for monitoring individual well performance.

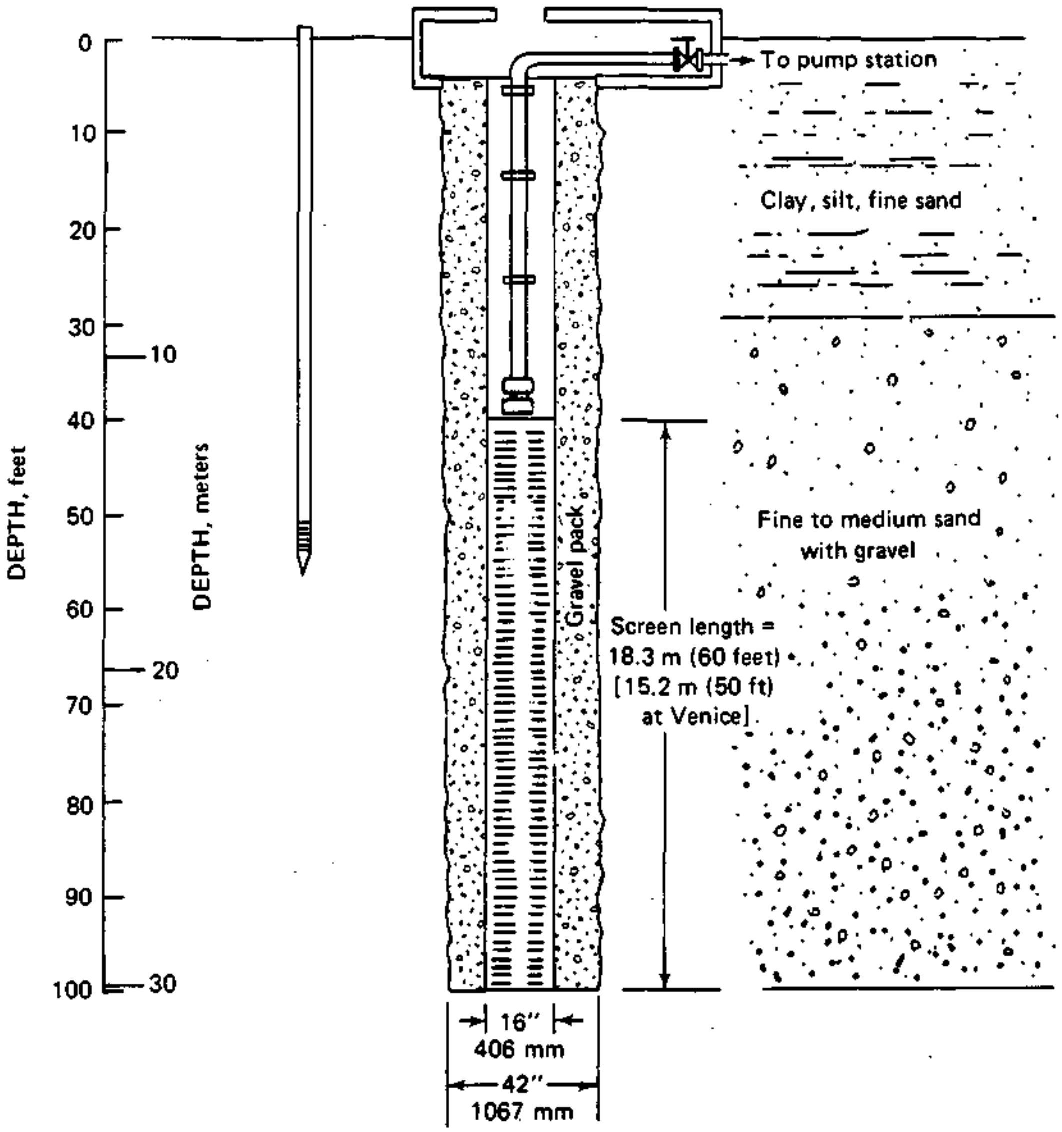


Figure 4. Typical features of a dewatering well

Usually, about one-third of the wells are in operation simultaneously. Total pumpage was estimated to be about 10.8 million gallons per day in 1986.

DEWATERING SYSTEM MONITORING

When originally constructed, the well installations at I-70, I-64, and 25th Street included flow-rate meters of the pitot-tube type. Reportedly, a combination of corrosion and chemical deposition caused premature failure of these devices. Flow rates are now occasionally checked with a temporarily inserted pitot-tube meter, but erratic results are reported by the field crew. The six new installations at Venice include a venturi tube coupled to a bellows-type differential pressure indicator to measure the flow rate. Flow measurements from the venturi tube are reported to be accurate to. within ±1% of full pipe flow rate, and the differential pressure indicators to within ±0.75% of the deflection. The bronze-lined venturi tubes will probably remain unaffected over time by the quality of water pumped from these wells; however, the water comes in direct contact with the bellows in the differential pressure indicators via two ¼-inch water lines from the venturi tubes. The same corrosion and chemical deposition affecting the pitot tubes could, over time, cause obstructions in the water lines and/or water chambers or direct failure of the bellows.

Operational records show that wells are pumped for periods of about two to nine months and then left off for longer periods while another set of wells is operated. No standard sequence of pumping rotation is followed because of maintenance and rehabilitation requirements. Bar charts showing the periods of operation are prepared by IDOT for monitoring the accumulated hours of operation. Annual withdrawals currently are calculated on the basis of pumping time and estimated or measured pumping rates.

Water levels in the piezometer adjacent to each dewatering well are measured every two to four months. The pumping water level in each operating well also is measured. These water-level data are reviewed by IDOT supervisors to monitor ground-water levels in relation to the pavement elevation and to assess the condition of individual dewatering wells. Water-level differences of 3 to 5 feet between the pumping wells and the adjacent piezometers usually are considered normal by IDOT. Greater differences are interpreted to indicate that well deterioration is occurring. Piezometer water levels also are superposed on drawings of longitudinal sections of the highway for visual comparison. This technique suggests probable errors in field measurements or a plugged piezometer when the water-level elevation for a given piezometer is not consistent with water levels in adjacent piezometers.

Finally, each dewatering well site includes an observation well equipped with a Leupold-Stevens water-level recorder. The recorder charts are changed monthly and are intended to provide a continuous record of water levels near the critical location at each dewatering site.

INVESTIGATIVE METHODS AND PROCEDURES

Well Loss

When a well is pumped, water is removed from the aquifer surrounding the well, and the water levels are lowered. The distance that the water level is lowered, whether within the well or in the surrounding aquifer, is referred to as drawdown, which under ideal conditions is a function of pumping rate, time, and the aquifer's hydraulic properties. However, other geohydrologic and hydraulic factors also can affect the observed drawdown, especially within the pumped well. Aquifer boundaries, changes in aquifer thickness or hydraulic properties, interference from nearby wells, partial-penetration conditions, and well losses all can affect observed drawdowns. Well losses usually are associated only with the pumped well and are the only non-ideal condition addressed in this report.

The observed drawdown in a pumped well is usually greater than that in the aquifer formation outside the borehole because of the well losses caused by the water moving from the fully penetrated aquifer into the well. The amount of well loss depends on the materials used and the job done in constructing the well. A limited amount of well loss is to be expected as natural because of the physical blocking of the aquifer interstices caused by the well screen and the disturbance of aquifer material around the borehole during construction. However, an improperly designed well and/or ineffective well construction and development techniques can result in unacceptable well losses. In addition, well losses often reflect a deterioration in the condition of an existing well, especially if they are observed to increase with time.

Well losses are related to pumping rate and ideally are not a function of time. These losses are associated with changes in flow velocity in the immediate vicinity of the well, resistance to flow through the well screen, and changes in flow path and velocity inside the well. In some cases, well loss occurs entirely under conditions of laminar flow; however, velocities may become sufficiently large that a change from laminar to turbulent flow occurs. Under these conditions the well-loss component of drawdown can rapidly become excessive, increasing in a nonlinear manner with increases in pumping rate.

Thus, under near-ideal conditions, the observed drawdown (s_0) in a pumping well is made up of two components: the formation loss (s_a), resulting from laminar (and sometimes turbulent) flow head loss within the aquifer, and well loss (s_w) resulting from the turbulent (and sometimes laminar) flow of water into and inside the well, as shown in equation 1.

$$s_o = s_a + s_w \qquad (1)$$

Jacob (1947) devised a technique for separating the well losses from the formation losses, assuming that all formation losses are laminar and all well losses are turbulent. These components are then expressed as being proportional to pumping rate (Q) in the following manner:

$$s = BQ + CQ^2 \qquad (2)$$

where s is the drawdown, B is the formation loss coefficient at the well-aquifer interface per unit discharge, and C is the well loss coefficient. Rorabaugh (1953) suggested that the well loss component be expressed as CQ^n, where n is a constant greater than 1. He thus expressed the drawdown (s) as

$$s = BQ + CQ^n \tag{3}$$

To evaluate the well loss component of the total drawdown, one must know the well loss coefficient (if using equation 2) or both the coefficient and the exponent (if using equation 3). This analysis requires a controlled pumping test, called a step drawdown test, in which total drawdown is systematically measured while pumping rates are varied in a stepwise manner.

Methodology for Determining Well Loss

If Jacob's equation is used to express drawdown, then the coefficients B and C must be determined. A graphical procedure can be employed after first modifying equation 2 as

$$s/Q = B + CQ$$

After this modification, a plot of s_0/Q versus Q can be prepared on arithmetic graph paper from data collected during a step drawdown test, with the observed drawdown, s_o, substituted for s. The slope of a line fitted to these data is equal to C, while the y-intercept is equal to B, as shown in figure 5. If the data do not fall on a straight line but, instead, curve concavely upward, then Rorabaugh's method usually is suggested. The curvature of the plotted data indicates that the 2nd order relationship between Q and s_0 is not valid.

If Rorabaugh's equation is used, then the coefficients B and C as well as the exponent n must be determined. To facilitate a graphical procedure, equation 3 is rearranged as

$$(s/Q) - B = CQ^{n-1} \tag{5}$$

Taking logs of both sides of the equation leads to

$$\log [(s/Q) - B] = \log C + (n - 1) \log Q \tag{6}$$

A plot of (s_o/Q) - B versus Q can be made on logarithmic graph paper from step test data, again using s_0 for s. Values of B are tested until the data fall on a straight line (figure 6). The slope of the line equals n - 1, from which n can be found. The value of C is determined from the y-intercept at Q - 1. In the example shown, the graphical procedure is facilitated if Q is plotted as cubic feet per second and (s_0/Q) - B is plotted as seconds per foot squared. It is also convenient (although not mandatory) to use these same units in the Jacob method.

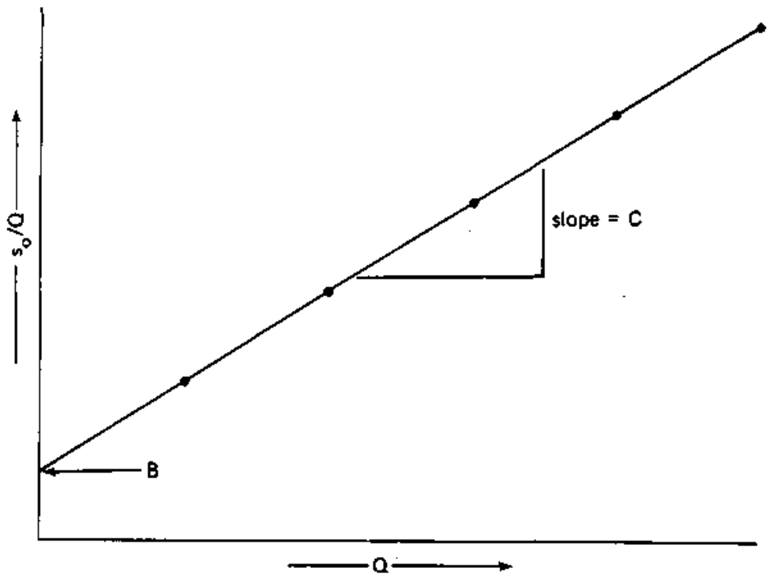


Figure 5. Graphical solution of Jacob's equation for well loss coefficient, C

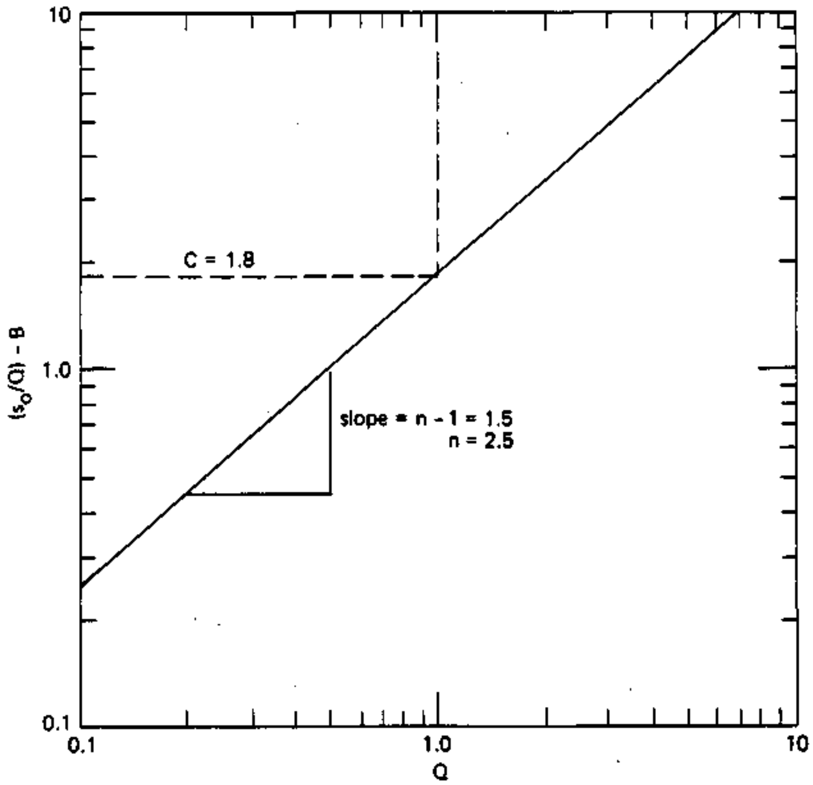


Figure 6. Graphical solution of Rorabaugh's equation for well loss coefficient (C) and exponent (n)

Step Test Procedure

The primary objective of a step drawdown test (or step test) is determination of the well loss coefficient (and exponent, if Rorabaugh's method is used). With this information, the turbulent well loss portion of drawdown for any pumping rate of interest can be estimated. During the test, the well is pumped successively at a number of selected pumping rates. Equally spaced pumping rates are selected to facilitate the data analysis. Each pumping period at a given rate is called a step, and all steps are of equal time duration. Generally, the pumping rates increase from step to step, but the test also can be conducted by decreasing pumping rates.

During each step pumpage is held constant. Water-level measurements are made every minute for the first six minutes, every two minutes for the next ten minutes, and then every four to five minutes thereafter until the end of the step. Recently, experiments with computerized data collection have been attempted. The ISWS developed the Micro-computer Data Acquisition System (McDAS) for purposes such as step tests. It reads the data logarithmically, starting with several readings a second at the start of the step to readings every two to three minutes at the end of each step. In this investigation, water levels were measured for 30 minutes per step. At the end of each 30-minute interval, the pumping rate was immediately changed, the water-level measurements reverted to the one-minute frequency again (or with McDAS, back to several per second), and so on until a wide range of pumping rates within the capacity of the pump was tested.

Schematically, the relationship between time and water level resembles that shown for a five-step test in figure 7. Drawdowns for each step (shown as Δs_i are measured as the distance between the extrapolated water levels from the previous step and the final water level of the current step. For step 1, the nonpumping water-level trend prior to the start of the test is extrapolated, and Δs_1 is measured from this datum. All data extrapolations should be performed on semilog graph paper for the most accurate results. For the purpose of plotting s_0/Q versus Q or $(s_0/Q) - B$ versus Q, values of observed drawdown s_0 are equal to the sum of ΔS_i for the step of interest. Thus, for step 3, $s_0 - \Delta s_1 + \Delta s_2 + \Delta s_3$.

Piezometers

Piezometers--small-diameter wells with a short length of screen--are used to measure water levels at a point in space within an aquifer and are often used in clustered sets to measure variations in water levels (head) with depth. In the case of well loss studies, piezometers can be employed to measure head losses across a well screen or across a gravel pack or well bore.

All 48 of the IDOT dewatering wells have piezometers drilled approximately 5 feet from the center line of each well and finished at a depth corresponding to approximately the upper third point of the screen in the pumping well. An indication of well losses in a pumped well can be found in such an arrangement by comparing the difference in head between

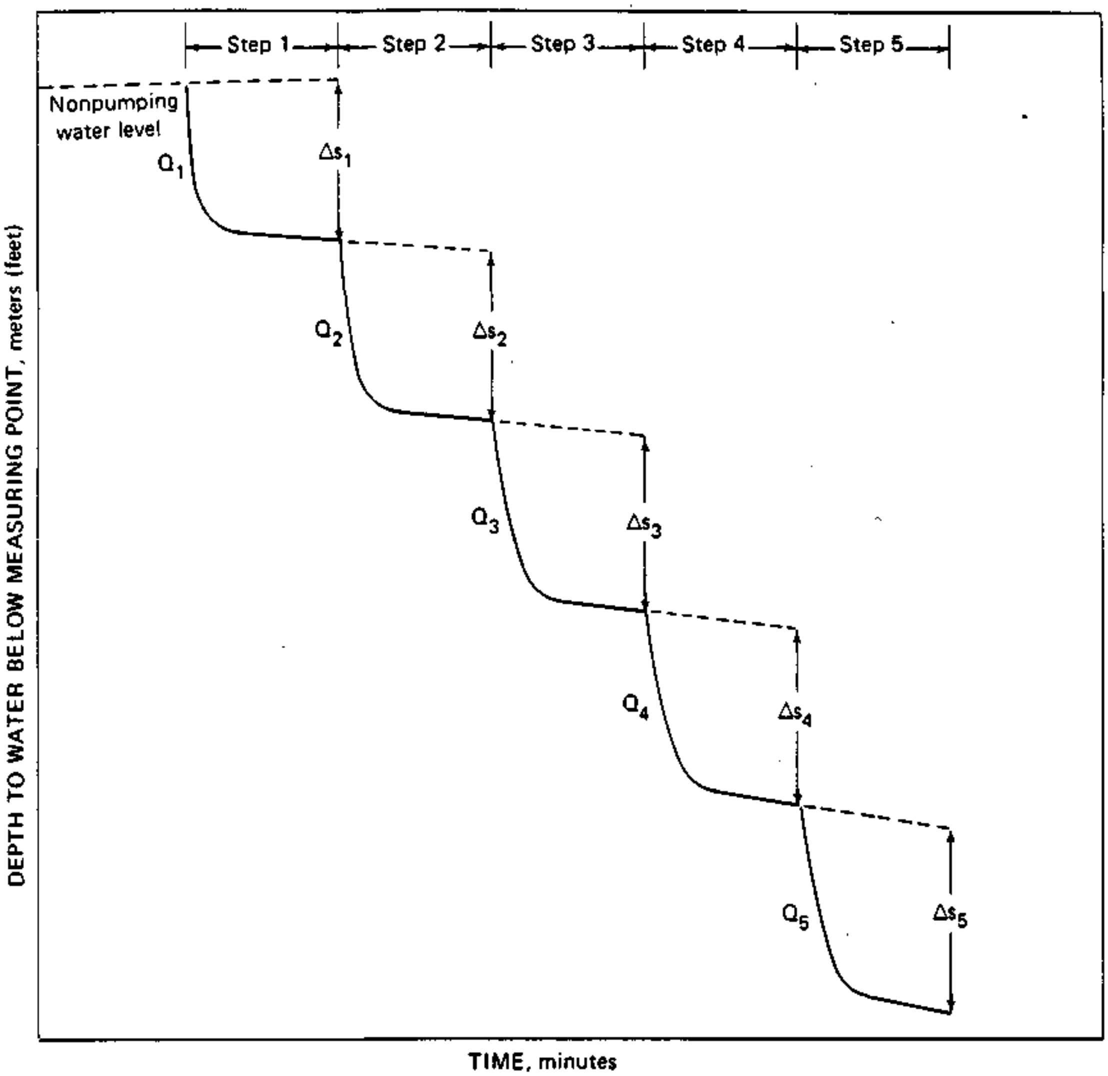


Figure 7. Relationship between time and water level during a five-step drawdown test

water levels in the well and those in the adjacent piezometer over a sufficiently large range of pumping rates. If turbulent losses exist within that range, the difference in heads should be nonlinear with increasing pumping rate. It can also sometimes be useful to simply plot depth to water (or drawdown) in the piezometer versus pumping rate. If turbulence extends outward from the well to the piezometer, then this relationship will also be nonlinear. Additionally, the piezometers can be used as mechanisms to continually monitor head differences between the wells and the piezometers to detect deterioration at any well. This has been IDOT's primary use of data from the piezometers.

FIELD RESULTS

Well Selection

Nine wells were selected for ten step tests in Phase 4. Four of the wells were chosen on the basis of water-level (Ah) data provided by IDOT, which suggested that these wells might have significant deterioration. The other five wells were selected for rehabilitation using chemical treatment and were tested in post-treatment step tests afterward. One of these wells (I-70 Well No. 3) was also given a pre-treatment step test because it had not been tested since 1983.

The four wells chosen because of possible well deterioration were:

I-70	No. 12	
	No. 14	(7a)
I-64	No. 1	
25th St.	No. 9	

The five wells treated and then tested in post-treatment step tests were:

I-70	No. 3	(Also given a pre-treatment step test)
	No. 4	
	No. 5	
25th St.	No. 6	
Venice	No. 3	

Field Testing Procedure

Field work was conducted by Water Survey staff with the assistance of the IDOT Maintenance Division pump crew under the supervision of Stan Gregowicz. The IDOT pump crew made all necessary pipe modifications and provided special piping adapters. This allowed the water from the pumped wells to be discharged through a flexible hose and orifice tube provided by the Water Survey. Discharge from the orifice tube was directed to nearby stormwater drains.

Orifice tubes are considered standard equipment for measuring flow rates. The orifice plate used to measure the range of flow rates was calibrated at the University of Illinois Hydraulics Lab under discharge conditions similar to those expected in the field. The rating curve developed from the calibration procedure is shown in figure 8.

Prior to the start of each test, the nonpumping water levels in the well and piezometer were measured with a steel tape. Standard electric droplines, or pressure transducers coupled to a field computer for analog to digital conversion and data storage (McDAS), were used to determine depths to water during step tests.

The objective of each step test on the selected wells was to control the flow rate at increments of 50 gpm and to include as many steps as possible at 300 gpm or greater for each well. In addition, since routine monitoring by IDOT personnel is based upon the difference in water levels between the operating well and the piezometer, water-level declines (drawdowns) during the step tests were observed in both the pumped well and the piezometer. This routine provided data for comparison with the historical monitoring data available from IDOT.

Three wells (I-70 Wells 3 and 12, and 25th Street Well No. 9) were tested in June and July 1986. Two wells (I-70 Well No. 14 (7a) and I-64 Well No. 1) were tested in July 1987. A step test of I-64 Well No. 1 was attempted the previous summer, but pump problems delayed the test; and I-70 Well No. 14 (7a) was not constructed until November 1986.

The treatment of I-70 Wells 3, 4, and 5; 25th Street Well No. 6; and Venice Well No. 3 was completed late in the fall of 1986, and these five wells were then step-tested in January 1987.

The data for the ten step tests are included in Appendix A. Water samples were collected at the time of each test and analyzed for chemical/mineral content. The chemical analyses are presented in Appendix B.

Results of Step Tests

The step test data were analyzed by using the Jacob method. This procedure breaks down the head losses into two components, the losses from the formation and the losses from the well. The procedure is outlined in detail in *Groundwater and Wells* (Driscoll, 1986), pp. 555-558. To illustrate its use, the analysis of I-70 Well No. 3, tested on January 14, 1987, follows.

The test began at 10:40 a.m. at a rate of 600 gpm. Thirty-minute steps were run, with the rate decreased by 50 gpm at each step. Seven steps were completed, ending at 2:10 p.m. with a pumping rate of 300 gpm.

The actual field data are given in table 1. Figure 9 is a plot of those data as s_0/Q versus Q. Q is the flow rate in cubic feet per second, and s_0 is the observed drawdown in feet. As mentioned earlier, the Jacob method separates the well loss and the formation loss. A best-fit line is drawn through the graph (figure 9). The slope is the coefficient for well loss, C, and the y-intercept is the coefficient for formation loss, B.

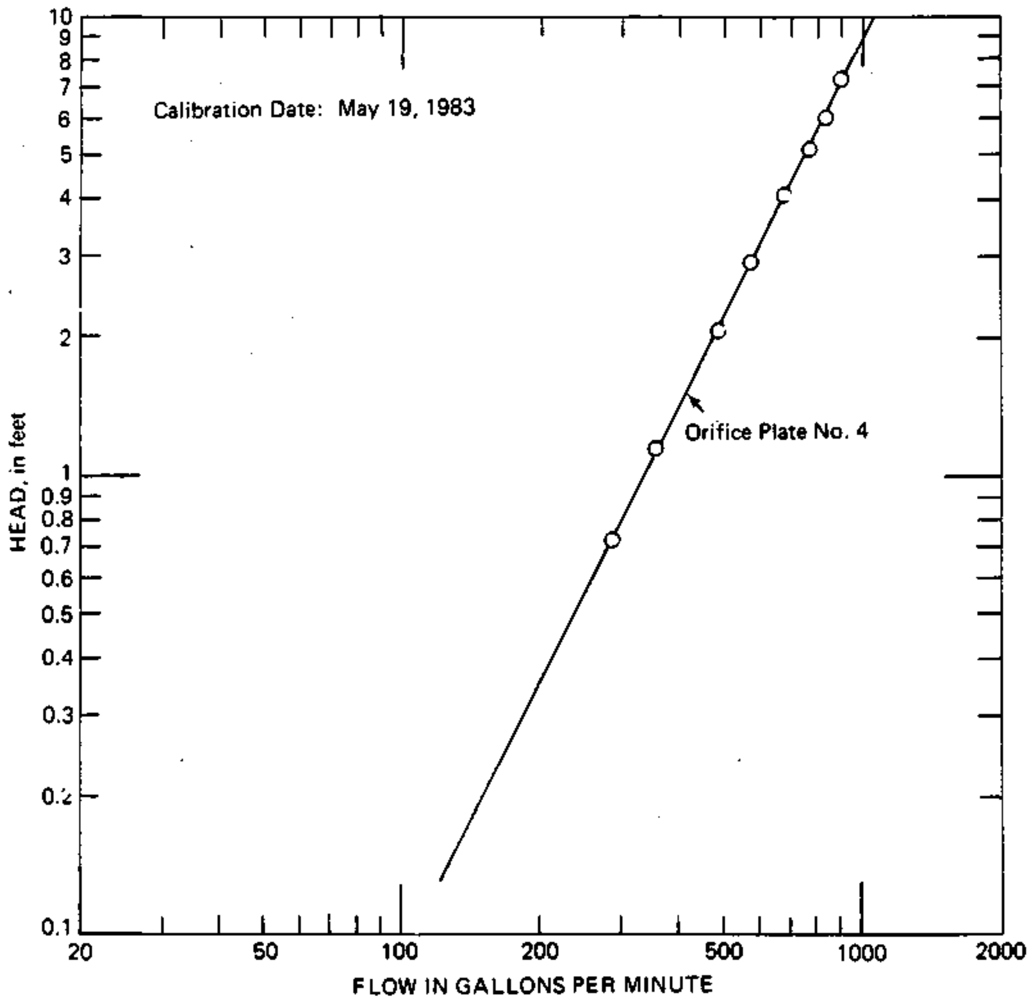


Figure 8. Rating curve for ISWS 8-inch orifice tube with plate no. 4

Table 1. I-70 Well No. 3 Step Test Data

Step	Q-(gpm)	Q-(cfs)	ΔQ-(cfs)	Δs_0-(ft)	s_0-(ft)	s_0/Q
1	600	1.337	1.337	6.09	6.09	4.55
2	550	1.225	-.112	-.61	5.48	4.47
3	500	1.114	-.111	-.56	4.92	4.42
4	450	1.003	-.111	-.53	4.39	4.38
5	400	0.891	-.112	-.54	3.85	4.32
6	350	0.780	-.111	-.49	3.36	4.31
7	300	0.668	-.112	-.54	2.82	4.22

Q - flow rate
ΔQ - change in flow rate between steps
Δs_0 - change in drawdown between steps
s_0 - observed drawdown

From the analysis, B and C were determined to be 3.93 sec/ft^2 and 0.45 sec^2/ft^5, respectively. Therefore, at 600 gpm (1.337 cfs), drawdown, s, becomes:

$$\begin{aligned} s &= BQ + CQ^2 \qquad (7) \\ &= 3.93(1.337) + 0.45(1.337)^2 \\ &= 5.25 + 0.82 \\ &= 6.07 \text{ ft} \end{aligned}$$

The total drawdown of 6.07 ft compares favorably with the observed drawdown, which was 6.09 ft. This suggests a good correlation between theoretical and observed results.

