

Water Right Number 2019-3

1. Considered November 14, 1973
2. Name of Applicant City of Sioux Falls
3. Post Office Address Sioux Falls, S.D.
4. Amount of Water claimed 3.10
5. Source of Water supply ground water
6. Water to be used for municipal use

Acres to be irrigated _____

7. Water to be diverted and used in Minnehaha County
about 3.10 miles of Sioux Falls

8. Proof of Publication Received 11-5-73

Not Received _____

9. Application Approved _____

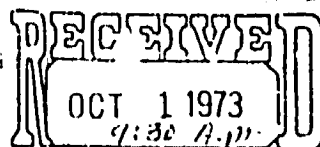
Subject to _____

Not Approved _____

Action Deferred _____

10. Remarks:

Map No. 1431-3 Water Division No. 3 BIG SIOUX RIVER Di
 (Blanks to be Filled by the Engineer for the W. H. C.)



APPLICATION FOR PERMIT STATE WATER RIGHTS COMM PIERRE, SOUTH DAKOTA

To Appropriate Water within the State of South Dakota

(NOTE: Draw a line through items not applicable)

1. Name of Applicant City of Sioux Falls
 Postoffice address City Hall, 9th & Dakota State South Dakota
 If a corporation show date and place of incorporation -----
2. Method of accomplishing work (contract, employment of others, or by direct labor) Contract
3. Name of diversion work Well #37
4. Amount of water claimed (cubic feet per second) 3.1 cfs
5. Source of water supply Ground water
6. Location of point of diversion NW 1/4 of the NW 1/4 of Sec 20 T102 N.;
R49 W on the west bank of the Big Sioux River

County Minnehaha

7. Annual period or periods during which water is to be used Continuous
8. Use to be made of water. (irrigation, industrial, municipal, commercial, recreation, etc.) Municipal
9. For irrigation use, ----- Total number of acres to be irrigated -----

List below each forty acre subdivision, or lot, or fraction thereof and show number of acres to be irrigated in each.

Land Description	No. Acres Irr.	Land Description	No. Acres Irr.

Attach sheet if more space is needed

10. Time required to complete construction of water supply system 1 years. Additional time required to complete application of water to the proposed beneficial use 0 years.
11. Choice of newspaper for Notice of Intent to Appropriate Water publication Sioux Falls ARGUS LEADER
12. Principal Features of the Proposed Water Supply System.

A. Works proposed to divert water from its natural source.

Sixteen foot diameter caisson 40 ft. deep with four to six perforated lateral pipe projecting from 100' to 200' horizontally into the water bearing sands and gravels

B. Works proposed to transport water to place of use.

Underground pipe line

C. Works proposed to apply water to beneficial use.

Existing water purification plant and distribution system
 Estimated Total Cost \$ 200,000.

Attachments: Attach Form 2A if diversion from a well or dugout, or if storage of water, is proposed. Attach map (See instruction concerning preparation.)

STATE OF SOUTH DAKOTA

County of Minnehaha

I, James H. Smith the applicant, certify that I have read the foregoing application and have examined the attached map and that the matters therein stated are true and that I intend, and am able to complete the necessary construction.

Subscribed and sworn to before me this 3 day of October 1973

Signed Les H. Hask Gen. Supt.
Clara M. Weber
 Notary Public (or other qualified officer)

COMMISSION EXPIRES
 JULY 1, 1981

WATER RIGHT APPLICATION APPROVAL

The Water ^{Rights} Commission hereby approves Water Right Application No. 2019-3
CITY OF SIOUX FALLS CITY HALL, 9TH & DAKOTA
(Applicant) (Post Office Address)
SOUTH DAKOTA With the following modifications:

The ~~irrigation~~ well approved under this Permit will be located near domestic wells and other ~~irrigation~~ wells which may obtain water from the same aquifer. The ~~irrigation~~ well owner, under this Permit, shall control his ~~irrigation~~ withdrawals so there is not a reduction of needed water supplies in existing domestic wells or in ~~irrigation~~ wells having prior water rights.

PRIORITY FOR THIS PERMIT WAS ESTABLISHED UNDER FUTURE USE WITHDRAWAL 44B-3. DEVELOPMENT OF THIS WELL REDUCES PERMIT NO 44B BY 3.1 CFS, LEAVING 40.58 CFS REMAINING FOR FUTURE DEVELOPMENT

Date of first receipt of application OCTOBER 1 19 73
 Date of return to applicant for correction, amendments or changes required --- 19 ---
 Date of receipt of corrected application --- 19 ---
 Approved NOVEMBER 14 19 73 Recorded in Book 12 Page 277

WATER RIGHT PERMIT NO. 2019-3

The Water ^{Rights} Commission hereby grants and issues this Water Right Permit No. 2019-3 authorizing the construction of the water use system and the putting of water to beneficial use as stated in the Application and as modified in the Water Right Application approval, subject, however, to the following limitations and conditions:

1. The date from which applicant may claim right is APRIL 8 19 57
2. The equivalent of at least one-fifth of the work above specified is to be completed on or before MAY 14 19 74
3. The whole of said work is to be completed on or before NOVEMBER 14 19 74
4. The limit of time from proof of beneficial use of water appropriated in accordance herewith is NOVEMBER 14 19 74
5. The water appropriated shall be used for the purpose of MUNICIPAL USE

6. The prior right of all persons who, by compliance with the laws of the State of South Dakota, have acquired a right to the use of water must not be injuriously affected by this appropriation.

7. The amount of the appropriation herein granted shall not exceed 3.1 cubic feet per second, neither shall it exceed the capacity of the above described water supply system, nor shall it exceed the amount of water needed for ~~beneficial use~~ and if for other than agricultural purposes, for domestic, industrial, municipal, or power purposes, for which water is
USED FOR MUNICIPAL PURPOSES.
 actually and beneficially ~~applied to the land~~ used on or before NOVEMBER 14 19 74 and water to be used during the following described annual period: CONTINUOUSLY

Witness my hand this 16TH day of NOVEMBER 19 73

WATER RIGHTS COMMISSION

By:

Donald Driscoll
 Chief Engineer, Executive Officer

Certificate of Construction Issued FEBRUARY 2 19 78

Water License Issued FEBRUARY 2 19 78

12. Principal Features of the Proposed Water Supply System (continued.)

D. Well Information or Estimates

(1) Drill Hole, Diameter 19 feet, Depth 30 feet(2) Casing, Type Concrete Diameter 16 feet Thickness 18 inches
(wood, concrete, steel, etc.)

(3) Perforated Screen.

Type Steel, Diameter 12", Length _____

(4) Gravel Pack, Thickness _____, Length of gravel pack _____

E. Dugout Information or Estimates. -----

(1) Surface dimensions _____, Depth _____

F. Fill out for Either a Well or a Dugout.

(1) Water Bearing Materials. (Please attach a copy to test well log if available.)

Character of Water bearing materials Fine to medium sand

Depth to top of water bearing material 9 feetDepth to bottom of water bearing material 38 feetThickness of water bearing material 29 feetDepth to water (ground surface to water level) 10 feet

(2) Distance to nearest existing household or livestock watering wells.

On same owner's property 136 rds. On property owned by others 146 rds.

G. Water Storage Dams. -----

If the proposed water use system contains one or more water storage dams, please show in the space below, the height, maximum water depth, surface area and storage capacity of each storage dam. The location of each water storage dam should be shown on the water right map.

