Illinois State Water Survey
HYDROLOGY DIVISION

SWS Contract Report 509

DEWATERING WELL ASSESSMENT FOR THE HIGHWAY DRAINAGE SYSTEM AT FOUR SITES IN THE EAST ST. LOUIS AREA, ILLINOIS (PHASE 5)

by Steven D. Wilson and Robert D. Olson
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and

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Prepared for the
Illinois Department of Transportation

Champaign, Illinois

April 1991

Illinois Department of Energy end 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 to 115 feet thick and consist of fine sand, silt, and clay in the upper 10 to 30 feet, underlain by medium to coarse sand about 70 to 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 Illinois State Water Survey to more adequately assess the operation and condition of the wells, to begin an attempt to understand the probable causes of well deterioration, and to evaluate rehabilitation procedures used on the wells. Five phases of the investigation have now been completed.

During Phase 5, nine step tests were performed, the rehabilitation of four wells was field-documented, three dewatering wells were investigated for sand pumpage, and an initial inspection of four relief wells was made. Five of the step tests were conducted to assess the condition of wells that had been chemically treated during Phase 3 (I-70 Wells 2, 8, 10, and 11, and I-64 Well 15). For these five wells, the average specific capacity was 53.5 gallons per minute per foot (gpm/ft). All but I-64 Well 15 (specific capacity = 86.5 gpm/ft) are in poor condition, having deteriorated from previous step test results, and are recommended for treatment.

Post-treatment step tests were used to help document the rehabilitation of four dewatering wells (I-70 Well 12, I-64 Well 3, 25th Street Well 10, and Venice Well 6) during Phase 5. Chemical treatments were used to restore the capacity of these four wells, and they were generally successful, as the improvement in specific capacity per well averaged about 39%. The average specific capacity for the four wells based on the post-treatment step tests was 150.3 gpm/ft. Venice Well 6 also pumped sand during the post-treatment step test.

An initial inspection was conducted on four relief wells at two detention ponds near the intersection of I-255 and I-55/I-70. The inspection did not reveal any obvious evidence of problems in the wells, but it was limited in scope because of limited access due to well-head, pit, and discharge line configurations. IDOT will need to modify the

wells before a more detailed investigation with pumping and sampling activities can be conducted.

The sand pumpage investigation conducted during three step tests revealed that Venice Well 6 is pumping sand and gravel-pack material, and I-70 Well 2 and Well 8 are pumping sand. This is an unacceptable condition for operating purposes. The wells should be inspected with underwater video equipment to determine what can be done to ameliorate the condition or if the wells should be replaced.

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 by the area's industries. Because of 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 at least 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 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 March 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.

Phase 2, begun in March 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 moved toward an operating well.

Phase 3, begun in July 1985, included an assessment of the condition of six wells; demonstration of a non-invasive, portable flowmeter; a continued study of ground-water chemistry; and documentation of the rehabilitation of seven dewatering wells, along with follow-up step tests.

Phase 4, begun in July 1986, included ten step tests, documentation of the treatment of five wells, documentation of the construction of I-70 Well 14(7a), investigation of I-70 Well 9 to determine the probable cause of gravel-pack settlement, specific-capacity testing using the non-invasive, portable flowmeter, and installation of piezometers at two underpass sites in East St. Louis.

Phase 5, begun in July 1987, included nine step tests, documentation of the treatment of four wells, investigation of possible sand pumpage at three wells, and initial investigation of the condition of relief wells at two detention ponds near the intersection of I-255 and I-55/I-70.

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 it is diverted by pumpage or drainage systems.

Detailed location maps 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 to 415 feet above mean sea level (ft msl). The alluvial deposits are about 90 to 115 ft thick, meaning the bedrock surface lies at approximately 300 to 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 to 100 feet thick. The elevation of the top of the aquifer is about 390 to 395 ft msl.

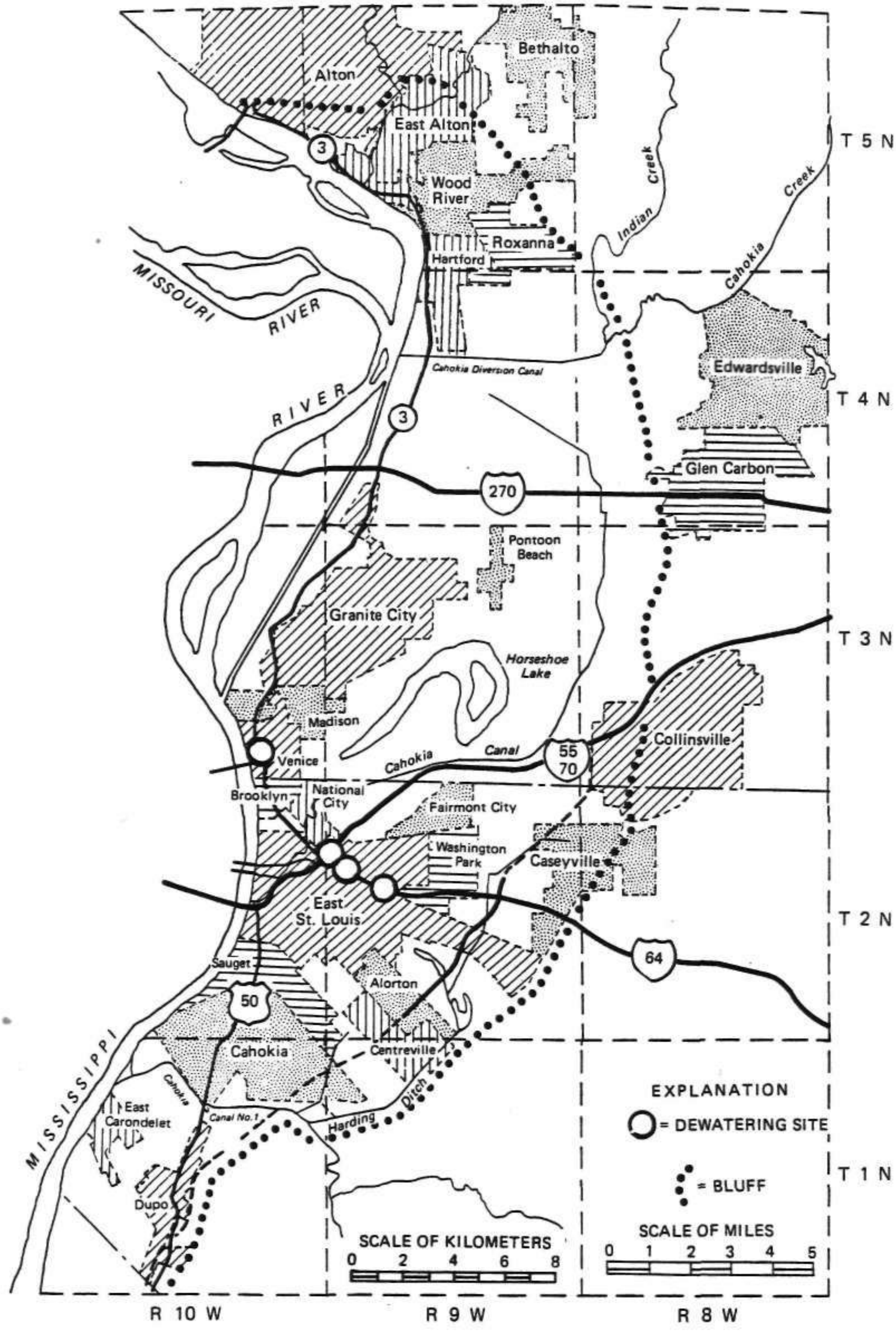

Figure 1. Location of the East St. Louis area

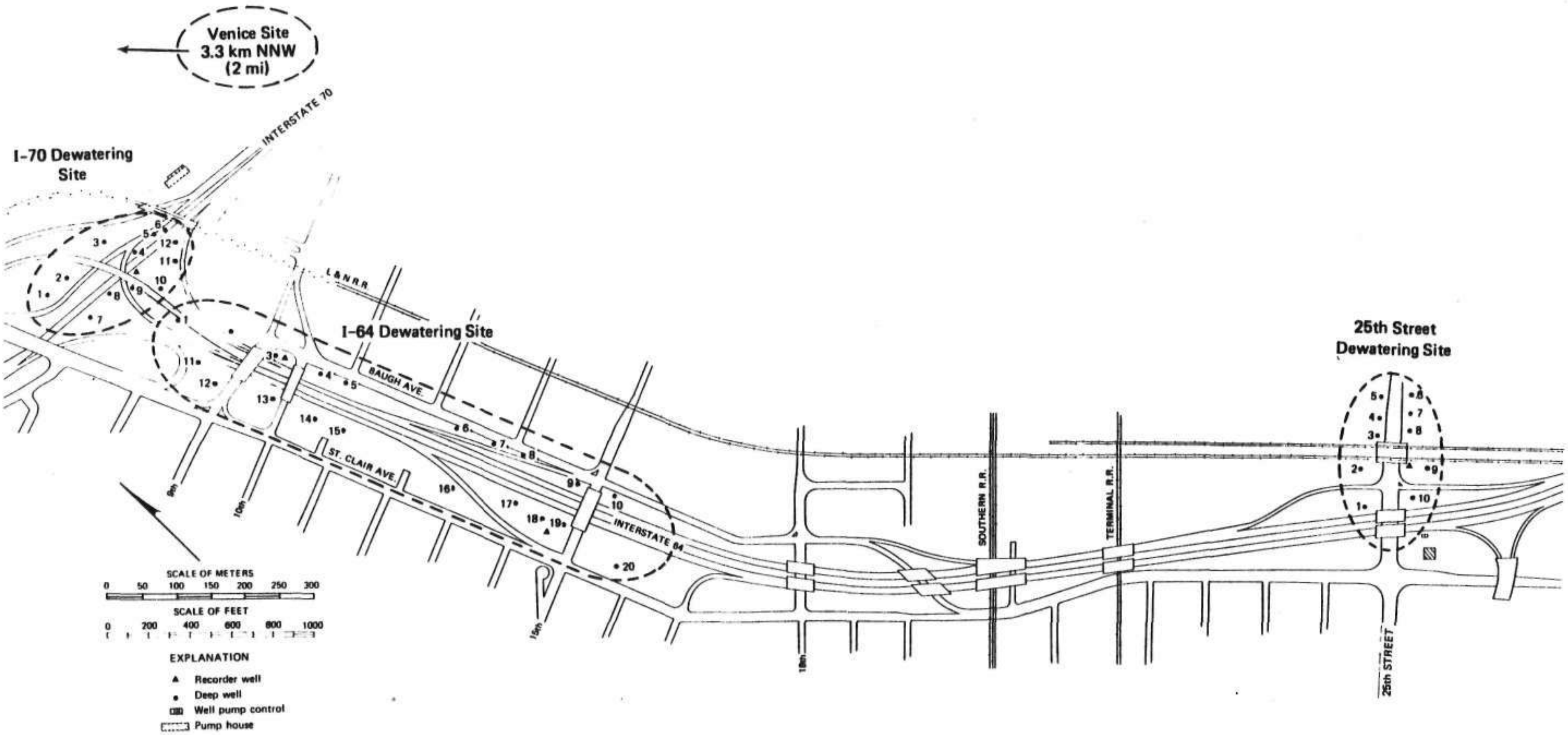

Figure 2. Locations of dewaterlng wells at the I-70 Tri-Level Bridge, I-64, and 25th Street

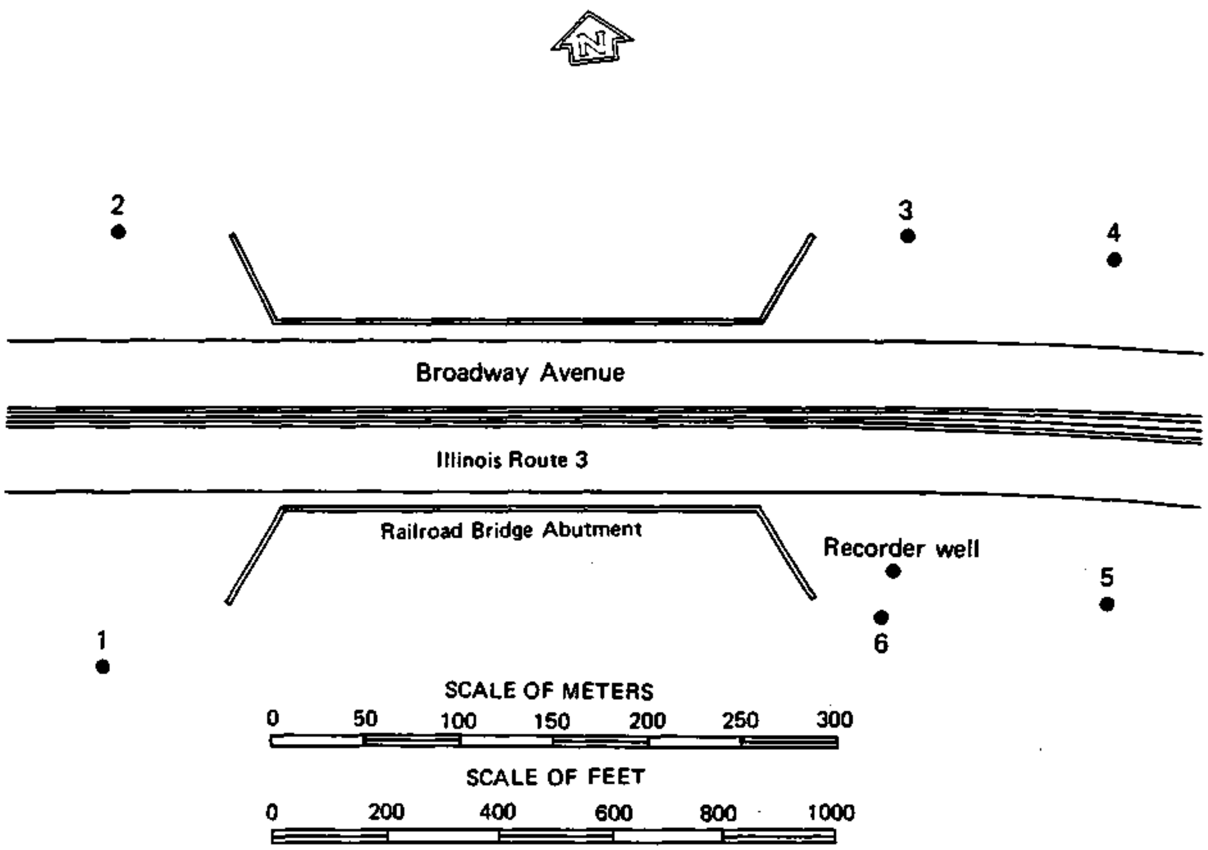

Figure 3. Locations of dewatering wells at the Venice Subway (Illinois Route 3)

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, Gregory W. Baise, 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. Water Survey staff who ably assisted the authors with field data and water sample collection included Robert Kohlhase, Jeff Stollhans, Ken Hlinka, Doug Kelly, John Nealon, and Rachael Hammen.

Analytical work was done by the Analytical Chemistry Unit under the direction of Mark Peden, with Brian Kaiser, Lauren Sievers, and Mildred O'Brien performing the lab analyses. Manuscript editing was done by Gail Taylor, and the illustrations were prepared by John Brother, Jr., David Cox, and Linda Hascall. Word processing was done by Pamela Lovett.

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 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). Highway construction was carried out in 1961-1962.

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-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 ¼-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 ¼-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 been 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 ⅜-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 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 of the water. 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 the use of 304 stainless steel pipes 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, therefore, was given further study as a permanent system. 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 10 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 6200 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 in 1975 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 *2k* 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 2000 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 well's 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.

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 pitot-tube flow-rate meters. Reportedly, a combination of corrosion and chemical deposition caused premature failure of these devices. Flow rates were occasionally checked with a temporarily inserted pitot-tube meter, but erratic results were 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 have shown 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. 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

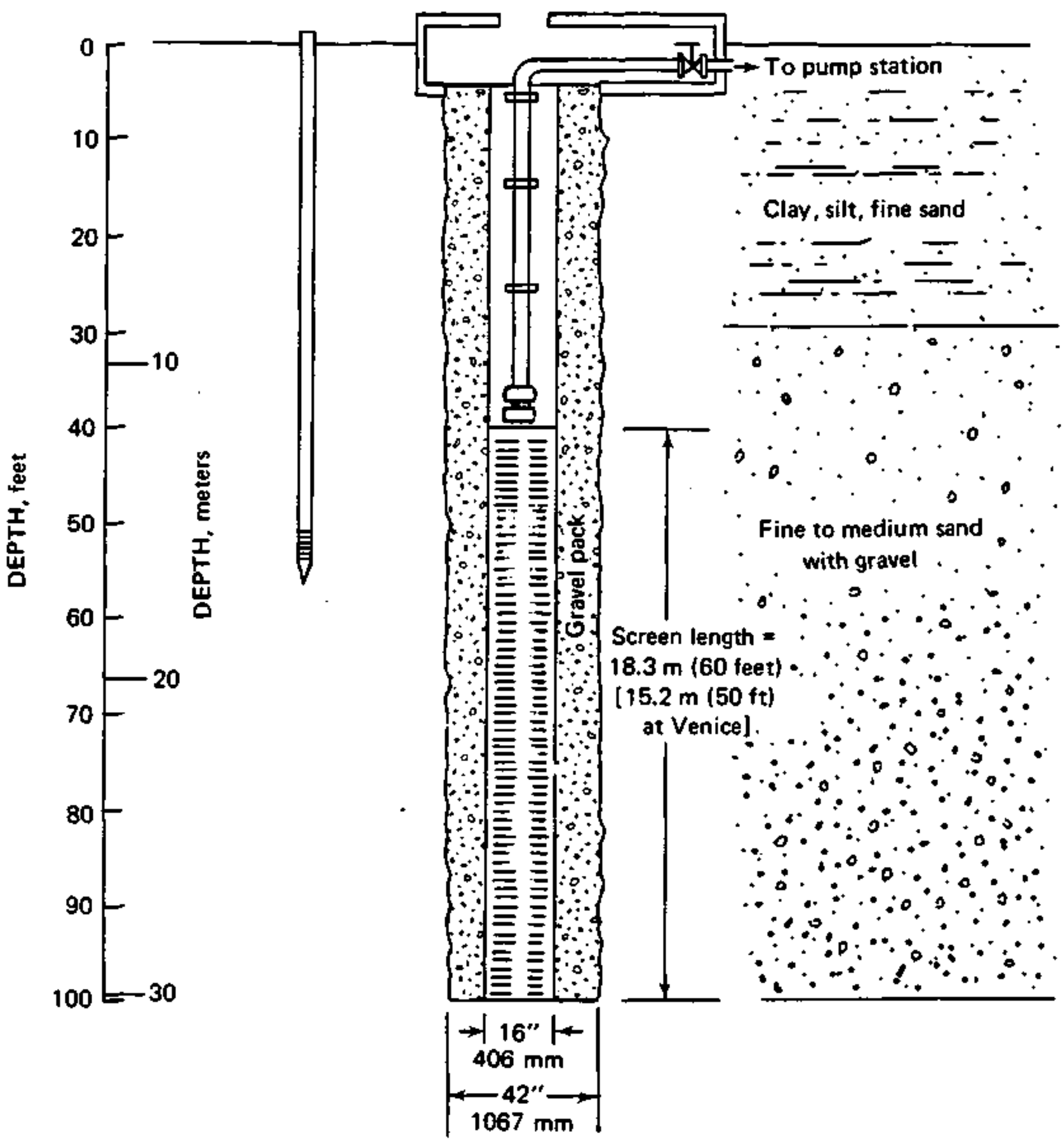

Figure 4. Typical features of a dewatering well

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_o) 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 of theoretical drawdown, s, in the pumped well are then expressed as being proportional to pumping rate, Q, in the following manner:

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

where 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 as

$$s = BQ + CQ^n \qquad (3)$$

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

$$s/Q = B + CQ \qquad (4)$$

After this modification, a plot of s_o/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_o 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

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

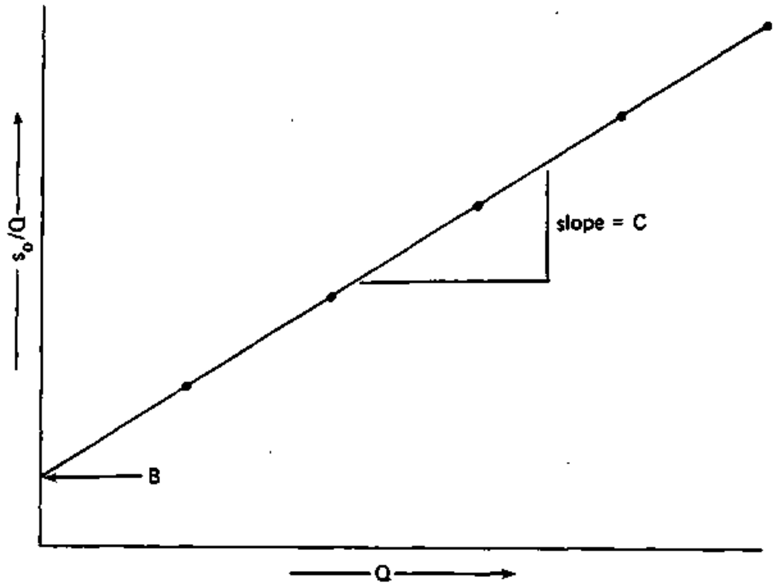

Figure 5. Graphical solution of Jacob's equation for well loss coefficient, C

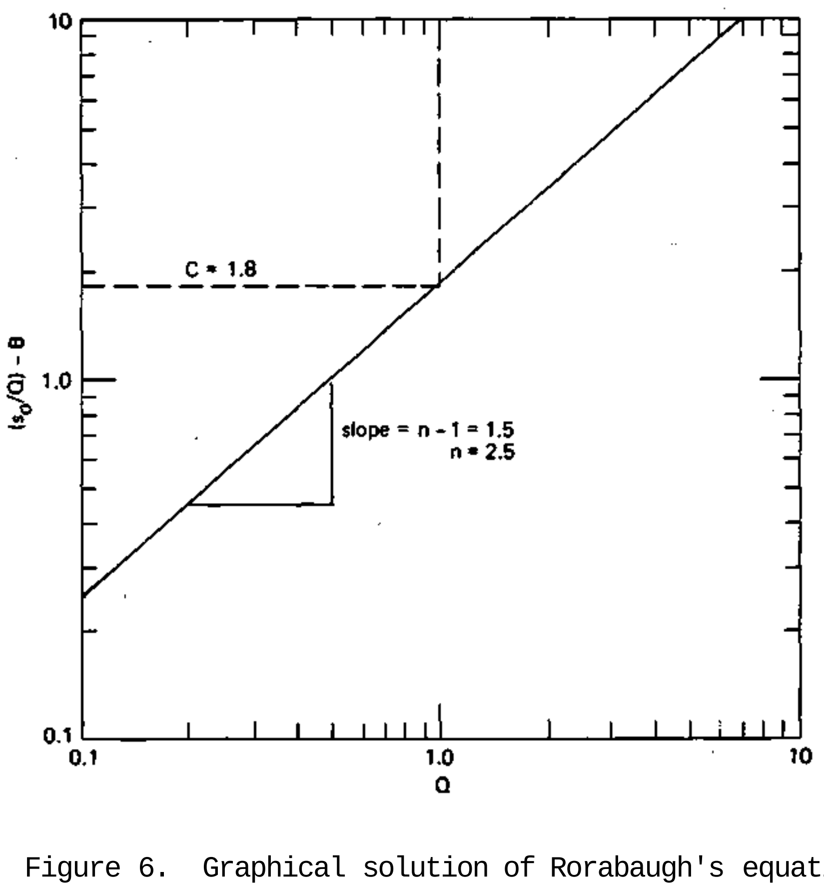

Figure 6. Graphical solution of Rorabaugh's equation for well loss coefficient (C) and exponent (n)

Taking logs of both sides of the equation leads to

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

A plot of $(s_o/Q) - B$ versus Q can be made on logarithmic graph paper from step test data, again using s_o 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 $(s_o/Q) - B$ is plotted as seconds per foot squared. It is also convenient (although not mandatory) to use these same units in the Jacob method.