To verify the C value, a plot of s_0 versus Q is used (figure 10). When C = 0, equation 2 becomes s - BQ. s = BQ would plot as a straight line through the origin. If $C \neq 0$, then the non-linear CQ^2 term will cause the line to curve upward increasingly as Q increases. The amount of displacement from the straight line is the amount of well loss at each pumping rate. In our case, $C \neq 0$. Using $s - CQ^2 = BQ$ and substituting s_0 for s, we should be able to subtract CQ^2 from each value of drawdown, leaving the value of BQ. If our evaluation of C is correct, the BQ values should plot on a straight line through the origin. Each of these lines is plotted in figure 10. One is labeled s_0, and the other is labeled $s_0 - CQ^2$ - BQ. As can be seen, the BQ line is a straight line through the origin, which verifies that C = 0.45, obtained from figure 9, is the correct value.

The analysis indicates that when operating at a rate of 600 gpm, the portion of drawdown caused by turbulent well losses at the well screen and inside the well was 0.82 feet or 13.5% of the total drawdown for I-70 Well No. 3. This is a moderate but not significant well loss. Another indication that the well is in good hydraulic condition is the specific

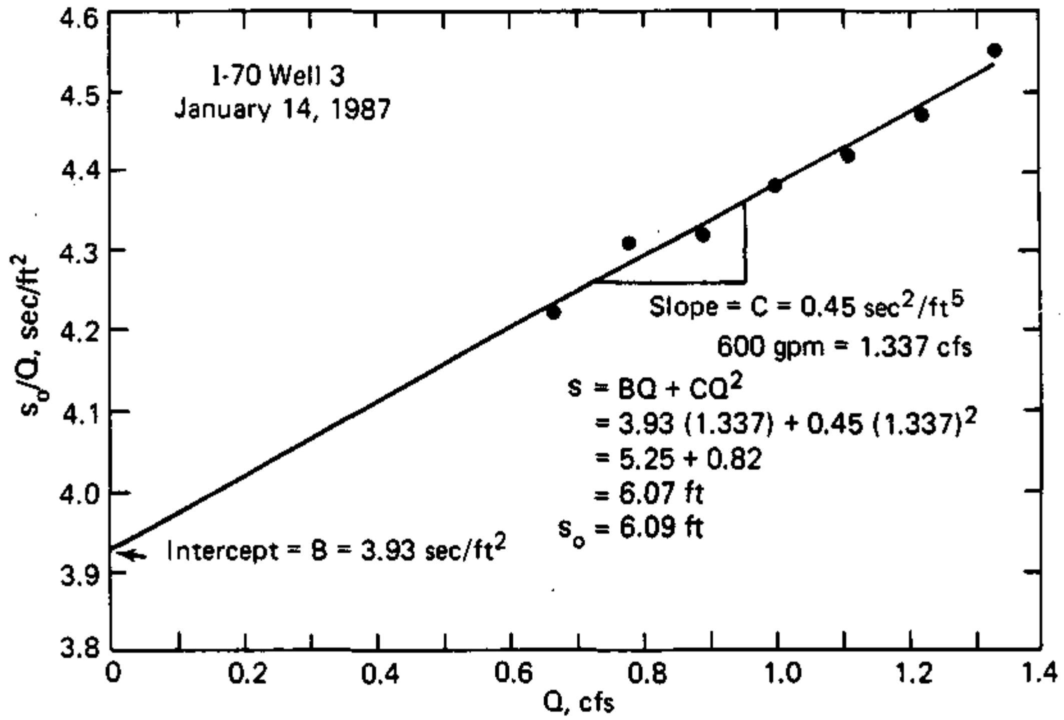


Figure 9. Graphical analysis for I-70 Well No. 3

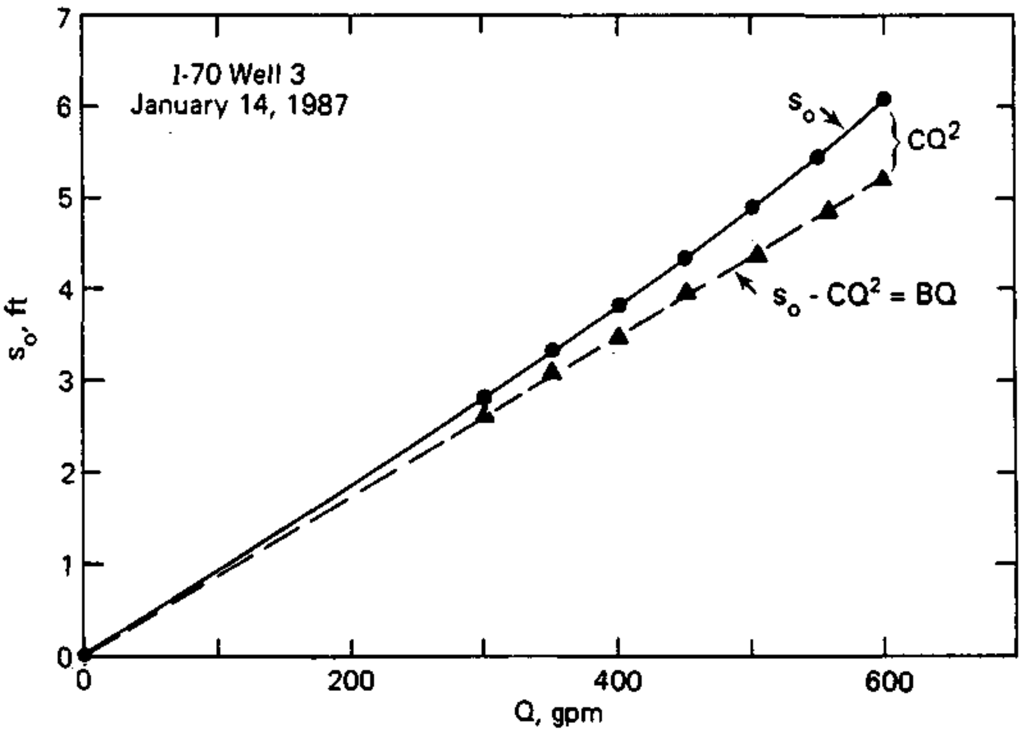


Figure 10. Observed drawdown, s_0, vs. well discharge, Q, I-70 Well No. 3

capacity. At 600 gpm, the observed specific capacity was 98.5 gpm/ft, which compares favorably with the values obtained at the other sites and with the theoretical values for the I-70 area (based on regional hydraulic properties).

Figure 11 shows water-level differences (Ah) between I-70 Well No. 3 and its nearby piezometer during the test. The relationship appears to be linear, suggesting that turbulent losses in the vicinity of the well are small. This is corroborated by a plot of drawdowns at the piezometer versus pumpage, which showed a linear relationship. The average water-level difference (Ah) for I-70 Well No. 3 and the measured piezometer was 0.40 ft per 100 gpm.

The results of analyses performed on data gathered from the ten step tests during Phase 4 are summarized in table 2. As seen in the table, well losses in most cases were a relatively small portion of drawdown at 600 gpm. Table 2 also includes the Ah head difference information for the wells tested.

I-70 Well No. 3 was the only well with a measurable well loss that was more than 10% of total drawdown (13.5% after treatment). For six of the step tests, well loss was negligible at the pumping rates tested. I-70 Well No. 12 had negligible well loss, but it had an extremely low specific capacity and high drawdown. The well loss may have appeared insignificant because at the low pumping rate, the losses were laminar. At the high end of pumpage, the s_0/Q versus Q graph indicated a possible trend toward turbulent well loss. Another possibility is that at the lower pumping rates, not all of the well screen is needed to provide water. Those sections that are incrusted and that cause the well loss are simply not providing water. Once the well is pumped at a high enough rate, the entire screen is needed to provide water. Then the incrusted areas of the screen start to reduce the efficiency of the well and to generate well loss.

Specific capacity values were encouraging for the wells tested in Phase 4. All but three wells had specific capacity values greater than 75 gpm/ft. The lowest value was at I-70 Well No. 12 with 45.1 gpm/ft. The highest specific capacity was 145.3 gpm/ft at I-64 Well No. 1. The average for the ten tests was 94.4 gpm/ft.

Forty-two step tests have been completed thus far in Phases 1 through 4. The results of these step tests are presented in Appendix C. The average specific capacity for all 42 tests is 88.8 gpm/ft. Seven tests have been completed at the 25th Street complex. These wells averaged 104.1 gpm/ft, the highest of the four areas. At I-70, I-64, and Venice, 18, 10, and 7 tests have been completed, respectively, with average specific capacities of 70.5, 94.7, and 88.4 gpm/ft. I-70 has the lowest average. The greater intensity of use of the I-70 wells and their age contribute to more well deterioration problems at this site.

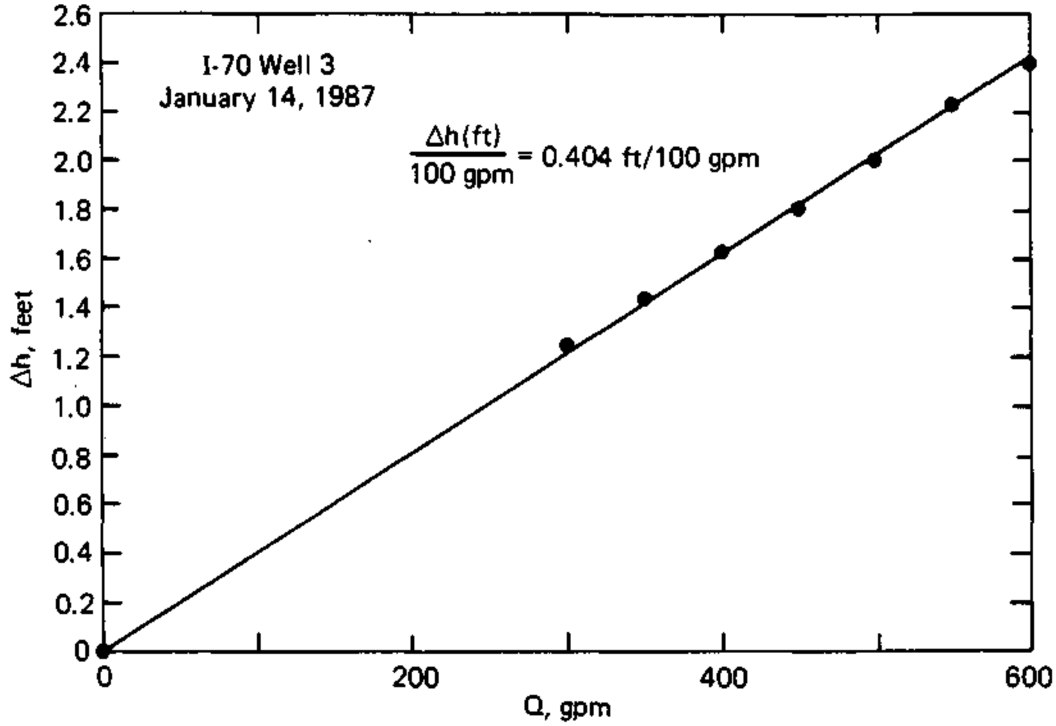


Figure 11. Water-level difference, Ah, vs. discharge, Q, I-70 Well No. 3

Table 2. Results of Step Tests on IDOT Wells, Fiscal Year 1987 (Phase 4)

Well	Date of test	Well loss @ 600 gpm (ft)	Drawdown @ 600 gpm (ft)	Well loss portion (%)	Specific capacity (gpm/ft)	Δh* @ 600 gpm (ft)	Remarks
I-70							
No. 3	6/24/86	1.11	7.47	14.9	80.3	3.64	Q_{max} = 610 gpm
No. 3T	1/14/87	0.82	6.09	13.5	98.5	2.40	Q_{max} = 620 gpm
No. 4T	1/8/87	**	5.89	**	101.9	--	Q_{max} = 660 gpm, Piezometer plugged
No. 5T	1/13/87	**	7.98	**	75.2	4.76	Q_{max} = 665 gpm
No. 12	7/30/86	**	13.30 e	**	45.1	--	Q_{max} = 450 gpm, Piezometer plugged
No. 14 (7a)	7/23/87	**	8.39	**	71.5	2.13	Q_{max} = 770 gpm
I-64							
No. 1	7/21/87	**	4.13	**	145.3	0.85	Q_{max} = 660 gpm
25th St.							
No. 6T	1/7/87	0.23	4.38	5.3	137.0	--	Q_{max} = 775 gpm, Piezometer plugged
No. 9	6/25/86	**	5.55 e	**	110.4	2.04 e	Q_{max} = 520 gpm
Venice							
No. 3T	1/6/87	0.35	7.60	4.6	78.3	--	Q_{max} = 775 gpm, Piezometer plugged

e-Estimate based on interpolated values adjusted to 600 gpm
*-Head difference between pumped well and adjacent piezometer
**-Coefficient immeasurable. Turbulent well loss negligible over the pumping rates tested.
T-Post-treatment step test

Evaluation of Ground-Water Quality

All nine wells were sampled for analysis by the State Water Survey Analytical Laboratory. The results are reported in Appendix B. Analytical methods conformed to procedures presented in the 16th edition of *Standard Methods for the Examination of Water And Wastewater* (1985). Samples were preserved with acid for determining iron, calcium, and magnesium concentrations. The sample temperature was determined at each well site, and pH was determined in the laboratory immediately after transit of the samples. The ranges of concentrations and anticipated influence of each parameter are presented in table 3.

Although the ground-water samples vary in water chemistry, the ground water can generally be described as highly mineralized, very hard, and alkaline, with unusually high soluble iron concentrations. The water quality is consistent with that of samples previously analyzed and reported for wells in the nearby area.

Well Rehabilitation

During Phase 4, five dewatering wells were chemically treated by Aylor Aqua Services, Inc. (I-70 Nos. 3, 4, and 5; 25th Street No. 6; and Venice No. 3). The treatment work was performed from October 14 to December 5, 1986.

Table 3. Ranges of Concentrations and Potential Influence of Common Dissolved Constituents

Parameter	Concentration, mg/1 Min.	Max.	Potential Influence
Iron (Fe)	6.9	18.9	Major - incrustative
Calcium (Ca)	123.0	253.0	Major - incrustative
Magnesium (Mg)	36.8	57.6	Minor - incrustative
Sodium (Na)	15.2	180.0	Neutral
Silica ($Si0_2$)	29.6	34.4	Minor - incrustative
Nitrate ($N0_3$)	< 0.3	1.2	Neutral
Chloride (C1)	21.0	230.0	Moderate - corrosive
Sulfate ($S0_4$)	167.0	411.0	Major - corrosive
Alkalinity (as $CaC0_3$)	334.0	469.0	Major - incrustative
Hardness (as $CaC0_3$)	480.0	845.0	Major - incrustative
Total Dissolved Solids	644.0	1250.0	Major - corrosive
pH	6.9	7.3	Major - incrustative

Similar treatment procedures were used for all of the wells, although adjustments occurred as specific conditions were encountered from day to day and from well to well. An outline of the treatment procedure is presented in table 4. The well rehabilitation work was observed and documented by ISWS personnel. The field notes for each treated well are in Appendix D.

Figure 12 depicts the typical injection assembly for injecting solutions into the wells and the discharge apparatus used for pumping solutions to waste and conducting pumping tests. Figure 13 illustrates the typical assembly used for acidization.

The results of the rehabilitation work are given in table 5. Table 6 presents the individual well statistics for each step in the treatment of each well. The Venice No. 3 well recovered the most, with specific capacity increasing 68%. The lowest amount of increase was at 25th Street Well No. 6, which increased 39%. The average increase in specific capacity was 55%.

In table 5, note that the values collected by the contractor may be more representative of the success of the treatment than the ISWS values. Although data from the most recent ISWS step tests were used in computing the specific capacity prior to and following treatment, in the case of four of the five treated wells, more than a year elapsed from the tests to the treatments. Thus the specific capacities may not reflect actual well condition prior to treatment. All of the ISWS follow-up step tests were conducted shortly after the treatment and, with the exception of the test for I-70 Well No. 3, they give specific capacity results that are comparable to the contractor's.

Specific Capacity Tests Using a Flowmeter

Twenty-one wells were tested with the Polysonics DHT-P flowmeter. A summary of these tests is given in table 7. The flowmeter actually measures pipe flow velocity, which is used along with the inside diameter of the discharge pipe to calculate flow rate. It is crucial to have the correct inside diameter to achieve accurate results.

Several of the calculated flow rates were higher than expected. A possible reason for this is an inaccurate estimate of the inside pipe diameter due to reduction of the effective inside diameter in these pipes as a result of incrustation. If the inside diameter is in error, then the calculated flow rate will also be in error. For example, I-70 Well No. 6 has a flow rate of 679 gpm, a drawdown of 5.41 ft, and a specific capacity of 125.5 gpm/ft. If the actual inside diameter of the measured pipe were 5 inches instead of the assumed 6 inches because of incrustation in the pipe, the flow rate would not be the calculated value of 679 gpm, but would be only 472 gpm. The specific capacity would be reduced to 87.2 gpm/ft.

The buildup of incrustation or foreign matter on the interior of the discharge pipe may also interfere with the mechanical operation of the flowmeter, potentially resulting in measurement error. Transducers mounted

Table 4. Outline of Typical Well Rehabilitation

Day 1

1. Pre-treatment specific capacity test (contractor orifice tube open to free discharge used for flow measurements).

    a. Measurement of SWL (static water level) following 30 or more minutes of well inactivity.
    b. Measurement of PWL (pumping water level) and orifice piezometer tube following 60 or more minutes of pumping.

2. Polyphosphate application, 400 lbs., and displacement with 16,000 gallons water containing at least 500 ppm chlorine.

    a. Initial chlorination of well with water containing 500 ppm or more chlorine injected at approximately 500 gpm.
    b. Injection of polyphosphate solution at a rate of approximately 500 gpm in two 2,000-gallon batches, each batch containing 200 lbs. polyphosphate, at least 500 ppm chlorine, and 1-2 cups unknown agent.
    c. Injection of 16,000 gallons water chlorinated to at least 500 ppm in 2,000-gallon batches (injection rate varied widely from a few gpm to greater than 1,200 gpm).
    d. Time allowance for chemicals to react, 30 or more minutes.

3. Pump to waste and check specific capacity.

    a. Same procedure as step 1 above.
    b. Pumping continued 60 or more minutes to clear well of chemicals.

Day 2

1. Acidization with 990 gallons 20° Baume inhibited muriatic acid and displacement with 2,500 gallons water (not chlorinated).

    a. Siphon acid from 18 55-gallon drums into wells at approximately 30 gpm.
    b. Allowance for acid to react, 60 or more minutes.
    c. Injection of 2,500 gallons water (rate varies widely from a few gpm to greater than 1,000 gpm).
    d. Allowance for reaction, 30 or more minutes.

2. Pump to waste and check specific capacity.

    a. Same procedure as day 1, step 1 above.
    b. Buffer solution prepared with 400 lbs. soda ash and injected into discharge stream to neutralize well discharge.
    c. Pumping continued 60 or more minutes to clear well of acid.

Table 4. Concluded

Day 3

1. Polyphosphate application, 600 lbs., and displacement with 30,000 gallons water containing at least 500 ppm chlorine.

   Same procedure as day 1, step 2 above, except batch injections of 200 lbs each in part b, and injection of 30,000 gallons in part c.

2. Pump to waste and check specific capacity.

   a. Same procedure as day 1, step 1 above.
   b. Pumping continued 60 or more minutes to clear well of chemicals.

Day 4

1. Polyphosphate application, 600 lbs., and displacement with 54,000 gallons water containing at least 500 ppm chlorine.

   Same procedure as day 1, step 2 above, except three batch injections of 200 lbs each in part b, and injection of 54,000 gallons in part c.

2. Pump to waste and check specific capacity.

   a. Same procedure as day 1, step 1 above.
   b. Pumping continued 60 or more minutes to clear well of chemicals.

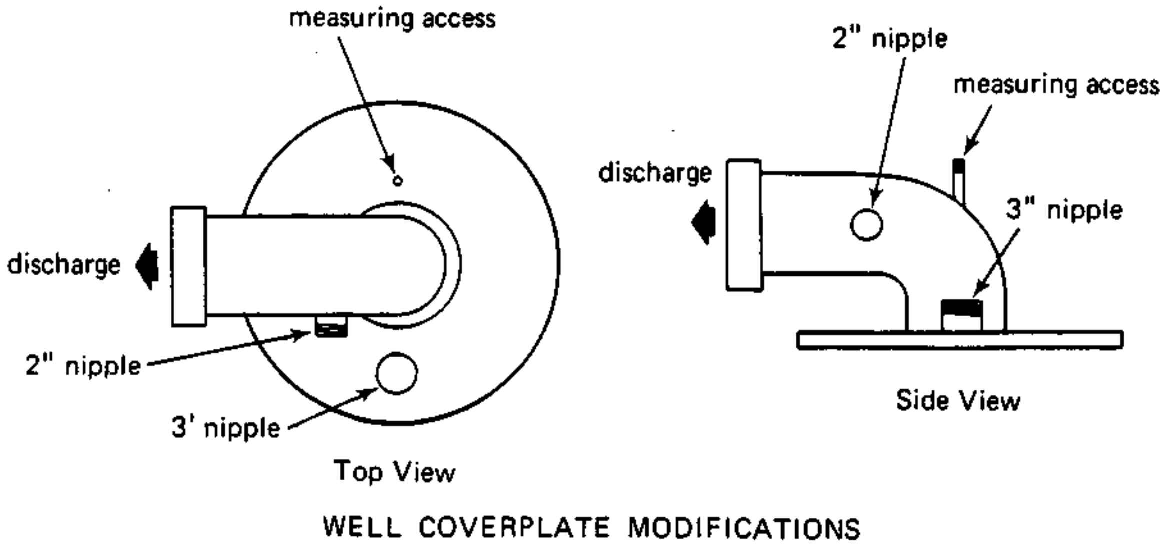
Day 5

1. Polyphosphate application, 400 lbs., and displacement with 16,000 gallons water containing at least 500 ppm chlorine.

   Same procedure as day 1, step 2 above.

2. Pump to waste and final specific capacity test.

   a. Same procedure as day 1, step 1 above.
   b. Pumping continued 60 or more minutes to clear well of chemicals.