Leo Walsh, Gen. Supt.
Signature of Applicant
City Water Dept.

Form 15.

Permit No. 2010-3

Water Diversion No. 3 Big Sioux River Water District

CERTIFICATE OF CONSTRUCTION

This is to Certify, That the City of Sioux Falls

_____ the holder _____ of
Permit No. 2010-3, issued upon Application No. 2010-3, bearing date of priority of April 8,
1957 authorizing the diversion of 3.1 cu. ft. per second of the waters of _____
groundwater County of Minnehaha, State of South Dakota at _____
a point 1250' E and 60' S of the NW corner, Section 20, T102N,
R 49W

_____, for _____

purposes, has _____ complied with the provisions of the laws of the State of South Dakota relating to proof of
completion of the works of diversion set out and described in said Permit; that said works are found in satisfactory
condition for diverting and conveying to the place of intended use 3.1 cu. ft. per second of water.

Date February 2, 1978

By:

WATER RIGHTS COMMISSION

John Hatch

JOHN HATCH, Chief Engineer

WATER LICENSE NO. 2010-3

(1) WHEREAS, On the 1st day of October A. D. 19 73
the City of Sioux Falls

made Water Right Application No. 2010-3 for a permit to use 3.1 cubic feet per second of the waters
of ground water
County of Minnehaha, State of South Dakota, for municipal
purposes; and

(2) WHEREAS, On the 16th day of November A. D. 19 73
Permit No. 2010-3, with a date of priority of April 8, 1957

was issued to said applicant for the diversion of said water, and provided for the completion of construction of the water
supply system therein described on or before the 14th day of November A. D. 19 74 and for the
application to beneficial use of said water on or before the 14th day of November A. D. 19 74

and;

(3) WHEREAS, It is hereby certified that the applicant has complied with the provisions of the laws of the State of South Dakota
relating to completion of the construction of the water supply system and is entitled to divert 3.1 cubic feet
per second of water for beneficial use and,

(4) WHEREAS, It is hereby certified that the applicant has complied with the provisions of the laws of the State of South Dakota
relating to the application of water to beneficial use of the following extent,

water is diverted through the city water distribution system for
municipal use

(5) NOW, THEREFORE, By the virtue of the authority vested in us by the laws of the State of South Dakota, We hereby grant and confirm to the City of Sioux Falls

~~XXX~~

the holder ~~and owner~~ of said permit No. 2019-3 a water right, dating from April 6, 1927 to use of 3.1 cubic feet per second of the waters

of groundwater in the County of Minnehaha and State of South Dakota, or so much thereof as may be necessary for the purposes hereinbelow mentioned, to be diverted at a point 1250'E and 60°S of the NW corner, Section, 20, T 102N, R40W

and conduct to and upon ~~XXXXXX~~ through the city water distribution system

for the purpose of municipal use

Subject to any limitations listed in Water Right Permit No. 2019-3 and subject to the laws of the State of South Dakota.

WITNESS, My hand and seal of our office at Pierre, South Dakota
this 2nd day of February A. D.
Nineteen Hundred and seventy-eight

WATER RIGHTS COMMISSION

By:

John Hatch
Chief Engineer, Executive Officer

**NOTICE
INTENT TO APPROPRIATE WATER**

October 1, 1973

cc: Lee Haah, General Superintendent, Sioux Falls Water Department, City Hall,
9th and Dakota, Sioux Falls, S.D. 57101

AFFIDAVIT OF PUBLICATION

STATE OF SOUTH DAKOTA, }
COUNTY OF MINNEHAHA } ss.

C. W. Lockhart, being duly sworn, says: That The Sioux Falls Argus-Leader is, and during all the times hereinafter mentioned was, a daily legal newspaper as defined by SDC Supp. 65,0509, as amended published at Sioux Falls, Minnehaha County, South Dakota by Sioux Falls Newspapers Inc.; that affiant is and during all of said times, was an employee of the publisher of such newspaper and has personal knowledge of the facts stated in this affidavit; that the notice, order or advertisement, a printed copy of which is hereto attached, was published in said newspaper upon

Thursday, the 25 day of October, 1973

Thursday, the 1 day of November, 1973

the day of 19

the day of 19

the day of 19

the day of 19

the day of 19

and that \$ 2.32 was charged for publishing the same.

C. W. Lockhart

Subscribed and sworn to before me November 1, 1973

Eleanor Taguo
Notary Public, South Dakota

Eleanor Taguo
My Commission Expires
June 30, 1974

(SEAL)

No. 20193
NOTICE
INTENT TO APPROPRIATE WATER
Notice is hereby given that the City of Sioux Falls, South Dakota, has made an application in accordance with the provisions of the water laws of South Dakota for a permit to develop from future use, and appropriate for beneficial use 3.1 cubic feet of water per second of time from ground water through the City Well No. 37, the point of diversion of which is to be located in the NW 1/4 NW 1/4 of Section 20, Twp. 102N, Range 48W. Said water to be used for the purpose of providing municipal supplies for the City of Sioux Falls.
This application No. 20193 will be considered by the Water Rights Commission at their office at Pierre upon the 14th day of November, 1973, at 2:30 P.M. All interested persons may appear and be heard.
WATER RIGHTS COMMISSION
By: BURTON J. JONES,
Water Rights Specialist
Oct. 25, Nov. 1, 1973

RECEIVED
NOV 5 1973

STATE WATER RIGHTS COMMISSION
PIERRE, SOUTH DAKOTA

2019 2 City of San Jose 11/1/19

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Scamp. 11/1/19

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Permit No. 2019-3Well # 37Water Division 3 Big Sioux River Water District

**REPORT OF EXAMINATION OF WORKS
AND/OR APPLICATION OF WATER TO BENEFICIAL USE**

TO: Water Resources Commission, State Office Building No. 2, Pierre, South Dakota 57501

I have this day made a thorough examination of the water use system constructed by City of
Sioux Falls of City Hall, 9th & Dakota, Sioux Falls, S.D. holder 57102
of Permit No. 2019-3, bearing date of priority of April 8, 1957
authorizing the diversion of 3.1 cu. ft. per second of the waters of Ground
for Municipal purposes, in Minnehaha County.

I have to report on the condition of the same as follows:

The Water Use System consists of,

A. Works used to divert the water:

Motor - U.S. Elec., ID # C521523 54-0754-434
100 HP, 1180 RPM.
Pump - Fairbanks Morris, 75 HP, 1170 RPM
Pumping 1000 gpm max.

B. Works used to transport water to place of use,

Underground Pipeline

C. Works used to apply water to beneficial use.

Municipal Water SystemThe system is in the following condition: Excellent

The point of diversion is located 1250 ft East and 60 ft South of the
NW corner of Section 20, T102N R49W.

The works are capable of diverting and conveying to the place of use 3.1cu. ft. per second of water which is to be used for Municipal Use

Water has been put to beneficial use to the maximum extent as follows:

comprising a total of _____ acres of land.

Well Data

Depth 40 ft.