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. For many of the step tests, the Illinois State Water Survey's Micro-computer Data Acquisition System (referred to as McDAS) was used to collect the data. It reads the data logarithmically, progressing from 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_o/Q versus Q or $(s_o/Q) - B$ versus Q, values of observed drawdown s_o are equal to the sum of As_i for the step of interest. Thus, for step 3, $s_o = \Delta s_1 + \Delta s_2 + \Delta s_3$.

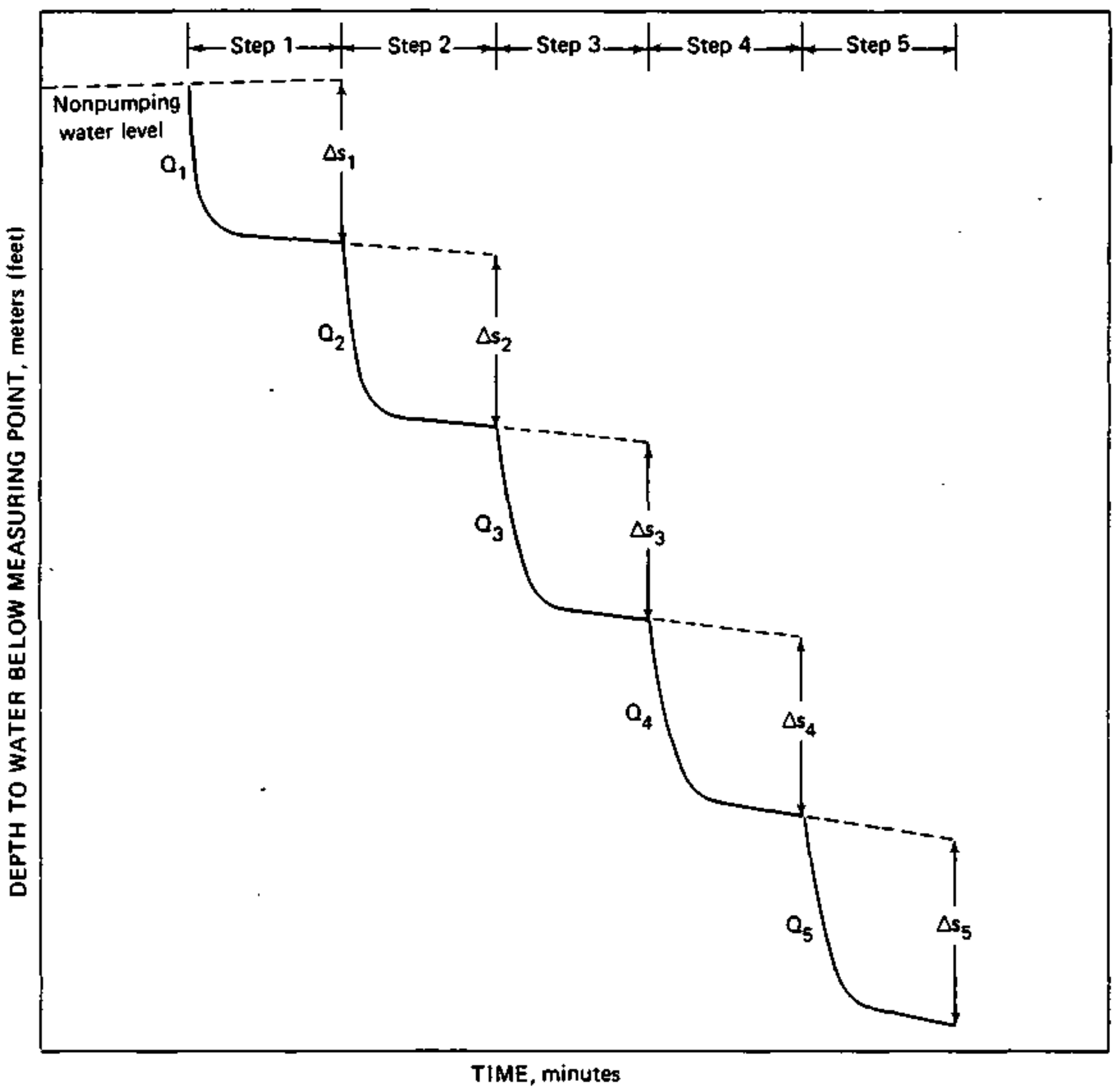

Figure 7. Relationship between time and water level during a five-step drawdown test

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 turbulent well losses in a pumped well can be found in such an arrangement by comparing the difference in head (Ah) between 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 non-linear 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 step-tested in Phase 5. Five of the tests were conducted on wells rehabilitated during July-August 1985 (Phase 3), to continue the post-treatment monitoring of well performance. The other four wells were rehabilitated by chemical treatment during Phase 5 and were then tested in post-treatment step tests.

The five previously rehabilitated wells that were step-tested were:

I-70	Well 2
	Well 8
	Well 10
	Well 11
I-64	Well 15

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

I-70	Well 12
I-64	Well 3
25th St.	Well 10
Venice	Well 6

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.

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 the 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-64 Well 15 and I-70 Wells 10 and 11) were tested in July and August 1987. Rehabilitation took place on I-70 Well 12, I-64 Well 3, 25th Street Well 10, and Venice Well 6 in the fall of 1987, and all but I-64 Well 3 received post-treatment step tests in November 1987. This well was tested in June 1988, along with I-70 Wells 2 and 8.

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

Results of Step Tests

The step test data were analyzed by using the Jacob method, as described earlier in this report. This procedure breaks down the head losses into two components, the losses from the formation and the losses from the well. To illustrate its use, the analysis of I-64 Well 15, tested July 22, 1987, follows.

The test began at 9:26 a.m. at a rate of 300 gpm and ended at 12:26 p.m. at 550 gpm. The test had six steps, each 30 minutes in length, with pumping rate increments of 50 gpm.

Data from the analysis are presented in table 1. Figure 8 is a plot of those data as s_o/Q versus Q. As mentioned earlier, the Jacob method separates the well loss and the formation loss. A best-fit line is drawn through the data (figure 8). The slope is the coefficient for well loss, C, and the y-intercept is the coefficient for formation loss, B. From the analysis, B and C were determined to be 4.564 ft/sec^2 and 0.470 sec^2/ft^5, respectively. Therefore, at 550 gpm (1.225 cfs), drawdown, s, becomes:

$$s = BQ + CQ^2 \quad (7)$$

$$= 4.564(1.225) + 0.470(1.225)^2$$

$$= 5.59 + 0.71$$

$$= 6.30 \text{ ft}$$

The total drawdown of 6.30 feet compares favorably with the observed drawdown, which was 6.32 feet. This suggests a good correlation between theoretical and observed results.

Table 1. I-64 Well 15 Step Test Data

Step	Q (gpm)	Q (cfs)	Δs_o (ft)	s_o (ft)	s_o/Q	CQ^2
1	300	0.668	3.30	3.30	4.94	0.21
2	350	0.780	0.57	3.87	4.96	0.29
3	400	0.891	0.57	4.44	4.98	0.37
4	450	1.003	0.61	5.05	5.04	0.47
5	500	1.114	0.63	5.68	5.10	0.58
6	550	1.225	0.64	6.32	5.16	0.71

Q = flow rate
Δs_o = change in drawdown observed in each step
s_o = observed drawdown
C - coefficient for well loss

To verify the C value, a plot of s_o versus Q is used (figure 9). When C = 0, equation 2 becomes s — BQ, which would plot as a straight line through the origin. If C ≠ 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 ≠ 0. Using $s - CQ^2 = BQ$, and substituting s_o for s, we should be able to subtract the 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 9. One is labeled s_o, and the other is labeled $s_o - CQ^2 = BQ$. As can be seen, the BQ line is a straight line through the origin, which verifies that C = 0.470, obtained from figure 8, is a good estimate for C.

The analysis indicates that at a rate of 600 gpm, the portion of drawdown caused by turbulent well losses at the well screen and inside the

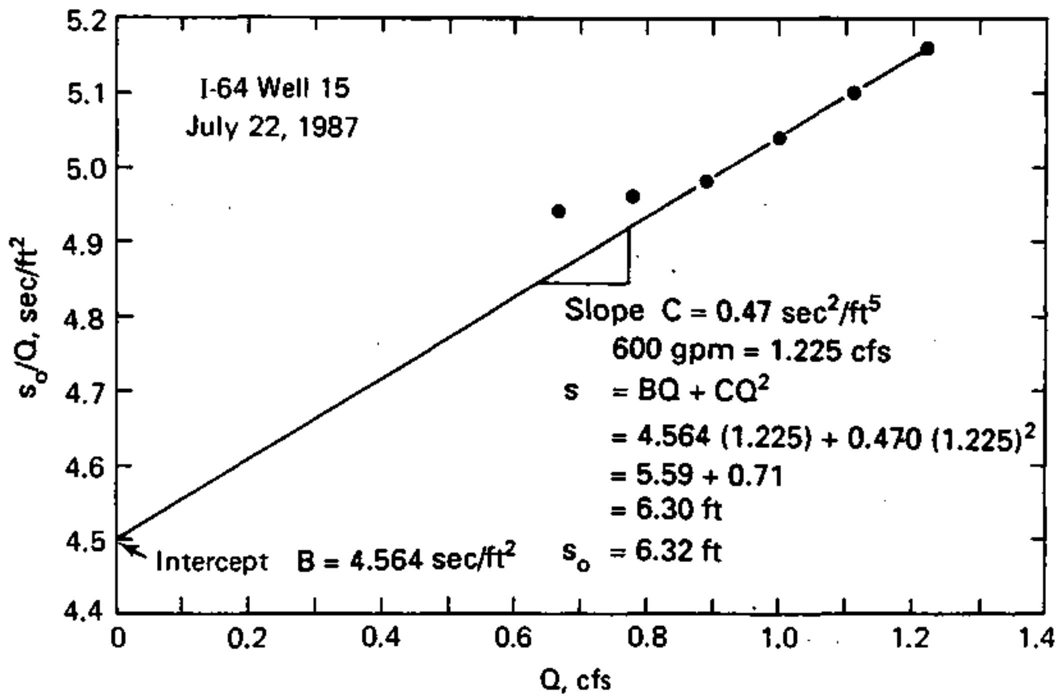

Figure 8. Graphical analysis for I-64 Well 15

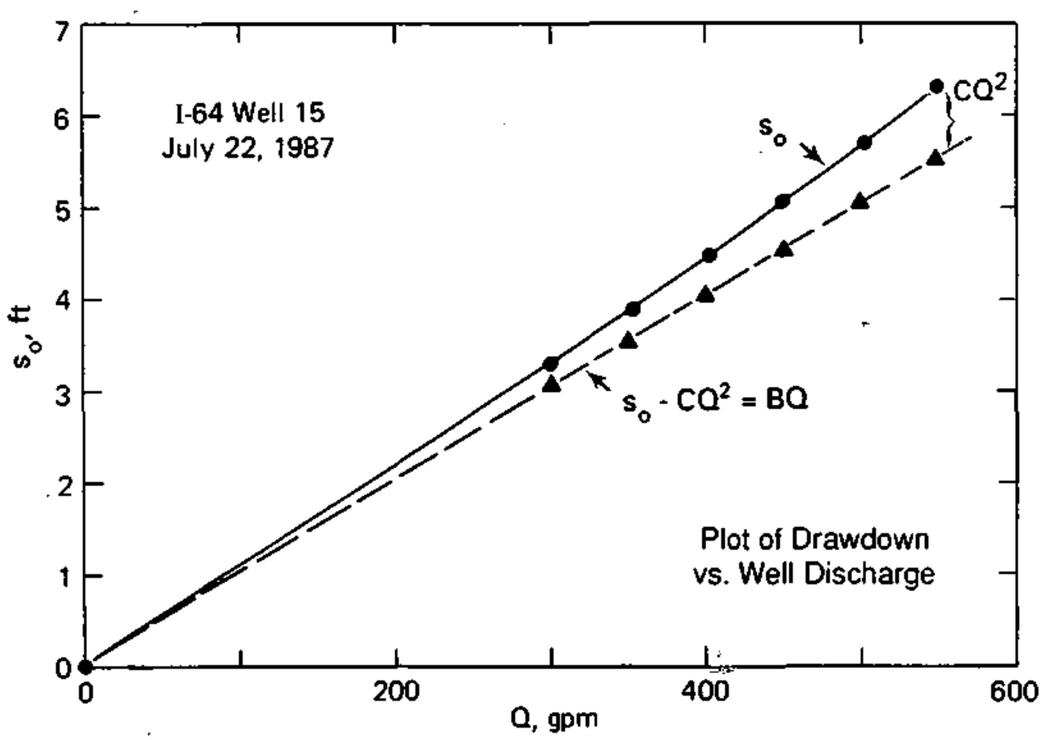

Figure 9. Observed drawdown, s_o, versus well discharge, Q, I-64 Well 15

well would be 0.84 feet or 12.0% of the total drawdown for I-64 Well 15. This is a moderate amount of well loss, although the well is apparently in good hydraulic condition, as shown by its 86.5 gpm/ft specific capacity at 600 gpm and the water-level differences observed between the well and its nearby piezometer during the step test.

Figure 10 shows water-level differences (Ah) between I-64 Well 15 and its nearby piezometer during the test. The apparently linear relationship suggests 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 also show a linear relationship. The average Ah for I-64 Well 15 was 0.42 ft per 100 gpm. The results of analyses performed on data gathered from the nine step tests conducted during Phase 5 are summarized in table 2.

The step tests show that the four rehabilitated wells (I-70 Well 12, I-64 Well 3, 25th Street Well 10, and Venice Well 6) are in good condition, as the specific capacities ranged from 96.2 to 254.2 gpm/ft and averaged 150.3 gpm/ft. The results are unusual in that the two wells with the highest specific capacities of all the wells step-tested in Phase 5 (I-70 Well 12 and Venice Well 6) also exhibit the highest well losses. The Ah measurement for Venice Well 6 was also low. (This measurement was not available for I-70 Well 12.) Factors contributing to the high well loss may be the low total drawdown (resulting in a high calculated percentage of well loss) and the unequal contribution of flow from the entire length of well screen. The "Well Rehabilitation" section of this report provides additional discussion about the condition of these wells and their response to treatment.

For the five wells chemically treated in 1985 during Phase 3 (I-70 Wells 2, 8, 10, and 11, and I-64 Well 15), the step tests indicate that I-64 Well 15 is in good shape but that all the others have deteriorated to poor to fair condition. Excluding I-64 Well 15, the specific capacities range from 31.6 to 51.9 gpm/ft and average 45.3 gpm/ft. In addition, the Ah measurements are high at the two wells with operable piezometers. Well losses could not be accurately estimated, probably because the wells were developing during the tests or because of laminar flow conditions at the low pumping rates.

The present condition of I-64 Well 15 compares favorably with that found in the post-treatment step test in 1985. The condition of I-70 Wells 2, 8, 10, and 11, which was relatively good following treatment in 1985, has deteriorated to pre-treatment levels. This means that their condition declined in about a two- to three-year period. During the same period, the condition of I-64 Well 15 did not change. Operational records for this period are very limited, but it is believed likely that I-64 Well 15 was not operated after the chemical treatment in August 1985.

Collectively, the data indicate that some blockage of the well screens and/or permeable materials around I-70 Wells 2, 8, 10, and 11 has occurred. This condition would likely be improved with phosphate/acid treatment, as was used previously.

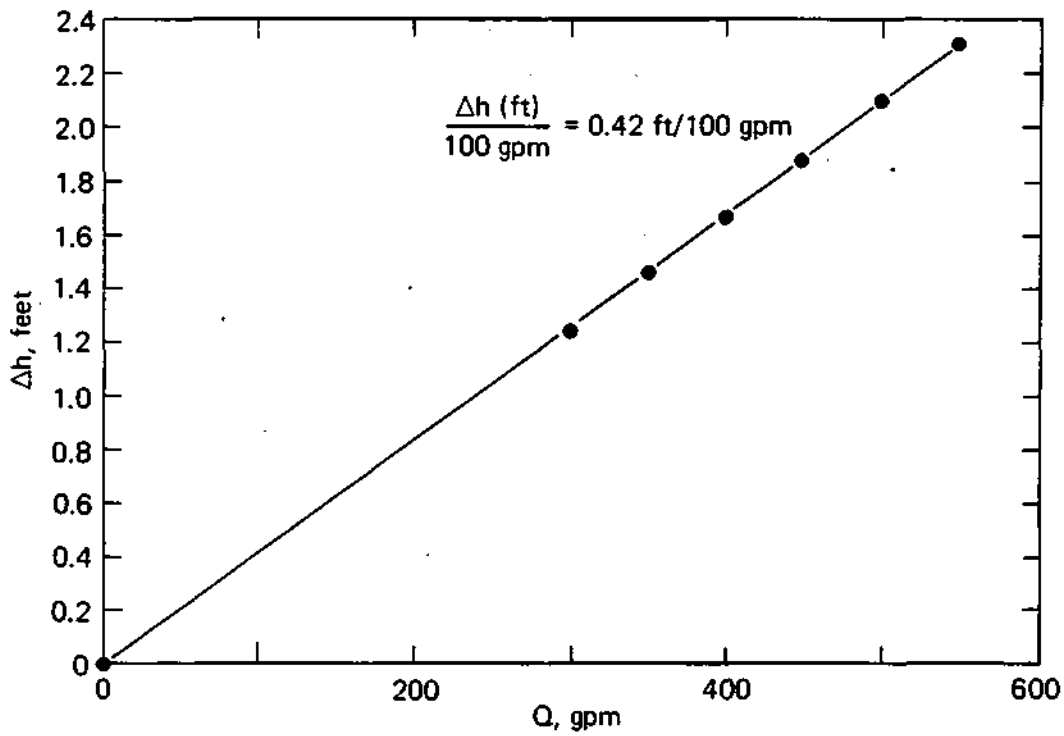

Figure 10. Head difference, Ah, between piezometer and pumped well versus discharge, Q, I-64 Well 15

Table 2. Results of Step Tests on IDOT Wells, Fiscal Year 1988 (Phase 5)

Well	Date of test	Well loss @ 600 gpm (ft)	Drawdown @ 600 gpm (ft)	Well loss portion (%)	Specific capacity (gpm/ft)	Ah* @ 600 gpm (ft)	Remarks
I-70							
Well 2	6/20/88	**	11.98 e	**	50.1 e	p	Q_{max} = 365 gpm, piezometer partially plugged
Well 8	6/22/88	**	12.62	**	47.5	8.22	Q_{max} = 600 gpm
Well 10	8/13/87	1.07	18.98 e	5.6 e	31.6 e	10.4 e	Q_{max} = 390 gpm
Well 11	8/12/87	**	11.56 e	**	51.9 e	p	Q_{max} = 550 gpm, piezometer partially plugged
Well 12T	11/16/87	1.45	2.36	61.4	254.2	p	Q_{max} = 750 gpm
I-64							
Well 3T	6/21/88	0.68 e	5.68 e	12.0 e	105.6 e	p	Q_{max} = 555 gpm
Well 15	7/22/87	0.84 e	6.94 e	12.1 e	86.5 e	2.52	Q_{max} = 570 gpm
25th St.							
Well 10T	11/18/87	0.43	6.24	6.9	96.2	2.06	Q_{max} = 800 gpm
Venice							
Well 6T	11/17/87	3.18	4.13	77.0	145.3	2.61	Unknown piezometer elevation Q_{max} = 800 gpm

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

Fifty-eight step tests have been completed thus far in Phases 1 through 5. The results of these step tests are included in Appendix C. The average specific capacity for all 58 tests is 86.5 gpm/ft. Eight tests have been completed at the 25th Street complex. Specific capacities of these wells averaged 103 gpm/ft, the highest of the four areas. At I-70, I-64, and Venice, respectively, 28, 13, and 9 tests have been completed with average specific capacities of 76, 95, and 93 gpm/ft. The greater intensity of use of the I-70 wells along with their greater age may lead to more well deterioration problems at this site and may help explain the low average specific capacity.

Evaluation of Ground-Water Quality

All nine wells were sampled for analysis by the Water Survey Analytical Chemistry Unit. The results are reported in Appendix B. Analytical methods conform 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 range of concentrations and potential influence of each parameter are presented in table 3.

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

Parameter	Concentration, mg/l Min.	Concentration, mg/l Max.	Potential influence
Iron (Fe)	4.5	18.4	Major - incrustative
Calcium (Ca)	152.0	258.0	Major - incrustative
Magnesium (Mg)	36.8	64.0	Minor - incrustative
Sodium (Na)	40.4	166.0	Neutral
Silica (SiO_2)	27.3	36.5	Minor - incrustative
Nitrate (NO_3)	< 0.2	0.4	Neutral
Chloride (Cl)	39.2	138.0	Moderate - corrosive
Sulfate (SO_4)	222.0	787.0	Major - corrosive
Alkalinity (as $CaCO_3$)	316.0	465.0	Major - incrustative
Hardness (as $CaCO_3$)	531.0	899.0	Major - incrustative
Total dissolved solids	816.0	1750.0	Major - corrosive
pH	7.0	7.3	Major - incrustative

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

Well Rehabilitation

The chemical treatment of four dewatering wells (I-70 Well 12, I-64 Well 3, 25th Street Well 10, and Venice Well 6) during Phase 5 was carried out by Brotcke Engineering Co., Inc. The treatment work was performed from October 14 to November 19, 1987.

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. Table 4 summarizes the treatment procedure required by IDOT specifications. The actual procedure used by the contractor varied in some instances, and the significant changes are also noted. The well rehabilitation work was observed and documented by Water Survey personnel. The field notes for each treated well are in Appendix D.

Figure 11 schematically depicts the typical injection assembly/ discharge apparatus used for injecting solutions and acid into the wells, pumping spent solutions to waste, and conducting pumping tests.