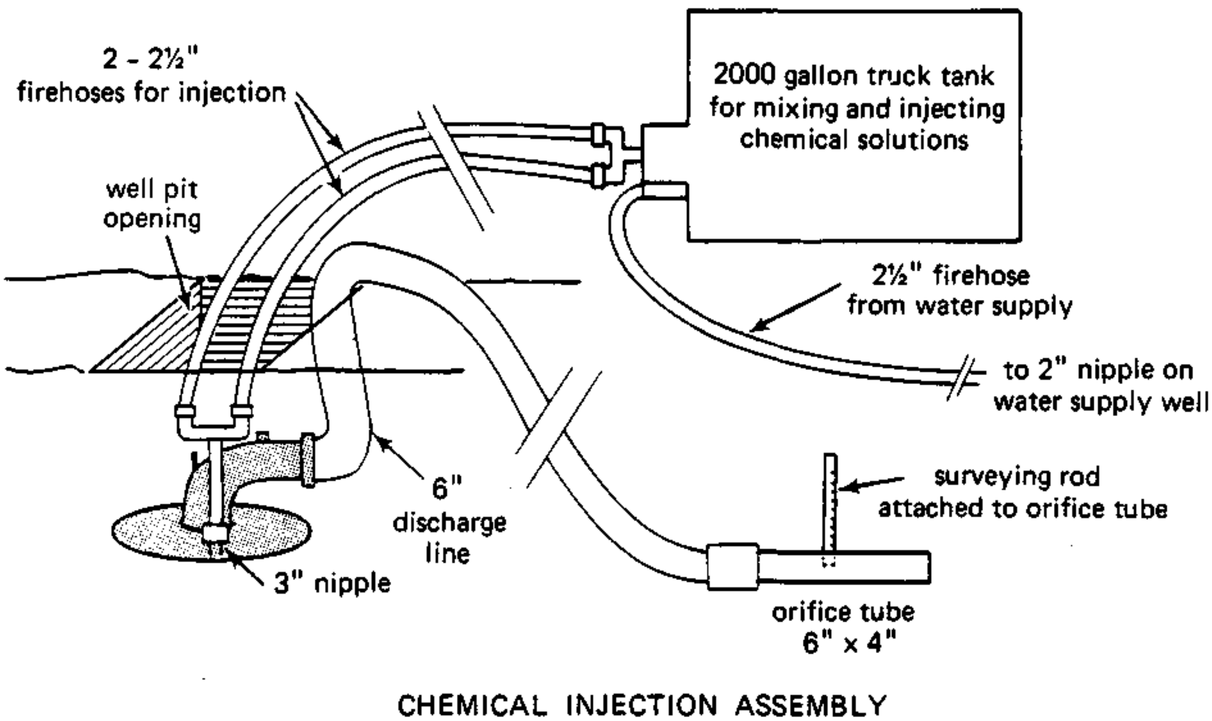


Figure 12. Injection assembly and discharge apparatus

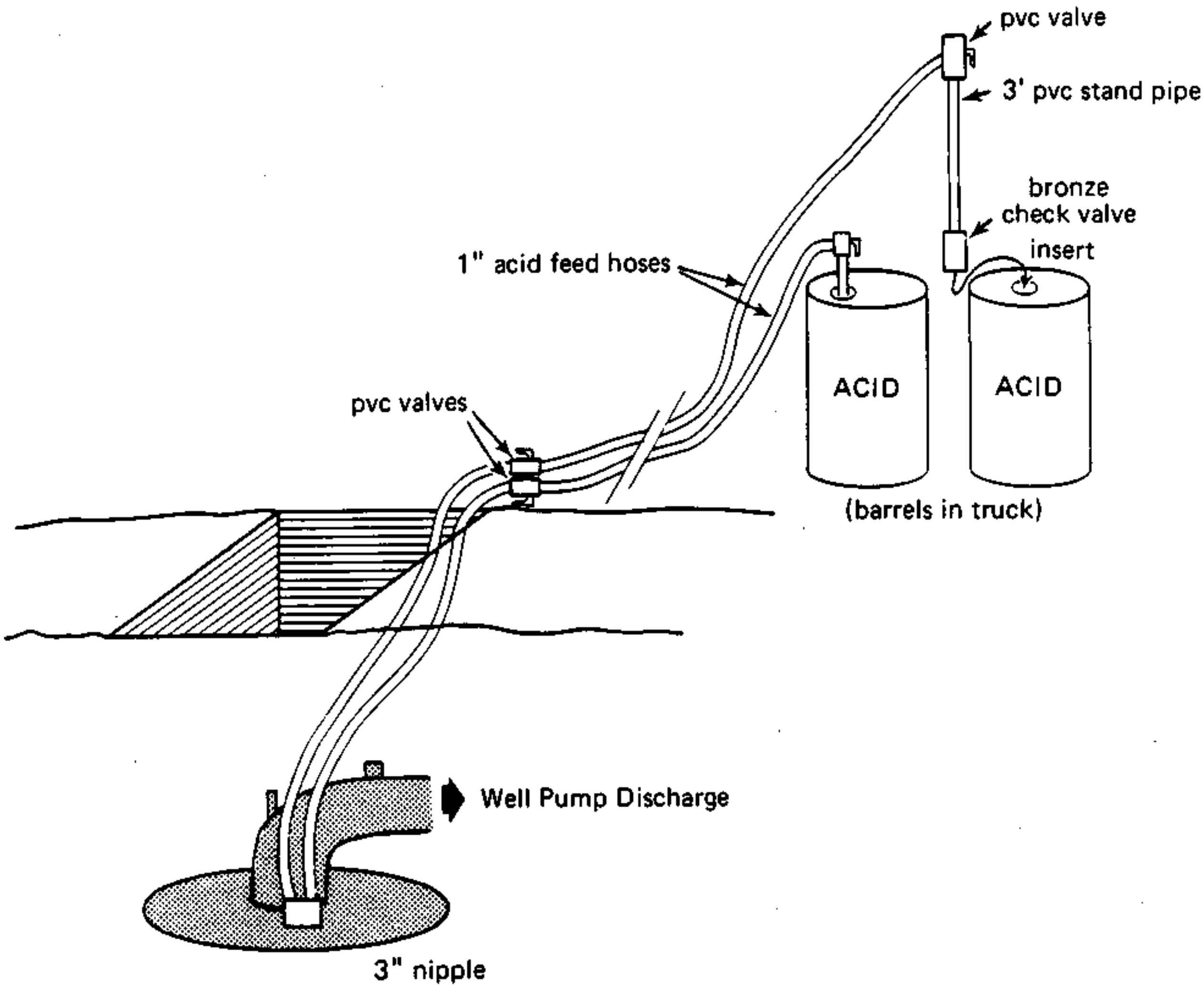


Figure 13. Acidization assembly

Table 5. Results of Chemical Treatment

Site	Well	Pre-treatment Date	Pre-treatment Q/s (gpm/ft)	Post-treatment Date	Post-treatment Q/s (gpm/ft)	% Change
I-70						
No. 3	ISWS	6/24/86	77.7	1/14/87	98.5	+27
	AASI	10/14/86	82.9	10/21/86	135.2	+ 63
No. 4	ISWS	8/16/84	64.3	1/8/87	100.3	+ 56
	AASI	10/20/86	68.2	10/28/86	98.1	+44
No. 5	ISWS	7/10/84	91.9	1/13/87	84.3	- 8
	AASI	10/28/86	51.6	11/13/86	82.9	+61
25th Street						
No. 6	ISWS	6/27/84	63.6	1/7/87	137.0	+115
	AASI	11/19/86	94.2	12/5/86	131.1	+ 39
Venice						
No. 3	ISWS	11/28/83	65.2	1/6/87	78.3	+20
	AASI	11/4/86	47.7	11/18/86	80.2	+68

Q/s = specific capacity
ISWS = Illinois State Water Survey
AASI = Aylor Aqua Services, Inc.

Table 6. Individual Well Treatment Steps

I-70 No. 3

	10/14 Pretreatment	10/15 1st PPP treatment	10/16 Acid treatment	10/17 2nd PPP treatment	10/19 3rd PPP treatment	10/21 4th PPP treatment
SWL	27.29	27.30	28.35	28.49	27.07	28.44
PWL	33.20	32.17	32.44	32.87	32.93	32.67
DD	5.91	4.87	4.09	4.38	5.86	4.23
Flow	490	524	448	584	566	572
Q/s	82.9	107.6	109.5	133.3	96.6	135.2

I-70 No. 4

	10/20 Pretreatment	10/21 1st PPP treatment	10/22 Acid treatment	10/23 2nd PPP treatment	10/24 3rd PPP treatment	10/28 4th PPP treatment
SWL	20.40	19.77	20.10	19.90	20.00	18.89
PWL	28.52	27.63	27.06	26.52	26.05	24.78
DD	8.12	7.86	6.96	6.62	6.05	5.89
Flow	554	596	584	596	584	578
Q/s	68.2	75.8	83.9	90.0	97.2	98.1

I-70 No. 5

	10/28 Pretreatment	10/29 1st PPP treatment	10/30 Acid treatment	10/31 2nd PPP treatment	10/31 3rd PPP treatment	11/3 4th PPP treatment
SWL	13.04	12.96	13.28	12.92	13.33	12.72
PWL	22.49	20.44	21.20	20.40	21.08	20.05
DD	9.45	7.48	7.92	7.48	7.75	7.33
Flow	488	524	590	584	584	608
Q/s	51.6	70.1	74.5	78.1	75.4	82.9

Table 6. Concluded

25th Street No. 6

	11/19	12/2	12/3	12/4	12/4	12/5
	Pretreatment	1st PPP treatment	Acid treatment	2nd PPP treatment	3rd PPP treatment	4th PPP treatment
SWL	20.66	20.59	20.59	20.88	20.84	20.72
PWL	28.25	27.40	27.22	27.27	27.04	26.47
DD	7.59	6.81	6.63	6.39	6.20	5.75
Flow	715	737	737	737	754	754
Q/s	94.2	108.0	111.0	115.0	121.6	131.1

Venice No. 3

	11/4	11/5	11/6	11/11	11/12	10/18
	Pretreatment	1st PPP treatment	Acid treatment	2nd PPP treatment	3rd PPP treatment	4th PPP treatment
SWL	13.50	13.54	14.18	13.80	14.15	14.30
PWL	30.47	25.30	25.94	24.81	25.18	24.10
DD	16.97	11.76	11.76	11.01	11.03	9.80
Flow	810	800	800	805	832	786
Q/s	47.7	68.0	68.0	73.1	75.4	80.2

PPP - polyphosphate
SWL - static water level (ft)
PWL - pumped water level (ft)
DD - drawdown (ft)
Flow - flow rate (gpm)
Q/s - specific capacity (gpm/ft)

Table 7. Results of Specific Capacity Tests with Ultrasonic Flowmeter

Well	Date of test	Signal* alert	0 (gpm)	Observed drawdown (ft)	Observed specific capacity (gpm/ft)	Ah (ft)	Remarks
I-70							
No. 1	7/22/87	On	1764	1.37	1287.6	0.70	Calculated flow unreasonable. Deposits on inside of discharge line noted previously, repositioned transducer mounting - no improvement
No. 2	7/14/87	OK	529	8.11	65.2	5.32	
No. 3	7/21/87	OK	714	8.94	79.9	3.86	Q measurements erratic at times
No. 4	7/22/87	OK	662	9.27	71.4	-	Piezometer plugged
No. 5	7/16/87	On	917	11.65	78.7	8.07	Calculated flow appears too high. Repositioned transducer mounting - no improvement
No. 6	7/21/87	On	679	5.41	125.5	-	Piezometer plugged
No. 8	7/14/87						Pump cuts out after a minute or so
No. 10	7/15/87	OK	573	16.99	33.7	9.94	Sounds like pump is breaking suction
No. 11	7/16/87	OK	617	12.93	47.7	8.46	
No. 12 (13th)	7/15/87	On	626	6.40	97.8	-	Piezometer plugged, Q measurements erratic, poor transducer mounting

Table 7. Continued

Well	Date of test	Signal* alert	Q (gpm)	Observed drawdown (ft)	Observed specific capacity (gpm/ft)	Ah (ft)	Remarks
No. 14 (7a)	7/15/87	OK	917	11.06	82.9	2.88	Poor transducer mounting, Q measurement erratic
I-64							
No. 1	7/14/87	OK	776	5.39	144.0	1.18	Calculated flow rate may be high
No. 3	7/14/87						Disconnected from the system
No. 15	7/14/87	OK	759	7.73	98.2	2.89	Calculated flow rate may be high
25th Street							
No. 6	7/17/87	OK	556	5.25	105.9	-	Weak signal, piezometer plugged
No. 9	7/14/87						Disconnected from the system
No. 10	7/16/87	OK	573	7.65	74.9	2.40	
Venice							
No. 1	7/22/87	On	1146	0	-	-	Calculated pumping rate in error. Pump running but no Q, venturi gauge unreadable

Table 7. Concluded

Well	Date of test	Signal* alert	Q (gpm)	Observed drawdown (ft)	Observed specific capacity (gpm/ft)	Ah (ft)	Remarks
No. 3	7/17/87	OK	512	5.87	87.2	4.95	Venturi meter reads 450-460 gpm. Piezometer was partially plugged.
No. 5.	7/24/87						Inoperative as reported by pump crew
No. 6	7/17/87	OK	732	5.87	124.7	4.65	Calculated flow rate may be high. Venturi meter inoperative.

*An "On" signal alert indicates that the measurements may be in error due to interference with the instrument's ultrasonic signal.

on the discharge pipe for taking measurements with the DHT-P unit must be sonically coupled with the water flowing in the pipe. Incrustation may effectively insulate the pipe and inhibit attempts to make a sonic connection with the flowing water.

I-70 Well No. 9 Sand Pumpaee Investigation

A detailed investigation of I-70 Well No. 9 was performed after observation of a drop in the level of the gravel pack around the well casing. A sample of sand was collected from the pump discharge by the ISWS. This well was assumed to have an excessive buildup of sand and possibly of larger particles inside the well screen. The entry of sand would eventually result in abrasion of the well pump. The investigation included sieve analyses on the pumped sand, gravel pack, and aquifer boring samples, and a TV inspection of the well to determine the locations of incrustation, corrosion, and possible cracks in the well screen.

The TV inspection was conducted November 20, 1986. The work was performed by Layne-Western Co., Inc., Aurora, IL, and observed by ISWS staff. Layne-Western provided all equipment and personnel necessary to conduct the TV inspection. They also provided a submersible pump and equipment to allow a free discharge of 100 to 125 gpm during the TV inspection. The TV inspection was videotaped to allow for additional review. The videotape comments are listed in Appendix E.

The inspection revealed that, with the exception of the upper 5 feet, the screen is relatively free of incrustation and corrosion. In addition, there appears to be little buildup of sand in the bottom of the screen. The top of the well screen is 34 feet below the well head. The pump intake is at 36 feet. The upper 5 feet of screen, between depths of about 34 to 39 feet, would appear to have a strong horizontal influence on flow around the intake. Review of the videotape indicated that some fine particles of sand were being produced from this part of the screen. The review also revealed a possible split in a weld seam between screen sections at 39 feet. The absence of gravel pack material in the discharge suggests that if there is a split in the weld seam, it is not serious or is not the cause of the problem.

Sieve analyses of formation samples from a nearby bore hole, gravel pack materials, and pumped sand from the well were studied to help confirm where the sand was entering the well. The sieve analyses data and boring logs are in Appendix F. Figure 14 shows the sieving results to two depth intervals along with the pumped sand and the gravel pack material. The analyses indicate that the pumped sand could be coming from any portion of the aquifer between depths of about 39 to 51 feet. This zone is in the upper 15 feet of well screen. The videotape showed some fines entering the upper 5 feet of screen, but the grain size of the pumped sand suggests that some also may be entering lower than this.

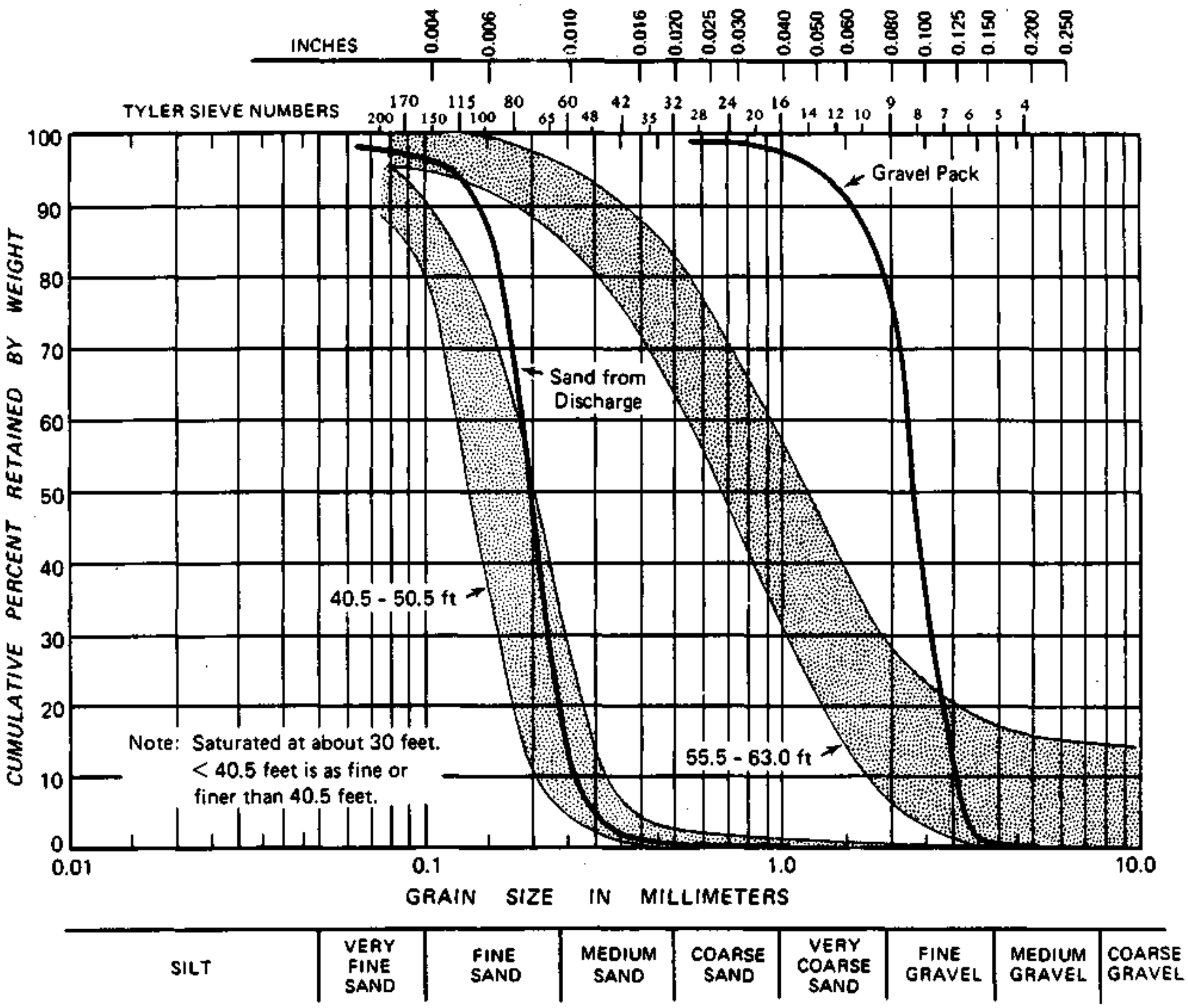


Figure 14. Sieve analysis results of I-70 Well No. 9 sand pumpage investigation

Piezometer Installation

IDOT maintenance staff became concerned about a high water table at three of their nearby roadway underpasses of railroad right-of-ways which they maintain. These underpasses are found along 8th Street, 9th Street, and 42nd Street in East St. Louis. The ISWS assisted IDOT with assessing each site to determine the number and location of the piezometers needed to adequately monitor ground-water levels. ISWS staff also assisted the IDOT drill crew with installation of the piezometers.

Six new piezometers were installed at two new sites, 9th Street and 42nd Street (three at each site). The installation work was completed August 21 and 22, 1986. The 8th Street site was eventually dropped from consideration because maintenance was turned over to the city of East St. Louis.

At the 9th Street site, piezometers were installed near the pump station, in the highway median, and by the embankment. The pump station well is 45 feet deep with 5 feet of 10-slot screen. The static water level was 14.68 below measuring point (MP). The other two wells are each 40 feet deep with 5 feet of 10-slot screen. The median well had a static water level of 10.34 feet. The embankment well had a static water level of 14.28 feet.

At the 42nd Street site, one piezometer was drilled near the pump station, and the other piezometers were drilled on the west side and the east side of the bridge pier in the median. The piezometer near the pump station was drilled on the east side of the building to avoid underground pipes and utilities. Each piezometer is 40 feet deep with 5 feet of well screen. The pump station piezometer has 10-slot screen, and the two pier piezometers have 6-slot screen. The static water level was 14.78 feet at the pump station piezometer. At the pier piezometers, the water table was less than 5 feet below grade and was intercepted with the first flight of the auger.

Status of Dewatering Well Piezometers

The piezometer wells are relied upon to aid in evaluating wells for possible well deterioration. It is important that they remain open. Table 8 lists the current information on the condition of the piezometers. Included are the dates and the status of the well on each of the dates. Currently, eight piezometers are known to be plugged or partially plugged.

I-70 Well No. 14 (7a) Construction

The ISWS staff participated in all aspects of the construction of I-70 Well No. 14 (7a). Initial well design specifications and design changes were recommended by ISWS staff. A summary of these design specifications is given in Appendix G. The proposed well design was tailored to this site and called for two sizes of well screen and gravel pack. The construction was observed by ISWS staff.

Table 8. Status of IDOT Dewatering Well Piezometers

<u>I-70</u>

P-l	8/15/84, 8/14/85, 7/22/87* open
P-2	7/19/83, 8/15/85, 7/14/87* open
P-3	6/28/83, 6/24/86, 1/14/87, 7/21/87* open
P-4	8/16/84, 1/08/87, 7/22/87* plugged
P-5	7/10/84, 1/13/87, 7/16/87* open
P-6	7/19/85, 7/21/87* plugged
P-8	8/1/84, 12/5/85 open
P-9	6/28/84 open
P-10	7/11/84, 9/4/85 plugged; 7/15/87* open
P-ll	8/2/84 open; 9/5/85 partially plugged; 7/16/87* open
P-12	6/16/83, 7/30/86, 7/15/87* plugged
P-14 (7a)	7/15/87*, 7/23/87 open

<u>I-64</u>

P-l	7/14/87*. 7/21/87 open
P-2	7/25/85 open
P-3	6/26/84 plugged
P-4	7/15/85 plugged
P-9	10/5/83 open
P-10	7/11/84 open
P-ll	8/14/84 open
P-12	7/18/85 open
P-13	7/12/84 open
P-15	6/29/83, 6/29/85, 8/13/85, 7/14/87* open

<u>25th Street</u>

P-2	7/20/83 open
P-3	8/26/85 open
P-6	6/27/84, 1/7/87, 7/17/87* plugged
P-8	6/15/83 open
P-9	6/25/86 open
P-10	7/26/85, 7/16/87* open

<u>Venice</u>

P-l	11/30/83, 12/4/85, 7/22/87* open
P-2	11/17/83 open
P-3	11/28/83 open; 1/6/87, 7/17/87* partially plugged (responds very slowly)
P-4	12/1/83 open
P-5	11/15/83 open
P-6	11/29/83, 7/17/87* open

* Denotes date of specific capacity test using ultrasonic flowmeter

The construction of I-70 Well No. 14 (7a), the replacement for I-70 Well No. 7, took place November 23-25, 1986. The drilling contractor was Luhr Bros. (Bob Kennedy, driller). The well was drilled 88 feet deep with 60 feet of screen. The bottom 30 feet of screen was 55-slot and the upper 30 feet was 25-slot. Water from I-70 Wells 7 and 8 was used to fill the mud pit with water. During drilling, stiff blue clay was encountered at 15 feet and cobbles were found at about 70 feet. The cobbles slowed the drilling considerably. Northern No. 1 (Type A) gravel pack was used for the bottom 30 feet. It overlapped the upper 30 feet of screen by four feet. Northern No. 0 (Type B) gravel pack was placed to the top of the screen. The well was bailed and surged until the drilling crew determined that sand-free operation was assured. Sand was added between 2 and 3 feet over the pack, and a bentonite/concrete grout was used for a plug. The full documentation for the construction of I-70 Well No. 14 (7a) is in Appendix G. Figure 15 is a diagram of the construction features of I-70 Well No. 14 (7a). Appendix H presents the sieve analyses of the washed samples taken during the construction.

CONCLUSIONS AND RECOMMENDATIONS

Condition of Wells

All of the nine wells step-tested, with the exception of I-70 Well No. 12, appeared to be in good condition. Deleting the I-70 No. 12 value, the average specific capacity was 99.9 gpm/ft. The wells break into two groups. Three wells (I-70 No. 5, I-70 No. 14 (7a), and Venice No. 3) are in acceptable condition. Their specific capacity averages 75.0 gpm/ft, and drawdown at 600 gpm is about 8 feet. The other five wells are in excellent condition. The average specific capacity for these wells is 118.6 gpm/ft. I-70 Well No. 3 is the only well with moderate well loss.

To restore capacity, chemical treatment is recommended for I-70 Well No. 12. The specific capacity of about 45 gpm/foot of drawdown is very low.

I-70 Well No. 3 should be closely monitored. Though it appears in good condition, it could deteriorate rapidly if pumped very much. This is the case with all of the I-70 wells. They are pumped more than wells at other sites and are in a critical area. The I-70 wells need to be checked monthly to help assure normal operation.

Four of the nine piezometers were plugged. While helpful for an accurate step test, they are the primary means of monitoring the performance of individual wells in the system. To adequately manage the well field, the Ah information, gathered at regular intervals, must be sustained.

Well Rehabilitation

For Phase 4, the chemical treatments to restore well capacity appeared to be successful. The average increase in specific capacity of

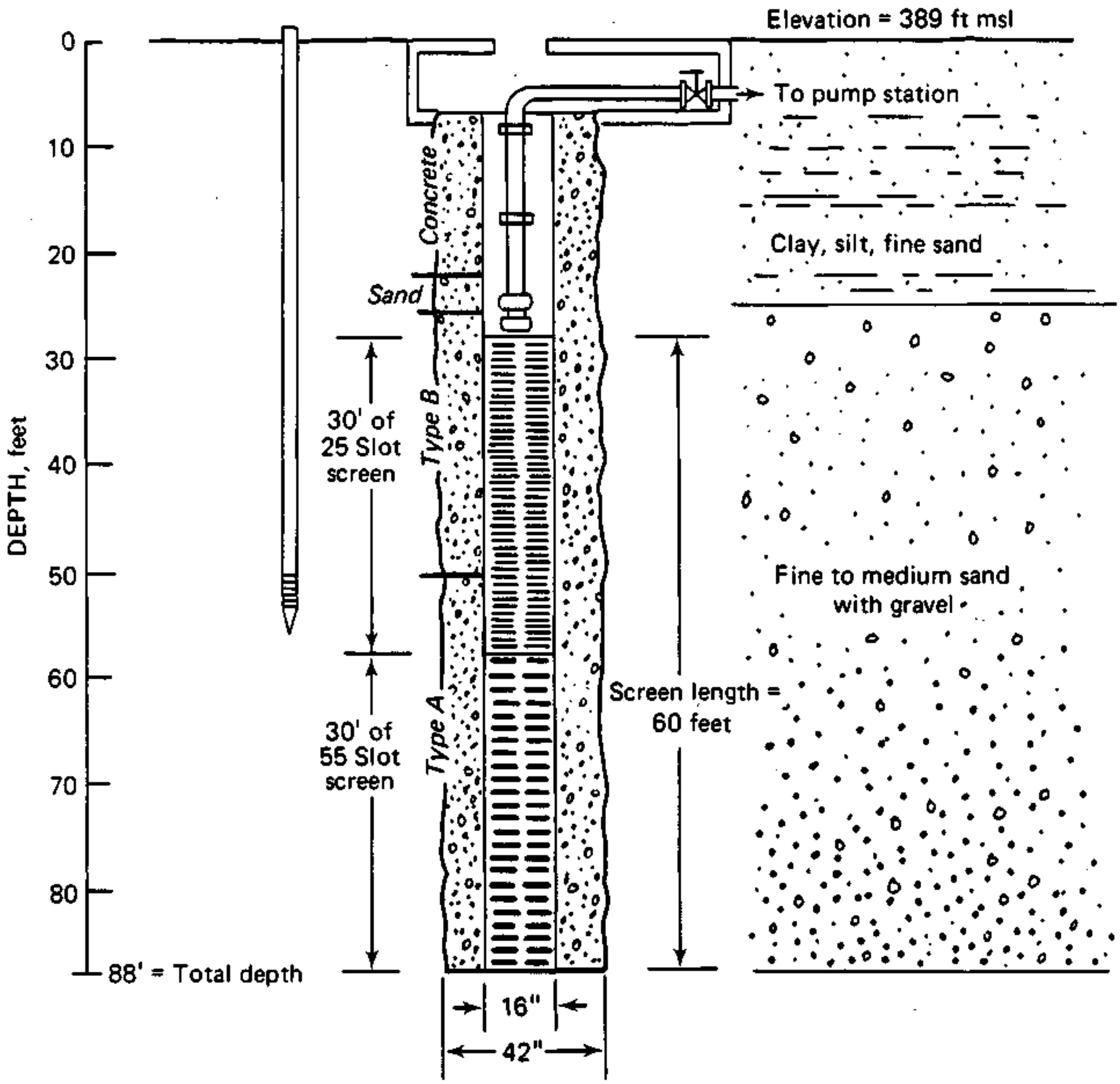


Figure 15. I-70 Well No. 14 (7a) design features

the five wells was about 55%. To manage and rehabilitate the well system effectively, a procedure to determine which wells to treat and when to limit treatment steps should be developed.