Dia. 16 ft with 4 laterals
up to 200 ft long and 8" dia
Steel Slotted pipe collector
1 ft from bottom

Pumping 1000 gpm. (max)Date November 17, 1977

LeRoy J. McLaughlin
(Signature)

RECEIPT

WATER RIGHTS COMMISSION

No 4 6296

State of South Dakota

PIERRE, January 5, 1979

RECEIVED OF City of Sioux Falls

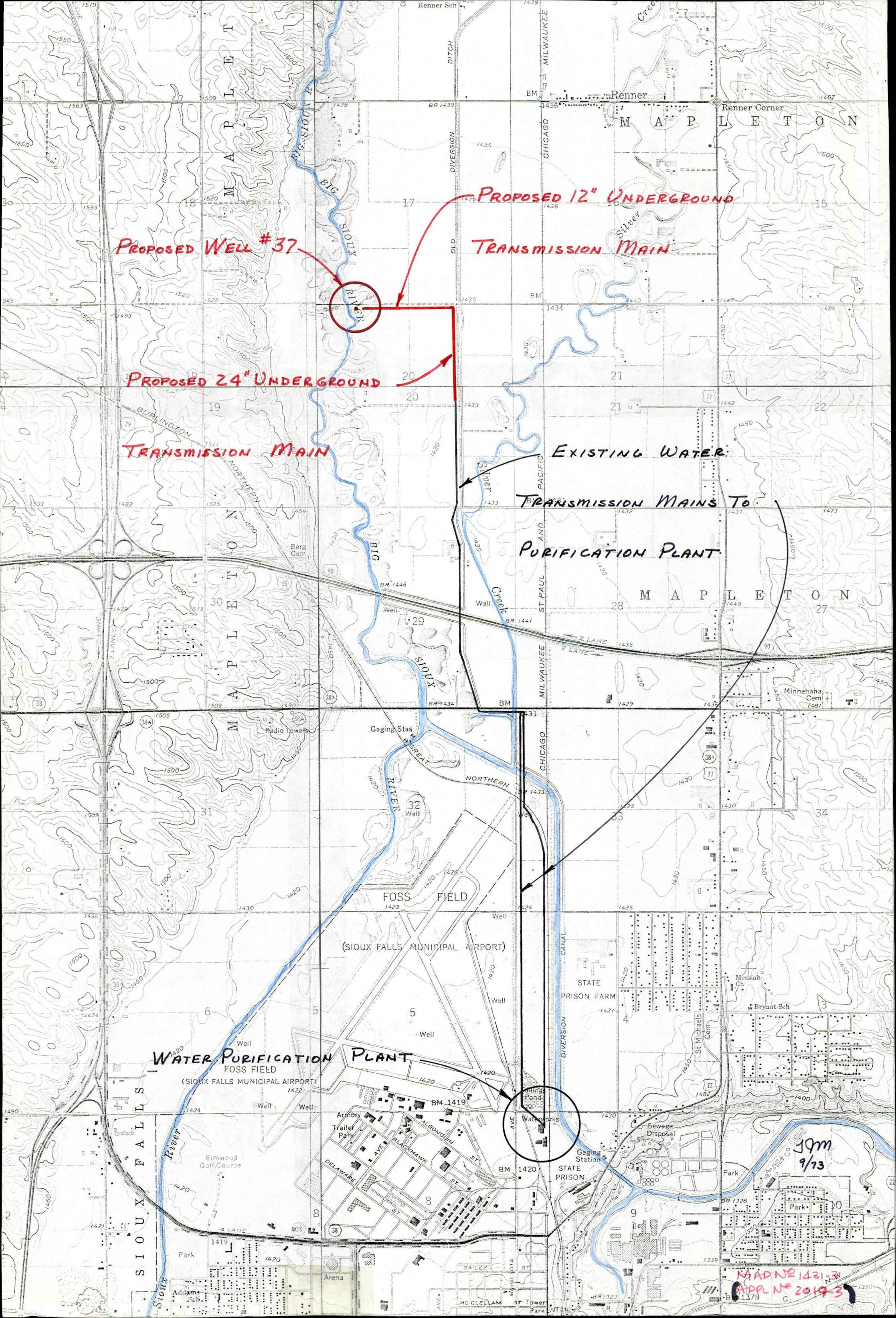
the following amount in fees for services rendered as provided for by law:

Fee for Application for Permit to Appropriate Water No. (examination, processing, recording and filling)		
Fee for inspecting Construction, and issuing Cert. of Construction No. (2010-1)	12	00
Fee for inspecting Beneficial Use, and issuing Water License No. (2010-2)		
Fee for issuing Location Certificate-Dry Draw, No.		
Fee for filling		
Fee for certified copy of		
Fee for Print copy of map		
Fee for Certifying		
Fee for		
(any other work as provided by law)		
TOTAL	12	00

WATER RIGHTS COMMISSION

By John Bateman
Chief Engineer, Executive Officer
JOHN BATCHELOR

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PROPOSED WELL #37

PROPOSED 12" UNDERGROUND
TRANSMISSION MAIN

PROPOSED 24" UNDERGROUND

TRANSMISSION MAIN

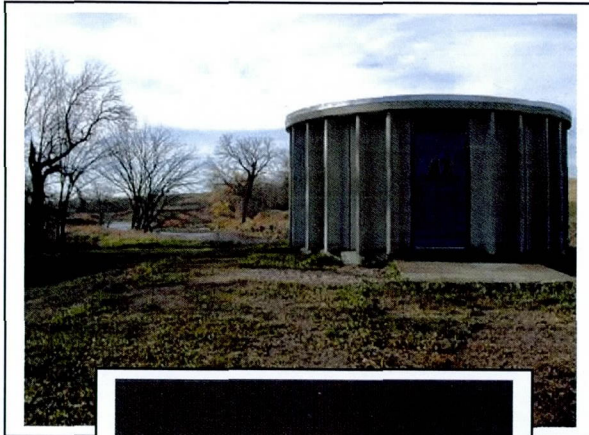
EXISTING WATER

TRANSMISSION MAINS TO
PURIFICATION PLANT

WATER PURIFICATION PLANT
FOSS FIELD
(SIOUX FALLS MUNICIPAL AIRPORT)

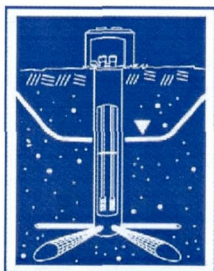
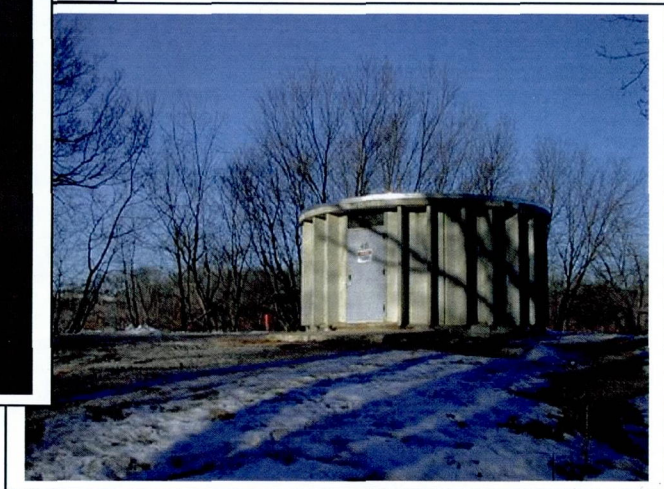
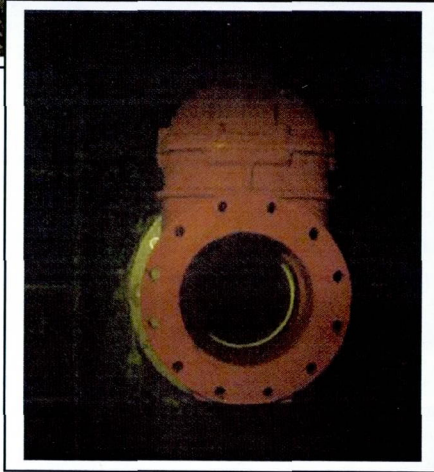
MAP NO 1431-3
APPL NO 2019-3
C 1378

Rehabilitation Report Collector Wells 46 and 47



Prepared for:

*The City of Sioux
Falls, South Dakota*



Prepared by:

Collector Wells International, Inc.