Table 5 summarizes the pumping test data collected as part of the field documentation during the treatment of each well. It contains an estimate of specific capacity prior to the start of treatment and following each step in the treatment process (phosphate or acid injection episode). The average specific capacity for all of the wells at each step in the treatment process is given at the end of the table along with an analysis of the improvement between steps. Diminished returns in improvement are noted for each successive step of the treatment. About two-thirds of the total improvement occurs with the first phosphate treatment, and nearly one-quarter during the second phosphate treatment (following acidization). By the end of this second phosphate treatment, 96% of total improvement was obtained, on the average.

A group of wells has now been rehabilitated in each of three years (7 in 1985, 5 in 1986, and 4 in 1987). Two contractors have performed the treatments, one during the first two years and the other in 1987. The results obtained by each contractor have been similar, although the second contractor may not have treated a sufficient number of wells to enable a fair comparison.

The same trend of reduced improvement for treatment steps beyond the second phosphate treatment has been exhibited during the rehabilitation work each year. An overall reduction in the treatment cost may thus be realized by eliminating unnecessary treatment steps. To do this, progress and results from steps in the rehabilitation work must be closely monitored in the field. Treatment can be stopped when a target specific capacity is reached or when improvement between steps reaches a plateau.

Following the chemical treatments in 1987, the Water Survey conducted step tests on each of the treated wells to evaluate their condition and to provide results for comparison with the contractor's specific capacity tests. The results of these tests are in table 2. They also appear in Appendix C, along with results from step tests conducted previously on the wells. A comparison with the pre-treatment step test results shows that

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 (mg/l) chlorine.

   a. Initial chlorination of well with 2500 gallons water containing 500 ppm or more chlorine injected at a minimum of 200 gpm (actual 500 to 1710 gpm).
   b. Injection of polyphosphate solution at a minimum rate of 500 gpm (actual, 450 to 1800 gpm) in two 1800-gallon batches, each batch containing 200 lbs. polyphosphate, at least 500 ppm chlorine, and inhibitor at the rate of 1 gallon per 1000 gallons solution.
   c. Injection of 16,000 gallons water chlorinated to at least 500 mg/l in 2000-gallon batches at 200 to 1000 gpm (actual rates, 720 to 1800 gpm).
   d. Time allowance for chemicals to react, 60 or more minutes (actual 1 to 5 hours).

3. Pump to waste and check specific capacity.

   a. Same procedure as step 1 above.
   b. Pumping continued 6 or more hours to clear well of chemicals (actual time, 6 to 64 hours).

Day 2

1. Acidization with 1000 gallons 20° Baume inhibited muriatic (hydrochloric) acid and displacement with 3000 to 4000 gallons water (not chlorinated).

   a. Pump 1000 gallons of bulk-inhibited acid into well at 330 to 670 gpm (17 gpm required).
   b. Allowance for acid to react, 60 or more minutes (actual 45 to 60 min).
   c. Injection of 3000 to 4000 gallons water at 25 to 200 gpm (actual 1140 to 1800 gpm).
   d. Allowance for reaction, 2 hours or more (actual 1 hr 45 min to 5 hrs 20 min).

Table 4. Concluded

2. Pump to waste and check specific capacity.

   a. Same procedure as Day 1, step 1 above.
   c. Pumping continued 3 hours or more (actual 3 to 15 hours) to clear well of acid.

<u>Day 3</u>

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 3 batch injections of 1800 gallons (5400 gallons total) with 200 lbs phosphate 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 6 or more hours to clear well of chemicals.

<u>Day 4</u>

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 3 batch injections of 1800 gallons (5400 gallons total) with 200 lbs phosphate 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 6 or more hours to clear well of chemicals.

<u>Day 5</u>

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 6 or more hours to clear well of chemicals.

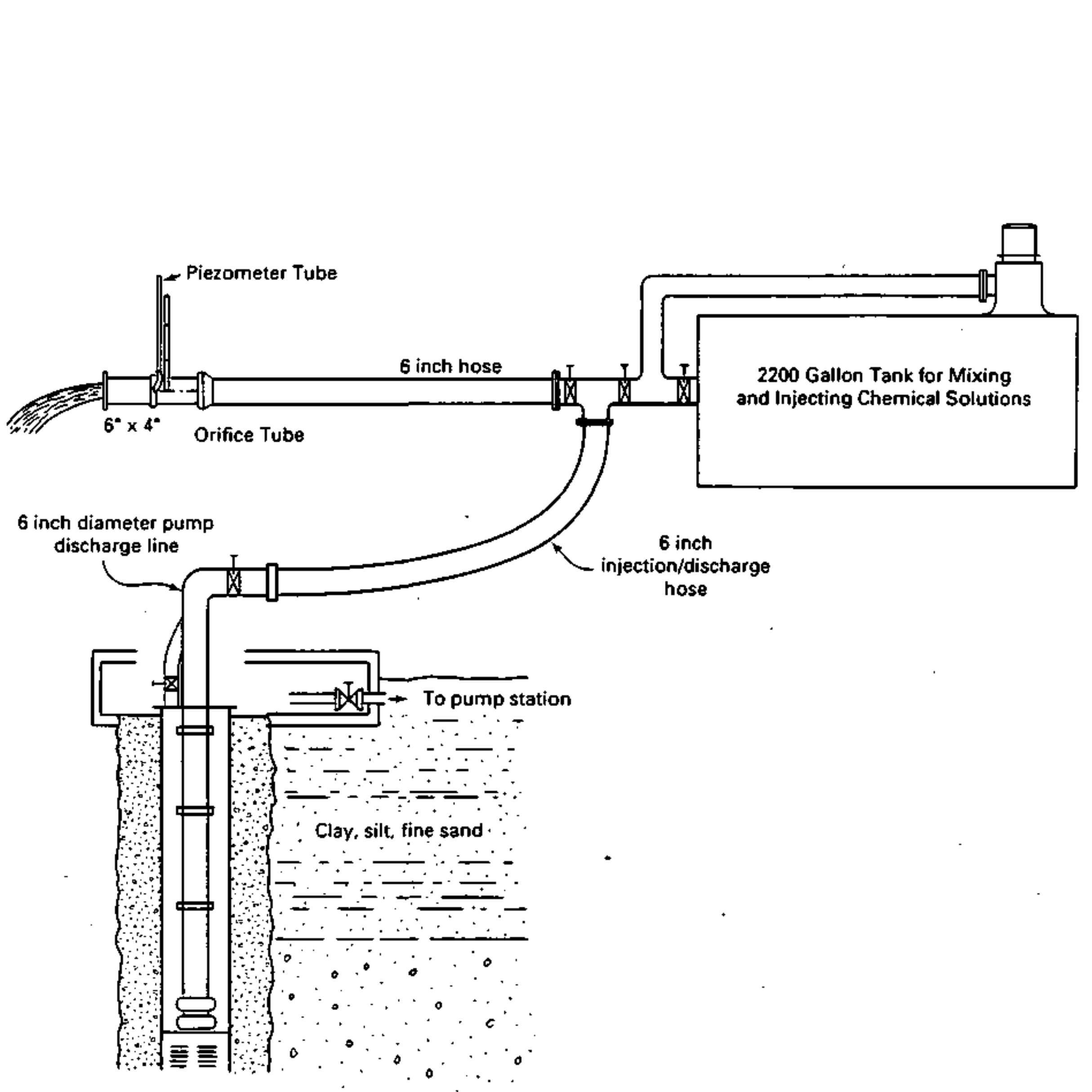

Figure 11. Schematic diagram of equipment used in well rehabilitation

Table 5. Pumping Test Data Collected before Treatment and after Each Treatment Step

	Pre-treatment	1st PPP treatment	Acid treatment	2nd PPP treatment	3rd PPP treatment	4th PPP treatment
I-70 Well 12						
	10/14	10/19	10/20	10/21	10/22	10/22
SWL	14.62	14.63	14.78	14.89	14.86	15.86
PWL	22.65	20.35	20.15	20.02	19.94	20.52
DD	8.03	5.72	5.37	5.13	5.08	4.66
Flow	567	776	818	825	831	818
Q/s	70.6	135.7	152.0	159.6	163.6	175.5
I-64 Well 3						
	11/13	11/16	11/17	11/18	11/19	11/19
SWL	19.72	21.30	21.10	21.49	21.32	21.43
PWL	26.57	26.86	26.57	26.84	26.56	26.62
DD	6.85	5.56	5.47	5.35	5.24	5.19
Flow	600	600	600	600	600	600
Q/s	87.6	107.9	109.7	112.1	114.5	115.6
25th Street Well 10						
	11/5	11/6	11/10	11/11	11/12	11/13
SWL	19.30	20.17	19.98	20.24	20.34	20.42
PWL	28.33	28.16	. 30.29	28.54	28.78	28.75
DD	9.54	7.99	10.33	8.30	8.44	8.33
Flow	850	810	865.	865	865	865
Q/s	89.1	101.4	83.7	104.2	102.5	103.8
Venice Well 6						
	10/27	10/28	10/29	10/30	11/2	11/4
SWL	18.88	19.01	18.92	19.03	18.95	19.10
PWL	28.21	29.11	28.12	28.35	29.16	29.18
DD	9.33	10.10	9.20	9.32	10.21	10.08
Flow	882	869	869	876	876	810
Q/s	94.5	86.0	94.5	94.3	85.8	80.4
Averages						
Q/s	85.5	107.8	110.0	117.6	116.6	118.8
ΔQ/s		22.3	2.2	7.6	-1.0	2.2
% increase over initial Q/s		26.1	2.6	8.9	-	2.6
% of total improvement		67.0	6.6	22.8	-	6.6

Note: Total ΔQ/s = 33.3 (38.9% improvement over initial Q/s)
PPP - Polyphosphate
SWL - Static Water Level (ft)
PWL - Pumping Water Level (ft)
DD - Drawdown (ft)
Flow - Pumping rate (gpm)
Q/s - Specific capacity (gpm/ft)

the amount of well loss remained unchanged or increased (although it was still low) following treatment. As described previously in the section, "Results of Step Tests," this puzzling finding could have resulted from the low total drawdown after treatment, resulting in a higher percentage of well loss, and from the unequal contribution to flow from the entire length of well screen.

Table 6 contains a comparison of the pre- and post-treatment specific capacity data for the Water Survey step tests and the specific capacity tests conducted by the contractor. For two wells, the post-treatment specific capacity from the step tests is higher than that from the contractor's tests. This may indicate that additional development occurred in the wells after the contractor's final tests were conducted but before the Water Survey performed the step tests. In all cases, the pre-treatment specific capacities from the contractor's tests are greater than those indicated by the Water Survey's step tests. The combined result of these variations is that the total improvement indicated by the contractor's tests (average about 39%) is much less than that from the step tests (average about 150%).

The results from the step tests and the contractor's tests both show that I-70 Well 12 improved the most, by far. Improvement was also substantial at I-64 Well 3 and 25th Street Well 10.

Results were not nearly as clear for Venice Well 6. Field documentation shows a decline in the specific capacity data (table 5) as treatment progressed. The well pumped phosphates for an uncharacteristically long period of more than two days following treatment, which caused large amounts of suds or foam in the discharge. The Water Survey step test, conducted 13 days after treatment, indicated marked improvement in the specific capacity as compared to pre-treatment data and the contractor's final test (table 6). The well also produced sand during the step test (which is discussed in a later section of this report). Presently, it is not fully understood how or if these symptoms might be related to the treatment. The unusual phosphate pumpage could simply be the effect of phosphate migration away from the well during treatment. Such movement might be caused by the pumping cones of other nearby dewatering wells or a preferential path in an interval of coarse gravel with high hydraulic conductivity. Another possibility is that a break in the casing or screen has caused the sand pumpage and distorted the path taken by phosphates. The probable result for any of these scenarios is that it takes longer to remove the phosphate from the system.

Sand Pumpage Investigation

During Phase 4, I-70 Well 9 was discovered to be pumping a substantial amount of fine sand, necessitating its shutdown for all but emergency use. It is now awaiting replacement. To address concerns that the other wells might be pumping sand, the possibility of sand pumpage was investigated at I-70 Well 2, I-70 Well 8, and Venice Well 6 during Phase 5. During the step tests at these wells, the water was discharged from an orifice tube into a portable 1000-gallon tank. Siphon tubes were

Table 6. 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							
	Well 12	ISWS	7/30/86	45.1	11/16/87	254.2	+463.6
		BEC	10/14/87	70.6	10/22/87	175.5	+149.0
I-64							
	Well 3	ISWS	6/26/84	55.9	6/21/88	105.6	+88.9
		BEC	11/13/87	87.6	11/19/87	115.6	+32.0
25th Street							
	Well 10	ISWS	7/26/85	62.8	11/18/87	96.2	+53.2
		BEC	11/5/87	89.1	11/13/87	103.8	+16.5
Venice							
	Well 6	ISWS	11/29/83	76.7	11/17/87	145.3	+89.4
		BEC	10/27/87	94.5	11/4/87	80.4	- 14.9*
Average							
		ISWS		60.1		150.3	+150.1
		BEC		85.5		118.8	+38.9

Q/s = specific capacity
ISWS = Illinois State Water Survey
BEC = Brotcke Engineering Co, Inc.

* Pumped phosphates, sand, and gravel-pack materials

used to control the discharge from the tank (see figure 12 for a diagram of the setup).

The 1000-gallon tank acts as a sedimentation basin that, under ideal conditions, should allow sand with minimum grain diameters of no more than 0.1 mm to settle out at the design pumping rates of the wells (600 to 800 gpm). Usually 80 to 90% or more of the aquifer material in the screened interval of the wells exceeds the 0.1 mm grain size.

During the step test on I-70 Well 2, a small amount of sand collected in the tank, but for I-70 Well 8 and Venice Well 6, the amount of sand that accumulated was considerably larger. The maximum pumping rate for I-70 Well 2 was only 365 gpm (versus 600 and 800 gpm for I-70 Well 8 and Venice Well 6, respectively), which may have limited the amount of sand pumped, although settlement had not been evident around this well. A sample of the sand was saved after each test to be sieved for the grain size distribution. (For I-70 Wells 2 and 8, two samples were collected from different areas of the tank.) The sand grain size data for each sample are plotted in figures 13, 14, and 15 and appear in Appendix F.

The sieve results for I-70 Wells 2 and 8 are very comparable to those obtained from I-70 Well 9 during Phase 4 (Wilson et al., 1990), although the sand sample from I-70 Well 2 is somewhat finer. Review of this information, the limited original well construction data, and sieve data from the Tri-Level borings indicates that fine aquifer material above about elevation 340 to 350 feet could be the source of the sand pumped from these two wells. Given these conditions, 10 to 20 feet of the upper well screen and an even longer interval of the gravel pack would be opposite the suspect source material.

Based on the gravel pack originally recommended for use in the I-70 wells and on our well design criteria, it appears that the aquifer material in zones above elevation 340 to 350 feet is fine enough to migrate through the pack. If the above assumptions are valid, a liner could be installed, blanking off the upper 10 to 20 feet of well screen, as was suggested for I-70 Well 9 (see figure 16, Phase 4, Wilson et al., 1990), to attempt to remediate the condition. Other possibilities to be considered are inspection of the wells with underwater video equipment under pumping conditions and borings drilled next to each well (for formation sampling and grain size analysis) to help verify where the sand is entering the wells. Given the volume of sand pumped during the step test, the recurring settlement problems reported by IDOT around this well, and the relative importance of its location, Well 8 requires attention or replacement in the near future.

The scenario is much different for Venice Well 6, as seen in figure 15. The bimodal distribution indicates two distinct sizes of sand, suggesting that both formation material and gravel pack were pumped. It also appeared from visual inspection of the sample that the coarser fraction of sand is gravel-pack material. Unlike the pumpage of fine sand, the presence of gravel pack in the discharge from Venice Well 6 indicates a problem with the well screen or casing such as would be caused by an opening or crack. As previously discussed, this well exhibited other puzzling symptoms following treatment. In this case, it is not