The wells to be treated should be selected for treatment on the basis of recent ISWS step tests. This part of the procedure is already in place. A well selected for treatment should be treated during the same year the step test is conducted, preferably within a few months. Not only is this an orderly and timely way to keep the wells in proper condition, but it creates a check system that is currently lacking. The step-test data can verify the treatment data and vice versa. An ISWS pre-treatment step test should be conducted to confirm the selection of a well to be treated if the previous step test was completed more than one year before the well treatment.

The treatment project specifications should be modified to allow the treatment to be tailored to each specific well. The available data indicate that in some cases the third and fourth polyphosphate treatment steps are not needed (see table 6). In other cases, cleaning the column pipes and discharge lines may correct the loss in pumping capacity of a well.

This approach requires review of the field results after each step of treatment is completed. If a designated person, possibly an observer from the ISWS, could be on hand to review this information and make an evaluation, then the determination for further steps could be made. Each well is independent. By applying the same procedure to each well, there can be inefficiency because of extra, unneeded steps.

Unneeded steps can be eliminated. The data in Table 6 indicate that, in general, the last two treatment steps produce only small increases in specific capacity. A pre-determined specific capacity goal for each well is suggested. Once a well has recovered to this goal, further steps may not be worthwhile. The specific capacity goal can be established by studying previous step test results, rehabilitation history, and original specific capacity data, if available.

For Phase 4, this method would not have had a dramatic effect on the treatment procedures. Only I-70 Well No. 3 would have been affected. The treatment could have stopped after the second polyphosphate treatment. But in previous work for Phase 3, several of the treatments would have been altered. Data collected by the contractor suggested that four of the seven wells treated in Phase 3 lost specific capacity from the fourth polyphosphate treatment. Of the other three, the largest increase in specific capacity from the last treatment step was 6.1 gpm/ft.

Using just one standard approach to the chemical treatment of the dewatering wells is not the most economical or beneficial way to restore their capacity. The data show that the wells do not perform the same or react to treatment the same. To insure optimum rehabilitation, field analysis of each treatment step should be implemented.

Specific Capacity Tests

The flowmeter worked moderately well. It is a relatively simple and, under many conditions, a reliable way to determine flow rate. During the field testing of the flowmeter at the individual sites, it was found that its accuracy depended on the changes in inside pipe diameter caused by the mineral incrustation. In the future, when the flowmeter is used and measurements are suspect, the discharge pipe should be inspected to determine the presence of incrustation and the actual inside diameter. The accuracy of the flowmeter can be no greater than the accuracy of the estimate of the inside pipe diameter.

I-70 Well No. 9 Investigation

The TV inspection and sieve analysis data of aquifer samples suggest that the upper 15 feet of screen is the source of the sand being pumped at I-70 Well No. 9. The pump intake is located in this screened interval, which promotes a strong turbulent flow in this region.

The gathered information indicates that eliminating the ground-water contribution from this part of the screen by inserting a liner is a feasible solution to the sand pumpage problem. This approach would be better than adding an inner screen and gravel pack to the well because it would be less expensive, and the liner could be removed if not successful. In addition, the inner screen and gravel pack would cause additional head loss.

Insertion of a steel liner equipped with a neoprene K-type packer at the bottom end (figure 16) is recommended. This would effectively seal off any contribution from the upper section of screen. The remaining 40-foot length of exposed well screen will safely accommodate the 600 gpm pumping rate.

Plugged Piezometers

The present design features and field conditions have resulted in plugging of many of the piezometers. Lack of proper maintenance also has contributed to these circumstances. The present design does not properly protect the piezometer heads from surface drainage and other roadside hazards. Many of the piezometer caps are missing or broken.

Replacement of the plugged piezometers is recommended. In addition, modification of the remaining piezometers is recommended to better protect them from drainage and damage. The pump crew is reported to have periodically performed some cleaning operations on the piezometers. Once the piezometer was unplugged, the top could be modified to insure that it will remain open.

Figure 17 is a diagram of the proposed modification of the piezometer tops. This modification will protect the piezometers from entry of surface drainage and damage from roadside maintenance vehicles.

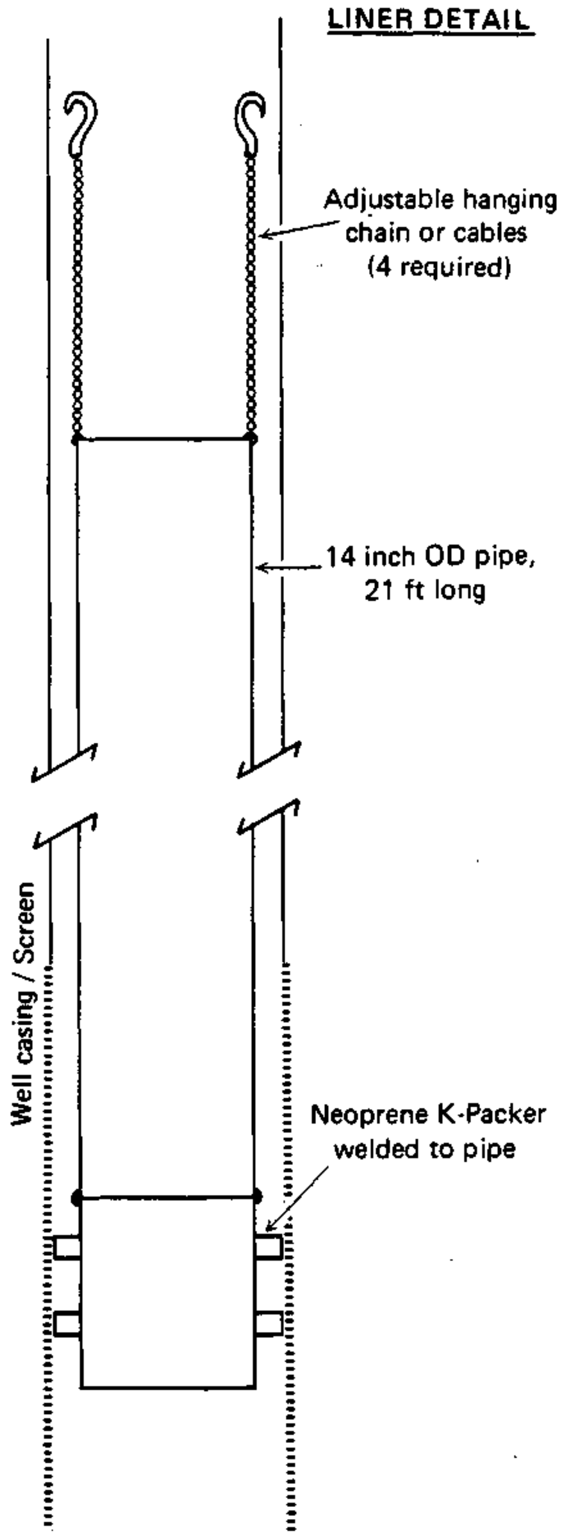


Figure 16. Proposed liner for I-70 Well No. 9

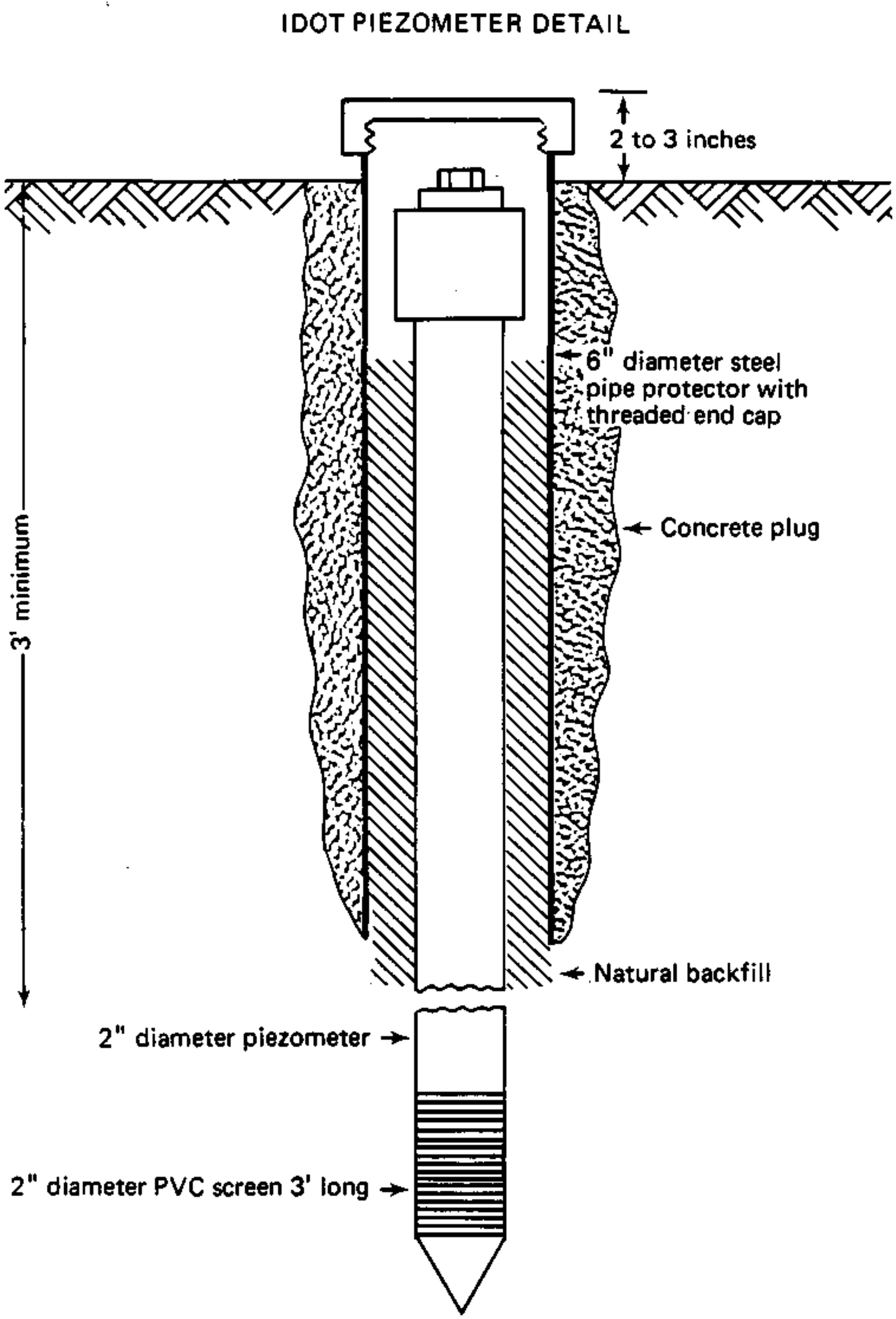


Figure 17. Proposed head modification for dewatering well piezometers

Future Investigations

A program of continued investigation of the condition of the dewatering wells is recommended. It will continue to be important to obtain the water-level-difference measurements in the piezometer and the adjacent well as a first step in determining future wells as candidates for step tests or treatment.

At this time I-70 Well No. 12 is recommended for treatment. The rest of the wells tested appear to be operating effectively. Close monitoring should be continued, however, especially at the critical I-70 site. The nature of the water chemistry is such that well deterioration may occur rapidly. From the IDOT Ah measurements and previous ISWS step tests, several additional wells appear to be candidates for chemical treatment: I-64 No. 3, Venice No. 6, and 25th Street No. 10.

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Appendix A.

Step Test Data

DEWATERING WELL DATA

	Well No. I-70 W3	Piezometer No. I-70 P3
Date Drilled:	1973	1973
Casing		
Top elevation:	397.4	406.7
Diameter:	16-in. SS	2-in. PVC
Length:	33 ft	na
Screen		
Bottom elevation:	304.43	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.80-in.	na
Measuring Point Elevation:	398.2	406.7
Nonpumping Water Level		
Depth below temp. MP:	27.77	29.97
Length of temp. MP extension:	7.41 ft	0.25 ft
Depth below perm. MP:	20.36	29.72
Elevation:	377.84	376.98
Date of Step Test:	6/24/86	-
Water Sample		
Time:	2:24 PM	-
Temperature:	60° F	-
Laboratory No.:	86062301A 86062304A	-

Distance and Direction to Piez. from PW: 9.0 ft North

Time PW Off Before Step Test: Unknown, but at least several weeks

Wells in Operation at Site at Time of Step Test:* 1, 6, 7, 8

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using electric droplines

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well I-70 No. 3

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
10:52 AM		27.63				
10:55			29.98			
10:56		27.77				
10:57		27.68	29.98			
10:59		27.68	29.97			
11:09		27.77				
11:10	0					Pump on
11:11	1	31.02	31.47	.78	300	Step 1
11:12	2	31.08	31.62	.78	300	
	3	31.12	31.65	.80	310	
	4	31.17	31.69	.80	310	
11:15	5	31.19	31.71			
	8	31.23	31.75			
11:20	10	31.25	31.76			
	12	31.28	31.78			
	14	31.31	31.80			
	16	31.33	31.82			
11:30	20	31.34	31.83			
	25	31.36	31.85	.80	310	
11:40	30					Increase rate
	1	31.90	32.08	1.07	3.40	Step 2
	3	31.94	32.10			
	4	31.97	32.14			
11:45	5	31.98	32.17			
	6	31.99	32.18			
	8	32.00	32.20	1.07	340	
11:50	10	32.01	32.20			
	12	32.00	32.21			
	14	32.02	32.21	1.08	345	
	16	32.02	32.22			
12:00 PM	20	32.03	32.22			
	25	32.04	32.24			
	29	32.05	32.24			
12:10	30	32.05	32.24	1.42	400	Increase rate
	1	32.68	32.45			Step 3
	2		32.53			
	3	32.71	32.55			
	4	32.73	32.57			
12:15	5	72.73	32.58			
	6	32.73	32.58			
	8	32.74	32.58	1.43	405	
12:20	10	32.74	32.60			
	12	32.74	32.62			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 3

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	14	32.75	32.62			
	16	32.75	32.62	1.43	405	
12:30	20	32.77	32.63			
	25	32.77	32.66	1.43	405	
	29		32.65			
12:40	30	32.81	32.65			Increase rate
	1	33.44	32.98	1.82	450	Step 4
	2	33.46	32.97			
	3	33.48	32.95			
	4	33.49	32.97			
12:45	5	33.45	32.97			
	6	33.45	32.99			
	8	33.47	32.99			
12:50	10	33.48	33.00	1.81	448	
	12	33.49	33.00			
	14	33.50	33.01			
	16	33.52	33.01			
1:00	20	33.49	33.01			
	25	33.51	33.02			
			33.61			Steel tape; Δ = 33.61 - 33.02 - 0.59
	29	33.51	33.03			Distance between 30 &
1:10	30	33.51	33.03			35 ft beads = 4.93 ft
	1	34.09	33.24	2.22	500	Step 5
	2	34.10	33.28			
	3	34.12	33.31			
	4	34.15	33.35			
1:15	5	34.15	33.34			
	6	34.15	33.34			
	8	34.15	33.34	2.22	500	
1:20	10	34.13	33.35			
	12	34.15	33.36			
	14	34.17	33.40			
	16	34.19	33.40			
1:30	20	34.19	33.40			
1:33		32.24				Steel tape; Δ = 34.20 - 32.24 = 1.96
1:35	25	34.37	33.40	2.24	505	Distance between 30 &
	29		33.41			35 ft beads = 5.13 ft
1:40	30		33.41	2.24	505	Increase rate
	1	34.33	33.57	2.73	550	Step 6
	2	34.85	33.67			
	3	34.87	33.70			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 3

Hour	Time (mln)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	4	34.88	33.71			
1:45	5	34.90	33.71			
	6	34.90	33.72			
	8	34.92	33.72			
1:50	10	34.92	33.75	2.75	555	
	12		33.75			
	14	34.93	33.76	2.74	554	
	16	34.92	33.76	2.72	550	
2:00	20	34.94	33.78			
	25	34.94	33.78			
	29	34.95	33.80			
2:10	30	34.95	33.80	2.74	554	
	1	35.51	33.98	3.25	605	Step 7
	2	35.56	34.05			
	4	35.52	34.07			
2:15	5	35.52	34.08			
	6	35.53	34.08			
2:20	10	35.54	34.10			
	12	35.55	34.11			
	14	35.54	34.11	3.22	600	Temp 60° F and samples collected
	16	35.55	34.11			
2:30	20	35.57	34.12	3.24	603	
	25	35.56	34.14			
	29	35.57	34.14	3.23	607	
2:40	30	35.58	34.15			
				3.29	610	Wide open

DEWATERING WELL DATA

	Well No. I-70 W3	Piezometer No. I-70 P3
Date Drilled:	1973	1973
Casing		
Top elevation:	397.4	406.7
Diameter:	16-in. SS	2-in. PVC
Length:	33	na
Screen		
Bottom elevation:	304.43	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.80-in.	na
Measuring Point Elevation:	398.2	406.7
Nonpumping Water Level		
Depth below temp. MP:	29.16	30.15
Length of temp. MP extension:	7.35 ft	0.25 ft
Depth below perm. MP:	21.81 ft	29.90
Elevation:	376.39	376.80
Date of Step Test:	1/14/87	-
Water Sample		
Time:	1:56 PM	-
Temperature:	59° F	-
Laboratory No.:		-
Distance and Direction to Piez. from PW:		9.0 ft North
Time PW Off Before Step Test:		na

Wells in Operation at Site at Time of Step Test:* 1, 6, 14, 8

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using electric droplines

SWS Crew: Sanderson, Stollhans, Wilson, Cartwright

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well I-70 No. 3

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
10:04 AM		29.16				Steel tape
10:06		29.16				" "
10:08			30.15			Steel tape
10:10			30.15			" "
10:17			30.18			Electric dropline
10:25			30.14			" "
10:28		28.90				" "
10:29		28.93				" "
10:30		28.90	30.12			" "
10:31			30.12			" "
10:32			30.12			" "
10:34			30.12			" "
10:36		28.87	30.11			" "
10:38		28.86	30.12			" "
10:39		28.87				" "
10:40	0					Pump on
10:41	1	31.94	33.03	-3.5	620	Step 1
	2		33.45			
	3		33.57			
	4		33.61	3.20	600	
10:45	5		33.66			
	6		33.70			
	8	34.96	33.73	3.16	590	Adjust rate up
10:50	10	35.07	33.73			
	12	35.18	33.78	3.20	600	
	14	34.82	33.83	3.20	600	
	16	34.83	33.87			
11:00	20		33.87			
11:05	25		33.92			
	29	34.96	33.97			
11:10	30		33.97			Decreased rate
11:11	1		33.74	2.71	550	Step 2
	2		33.72			
	3		33.75			
	4		33.69			
11:15	5		33.69			
	6		33.68	2.72	550	
	8	34.49	33.68			
11:20	10		33.69			
	12	34.51	33.68			
	14	34.47	33.68	2.73	550	
	16	34.48	33.68			
11:30	20	34.50	33.68			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 3

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	25	34.50	33.69			
	28			2.74	550	
	29	34.51	33.68	2.73	550	
11:40	30	34.49	33.69			Decreased rate
11:41	1	33.97	33.47	2.22	500	Step 3
	2		33.41			
	3	33.98	33.37			
	4		33.37			
11:45	5	33.98	33.36			
	6	33.94	33.36			
	8	33.96	33.36	2.23	500	
11:50	10	33.96	33.36			
	12	33.95	33.35			
	14	33.96	33.35			
	16	33.94	33.35			
12:00 PM	20	33.94	33.34			
	24			2.22	500	
12:05	25	33.94	33.34			
	29	33.94	33.35			
12:10	30	33.94	33.35			Decreased rate
12:11	1	33.49	33.15	1.80	450	Step 4
	2	33.45	33.07			
	3	33.46	33.05			
	4	33.45	33.04			
12:15	5	33.45	33.03			
	6	33.42	33.03			
	8	33.43	33.03			
12:20	10	33.42	33.03			
	12	33.43	33.02			
	14	33.43	33.02			
	16	33.49	33.02			
12:30	20	33.42	33.01	1.81	450	
	25	33.41	33.01			
	29	33.40	33.01			
12:40	30	33.41	33.01			Decreased rate
12:41	1	32.93	32.78			Step 5
	2	32.91	32.73	1.41	400	
	3	32.90	32.73			
	4	32.90	32.71			
12:45	5	32.92	32.71			
	6	32.91	32.69			
	8	32.88	32.70			
12:50	10	32.89	32.67			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 3

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	12	32.88	32.67			
	14	32.87	32.67			
	16	32.87	32.67	1.42	400	
1:00	20	32.86	32.65			
	26	32.84	32.65			
	29	32.84	32.64			
1:10	30	32.86	32.64			Decreased rate
1:11	1	32.41	32.44	1.10	355	Step 6
	2	32.39	32.38			
	3	32.40	32.36			
	4	32.39	32.36			
1:15	5	32.39	32.36			
	6	32.38	32.35	1.10	355	
	8	32.39	32.35			
1:20	10	32.37	32.33			
	12	32.37	32.33			
	14	32.37	32.34			
	16	32.36	32.33			
	17			1.10	355	
1:30	20	32.36	32.32			
	25	32.35	32.32			
	29	32.35	32.32			
1:40	30	32.35	32.32			Decreased rate
	1	31.89	32.11	0.80	300	Step 7
	2	31.85	32.04			
	3	31.85	32.02			
	4	31.85	32.01			
1:45	5	31.84	32.00			
	6	31.82	32.00			
	8	31.82	32.00			
1:50	10	31.83	32.00			
	12	31.82	31.99			
	14	31.81	31.98			
	16	31.82	31.98			Water sample collected
2:00	20	31.80	31.97			Temp. = 59° F
	25	31.81	31.97			
	29	31.80	31.96			
2:10	30		31.96			End of test

DEWATERING WELL DATA

	Well No. I-70 W4	Piezometer No. I-70 P4
Date Drilled:	1973	1973
Casing		
Top elevation:	na	398.9
Diameter:	16-in. SS	2-in. PVC
Length:	na	na
Screen		
Bottom elevation:	303.13	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.80-in.	na
Measuring Point Elevation:	389.1	398.9
Nonpumping Water Level		
Depth below temp. MP:	21.66	23.84
Length of temp. MP extension:	8.35	-
Depth below perm. MP:	13.31	23.84
Elevation:	375.79	375.06
Date of Step Test:	1/8/87	-
Water Sample		
Time:	12:54 PM*	-
Temperature:	59.5° F	-
Laboratory No.:	-	-
Distance and Direction to Piez. from PW:		-
Time PW Off Before Step Test:		-
Wells in Operation at Site at Time of Step Test:		

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using McDAS

SWS Crew: Olson, Stollhans, Kelly, Wilson

* Pumped at rates of 600 to 450 gpm for 129 minutes prior to collection of water sample.