*6360 Huntley Road
Columbus, Ohio*

February 2006

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1.0 INTRODUCTION

Collector Wells International, Inc. (CWI) was contracted in July 2005, by the City of Sioux Falls, South Dakota (City) to rehabilitate the City's Collector Wells No. 46 and No. 47. The rehabilitation included sealing the existing laterals, cleaning debris from the caisson, installation of new ports in the caisson wall, installation of new laterals and performance testing of the wells. The work was conducted as authorized by Contract 05-1063 dated July 7, 2005. The rehabilitation of the collector wells was accomplished during the period from August 2005 through January 2006. Procedures and results for the rehabilitation and testing are included in this report along with recommendations regarding future collector well operations.

1.1 BACKGROUND

The City of Sioux Falls obtains its potable water supply from surface water and from ground water utilizing over 60 wells including a number of collector wells, gravel-packed vertical wells and Bragstad wells. Collector Wells No. 46 and 47 were installed by the Ranney Company of Westerville, Ohio and were both in service by 1981. Wells No. 46 and Well No. 47 are located north of the City, about 3.7 and 4.1 miles, respectively, north of the Sioux Falls Municipal Airport. Well No. 46 is located about 3,000 feet west and 2,600 feet south of the intersection of 258th Street and Ditch Road, while Well No. 47 is located about 3,900 feet west and 500 feet south of this intersection (Figure 1). Both wells are located on the east bank of the Big Sioux River, and draw water from the sand and gravel deposits of the Big Sioux Aquifer.

The original design capacity of Collector Well No. 46 was considered to be 1,800 gallons per minute (gpm) or 2.59 million gallons per day (MGD). The City's operating records show that in recent years the well has been operated at rates between 900 and 2,200 gpm. The original design capacity of Collector Well No. 47 was considered to be 1,670 gpm or 2.40 MGD. The operating records indicate that in recent years Well No. 47 has been operated at rates between 150 and 1,000 gpm.

It is estimated that when installed, Well No. 46 had specific capacity of approximately 190 gallons per minute per foot of drawdown (gpm/ft). Operating records for the well for the years 1989 through 2004 indicate that the specific capacity had dropped off to 90 gpm/ft by May 1993

at which time the laterals were redeveloped by the City. The redevelopment increased the specific capacity to about 200 gpm/ft. The specific capacity gradually decreased until the laterals were redeveloped again in April 2000, resulting in increasing the specific capacity from about 70 gpm/ft to about 120 gpm/ft. The operating records for Well No. 46 indicate that in the last half of 2004 the specific capacity averaged about 60 gpm/ft.

A pumping test conducted in Well No. 47 in 1981 indicated that it had an estimated specific capacity of about 90 gpm/ft after 72-hours of pumping. Operating records for the well for the years 1989 through 2004 indicate that the specific capacity had dropped off to 40 gpm/ft by February 1992 at which time the laterals were redeveloped. The redevelopment increased the specific capacity to about 80 gpm/ft. The specific capacity gradually decreased until the laterals were redeveloped again in September 1996, resulting in increasing the specific capacity from about 20 gpm/ft to about 100 gpm/ft. Redevelopment was conducted again in March 2000, but this redevelopment was only successful in increasing the specific capacity from about 30 to about 50 gpm/ft. The operating records for Well No. 47 indicate that in the first half of 2005 the specific capacity averaged about 20 gpm/ft.

1.2 LIMITATIONS

This report was prepared for the exclusive use of the City of Sioux Falls, South Dakota for the specific application to Collector Well Nos. 46 and 47 as specified in the report. Conclusions reached in this report are based upon the objective data available at the time of forming our opinions and the accuracy of the report depends upon the accuracy of these data. Every effort is made to evaluate the information by the methods generally recognized to constitute accepted standard practices for ground water investigations at the time of rendering and the conclusions reached therein to represent our opinions. CWI cannot be responsible for actual conditions proved to be materially at variance with the data collected or supplied to us, upon which our opinions are based.

2.0 COLLECTOR WELL DESCRIPTIONS

Plan and section views for the rehabilitated collector wells are depicted in Figures 2 and 3, and construction details are summarized in Tables 1 and 2. Information on these figures and tables is in part based on information provided in the Project 05-1063 Bid Documents (H.R. Green Co., 2005), which reference The Ranney Company revised as-built drawings dated 1/25/80.

2.1 WELL NO. 46

Well No. 46 was constructed with a 16-foot ID, 19-foot OD reinforced concrete caisson that was installed to a depth of about 46 feet below the pump house floor. There were originally four (4) laterals installed in Well No. 46 with two on the west side of the caisson spaced 60° apart and two on the east side of the caisson spaced 60° apart. Lengths of the original laterals ranged from 113 to 137 feet.

The three (3) newly installed laterals are comprised of 12-inch diameter, stainless steel, wire-wrapped well screen. The new laterals were installed at an elevation of 1398.2 feet, or about three feet above the floor of the caisson. The new Lateral No. 1 was projected on the south side of the caisson to a length of 107 feet. The new Lateral No. 2 was projected on the southwest side of the caisson to a length of 127 feet, and the new Lateral No. 3 was projected on the northwest side of the caisson to a length of 117 feet. It was planned to install three new laterals with each having a length of 117 feet (110 feet of screen and a 7 foot blank). The new Lateral No. 3 was the first to be installed and was completed to 117 feet. However, the aquifer material encountered during the projection of Lateral No. 3 was relatively fine-grained at the end of the lateral away from the caisson. During the projection of the new Lateral No. 2, which was installed second, the coarsest sand and gravel was encountered at the end of the lateral away from the caisson. Because of this, the new Laterals No. 2 was projected an additional 10 feet to 127 feet. Because Lateral No. 2 had been projected an additional 10 feet to take advantage of the coarser aquifer material, Lateral No. 1, the last to be installed, was projected only to a length of 107 feet. This gives a total of 351 feet of new lateral length installed in Collector Well No. 46.

Collector Well No. 46 is equipped with a single turbine pump. The original design capacity of the collector well was considered to be 1,800 gallons per minute (gpm) or 2.59 million gallons per day (MGD). In recent years it has been operated at rates between 900 and 2,200 gpm.

2.2 WELL NO. 47

Well No. 47 was constructed with a 16-foot ID, 19-foot OD reinforced concrete caisson that was installed to a depth of about 40 feet below the pump house floor. There were originally five (5) laterals installed in Well No. 47 spaced 60° apart with two on the east side of the caisson; two on the west side of the caisson; and one projecting to the north. The original lateral lengths ranged from 33 feet to 129 feet.