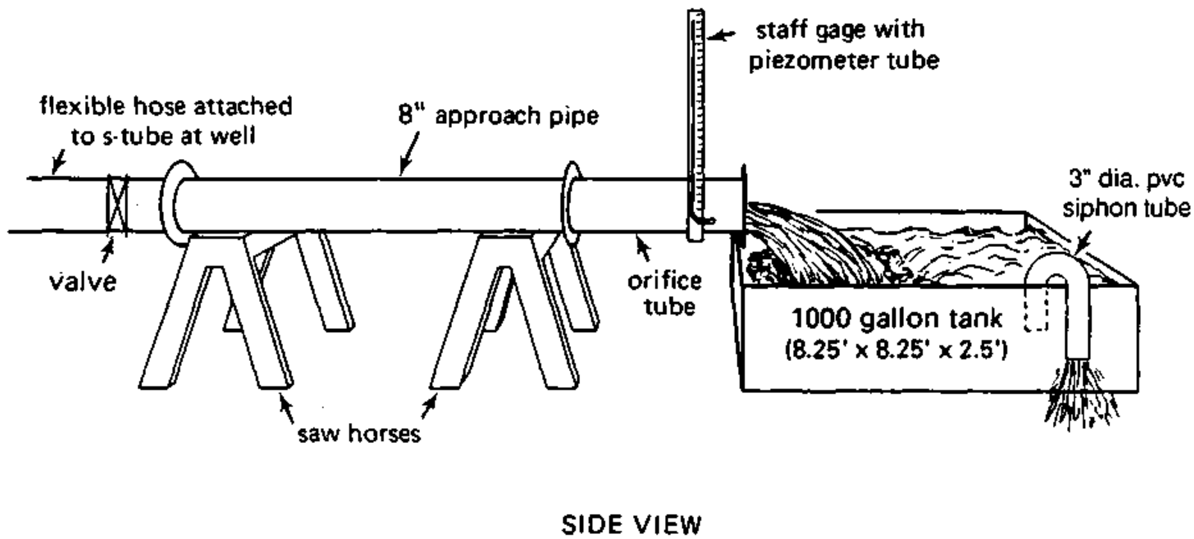

Figure 12. Sand pumpage test setup

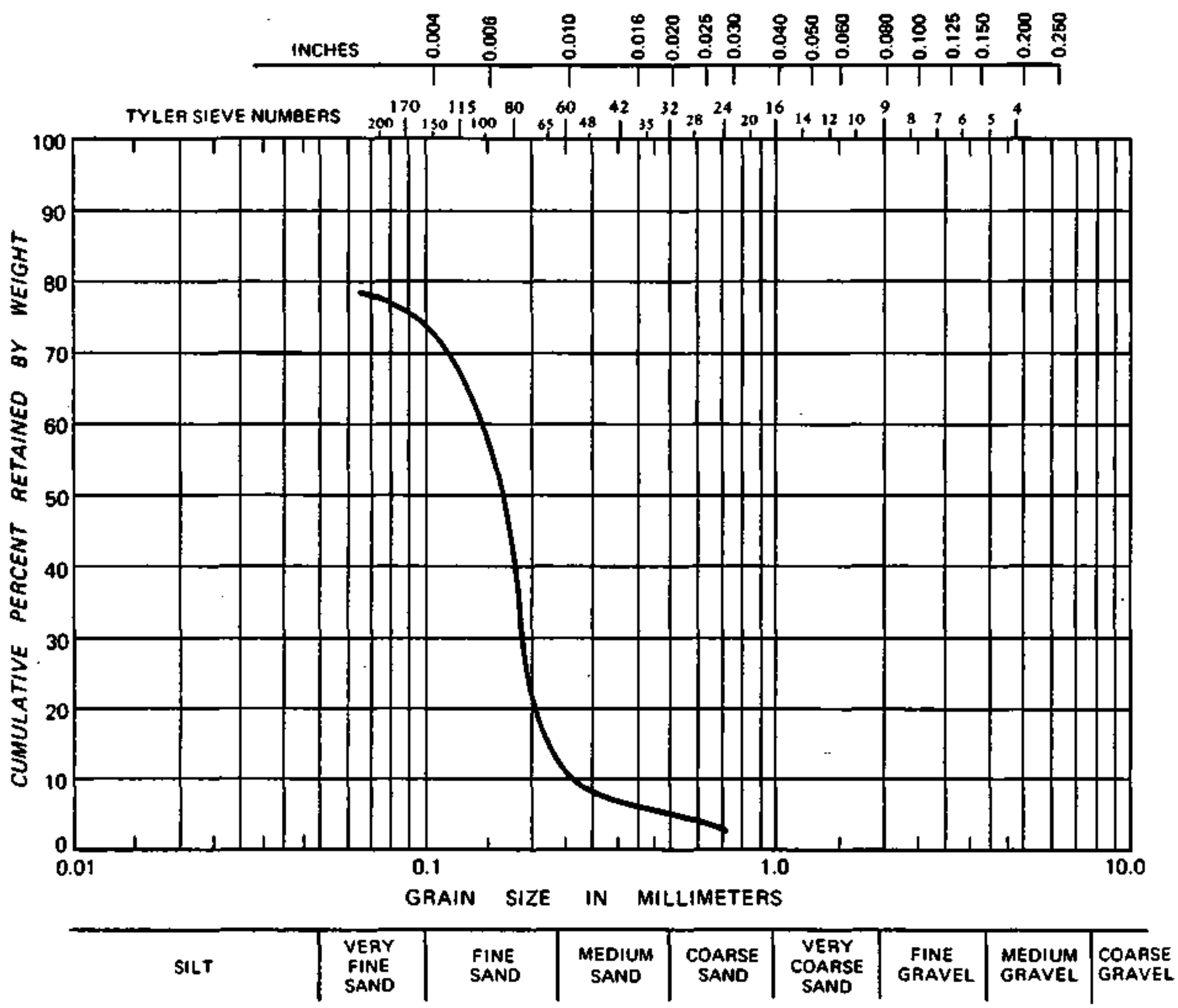

Figure 13. Sieve analysis of sand pumped from I-70 Well 2

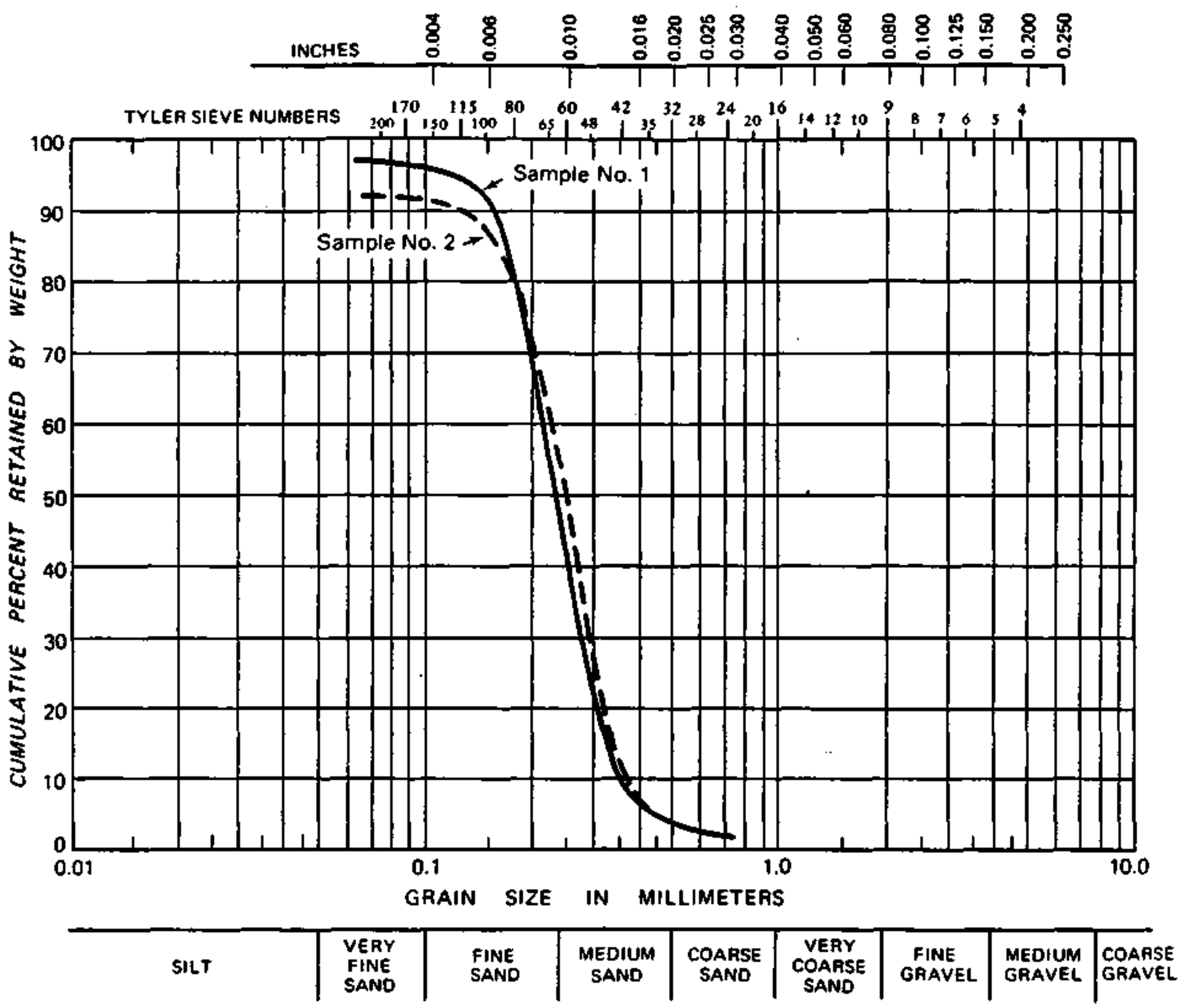

Figure 14. Sieve analysis of sand pumped from I-70 Well 8

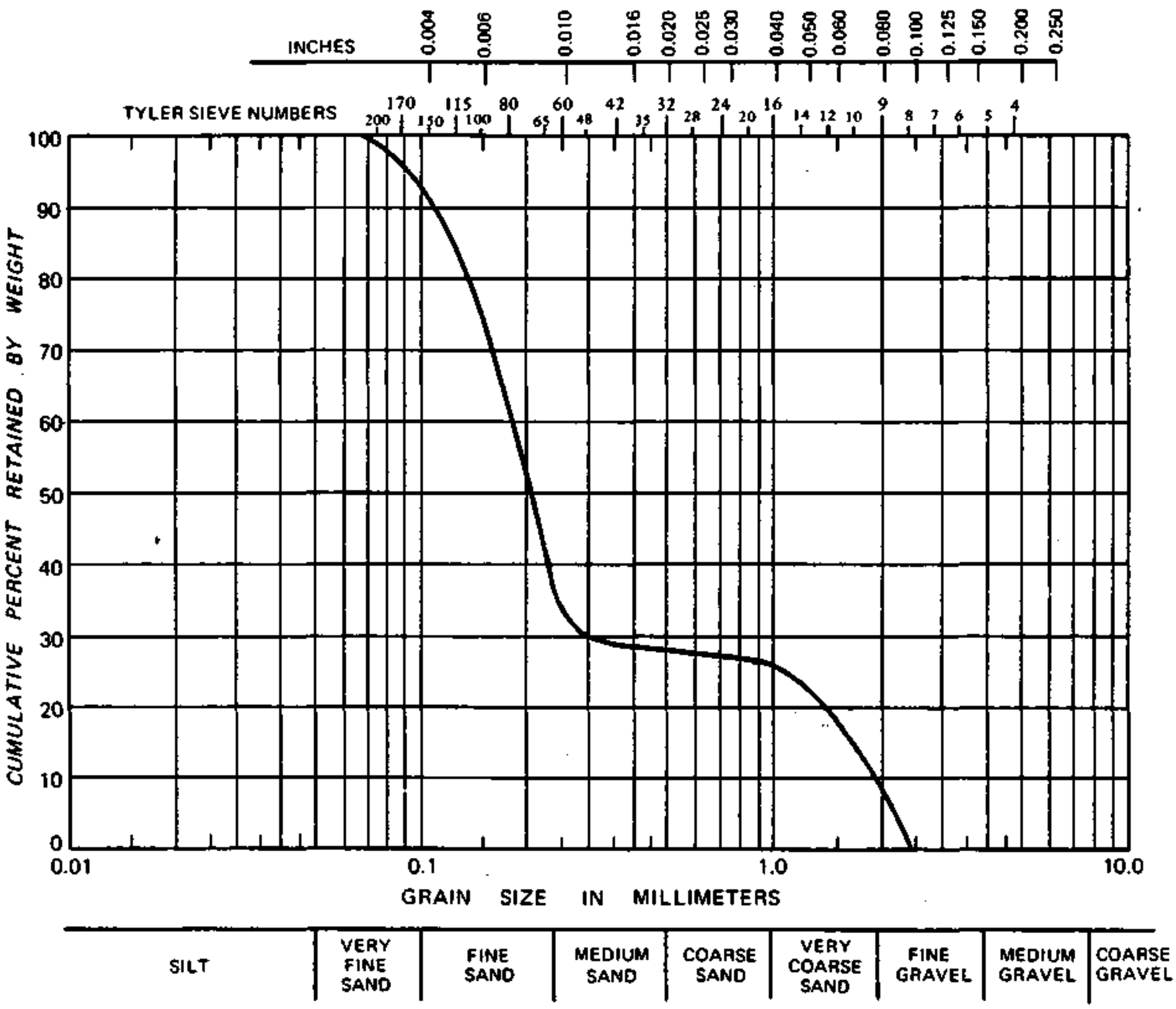

Figure 15. Sieve analysis of sand pumped from Venice Well 6

possible to determine whether the sand pumpage is related to the treatment activities; but historically, we are not aware of any reports of settlement at this well site. Although replacement of this well may be the only option, the recommended course of action would be first to inspect the well with underwater video equipment to determine whether repairs are possible.

Condition of Relief Wells at Two I-255 Detention Ponds

IDOT maintains two stormwater detention ponds southeast of the intersection of I-255 and I-55/I-70. To help maintain stability of the reservoir berms and bottoms and to mitigate other problems at the site caused by high ground-water levels, 39 relief wells were built around the ponds (figure 16) during February-April 1985. Typical construction features of the relief wells are depicted in figure 17.

To help in observing the operating condition of the wells and to allow scheduling of rehabilitative procedures if needed, a monitoring and inspection program was recommended by John Mathes & Associates, consultant to IDOT for the original design of the relief well system. The recommended monitoring and inspection program includes inspection of the well-head manholes, vaults, and check valves; well depth and water-level (well, piezometer, and pond) measurements; and testing for nuisance bacteria (e.g., iron bacteria). These monitoring and inspection practices will help detect problems in the relief wells such as those caused by chemical incrustation/corrosion, biofilms, or siltation.

The Water Survey was asked to assist in the inspection of the relief wells. Since access to the relief wells through the manholes is limited (by a heavy concrete cover) and IDOT personnel were unfamiliar with the wells Insofar as their accessibility for monitoring and inspection, arrangements were made to remove the concrete well manhole covers from a few selected wells. The wells would be visually inspected as far as possible, and information would be collected to aid in planning for additional monitoring work. Four relief wells, two at each pond, were selected for the initial inspection. Selections were based primarily on well site accessibility for the IDOT boom truck that was used to remove the concrete covers. The inspections were conducted on July 6, 1988.

At the north detention pond, Relief Well (RW) 13 and RW 16 were inspected. Approximately 2.5 feet of water was in the bottom of each vault, covering the well-head check valves and basin outlet pipes. A set of steps are attached to the vault caissons to allow entry into the pit; however, the vault cover prevents safe access to the steps. A ladder will need to be Inserted into the vaults before the well heads can be reached.

It was observed that the discharge pipes from the vaults to the pond are not equipped with valves. Use of valves would allow the relief wells to be isolated from water in the pond during inspection and maintenance activities. During this inspection, water levels in the vaults were at the same elevation as the pond water level. Thus the vault bottom and outlet pipes are at a low enough elevation to receive backflow from the pond. Some type of temporary valving and pumping equipment probably will

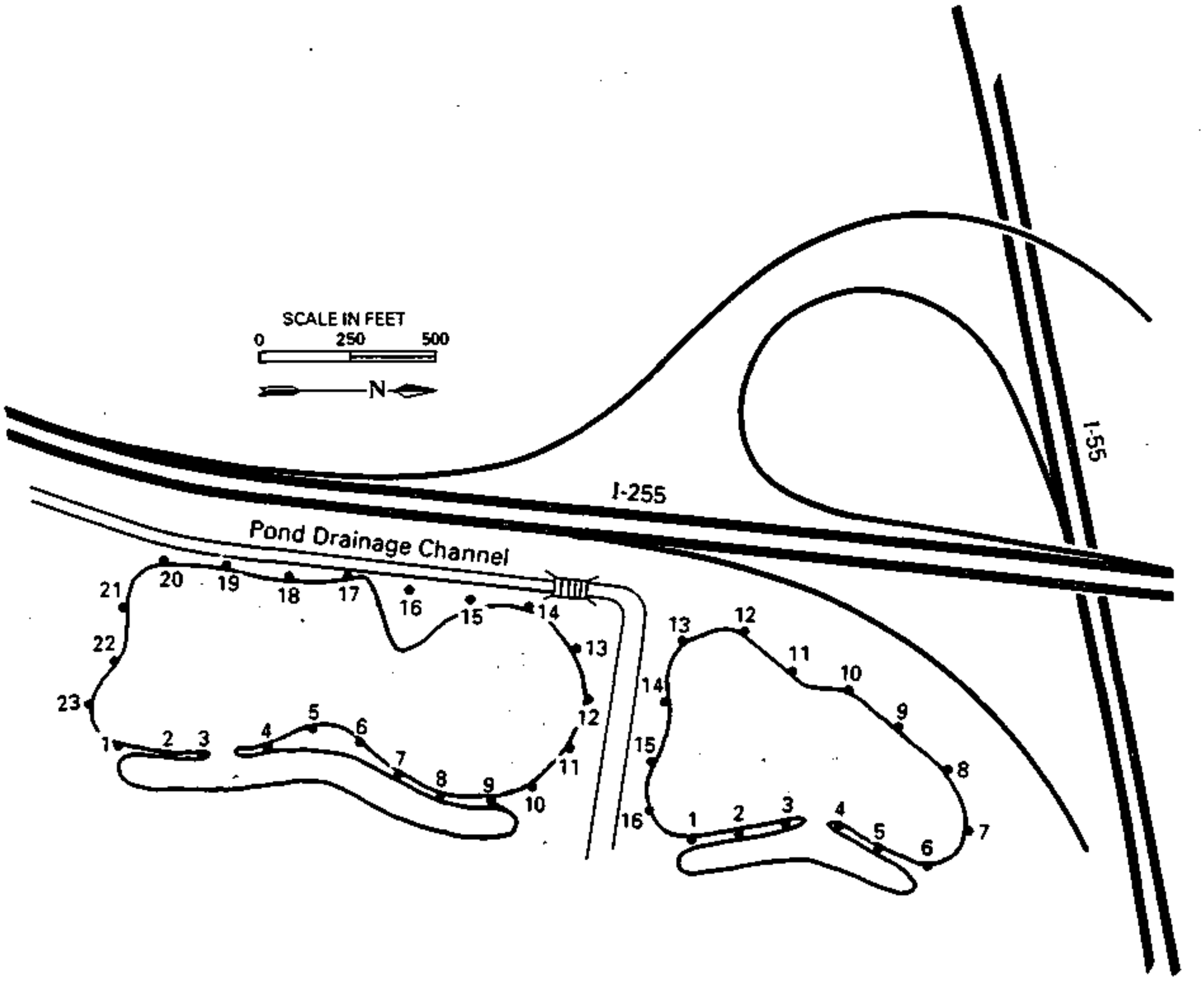

Figure 16. Locations of relief wells around two stormwater detention ponds (Adapted from John Mathes and Associates, Inc., 1986)

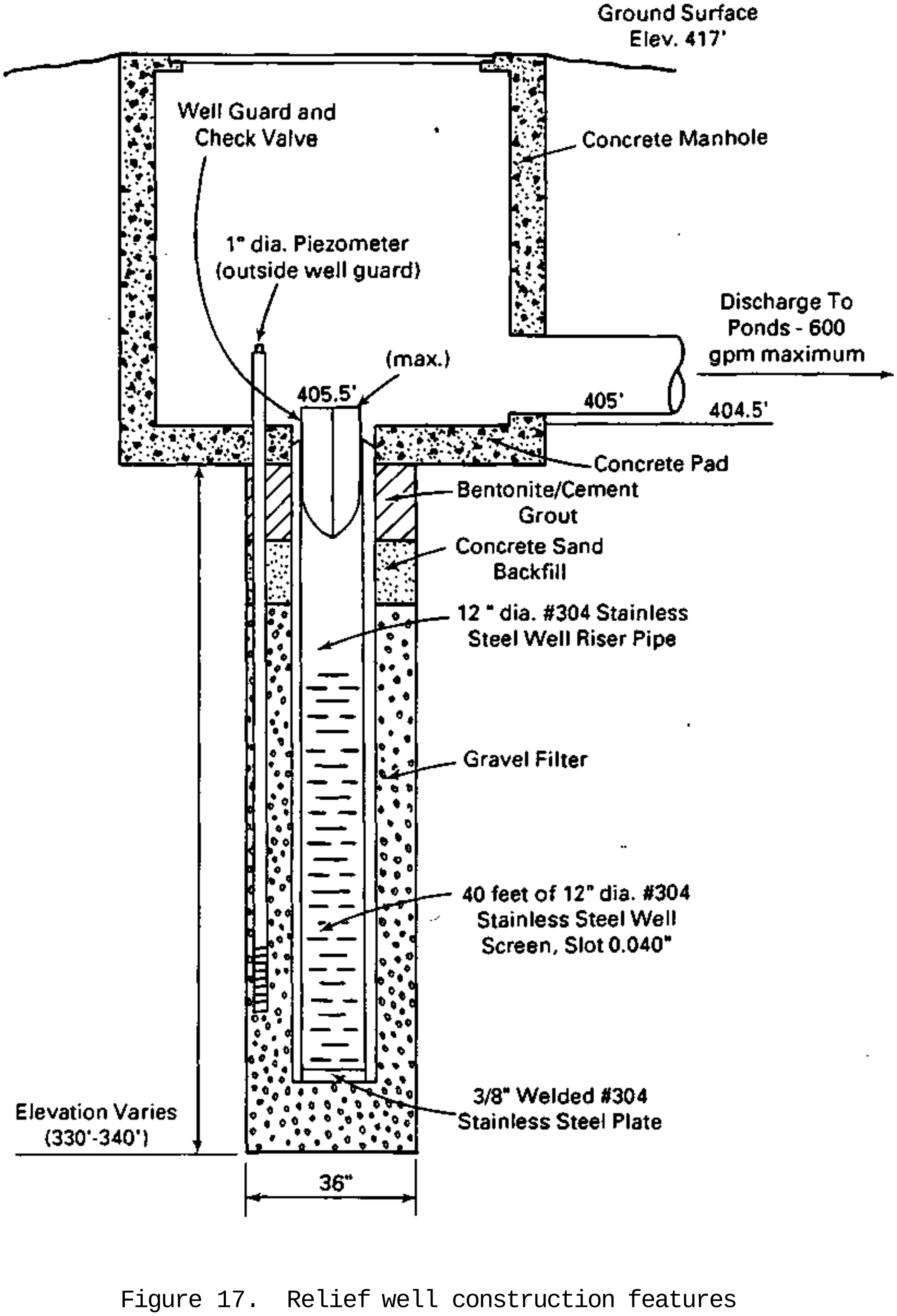

Figure 17. Relief well construction features
(From John Mathes and Associates, Inc., 1986)

be needed to inspect the well heads and to conduct tests. From ground level, there was no apparent sign of biological activity or other operational problems in either vault.

At the south detention pond, RW 13 and RW 19 were inspected. The conditions found were similar to those for the wells at the north pond. Approximately 1.9 feet of water was in the vault bottom of RW 13, and 2.3 feet of water was in RW 19. The vault water levels were at the same elevation as the pond (406.58 feet). Both well heads were submerged, but the top was visible at RW 13. From ground level there was no apparent sign of biological activity or other operational problems in either vault.

A final observation was that the tops of the gravel-pack piezometers were terminated within about 1 foot of the top of the vault. In this position, access for water-level measurements was not possible from within the vault or from the top of the manhole.

CONCLUSIONS AND RECOMMENDATIONS

Condition of Wells

The results of the step tests show that I-70 Wells 2, 8, 10, and 11 are in poor condition. All four have low specific capacities, ranging from 31.6 to 51.9 gpm/ft. The inability to calculate turbulent well loss probably results from laminar conditions at low pumping rates or from unstable conditions in the vicinity of the well screens. The polyphosphate/acid treatment used on the dewatering wells in Phases 3, 4, and 5 is recommended to improve the condition of these wells. The step test for I-64 Well 15 shows the well to be in good condition. I-64 Well 15 should be monitored closely when it is used, since the well-loss portion of drawdown is more than 10%.

As previously discussed, the four wells step-tested after chemical treatment (I-70 Well 12, I-64 Well 3, 25th Street Well 10, and Venice Well 6) appear to be in good hydraulic condition. The high percentage of drawdown attributed to well loss in two of the wells is only a minor factor in determining their condition. More important is the specific capacity that is reasonable for each of these wells.

Well Rehabilitation

The chemical treatments used to restore well capacity in Phase 5 were successful. The data collected during the treatment indicate that the average increase in specific capacity of the four wells was about 39%, and 60% if Venice Well 6 is not included.

Venice Well 6 was pumped for more than two days following treatment without being cleared of polyphosphates. This well also pumped sand and gravel-pack material during the step test. It is not fully understood what caused these symptoms. Obviously, the latter condition could indicate a major problem and requires immediate attention. The next section presents recommendations regarding this well.

The wells to be chemically treated are selected on the basis of data from the most recent Water Survey step tests and available water-level difference (Ah) information. However, in some cases the elapsed time between the Water Survey step test and the chemical treatment exceeds a year. In these cases, another Water Survey step test should be conducted a few weeks prior to the start of treatment. This would confirm the need for chemical treatment and would improve verification of the data collected by the contractor during chemical treatment.

A review of the specific capacity data for the individual treatment steps indicates that in some cases the third and fourth polyphosphate treatment steps provide only limited improvement. This can be seen in table 5; in table 5 for Phase 3 (Olson et al., 1990); and in table 6 for Phase 4 (Wilson et al., 1990). This finding suggests that the treatment project specifications could be modified to allow the treatment to be tailored to each specific well, thereby increasing the efficiency and reducing the overall cost of the treatment by elimination of unneeded steps.

This approach will require careful review of the field results after each step of treatment is completed. A designated person(s), possibly the IDOT Resident Engineer (RE) and an observer from the Water Survey, should be on hand to review this information and make the decision for further steps. This decision probably should be based on a pre-determined specific capacity goal for each well, supplemented by information on the improvement trend between steps. Once a well has been restored to this goal, further treatment steps may not be worthwhile. A reasonable specific capacity goal may be some percentage of original specific capacity, if known, or it may be based upon the average specific capacity of the wells at the dewatering site.

For Phase 5, using the above method would likely have reduced the treatment procedures by at least one phosphate step at most of the wells. The data in table 5 show little or no improvement in specific capacity after the second phosphate step. In addition, except for Venice Well 6, the specific capacity goals were also attained by the end of this step, making the prospects for further improvement improbable.

Sand Pumpage Investigation

I-70 Wells 2 and 8 and Venice Well 6 were tested for sand pumpage during the step tests. All three wells pumped sand. Only a small amount was detected in the discharge from I-70 Well 2. Although the low pumping rate (365 gpm) may have helped limit the amount of sand, there is little visual evidence of settlement around the well at land surface. If the source of the sand is from aquifer material above elevation 340 to 350, a liner may remedy the condition, as was suggested for I-70 Well 9 (Phase 4, Wilson et al., 1990). A downhole video inspection, placement of a boring next to the well (for formation sampling and grain size analysis), and close monitoring of the well's performance should be considered as follow-up to this problem.

I-70 Well 8 pumped a considerable amount of fine sand similar to that obtained at I-70 Well 9 during Phase 4. As mentioned above, the use of a liner may remedy the condition. A downhole video inspection and placement of a boring next to the well for sampling and grain size analysis should help determine where sand is entering the well. This well requires immediate attention or replacement because settlement, presumably caused by the sand pumpage, has been a problem and the well is at a key location for the dewatering system.

Venice Well 6 pumped excessive material at a rate of 800 gpm. The sieve results suggest that both sand and gravel pack are being pulled into the well, perhaps through a large crack or opening. A downhole video inspection of this well is recommended to help identify the problem to see if repairs are possible. Because mechanical defects are the likely cause, a second alternative is replacement of the well.

I-255 Detention Pond Relief Wells

Because of physical constraints at the relief wells, the preliminary investigation was limited to visual observations from the well-head vault manhole at ground level. While this inspection did not reveal any obvious evidence that the condition of the wells might be in jeopardy, a more detailed inspection should be considered for a better assessment. Before this can be done, arrangements must be made to allow access to the well heads. Access may possibly be gained either by lowering the pond water levels below the vault bottoms or, preferably, by inserting a temporary valve/plug into the outlet pipes. The vaults can then be pumped out to expose the well heads.

Once the well heads are exposed, it should be possible to remove the check valves and gain access to the wells. Each well can then be visually inspected, measurements can be made, and samples of water (or suspect material that might be present) can be collected for analysis. Depending on what is found, step-testing the wells and inspecting the wells with underwater video equipment may also be considered.

Future Investigations

A program of continued investigation of the condition of the dewatering wells is recommended. Measuring the difference between water levels in the piezometer and the adjacent well will continue to be important as a first step in determining whether wells are candidates for future step tests or treatment. In addition, if a well is pumping sand, this points out a potentially major problem with the well. A sand pumpage investigation is recommended as a standard part of each step test.

At this time, we recommend treatment for the four wells in poor condition (I-70 Wells 2, 8, 10, 11). We also suggest TV inspection of these wells for excessive buildup of incrusting minerals.