WATER LEVEL MEASUREMENTS
Well I-70 No. 4

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
10:15 AM			23.84			Steel tape
10:19			23.86			Electric dropline
10:24		21.66				Steel tape
10:32		21.53				
10:41			23.55			Piezometer is plugged
10:43						Placing transducer in
10:44		21.55				piez. Raised water level from 23.86-23.55
10:45	0					
	2	27.49		3.78		
	3					
	4	27.67				
	5	27.75				
	10	27.85		3.85		
	15	27.89				
	20	28.00		3.96		
	25	28.03		3.92	660	
11:15	30	28.05				Decrease rate
	1	27.56		3.21	600	Step 2
	5	27.48		3.19	600	
	10	27.48				
	15	27.48				
	20	27.49		3.16		Increase rate
	25	27.52				
11:45	30	27.53				Decrease rate
	1	27.10		2.70	550	Step 3
	5	27.11				
	10	27.07		2.69		
	15	27.07				
	20	27.07				
	22			2.67		Increase rate
	23			2.70		
12:10 PM	25	27.01				
	27			2.60		
	28			2.70		
12:15	30	27.09				Decrease rate
	1	26.64		2.22	500	Step 4
	5	26.66				
	10	26.64		2.22	500	
	16	26.64				
	20	26.65		2.22		
	25	26.63				
12:45	30	26.64		2.21		Decrease rate

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 4

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	1	26.20		1.82		Step 5
	5	26.18		1.81		
12:55	10	26.18				
	16	26.18				
	20	26.19		1.82	450	
	25	26.19				
1:15	30	26.19		1.81		Decrease rate
	1	25.75		1.43	400	Step 7
	5	25.69		1.43	400	
	10	25.67				
	15	25.68		1.42	400	
	20	25.69				
	25	25.70				
	30	25.73				Decrease rate
	1	25.30		1.09	350	Step 7
	5	25.25		1.10	350	
	10	25.23				
	15	25.23		1.09	350	
	20	25.23				
2:10	25	25.23				
	30	25.23		1.10	355	

DEWATERING WELL DATA

	Well No. I-70 W5	Piezometer No. I-70 P5
Date Drilled:	1973	1973
Casing		
Top elevation:	385.3	391.1
Diameter:	16-in. SS	2-in. PVC
Length:	21.4	na
Screen		
Bottom elevation:	303.91	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.80-in.	na
Measuring Point Elevation:	385.9	391.1
Nonpumping Water Level		
Depth below temp. MP:	14.74	14.66
Length of temp. MP extension:	5.3 ft	0.0 ft
Depth below perm. MP:	9.41	14.66
Elevation:	376.46	376.44
Date of Step Test:	1/13/87	-
Water Sample		
Time:	3:01 PM	-
Temperature:	59° F	-
Laboratory No.:		-
Distance and Direction to Piez. from PW:		6.5 ft East
Time PW Off Before Step Test:		na

Wells in Operation at Site at Time of Step Test:* 1, 6, 14, 8

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using electric droplines

SWS Crew: Sanderson, Stollhans, Wilson, Cartwright

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well I-70 No. 5

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
11:20 AM		14.61				Steel tape
11:25		14.75				Steel tape
11:29		10.71				Steel tape
11:31		14.74				Steel tape
11:33			14.65			Steel tape
11:34			14.66			Steel tape
11:45		14.71	14.57			Dropline
11:47		14.69				Dropline
11:48		14.70	14.58			Dropline
11:50			14.65			Steel tape
11:51			14.66			Steel tape
11:52		14.71	14.59			
11:55	0	14.71	14.58			Start Pump, Step 1
11:56	1		15.05	-4.0	665	Rusty colored water
	2	16.98	15.41	3.80	650	
	3		15.74			PW: Dropline malfunction
	4		16.02	3.76	650	Adjust rate
12:00 PM	5		16.38			Water clear
	6		16.53			
	8		16.91			
12:05	10		17.17	3.76	650	
	12	23.08	17.38			PW: New dropline 6908
	14	23.12	17.89			
	16	23.16	17.71	3.76	650	
12:15	20	23.18	17.78			
	25	23.20	17.98			
	29	23.20	18.03			
12:25	30	23.20	18.03			Decrease rate
12:26	1	22.73	17.98	3.21	600	Step 2
	2	22.68	17.94			
	3	22.64	17.91			
	4	22.69	17.90			
12:30	5	22.70	17.88			
	6	22.75	17.88	3.21	600	
	8	22.76	17.88	3.21	600	
12:35	10	22.76	17.87			
	12	22.75	17.86			
	14	22.75	17.87	3.21	600	
	16	22.73	17.88			
12:45	20	22.72	17.89			
	25	22.72	17.91	3.21	600	
	29	22.74	17.91			
12:55	30	22.78	17.90			Decrease rate

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 5

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
12:56	1	22.18	17.82	2.68	550	Step 3
	2	22.11	17.76	2.70	550	
	3	22.13	17.73			
	4	22.13	17.71			
1:00	5	22.10	17.70	2.70	550	
	6	22.13	17.69			
	8	22.14	17.68			
1:05.	10	22.14	17.68			
	12	22.13	17.69			
	14	22.13	17.68	2.71	550	
	16	22.12	17.68			
1:15	20	22.14	17.69			
	25	22.14	17.69	2.71	550	
	29	22.14	17.71			
1:25	30	22.15	17.70			Decrease rate
1:26	1	21.54	17.64	2.23	500	Step 4
	2	21.52	17.56			
	3	21.50	17.52			
	4	21.49	17.50			
1:30	5	21.52	17.47	2.21	500	
	6	21.51	17.44			
	8	21.52	17.44			
1:35	10	21.50	17.45			
	11	20.55				Steel tape
	12	21.51	17.45	2.21	500	
	14	21.51	17.45			
1:40	15	20.64				Steel tape
	16	21.51	17.46			
1:45	20	21.52	17.46			
	25	21.51	17.46			
	29	21.51	17.46	2.21	500	
1:55	30	21.51	17.46			Decrease rate
1:56	1	20.98	17.41	1.82	450	Step 5
	2	20.98	17.32			
	3	20.98	17.27			
	4	20.97	17.25			
2:00	5	20.97	17.25	1.81	450	
	6	20.97	17.23			
	8	20.96	17.22			
2:05	10	20.96	17.23	1.81	450	
	12	20.96	17.23			
	14	20.96	17.23			
	16	20.97	17.23	1.81	450	

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 5

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
2:15	20	20.97	17.23			
	25	20.97	17.24			
	29	20.97	17.24	1.81	450	
2:25	30	20.97	17.24			Decrease rate
2:26	1	20.40	17.	1.42	400	Step 6
	2	30.38	17.06			
	3	20.37	17.02			
	4	20.37	17.00			
2:30	5	20.38	17.00			
	6	20.38	16.99	1.43	400	
	8	20.38	16.98			
2:35	10	20.38	16.98			
	12	20.38	16.97	1.43	400	
	14	20.39	16.97			
	16	20.38	16.97			
2:45	20	20.39	16.97			
	25	20.39	16.97	1.43	400	
	29	20.39	16.97			
2:55	30	20.39	16.97			Decreased rate
2:56	1	19.86	16.87	1.11	350	Step 7
	2	19.83	16.81			
	3	19.83	16.78			
	4	19.84	16.77			
3:00	5	19.83	16.74			T - 59° F
	6	19.83	16.74			Water sample collected
	8	19.84	16.75			
3:05	10	19.84	16.74			
	12	19.83	16.74			
	14	19.84	16.75	1.11	350	
	16	19.83	16.75			
3:15	20	19.84	16.78	1.11	350	
	25	19.84	16.74			
	29	19.84	16.76			
3:25	30	19.84	16.75			

DEWATERING WELL DATA

	Well No. I-70 W12	Piezometer No. I-70 P12
Date Drilled:	1980	1980
Casing		
Top elevation:	405.5	408.49
Diameter:	16-in. SS	2-in. PVC
Length:	na	na
Screen		
Bottom elevation:	na	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.80-in.	na
Measuring Point Elevation:	404.31	408.49
Nonpumping Water Level		
Depth below temp. MP:	16.26	Piezometer
Length of temp. MP extension:	4.4 ft	plugged
Depth below perm. MP:	11.86	-
Elevation:	392.45	-
Date of Step Test:	7/30/86	-
Water Sample		
Time:	11:00 AM	-
Temperature:	59° F	-
Laboratory No.:	86062303C 86062306C	-

Distance and Direction to Piez. from PW: 6.0 ft NW

Time PW Off Before Step Test: na

Wells in Operation at Site at Time of Step Test:* 1, 6, 7, 8

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using McDAS

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well I-70 No. 12

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
8:35 AM		16.26				Steel tape
8:42			10.80			Steel tape
8:53			11.66			Dropline
8:58		18.45				Dropline
9:01		18.45				Installed transd. in
9:03		18.46	11.37			piez.
9:05		18.45	11.37			
9:07			11.37			
9:08		18.45	11.36			
9:10	0					Pump on
9:11	1	28.70	11.35			Step 1
	2	28.63	11.36	1.77	445	
	3	38.54	11.36			
	4	28.51	11.35	1.77	445	
9:15	5	28.54	11.36			
	6	28.51	11.36			
	8	28.53	11.36			
9:20	10	28.52	11.36	1.79	450	
	12	28.51	11.36			
	14	28.50	11.36			
	16	28.45	11.36			
9:30	20	28.45	11.36	1.83	452	Piez. plugged
	25	28.45	-			
	29	28.44	-	1.83	452	
9:40	30	28.44	-			Decreased rate
	1	27.89	-			Step 2
	2	-	-	1.60	420	Rate too high
	3.5	27.12	-			
	4	27.14	-			
9:45	5	27.14	-	1.40	400	
	6	27.14	-			Blew out piez. well,
	8	27.14	-			trying to unplug well
9:50	10	27.13	-	1.40	400	
	12	27.14	33.28			
	14	27.14	33.26			
	16	27.13		1.40	400	
10:00	20	27.13	33.25	1.40	400	
	25	27.13	33.24			
	29	27.14	33.24	1.40	400	
10:10	30	27.14	33.24			Decreased rate
	1	26.04	33.22	1.08	350	Step 3
	2	26.05	33.22	1.08	350	
	3	26.07	33.22			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 12

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	4	26.06	33.22	1.08	350	
10:15	5	26.06	33.22		Temp.	of disch. 60° F
	6	26.06	33.22			
	8	26.05	33.22			
10:20	10	26.05	33.22	1.08	350	
	12	26.06	33.22			
	14	26.06	33.22			Piez. still plugged
	16	26.06	33.22			
10:30	20	26.06	33.22	1.08	350	
	25	26.06	33.22			
	29	26.07	33.22			
10:40	30	26.07	33.20	.80	300	Decreased rate
	1	25.04	33.20			Step 4
	2	25.02	33.20			
	3	25.01	33.20	.80	300	
	4	25.01	33.20			
10:45	5	25.01	33.20			
	6	25.01	33.20			
	8	25.00	33.20	.80	300	
10:50	10	25.00	33.20			
	12	25.01	33.20			
	14	25.01	33.20			
	16	25.01	33.20	.80	300	
11:00	20	25.02	33.20			Water sample taken,
	25	25.04	33.19	.80	300	T = 59° F
	29	25.04	33.19			Bottle #86062303C
11:10	30	25.04	33.19	.80	300	#86062306C

DEWATERING WELL DATA

	Well No. I-70 W14 (7a)	Piezometer No. I-70 P14 (7a)
Date Drilled:	1986	1986
Casing		
Top elevation:	-	-
Diameter:	16-in. SS	2-in. PVC
Length:	-	na
Screen		
Bottom elevation:	-	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	-	na
Measuring Point Elevation:	na	na
Nonpumping Water Level		
Depth below temp. MP:	-	-
Length of temp. MP extension:	7.02 ft	-
Depth below perm. MP:	6.23 ft	11.42 ft
Elevation:	-	-
Date of Step Test:	7/23/87	-
Water Sample		
Time:	2:24 PM	-
Temperature:	61° F	-
Laboratory No.:	87072003 87072006	-
Distance and Direction to Piez. from PW:		5 ft E

Time PW Off Before Step Test:

Wells in Operation at Site at Time of Step Test:*

Notes: SWS 8-ln. dia. orifice tube w/plate No. 4
Data collected using electric droplines

SWS Crew: Sanderson, Nealon, Hammen

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well I-70 No. 14 (7a)

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
8:29 AM			11.42			5.11' top of rim to well cover plate Steel tape
			11.42			Steel tape
9:06		6.23				Steel tape
9:14	0	13.20	11.54			Droplines
9:15	0	13.19	11.54			
9:18	0					Pump on
9:19	1	17.29	14.44	0.81	300	Step 1; start of test
	2	17.05	14.40			
	3	17.09	14.43	0.80	300	PW extension 7.02'
	4	17.12	14.47			
	5	17.16	14.50			
	6	17.19	14.50	0.80	300	
	8	17.22	14.55			
9:28	10	17.25	14.59	0.79	300	
	12	17.28	14.60			
	14	17.29	14.62			
	16	17.29	14.63	0.79	300	
9:38	20	17.32	14.65			
	25	17.33	14.66			
	29	17.34	14.66			
9:48	30	17.34	14.68			Increase rate
	1	17.86	15.06			Step 2
	2	18.05	15.18			
	3	17.94	15.12			
	4	17.94	15.11	1.07	350	
	5	18.00	15.17			
	6	18.02	15.17			
	8	18.02	15.17			
9:58	10	18.04	15.17	1.08	350	
	12	18.05	15.20			
	14	18.05	15.21			
	16	18.06	15.22			
10:08	20	18.06	15.22	1.08	350	
	25	18.07	15.22			
	29	18.08	15.23			
10:18	30	18.08	15.23			Increase rate
	1	18.78	15.67	1.42	400	Step 3
	2	18.74	15.70			
	3	18.75	15.72			
	4	18.76	15.72			
	5	18.77	15.72			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 14 (7a)

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	6	18.77	15.73	1.42	400	
	8	18.77	15.73			
10:28	10	18.78	15.73			
	12	18.80	15.76			
	14	18.80	15.76			
	16	18.80	15.76	1.42	400	
10:38	20	18.82	15.77			
	25	18.82	15.78			
	29	18.82				Increase rate
10:48	30	18.82				
	1	19.44	16.21	1.79	450	Step 4
	2	19.45	16.23			
	3	19.47	16.24			
	4	19.49	16.25			
	5	19.48	16.27			
	6	19.49	16.26			
	8	19.50	16.28	1.79	450	
10:58	10	19.51	16.28			
	12	19.52	16.29			
	14	19.52	16.30			
	16	19.53	16.31			
11:08	20	19.52	16.31	1.79	450	
	25	19.55	16.31			
	29	19.54	16.32			
11:18	30	19.54	16.32			Increase rate
	1	20.18	16.78	2.22	500	Step 5
	2	20.21	16.80			
	3	20.22	16.81			
	4	20.22	16.81			
	5	20.24	16.83			
	6	20.23	16.83	2.22	500	
	8	20.23	16.83			
11:28	10	20.24	16.84			
	12	20.24	16.84			
	14	20.25	16.85			
	16	20.25	16.85			
11:38	20	20.26	16.85			
	25	20.28	16.85			
	29	20.28	16.87			
11:48	30	20.28	16.87			Increase rate
	1	20.90	17.28	2.70	550	Step 6
	2	20.92	17.31			
	3	20.93	17.33			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 14 (7a)

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	4	20.95	17.34			
	5	20.96	17.35			
	6	20.96	17.35	2.68	550	
	8	20.97	17.37			
11:58	10	20.97	17.37			
	12	20.97	17.37			
	14	20.98	17.37			
	16	20.98	17.38	2.68	550	
12:08 PM	20	20.97	17.39			
	25	20.98	17.40			
	29	20.99	17.40			
12:18	30	20.99	17.39			Increase rate
	1	21.65	17.87	3.22	600	Step 7
	2.5	21.69	17.87			
	3	21.68	17.88			
	4	21.69	17.90			
	5	21.70	17.90			
	6	21.71	17.91	3.22	600	Sun in; breeze up
	8	21.71	17.92			Sun back out already
12:28	10	21.71	17.93			
	12	21.72	17.93			
	14	21.73	17.93			
	16	21.73	17.93	3.22	600	
12:38	20	21.74	17.94			
	25	21.74	17.95			
	29	21.74	17.97			
12:48	30	21.74	17.96			Increase rate
	1	22.40	18.42	3.80	650	Step 8
	2	22.42	18.43			
	3	22.43	18.42			4.91' between 15' & 20'
	4	22.43	18.42			beads on piez. dropline
	5	22.44	18.43			
	7	22.47	18.45			
	8	22.47	18.46	3.80	650	
12:58	10	22.46	18.46			
	12	22.46	18.46			
	14	22.47	18.46			
	16	22.47	18.47			
1:08	20	22.47	18.47			
	25	22.48	18.47			
	29	22.49	18.47			
1:18	30	22.49	18.49			Increase rate
	1	22.99	18.85	4.34	700	Step 9

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 14 (7a)

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	2	23.03	18.87			
	3	23.04	18.88			
	4	23.04	18.89			
	5	23.05	18.90			
	6	23.05	18.90	4.29	700	
	8	23.09	18.93	4.35	700	Rate adjusted
1:28	10	23.15	18.95			
	12	23.12	18.95	4.34	700	
	14	23.13	18.95			
	16	23.13	18.96			
1:38	20	23.14	18.96	4.35	700	
	25	23.15	18.98			
	29	23.16	18.97			
1:48	30	23.15	18.98			Increase rate
	1	23.83	19.44	5.04	750	Step 10
	2	23.85	19.46			
	3	23.85	19.47			
	4	23.85	19.47			
	5	23.87	19.49			
	6	23.87	19.49			
	8	23.88	19.51			jsn meas. for reh
1:58	10	23.88	19.51	5.05	750	
	12	23.88	19.51			
	14	23.88	19.55			
	16	23.89	19.54			
2:08	20	23.89	19.54			
	25	23.90	19.54			
	29	23.91	19.53			
2:18	30	23.91	19.53			Increase rate
2:19	1			5.33		Step 11
	2					End of test
2:24	6					Samples kit C-- Temp. - 61° F

DEWATERING WELL DATA

	Well No. I-64 Wl	Piezometer No. I-64 Pl
Date Drilled:	3/31/75	1975
Casing		
Top elevation:	398.75	-
Diameter:	16-in. SS	2-in. PVC
Length:	34.6 ft	na
Screen		
Bottom elevation:	303.85	na
Diameter:	16-in. SS	2-in. PVC
Length:	60.3 ft	3 ft
Slot size:	0.80-in.	na
Measuring Point Elevation:	399.7	Top broken
Nonpumping Water Level		
Depth below temp. MP:	-	-
Length of temp. MP extension:	8.34 ft	-
Depth below perm. MP:	21.37 ft	28.28 ft
Elevation:	378.33	-
Date of Step Test:	7/21/87	-
Water Sample		
Time:	3:28 PM	-
Temperature:	61° F	-
Laboratory No.:	87072001 87072004	-
Distance and Direction to Piez. from PW:		
Time PW Off Before Step Test:		na
Wells in Operation at Site at Time of Step Test:		na

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using electric droplines

SWS Crew: Sanderson, Nealon, Hammen

WATER LEVEL MEASUREMENTS
Well I-64 No. 1

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
10:00 AM	0		28.28			Steel tape
10:02	0		28.28			Steel tape
10:15		21.38				Steel tape
10:16		21.36				Steel tape
10:17		21.37				Steel tape
11:30	0	29.74	28.13			Dropline
11:33	0	29.75	28.11			Dropline
11:34	0	29.74				
11:35	0					Pump on
11:36	1	31.70	28.66	0.80		Step 1
	2	31.71	28.95			
	3	31.84	29.16	0.79		
	4	31.89	29.30			
11:40	5	31.85	29.50			
	6	31.84	29.48	0.79		
	8	32.00	29.59			
11:45	10	31.82	29.64	0.79	300	
	12	32.00	29.66			
	14	32.00	29.69			
	16	32.13	29.69			
11:55	20	31.92	29.73	0.80		
	25	31.87	29.74	0.80		
	29	31.83	29.74			
12:05 PM	30	31.81	29.73			Increase rate
12:06	1	32.24	29.84	1.08	350	Step 2
	2	32.18	29.90			
	3	32.17	29.95			
	4	32.16	29.98	1.08	350	
12:10	5	32.15	29.99			
	6	32.19	29.99			
	9	32.16	30.01			
12:15	10	32.17	30.02			
	12	32.30	30.02	1.09	350	
	14	32.20	30.04			
	16	32.20	30.04	1.09	350	
12:25	20	32.20	30.04			
	25	32.21	30.05	1.09	350	
	29	32.21	30.07			
12:35	30	32.20	30.07			Increase rate
12:36	1	32.52	30.19			Step 3
	2	32.53	30.27	1.42	400	
	3	32.53	30.31			
	4	32.54	30.31			

WATER LEVEL MEASUREMENTS (Continued)
Well I-64 No. 1

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
12:40	5	32.56	30.31	1.42	400	
	6	32.55	30.33			
	8	32.56	30.32			
12:50	10	32.55	30.35			
	12	32.57	30.54	1.43	400	
	14	32.56	30.35			
	16	32.56	30.35			
	20	32.54	30.36			EWS meas. for pump well
	25	32.54	30.36	1.42	400	
	29	32.54	30.38			
1:05	30	32.54	30.37			
1:06	1	32.87	30.48	1.81	450	Step 4
	2	32.89	30.56			
	3	32.89	30.61			
	4	32.89	30.63			
1:10	5	32.89	30.62			
	6	32.89	30.63			
	8	32.89	30.66	1.81	450	
1:15	10	32.89	30.65			
	12	32.90	30.65			
	14	32.91	30.66			
	16	32.91	30.66	1.81	450	
1:25	20	32.92	30.68			
	25	32.94	30.68	1.81	450	
	29	32.94	30.68			
1:35	30	32.94	30.68			
1:36	1	33.24	30.78			Step 5 - REH record
	2	33.24	30.88			JSN meas.
	3	33.23	30.90			
	4	33.23	30.90			
1:40	5	33.23	20.92			
	6	33.23	30.93	2.24	500	
	8	33.23	30.92			
1:45	10	33.22	30.93			
	12	33.22	30.92			
	14	33.22	30.92	2.24	500	
	16	33.22	30.92			
1:55	20	33.23	30.92	2.24	500	
	25	33.22	30.92			
	29	35.23				
2:05	30	33.23				
2:06	1	33.50	30.98	2.70	550	Step 6
	2	33.56	31.08			

WATER LEVEL MEASUREMENTS (Continued)
Well I-64 No. 1

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	3	33.55	31.14			
	4	33.58	31.17			
2:10	5	33.58	31.18			
	6	33.58	31.20			
	8	33.58	31.19	2.73	550	
2:15	10	33.59	31.22			
	12	33.58	31.21			
	14	33.58	31.20			
	16	33.59	31.22	2.73	550	
2:25	20	33.60	31.21			
	25	33.59	31.21	2.73	550	
	29	33.60				
2:35	30		31.22			No reading -- Increased rate too soon
2:36	1	33.99	31.34	3.25	600	Step 7
	2	33.92	31.40			
	3	33.93	31.42			
	4	33.93	31.45			
2:40	5	33.94	31.46			
	6	33.95	31.48	3.26	600	
	8	33.95	31.48			
2:45	10	33.95				
	12	33.96	31.48			
	14	33.96	31.49			
	16	33.96	31.50	3.28	600	
2:55	20	33.97	31.50			
	25	33.97	31.50			
	29	33.98	31.50			
	30	33.98	31.50			Increase rate
3:06	1	34.24	31.59	3.78	650	Step 8
	2	34.28	31.66			
	3	34.29	31.70			
	4	34.29	31.73			
3:10	5	34.29	31.75			
	6	34.30	31.75			
	8	34.30	31.76			
3:15	10	34.31	31.78			
	12	34.31	31.78	3.80	650	
	14	34.32	31.78			
	16	34.32	31.78			
3:25	20	34.32	31.78	3.81	650	Sample collected
	25	34.33	31.79			at 3:28 - 61° F
	29	34.33	31.78	3.82	650	Sample kit A

WATER LEVEL MEASUREMENTS (Continued)
Well I-64 No. 1

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
3:35	30	34.34	31.79	3.82		Pipe ext. - 8.34'

DEWATERING WELL DATA

	Well No. 25th St. W6	Piezometer No. 25th St. P6
Date Drilled:	7/14/75	7/14/75
Casing		
Top elevation:	395.57	404.47
Diameter:	16-in. SS	2-in. PVC
Length:	34.17	na
Screen		
Bottom elevation:	301.40	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.80-in.	na
Permanent MP Elevation:	395.57	404.47
Nonpumping Water Level		
Depth below temp. MP: (pit cover plate)	21.75	17.54*
Length above perm. MP:	-	-
Depth below perm. MP:	-	17.54
Elevation:	-	386.93
Date of Step Test:	1/7/87	-
Water Sample		
Time:	12:18 PM	-
Temperature:	59˚ F	-
Laboratory No.:	na	-

Distance and Direction to Piez. from PW: 4.85 ft NW

Time PW Off Before Step Test: several weeks

Wells in Operation at Site at Time of Step Test:** 1, 2, 3, 5

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using electric droplines

SWS Crew: Olson, Stollhans, Kelly, Wilson

* Test data indicates piezometer is plugged
** Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well 25th St. No. 6

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
9:33 AM		21.75				Steel tape
9:35			17.54			" "
9:39		21.71	17.57			Electric dropline
9:41						
9:44		21.72				
9:45	0					Start; Plate 4
	1			5.41	775	Step 1
	2	27.10				
	3	27.12				
	4	27.17				
9:50	5	27.19				
	6	27.18		5.40	775	
	8	27.20				
9:55	10	27.20				
	12	27.20				
	14	27.22				
	16	27.25				
10:05	20	27.25				
	25	27.26				
	29	27.28				
10:15	30	27.29				Decrease rate
10:16	1	26.74				Step 2
	2	26.76		4.40	700	
	3	26.77				
	4	26.76				
10:20	5	26.76				
	6	26.76				
	8	26.76		4.40	700	
10:25	10	26.76				
	12	26.77				
10:29	14	26.78				
	16	26.78				
10:35	20	26.79		4.39	700	
	25	26.79				
	29	26.80				
10:45	30	26.81				Decrease rate
	1	26.45				Step 3
	2	26.45	17.53	3.76	650	
10:50	5	26.51				
10:55	10	26.48		3.76	650	
	15	26.09				
11:35	20	26.06		3.20	600	
	25	26.11				

WATER LEVEL MEASUREMENTS (Continued)
Well 25th St. No. 6

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	29	26.10				
11:45	30	26.160		2.69	550	Decrease rate
	5	25.75				Step 5
	10	25.78	17.50	2.70	550	
	15	25.78				
	20	25.79				
	25	25.80		2.71	550	
12:15 PM	30	25.83				Decrease rate
	2	25.42		2.21	500	Step 6
	4					Water sample collected
	5	25.40				Temp. - 59° F
	10	25.42				
	15	25.45		2.22	500	
	20	25.42				
	26	25.42				
12:45	30	25.42		2.21	500	Decrease rate
	1			1.79	450	Step 7
	2	25.10		1.78	450	
	5	25.11				
	10	25.11				
	15	25.13				
	20	25.12		1.78	450	
	25	25.12		1.78	450	
1:15	30	25.12				

DEWATERING WELL DATA

	Well No. 25th St. W9	Piezometer No. 25th St. P9
Date Drilled:	3/26/74	1974
Casing		
Top elevation:	408.5	414.7
Diameter:	16-in. SS	2-in. PVC
Length:	47 ft	na
Screen		
Bottom elevation:	301.41	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.80-in.	na
Measuring Point Elevation:	409.4	414.7
Nonpumping Water Level		
Depth below temp. MP:	26.56	26.67
Length of temp. MP extension:	5.00	0
Depth below perm. MP:	21.56	26.67
Elevation:	387.84	388.03
Date of Step Test:	6/25/86	-
Water Sample		
Time:	1:24 PM	-
Temperature:	59° F	-
Laboratory No.:	86062302B 86062305B (preserved)	-
Distance and Direction to Piez. from PW:		5 ft North

Time PW Off Before Step Test:

Wells in Operation at Site at Time of Step Test:* I-70 Wl, I-70 W6, 1-70 W7, 1-70 W8, 1-64 W4, 1-64 W9, 1-64 W17, 25th St. Wl, 25th St. W2, 25th St. W3, 25th St. W5

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using electric droplines

SWS Crew:

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well 25th St. No. 9

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
10:00 AM		26.56				Steel tape
10:05			26.67			Steel tape
10:15		27.45	28.03			Dropline, piez.: 6909
10:17		27.46	28.03			pumped: 4464
10:24	0	27.46	28.03			Pump on
10:26	1		29.56			Adjusting rate
	2	30.21	29.58			
	3	30.21	29.58	.77	297	
	4	30.21	29.60			
10:29	5	30.21	29.60			
	6	30.21	29.60	.76	295	
	8	30.21	29.60			
10:34	10	30.21	29.60			
	12	30.22	29.60	.76	295	
	14	30.22	29.61			
	16	30.23	29.60			
10:44	20	30.23	29.59	.76	295	
	25	30.23	29.58			
	29	30.24	29.60			
10:54	30	30.24	29.60			Increase rate
	1	30.72	29.89	1.11	355	Step 2
	2	30.73	29.91			
	3	30.73	29.92	1.11	355	
	4	30.73	29.94			
10:59	5	30.74	29.92			
	6	30.75	29.93			
	8	30.74	29.94	1.11	355	
11:04	10	30.75	29.94			
	12	30.75	29.94			
	14	30.75	29.94			
	16	30.75	29.94	1.11	355	
11:14	20	30.78	29.94			
	25	30.80	29.95			
	29	30.80	29.95			
11:24	30	30.80	29.95	1.11	355	Increase rate
	1	31.22	30.20			Step 3
	2	31.24	30.21	1.45	405	
	3	31.24	30.22			
	4		30.22			
11:29	5	31.26	30.23			
	6	31.25	30.24			
	8	31.25	30.22	1.45	405	
11:34	10	31.24	30.22			