The four (4) newly installed laterals are comprised of 12-inch diameter, stainless steel, wire-wrapped well screen. The new laterals were installed at an elevation of 1405.1 feet, or about three feet above the floor of the caisson. The new Lateral No. 1 was projected on the east side of the caisson to a length of 117 feet. The new Lateral No. 2 was projected on the southeast side of the caisson. The new Lateral No. 3 was projected on the southwest side of the caisson, and the new Lateral No. 4 was projected on the west side of the caisson. It was planned to install three new laterals with each having a length of 117 feet (110 feet of screen and a 7 foot blank). However, during the projection of the new Lateral No. 3, fine sand was encountered between 75 and 85 feet from the caisson. During the projection of the new Lateral No. 4, clay was encountered between 85 and 100 feet from the caisson. Because of this, screen was installed in Laterals No. 3 and No. 4 to 67 feet (60 feet of screen and a 7 foot blank) and 87 feet (80 feet of screen and a 7 foot blank), respectively. A fourth new lateral (Lateral No. 2) was installed to a length of 102 feet to give a total of 373 feet of new lateral length installed in Well No. 47.

Collector Well No. 47 is equipped with a single turbine pump. The original design capacity of the collector well was considered to be 1,670 gpm or 2.40 MGD. In recent years it has been operated at rates between 150 and 1,000 gpm.

3.0 REHABILITATION PROCEDURES

The rehabilitation of Collector Wells No. 46 and 47 included sealing the existing laterals, cleaning debris from the caisson, installation of new ports in the caisson walls, installation and development of new laterals and performance testing of the wells. The rehabilitation of Well No. 47 was conducted first with project mobilization starting in August 2005. The rehabilitation of Well No. 47 was completed by the end of October 2005, at which time work was begun at Well No. 46. Rehabilitation of Well No. 46 was completed in January 2006.

Rehabilitation of Collector Wells No. 46 and No. 47 was accomplished as described below:

- The existing valves and valve stems on the laterals were removed.
- The existing laterals were sealed with blind flanges and gaskets.
- The caisson was then dewatered and prepared for installation of the new laterals.
- Holes were cored and four (4) new ports were installed in the caisson wall in Well No. 46 and four (4) new ports were installed in the caisson wall in Well No. 47.
- Three (3) new laterals, designated No. 1, No. 2, and No. 3, were installed in Well No. 46, and four (4) new laterals, designated No. 1 through No. 4, were installed in Well No. 47.
- The full length of each of the new laterals was thoroughly developed.
- Following the installation of the new laterals, valves and valve stems, the floor of the caissons were cleared of remaining debris and loose materials.
- The laterals were chlorinated by introducing a chlorine solution at the extreme end of each lateral using a perforated pipe extending from the surface. The chlorine solution was pumped at a uniform measured rate through the pipe as it is pulled back to ensure that the complete length of each lateral was be chlorinated.
- After this, the well was flooded by opening the gate valves for each lateral. Additional chlorine solution was added to disinfect the caisson.
- A post-maintenance pumping test was conducted on Collector Wells No. 46 and No. 47 using the permanent well pumps. During the testing, water level measurements were taken in the collector caissons and the adjacent observation wells to evaluate the effectiveness of the rehabilitation.

- During the post-maintenance tests, divers entered the collector wells to take photographs of the laterals and monitor the relative water velocity and water temperature from each lateral while the wells were being pumped.

Prior to the start of the rehabilitation activities, the City removed the pump from each of the wells. The City reinstalled the pumps following the rehabilitation activities, and the permanent pumps were used for the post-maintenance testing activities

The new laterals in Wells No. 46 and 47 were installed by initially projecting nominal 16-inch OD pipe to the desired length and sampling the aquifer materials as the pipe was projected. Next, the 12-inch diameter stainless steel (type 304) screen assemblage was installed within the projection pipe. The projection pipe was then hydraulically extracted from the aquifer, exposing the screened lateral to the aquifer. The screen material used consists of 12-inch pipe size heavy-duty wire-wound continuous slot well screen with a collapse strength of greater than 300 psi. The screen slot sizes were varied depending on the coarseness of the material encountered, which was based upon samples collected during the projection of the drive pipe. Following installation, each lateral was fully developed using a sand line.

Information on the screen slot sizes used in for Well No. 46 is presented in Table 1 and the screen slot sizes used in Well No. 47 are presented in Table 2. As listed in the tables, screen slot openings varied between 0.030 inches and 0.125 inches. The total new screen open area installed in Well No. 46, adjusting for couplings and blank sections, is 412 square feet. At the design yield of 1,800 gpm, this equates to an average entrance velocity of 1.2 feet per minute (fpm) (assuming 50 % blockage of the screen with aquifer materials). The total new screen open area installed in Well No. 47 is 390 square feet. At the design yield of 1,670 gpm, this equates to an average entrance velocity of 1.1 fpm (assuming 50 % blockage of the screen with aquifer materials).

4.0 TESTING PROCEDURES

Post-maintenance testing of Collector Well No. 46 related to the rehabilitation activities was completed on January 16, 2006. Post-maintenance testing of Well No. 47 was conducted at the end of October and beginning of November 2005. The testing for both wells included a multiple-rate step pumping test and a constant-rate pumping test. All of the testing was conducted under the supervision of a hydrogeologist experienced in collector well evaluation. The pumping tests were conducted on the well to determine its installed capacity and efficiency following the rehabilitation.

4.1 GENERAL TESTING PROCEDURES

The first portion of the test pumping for each of the two collector wells involved an 8-hour multiple-rate step test, conducted in two-hour steps at increasing rates of discharge. The step test results were evaluated to determine the relative efficiency of the pumping well, confirm the proper operation of equipment, and determine the discharge rate for the subsequent constant-rate test. Following the step test, a 72-hour constant-rate pumping test was conducted. The constant-rate pumping test was conducted to determine the post-maintenance well yield.

During the testing periods, water levels were collected at pertinent intervals to the nearest 0.01 foot referenced from a surveyed point (i.e. –top of casing, pump house floor, etc.) using a direct read electronic water measuring device and computerized data acquisition units and transducers. Temporary staff gages were installed in the Big Sioux River near each well site to monitor river level changes during the testing activities. Relative elevations of the water level monitoring points were surveyed by the H. R. Green Company.

The wells and points at which water levels were monitored during the testing periods at each of the two collector wells include the following:

Collector Well No. 46
OW78-2-2 (R1), South Observation Well
OW78-2-4 (P1), Middle Observation Well
OW78-2-3 (P2), North Observation Well
Big Sioux River

Collector Well No. 47
OW78-1-3 (R1), Middle Observation Well
OW78-1-5 (P1), South Observation Well
OW78-1-4 (P2), North Observation Well
Big Sioux River

Water level data recorded during the testing of Well No. 46 are presented in Appendices A and B, and water level data recorded during the testing of Well No. 47 are presented in Appendices D and E.

Water levels in the collector wells, observation wells and the river were monitored during the testing period with computerized data acquisition units and transducers manufactured by In-Situ Inc. The wells were periodically measured using direct-read electronic water level meters to calibrate and check the performance of the transducers.

During the testing of Well No. 46, the water levels in observation well OW78-2-3 (P2), the furthest north of the three observation wells, showed very limited response to pumping, and continued to decline during the recovery period following the constant-rate test. Consequently, this well is considered to be plugged. Only limited amounts of data were collected from OW78-2-3 (P2), and these data were not used in the subsequent analyses of the performance of Well No. 46.