Four of the well piezometers were identified as plugged during the step tests. They are important parts of the monitoring system and the step tests. We suggest that they be rehabilitated, if possible, or replaced.

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Appendix A.

Step Test Data

I-70	Well 2	6/20/88
	Well 8	6/22/88
	Well 10	8/13/87
	Well 11	8/12/87
	Well 12	11/16/87
I-64	Well 3	6/21/88
	Well 15	7/22/87
25th St.	Well 10	11/18/87
Venice	Well 6	11/17/87

DEWATERING WELL DATA

	Well No. I-70 W2	Piezometer No. I-70 P2
Date Drilled:	1973	1973
Casing		
Top elevation:	405.7 ft	414.6 ft
Diameter:	16-in. SS	2-in. PVC
Length:	-	na
Screen		
Bottom elevation:	307.36	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.080-in.	na
Measuring Point Elevation:	406.5	414.6
Nonpumping Water Level		
Depth below temp. MP:	36.28 ft	-
Length of temp. MP extension:	3.5	-
Depth below perm. MP:	27.78	35.44
Elevation:	378.72	379.16
Date of Step Test:	6/20/88	-
Water Sample		
Time:	2:18 PM	-
Temperature:	60.5° F	-
Laboratory No.:	A88061701 A88061704	-
Distance and Direction to Piez. from PW:		6.25 ft W
Time PW Off Before Step Test:		na

Wells in Operation at Site at Time of Step Test:* I-70 Nos. 3, 4, 5, and 14

Note: SWS 8-in. dia. orifice tube w/plate No. 4 used to measure pumping rate. The tube was discharged into a 1000-gallon portable tank to check for sand pumpage. The well produced sand during the test and a sample was collected for analysis of the grain size distribution.

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well I-70 No. 2

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
11:58 AM		36.29				Will perform sand
12:06			35.79			pumpage test.
12:20		36.28				Steel tape readings
12:24			35.44			Using McDas
12:40	0	36.28	35.44			Pump on
	1	41.53	35.61	0.80	300	
	2	41.92	35.65			
	3	41.97	35.68			
	4	42.03	35.72			
	6	42.09	35.78			
	8	42.13	35.86	0.81	305	
12:50	10	42.16	35.91			
	12	42.17	35.97	0.80	300	
	14	42.20	36.05			
	16	42.21	36.08			
01:00	20	42.23	36.20			
	25	42.26	36.35	0.79	300	
01:10	30	42.29	36.47	0.80	300	Increase rate
	1	43.21	36.51	1.09	350	Step 2
	2	43.24	36.54			
	3	43.25	36.56			Piezometer partially
	4	43.26	36.60			plugged
	6	43.27	36.65			
	8	43.28	36.70			
01:20	10	43.30	36.74			
	12	43.30	36.80	1.08	350	
	14	43.30	36.86			
	16	43.29	36.89			
01:30	20	43.39	36.98	1.06	345	
	25	43.42	37.09			
01:40	30	43.43	37.21	1.10	350	Increase rate
	1	43.66	37.23	1.18	365	Step 3
	2	43.66	37.25			Wide open
	3	43.67	37.27			
	4	43.67	37.30			
	6	43.67	37.33			
	8	43.66	37.37			
01:50	10	43.66	37.41			
	12	43.68	37.45	1.17	365	
	14	43.69	37.48			
	16	43.69	37.52			
02:00	20	43.70	37.58			
02:05	25	43.70	37.66	1.17	365	
02:10	30	43.69	37.73			
02:18						Collected water sample

DEWATERING WELL DATA

	Well No. I-70 W8	Piezometer No. I-70 P8
Date Drilled: - -		
Casing		
Top elevation:	381.4 ft	387.5 ft
Diameter:	16-in. SS	2-in. PVC
Length:	16.6 ft	na
Screen		
Bottom elevation:	304.76 ft	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.080-in.	na
Measuring Point Elevation:	382.3 ft	387.5
Nonpumping Water Level		
Depth below temp. MP:	8.81 ft	-
Length of temp. MP extension:	3.9	-
Depth below perm. MP:	4.91	10.22
Elevation:	377.39	377.28
Date of Step Test:	6/22/88	-
Water Sample		
Time:	2:10 PM	-
Temperature:	61° F	-
Laboratory No.:	C88061703 C88061706	-
Distance and Direction to Piez. from PW:		9.9 ft SW
Time PW Off Before Step Test:		Unknown but well not in operating condition prior to test

Wells in Operation at Site at Time of Step Test:* I-70 Nos. 3, 4, 5, and 14

Note: SWS 8-in. dia. orifice tube w/plate No. 4 used to measure pumping rate. The tube was discharged into a 1000-gallon portable tank to check for sand pumpage. A sizeable amount of sand was collected during the test and was sampled for analysis of the grain size distribution.

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well I-70 No. 8

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
10:58 AM		8.81		0.80	300	Using McDAS
11:03		8.75				
11:06			10.22			
11:15	0	8.81	10.22			Pump on
	1	15.45	11.41	0.80	300	Step 1
	2	15.57	11.89			
	3	15.58	11.94			
	4	15.63	11.99			
	6	15.65	12.04			
	8	15.64	12.09			
11:25	10	15.64	12.12			
	12	15.65	12.15			
	14	15.65	12.17			
	16	15.64	12.18			
11:35	20	15.66	12.21			
	25	15.68	12.23			
	30	15.68	12.25	0.80	300	
11:46	31	15.68	12.27			Increase rate
	1	16.84	12.51	1.10	350	Step 2
	2	16.79	12.53			
	3	16.77	12.55			
	4	16.75	12.56			
	6	16.73	12.57			
	8	16.71	12.58	1.09	350	
11:56	10	16.71	12.59			
	12	16.71	12.60			
	14	16.70	12.61			
	16	16.70	12.61	1.09	350	
12:06	20	16.70	12.63			
	25	16.69	12.64			
	29	16.70	12.65	1.09	350	
12:16	30	16.75	12.65			Increase Rate
	1	17.84	12.90			Step 3
	2	17.83	12.94			
	3	17.81	12.96			
	4	17.80	12.97			
	6	17.78	12.98			
	8	17.76	13.00			
12:26	10	17.75	13.00			
	12	17.75	13.01	1.42	400	
	14	17.74	13.02			
	16	17.73	13.03			
12:.36	20	17.74	13.05	1.43	400	
12:41	25	17.73	13.05			

WATER LEVEL MEASUREMENTS (Continued)
I-70 Well No. 8

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
12:45	29	17.74	13.06	1.43	400	
12:46	30	17.76	13.08			Increase Rate
	1	18.84	13.31	1.80	450	Step 4
	2	18.81	13.34			
	3	18.79	13.36			
	4	18.79	13.37			
	6	18.75	13.38			
	8	18.74	13.39			
12:56	10	18.75	13.41			
	12	18.75	13.42	1.81	450	
	14	18.75	13.42			
	16	18.74	13.43			
01:06	20	18.73	13.44			
	25	18.73	13.45			
	29	18.74	13.46	1.82	450	
01:16	30	18.71	13.48			Increase Rate
	1	19.83	13.70	2.22	500	Step 5
	2	19.92	13.77			
	3	19.70	13.75			
	4	19.68	13.75			
	6	19.80	13.79			
	8	19.84	13.82			
01:26	10	19.84	13.84			
	12	19.85	13.85			
	14	19.84	13.86			
	16	19.84	13.87	2.32	510	Decrease rate
01:36	20	19.45	13.80	2.21	500	
	25	19.55	13.83			
	29	19.54	13.83	2.21	500	
01:46	30	19.52	13.83			Increase rate
	1	20.68	14.10	2.69	550	Step 6
	2	20.64	14.12			
	3	20.63	14.12			
	4	20.62	14.13			
	6	20.60	14.15	2.70	550	
	8	20.59	14.16			
01:56	10	20.60	14.18			
	12	20.59	14.18			
	14	20.58	14.19			
	16	20.58	14.20			
02:06	20	20.56	14.20	2.71	550	
	25	20.56	14.22			
	29	20.58	14.24	2.74	555	
02:16	30	20.62	14.23			Increase rate

WATER LEVEL MEASUREMENTS (Continued)
I-70 Well No. 8

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	21.66	14.48	3.22	600	Step 7
	2	21.70	14.52			Wide open
	3	21.70	14.54			
	4	21.69	14.56			
	6	21.70	14.57			
	8	21.70	14.59	3.33	610	Decrease rate
02:26	10	21.60	14.57	3.24	600	
	12	21.42	14.55			
	14	21.43	14.56			
	16	21.43	14.56			
02:36	20	21.42	14.57	3.25	600	
	25	21.42	14.59			
02:46	30	21.41	14.60	3.22	600	Pump off

DEWATERING WELL DATA

	Well No. I-70 W10	Piezometer No. I-70 P10
Date Drilled:	-	-
Casing		
Top elevation:	400.8 ft	409.8 ft
Diameter:	16-in. SS	2-in. PVC
Length:	37.4 ft	na
Screen		
Bottom elevation:	303.4	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.080-in.	na
Measuring Point Elevation:	401.5	409.8
Nonpumping Water Level		
Depth below temp. MP:	31.94 ft	-
Length of temp. MP extension:	9.38 ft	-
Depth below perm. MP:	22.56	31.50
Elevation:	378.94	378.30
Date of Step Test:	8/13/87	-
Water Sample		
Time:	10:56 AM	-
Temperature:	61° F	-
Laboratory No.:	87081102 87081104	-
Distance and Direction to Piez. from PW:		5.8 ft SE
Time PW Off Before Step Test:		na

Note: SWS 8-in. dia. orifice tube w/plate No. 4

SWS Crew: Olson, Sanderson, Kohlhase, Hammen

WATER LEVEL MEASUREMENTS
Well I-70 No. 10

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
8:20 AM		31.94	31.50			Steel tape
8:40		32.95	32.30			Electric dropline
8:45			32.30			approx. 9.38 ft from MP
8:53		32.97	32.30			to top of cover plate
8:59	0	32.96	32.30			Start pump
9:01	1	41.75	36.38	0.79	300	Step 1
	2	41.89	36.75			
	3	41.99	36.79	0.80	300	
	4	42.04	36.83			
	5	42.07	36.85			
	6	42.08	36.87			
	8	42.09	36.89	0.81	305	
	10	42.09	36.89			
	12	42.13	36.92	0.81	305	
	14	42.14	36.92			
	16	42.14	36.92			
	20	42.16	36.94	0.81	305	
	25	42.16	36.95			
	29	42.18	37.01	0.80	300	
9:30	30	42.18	36.96			Start collecting water in tank
	1	43.44	37.23			Step 2
	2	43.77	37.51			
	3	43.77	37.56			
	4	43.75	37.56	1.08	350	
	5	43.70	37.57			
	6	43.76	37.57			
	8	43.76	37.59	1.08	350	
	10	43.75	37.58			
	12	43.74	37.58			
	14	43.77	37.59			
	16	43.77	37.60	1.07	350	
	20	43.77	37.61			
	25	43.79	36.61			
	29	43.82	37.62	1.07	350	
10:00	30	43.82	37.68			Increase rate
	1	44.85	37.78			Step 3
	2	45.10	38.05	1.34	390	Valve wide open
	3	45.10	38.12			
	4	45.10	38.12	1.34	390	
	5	45.10	38.12			
	6	45.10	38.13			
	8	45.13	38.13	1.34	390	

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 10

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	45.13	38.15			
	12	45.10	38.13	1.34	390	
	14	45.12	38.14			
	16	45.13	38.15			
	20	45.12	38.14	1.34	390	
	25	45.12	38.14	1.34	390	
	29	45.12	38.15	1.32	385	
10:30	30	45.13	38.16			

DEWATERING WELL DATA

	Well No.		Piezometer No.	
	I-70	Wll	I-70	Pll
Date Drilled:	-		-	
Casing				
Top elevation:	396.1 ft		403.2 ft	
Diameter:	16-in. SS		2-in. PVC	
Length:	32.0 ft		na	
Screen				
Bottom elevation:	304.1		na	
Diameter:	16-in. SS		2-in. PVC	
Length:	60 ft		3 ft	
Slot size:	0.080-in.		na	
Measuring Point Elevation:	396.9		403.2	
Nonpumping Water Level				
Depth below temp. MP:	23.92 ft		-	
Length of temp. MP extension:	6.56 ft		-	
Depth below perm. MP:	17.36 ft		24.59 ft	
Elevation:	379.54		378.61	
Date of Step Test:	8/12/87		-	
Water Sample				
Time:	1:00 PM		-	
Temperature:	60° F		-	
Laboratory No.:	87081101 87081103		-	
Distance and Direction to Piez. from PW:			5.2 ft W	
Time PW Off Before Step Test:			na	

Note: SWS 8-in. dia. orifice tube w/plate No. 4

SWS Crew: Olson, Sanderson, Kohlhase, Hammen

WATER LEVEL MEASUREMENTS
Well I-70 No. 11

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
8:26 AM		23.92	24.59			Steel tape
			25.68			Electric dropline
8:39		25.24	25.67			
8:46		25.13				
8:47		25.13	25.67			
8:54		25.12	25.65			
9:25		25.14	25.64			
9:39		25.11	25.63			
9:47	0	25.10	25.62			Pump on
	1		25.69	0.79	300	Step 1
	2	30.79	25.70			
	3	30.81	25.70			
	4	30.85	25.70	0.78		
	5	30.86	25.71			
	6	30.86	25.72			
	8	30.89	25.72	0.78		
9:57	10	30.90	25.74			
	12	30.92	25.75	0.78		
	14	30.93	25.75			
	16	30.93	25.76			
10:07	20	30.92	25.78			
	25	30.95	25.81	0.78		
	29		25.83			
10:17	30	30.96	25.84			
10:18	1	31.85	25.84	1.08	350	Q diverted to flexible tank
	2	31.84	25.85			
	3	31.84	25.85			Step 2
	4	31.87	25.86	1.07		
	5	31.87	25.87			
	6	31.88	25.88			
	8	31.89	25.90	1.07		
10:27	10	31.89	25.92			
	12	31.88	25.94			
	14	31.90	25.95	1.07		
	16	31.89	25.97			
10:37	20	31.88	26.01	1.07		
	25	31.90	26.05	1.07		
	29	31.90	26.09	1.07		
10:47	30	31.90	26.10			Increase rate
10:48	1	32.84	26.12	1.42	400	Step 3
	2	32.86	26.12			
	3	32.87	26.15			
	4	32.87	26.16			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 11

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
	5	32.86	26.18			
	6		26.19	1.42		
	8	32.87	26.23			
10:57	10	32.87	26.24	1.41		
	12	32.87	26.27			
	14	32.87	26.29			
	16	32.87	26.32			
11:07	20	32.86	26.37	1.41		
	25	32.87	26.44			
	29	32.87	26.49			
11:17	30		26.49			Increase rate
11:18	1	33.70	26.52	1.80	450	Step 4
	2	33.77	26.53			
	3	33.78	26.54	1.80	450	
	4	33.78	26.56			
	5	33.77	26.57			
	6	33.77	26.58			
	8	33.80	26.60			
11:27	10	33.80	26.64	1.79		
	12	33.80	26.67	1.79		
	14	33.79	26.70			
	16	33.80	26.73			
11:37	20	33.81	26.79			
	25	33.82	26.84	1.79		
	29	33.81	26.89			
11:47	30	33.81	26.89			Increase rate
	1	34.71	26.93		500	Step 5
	2	34.75	26.94	'2.22		
	3	34.76	26.96	2.22		
	4	34.75	26.96			
	5	34.77	26.97			
	6	34.75	26.99	2.20		
	8	34.75	27.04			
11:57	10	34.76	27.08	2.21		
	12	34.77	27.09			
	14	34.75	27.12			
	16	34.76	27.18	2.21		
12:07 PM	20	34.77	27.23			
	25	34.77	27.31	2.20		
	29	34.76	27.34			
12:17	30	34.77	27.36			Increase rate
12:18	1	35.65	27.39	2.70	550	Step 6
	2	35.70	27.40			

WATER LEVEL MEASUREMENTS (Continued)
Well I-70 No. 11

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	35.72	27.42			
	4	35.72	27.44			
	5	35.72	27.45	2.70	550	
	6	35.71	27.46	2.68		Adjusted rate
	8	35.74	27.50			New measurer
12:27	10	35.74	27.54			
	12	35.75	27.58	2.71		
	14	35.73	27.70			
	16	35.74	27.74	2.71		
12:37	20	35.75	27.81			
	25	35.75	27.89			
	29	35.74	27.95	2.69	550	
12:47	30	35.74	27.95			
12:48	1	35.74		2.77		Maximum rate - pumping continues into settling tank
1:00	13					Water sample collected, T = 60° F
2:47						Pump off - average Q = 550 gpm

DEWATERING WELL DATA

	Well No. I-70 W12	Piezometer No. I-70 P12
Date Drilled:	1980	1980
Casing		
Top elevation:	403.12 ft	408.49 ft
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:	0.080-in.	na
Measuring Point Elevation:	404.31	-
Nonpumping Water Level		
Depth below temp. MP:	18.08 ft	Plugged
Length of temp. MP extension:	4.31	-
Depth below perm. MP:	13.77	-
Elevation:	390.54	-
Date of Step Test:	11/16/87	-
Water Sample**		
Time:	2:13 PM	-
Temperature:	59° F	-
Laboratory No.:	A87111306 A87111301	-
Distance and Direction to Piez. from PW:		6.0 ft NW
Time PW Off Before Step Test:		Unknown

Note: SWS 8-in. dia. orifice tube w/plate No. 4

SWS Crew: Sanderson, Hlinka, Stollhans, Olson

* na - information not available
** water sample collected after pumping well at rates of 400 to 750 gpm for 223 minutes.

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
10:04 AM		18.08				Steel tape Using McDAS
10:25	0	18.08				Pump on
10:26	1	19.16		1.44	400	
	2	19.19				
	3	19.22				
	4	19.23		1.42		
	6	19.25				
	8	19.23				
	10	19.27				
	12	19.26		1.43		
	20	19.29				
	22	19.28		1.44		
10:50						Power went off
11:00	0	18.48				Power back on; adjusted
	1	19.19		1.80	450	to 450
	2	19.35				
	3	19.36				
	4	19.38				
	6	19.40				
	8	19.42				
	10	19.42		1.79		Adjusted rate
	12	19.46				
	14	19.48				
	20	19.52		1.80		
	25	19.52				
11:30	30	19.54				
	31	19.54				
	1	19.78				Increased rate
	2	19.76				
	3	19.79				
	4	19.81				
	6	19.81				
	8	19.82				
	10	19.82		2.23	500	
	12	19.82				
	14	19.85				
	16	19.85				
	20	19.82				
12:01 PM	30	19.86				
	1	20.23				Increase rate
	2	20.12		2.70	550	
	3	20.13				

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	20.13				
	6	20.13				
	8	20.14				
	10	20.14				
	12	20.15				
	14	20.13				
	20	20.15				
	25	20.16		2.70	550	
12:31	30	20.17				Increase rate
	1	20.44		3.23	600	
	2	20.45				
	3	20.46				
	4	20.46				
	6	20.49				
	8	20.47				
	10	20.49		3.23		
	12	20.51				
	16	20.51		3.23		
1:01	30	20.54				Increase rate
	1	20.80		3.81	650	
	2	20.81				
	3	20.81				
	4	20.79				
	6	20.80				
	8	20.82				
	10	20.83				
	12	20.83		3.80		
	14	20.83				
	16	20.84				
	21	20.86				
	26	20.86		3.80		
1:31	30	20.87				Increase rate
	1	21.11		4.37	700	
	2	21.13				
	3	21.12				
	4	21.13				
	6	21.15				
	8'	21.14				
	10	21.16				
	12	21.16				
	14	21.16				
	16	21.18				
	21	21.18				
	26	21.20		4.36	700	

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
2:01	30	21.22				Increase rate
	1	21.49		5.09	750	
	2	21.49				
	3	21.50				
	4	21.49				
	6	21.50				
	8	21.50				
	10	21.50				
	14	21.54		5.08	750	
	20	21.53				
	25	21.54				
2:31	30	21.55				Pump off

DEWATERING WELL DATA

	Well No. I-64 W3	Piezometer No. I-64 P3
Date Drilled:	4/9/75	1975
Casing		
Top elevation:	393.63 ft	401.03 ft
Diameter:	16-in. SS	2-in. PVC
Length:	28.97	na
Screen		
Bottom elevation:	304.24 ft	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.080-in.	na
Measuring Point Elevation:	394.6	401.03
Nonpumping Water Level		
Depth below temp. MP:	19.89 ft	Plugged
Length of temp. MP extension:	7.45	-
Depth below perm. MP:	12.44	-
Elevation:	382.16	-
Date of Step Test:	6/21/88	-
Water Sample		
Time:	2:01 PM	-
Temperature:	60° F	-
Laboratory No.:	B88061702 B88061705	-
Distance and Direction to Piez. from PW:		5.2 ft SW
Time PW Off Before Step Test:		na

Note: SWS 8-in. dia. orifice tube w/plate No. 4

WATER LEVEL MEASUREMENTS
Well I-64 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
10:26 AM		19.90				Using McDAS
10:27		19.89				
10:33			17.43			
11:00	0	19.90	17.43	0.79	300	Pump on
	1	21.14	17.44			
	2	22.18				Piezometer plugged
	3	22.35				
	4	22.39				
	6	22.44				
	8	22.45				
11:10	10	22.49	17.44			
	12	22.51		0.81	305	
	14	22.52				
	16	22.54				
11:20	20	22.56	17.43			
	25	22.60				
11:30	30	22.61	17.44	0.82	305	Increase rate
	1	23.04				Step 2
	2	23.05		1.12	355	
	3	23.05				
	4	23.06				
	6	23.07				
	8	23.10				
11:40	10	23.10				
	12	23.10				
	14	23.12		1.11	355	
	16	23.13				
11:50	20	23.13				
	25	23.14				
	29	23.17		1.11	355	
12:00	30	23.17				Increase rate
	1	23.58		1.44	400	Step 3
	2	23.59				
	3	23.60				
	4	23.61				
	6	23.61				
	8	23.62				
12:10	10	23.63				
	12	23.64				
	14	23.65		1.44	400	
	16	23.64				
12:20	20	23.65				
	25	23.67				
12:30	30	23.68		1.44	400	Increase rate

WATER LEVEL MEASUREMENTS (Continued)
Well I-64 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
	1	24.08		1.80	450	Step 4
	2	24.11				
	3	24.10				
	4	24.10				
	6	24.11				
	8	24.13				
12:40	10	24.12				
	12	24.13				
	14	24.14				
	16	24.14		1.80	450	
12:50	20	24.15				
12:54	25	24.16				
12:59	29	24.17		1.80	450	
01:00	30	24.17				Increase rate
	1	24.57				Step 5
	2	24.58		2.19	495	
	3	24.58				
	4	24.60				
	6	24.60				
	8	24.61				
01:10	10	24.62				
	12	24.63				
	14	24.62				
	16	24.62				
01:20	20	24.62				
	25	24.65		2.19	495	
01:30	30	24.66		2.19	495	Increase rate
	1	25.13		2.70	550	Step 6
	2	25.13				
	3	25.14				
	4	25.15				
	6	25.17				
	8	25.16				
01:40	10	25.18				
	12	25.17				
	14	25.18				
	16	25.18		2.68	550	
01:50	20	25.21		2.70	550	
	25	25.23				
02:00	30	25.23		2.70	550	Increase rate
02:01	1	25.27				Step 7
02:02	2	25.28		2.74	555	Wide open
02:03	3	25.28				Temp. = 60° F
02:04	4	25.29				Water sample collected