WATER LEVEL MEASUREMENTS (Continued)
Well 25th St. No. 9

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	12	31.23	30.24			
	14	31.24	30.25			
	16	31.24	30.25			
11:44	20	31.25	30.26	1.45	405	
	25	31.26	30.28			
	29	31.27	30.25			
11:54	30	31.27	30.26			Increase rate
	1	31.68	30.49	1.80	450	Step 4
	2	31.64	30.50			
	3	31.66	30.50			
	4	31.67	30.50			
11:59	5	31.67	30.50			
	6	31.66	30.50			
	8	31.66	30.50			
12:04 PM	10	31.67	30.51	1.81	450	
	12	31.67	30.51			
	14	31.68	30.52			
	17	31.68	30.52			
12:14	20	31.69	30.53			
	25	31.68	30.53			
	29	31.70	30.52			
12:24	30	31.70	30.53	1.81	450	Increase rate
	1		30.71	2.22	500	Step 5
	2		30.72			
	3	32.08	30.76			
	4	32.12	30.73			
12:29	5	32.10	30.74			
	6	32.08	30.73			
	8	32.08	30.74			
12:34	10	32.08	30.76			
	12	32.08	30.75	2.22	500	
	14	32.08	30.76			
	16	32.08	30.76			
12:44	20	32.11	30.76			
	25	32.11	30.76	2.22	500	
	29	32.11	30.77			
12:54	30	32.11	30.77			Increase rate
	1	32.29	30.87	2.40	520	Step 6
	2	32.28	30.87			Wide open valve
	3	32.27	30.87			
	4	32.27	30.87			
12:59	5	32.27	30.88			
	6	32.27	30.88			

WATER LEVEL MEASUREMENTS (Continued)
Well 25th St. No. 9

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	8	32.27	30.88			
1:04	10	32.28	30.88			
	12	32.28	30.87			
	14	32.29	30.88			
	16	32.29	30.90			
1:14	20	32.29	30.90			
	25	32.28	30.91			
1:23	29	32.28	30.91			End of test

DEWATERING WELL DATA

	Well No. Venice W3	Piezometer No. Venice P3
Date Drilled:	1982	1982
Casing		
Top elevation:	402.3	408.36
Diameter:	16-in. SS	2-in. PVC
Length:	26.7 ft	na
Screen		
Bottom elevation:	324.7	na
Diameter:	16-in. SS	2-in. PVC
Length:	50.9 ft	3 ft
Slot size:	0.80-in.	na
Measuring Point Elevation:	402.55	408.36
Nonpumping Water Level		
Depth below temp. MP: (pit cover plate)	17.46	16.65*
Length of temp. MP extension:	6.0	-
Depth below perm. MP:	11.46	16.65
Elevation:	391.09	391.71
Date of Step Test:	1/6/87	-
Water Sample		
Time:	3:25 PM	-
Temperature:	59° F	-
Laboratory No.:	na	-
Distance and Direction to Piez. from PW:		5.0 ft west
Time PW Off Before Step Test:		na

Wells in Operation at Site at Time of Step Test:** 2, 4, 5

Notes: SWS 8-in. dia. orifice tube w/plate No. 4
Data collected using electric droplines

SWS Crew: Olson, Stollhans, Kelly, Wilson

* Test data indicate that piezometer is partially plugged
** Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well Venice No. 3

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
12:13 PM		17.46				Steel tape
12:21			16.65			Steel tape
12:23			16.78			Electric dropline
12:25			16.91			measurements hereafter
12:26			16.98			Dropline No. 2
12:27			17.01			
12:30		17.40				Dropline No. 1
12:33			17.12			
12:34		17.30				
12:35		17.30	17.12			
12:37			17.14			
12:38			17.15			
12:39			17.12			
12:40	0					Start test
	1	25.62	17.38	5.45	775	Step 1
	2.5		17.49			Plate No. 4
	3	25.91	17.55			
	4	26.09	17.65			
12:45	5	26.21	17.78			
	6	26.24	17.87			
	8	26.34				
	9		18.08			
12:50	10	26.46	18.20	5.45	775	
	12	26.48	18.33			
	14	26.52	18.46			
	16	26.56	18.54			
1:00	20	26.63	18.76	5.45	775	
	25	26.70	18.98			
	29	26.73	19.18			
1:10	30	26.77	19.22			Decrease rate
1:11	1	26.42	19.28	5.02	750	Step 2
	2	26.42	19.32			
	3	26.41	19.37			
	4	26.41	19.42			
1:15	5	26.44	19.46	5.02	750	
	6	26.44				
	7		19.55	5.02	750	
	8	26.46	19.58			
1:20	10	26.50	19.66			
	12	26.51	19.75			
	14		19.82			
	16	26.52	19.90	5.03	750	
1:30	20	26.55	20.03			

WATER LEVEL MEASUREMENTS (Continued)
Well Venice No. 3

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	25	26.58	20.19			
	29	26.60	20.30	5.03	750	
1:40	30	26.58	20.31			Decrease rate
1:41	1	26.06	20.33	4.40	700	Step 3
	2	26.09	20.35			
	3	26.09	20.37			
	4	26.09	20.39			
1:45	5	26.09	20.42			
	6	26.09	20.43	4.40	700	
	8	26.04	20.47			
1:50	10	26.04	20.51			
	12	26.04	20.55			
	14	26.04	20.59			
	16	26.04	20.65	4.40	700	
2:00	20	26.08	20.69			
	25	26.10	20.79			
	29	26.11	20.85	4.40	700	
2:10	30	26.12	20.86			Decrease rate
2:11	1	25.56	20.88	3.76	645	Step 4
	2	25.54	20.90			
	3	25.52	20.92	3.77	645	
	4	25.50	20.92			
2:15	5	25.50	20.93			
	6	25.49	20.95			
	8	25.48	20.98			
2:20	10	25.48	21.00			
	12	25.50	21.03			
	14	25.50	21.07			
	16	25.50	21.08			
2:30	20	25.51	21.14	3.75	645	
	25	25.52	21.21			
	29	25.54	21.27			
2:40	30	25.53	21.27			Decrease rate
2:41	1	24.94	21.28	3.18	595	Step 5
	2	24.92	21.29			
	3	24.90	21.31	3.19	595	
	4	24.90	21.32			
2:45	5	24.89	21.33	3.19	595	
	6	24.89	21.34			
	8	24.89	21.35			
2:50	10	24.89	21.36			
	12	24.89	21.38			
	14	24.89	21.40	3.19	595	

WATER LEVEL MEASUREMENTS (Continued)
Well Venice No. 3

Hour	Time (min)	Adjusted depth to water in well (ft)	Adjusted depth to water in piezometer (ft)	Orifice tube piez. (ft)	Pumping rate (gpm)	Remarks
	16	24.89	21.42			
3:00	20	24.90	21.46			
	25	24.90	21.50	3.18	595	
	29	24.90	21.54			
3:10	30	24.90	21.55			Decrease rate
3:11	1	24.41	21.55	2.70	550	Step 6
	2	24.39	21.59	2.71	550	
	3	24.38	21.58			
	4	24.38	21.57			
3:15	5	24.38	21.57			
	6	24.37	21.58	2.71	550	
	8	24.37	21.61			
3:20	10	24.37	21.62			
	12	24.37	21.62			
	14	24.36	21.63			
	16	24.36	21.64			
3:30	20	24.35	21.67			
	25	24.36	21.71			
	29	24.35	21.72			
3:40	30	24.35	21.73			

Appendix B.

Chemical Analyses of Dewatering Wells

Appendix B. Chemical Quality of Ground Water at IDOT Dewatering Sites

Site	I-70	I-70	I-70	I-70	I-70
Well No.	3	3	4	5	12
Section Location T.2N., R.9W., St. Clair Co.	7.7b	7.7b	7.7b	7.7b	7.7b
Date Collected	6/24/86	1/14/87	1/8/87	1/13/87	7/30/86
Laboratory No.	221686	221954	221949	221953	221717
Iron (Fe), mg/1	14.8	8.7	6.9	7.5	18.1
Manganese (Mn), mg/1	0.86	0.81	0.95	0.88	0.69
Calcium (Ca), mg/1	162	211	219	187	172
Magnesium (Mg), mg/1	40.0	40.8	40.0	38.8	47.0
Sodium (Na), mg/1	180.0	99.0	33.6	33.2	86.0
Potassium (K), mg/1	<0.1	<0.1	4.8	<0.1	<0.1
Silica ($Si0_2$), mg/1	31.6	31.6	29.6	31.1	34.4
Fluoride (F), mg/1	<0.1	0.6	0.5	0.4	0.3
Nitrate ($N0_3$), mg/1	<0.2	<0.2	0.9	1.2	<0.2
Chloride (C1), mg/1	230	154	79	83	185
Sulfate ($S0_4$), mg/1	300	266	221	195	250
Alkalinity (as $CaC0_3$), mg/1	444	416	369	360	360
Hardness (as $CaC0_3$), mg/1	569	6.94	711	626	622
Total dissolved minerals, mg/1	1250	1074	854	787	1050
Turbidity (lab)	<1	70	53	62	<1
Color	<1	<1	<1	<1	<1
Odor	None	None	None	None	None
pH (lab)	7.3	6.9	7.0	7.1	7.1
Temperature, °F	60	59	59.5	59	na

Appendix B. Concluded.

Site	I-70	I-64	25th St.	25th St.	Venice
Well No.	14 (7a)	1	6	9	3
Section Location T.2N., R.9W., St. Clair Co.	7.7b	7.7a	17.6d	17.6d	T3N.R10W 35.3g
Date Collected	7/23/87	7/21/87	1/7/87	6/25/86	1/6/87
Laboratory No.	222215	222213	221948	221687	221947
Iron (Fe), mg/1	8.3	12.3	8.4	18.9	15.3
Manganese (Mn), mg/1	0.63	0.47	0.36	0.82	0.56
Calcium (Ca), mg/1	152	221	152	123	253
Magnesium (Mg), mg/1	36.8	57.6	38.0	42.0	52.0
Sodium (Na), mg/1	50.8	40.4	15.2	17.5	39.2
Potassium (K), mg/1	9.4	8.9	3.2	<0.1	5.2
Silica (SiO_2), mg/1	33.8	31.9	33.3	32.5	34.3
Fluoride (F), mg/1	0.5	0.7	0.4	<0.1	0.7
Nitrate (NO_3), mg/1	<0.2	<0.2	<0.2	<0.2	<0.2
Chloride (C1), mg/1	98	61	26	21	55
Sulfate (SO_4), mg/1	244	411	167	190	343
Alkalinity (as $CaCO_3$), mg/1	355	456	334	352	469
Hardness (as $CaCO_3$), mg/1	531	788	536	480	845
Total dissolved minerals, mg/1	926	1183	644	688	1060
Turbidity (lab)	<1	<1	80	<1	125
Color	<1	<1	<1	- <1	<1
Odor	None	None	None	None	None
pH (lab)	7.2	7.3	7.0	7.2	7.0
Temperature, °F	61	61	59	59	59

Appendix C.

Step Test Results
Phases 1 through 4

Appendix C. Results of Step Tests on IDOT Wells

Well	Date of test	Well loss @ 600 gpm (ft)	Drawdown @ 600 gpm (ft)	Well loss portion (%)	Specific capacity (gpm/ft)	Δh* @ 600 gpm (ft)	Remarks
I-70							
No. 1	8/15/84	**	18.1 e	**	33.1 e	12.8 e	Q_{max} = 328 gpm
No. 2	7/19/83	**	11.9 e	**	50.4 e	7.9 e	Q_{max} = 500 gpm
No. 3	6/28/83	**	8.53	**	70.9	5.65	
No. 3	6/24/86	1.11	7.47	14.9	80.3	3.64	Q_{max} = 610 gpm
No. 3T	1/14/87	0.82	6.09	13.5	98.5	2.40	Q_{max} = 620 gpm
No. 4	8/16/84	.07	9.33	0.8	64.3	--	Piezometer plugged
No. 4T	1/8/87	**	5.89	**	101.9	--	Q_{max} = 660 gpm, Piezometer plugged
No. 5	7/10/84	.89	6.53	13.6	91.9	2.11	Q_{max} = 740 gpm
No. 5T	1/13/87	**	7.98	**	75.2	4.76	Q_{max} = 665 gpm
No. 6	7/19/85	.23	5.39	4.3	111.1	--	Piezmeter plugged
No. 7	6/30/83	1.88	18.55	10.1	32.3	15.0	Piezometer at 7.5 ft
No. 8	8/1/84	2.68	13.54	19.8	44.3	9.94	Q_{max} = 625 gpm
No. 9	6/28/84	**	9.46	**	63.4	5.94	Q_{max} = 630 gpm
No. 10	7/11/84	4.47 e	15.49 e	28.9	38.7 e	--	Piezometer plugged, Q_{max} = 480 gpm
No. 11	8/2/84	1.58 e	15.41 e	10.2	38.9 e	13.45 e	Q_{max} = 555 gpm
No. 12	6/16/83	0.20	3.82	5.2	157.1	--	Piezometer plugged
No. 12	7/30/86	**	13.30 e	**	45.1	--	Q_{max} = 450 gpm, Piezometer plugged
No. 14 (7a)	7/23/87	**	8.39	**	71.5	2.13	Q_{max} = 770 gpm
I-64							
No. 1	7/21/87	**	4.13	**	145.3	0.85	Q_{max} = 660 gpm
No. 2	7/25/85	.09	5.53 e	1.6	108.5	5.39	Q_{max} = 550 gpm
No. 3	6/26/84	.52	10.73 e	4.8	55.9 e	--	Piezometer plugged, Q_{max} = 525 gpm
No. 4	7/15/85	.66	4.40	15.0	127.9	--	Piezometer plugged
No. 9	10/5/83	0.37	6.22	5.9	96.5	2.3	
No. 10	7/11/84	**	7.46	**	80.4	2.73	Q_{max} = 605 gpm

Appendix C. Concluded

Well	Date of test	Well loss @ 600 gpm (ft)	Drawdown @ 600 gpm (ft)	Well loss portion (%)	Specific capacity (gpm/ft)	h* @ 600 gpm (ft)	Remarks
I-64 (Cont'd)							
No. 11	8/14/84	**	7.22 e	**	83.1 e	3.2 e	Q_{max} = 520 gpm
No. 12	7/18/85	.17	6.22 e	2.8	96.4	1.30 e	Q_{max} = 590 gpm
No. 13	7/12/84	**	6.44	**	93.2	2.65	Q_{max} = 600 gpm
No. 15	6/29/83	4.29	9.94	43.2	60.4	4.6	
25th St.							
No. 2	7/20/83	0.54	5.69	9.5	105.4	1.1	
No. 3	8/26/85	.03	4.89	0.6	121.7	1.75	
No. 6	6/27/84	.14	9.44	1.5	63.6	--	Piezometer plugged, Q_{max} = 775 gpm
No. 6T	1/7/87	0.23	4.38	5.3	137.0	--	Q_{max} = 775 gpm, Piezometer plugged
No. 8	6/15/83	0.11	4.70	2.3	127.6	1.5	
No. 9	6/25/86	**	5.55 e	**	110.4	2.04 e	Q_{max} = 520 gpm
No. 10	7/26/85	**	9.56	**	62.8	3.59	
Venice							
No. 1	11/30/83	2.29	18.04 e	12.7	34.1	10.9 e	Q_{max} = 500 gpm
No. 2	11/17/83	0.05	4.70	1.0	127.6	1.2	
No. 3	11/28/83	**	9.20	**	65.2	4.2	
No. 3T	1/6/87	0.35	7.60	4.6	78.3	--	Q_{max} = 775 gpm, Piezometer plugged
No. 4	12/1/83	0.39	5.15	7.6	116.5	2.3	
No. 5	11/15/83	0.16	4.98	3.2	120.5	1.9	
No. 6	11/29/83	0.16	7.82	2.0	76.7	6.1	

e-Estimate based on interpolated values adjusted to 600 gpra
*-Head difference between pumped well and adjacent piezometer
**-Coefficient immeasurable. Turbulent well loss negligible over the pumping rates tested.
T-Denotes step test following rehabilitative treatment for that well

Appendix D.

Chemical Treatment
Field Data

CHEMICAL TREATMENT SEQUENCE

OBSERVER: Jeff Stollhans   SITE: I-70 No. 3

1. SPECIFIC CAPACITY TEST   DATE: 10/14/86

Static water level: 27.29 ft at 10:00 AM (following 30 min. of well inactivity)

Measuring point: 7.36 ft above top of vent pipe

Pump on: 10:16 AM

Pumping water level: 33.20 ft at 11:10 AM (at least 60 min. pumpage)

Orifice tube piezometer tube:	Pumping rate:
16.20 in. at 10:19 AM	495 gpm
16.20 in. at 10:24	495 gpm
17.40 in. at 10:46	517 gpm
17.40 in. at 11:00	517 gpm
13.80 in. at 11:12	465 gpm
13.20 in. at 11:20	448 gpm

(from Layne & Bowler tables)

Specific capacity: 76.8 gpm/ft

Comments: Pumping rate decreased at approx. 11:10 AM

2. 400 lbs. POLYPHOSPHATE APPLICATION   DATE: 10/14/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons   Strength: 500 mg/L (ppm)

Time - initial: 1:13 PM   Injection rate: 357 gpm
- complete: 1:20

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 gals H_2O	1000 gals H_2O
Phosphate:	300 lbs	100 lbs
Time - initial:	1:50 PM	2:05 PM
- complete:	1:54	2:07
Injection rate:	625 gpm	500 gpm

Comments: I-70 No. 1 used for water supply, the 2.5 in. fire hose is obtaining about 100 gpm. Its taking 25 minutes to fill the 2500 gal. tank. Chemical injected with a 2.5 in. fire hose.

C. DISPLACEMENT, 16,000 gallons chlorinated water

Time - initial: 2:36 PM
- complete: 4:51

Injection rate: 725 gpm per tank, an additional 400 gallons was obtained from the supply well during each injection.

Contact time: 195 min.

3. SPECIFIC CAPACITY TEST DATE: 10/15/86

Static water level: 27.30 ft at 8:20 AM (following 30 min. of well inactivity)

Measuring point: same

Pumping water level: 32.17 ft at 9:34 AM (at least 60 min. pumpage)

Pump on: 3:34 AM

Orifice tube piezometer tube: 18 in. at 9:24 AM

Pumping rate: 524 gpm (L & B tables)

Specific Capacity: 107.6 gpm/ft

4. ACIDIZATION - Inhibited Muriatic Acid DATE: 10/15/86

A. ACID INJECTION

Acid strength: 20° Be' Total gallons: 990

Time - initial: 12:39 PM
- complete: 1:45

Siphon rate per barrel: 12 to 15 gpm

Contact Time: 12:39 to 1:45 PM

B. DISPLACEMENT - nonchlorinated water

Time - initial: 2:38 PM
- complete: 2:54

Total gallons: 3500 gallons Injection rate: 150 gpm

Contact time: Started pumping to waste at 2:01 PM on 10/16

Comments: At 5:35 PM on 10/15 the pump was briefly (5 to 20 seconds) turned on. A violent reaction subsequently occurred. A mixture of 20 Be' Muatic acid and water began to run out of the vent pipe, while at the same time gas filled the pit. The fuse box exploded.

On the following day (10/16) the fuse box was replaced. At 2:01 PM the acid was pumped to waste. The initial discharge had a pH of approximately 2; at 3:20 PM the pH was 3. The pH was checked with litmus paper. This discharge was extremely foamy. 500 pounds of soda ash was added to the effluent to raise the pH before it entered the sewer.

Well Nos. I-70 No. 1 and I-70 No. 2 were on for dewatering while we were pumping the acid to waste.

5. SPECIFIC CAPACITY TEST DATE: 10/16/86

Static water level: 28.35 ft at 8:20 AM (following 30 min. of well inactivity)

Measuring point: Same

Pump On: 8:50 AM

Pumping water levels: 32.44 ft (at least 60 min. pumpage)

Orifice tube piezometer tube: 18 in. at 8:39 and 9:24 AM

Pumping rate: 448 gpm (L & B tables)

Specific capacity: 109.5 gpm/ft

Comments: The well was pumped to waste for 3 hrs. During this time the pumping water level was obtained, then one hour later the static was recorded.

6. 600 lbs. POLYPHOSPHATE APPLICATION DATE: 10/16/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons Strength: 500 mg/L (ppm)

Time - initial: 10:21 AM Injection rate: 1250 gpm
- complete: 10:23

B. INJECTION OF POLYPHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 gal. +	2500 gal. +
Polyphosphate:	300 lbs.	300 lbs.
Time - initial:	10:44 PM	11:10 PM
- complete:	10:49	11:15
Injection rate:	500 gpm	500 gpm

Comments: Additional water was added by means of continuous flow from the supply well into the holding tank. I-70 No. 2 is yielding approx. 130 gpm.

C. DISPLACEMENT, 27,000 gallons chlorinated water

Time - initial: 11:35 AM
- complete: 3:00 PM

Injection rate: 200 to >1000 gpm

Contact time: Started pumping to waste as 4:00 PM. Pump off at 10:00 PM.

Comments: Concrete seal and two PVC drains were put in I-70 No. 4. Injected approximately 2500 gals, (one tank) every 20 min.

7. SPECIFIC CAPACITY TEST DATE: 10/17/86

Static water level: 28.49 ft at 6:10 AM (following 30 min. of well inactivity)

Measuring point: Same

Pumping water level: 32.87 ft (at least 60 min. pumpage)

Pump on: 6:15 AM; Pump off: 7:15 AM

Orifice tube piezometer tube: 22.80 in. throughout test

Pumping rate: 584 gpm (L & B tables)

Specific capacity: 133.3 gpm/ft

8. 600 lbs. POLYPHOSPHATE APPLICATION DATE: 10/17/86

A. INITIAL CHLORINATION

Quantity: 2500 gal Strength: 500 mg/L (ppm)

Time - initial: 8:38 AM Injection rate: 833 gpm
- complete: 8:42

B. INJECTION OF POLYPHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 gal. +	2500 gal. +
Polyphosphate:	300 lbs.	300 lbs.
Time - initial:	8:55 AM	9:10 AM
- complete:	8:58	9:14
Injection rate:	833 gpm	725 gpm

C. DISPLACEMENT 54,000 gallons chlorinated water

Time - initial: 9:26 AM
- complete: 1:46 PM

Injection rate: 200 to >1000 gpm

Contact time: Started pumping to waste at 2:50 PM on 10/17/86

Comments: Several tanks were fed at accelerated rates. Pumped to waste for approximately 6 hrs., beginning at 2:50 PM.

9. SPECIFIC CAPACITY TEST DATE: 10/19/86

Static water level: 27.07 ft at 7:55 AM (following 30 min. of well inactivity)

Measuring point: Same

Pumping water level: 32.93 ft at 9:05 AM (at least 60 min. pumpage)

Pump on: 7:59 AM; Pump off: 9:50 AM

Orifice tube piezometer tube: 19.2 in. at 8:20 AM; 21.6 in. at 9:01 AM

Pumping rate: 536 to 566 gpm (L & B tables)

Specific capacity: 96.7 gpm/ft

10. 400 lbs. POLYPHOSPHATE APPLICATION DATE: 10/20/86

A. INITIAL CHL0RINATI0N

Quantity: 2250 gallons Strength: 500 mg/L (ppm)

Time - initial: 9:10 AM Injection rate: 750 gpm
- complete: 9:13

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity:	200 lbs.	200 lbs.
Polyphosphate:	1800 gal.	1800 gal.
Time - initial:	10:07 AM	10:22 AM
- complete:	10:10	10:25
Injection rate:	600 gpm	600 gpm

C. DISPLACEMENT 16,000 gallons chlorinated water

Time - initial: 10:39 AM
- complete: 11:55

Injection rate: 200 to >1000 gpm

Contact time: 77 min.

Comments: A total of six tank fulls as well as the continuous flow from the supply well was injected. Two tanks were injected at rates of approximately 1000 gpm.

11. SPECIFIC CAPACITY TEST DATE: 10/21/86

Static water level: 28.44 ft at 12:34 PM (new 300 ft--dropline) (following 30 min. of well inactivity)

Pump on: 12:36 PM; Pump off: 1:49 PM

Measuring point: Same

Pumping water level: 32.67 ft at 1:36 PM (dropline) (at least 60 min. pumpage)

Orifice tube piezometer tube: 22.2 in. throughout test

Pumping rate: 572 gpm (L & B tables)

Specific capacity: 135.2 gpm/ft

CHEMICAL TREATMENT SEQUENCE

OBSERVER: Jeff Stollhans SITE: I-70 No. 4

1. SPECIFIC CAPACITY TEST DATE: 10/20/86

Static water level: 20.40 ft* at 2:13 PM (following 30 min. of well inactivity) Steel tape - 19.48 ft at 2:13 PM

Measuring point: 7.45 ft above top of vent pipe

Pump on: 2:30 PM

Pumping water level: 28.52 ft at 3:33 PM (at least 60 min. pumpage)

Orifice tube piezometer tube: 20.4 in. at 2:40 PM and 3:00 PM

Pumping rate: 554 gpm (from Layne & Bowler tables)

Specific capacity: 68.23 gpm/ft

Comments: Water supply for treatment obtained from I-70 No. 5. I-70 No. 3 pumped to waste throughout the entire test.

2. 400 lbs. POLYPHOSPHATE APPLICATION DATE: 10/20/86

A. INITIAL CHLORINATION

Quantity: 2500 gals Strength: 500 mg/L (ppm)

Time - initial: 3:50 PM
- complete: 3:55

Injection rate: 500 gpm

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity:	1800 gals	1800 gals
Phosphate:	200 lbs.	200 lbs.
Time - intial:	4:00 PM	4:09 PM
- complete:	4:03	4:12
Injection rate:	600 gpm	600 gpm

C. DISPLACEMENT, 16,000 gallons chlorinated water

Time - initial: 4:10 PM
- complete: 5:00

Injection rate: 200 to >1000 gpm

Contact time: Started pumping to waste at 6:05 PM

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* Electric dropline No. 6908 measurement

3. SPECIFIC CAPACITY TEST DATE: 10/21/86

Static water level: 19.77 ft (following 30 min. of well inactivity)

Measuring point: same

Pumping water level: 27.63 ft at 11:15 AM (at least 60 min. pumpage)

Pump on: 10:02 AM

Orifice tube piezometer tube: 24 in. at 10:20 AM and 27.6 in. at 10:45 AM

Pumping rate: 596 to 638 gpm (L & B tables)

Specific Capacity: 75.83 gpm/ft

4. ACIDIZATION - Inhibited Muriatic Acid DATE: 10/21/86

A. ACID INJECTION

Acid strength: 20° Be' Total gallons: 990

Time - initial: 1:50 PM
- complete: 3:38

Siphon rate per barrel: 12 to 15 gpm

B. DISPLACEMENT

Time - initial: 3:44 PM
- complete: 4:04

Total gallons: 3000 gallons Injection rate: 150 gpm

Contact time: Acid was left in well overnight. Started pumping to waste at 7:45 AM on 10/22.

Comments:
A. 4.5 minutes/barrel, only one hose is being used to inject acid
B. Water supply was obtained directly from I-70 No. 5, this was not chlorinated.

One 2 1/2 inch firehose was run directly from I-70 No. 5 to I-70 No. 4 and placed into the 3-inch fitting

5. SPECIFIC CAPACITY TEST DATE: 10/22/86

Static water level: 20.10 ft at 11:45 AM (following 30 min. of well inactivity

Measuring point: Same

Pumping water levels: 27.06 ft at 10:45 AM (at least 60 min. pumpage)

Orifice tube piezometer tube: 22.8 in. at 10:51 AM

Pumping rate: 584 gpm (L & B tables)

Specific capacity: 83.91 gpm/ft

Comments: The well was pumped to waste for 3 hrs. During this time the pumping water level was obtained, then one hour later the static was recorded.