Also, during the testing at Well No. 46 the Big Sioux River was ice covered. Water level measurements were taken in the river through a hole bored in the ice. During the beginning of the testing period, the cold temperatures appeared to have caused problems with the In-Situ Troll device that was installed in the river, and consequently only manual water level measurements are available for the river for the start of the test period. Later in the testing period when it became apparent that the Troll unit was malfunctioning it was replaced with the Troll that was originally installed in well OW78-2-3 (P2).

Only one transducer was available during the step test conducted at Well No. 47 and this was installed in observation well OW78-1-3 (R1). The collector well, observation wells and the river were monitored using a direct-read electronic water level meter during this test.

The City's permanent well pumps and in-line flow meters were used for the Well No. 46 and Well No. 47 performance testing. During the testing of the wells, the discharge water was conveyed to the City's treatment plant through the normal raw water piping system. Changes in

the raw water system pressure caused some fluctuations in the well pumping rates during the testing. The line pressure indicated by the gages on the discharge lines just downstream of the control valves in the well houses were recorded along with the pumping rate records.

To determine adequacy of development, a centrifugal sand-separating device manufactured by the Roscoe Moss Company was used to measure sand production from the collector wells during the performance testing. The sand sampler was attached to the top of the well discharge pipe just ahead of the in-line flow meters. To conduct the sand tests, a flow of 0.5 gpm was allowed to pass through the sampler, and the amount of sand collected in the sample tube was observed after a minimum of 5 minutes had elapsed. Samples were collected at intervals of about 1 hour, 24 hours, 48 hours and 72 hours after the start of the constant-rate pumping test. The standard for sand production was specified to be less than 2 parts per million (ppm) during test pumping of the collector well.

After the pumping level in the collector well being tested had substantially stabilized during the constant rate test, the relative flow (velocity) and temperature from each lateral were measured. This was accomplished by a diver using remote measuring equipment. Additionally, color photographs of the valves and laterals were taken by the diver, and copies of the photographs from Well No. 46 are included in Appendix C and from Well No. 47 are included in Appendix F.

4.2 MULTIPLE-RATE STEP PUMPING TEST PROCEDURES

4.2.1 Well No. 46 Step Test

A multiple-rate step test was conducted in Well No. 46 on January 11, 2006. However, during the constant-rate test, it was discovered that the valves on the laterals were nearly closed, and so consequently the results of the first step test are not considered representative of the well's performance. The lateral valves were opened fully during the constant-rate test, and a second multiple-rate step test for Well No. 46 was conducted on January 16, 2006. The eight (8) hour multiple-rate test was conducted in two-hour steps at increasing rates of discharge. Based on average rates determined from the in-line flow meter totalizer, the pumping rates for the four steps were as listed below:

- Step 1 – 800 gpm
- Step 2 – 1,000 gpm
- Step 3 – 1,200 gpm
- Step 4 – 1,830 gpm

Pumping rates were controlled using the valve on the discharge line just downstream of the in-line flow meter. The pumping rates were adjusted as quickly as possible at the start of each step.

Pumping was started at 8:00 AM and continued until 4:10 PM. Before, during and following the multiple-rate test, water levels and flow rates were measured at the pertinent frequencies in Well No. 46 and the adjacent observation wells.

4.2.2 Well No. 47 Step Test

The Well No.47 multiple-rate step test was conducted on October 31, 2005. The eight (8) hour multiple-rate test was conducted in two-hour steps at increasing rates of discharge. Based on average rates determined from the in-line flow meter totalizer, the pumping rates for the four steps were as listed below:

- Step 1 – 290 gpm
- Step 2 – 570 gpm
- Step 3 – 930 gpm
- Step 4 – 1220 gpm

Pumping rates were controlled using the valve on the discharge line to the north of the Well No. 47 caisson. The pumping rates were adjusted as quickly as possible at the start of each step.

Pumping was started at 11:55 AM and continued until 7:59 PM. Before, during and following the multiple-rate test, water levels and flow rates were measured at pertinent frequencies in Well No. 47. Water levels were measured in the collector well, the adjacent observation wells, and the Big Sioux River with an electronic water level meter. Water levels in observation well OW78-1-3 (R1) were also monitored with a computerized data acquisition unit and transducer (In-Situ Troll unit).

Following the end of the pumping period for the multiple-rate test, water levels in the collector well were allowed to recover for approximately 15 hours. At this time the water level in the Well No. 47 caisson had recovered to within 0.2 feet of the previous day's static water level and was showing negligible changes (rise of 0.04 feet over 3 hours).

4.3 CONSTANT-RATE TEST PROCEDURES

4.3.1 Well No. 46 Constant-Rate Test

Following the recovery from the initial multiple-rate step test, the constant-rate test was started at 9:50 AM on January 12, 2006 and run for 71.5 hours until 9:30 on January 15, 2006. Based on the initial step-test results, it was determined that the well should be capable of sustained pumping at the maximum rate that the pump was capable of. The constant-rate test was run with the control valve on the discharge line in the partially closed to allow for adjustment in case the line-pressure changed.

On January 13, 2006, a diver entered the well to conduct the lateral flow analysis. Upon entering the well, the diver indicated that the valves on Laterals 1 and 2 were nearly shut, and the valve on Lateral 3 was completely closed. At this point, the valves were opened and the test was continued. Prior to opening the lateral valves, the average discharge from the collector well based on the totalizer readings was 1,510 gpm (2.17 MGD). After the lateral valves were opened, the pumping rate based on the totalizer readings averaged 1,590 gpm (2.29 MGD).

During the constant-rate test, water levels and flow rates were measured at pertinent intervals. At the conclusion of the test, the pump was shut off and the recovery of water levels monitored for 24 hours. Water level data and pumping rate data collected during the constant-rate period are included in Appendices B and C.

Approximately twenty-four (24) hours after the start of the constant-rate pumping period, a qualified diver performed a lateral flow analyses. As previously indicated, the diver discovered that two of the lateral valves were nearly shut and one was completely shut. The flow analysis was performed shortly after the valves were fully opened. To ensure that opening the valves did not affect the flow analysis results, the flow analysis was repeated approximately 1-1/2 hours

after the initial measurements. The flow velocity and temperature at the caisson end of each lateral were measured by the diver using a handheld meters, which were remotely read by the CWI hydrogeologist. The flow velocity measurements and the total pumping rate from the collector were used to determine the flow rate and percent of total flow from each lateral and the relative efficiency expressed as gallons per minute per foot of screen. Although not required, the diver also attempted to photograph the lateral valves, but the camera malfunctioned and no photographs were taken inside the caisson.

4.3.2 Well No. 47 Constant-Rate Test

Following the recovery from the multiple-rate step test, the constant-rate test was started at 10:59 AM on November 1, 2005 and run for 72 hours until 11:00 AM on November 4, 2005. Based on the step-test results, it was determined that the well should be capable of sustained pumping at the maximum rate that the pump was capable of. Consequently, the constant-rate test was run with the control valve on the discharge line in the full open position. The average discharge from the collector well based on the totalizer readings for the 72-hour period was 1245 gpm (1.79 MGD) during the test. The flow rates based on individual totalizer readings ranged from about 1210 to 1280 gpm. The fluctuations in the pumping rate were due to fluctuations in the discharge line system pressure.