DEWATERING WELL DATA

	Well No. I-64 W15	Piezometer No. I-64 P15
Date Drilled:	4/15/75	1975
Casing		
Top elevation:	394.29 ft	399.97 ft
Diameter:	16-in. SS	2-in. PVC
Length:	28.67 ft	na
Screen		
Bottom elevation:	305.15	na
Diameter:	16-in. SS	2-in. PVC
Length:	60.25 ft	3 ft
Slot size:	0.080-in.	na
Measuring Point Elevation:	395.1	399.97
Nonpumping Water Level		
Depth below temp. MP:	-	-
Length of temp. MP extension:	7.02 ft	-
Depth below perm. MP:	11.22 ft	15.96 ft
Elevation:	383.88	384.01
Date of Step Test:	7/22/87	-
Water Sample		
Time:	12:35 PM	-
Temperature:	61° F	-
Laboratory No.: (Sample Kit B)	87072002 38702005	-
Distance and Direction to Piez. from PW:		5.25 ft NNE
Time PW Off Before Step Test:		na

Note: SWS 8-in. dia. orifice tube w/plate No. 4

SWS Crew: Sanderson, Nealon, Hammen

* Operation based upon IDOT records

WATER LEVEL MEASUREMENTS
Well I-64 No. 15

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
8:10 AM			15.96			Steel tape meas.
8:12			15.96			" " "
8:14		11.22				" " "
8:16		11.22				" " "
8:39			15.95			" " "
8:42			15.96			" " "
8:44			15.95			" " "
9:08						Droplines
9:14		18.18				Pumped well extension
9:15		18.17				7.02 ft
9:17			16.25			
9:23		18.19				
9:24		18.18	16.15			
9:26						Pump on
9:27	1	20.73	17,82	0.79	300	Step 1
9:28	2	21.14	17.81			
9:29	3	21.18	17.90			
9:30	4	21.20	17.99			
9:31	5	21.22	17.95			
9:32	6	21.24	17.97			
9:34	8	21.28	18.00	0.79	300	
9:36	10	21.30	18.05			
9:38	12	21.32	18.06			
9:40	14	21.34	18.08			
9:42	16	21.37	18.09			
9:46	20	21.39	18.10	0.79	300	
9:51	25	21.41	18.18			
9:55	29	21.43	18.17			
9:56	30	21.44	18.17			Increase rate
9:57	1	21.90	18.21	1.07	350	Step 2
	2	21.95	18.46			
	3	21.96	18.49			
	4	22.03	18.49			Difference between 20-25 ft markers
	5	22.04	18.50			4.96 ft on pumped well dropline
	6	22.03	18.52			
	8	22.05	18.52			
	10	22.06	18.54	1.07	350	
	12	22.07	18.55			
	14	22.09	18.56			
	16	22.09	18.55			
	20	22.10	18.58	1.07	350	

WATER LEVEL MEASUREMENTS (Continued)
Well I-64 No. 15

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	22.11	18.59			
	29	22.13	18.60			
10:26	30	22.13	18.60			Increase rate
10:27	1	22.64	18.89	1.42	400	Step 3
	2	22.66	18.90			
	3	22.66	18.91			
	4	22.68	18.93			
	5	22.68	18.93			
	6	22.68	18.94	1.41	400	
	8	22.70	18.96			
10:36	10	22.70	18.96			
	12	22.71	18.98			
	14	22.71	18.98			
	16	22.72	19.00			
	20	22.74	19.00	1.41	400	
	25	22.76	19.02			
	29	22.75	19.02			
10:56	30	22.76	19.03			Increase rate
10:57	1	23.28	19.32	1.80	450	Step 4
	2	23.29	19.33			
	3	23.30	19.36			
	4	23.31	19.35			
	5	23.32	19.37			
	6	23.32	19.37			
	8	23.33	19.38	1.80	450	
11:06	10	23.34	19.39			
	12	23.35	19.39			
	14	23.36	19.42			
	16	23.37	19.42			
11:16	20	23.39	19.43			
	25	23.41	19.43			
	29	23.42	19.44			
11:26	30	23.41	19.46			Increase rate
11:27	1	23.93	19.72	2.22	500	Step 5
	2	23.94	19.74			
	3	23.94	19.76			
	4	23.96	19.76			
	5	23.96	19.76			
	6	23.96	19.76	2.22	500	
	8	23.98	19.77			
11:36	10	23.98	19.78			
	12	23.99	19.79			
	14	23.99	19.79			

WATER LEVEL MEASUREMENTS (Continued)
Well I-64 No. 15

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	24.00	19.80			
	20	24.01	19.83	2.21	500	
	25	24.04	19.88			
	29	24.04	19.88			
11:56	30	24.04	19.87			Increase rate
11:57	1	24.58	20.17	2.70	550	Step 6
	2	24.59	20.20			
	3	24.60	20.21			
	4	24.61	20.21			
	5	24.62	20.20			
	6	24.62	20.22			
	8	24.63	20.24	2.70	550	
12:06 PM	10	24.64	20.22			
	12	24.65	.20.22			
	14	24.65	20.25			
	16	24.65	20.28	2.69	550	
12:16	20	24.67	20.25			
	25	24.68	20.29			
	29	24.68	20.29			
12:26	30	24.68	20.30			Increase rate
12:27	1	24.96	20.45			Step 7
	2	24.99	20.48	2.99	580	
	3	25.01	20.48			
	4	24.92	20.45	2.90	570	
	5	24.94	20.44			
12:32	6	24.94	20.46			Max. rate - end test
	8					Samples kit B - 61° F
12:35	9					

DEWATERING WELL DATA

	Well No. 25th St. W10	Piezometer No. 25th St. P10
Date Drilled:	7/10/75	1975
Casing		
Top elevation:	397.67 ft	406.07 ft
Diameter:	16-in. SS	2-in. PVC
Length:	36.4 ft	na
Screen		
Bottom elevation:	301.27	na
Diameter:	16-in. SS	2-in. PVC
Length:	60 ft	3 ft
Slot size:	0.080-in.	na
Measuring Point Elevation:	398.6	406.07
Nonpumping Water Level		
Depth below temp. MP:	18.74 ft	-
Length of temp. MP extension:	8.98	-
Depth below perm. MP:	9.76	17.35
Elevation:	388.84	388.72
Date of Step Test:	11/18/87	-
Water Sample*		
Time:	2:40 PM	-
Temperature:	59°F	-
Laboratory No.:	C87111305 C87111303	-
Distance and Direction to Piez. from PW:		5.20 ft E
Time PW Off Before Step Test:		> 4 days

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

Note: SWS 8-in. dia. orifice tube w/plate No. 4

* water samples collected after pumping well at rates of 550 to 800 gpm for 156 minutes.

** na - information not available

WATER LEVEL MEASUREMENTS
Well 25th St. No. 10

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
9:40 AM			17.43			Using McDAS
9:42			17.45			
9:50		18.78				
9:51		18.77				
11:06			17.44			
11:20		18.76				
11:29			17.43			
11:48		18.74	17.42			
12:04 PM	0	18.74	17.42			Pump on
	1	24.15	20.96			Step 1
	2	24.22	21.01			
	3	24.27	21.06	2.73	550	
	4	24.27	21.08	2.72		
	6	24.31	21.13			
	8	24.33	21.14			
	12	24.34	21.15			
	16	24.35	21.15	2.72		
	20	24.40	21.18			
	25	24.42	21.19			
12:34	30	24.42	21.19	2.71		Increase rate
	1	24.92	21.51	3.23	600	Step 2
	2	24.95	21.52			
	3	24.95	21.52			
	4	24.96	21.52			
	8	24.99	21.52			
	12	24.99	21.53			
	16	25.04	21.55	3.23		
	20	25.04	21.56			
	25	25.04	21.59			
1:04	30	25.00	21.60	3.22		Increase rate
	1	25.51	21.93			Step 3
	2	25.54	21.94	3.79	650	
	3	25.55	21.95			
	4	25.53	21.93			
	6	25.54	21.95			
	8	25.53	21.95			
	12	25.56	21.94			
	16	25.57	21.95			
	20	25.55	21.96	3.77		
	25	25.54	21.94			
1:34	30	25.55	21.92	3.78		Increase rate
	1	26.07	22.24	4.38	700	Step 4
	2	26.08	22.24			

WATER LEVEL MEASUREMENTS (Continued)
Well 25th St. No. 10

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	26.09	22.25			
	4	26.08	22.24			
	6	26.09	22.24			
	8	26.09	22.23			
	12	26.11	22.22			
	16	26.13	22.23	4.36		
	20	26.16	22.22			
	25	26.18	22.23			
2:04	30	26.19	22.24	4.36		Increase rate
	1	26.75	22.60			Step 5
	2	26.79	22.63	5.11	750	
	3	26.79	22.64			
	4	26.79	22.64			
	6	26.80	22.65			
	8	26.81	22.66			
	12	26.84	22.67			
	16	26.82	22.69	5.10		
	20	26.79	22.71			
	25	26.79	22.72	5.10		
2:34	30	26.76	22.70	5.10		Increase rate
	1	27.32	23.05	5.84	800	Step 6
	2	27.33	23.05			
	3	27.33	23.04			
	4	27.34	23.05			
	6	27.34	23.04			
	8	27.37	23.04	5.83		
	12	27.36	23.03			
	16	27.38	23.04	5.83		
	20	27.39	23.03			
	25	27.38	23.02			
3:04	30	27.39	23.01	5.81		
3:12				6.20	820	Maximum rate

DEWATERING WELL DATA

	Well No. Venice W6	Piezometer No. Venice P6
Date Drilled:	1982	1982
Casing		
Top elevation:	401.8 ft	407.86 ft
Diameter:	16-in. SS	2-in. PVC
Length:	25.7 ft	na
Screen		
Bottom elevation:	325.2	na
Diameter:	16-in. SS	2-in. PVC
Length:	50.9 ft	3 ft
Slot size:	0.080-in.	na
Measuring Point Elevation:	402.05	407.86
Nonpumping Water Level		
Depth below temp. MP:	18.98 ft	-
Length of temp. MP extension:	6.00	-
Depth below perm. MP:	12.98	18.66
Elevation:	389.07	389.20
Date of Step Test:	11/17/87	-
Water Sample*		
Time:	4:14 PM	-
Temperature:	59°F	-
Laboratory No.:	B87111302 B87111304	-

Distance and Direction to Piez. from PW: 5.4 ft east

Time PW Off Before Step Test: Unknown

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

Data collected by McDAS field instrumentation

Note: SWS 8-in. dia. orifice tube w/plate No. 4 used to measure pumping rate. The tube was discharged into a 1000-gallon portable tank to check for sand pumpage. The well produced sand and what appeared to be gravel pack --a sample was collected for analysis of the grain size distribution.

* water sample collected after pumping well at rates of 400 to 650 gpm for 159 minutes.

** na - information not available

WATER LEVEL MEASUREMENTS
Well Venice 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
10:03 AM			18.66			Steel tape
10:22		18.98	18.66			Using McDAS
1:35 PM	0	18.97	18.57			Pump on
	1	19.74	19.43			Step 1
	2	20.46	19.65	1.50		
	3	20.58	19.77			
	4	20.59	19.77	1.42		
	6	20.57	19.78			
	8	20.68	19.83			
	10	20.77	19.86			
	12	20.80	-	1.47	400	
	16	20.83	-			Transducer problem in piezometer well
	20	20.84	19.58			
	25	20.89	-			
2:05	30	20.89	-	1.47	400	Increase rate
	1	21.35	-	1.82	450	Step 2
	2	21.39	-			
	3	21.52	-			
	4	21.50	-			
	6	21.54	-	1.82		
	8	21.55	-			
	10	21.54	-			
	14	21.58	-			
	20	21.60	-	1.83		
	25	21.58	-			
2:35	30	21.61	20.04	1.78		Increase rate
	1	22.18	20.13	2.23	500	Step 3
	2	22.21	20.16			
2:38	3	22.22	20.21			
	4	22.24	20.21			
	6	22.23	20.22			
	8	22.25	20.24			
	10	22.28	20.25			
	14	22.30	20.23	2.21		
	20	22.32	20.27			
	25	22.36	20.29	2.21		
3:05	30	22.40	20.27	2.21		Increase rate
	1	22.95	20.39			Step 4
	2	23.00	20.45			
	3	23.03	20.45			
	4	23.02	20.47	2.71	550	
	6	23.08	20.51			
	8	23.07	20.47			

WATER LEVEL MEASUREMENTS (Continued)
Well Venice 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
	10	23.09	20.50			
	12	23.12	20.54			
	14	23.12	20.55	2.72		
	16	23.14	20.55			
	22	23.15	20.56	2.72		
	25	23.16	20.62			
3:35	30	23.18	20.63	2.72		Increase rate
	1	23.72	20.73	3.24	600	Step 5
	2	23.68	20.76			
	3	23.71	20.76			
	4	23.70	20.78			
	6	23.75	20.77	3.24		
	8	23.76	20.80			
3:45	10	23.78	20.80			
	14	23.76	20.80	3.24		
	20	23.76	20.81			
	25	23.73	20.82	3.24		
4:05	30	23.80	20.87			Increase rate
	1	24.34	20.96			Step 6
	2	24.37	21.00	3.81	650	
	3	24.40	21.00			
	4	24.41	21.02			
	6	24.43	21.03			
	8	24.41	21.01			
	10	24.45	21.03			
	12	24.44	21.01	3.80		
	16	24.46	20.99			
	20	24.45	20.99			
	24	24.46	21.01	3.81		
4:35	30	24.45	20.99	3.81		Increase rate
	1	25.00	21.13			Step 7
	2	25.02	21.12	4.37	700	
	3	25.04	21.12			
	4	25.01	21.14			
	6	25.04	21.14			
	8	25.05	21.11			
	10	25.05	21.14			
	12	25.07	21.12			
	16	25.11	21.15			
	20	25.11	21.15	4.37		
	26	25.10	21.12			
5:05	30	25.11	21.12	4.37		Increase rate
	1	25.76	21.26			Step 8
	2	25.78	21.28	5.11	750	

WATER LEVEL MEASUREMENTS (Continued)
Well Venice 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
	3	25.75	21.32			
	4	25.83	21.30			
	6	25.85	21.31			
	8	25.86	21.34			
	10	25.89	21.31			
	12	25.89	21.34	5.11		
	16	25.94	21.34			
	20	26.01	21.35			
	26	26.05	21.39	5.12		
5:35	30	26.00	21.44			Increase rate
	1	26.50	21.51			Step 9
	2	26.53	21.55	5.80	800	
	3	26.67	21.60			
	4	26.59	21.58	5.79		
	6	26.63	21.61			
	8	26.67	21.62	5.78		
	10	26.65	21.62			
	12	26.65	21.64			
	16	26.66	21.67	5.78		
	20	26.67	21.69			
	24	26.71	21.71	5.77		
	29	26.70	21.74			
6:05	30	26.67	21.75			Pump off

Appendix B.

Results from Chemical Analysis of Dewatering Well Water Samples

Appendix B. Results from Chemical Analysis of Dewatering Well Water Samples

Site		I-70	I-70	I-70
Well No.		2	8	10
Section Location T.2N., R.9W., St. Clair Co.		7.7b	7.7b	7.7b
Date Collected		6/20/88	6/20/88	8/13/87
Laboratory No.		222598	222600	222254
Iron (Fe),	mg/l	11.2	15.5	11.3
Manganese (Mn),	mg/l	1.2	0.8	0.6
Calcium (Ca),	mg/l	177.0	210.0	218.0
Magnesium (Mg),	mg/l	40.0	46.5	54.4
Sodium (Na),	mg/l	110.0	43.2	44.4
Silica (SiO_2),	mg/l	30.9	31.0	36.5
Fluoride (F),	mg/l	0.7	1.2	0.3
Nitrate (NO_3),	mg/l	0.4	<0.2	0.2
Chloride (Cl),	mg/l	138.0	56.5	68.0
Sulfate (SO_4),	mg/l	246.0	317.0	376.0
Alkalinity (as $CaCO_3$), mg/l		465.0	451.0	424.0
Hardness (as $CaCO_3$), mg/l		606.0	715.0	768.0
Total dissolved minerals,	mg/l	1088.0	1089.0	1132.0
Turbidity (lab), NTU		90	110	115
Color, PCU		5	5	<1
Odor		H_2S	H_2S	Hydro-carbon
pH (lab)		7.2	7.1	7.0
Temperature, °F		60.5	61.0	61.0

ND = Not determined/Information not available

Appendix B. (Continued)

Site		I-70		I-70	I-64
Well No.		11	12	3	
Section Location T.2N., R.9W., St. Clair Co.		7.7b	7.7b	7.6a	
Date Collected		8/12/87	11/16/87	6/21/88	
Laboratory No.		222253	222342	222599	
Iron (Fe),	mg/l	9.0	8.5	18.4	
Manganese (Mn),	mg/l	0.5	0.5	0.6	
Calcium (Ca),	mg/l	170.0	158.0	258.0	
Magnesium (Mg),	mg/l	44.8	43.6	62.0	
Sodium (Na),	mg/l	55.6	62.5	64.8	
Silica (SiO_2),	mg/l	28.6	27.3	33.4	
Fluoride (F),	mg/l	.0.4	0.4	0.9	
Nitrate (NO_3),	mg/l	0.2	<0.2	0.4	
Chloride (Cl),	mg/l	102.0	113.0	64.2	
Sulfate (SO_4),	mg/l	271.0	222.0	516.0	
Alkalinity (as $CaCO_3$), mg/l		349.0	316.0	461.0	
Hardness (as $CaCO_3$), mg/l		608.0	574.0	899.0	
Total dissolved minerals,	mg/l	930.0	816.0	1439.0	
Turbidity (lab), NTU		85	<1	120	
Color, PCU		<1	<1	ND	
Odor		Hydro-carbon	None	None	
pH (lab)		7.1	7.1	7.2	
Temperature, °F		60.0	59.0	60.0	

Appendix B. (Concluded)

Site	I-64	25th St.	Venice
Well No.	15	10	6
Section Location T.2N., R.9W., St. Clair Co.	7.6h	17.6e	T.3N.,R.10W. STC Co. 35.3g
Date Collected	7/22/87	11/18/87	11/17/87
Laboratory No.	222214	222344	222343
Iron (Fe), mg/l	14.0	4.5	9.6
Manganese (Mn), mg/l	0.6	0.5	0.4
Calcium (Ca), mg/l	243.0	176.0	196.0
Magnesium (Mg), mg/l	64.0	52.5	55.4
Sodium (Na), mg/l	166.0	153.0	41.3
Silica (SiO_2), mg/l	33.6	32.7	33.8
Fluoride (F), mg/l	1.1	0.8	0.6
Nitrate (NO_3), mg/l	<0.2	0.2	<0.2
Chloride (Cl), mg/l	62.3	39.2	55.0
Sulfate (SO_4), mg/l	787.0	571.0	419.0
Alkalinity (as $CaCO_3$), mg/l	456.0	406.0	387.0
Hardness (as $CaCO_3$), mg/l	870.0	655.0	717.0
Total dissolved minerals, mg/l	1750.0	1332.0	1087.0
Turbidity (lab), NTU	<1	<1	<1
Color, PCU	<1	<1	<1
Odor	None	None	None
pH (lab)	7.2	7.2	7.2
Temperature, °F	61.0	59.0	59.0

Appendix C.

Step Test Results,
Phases 1 through 5

Appendix C. Step Test Results, Phases 1 through 5

Well	Date of test	Well loss @ 600 gpm (ft)	Drawdown @ 600 gpm (ft)	Well loss portion (%)	Specific capacity (gpm/ft)	Ah* @ 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. IT	8/14/85	**	8.89 e	**	67.5 e	3.3 e	Q_{max} = 390 gpm
No. 2	7/19/83	**	11.9 e	**	50.4 e	7.9 e	Q_{max} = 500 gpm
No. 2T	8/15/85	**	8.32 e	**	72.1 e	P	Q_{max} = 410 gpm
No. 2	6/20/88	**	11.98 e	**	50.1 e	P	Q_{max} = 365 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	0.07	9.33	0.8	64.3	P	
No. 4T	1/8/87	**	5.89	**	101.9	P	Q_{max} = 660 gpm
No. 5	7/10/84	0.89	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	0.23	5.39	4.3	111.3	P	Q_{max} = 625 gpm
No. 7	6/30/83	1.88	18.55	10.1	32.3	15.0	Piezometer: at 7.5 ft
No. 7a	7/23/87	**	8.39	**	71.5	2.13	Q_{max} = 770 gpm
No. 8	8/1/84	2.68	13.54	19.8	44.3	9.94	Q_{max} = 625 gpm
No. 8T	12/5/85	0.07	6.83	1.0	87.8	2.21	Q_{max} = 750 gpm
No. 8	6/22/88	**	12.62	**	47.5 e	8.22	Q_{max} = 600 gpm
No. 9	6/28/84	**	9.46	**	63.4	5.94	Q_{max} = 630 gpm
No. 10	7/31/84	5.97 e	16.93 e	35.3 e	35.4 e	P	Q_{max} = 480 gpm
No. 10T	9/4/85	0.66	6.61 e	10.0	90.8	P	Q_{max} = 490 gpm
No. 10	8/13/87	1.07	18.98 e	5.6	31.6 e	10.4 e	Q_{max} = 390 gpm
No. 11	8/2/84	1.58 e	15.55 e	10.2	38.6 e	13.35 e	Q_{max} = 555 gpm
No. 11T	9/5/85	**	5.63	**	106.6	P	
No. 11	8/12/87	**	11.56 e	**	51.9 e	P	Q_{max} = 550 gpm
No. 12	6/16/83	0.20	3.82	5.2	157.1	P	
No. 12	7/30/86	**	13.30 e	**	45.1	P	Q_{max} = 450 gpm
No. 12T	11/16/87	1.45	2.36	61.4	254.2	P	Q_{max} = 750 gpm

Appendix C. (Continued)

Well	Date of test	Well loss @ 600 gpm (ft)	Drawdown @ 600 gpm (ft}	Well loss portion	Specific capacity (gpm/ft)	Ah* @ 600 gpra (ft)	Remarks
I-64							
No.. 1	7/21/87	**	4.13	**	145.3	0.85	Q_{max} = 660 gpm
No.. 2	7/25/85	0.09	5.32 e	1.7	112.8 e	5.22 e	Q_{max} = 550 gpm
No.. 3	6/26/84	0.52	10.73 e	4.8	55.9 e	P	Q_{max} = 525 gpm
No. 3T	6/21/88	0.68 e	5.68 e	12.0 e	105.6 e	P	Q_{max} = 555 gpm
No. 4	7/15/85	0.66	4.40	15.0	136.4	P	
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
No. 11	8/14/84	**	7.22 e	**	83.1 e	3.2 e	Q_{max} = 520 gpm
No. 12	7/18/85	0.17	6.22 e	2.8	96.5	1.62 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	0.73	9.94	7.3	60.4	4.6	
No. 15T	8/13/85	0.71	7.24	9.8	82.9	2.97	Q_{max} = 615 gpm
No. 15	7/22/87	0.84 e	6.94 e	12.1 e	86.5 e	2.52	Q_{max} = 570 gpm
25th St.							
No. 2	7/20/83	0.54	5.69	9.5	105.4	1.1	
No. 3	9/6/85	0.03	4.89	0.6	122.5	1 75	
No. 6	6/27/84	0.14	9.44	1.5	63.6	P	Q_{max} = 775 gpm
No. 6T	1/7/87	0.23	4.38	5.3	137.0	P	Q_{max} = 775 gpm
No. 8	6/15/83	0.11	4.70	2.3	127.7	1.5	
No. 9	6/25/86	**	5.55 e	**	110.4 e	2.04 e	Q_{max} = 520 gpm
No. 10	7/26/85	**	9.56	**	62.8	3.59	
No. 10T	11/18/87	0.43	6.24	6.9	96.2	2.06	Q_{max} = 800 gpm
Venice							
No. 1	11/30/83	2.29	18.33 e	12.5	32.7	10.9 e	Q_{max} = 500 gpm
No. 1T	12/4/85	0.39	7.89	4.9	74.5	2.33	Q_{max} = 870 gpm
No. 2	11/17/83	0.05	4.70	1.0	127.7	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	P	Q_{max} = 775 gpm

Appendix C. (Concluded)

Well	Date of test	Well loss @ 600 gpm (ft)	Drawdown @ 600 gpm (ft)	Well loss portion (%)	Specific capacity (gpm/ft)	Ah* @ 600 gpm (ft)	Remarks
Venice (Cont'd)							
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	
No. 6T	11/17/87	3.18	4.13	77.0	145.3	2.61	Q_{max} = 800 gpm

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-Indicates step test after chemical treatment
P-Piezometer plugged or partially plugged

Appendix D.