6. 600 lbs. POLYPHOSPHATE APPLICATION — DATE: 10/22/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons — Strength: 500 mg/L (ppm)

Time - initial: 11:53 AM — Injection rate: 833 gpm
- complete: 11:56

B. INJECTION OF POLYPHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 gal. +	2500 gal. +
Polyphosphate:	300 lbs.	300 lbs.
Time - initial:	12:06 PM	12:17 PM
- complete:	12:10	12:20
Injection rate:	750 gpm	833 gpm

Comments: Additional water was added by means of continuous flow from the supply well into the holding tank. I-70 No. 5 is yielding approx. 300 gpm from the 2 1/2" fire hose.

C. DISPLACEMENT, 30,000 gallons chlorinated water

Time - initial: 12:30 PM
- complete: 1:55

Injection rate: 300 to >1000 gpm

Contact time: Started pumping to waste as 2:57 PM, shut off at 9:00 PM.

Comments: 4 tankfuls were injected at 1000 gpm or greater during displacement.

7. SPECIFIC CAPACITY TEST DATE: 10/23/86

Static water level: 19.90 ft (following 30 min. of well inactivity)

Measuring point: Same

Pumping water level: 26.52 ft (at least 60 min. pumpage)

Pump on: 8:15 AM; Pump off: 9:15 AM

Orifice tube piezometer tube: 24 in. throughout test

Pumping rate: 596 gpm (L & B tables)

Specific capacity: 90.03 gpm/ft

8. 600 lbs. POLYPHOSPHATE APPLICATION DATE: 10/23/86

A. INITIAL CHLORINATION

Quantity: 2500 gal Strength: 500 mg/L (ppm)

Time - initial: 9:18 AM Injection rate: 833 gpm
- complete: 9:21

B. INJECTION OF POLYPHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 gal. +	2500 gal. +
Polyphosphate:	300 lbs.	300 lbs.
Time - initial:	9:28 AM	9:37 AM
- complete:	9:31	9:40
Injection rate:	833 gpm	833 gpm

C. DISPLACEMENT, 54,000 gallons chlorinated water

Time - initial: 9:46 AM
- complete: 12:48 PM

Injection rate: 300 to >1000 gpm

Contact time: Started pumping to waste at 2:00 PM on 10/23/86

Comments: Several tanks were fed at accelerated rates

9. SPECIFIC CAPACITY TEST DATE: 10/24/86

Static water level: 20.00 ft (following 30 min. of well inactivity)

Measuring point: Same

Pumping water level: 26.05 ft at 8:37 AM (at least 60 min. pumpage)

Pump on: 7:35 AM

Orifice tube piezometer tube: 22.8 in. throughout test

Pumping rate: 584 gpm from Layne & Bowler charts

Specific capacity: 97.17 gpm/ft

Comments: Dropline appears to be getting caught on flange

10. 400 lbs. POLYPHOSPHATE APPLICATION DATE: 10/24/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons Strength: 500 mg/L (ppm)

Time - initial: 9:10 AM Injection rate: 833 gpm
- complete: 9:13

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity:	200 lbs.	200 lbs.
Polyphosphate:	1800 gal.	1800 gal.
Time - initial:	9:21 AM	9:31 AM
- complete:	9:25	9:33
Injection rate:	450 gpm	900 gpm

C. DISPLACEMENT 16,000 gallons chlorinated water

Time - initial: 9:40 AM
- complete: 10:35

Injection rate: 300 to >1000 gpm

Contact time: 55 min. Started pumping to waste at 11:30 AM. Under Aylor's instruction, shut pump off for the weekend at 12:00 PM.

Additional comments: All the hoses were placed in the pits, I-70 No. 3, 4, & 5 for storage over the weekend.

11. SPECIFIC CAPACITY TEST DATE: 10/28/86

Static water level: 18.89 ft at 7:50 AM (new 300 ft--dropline)
(following 30 min. of well inactivity)
Steel tape - 18.92 ft from MP at 7:40 AM

Pump on: 8:02 AM

Measuring point: Same

WELL REHABILITATION -- I-70 No. 4 (Continued)

Pumping water level: 24.78 ft (dropline) (at 1 east 60 min. pumpage)

Orifice tube piezometer tube: 8:45 AM 22.8" = 584 gpm
9:05 22.5" = 578

Pumping rate: 578 to 584 gpm (L & B tables, 6x5 orifice)

Specific capacity: 98.13 gpm/ft

Comments: 9:10 AM Well No. 4 treatment finished -- increase in S.C. from 68.23 gpm/ft to 98.13 gpm/ft.

CHEMICAL TREATMENT SEQUENCE

OBSERVER: Ken Hlinka SITE: I-70 No. 5

1. SPECIFIC CAPACITY TEST . DATE: 10/28/86

Steel tape - 13.10 ft. at 9:50 AM

Static water level: 13.04 ft. at 10:15 AM (following 30 min. of well inactivity)

Measuring point: 5.3 ft. from access hole, same as contractors

Pumping water level: 22.49 ft. (at least 60 min. pumpage)

Orifice tube: 6" x 5" (contractors)

Orifice tube piezometer tube:	Pumping rate:
17.5 in. at 10:23 AM	517 gpm
17.0 in. at 10:49	510 gpm
16.5 in. at 11:04	503 gpm
15.5 in. at 12:18 PM	488 gpm

(from Layne & Bowler tables)

Specific capacity: 51.64 gpm/ft.

2. 400 lbs. POLYPHOSPHATE APPLICATION DATE: 10/28/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons Strength: 500 mg/L (ppm)

Time - initial: 12:35 PM Injection rate: 500 gpm
- complete: 12:40

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity:	1800 gals	1800 gals
Phosphate:	200 lbs.	200 lbs.
Time - initial:	12:42 PM	12:54 PM
- complete:	12:46	12:58
Injection rate:	300-800 gpm	300-800 gpm

Contact time: 2:20 PM - well was pumped for 20 minutes. Daryl was concerned about the low specific capacity and wanted to bring the polyphosphates and chlorine back into the well and gravel pack to soak the well. He figured the 20 minutes at - 500 gpm would bring the chemicals into the well and surrounding materials. The well was turned on at 5:00 pm and turned off at 9:20 pm.

C. DISPLACEMENT, 16,000 gallons chlorinated water

3. SPECIFIC CAPACITY TEST DATE: 10/29/86

Static water level: steel tape - 12.96 ft. at 8:00 AM

Measuring point: same

Pumping water level: 20.44 (steel tape) at 9:03 AM (at least 60 min. pumpages)

Pump on: 7:55 AM

Orifice tube piezometer tube:	Pumping rate:
17.5 in at 8:01 AM	517 gpm
18.0 in at 8:25	524 gpm
18.0 in at 8:44	524 gpm

Specific capacity: 70.0 gpm/ft.

4. ACIDIZATION - Inhibited Muriatic Acid Date: 10/29/86

A. ACID INJECTION

Acid strength: 20° Be' Total gallons: 990

Time - initial: 12:03 PM
- complete: 1:09

Siphon rate per barrel: 12 to 15 gpm

Contact time: 1:09 PM - 4:57 PM

B. DISPLACEMENT

Time - initial: 4:57 PM
- complete: 5:16 - Well No. 4 shut down

Total gallons: 3800 gallons Injection rate: 200 gpm

Contact time: 3 hours, 48 minutes

Comments: Well No. 4 used for water supply to push HCL out into the formation/pack. Two hoses attached to No. 4 - one to free discharge and the other to Well No. 5.

Free discharge from 8:40 AM-12:50 PM on 10/30/86.

5. SPECIFIC CAPACITY TEST DATE: 10/30/86

Static water level: 13.28 ft at 1:21 PM (following 30 min. of well inactivity)

Measuring point: Same

Pumping water level: steel tape - 21.2 ft. at 12:50 PM (at least 60 min. pumpage)

Orifice tube piezometer tube: 23.5 in. at 12:50 PM

Pumping rate: 590 gpm

Specific capacity: 74.5 gpm/ft.

Comments: Pumping water level was collected 3.5 hours after pumping began.

6. 600 lbs. POLYPHOSPHATE APPLICATION DATE: 10/30/86

A. INITIAL CHLORINATION:

Quantity: 2500 gallons Strength: 500 mg/L (ppm)

Time - initial: 1:35 PM Injection rate: 500 gpm
- complete: 1:40

Comments: 5 scoops powdered chlorine (2 lbs per scoop).

B. INJECTION OF POLYPHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity	2500+ gals	2500+ gals
Phosphate:	6 50-lb. bags food grade	2 50-lb. bags sodium hexameta-phosphate 4 50-lb. bags food grade
	5 2-lb. scps. baking soda	5 2-lb. scps. baking soda
Time - initial	1:49 PM	2:00 PM
- complete	1:52	2:04

Comments: While injecting polyphosphate into the well, Aylor adds water from the 200 gpm line from well No. 4 so the total volume of water is slightly greater than 2500 gallons.

C. DISPLACEMENT with 30,000 gallons chlorinated water

Time	Chlorine added
2:11 PM	20 lbs.
2:23	20 lbs.
2:35	10 lbs.
2:44	10 lbs.
2:53	10 lbs.
3:02	20 lbs.
3:11	20 lbs.
3:23	20 lbs.
	130 lbs. Total

Time - initial: 2:11 PM
- complete: 3:43

Well No. 4 was on, discharging into the tank while the water from the tank was being injected into the well.

Injection rate: 300 gpm to >1300 gpra

Contact rate: 1 hour, 31 minutes

Comments: 2600 gallons was injected within 2 min. Pump on 5:30 PM; Pump off at 10:30 PM.

7. SPECIFIC CAPACITY TEST DATE: 10/31/86

Static water level: 12.92 ft. (following 30 min. of well inactivity)

Pump on: 7:57 AM Pump Off: 9:06 AM

Measuring Point: Same

Pumping water level: 20.40 ft. (at least 60 min. pumpage)

Orifice tube piezometer tube: 23 in. at 8:29 AM
23 in. at 8:57

Pumping rate: 584 gpm

Specific capacity: 77.6 gpm/ft.

8. 600 lbs. POLYPHOSPHATE APPLICATION DATE:_ 10/31/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons Strength: 500 mg/L (ppm)

Time - initial: 9:15 AM Injection rate: 500 gpm
- complete: 9:20

B. Injection of polyphosphate, 600 lbs. total

	BATCH 1	BATCH 4
Quantity:	1800 gal	1800 gal
Phosphate:	300 lbs.	300 lbs.
Time - initial:	9:28 AM	9:42 AM
- complete:	9:31	9:46
Injection rate:	700 gpm	700 gpm

Comments: Water supply ws obtained from I-70 No. 4.

C. DISPLACEMENT with 54,000 gallons chlorinated water

Time - initial: 9:47 AM
- complete: 12:51 PM (184 min.)

Injection rate: 300-1000 gpm

Contact time: 12:51 to 2:35 PM (1 hr. 44 min.)

	Chlorine added	
Time	Scoops	lbs.
9:54	10	20 lbs.
10:15	10	20 lbs.
10:35	10	20 lbs.
10:55	10	20 lbs.
11:15	10	20 lbs.
11:35	10	20 lbs.
11:56	10	20 lbs.
12:20	10	20 lbs.
12:25	10	20 lbs.
12:35	10	20 lbs.
		200 lbs.

Comments: Varied rate of injection throughout 3 hours.

9. SPECIFIC CAPACITY TEST DATE: 10/31/86

Static water level: 13.33 ft. at 8:03 PM (following 30 min. of well inactivity)

Measuring point: Same

Pumping water level: 21.08 ft. at 7:31 PM (at least 60 min. pumpage)

Orifice tube piezometer tube: 23 in. at 8:07 PM

Pumping rate: 584 gpm (L & B tables)

Specific capacity: 75.4 gpm/ft.

Comments: 11/1/86 Pump on at 8:15 AM
Pump off at 8:40 AM

10. 400 lbs. POLYPHOSPHATE APPLICATION DATE: 11/1/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons with 10 lbs. CL

Strength: 500 mg/L (ppm)

Time - initial: 8:33 AM
- complete: 8:37

Injection rate: 625 gpm

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity:	1800 gal H_2O,	Same as Batch 1
Phosphate:	3 50-lb. bags food grade, 1 50-lb. bag Sodium Hexameta-phosphate, 2 2-lb. scoops baking soda	

Injection rate: 833 gpm

Comments: Water is constantly coming in from Well No. 4 into the tank.

C. DISPLACEMENT with 16,000 gallons chlorinated water

Time - initial: 9:07 AM
- complete: 9:57

Injection rate: 200 to 1200 gpm

Contact time: 29 hours. This application was pumped to waste from 3:00 PM to 8:00 PM on 11/2/86.

Time	Chlorine added Scoops	Chlorine added lbs.
9:06 AM	--	10 lbs.
9:18	5	10
9:20	5	10
9:25	5	10
9:37	5	10
9:48	--	15
		65 lbs.

Comments: Water was continuously added to the tank during displacement of polyphosphate - this adds 200 gpm into the tank while pumping into the well, so Aylor is adding about 1,000 gallons more for each 2500 gallon tank of displacement (3500 gal./3 min. = ~ 1200 gpm) (9:07-9:10 AM)

11. SPECIFIC CAPACITY TEST DATE: 11/3/86

Static water level: 12.72 ft. (following 30 min. of well inactivity)

Measuring point: Same

Pumping water level: 20.05 ft. (at least 60 min. pumpage)

Pump on: 11:35 AM; Pump off: 12:40 PM

Orifice tube piezometer tube: 24.6 in. at 11:45 AM
25.2 in. at 12:00 PM

Pumping rate: 608 gpm (from Layne & Bowler Charts)

Specific capacity: 82.05 gpm/ft.

CHEMICAL TREATMENT SEQUENCE

OBSERVER: Jeff Stollhans SITE: 25th St. No. 6

1. SPECIFIC CAPACITY TEST DATE: 11/19/86

Static water level: 20.66 ft. at 12:27 PM (following 30 min. minimum of well inactivity)

Measuring point: Top of vent pipe to MP (SE_C) - 8.89 ft. from (LSD)

Pumping water level: 28.25 ft. (at least 60 min. pumpage)

Pump on: 12:45 PM; Pump off 1:46 PM

Orifice tube: Contractors 6 x 5 inch

Orifice tube piezometer tube: 34.20 in.

Pumping rate: 715 gpm (from Layne & Bowler tables)

Specific capacity: 94.20 gpm/ft.

Comments: H_2S odor

2. 400 lbs. POLYPHOSPHATE APPLICATION DATE: 11/19/86

A. INITIAL CHLORINATION

Quantity: 2500 gal. Strength: 500 mg/L (ppm)

Time - initial: 3:03 PM Injection rate: 750 gpm
- complete: 3:07

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	PATCH 2
Quantity:	1800 gal.+	1800 gal.+
Polyphosphate:	200 lbs.	200 lbs.
Time - initial:	3:14 PM	3:21 PM
- complete:	3:16	3:23
Injection rate:	900 gpm	900 gpm

Comments: Water supply obtained from 25th No. 8. Three white (Aylor) blend bags and 1 brown (Monsanto) bag per 1800 gal. mixture.

C. DISPLACEMENT, 16,000.gallons chlorinated water

Time - initial: 3:30 PM
- complete: 4:10

Injection rate: Two 3500-gal. batches were injected at >1000 gpm, the remaining amount was continuously being displaced.

Contact time: Started pumping to waste at 5:10 PM, pump off at 9:15 PM

3. SPECIFIC CAPACITY TEST DATE: 12/2/86

Static water level: 20.59 ft. (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 27.40 in. at 11:31 AM (at least 60 min. pumpage)

Pump on: 10:30 AM

Orifice tube piezometer tube: 36 in.

Pumping rate: 737 gpm (L & B tables)

Specific capacity: 108 gpm/ft.

4. ACIDIZATION - INHIBITED MURIATIC ACID DATE: 12/2/86

A. ACID INJECTION

Acid strength: 20° Be' Total gallons: 990

Time - initial: 11:34 AM
- complete: 12:47 PM

Siphon rate per barrel: 12 to 15 gpm

B. DISPLACEMENT

Time - initial: 3:50 PM
- complete: 4:15

Total gallons: 3750 gallons Injection rate: 150 gpm

Contact time: Started pumping to waste at 8:42 AM on 12/3/86

Comments: Acid set in well overnight. Pump off at 11:40 AM on 12/3/86.

5. SPECIFIC CAPACITY TEST DATE: 12/3/86

Static water level: 20.59 ft. at 8:40 AM (following 30 min. minimum of well inactivity)

Pumping water level: 27.22 ft. at 11:35 AM (at least 60 min. pumpage)

Orifice tube piezometer tube: 36 in.

Pumping rate: 737 gpm (L & B tables)

Specific capacity: 111 gpm/ft.

Comments: This Q/s was obtained after the well was pumped to waste for 2 hr. 55 min.

6. 600 lbs. POLYPHOSPHATE APPLICATION DATE: 12/3/86

A. INITIAL CHLORINATION

Quantity: 2500 gal.+ Strength: 500 mg/L (ppm)

Time - initial: 11:48 AM Injection rate: 750 gpm
- complete: 11:52

B. INJECTION OF POLYPHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 gal+	2500 gal+
Phosphate:	300 lbs.	300 lbs.
Time - initial:	12:01 PM	12:11 PM
- complete:	12:05	12:15
Injection rate:	750+ gpm	750+ gpm

Comments: Injected with two 2.5 inch fire hoses. Water supply obtained from 25th Street No. 8. Well No. 8 continuously flowed into the storage tank during injection, therefore the (+) represents slightly higher volumes.

C. DISPLACEMENT with 30,000 gallons chlorinated water

Time - initial: 12:26 PM
- complete: 1:30, drive shaft broke on tank truck or would have ran until 1:56 PM. Actual displacement was with only about 20,000 gallons.

Injection rate: Four injections at 1000 gpm, the remaining was injected at a continous flow of about 316 gpm

Contact time: started pumping to waste at 2:07 PM

7. SPECIFIC CAPACITY TEST DATE: 12/4/86

Static water level: 20.88 ft. at 8:45 AM (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 27.27 ft. at 9:47 AM (at least 60 min. pumpage)

Orifice tube piezometer tube: 36 in.

Pumping rate: 737 gpm (L & B tables)

Specific capacity: 115 gpm/ft.

8. 600 lbs. POLYPHOSPHATE APPLICATION DATE: 12/4/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons Strength: 500 mg/L (ppm)

Time - initial: 9:59 AM Injection rate: 750 gpm
- complete: 10:03

B. INJECTION OF POLYPHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 gal+	2500 gal+
Phosphate:	300 lbs	300 lbs
Time - initial:	10:13 AM	10:25 AM
- complete:	10:18	10:30
Injection rate:	500 gpm	500 gpm

C. DISPLACEMENT, 50,000 gallons chlorinated water

Time - initial: 10:39 AM
- complete: 1:17 PM (158 min.)

Injection rate: 318 to > 1000 gpm, 8 applications exceeded 1000 gpm

Contact time: Started pumping to waste at 1:35 PM

Comments: Contact time was reduced to prevent the polyphosphate from traveling to the adjacent wells. The specific capacity test immediately followed this application.

9. SPECIFIC CAPACITY TEST DATE: 12/4/86

Static water level: 20.84 ft. at 1:32 PM (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 27.04 ft. (at least 60 min. pumpage)

Pump on: 1:35 PM

Orifice tube piezometer tube: 37.2 to 37.8 inches throughout

Pumping rate: 754 gpm (L & B tables)

Specific capacity: 121.6 gpm/ft.

Comments: The static water level was obtained shortly (15 min.) after displacement was complete. We reduced the contact time because it was felt that the polyphosphate was being drawn away from the well by the pumping cone created by the adjacent wells.

10. 400 lbs. POLYPHOSPHATE APPLICATION DATE: 12/5/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons Strength: 500 mg/L (ppm)

Time - initial: 9:15 AM Injection rate: 750 gpm
- complete: 9:19

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity:	1800 gal+	1800 gal+
Phosphate:	200 lbs.	200 lbs.
Time - initial:	9:25AM	9:35AM
- complete:	9:28	9:38
Injection rate:	600 gpm	600 gpm

C. DISPLACEMENT, 16,000 gallons chlorinated water

Time - initial: 9:59 AM
- complete: 10:52

Injection rate: 318 to >1000 gpm, 2 batches were injected at rates exceeding 1000 gpm

Contact time: 3 hrs. 8 min. Started pumping to waste at 2:00 PM.

11. SPECIFIC CAPACITY TEST DATE: 12/5/86

Static water level: 20.72 ft. (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 26.47 ft. at 3:02 PM (at least 60 min. pumpage)

Pump on: 2:00 PM

Orifice tube piezometer tube: 37.2 in.

Pumping rate: 759 to 754 gpm (L & B Tables)

Specific capacity: 132.0 to 131.1 gpm/ft.

CHEMICAL TREATMENT SEQUENCE

OBSERVER: Jeff Stollhans SITE: Venice No. 3

1. SPECIFIC CAPACITY TEST DATE: 11/4/86

Static water level: 13.50 ft at 9:00 AM (following 30 min. minimum of well inactivity)

Measuring point: NW corner, 6.02 ft above hole in well head, the 2-inch vent pipe appears to be broken off

Pump on: 9:35 AM

Pumping water level: 30.47 ft at 10:37 AM (at least 60 min. pumpage)

Orifice tube: Contractor's 6x5 inch

Time	Orifice Piez. Tube	Pumping Rate*	Drawdown
9:45 AM	42 in.	800 gpm	
10:20	43.2 in.	810	
10:37			16.97 ft
10:39	43.2 in.	810	

*Layne & Bowler, Inc. orifice tables (L & B tables)

Specific Capacity: 47.73 gpm/ft

Comments: Water on road (Rt. 3), Aylor van parked in front w/caution lights on.

2. 400 lbs. POLYPHOSPHATE APPLICATION DATE: 11/4/86

A. INITIAL CHLORINATI0N

Quantity: 2500 gal Strength: 500 mg/L (ppm)

Time - initial: 11:43 AM Injection rate: 416 gpm
- complete 11:49

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity mixture:	1800 gals	1800 gals
Phosphate:	200 lbs.	200 lbs.
Time - initial	11:58 AM	12:08 PM
- complete:	12:01 PM	12:12
Injection rate:	833 gpm	750 gpm

Comments: The pump/tank truck was clogged briefly, some maintenance was required. Approx. 2000 gals, of water siphoned into the well during the maintenance work.

The supply well, Venice No. 4 was capable of delivering approximately 415 gpm. Well No. 4 is located 75 ft east of Venice No. 3.

C. DISPLACEMENT, 16,000 gallons chlorinated water

Time - initial: 12:14 PM
- complete: 2:52

Injection rate: Ranged from approximately 400 to 1000 gpm

Contact time: Started pumping to waste at 2:15 PM, stopped at 7:00 PM

Comments: Approximately 415 gpm was continuously pumped into the truck tank until 16,000 gal. of displacement water was obtained. Chlorine was periodically added and mixed in the truck tank to maintain at least a 500 mg/1 chlorine residual. Most of the water was allowed to siphon/ drain from the truck tank into the well at about 400 gpm. During the displacement period, two tank fulls of water were collected and injected at approximately 1000 gpm. A similar methodology was used as the displacement procedure throughout the treatment.

3. SPECIFIC CAPACITY TEST DATE: 11/5/86

Static water level: 13.54 ft steel tape measurement (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 25.30 ft (at least 60 min. pumpage)

Orifice tube piezometer tube: 42 in.

Pumping rate: 800 gpm (L & B tables)

Specific Capacity: 68.03 gpm/ft

4. ACIDIZATION - Inhibited Muriatic Acid DATE: 11/5/86

A. ACID INJECTION

Acid strength: 20° Be' Total gallons: 990 gal.

Time - initial: 11:59 AM
- complete: 1:07 PM

Siphon rate per barrel: 12 to 15 gpm

B. DISPLACEMENT

Time - initial: 2:50 PM
- complete: 3:04 PM

Total gallons: 3500 gal. Injection rate: 250 gpm

Contact time: 17.5 hrs. Started pumping to waste at 8:30 AM on 11/6/86

Comments: Acid was displaced with water obtained directly from Venice No. 4.

5. SPECIFIC CAPACITY TEST DATE: 11/6/86

Static water level: 14.18 ft at 12:00 PM (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 25.94 ft

Orifice tube piezometer tube: 42 in.

Pumping rate: 800 gpm (L & B tables)

Specific capacity: 68.03 gpm/ft

Comments: Pumping water level taken after the well had pumped to waste for 3 hrs. Static taken 30 min. thereafter at 12:00 PM.

6. 600 lbs. POLYPHOSPHATE APPLICATION (second) DATE: 11/6/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons, one full tank Strength: 500 mg/L (ppm)

Time - initial: 12:11 PM Injection rate: 500 gpm
- complete: 12:16

B. INJECTION OF POLYPHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 gal. +	2500 gal.+
Phosphate:	300 lbs	300 lbs
Time - initial:	12:27 PM	12:37 PM
- complete:	12:31	12:41
Injection rate:	750 gpm	750 gpm

Comments: Water injected with two 2.5-in. fire hoses. Gal + represents continuous flow from supply during displacement.

C. DISPLACEMENT, 30,000 gallons chlorinated water

Time - initial: 12:45 PM
- complete: 2:00

Injection rate: 500 to >1000 gpm

Contact time: 1 hr. 5 min. Started pumping to waste at 3:05 PM. Stopped pumping at 8:45 PM

Comments: Injected 4 tanks at rates exceeding 1000 gpm. Excluding the 4 injections of >1000 gpm, the additional volume was displaced by continuously flowing. (75 min. for 30,000 gal.)

7. SPECIFIC CAPACITY TEST DATE: 11/11/86

Static water level: 13.80 ft at 8:41 AM (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 24.81 ft at 9:40 AM (at least 60 min. pumpage)

Orifice tube piezometer tube: 41.6 in.

Pumping rate: 805 gpm (L & B tables)

Specific capacity: 73.12 gpm/ft

Comments: Check valves for Venice No. 3 and Venice No. 6 are not working.

8. 600 lbs. POLYPHOSPHATE APPLICATION (third) DATE: 11/11/86

A. INITIAL CHLORINATION

Quantity: 2500 gallons Strength: 500 mg/L (ppm)

Time - initial: 9:36 AM Injection rate: 833 gpm
- complete: 9:39

B. INJECTION OF PHOSPHATE, 600 lbs. total

	BATCH 1	BATCH 2
Quantity:	2500 + gal	2500 gal. +
Phosphate:	300 lbs	300 lbs
Time - initial:	9:51 AM	10:04 AM
- complete	9:54	10:07
Injection rate:	833 gpm	833 gpm

Comments: Obtaining approximately 415 gpm from Venice No. 4. 5 Aylor (White Polyphosphate Bags) and 1 Brown (Standard Polyphosphate Bag) were used in each 300-lb. batch.