During the constant-rate test, water levels and flow rates were measured at pertinent intervals. At the conclusion of the test, the pump was shut off and the recovery of water levels monitored for 24 hours. Before, during and following the multiple-rate test, water levels and flow rates were measured at pertinent frequencies in Well No. 47. Water levels were measured in the collector well, the adjacent observation wells, and the Big Sioux River with an electronic water level meter. Water levels in the collector well, the observation wells and the river were also monitored with a computerized data acquisition units and transducers (In-Situ Troll units).

Approximately forty-seven (47) hours after the start of the constant-rate pumping period, a qualified diver performed a lateral flow analyses and took underwater pictures of the laterals and lower portion of the caisson. The flow velocity and temperature at the caisson end of each lateral were measured by the diver using a handheld meters, which were remotely read by the CWI

hydrogeologist. The flow velocity measurements and the total pumping rate from the collector were used to determine the flow rate and percent of total flow from each lateral and the relative efficiency expressed as gallons per minute per foot of screen. The diver also took still photographs of the caisson ends of the laterals and lateral valves. These photographs are presented in Appendix E.

5.0 WELL NO. 46 POST MAINTENANCE TESTING RESULTS

The results of the post-maintenance performance testing were compiled and analyzed to evaluate the effectiveness of the rehabilitation and to evaluate the condition of the collector wells. Factors that are used to evaluate well performance and efficiency include specific capacity and drawdown differential. Specific capacity is the ratio of pumping rate of a well to the observed drawdown in the well and is expressed as gallons per minute per foot of drawdown (gpm/ft). The higher the specific capacity, the more productive the well is. Drawdown differential is the difference between the water level in a pumping well and the water level in the aquifer measured in a nearby observation well. It is expressed as feet of drawdown per unit rate of water pumped, e.g., feet per 1,000 gpm (ft/1000 gpm) for the collector well. The more efficient the well, the lower the differential value.

5.1 WELL NO. 46 MULTIPLE-RATE STEP TEST RESULTS

A summary of observed water levels and drawdowns in Well No. 46 during the step test conducted on January 16, 2006 are listed in Table 3. Hydrographs showing the water levels in Well No. 46 and the adjacent observation wells OW78-2-2 and OW78-2-4 during the step test are shown in Figure 6. Semi-log plots of the observed drawdown with respect to time for the step test are presented in Figure 7.

The water level in Well No. 46 prior to the start of the step test was slightly more than 15 feet below the pump house floor. The approximate water level elevation in the collector caisson prior to the start of the step test was 1426.0 feet, msl. Pumping for approximately 2 hours at a rate of 800 gpm resulted in an observed drawdown of 2.3 feet for an observed specific capacity of 349 gpm/ft. The observed drawdown at the end of the second step was 3.0 feet when pumping at 1000 gpm, and the observed drawdown at the end of the third step was 3.6 feet when pumping at 1200 gpm. The observed drawdown at the end of the fourth step was 5.5 feet when pumping at 1830 gpm, resulting in an observed specific capacity of the collector well 335 gpm/ft.

Analysis of the multiple-rate testing was performed using the Bruin and Hudson (1955) method. This is a graphical method used to determine the head losses attributed to laminar flow in the aquifer and turbulent flow into the well. These head losses are related to the equation:

$$s = (B \times Q) + (C \times Q^2)$$

Where: s = drawdown in the pumping well in feet
 B = the aquifer constant (laminar flow) in feet/gpm
 C = the well loss constant (turbulent flow) in feet/gpm²
 Q = the pumping rate in gpm

The Bruin and Hudson method is used to estimate the head losses in the aquifer and in the well itself. As shown in Table 3, laminar flow through the aquifer represents greater than 93% of the head loss at all pumping rates during the step drawdown test. As determined from this analysis, the "B" factor was computed to be 0.0028 ft/gpm and the "C" factor was calculated at 1.3×10^{-7} feet/gpm². These results indicate that Well No. 46 is very efficient in delivering the available water.

5.2 WELL NO. 46 CONSTANT-RATE TEST RESULTS

Table 4 summarizes the observed water levels and water level changes during the Well No. 46 constant-rate test. Hydrographs during the constant-rate testing period are presented in Figure 8. A semi-logarithmic plot of the observed drawdown values with respect to elapsed pumping time is depicted in Figure 9.

During the initial step test run on January 11, 2006 with the lateral valves nearly closed, the maximum pumping rate that could be achieved was slightly more than 1600 gpm. To allow for some adjustment of the pumping rate in case discharge line pressure fluctuated, the valve on the discharge line was partially closed prior to the start of the constant-rate test. When the constant-rate test was started, the Well No. 46 pumping rate was slightly more than 1500 gpm. Once the lateral valves were opened, the reduction in drawdown in the caisson caused a slight increase in the pumping rate. The average pumping rate for the last 48-hours of the constant-rate test based on the totalizer readings was 1590 gpm (2.29 MGD). As listed in Table 4, the observed drawdown in the collector well the end of the pumping period was about 5.8 feet. The water temperature discharged from the caisson averaged 57° F during the testing period. The observed drawdown in the observation well OW78-2-2 (the south observation well) at the end of the pumping period was 3.2 feet. As shown on the figures, the water levels in Well No. 46 and the adjacent observation well were still declining at the end of the constant-rate pumping period and

had not completely stabilized. During the pumping period, the Big Sioux River water level adjacent to Well No. 46 fluctuated between elevations of approximately 1426.3 and 1426.4 feet, and was approximately 0.07 feet lower at the end of the pumping period than it was at the beginning of the pumping period.

The observed specific capacity at the end of the constant-rate pumping test was 275 gpm/ft based on the average pumping rate of 1590 gpm. Because the drawdown in the collector did not stabilize, the specific capacity value would decrease with increased pumping time. Operating records for Well No. 46, which are depicted in Figure 14, indicate the specific capacity in Well No. 46 was approximately 60 gpm/ft at the end of 2004. This indicates that the rehabilitation of Well No. 46 has made a substantial improvement in the well performance.

The observed drawdown differential at the end of the Well No. 46 constant-rate test based on the water level in OW78-2-2 was 1.65 ft/1000 gpm. This is a relatively low value for drawdown differential given the distance between the observation well and the laterals. The relatively small difference of the water elevation in the Well No. 46 collector caisson and the water elevation in the Observation Well is another indication that the collector well is performing efficiently.

The results of the lateral flow analysis conducted during the Well No. 46 constant-rate test are presented in Table 5. As discussed in Section 4.3.1, the lateral flows and water temperatures were measured more than once following the opening of the valves on the laterals to ensure that this did not influence the results. The results presented in Table 5 are from the last set of flow and temperature measurements, although there was little difference between this set of measurements and the first set flow measurements. The lateral flow analysis conducted during the test indicated that the flow in the laterals ranged from 28% to 38% of the total. Lateral No. 1, which is projected to the south approximately parallel to the riverbank, showed the lowest flow rate. Lateral No. 3, which is projected to the northwest toward the river, showed the highest flow rate. The water temperature from the individual laterals ranged from 55.7° from Lateral No. 1 to 58.7° from Lateral No. 2.