Chemical Treatment
Field Data

<u>WELL REHABILITATION FIELD NOTES</u>

WELL SITE: I-70 Well No. 12 OBSERVER: Jeffrey R. Stollhans

CONTRACTOR: Brotcke Engineering Co., Inc., Fenton, MO.

MEASURING POINT: 65¼" from SE/c of manhole coverplate to temp, well head (corner no. 1) -- see coverplate numbering index

MEASURING EQUIP.: Stop watch, steel tape, contractor's 8x6 in. orifice tube

1. <u>SPECIFIC CAPACITY TEST</u> DATE: 10/14/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate* (gpm)	Remarks
1:46	14.62				Static water level
1:47	14.61				" " "
1:54	14.62				" " "
1:58					Pump on
2:05			12.5	567	Piez. tube highly variable (9-16 in.)
2:32	22.59	7.97	12.5	567	Piez. tube highly variable (9-16 in.)
2:58	22.65	8.03	12.5	567	Piez. tube highly variable (9-16 in.)

Note: All specific capacity tests--static water level (SWL) measured after minimum 30 min. period of well inactivity. Minimum period of pumpage for drawdown measurements is 60 min.

* All pumping rates from 8x6 in. orifice, Peerless-Midwest, Inc., Orifice Tables.

60 min. specific capacity: 70.6 gpm/ft

Comments: Material deposited on pump discharge line restricts diameter to approximately 4¼ in. Thurs, Oct. 15, Al Brown and Paul Brotcke agreed on a proposal of Brotcke's to pull and sandblast all the build-up within the column pipe.

2. <u>400 LBS POLYPHOSPHATE APPLICATION</u> DATE: 10/16/87

A. INITIAL CHLORINATION

Quantity: 2500 gal Strength: 500 mg/l

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:51 AM	10:00 AM
- complete:	9:55:00	10:01:00
Injection rate:	500 gpm	500 gpm

B. POLYPHOSPHATE INJECTION, 400 lbs total

	Batch 1	Batch 2
Phosphate:	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal
Time - initial:	10:15:00 AM	10:30:55 AM
- complete:	10:16:15	10:32:30
Injection rate:	1440 gpm	1140 gpm

Comments: Four 50-lb barrrels of phosphate used per batch. 8 gal of liquid Cl_2 per 2000 gal tank = 500 mg/l. 330 gpm from supply well (I-70 No. 11), it takes approx. 6 min. to fill the 2000 gal tank. 1 gallon of inhibitor per 1000 gallons of polyphosphate solution.

C. DISPLACEMENT, 16,000 gallons chlorinated water (500 mg/l)

Time - initial/complete	Quantity (gal)	Q (gpm)
10:41:45/10:43:00 AM	2,000	1440
10:51:00/10:52:15	2,000	1440
10:58:00/10:58:15	2,000	1440
11:07:15/11:08:30	2,000	1440
11:15:15/11:16:30	2,000	1440
11:18:15/11:19:30	2,000	1440
11:31:30/11:32:45	2,000	1440
11:39:45/11:41:00	2,000	1440
	16,000	

Comments: Eight separate injections, quantity equals 2000 gal per injection.

D. PUMPED TO WASTE

Time - initial: 12:45 PM
- complete: 6:45 PM

Q: 791 gpm (25 in.) Quantity: 285,000 gal

3. SPECIFIC CAPACITY TEST DATE: 10/19/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
8:36 AM	14.63				Static water level
8:38	14.63				Pump on
8:58	20.12	5.49	24	776	
9:28	20.32	5.69	24	776	
9:58	20.35	5.72	24	776	Pump off

60 min. specific capacity: 135.7 gpm/ft

Comments: Acid (Vertex) tanker arrived at 9:45 AM

4. ACIDIZATION - INHIBITED MURIATIC ACID DATE: 10/19/87

A. ACID INJECTION

Acid strength: 20° baume Quantity: 1000 gal

Time - initial: 10:07 AM
- complete: 10:09 AM

Pumping rate of 1000 gal injection: 500 gpm

Comments: Brotcke's tank truck leaks - approx. 5-10 gals of acid was lost or spilled. Acid was chased with 200 gals of water to flush the tank and lines clean immediately following injection.

B. DISPLACEMENT, 3500 gallons nonchlorinated water

	Batch 1	Batch 2
Quantity:	2000 gal	1500 gal
Time - initial:	11:10 AM	11:28 AM
- complete:	11:11:15	11:29:00
Injection rate:	1600 gpm	1500 gpm

C. PUMPED TO WASTE

Time - initial: 1:30 PM
- complete: 4:30 PM

Q: 805 gpm Quantity: 144,900 gal

Comments: Effluent clear at 2:25 PM; then at approx. 3:20 PM the effluent changed to yellowish brown. Q/s at 2:15 PM - 138 gpm/ft; Q/s at 3:25 PM = 142 gpm/ft

5. SPECIFIC CAPACITY TEST DATE: 10/20/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
8:11AM	14.80				Static water level
8:12	14.78				Static water level
8:14	14.78				Pump on
8:30	14.78	5.14	27	818	
8:45	20.12	5.34	27	818	
10:12	20.15	5.37	27	818	Pump off

60 min. specific capacity: 152.3 gpm/ft

6. 600 LBS. POLYPHOSPHATE APPLICATION DATE: 10/20/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:14 AM	9:18 AM
- complete:	9:16:00	9:18:30
Injection rate:	1000 gpm	1000 gpm

B. POLYPHOSPHATE INJECTION, 600 lbs total

	Batch 1	Batch 2	Batch 3
Phosphate:	200 lbs	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal	1800 gal
Time - initial:	9:27 AM	9:34 AM	9:43 AM
- complete:	9:28:00	9:35:15	9:44:00
Injection rate:	1800 gpm	1440 gpm	1800 gpm

Comments: See comments on first polyphosphate injection.

C. DISPLACEMENT, 30,000 gallons chlorinated water (500 mg/l)

Time - initial: 9:52 AM
- complete: 11:43 AM

Quantity: 30,000 gal Q: 1800 gpm

Comments: Fifteen 2000-gal injections, all injected at approx. 1800 gpm.

D. PUMPED TO WASTE

Time - initial: 12:45 PM
- complete: 6:45 PM

Q: 825 gpm (27.5 in.) Quantity: 297,000 gal

7. SPECIFIC CAPACITY TEST DATE: 10/21/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
7:55	14.89				Static water level
7:59	14.89				Static water level
8:00					Pump on
8:20	19.86	4.97	27.5	825	
8:41	20.04	5.15	27.5	825	
9:00	20.02	5.13	27.5	825	Pump off

60 min. specific capacity: 160.8 gpm/ft

8. 600 LBS POLYPHOSPHATE APPLICATION DATE: 10/21/87

A. INITIAL CHL0RINATI0N

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:04 AM	9:06:30
- complete:	9:05:15	9:07:00
Injection rate:	1600 gpm	1000 gpm

B. POLYPHOSPHATE INJECTION, 600 lbs total

	Batch 1	Batch 2	Batch 3
Phosphate:	200 lbs	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal	1800 gal
Time - initial:	9:14 AM	9:21 AM	9:27 AM
- complete:	9:15:00	9:22:00	9:28:00
Injection rate:	1800 gpm	1800 gpm	1800 gpm

Comments: See comments on first polyphosphate injection.

C. DISPLACEMENT, 54,000 gallons chlorinated water (500 mg/l)

Time - initial: 9:35 AM
- complete: 12:56 PM

Quantity: 54,000 gal Q: 1800 gpm

Comments: Twenty-seven 2000-gal injections, all injected at approximately 1800 gpm.

D. PUMPED TO WASTE

Time - initial: 1:56 PM
- complete: 7:56 PM

Q: 831 gpm (28 in.) Quantity: 299,000 gal

9. SPECIFIC CAPACITY TEST DATE: 10/22/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
9:37AM	14.86				Static water level
9:38	14.86				Pump on
9:52	19.66	4.80	28	831	
10:15	19.86	5.00	28	831	
10:39	19.94	5.08	28	831	Pump off

60 min. specific capacity: 163.6 gpm/ft

10. 400 LBS POLYPHOSPHATE APPLICATION DATE: 10/22/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	10:55 AM	10:58 AM
- complete:	10:56:15	10:58:30
Injection rate:	1600 gpm	1000 gpm

B. POLYPHOSPHATE INJECTION, 400 lbs total

	Batch 1	Batch 2
Phosphate:	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal
Time - initial:	11:05 AM	11:13 AM
- complete:	11:06:00	11:14:00
Injection rate:	1800 gpm	1800 gpm

C. DISPLACEMENT, 16,000 gallons chlorinated water (500 mg/l)

Time - initial: 11:20 AM
- complete: 12:12 PM

Quantity: 16,000 gal Q: 1800 gpm

Comments: Eight 2000-gal injections, all injected at approximately 1800 gpm.

D. PUMPED TO WASTE

Time - initial: 4:20 PM (10/22)
- complete: 8:04 AM (10/23)

Q: 818 gpm (27 in.) (10/22) Quantity: 772,000 gal
818 gpm (27 in.) (10/23)

Comments: The workers at the sewage pump station have requested that we not pump the polyphosphate to waste until 4:00 PM. They have complained about a strong sewage odor; it seems the polyphosphates are cleaning out the storm sewer lines.

11. SPECIFIC CAPACITY TEST DATE: 10/23/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
8:50 AM	15.86				Static water level
8:52	15.86				Pump on
9:06			27.5	825	Variable, 22-31 in.
9:08	20.40	4.54			
9:22	20.44	4.58	27	818	
9:51	20.54	4.68	27	818	
9:52	20.52	4.66			Pump shut down
9:54					

60 min. specific capacity: 175.5 gpm/ft

Comments: Level in orifice piez. tube bounces 6 in. or so regularly, making averaging difficult.

WELL REHABILITATION FIELD NOTES

WELL SITE: Venice Well No. 6 OBSERVER: Jeffrey R. Stollhans

CONTRACTOR: Brotcke Engineering Co., Inc., Fenton, MO

MEASURING POINT: Corner No. 1, 72.5" from manhole coverplate to temp. coverplate (see coverplate numbering index)

MEASURING EQUIP.: Stop watch, steel tape, contractor's 8x6 in. and 8x7 in. orifice tubes

1. SPECIFIC CAPACITY TEST

DATE: 10/27/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate* (gpm)	Remarks
8:00 AM	18.88				Static water level
8:10	18.88				
8:25	18.88				Pump on
8:40			32	882	
9:15	28.70	9.82			Steel tape caught up on flange--this is likely an erroneous reading
9:25	28.21	9.33	32	882	Brotcke elec. dropline

Note: All specific capacity tests--static water level (SWL) measured after minimum 30 min. period of well inactivity. Minimum period of pumpage for drawdown measurements is 60 min.

* All pumping rates from Peerless-Midwest, Inc., Orifice Tables for 8x6 in. orifice unless noted otherwise.

60 min. specific capacity: 94.5 gpm/ft

Comments: Brotcke's electric dropline will be used throughout the rest of this test. The column pipe had to be shifted to break the electric dropine and steel tape free. Measurements from Brotcke's new electric dropline are exactly the same as our steel tape.

2. 400 LBS POLYPHOSPHATE APPLICATION

DATE: 10/27/87

A. INITIAL CHLORINATION

Quantity: 2500 gal Strength: 500 mg/l

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:34 AM	9:36 AM
- complete:	9:35:15	9:36:30
Injection rate:	1600 gpm	1000 gpm

B. POLYPHOSPHATE INJECTION, 400 lbs total

	Batch 1	Batch 2
Phosphate:	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal
Time - initial:	9:42 Am	9:48 AM
- complete:	9:43:15	9:48:15
Injection rate:	1440 gpm	1440 gpm

Comments: 430 gpm from supply well (Venice No. 5), it takes approx. 70 sec. to obtain 500 gal. 8 gal of liquid Cl_2 per 2000 gal tank = 500 mg/l. 1 gallon of inhibitor per 1000 gallons of polyphosphate solution.

C. DISPLACEMENT, 16,000 gallons chlorinated water (500 mg/l)

Time - initial/complete	Quantity (gal)	Q (gpm)
9:54 AM/10:29 AM	16,000	1440

Comments: Eight 2000-gal injections. The breaker was also blown before the initial Q/s test. The breaker box should be replaced at this site.

D. PUMPED TO WASTE

Time - initial: 11:30 AM
- complete: 5:30 PM

Q: 882 gpm Quantity: 317,500 gal

Comments: Elbow was attached to the line so we could pump directly into the sewer. Pumping rate was assumed from previous Q/s test. Pumping station has cut out three times since we started pumping to waste.

J. SPECIFIC CAPACITY TEST DATE: 10/28/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
8:01 AM	19.01				Brotcke's elec. dropline
8:05	19.01				Pump on
8:16	27.63	8.62	27.5	825	
8:34	28.06	9.05	27.5	825	
8:37					Kinks were removed from
8:40			31.5	876	line
8:56	29.02	10.01	31.0	869	
9:05	29.11	10.10	31.0	869	

60 min. specific capacity: 86.0 gpm/ft

Comments: Early pumping rates are not accurate due to the kinks within the line. Acid arrived on site at 8:57 AM. We are always getting dropline caught up in the well. However, these seem to be accurate readings.

4. ACIDIZATION - INHIBITED MURIATIC ACID DATE: 10/28/87

A. ACID INJECTION

Acid strength: 20° baume Quantity: 1000 gal

Time - initial: 9:33 AM
- complete: 9:34:30

Pumping rate of 1000 gal injection: 333 gpm

Comments: The acid was chased with approx. 250 gal of water directly following the injection.

B. DISPLACEMENT, 3800 gallons nonchlorinated water

	Batch 1	Batch 2
Quantity:	1800 gal	2000 gal
Time - initial:	10:21 AM	10:35 AM
- complete:	10:22:30	10:36:45
Injection rate:	1200 gpm	1143 gpm

C. PUMPED TO WASTE

Time - initial: 12:22 PM
- complete: 3:22 PM

Q: 869 gpm Quantity: 156,400 gal

Comments: Pump rate was estimated from previous specific capacity test.

5. SPECIFIC CAPACITY TEST DATE: 10/29/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
8:30 AM	18.92				Static water level
8:23	18.92				Static water level
8:35	18.92				Pump on
8:55	27.48	8.56	21	869	
9:18	27.91	8.99	31	869	
9:35	28.12	9.20	31	869	Pump off

60 min. specific capacity: 94.5 gpm/ft

Comments: The test seems to be more accurate than the first and second tests.

6. 600 LBS POLYPHOSPHATE APPLICATION DATE: 10/29/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:46 AM	9:49 AM
- complete:	9:47:15	9:49:30
Injection rate:	1600 gpm	1000 gpm

B. POLYPHOSPHATE INJECTION, 600 lbs total

	Batch 1	Batch 2	Batch 3
Phosphate:	200 lbs	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal	1800 gal
Time - initial:	9:53 AM	9:58 AM	10:05:15 AM
- complete:	4:54:15	9:59:30	10:06:45
Injection rate:	1440 gpm	1200 gpm	1200 gpm

Comments: See comments in 2.B.

C. DISPLACEMENT, 30,000 gallons chlorinated water (500 mg/l)

Time - initial: 10:10 AM
- complete: 11:15 AM

Quantity: 30,000 gal Q: 1440 gpm

Comments: Fifteen 2000-gallon injections

D. PUMPED TO WASTE

Time - initial: 12:15 PM
- complete: 6:15 PM

Q: 869 gpm Quantity: 312,800 gal

Comments: Column pipe was lifted to free the electric dropline. In addition, things were adjusted to allow easier accessibility. The measuring point did not change.

7. SPECIFIC CAPACITY TEST DATE: 10/30/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
7:58 AM	19.03				Static water level
8:05	19.03				Static water level
8:09	19.03				Pump on
8:28	27.82	8.79	31.5	876	
8:50	28.13	9.10	31.5	876	
9:09	28.35	9.32	31.5	876	Pump off

60 min. specific capacity: 94.0 gpm/ft

8. 600 LBS POLYPHOSPHATE APPLICATION DATE: 10/30/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gpm	500 gpm
Time - initial:	9:18 AM	9:20 AM
- complete:	9:19:15	9:20:30
Injection rate:	1600 gpm	1000 gpm

B. POLYPHOSPHATE INJECTION, 600 lbs total

	Batch 1	Batch 2	Batch 3
Phosphate:	200 lbs	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal	1800 gal
Time - initial:	9:28 AM	9:32 AM	9:37 AM
- complete:	9:29:10	9:33:10	9:38:00
Injection rate:	1550 gpm	1550 gpm	1800 gpm

C. DISPLACEMENT, 54,000 gallons chlorinated water (500 mg/l)

Time - initial: 9:42 AM
- complete: 12:03 PM

Quantity: 54,000 gal Q: 1800 gpm

Comments: Twenty-seven 2000-gallon separate injections

D. PUMPED TO WASTE

Time - initial: 1:03 PM
- complete: 7:03 PM

Q: 876 gpm Quantity: 315,400 gal

9. SPECIFIC CAPACITY TEST — DATE: 11/2/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
9:25AM	18.95				Static water level
9:29	18.95				Static water level
9:30	18.95				Static water level
9:50	29.03	10.08	31.5	876	Pump on
10:10	29.13	10.18	31.5	876	
10:30	29.16	10.21	31.5	876	
10:34					Pump off

60 min. specific capacity: 85.8 gpm/ft

10. 400 LBS POLYPHOSPHATE APPLICATION — DATE: 11/2/87

A. INITIAL CHL0RINATI0N

Quantity: 3000 gal — Strength: 500 mg/l

	Batch 1	Batch 2
Quantity:	2000 gal	1000 gal
Time - initial:	10:42 AM	10:44 AM
- complete:	10:43:10	10:44:45.
Injection rate:	1710 gpm	1330 gpm

B. POLYPHOSPHATE INJECTION, 400 lbs total

	Batch 1	Batch 2
Phosphate:	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal
Time - initial:	9:48 AM	9:53 AM
- complete:	9:49:00	9:54:00
Injection rate:	1800 gpm	1800 gpm

C. DISPLACEMENT, 16,000 gallons chlorinated water (500 mg/l)

Time - initial: 10:58 AM
- complete: 11:32 AM

Quantity: 16,000 gal — Q: 1400 to 1800 gpm

Comments: Eight 2000-gallon injections, all injected at rates ranging from 1400 to 1800 gpm.

D. PUMPED TO WASTE

Time - initial: 12:34 PM
- complete: 6:35 PM

Q: 876 gpm   Quantity: 316,200 gal

Comments: The gravel pack has settled approximately one foot since we began rehab. work. The well visibly doesn't appear to be pumping sand.

11. SPECIFIC CAPACITY TEST   DATE: 11/3/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
9:36AM	19.02				Static water level
9:40	19.02				Static water level
9:45	19.03				Pump on
9:50					Orifice broke; Pump off--
10:18	19.06				fixing orifice
10:20	19.06				Pump on
10:43	29.15	10.09	28	831	
11:03	29.17	10.11	26.5	812	
11:23	29.17	10.11	9	780	Changed to 8x7 orifice tube

60 min. specific capacity: 77.2 gpm/ft

Comments: Discharge is extremely cloudy. It appears the polyphosphate is still being pumped out. Plastic orifice end has been taped back together - leaks are minimal. Pumped until 5:00 PM. The well is currently pumping less than earlier this week; it doesn't appear to be an orifice tube problem.

12. SPECIFIC CAPACITY TEST   DATE: 11/4/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate* (gpm)	Remarks
8:12 AM	19.10				Static water level
8:16	19.10				Static water level
8:21	19.10				Static water level
8:22					Pump on; 8x7 orifice
8:37	29.16	10.06	10.5	845	
9:00	29.17	10.07	9.5	810	
9:23	29.18	10.08	9.5	810	Test complete

60 min. specific capacity: 80.4 gpm/ft

WELL REHABILITATION -- Venice Well No. 6 (Continued)

Comments: The well is still pumping polyphosphates at the end of the test. Moreover, the rate has increased. Permanent column pipe etc. was reinstalled at 10:45 AM. There is a weak spot in the pump cable approximately 5 feet below the well head; it was taped but eventually the cable will need to be replaced. Will continue to pump to waste until the polyphosphates are no longer visibly present. This well was pumped to waste all day on 11/4/87 and it was hooked back up to the system on 11/9/87.