C. DISPLACEMENT, 54,000 gallons chlorinated water

Time - initial: 10:12 AM
- complete: 12:32 PM

Injection rate: 415 to >1000 gpm

Contact time: Started pumping to waste at 1:30 PM

Additional comments: Approximately 140 minutes was required to obtain 54,000 gallons. Six tanks were injected at 1000 gpm or greater. The remaining amount was by continuous gravity flow from the tank.

9. SPECIFIC CAPACITY TEST DATE: 11/12/86

Static water level: 14.15 ft at 8:53 AM (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 25.18 ft (at least 60 min. pumpage)

Orifice tube piezometer tube: 45.6 in.

Pumping rate: 832 gpm (Layne & Bowler tables)

Specific capacity: 75.43 gpm/ft

10. 400 lbs. POLYPHOSPHATE APPLICATION (fourth) DATE: 11/12/86

A. INITIAL CHLORINATION

Quantity: 2500 gal. Strength: 500 mg/L (ppm)

Time - initial: 10:23 AM Injection rate: 700 gal @ 600 gpm
- complete: 10:26 1800 gal @ 1000 gpm

B. INJECTION OF POLYPHOSPHATE, 400 lbs. total

	BATCH 1	BATCH 2
Quantity:	1800 + gal	1800 + gal
Phosphate:	200 lbs	200 lbs
Time - initial:	10:41 AM	10:51 AM
- complete:	10:43	10:53
Injection rate:	600 gpm +	600 gpm +

Comments: 3 Aylor bags of polyphosphate blend and 1 Monsanto bag of polyphosphate per batch.

C. DISPLACEMENT, 16,000 gallons chlorinated water

Time - initial: 11:00 AM
- complete: 11:40

Injection rate: Most of the water was allowed to siphon/drain from truck tank into the well at about 400 gpm. Two tanks containing 1800 gal. each were injected at rates of 1000 gpm.

Contact time: 60 min. Pumped to waste from 12:40 PM to 2:40 PM.

Additional comments: Q/S test ran next week.

11. SPECIFIC CAPACITY TEST DATE: 11/18/86

Static water level: 14.30 ft (following 30 min. minimum of well inactivity)

Measuring point: Same as previous

Pumping water level: 24.10 ft at 1:19 PM (at least 60 min. pumpage)

Pump on: 12:17 PM; Pump off: 1:19 PM

Orifice tube piezometer tube: 40.5 inches

Pumping rate: 786 gpm (L & B tables)

Specific capacity: 80.20 gpm/ft

Appendix E.

I-70 Well No. 9
Videotape Review

Appendix E. I-70 Well No. 9 Videotape Review

The videotapes of the I-70 Well No. 9 TV inspection were reviewed at the Illinois State Water Survey. The following notes were compiled by Bob Olson after careful review of the two videotapes.

TAPE #1

Counter #

146 Hit water 26 ft. Water cloudy until start of screen.

200 Can see suspended and horizontal movement of sediment. Camera proceeds on down at this point. Water appears to contain particles all the way down although their density decreased with depth.

470 Bottom reached 94 ft.

530 Begin ascent

730 Ascent halted at about 50 ft. and slow descent for a few feet. Turbidity great now and increasing

800 Back in the upper 5 ft. of screen, much turbidity is being caused by the movement of the camera.

850 Camera sitting next to pump. Pump off.

890 Pump turned back on.

925 We can see movement from the screen sides to the pump intake (or is it vertical movement?).

1035 At the pump intake 36 ft. Vertical and possibly horizontal movement of particulates. These particulates appear to be too large for sand.

1350 Particulates have cleared some. Movement can be tracked - the majority seems to be coming from below the intake.

1655 Began moving camera down into next screen. Wide weld is visible, water has cleared up. Camera proceeds on down.

1760 50-60 ft., incrustation on the well screen?

1929 On the bottom again, 94 ft. - immediately come back up.

2080 Camera set at 49 ft. until 2111. Small particles moving up.

2165 Back up to pump intake, 36 ft. Condition of the screen from 39 ft. and below seems to be consistent. Upper 5 ft. of screen is unquestionably the worst. Camera sits at the intake for some time, allowing settlement.

2265 We can see fine particles move at the pump intake.

2325 Burst of fines.

2345 Camera moving down again, much less movement of particles up.

2400 Camera has been set at 39 ft. for some time. Few fines are moving upward to the pump.

2450 Camera moved back up to pump intake at 35 ft. We can again see more fines moving to the pump.

2490 Burst of fines. It appears most of the fines are originating in the upper 5 ft. of screen based upon the predominance of fines when the camera is set at the pump intake inside the upper 5 ft. of screen versus when the camera is set at 39 ft. just below the upper 5 ft. of screen.

2580 Good shot of fines progressing to the pump intake.

2610 Camera moved up 1 ft. - some particles knocked loose.

2640 Camera moved up to 31 ft. Water very cloudy; unable to really see anything.

2680 Camera pulled up out of water, 27 ft.

2710 Camera back into water sets above top screen at 35 ft. Appears to be able to see fines move off this upper screen and to pump as we slowly move down to 39 ft. Fines do clear up some below pump intake.

2850 Fines moving horizontally off of well screen. Good Example.

2900 Fines have cleared up substantially. But we can still see some horizontal movement.

2935 Camera moved to 35 ft. More fines - slow movement some of which appears to be horizontal. Good Example.

3048 Burst of fines. Fines seem to come in bursts.

3100 Good example of the horizontal movement of fines.

3125 Camera moved down to 39 ft. At this point we can see few, very few fines coming up from the lower lengths of screen.

3330 Still at this level, no upward movement of fines is seen.

3385 Camera moved back up to 36 ft. (pump intake). There is more movement of fines.

3425 Pump turned off. Fine movement still appears to be coming off of the wall.

3490 Pump turned on.

3524 Pump turned off. Fines still suspended.

3620 Camera moved up to 33 ft. and back down to 35 ft. after fire hose has been inserted.

3655 Pump turned on for recirculation.

3665 Camera lowered to 41 ft. Little water movement. Camera face is now covered with some dirt.

3680 Camera raised to 34 ft. and back down to 45 ft. Particles still on camera face. We can only see turbulent movement of cloudiness above 38 ft.

3800 Camera lowered.

3850 Camera at bottom. Pump is off, begin camera ascent.

3930 Pump was turned on.

4000 Back at pump intake. Can see much movement of cloudy water.

4050 Camera moved to 32 ft. Picture cloudy. Moved back down to pump intake, 35 ft.

4070 Much of the fine, cloudy material seems to be originating in the screen area opposite the pump intake, whereas larger looking particles, for the most part, make up the fines coming up from the lower sections of screen.

4190 Fines disappear below 36 ft. Stayed at this level for some time, jockeying between 35 and 36 ft. Part of the problem is that we don't know what size of particles represent the extremely fine (cloudy) material in the picture. If we only knew what the sand particles looked like - how they appeared under the reflection from the camera's light.

4310 Moved camera up to 32 ft. - still cloudy - moved back down to the pump intake, 35 ft.

4345 End of tape

TAPE #2

Beginning of tape - dirty face of camera makes unclear picture. Later camera was raised out of water and lens was cleared of most particles.

34 ft. - top of screen
39 ft. - possible break in weld seam, 7 o'clock position

Counter #

Counter #	
0000	The pump is being raised along with the camera in an attempt to remove the cloudy water column at the top of the well volume. The camera lens had particles on it prior to moving the pump, but it has appeared to get worse having been drawn up into the cloudy column of water.
480	voice description of first two sections of screen
505	Water clearer in the second 5-ft. section of screen. Hard to see with dirty lens.
510	Voice description of dirty lens
630	Voice description of sand entering well
729	Camera raised out of water to clear lens. Camera was dropped down.
790	Encrustation - upper 5 ft. of screen
825	Wide weld seam noted at about 39-49 ft.
860	Voice noting unusual weld seam
900	Camera begins descent of full length of screen, examining the vertical weld as we go.
929	Voice describing location of weld in picture
1030	Can see some of the gravel pack against the screen. Screen appears to be fairly clean at this level, 70-80 ft.
1100	Well bottom, some debris but no real sign of sand build up.
1114	Voice description footage measurement error.
1243	Back at the wide weld. Camera movement has disturbed particulates in well. They appear to be moving up from below. Camera was allowed to sit at this level until 1330.
1340	Moved up a couple feet and then back down to compare particulate movement.

1397 At top of screen, camera sits awhile.

1450 Camera spent some time in upper 5 ft. of screen in an attempt to determine movement of particles. It is hard to tell if there is any horizontal movement from the screen. Most of the movement appears to be vertical.

1565 Voice explanation of measurement error again and end of survey.

1583 End of tape.

Appendix F.

Boring Results near
I-70 Well No. 9

Appendix F. Boring Results Near I-70 Well No. 9*

Depth of boring (ft)	Tyler sieve / Standard sieve	3/8 / 3/8	4 / 4	10 / 9	40 / 35	80 / 80	100 / 100	200 / 200
4		-	-	0	1.0	-	3.8	8.4
5.5		-	-	0	0.8	-	8.0	32.2
8.0		-	-	0	2.0	-	11.3	40.9
10.5		0	0.4	1.3	4.8	-	11.2	27.2
13.0		-	-	0	0.2	-	62.4	87.5
15.5		-	-	0	0.1	-	51.7	68.9
18.0		-	-	0	0.2	-	1.8	36.9
20.5		-	-	0	0	-	3.1	59.4
23.0		-	-	0	0	-	65.6	94.4
25.5		-	-	0	0	-	21.2	84.0
28.0		-	-	0	0	-	15.7	87.6
30.5		-	-	0	0	-	39.5	89.7
33.0		-	-	0	0.1	-	58.7	95.6
35.5		-	-	0	0	-	88.8	98.4
38.0		0	0	0	1.0	13.0	31.0	74.7
40.5		1.0	1.0	2.0	3.0	54.0	72.0	89.2
43.0		-	-	0	0	53.0	75.0	95.0
45.5		-	-	0	4.0	62.0	76.0	95.4
48.0		-	-	0	3.0	21.0	40.0	91.8
50.5		-	-	0	0	19.0	45.0	90.5
53.0		-	0	1.0	21.0	49.0	67.0	97.7
55.5		1.0	3.0	10.0	69.0	90.0	93.0	97.7
58.0		15.0	17.0	26.0	84.0	95.0	96.0	97.3
60.5		7.0	13.0	28.0	73.0	93.0	95.0	96.5
63.0		0	0	7.0	86.0	98.0	99.0	99.6

* Data furnished by IDOT
- = no data
0 = <0.1% by weight

Illinois Department of Transportation

Bridge Foundation Boring Log

Sh. 1 of 2 Sh.

PROJECT ______ BRIDGE FAI 70 Complex Date 3-3-87

ROUTE FAI 70 **Dewaterine Well #9** **Bored By** L. Ford

SEC. 82-3HVB-I **STA** ______ **Checked By** R. Nebelsick

COUNTY St. Clair

Boring No. 1

Station ______

Offset 15' S.of Well 9

Surface Water El. ______

Groundwater El. at Completion ______

After ______ Hours ______

Ground Surface 0

Description	Consistency	Elevation	N	Qu t/s.f.	w (%)
GRAY CLAY SAND	DAMP, MEDIUM		7	S/5 0.2	28
	DAMP, MEDIUM	5	7	S/5 0.2	24
	DAMP VERY LOOSE		2	S/5 0.2	25
	DAMP, MEDIUM	10	14	S/15 0.6	25
GRAY FINE TO MEDIUM GRAINED SAND	DAMP, MEDIUM		15	NC	5
GRAY CLAY	DAMP, SOFT	15	7	NC	14
	DAMP, MEDIUM		13	NC	13
	DAMP, STIFF	20	19	NC	7

Description	Consistency	Elevation	N	Qu t/s.f.	w (%)
BROWN AND GRAY FINE GRAINED SAND	DAMP, MEDIUM		9	NC	3
	DAMP, STIFF	25	19	NC	5
	DAMP, STIFF		20	NC	6
	DAMP, STIFF	30	19	NC	12
	WET, STIFF		18	NC	23
	WET, STIFF	35	16	NC	23
	WET, MEDIUM		15	NC	-
	WET, MEDIUM	40	24	NC	-
	WET, MEDIUM	45	23	NC	-

N-Stondard Ponetrotion Test-
Blows per foot to drive 2"
O.D. Split Spoon Sampler 12" with
140 No. hammer falling 30".

Qu-Unconfined Compressive
Strength - t/sf

w - Water Content - percentage
of oven dry weight-%.

Type failure:
B - Bulge Failure
S - Shear Failure
E - Estimated Value
P - Penetrometer

BRIDGE FOUNDATION BORING LOG

FAI 70 Section 82-3HVB-I St. Clair County Boring No. 1 Offset 15' S.of Well 9		Elevation	N	Qu t/s.f	w (%)	DATE 3-3-87 BORED BY L.Ford CHECKED BY R.Nebelsick	Elevation	N	Qu t/s.f.	w (%)
		-45					-75			
	WET, MEDIUM		25	NC	-					
	WET VERY DENSE		67	NC	-					
		-50					-80			
	WET, MEDIUM		20	NC	-					
	WET, LOOSE		9	NC	-					
		-55					-85			
	WET, LOOSE		9	NC	-					
GRAY MEDIUM TO COARSE SAND W/GRAVEL	WET, MEDIUM		15	NC	-					
		-60					-90			
	WET, MEDIUM		27	NC	-					
	WET, MEDIUM		29	NC	-					
		-65					-95			
GRAY FINE SAND	WET, DENSE		31	NC	-					
		-70					-100			
		-75					-105			

Appendix G.

I-70 Well No. 14 (7a) Construction Notes and Borings

Appendix G. Construction of IDOT I-70 Well No. 14 (7a)

November 24. 1986

6:45 AM -- Arrived at site before any activity was taking place for today. The drill rig is in position, ready for drilling. The material piled at the site is the excavated material from the mud pit. The well screen is at the site. It is 16 in. in diameter and appears to be the specified 30 ft of 55-slot screen and 30 ft of 25-slot screen, all in 15-ft long sections. It is Johnson stainless steel wire wrapped screen. The gravel pack is not yet at the site.

7:02 -- Three members from the Luhr Brothers firm have arrived at the site. They have begun pumping water from I-70 Well No. 8 through a 3-in. flexible hose to fill the mud pit.

8:00 -- The pit is still filling with water from Well No. 8. The crew from Luhr Brothers, consisting of five men, has been waiting for the mud pit to fill. Terry Feldman, IDOT regional engineer, arrived at the site at approximately 7:30 AM.

8:30 -- Drilling has commenced at a slow pace. Approximate progress is about four feet. The crew has positioned a backhoe to excavate cuttings from the mud pit. They also have their welder working in the pit of I-70 Well No. 7, welding on a 3-in. valve as a connection for additional water supply through a flexible hose. The mud pit is unlined and is excavated into very sandy material so that the sidewalls are sloughing off periodically. The sloughing has now exposed the electrical conduit to I-70 Well No. 7.

8:55 -- The first length of drill pipe has been attached and drilling has resumed.

9:20 -- The hole has now progressed to an approximate depth of 16 ft. The driller, Bob Kennedy, has pulled up the drill bit and has cut approximately two (2) inches from the reamer on the bit, decreasing the hole size by approximately four (4) inches. Drilling is now continuing to a depth of about 20 ft. The installation of the valve on I-70 Well No. 7 has been completed and a flexible hose is attached extending to the mud pit.

9:35 -- The 20-ft depth has now been reached in drilling. The clouds are now clearing away and the sun is beginning to shine through brightly, creating a nice winter day.

9:45 -- Drilling has resumed. The driller reports that he is drilling a 42-in. hole at this time. The upper part of the hole is approximately 48 in. in diameter. He also stated that there was a stiff blue clay encountered at a depth of about 15 ft.

9:55 -- Drilling has now reached 30 ft.

10:05 -- The third length of 6-inch, drill pipe has now been attached and drilling has resumed.

10:15 -- The hole has now reached the depth of approximately 40 ft.

10:25 -- The fourth length of drill pipe has now been attached and drilling has resumed.

10:35 -- Drilling is at a depth of approximately 45 ft. There has been very coarse material encountered at this depth. The drill pipe and bit rotate at the approximate rate of 18 rpm.

10:48 -- Drilling has now reached approximately 55 ft.

10:55 -- The fifth length of drill pipe has been attached and drilling has resumed.

11:20 -- Drilling has now reached approximately 60 ft.

11:42 -- The sixth length of drill pipe has been attached. Drilling has resumed. The cuttings being excavated from the mud pit include some cobble-sized stones.

12:05 PM -- The hole depth is now approximately 70 ft.

12:15 -- The seventh length of drill pipe has been attached and drilling has resumed.

1:15 -- Drilling has now reached the approximate depth of 80 ft. The drilling from about 70 to 80 ft took considerable time because of cobbles plugging the drill pipe.

1:30 -- Drilling resumed but is progressing very slowly.

2:00 -- Drilling has reached maximum depth. Progress was nil. Total depth has been measured to be approximately 87 ft below original grade. Depth was measured with steel tape by the driller.

2:00 -- The trucks of gravel pack arrived at the site. The pack appears to be the correct size. I collected a sample of the pack from each of the trucks.

2:45 -- The first 15-ft section of 25-slot well screen is being welded to the bottom 30-ft section of 55-slot well screen.

3:00 -- The welder has completed welding the first 15-ft section of well screen.

3:10 -- Welder is now attaching the top 15 ft of well screen to the bottom 45 ft.

3:25 -- The top section of screen is now welded on.

3:50 -- The first 10 ft of stainless steel well casing has been welded to the top of the screen.

4:10 -- A 5-ft section of stainless steel well casing has been welded to the first 10 ft.

4:35 -- A second section of well casing 4.9 ft long was welded on. This makes approximately a 20-ft length of stainless steel well casing above the well screen.

4:55 -- A 12-ft length of black iron well casing was temporarily-welded to the top of the stainless steel to allow correct positioning vertically of the stainless steel well screen and casing.

5:10 -- The first truckload of gravel pack is in position ready for dumping. A tremie pipe or protective casing at the top is not being used. They have used 6x6 wood blocks inside the truck bed in order to create a narrower stream of gravel pack coming from the raised truck bed. A piece of canvas was placed on the edge of the borehole to help minimize erosion of the edge of the borehole.

5:30 -- The second truckload of gravel pack is nearly in position ready for unloading. The type A gravel pack installation is now completed with about 4 ft of overlap into the 25-slot screen. The depth to the pack was checked at two different times during the installation by the IDOT regional engineer and the driller, Bob Kennedy.

6:15 -- The first truckload of type B gravel pack has now been dumped into the well bore. The pack is now above the top of the screen. The second load of type B gravel was returned to the yard.

6:30 -- A 20-ft length of 36-in. diameter steel pipe is being installed around the 16-in. casing down to the top of the gravel pack to protect the hole from caving overnight and allow them to finish placing selected material above the gravel pack tomorrow.

November 25. 1986

8:00 AM -- Arrived at site. Drill crew here preparing to bail material from inside 16-in. casing and screen.

8:25 -- First few bailerfuls seem to have very little sediment from inside the casing. The bailer being used is approximately 8 in. in diameter and about 10 ft long. It has a flapper valve on the bottom.

8:55 -- They have taken the bailer off and have put on a surge block to pull additional fines through the screen.

9:40 -- Began second period of bailing.

9:55 -- Finished bailing, resumed surging. The last sample from the bailer looked like it pulled up some fine silt along with some gravel pack.

10:35 -- Surging stopped. Bailing started between the well casing and the outer casing (once).

10:40 -- Started bailing the well.

10:50 -- Completed bailing. Small amount of fines where obtained and Bob was convinced they didn't need to surge any further. Measured depth of 88 feet. He also said there are some fines suspended which will probably settle to about 6 inches or so at the bottom. Pumped water from between the outer casing and the well casing to ready for plug.

1:00 PM -- Started pumping well to waste. Bob said they'll pump it until it clears.

1:30 -- Suction pump off (water clear).

1:40 -- Raised outer casing -6 inches and began adding sand all around. Added -2-3 ft of sand over pack.

1:50 -- Waiting for bentonite/cement grout for plug.

Left site.

State Water Survey Division

2204 Griffith Drive
Champaign, Illinois **61820**
217/333-2210

Illinois Department of
Energy and Natural Resources

February 28, 1986

Mr. John Stewart
Ill. Dept. of Transportation
Division of Highways/District 8
9300 St. Clair Avenue
Fairview Heights, IL 62208

Dear Mr. Stewart:

We have examined the data presented by the Layne-Western Company, Inc. in their report entitled "Ground-Water Drainage System, FAI Route 70 Tri-Level Location, East St. Louis, Illinois", dated May 22, 1972. Based on the sieve analysis data from the test hole borings, driller's log for I-70 Well No. 7, performance of the existing wells, and our well design criteria, several recommendations with regard to the design of the I-70 Well No. 7 replacement well, designated I-70 Well No. 7A, can be made.

The sieve analysis data from boring's L-1 and L-2, in conjunction with the driller's log for Well No. 7, suggest a distinct gradation in the grain size of the aquifer material both with depth and areally. The upper 50 feet of the aquifer material is of a finer grain size than the lower aquifer material.

Our recommended well design tailors two sizes of gravel pack material and well screen slot size to the upper and lower aquifer material.

Assuming the well is completed to a bottom elevation of 302 feet above mean sea level, the ideal gravel pack size for the lower aquifer interval ranges from 1.5 to 2.5 millimeters. The lower gravel packed interval should be placed between 302 and 337 feet above mean sea level, or approximately 52 to 87 feet below a land surface elevation of 389 feet. If material from Northern Gravel Company, Muscatine, Iowa is to be used, their No. 1 material (1.2 to 2.2 mm) is recommended. Above the lower, coarser pack, a finer gravel pack with an ideal size ranging from 0.8 to 1.3 mm should be used. The finer pack should be placed from 337 feet to 367 feet above mean sea level, or 22 to 52 feet below the land surface. If material from the Northern Gravel Company is to be used, their No. 0 material (.59 to 1.6 mm) is recommended.

The tailored screen design recommended for the gravel pack design described above requires a total of 60 feet of 16 inch diameter screen. For the lower gravel pack a 30 foot length of well screen with 0.055 inch continuous slots (55 slot) can be used. This screen should be set from 302 to 332 feet above mean sea level. For the upper gravel pack, a 30 foot length of screen with 0.025 inch continuous slots (25 slot) is recommended. The upper screen should be set from an elevation of 332 to 362 feet. It is important that the coarser gravel pack material be placed approximately 5 feet above the top of the lower (55 slot) screen to allow for settling of the gravel pack. The finer gravel pack material should be placed to 5 feet above the top of the upper (25 slot) screen. This design allows about 900 gpm of water to be safely transmitted.

Although we are confident that our tailored well design is satisfactory based on the available information, our confidence would be increased if a boring could be made at the specific site of the new well, especially in the upper 50 feet of the aquifer. Although data from borings L-1 and L-2 are available, in addition to the I-70 No. 7 driller's log, the lateral gradation in grain size of the aquifer material, combined with only ten foot sampling intervals, leaves in question the grain size of the materials at replacement well site No. 7A.

An alternative possibility for the replacement well design calls for screening only the lower, coarser interval of aquifer material. The ideal gravel pack size for this lower interval ranges from 1.5 to 2.5 millimeters. The gravel pack should be placed from an elevation of 302 to 342 feet above mean sea level, or approximately 47 to 87 feet below a land surface elevation of 389 feet. If material from the Northern Gravel Company is to be used, their No. 1 material (1.2 to 2.2 mm) should be adequate. A 35 foot length of 16 inch diameter well screen with 0.055 inch diameter continuous slots (55 slot) would be appropriate for use in this well design. The screen should be set from an elevation of 302 to 337 feet. Using this non-tailored design, an estimated 720 gpm can be safely transmitted. Although simpler in design than the tailored well, a greater risk of sand pumpage is involved because of the lack of boring data between the elevations of 334 and 344 feet.

If you have any questions concerning our recommendations for the replacement well design, or if an additional boring is to be made at the new well site, please contact us.

Sincerely,
ILLINOIS STATE WATER SURVEY

Stuart J. Cravens
Assistant Hydrologist
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SJC:EWS:psl
cc: Merle Wadsworth, IDOT
Frank Opfer, IDOT

Appendix H.

I-70 Well No. 14 (7a) Sieve Analysis Results of Well Construction Samples

Appendix H. Sieve Results of I-70 Well No. 14 (7a) Construction Samples

Depth (ft) / Tyler sieve / Standard sieve	2½ / 3/8	3¼ / 1/4	4 / 4	5 / 5	7 / 7	9 / 10	12 / 12	16 / 16	24 / 24	32 / 32	42 / 45	60 / 60	80 / 80	100 / 100	115 / 120	170 / 170	250 / 230	270 / 270
5-10		1.4			6.8	10.8	16.2	21.9	31.5	48.0	69.3	81.1	85.8	91.4	95.9	98.1		
10-20								0.7	1.2	2.0	2.8	3.7	7.3	11.3	15.7	26.5	35.9	36.5
20-25					7.4	10.9	14.0	18.1	24.2	33.6	42.0	61.2	85.0		95.1	98.3		
25-30					9.2	19.5	31.4	44.5	58.4	70.4	77.5	84.4	95.4		98.7	99.1		
30-35									4.8	15.7	26.4	44.1	82.1	92.2	97.1	99.1	99.4	99.5
35-40	1.5							3.5	7.0	17.9	28.9	45.6	82.2	92.7	97.3	99.4	99.6	99.7
40-45									0.1	0.2	1.8	9.3	50.5	74.3	91.4	98.8	99.6	99.6
45-50	7.3	9.7	12.6	15.7	25.0	34.1	44.6	54.3	71.5	90.6	96.5	98.3	99.0	99.2	99.4	99.5		
50-55	5.2				8.8	11.3	14.3	18.2	25.3	37.7	48.0	73.5	94.3	97.1	98.3	99.2		
55-60	18.9	22.4	24.0	27.1	30.4	33.5	37.7	42.3	50.7	71.5	83.9	89.4	96.2	98.0	98.8	99.3	99.5	
60-65	3.4			8.7	13.3	19.0	24.7	30.8	40.6	66.5	94.2	98.5	98.9					
65-70			1.6	2.8		9.3	15.4	25.1	45.1	76.7	90.6	95.7	98.5			99.4		
70-75(1)		5.1	8.8	12.8	24.4	41.1	61.5	78.0	91.1	97.9	99.2							
70-75(2)	4.0	6.2	9.3	11.9	22.8	39.1	59.3	75.4	89.1	96.9	98.6							
80-85	14.5			16.0	18.7	21.0	24.2	28.2	40.7	71.1	91.3	98.3	99.7					
85-90	5.8	14.9	26.9	37.9	55.0	68.4	77.0	83.7	89.6	95.9	99.0	99.7	99.9					
Type A #1 Gravel Pack					10.4	43.8	87.7	98.0	98.9		99.2				99.4			
Type B #0 Gravel Pack					2.2	7.6	45.9	86.4	97.7	99.0		99.2						