WELL REHABILITATION FIELD NOTES

WELL SITE: 25th Street Well No. 10 OBSERVER: Jeffrey R. Stollhans

CONTRACTOR: Brotcke Engineering Co., Inc., Fenton, MO

MEASURING POINT: Corner No. 2, 117 in. from NE/c of manhole coverplate to temp. well coverplate. (See coverplate numbering index)

MEASURING EQUIP.: Steel tape, electric dropline, contractor's 8x7 in. orifice tube, watch

1. SPECIFIC CAPACITY TEST

DATE: 11/5/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate* (gpm)	Remarks
9:53AM	19.25				Steel tape
10:00	19.30				Brotcke elec. dropline
10:03	19.30				Static water level
10:06	19.30				Static water level
10:12	19.30				Pump on
10:15					Pump off - orient orifice/ clean drain
10:20	19.34	0.00	7-15	850	Pump on - well is surging 680-1020 gpm; 850 is average
10:43	28.75	9.41	7-15	850	Surging strongly
11:04	28.83	9.49	7-15	850	Surging strongly
11:20	28.88	9.54	7-15	850	Surging strongly; pump off

Note: All specific capacity tests — static water level (SWL) measured after minimum 30 min. period of well inactivity. Minimum period of pumpage for drawdown measurements is 60 min.

* All pumping rates from 8x7 in. orifice, Peerless-Midwest, Inc., Orifice Tables unless noted otherwise.

60 min. specific capacity: 850 gpm/ft =89.1 gpm/ft

2. 400 LBS POLYPHOSPHATE APPLICATION

DATE: 11/5/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	12:00 PM	12:04 PM
- complete:	12:01:10	12:04:40
Injection rate:	1710 gpm	750 gpm

B. POLYPHOSPHATE INJECTION, 400 lbs total

	Batch 1	Batch 2
Phosphate:	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal
Time - initial:	12:17 PM	12:30 PM
- complete:	12:18:15	12:32:30
Injection rate:	1440 gpm	720 gpm

Comments: Were receiving approx. 154 gpm from system back-pressure or 500 gallons every 3 min. 15 sec.

C. DISPLACEMENT, gallons chlorinated water (500 mg/l)

Time - initial/complete	Quantity (gal)	Q (gpm)
12:45 PM/2:07 PM	16,000	1800

Comments: Eight 2000-gallon injections, all injected at approximately 1800 gpm.

D. PUMPED TO WASTE

Time - initial: 4:00 PM (11/5)
- complete: 8:58 AM (11/6)

Q: 850 gpm Quantity: 865,300 gal

Comments: The well-pumped to waste all night. This is due to the fact that we can't pump to waste until 4:00 PM.

3. SPECIFIC CAPACITY TEST DATE: 11/6/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
9:25AM	20.17				Static water level
9:29	20.17				Static water level
9:32	20.17				Pump on
9:52	28.09	7.92	9.5	810	Surging from 8-11 inches
10:11	28.14	7.97	9.5	810	
10:32	28.16	7.99	9.5	810	Pump off

60 min. specific capacity: 101.4 gpm/ft

Comments: We extended our discharge line in an attempt to reduce surging. It reduced the surging significantly. The pumping rates estimated during the intial test may have been high. Acid arrived at 11:00 AM.

4. ACIDIZATION - INHIBITED MURIATIC ACID DATE: 11/6/87

A. ACID INJECTION

Acid strength: 20° baume Quantity: 1000 gal

Time - initial: 11:30 AM
- complete: 11:31:30

Pumping rate of 1000 gal injection: 667 gpm

Comments: The acid was chased with approx. 500 gallons of water directly following injection.

B. DISPLACEMENT, 3,500 gallons water

	Batch 1	Batch 2
Quantity:	2000 gal	1500 gal
Time - initial:	12:31 PM	12:43 PM
- complete:	12:32:10	12:43:50
Injection rate:	1710 gpm	1800 gpm

Comments: IDOT will not allow us to start pumping to waste until 4:00 PM. This is due to the odor complaints at the pumping station.

C. PUMPED TO WASTE

Time - initial: 4:00 PM (11/9/87)
- complete: 7:55 AM (11/10/87)

Q: 810 gpm Quantity: 773,600 gal

Comments: The pressurized system discharge line was connected to the temporary column pipe, but the pump would not run. As a result water backflowed from the discharge line into the well from early on 11/7/87 until 10:15 AM on 11/9/87. At 10:55 AM, Al Brown (IDOT) arrived on site. The pump was pulled to investigate the failure. A cut was found in the pump wire which was spliced. The pump was placed back in the well and would now run.. The acid was then pumped to waste starting at 4:00 PM on 11/9/87.

5. SPECIFIC CAPACITY TEST DATE: 11/10/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
7:55 AM					Pump off
8:20	19.98				Static water level
8:25	19.96				Static water level
8:26	19.96				Pump on
8:45	30.20	10.24	10.5	845	
9:07	30.26	10.30	11	865	
9:26	30.29	10.33	11	865	Pump off

60 min. specific capacity: Q/s - 83.7 gpm/ft

6. 600 LBS POLYPHOSPHATE APPLICATION DATE: 11/10/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:48 AM	9:53 AM
- complete:	9:49:10	9:53:30
Injection rate:	1710 gpm	1000 gpm

B. POLYPHOSPHATE INJECTION, 600 lbs total

	Batch 1	Batch 2	Batch 3
Phosphate:	200 lbs	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal	1800 gal
Time - initial:.	10:01 AM	10:15 AM	10:30 AM
- complete:	10:02:00	10:16:00	10:31:00
Injection rate:	1800 gpm	1800 gpm	1800 gpm

C. DISPLACEMENT, 30,000 gallons chlorinated water (500 mg/l)

Time - initial: 10:44 AM
- complete: 1:28 PM

Quantity: 30,000 gal Q: 1800 gpm

Comments: Fifteen 2000-gallon injections, all injected at 1800 gpm

D. PUMPED TO WASTE

Time - initial: 4:00 PM (11/10)
- complete: 8:10 AM (11/11)

Q: 865 gpm   Quantity: 839,000 gal

Comments: Q assumed from previous specific capacity test

7. SPECIFIC CAPACITY TEST   DATE: 11/11/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
8:10 AM					Pump off
8:37	20.24				Static water level
8:40	20.24				Pump on
9:00	28.48	8.24	11.5	890	
9:26	28.54	8.30	11	865	
9:40	28.54	8.30	11	865	Pump off

60 min. specific capacity: 104.2 gpm/ft

8. 600 LBS POLYPHOSPHATE APPLICATION   DATE: 11/11/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	10:37 AM	10:40 AM
- complete:	10:38:45	10:41:00
Injection rate:	1140 gpm	500 gpm

B. POLYPHOSPHATE INJECTION, 600 lbs total

	Batch 1	Batch 2	Batch 3
Phosphate:	200 lbs	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal	1800 gal
Time - initial:	10:54 AM	11:07 AM	11:19 AM
- complete:	10:58:00	11:11:00	11:22:00
Injection rate:	450 gpm	450 gpm	600 gpm

Comments: The injection line developed a hole during the initial chlorination, thus the lower injection rates.

C. DISPLACEMENT, 54,000 gallons chlorinated water (500 mg/l)

Time - initial: 11:33 AM
- complete: 2:58 PM

Quantity: 54,000 gal   Q: 1800 gpm

Comments: Twenty-seven 2000-gallon injections

D. PUMPED TO WASTE

Time - initial: 4:00 PM (11/11)
- complete: 7:50 AM (11/12)

Q: 865 gpm   Quantity: 822,000 gal

Comments: Q assumed from previous specific capacity test

9. SPECIFIC CAPACITY TEST   DATE: 11/12/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (from)	Remarks
7:50 AM					Pump off
8:15	20.34				Static water level
8:17	20.34				
8:20	20.34				Pump on
8:40	28.72	8.38	11	865	
9:00	28.76	8.42	11	865	
9:20	28.78	8.44	11	865	Pump off

60 min. specific capacity: 102.5 gpm/ft

10. 400 LBS POLYPHOSPHATE APPLICATION   DATE: 11/12/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:40 AM	9:43 AM
- complete:	9:41:10	9:43:30
Injection rate:	1710 gpm	1000 gpm

B. POLYPHOSPHATE INJECTION, 400 lbs total

	Batch 1	Batch 2
Phosphate:	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal
Time - initial:	10:00 AM	10:11 AM
- complete:	10:01:00	10:.12:00
Injection rate:	1800 gpm	1800 gpm

C. DISPLACEMENT, 16,000 gallons chlorinated water (500 mg/l)

Time - initial: 10:20 AM
- complete: 11:43 AM

WELL REHABILITATION -- 25th Street Well No. 10 (Continued)

Quantity: 16,000 gal   Q: 1800 gpm

Comments: Eight 2000-gallon injections at 1800 gpm

D. PUMPED TO WASTE

Time - initial: 4:00 PM (11/12)
- complete: 7:50 AM (11/13)

Q: 865 gpm   Quantity: 822,000 gal

11. SPECIFIC CAPACITY TEST   DATE: 11/13/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
7:50 AM					Pump off
8:15	20.42				Static water level
8:18	20.42				
8:20	20.42				Pump on
8:30	28.64	8.22	11	865	
8:54	28.72	8.30	11	865	
9:20	28.75	8.33	11	865	Pump off

60 min. specific capacity: 103.8 gpm/ft

WELL REHABILITATION FIELD NOTES

WELL SITE: I-64 Well No. 3 OBSERVER: Jeffrey R. Stollhans

CONTRACTOR: Brotcke Engineering Co., Inc., Fenton, MO

MEASURING POINT: Corner No. 2, 99.5 in. from the NW/c of manhole coverplate to temp. well coverplate (see coverplate numbering index)

MEASURING EQUIP.: Electric dropline, watch, contractor's 8x7 in. orifice tube, tape measure

1. SPECIFIC CAPACITY TEST

DATE: 11/13/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate* (gpm)	Remarks
12:26PM	19.72				Static water level
12:28	19.72				Pump on
12:55	26.39	6.67	5.5	600	
1:29	26.57	6.85	5.5	600	Pump off

Note: All specific capacity tests--static water level (SWL) measured after minimum 30 min. period of well inactivity. Minimum period of pumpage for drawdown measurements is 60 min.

* All pumping rates from 8x7 in. orifice, Peerless-Midwest, Inc., Orifice Tables unless noted otherwise.

60 min. specific capacity: 87.6 gpm/ft

Comments: The well head was pulled and the column pipe was inspected on 11/9/87. The column pipe within this well is in excellent condition; no deposits are present. Brotcke will not sand blast the column pipe.

2. 400 LBS POLYPHOSPHATE APPLICATION

DATE: 11/13/87

A. INITIAL CHLORINATION

Quantity: 2500 gal Strength: 500 mg/l

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	2:03 PM	2:06 PM
- complete:	2:04:10	2:06:20
Injection rate:	1710 gpm	1500 gpm

B. POLYPHOSPHATE INJECTION, 400 lbs total

	Batch 1	Batch 2
Phosphate:	250 lbs	150 lbs
Quantity H_2O:	1800 gal	1800 gal
Time - initial:	2:16 PM	2:26 PM
- complete:	2:17:00	2:27:00
Injection rate:	1800 gpm	1800 gpm

Comments: 250 gpm from supply (I-64 No. 2)

C. DISPLACEMENT, 16,000 gallons chlorinated water (500 mg/l)

Time - initial/complete	Quantity (gal)	Q (gpm)
2:35 PM/3:45 PM	16,000	1800

Comments: Eight 2000-gallon injections

D. PUMPED TO WASTE

Time - initial: 4:45 PM (11/13)
- complete: 8:40 AM (11/16)

Q: 600 gpm Quantity: 2.3×10^6 gal

Comments: The well pumped all weekend.

3. SPECIFIC CAPACITY TEST DATE: 11/16/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
8:40 AM					Pump off
9:00	21.45				Static water level
9:05	21.36				
9:12	21.30				Pump on
9:36	26.78	5.48	5.5	600	
9:57	26.83	5.53	5.5	600	
10:12	26.06	4.76	5.5	600	Pump off

60 min. specific capacity: 126.1 gpm/ft

Comments: Acid arrived on site 9:55 AM.

WELL REHABILITATION -- I-64 Well No. 3 (Continued)

4. ACIDIZATION - INHIBITED MURIATIC ACID DATE: 11/16/87

A. ACID INJECTION

Acid strength: 20° baume Quantity: 1000 gal

Time - initial: 10:36 AM
- complete: 10:37:30

Pumping rate of 1000 gal injection: 670 gpm

Comments: Acid was immediately chased with approximately 250 gallons of water.

B. DISPLACEMENT, 3,500 gallons nonchlorinated water

	Batch 1	Batch 2
Quantity:	2000 gal	1500 gal
Time - initial:	11:38 AM	11:47 AM
- complete:	11:39:30	11:47:50
Injection rate:	1330 gpm	1800 gpm

C. PUMPED TO WASTE

Time - initial: 5:08 PM (11/16)
- complete: 8:30 AM (11/17)

Q: 600 gpm Quantity: 553,200 gal

5. SPECIFIC CAPACITY TEST DATE: 11/17/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
9:30AM	21.10				Static water level
9:35	21.10				Pump on
9:55	26.43	5.33	5.5	600	
10:15	26.50	5.40	5.5	600	
10:35	26.57	5.47	5.5	600	Pump off

60 min. specific capacity: 109.7 gpm/ft

6. 600 LBS POLYPHOSPHATE APPLICATION DATE: 11/17/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	10:54 AM	10:58 AM
- complete:	10:55:10	10:58:20
Injection rate:	1710 gpm	1500 gpm

B. POLYPHOSPHATE INJECTION, 600 lbs total

	Batch 1	Batch 2	Batch 3
Phosphate:	200 lbs	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal	1800 gal
Time - initial:	11:04 AM	11:13 AM	11:24 AM
- complete:	11:05:00	11:14:00	11:25:00
Injection rate:	1800 gpm	1800 gpm	1800 gpm

C. DISPLACEMENT, 30,000 gallons chlorinated water (500 mg/l)

Time - initial: 11:33 AM
- complete: 2:03 PM

Quantity: 30,000 gal Q: 1800 gpm

Comments: Fifteen 2000-gallon injections @ 1800 gpm.

D. PUMPED TO WASTE

Time - initial: 4:00 PM (11/17)
- complete: 7:55 AM (11/18)

Q: 600 gpm Quantity: 573,000 gal

7. SPECIFIC CAPACITY TEST DATE: 11/18/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
7:55 AM					Pump off
8:20	21.49				Static water level
8:28	21.49				Pump on
8:48	26.62	5.13	5.5	600	
9:10	26.78	5.29	5.5	600	
9:28	26.84	5.35	5.5	600	Pump off

60 min. specific capacity: 112.1 gpm/ft

8. 600 LBS POLYPHOSPHATE APPLICATION — DATE: 11/18/87

A. INITIAL CHLORINATION

Quantity: 2500 gal — Strength: 500 mg/l (ppm)

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:39 AM	9:43 AM
- complete:	9:40:20	9:43:20
Injection rate:	1500 gpm	1500 gpm

B. POLYPHOSPHATE INJECTION, 600 lbs total

	Batch 1	Batch 2	Batch 3
Phosphate:	200 lbs	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal	1800 gal
Time - initial:	9:52 AM	10:02 AM	10:04 AM
- complete:	9:53:00	10:03:00	10:05:00
Injection rate:	1800 gpm	1800 gpm	1800 gpm

C. DISPLACEMENT, 54,000 gallons chlorinated water (500 mg/l)

Time - initial: 10:19 AM
- complete: 1:48 PM

Quantity: 54,000 gal — Q: 1800 gpm

Comments: Twenty-seven 2000-gallon injections @ 1800 gpm.

D. PUMPED TO WASTE

Time - initial: 4:00 PM (11/18)
- complete: 7:50 AM (11/19)

Q: 600 gpm — Quantity: 570,000 gal

9. SPECIFIC CAPACITY TEST — DATE: 11/19/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
7:50 AM					Pump off
8:15	21.32				Static water level
8:20	21.32				Pump on
8:37	26.41	5.09	5.5	600	
8:56	26.53	5.21	5.5	600	
9:23	26.56	5.24	5.5	600	Pump off

60 min. specific capacity: 114.5 gpm/ft

10. 400 LBS POLYPHOSPHATE APPLICATION DATE: 11/18/87

A. INITIAL CHLORINATION

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

	Batch 1	Batch 2
Quantity:	2000 gal	500 gal
Time - initial:	9:36 AM	9:40 AM
- complete:	9:37:10	9:40:20
Injection rate:	1710 gpm	1500 gpm

B. POLYPHOSPHATE INJECTION, 400 lbs total

	Batch 1	Batch 2
Phosphate:	200 lbs	200 lbs
Quantity H_2O:	1800 gal	1800 gal
Time - initial:	9:49 AM	9:58 AM
- complete:	9:50:00	9:59:00
Injection rate:	1800 gpm	1800 gpm

C. DISPLACEMENT, 16,000 gallons chlorinated water (500 mg/l)

Time - initial: 10:07 AM (11/18)
- complete: 11:10 AM (11/19)

Quantity: 16,000 gal Q: 1800 gpm

Comments: Eight 2000-gallon injections.

D. PUMPED TO WASTE

Time - initial: 4:00 PM (11/18)
- complete: 7:50 AM (11/19)

Q: 600 gpm Quantity: 570,000 gal

11. SPECIFIC CAPACITY TEST DATE: 11/19/87

Time	Depth (ft)	Drawdown (ft)	Piez. tube (in.)	Pumping rate (gpm)	Remarks
7:50 AM					Pump off
8:15	21.43				Static water level
8:18	21.43				
8:22	21.43				Pump on
8:40	26.49	5.06	5.5	600	
9:02	26.58	5.15	5.5	600	
9:22	26.62	5.19	5.5	600	Pump off

60 min. specific capacity: 115.6 gpm/ft

Appendix E.

Water Sample Chemical Analysis Results from I-255 Detention Pond Relief Wells

Appendix E. Water Sample Chemical Analysis Results
from I-255 Detention Pond Relief Wells

Site		SP	SP	SP	SP
Relief Well No.		1	3	20	22
Section Location T.3N., R.8W., St. Clair Co.		31.3d	31.3e	31.3e	31.3d
Date Collected		5/29/85	5/30/85	5/24/85	5/29/85
Laboratory No.		221066	221067	221068	221069
Iron (Fe),	mg/l	0.57	0.68	0.91	0.90
Manganese (Mn),	mg/l	0.54	0.70	0.99	0.74
Calcium (Ca),	mg/l	93.9	96.1	133.0	106.0
Magnesium (Mg),	mg/l	31.5	35.1	44.4	38.2
Sodium (Na),	mg/l	19.8	17:2	16.8	21.8
Silica (SiO_2),	mg/l	26.5	25.3	29.8	27.2
Nitrate (NO_3),	mg/l	1.2	2.7	<0.3	0.3
Chloride (Cl),	mg/l	12.0	17.0	16.0	16.0
Sulfate (SO_4),	mg/l	130.0	130.0	190.0	150.0
Alkalinity (as $CaCO_3$), mg/l		272.0	268.0	368.0	312.0
Hardness (as $CaCO_3$), mg/l		364.0	384.0	514.0	422.0
Total dissolved minerals,	mg/l	475.0	482.0	673.0	558
Turbidity (lab), NTU		<1	<1	<1	<1
Color, PCU		<1	<1	<1	<1
Odor		None	None	None	None
pH (lab)		7.4	7.3	7.3	7.3

SP - south pond
NP - north pond

Appendix E. Continued

Site		SP	NP	SP	SP
Relief Well	No.	10	15	12	5
Section Location T.3N., R.8W., St. Clair Co.		31.3f	31.3g	31.3f	31.3e
Date Collected		5/15/85	5/9/85	5/16/85	5/8/85
Laboratory No.		220914	220915	220916	220917
Iron (Fe),	mg/l	0.38	0.27	0.52	0.48
Manganese (Mn),	mg/l	0.40	0.32	0.46	0.57
Calcium (Ca),	mg/l	82.8	79.2	78.4	92.8
Magnesium (Mg),	mg/l	29.6	30.9	27.7	31.7
Sodium (Na),	mg/l	21.7	22.9	16.4	16.3
Silica (SiO_2),	mg/l	24.3	25.1	16.9	22.3
Nitrate (NO_3),	mg/l	7.9	4.8	<0.3	<0.3
Chloride (Cl),	mg/l	27.0	26.0	22.0	15.0
Sulfate (SO_4),	mg/l	110.0	110.0	100.0	130.0
Alkalinity (as $CaCO_3$), mg/l		240.0	236.0	210.0	264.0
Hardness (as $CaCO_3$), mg/l		328.0	325.0	310.0	362.0
Total dissolved minerals,	mg/l	457.0	453.0	404.0	473.0
Turbidity (lab), NTU		3	4	3	2
Color, PCU		<1	<1	<1	<1
Odor		None	None	None	None
pH (lab)		7.4	7.6	7.4	7.2

SP - south pond
NP - north pond

Appendix E. Concluded

Site	SP	SP	SP
Relief Well No.	14	16	18
Section Location T.3N., R.8W., St. Clair Co.	31.3F	31.3f	31.3e
Date Collected	5/20/85	5/20/85	5/21/85
Laboratory No.	220918	220919	220920
Iron (Fe), mg/l	1.28	1.58	1.50
Manganese (Mn), mg/l	0.70	0.81	0.84
Calcium (Ca), mg/l	131.0	133.0	134.0
Magnesium (Mg), mg/l	45.4	46.6	45.5
Sodium (Na), mg/l	18.7	18.3	17.5
Silica (SiO_2), mg/l	27.9	28.5	29.9
Nitrate (NO_3), mg/l	0.4	<0.3	<0.3
Chloride (Cl), mg/l	25.0	18.0	15.0
Sulfate (SO_4), mg/l	180.0	190.0	190.0
Alkalinity (as $CaCO_3$), mg/l	358.0	372.0	362.0
Hardness (as $CaCO_3$), mg/l	514.0	524,0	521.0
Total dissolved minerals, mg/l	667.0	662.0	663.0
Turbidity (lab), NTU	12	13	12
Color, PCU	<1	<1	<1
Odor	None	None	None
pH (lab)	7.4	7.4	7.4

SP - south pond
NP - north pond

Appendix F.

Sand Pumpage Test Sieve Data

Appendix F. Sand Pumpage Test Sieve Data
(Cumulative % retained)

Sieve Diameter (mm)	I-70 Well 2*	I-70 Sample 1	Well 8 Sample 2	I-70 Well 9	Venice Well 6
2.00				0	6.59
1.00				0.06	26.21
0.710	2.61	1	1,14	0.13	
0.600	4.01	2.02	1.91		
0.500	5.23	3.17	3.09	0.23	27.96
0.425		4.35	4.36	0.42	28.63
0.355		8.78	10.17	1.25	
0.300		20.24	25.7	5.04	29.97
0.250	10.98	43.36	50.11	14.23	
0.212				37.9	
0.180	39.37	75.83	77.56	62.82	
0.150				85.08	
0.125	66.9	94.74	90.06	93.41	84.68
0.090	75.44	96.53	91.33	96.8	
0.075				97.03	98.66
0.063	78.22	97.1	91.93	97.4	100.13
PAN	100	99.74	99.67		101.08
Date	6/20/88	6/22/88	6/22/88	11/20/86	11/17/87

*Two field samples combined for analysis.

Analyses by the Inter-Survey Geotechnical Laboratory at the Illinois State Geological Survey