The results of the Well No. 46 post-maintenance sand testing are summarized in Table 6. The sand tester was attached to the discharge line in the Well No. 46 pump house, and the sand samples were collected during the step test and at intervals of about 1 hour, 24 hours, 48 hours and 72 hours after the start of the constant-rate pumping test and during the second multiple-rate step test. None of the sand test results from the constant-rate and second step test exceeded 0.5 ppm, and consequently all were within the sand specification of 2 ppm. The sand readings during the constant-rate test decreased following the opening of the lateral valves, and the somewhat elevated readings that preceded the opening of the lateral valves may have been caused by turbulent water flow at the lateral valves when they were nearly closed.

6.0 WELL NO. 47 POST MAINTENANCE TESTING RESULTS

The results of the post-maintenance performance testing were compiled and analyzed to evaluate the effectiveness of the cleaning and redevelopment and to evaluate the condition of the collector well.

6.1 WELL NO. 47 MULTIPLE-RATE STEP TEST RESULTS

A summary of observed water levels and drawdowns in Well No. 47 during the step test are listed in Table 7. Hydrographs showing the water levels in Well No. 47, the adjacent observation wells and the Big Sioux River during the step test are shown in Figure 10. Semi-log plots of the observed drawdown with respect to time for the step test are presented in Figure 11.

The water level in Well No. 47 prior to the start of the step test was slightly less than 16 feet below the pump house floor. The approximate water level elevation in the collector caisson prior to the start of the step test was 1426.4 feet, msl. Pumping for approximately 2 hours at a rate of 290 gpm resulted in an observed drawdown of 1.0 foot for an observed specific capacity of 276 gpm/ft. The observed drawdown at the end of the second step was 2.0 feet when pumping at 570 gpm, and the observed drawdown at the end of the third step was 3.4 feet when pumping at 930 gpm. The observed drawdown at the end of the fourth step was 4.8 feet when pumping at 1220 gpm, resulting in an observed specific capacity of the collector well 253 gpm/ft at the end of the last step.

Analysis of the multiple-rate testing was performed using the Bruin and Hudson (1955) method. As shown in Table 7, laminar flow through the aquifer represents greater than 91% of the head loss at all pumping rates during the step drawdown test. As determined from this analysis, the "B" factor was computed to be 0.003 ft/gpm and the "C" factor was calculated at 2.3×10^{-7} feet/gpm². These results indicate that Well No. 47 is very efficient in delivering the available water.

The step-test results also indicated that Well No. 47 was capable of pumping for sustained periods in excess of 1200 gpm. Consequently, it was decided to conduct the constant-rate test at

the maximum rate that the permanent pump could produce under the conditions of static water level and discharge line pressure.

6.2 WELL NO. 47 CONSTANT-RATE TEST RESULTS

Table 8 summarizes the observed water levels and water level changes during the constant-rate test. Hydrographs depicting the water levels in Well No. 47, the adjacent observation wells and the river are presented in Figure 12. A semi-logarithmic plot of the observed drawdown values with respect to elapsed pumping time is depicted in Figure 13.

The average pumping rate over the 72-hour pumping period based on the totalizer readings was 1245 gpm (1.79 MGD). As listed in Table 8, the observed drawdown in the collector well the end of the pumping period was about 7.0 feet. The temperature of the water discharged from the caisson was about 53° F at the end of testing period. The observed drawdown in observation well OW78-1-3 (R1) at the end of the pumping period was 5.1 feet. As shown on the figures, the water levels in Well No. 47 and the observation wells were still declining at the end of the constant-rate pumping period and had not completely stabilized. During the pumping period, the Big Sioux River water level showed a slight decreasing trend with a net drop of 0.12 feet over the pumping period.

The observed specific capacity at the end of the constant-rate pumping test was 178 gpm/ft based on the average pumping rate of 1245 gpm. Because the drawdown in the collector did not stabilize, the specific capacity value would decrease with increased pumping time. Data from performance testing of Well No. 47 that was conducted in 1981 indicates that the observed specific capacity after 72 hours of pumping at 800 gpm was approximately 92 gpm/ft, although there is limited information available about the conditions at the time of the testing. Operation data provided by the City for Well No. 47, depicted in Figure 15, indicates that the average apparent specific capacity in 2005 prior to maintenance was about 20 gpm/ft. The apparent specific capacity values from the operational data generally do not exceed 120 gpm/ft even for periods that followed cleaning of the laterals. Based on the operation data from Well No. 47, it is obvious that there has been a substantial improvement in the well performance, and the well may be performing better now than it did when it was originally installed.

The observed drawdown differential at the end of the Well No. 47 constant-rate test was 1.54 ft/1000 gpm at the closest observation well OW78-1-3 (R1). This is a relatively low value for drawdown differential. The relatively small difference of the water elevation in the Well No. 47 collector caisson and the water elevation in the Observation Well is another indication that the collector well is performing efficiently.

The results of the lateral flow analysis conducted during the Well No. 47 constant-rate test are presented in Table 9. The lateral flow analysis conducted during the test indicated that the flow in the laterals ranged from 11% to 44% of the total. Lateral No. 3, the shortest of the new laterals showed the lowest flow rate. Lateral No. 4, which is projected directly toward and extends underneath the river, had the highest flow rate. Lateral No. 1, although the longest, was producing about 16% of the total flow. The lower flow from Lateral No. 1 is likely because it is projected directly away from the river and consequently is farthest from the source of recharge. The water temperature from the individual laterals ranged from 50.9° from Lateral No. 4 to 55.9° from Lateral No. 3.

The results of the Well No. 47 post-maintenance sand testing are summarized in Table 10. The sand tester was attached to the discharge line in the Well No. 47 pump house, and the sand samples were collected during the constant-rate test at intervals of about 1 hour, 24 hours, 48 hours and 72 hours after the start of the constant-rate pumping. None of the sand test results exceeded 0.5 ppm, and consequently all were within the sand specification of 2 ppm.

7.0 COLLECTOR WELL YIELD PROJECTIONS

The yield from the collector well is dependent upon its efficiency, available drawdown and aquifer hydraulics. Available drawdown at Well No. 46 and Well No. 47 is directly related to the stage of the Big Sioux River. Aquifer hydraulics are related to saturated thickness, hydraulic conductivity and recharge. The hydraulic conductivity is affected by changing temperatures as the viscosity of water is inversely proportional to temperature. In other words, when the water is colder, the water is more viscous and the effective hydraulic conductivity of the aquifer is lower.

7.1 WELL NO. 46 YIELD PROJECTIONS

Because the water levels in Well No. 46 did not completely stabilize by the end of the constant-rate testing period, it is necessary to estimate the stabilized drawdown in order to estimate the collector well yields under conditions that vary from the testing conditions.

The estimated time to reach equilibrium pumping conditions can be determined using the following equation (Walton, 1970):

$$t_e = \frac{65.2 \ a^2 \ S}{T \ \log (2a/r)^2}$$

Where t_e = time required to reach equilibrium, in days
 a = effective distance to line source of recharge, in feet
 S = storativity, unitless
 T = transmissivity, in gpd/ft
 r = distance at which equilibrium conditions are reached, in feet

To estimate the time to equilibrium the following assumptions were made based upon interpretation of data obtained from the initial hydrogeological investigation report of the collector well sites (Klaer & Associates, 1979). The values used to compute the time to reach equilibrium at Well No. 46 were as follows:

a = 500 feet
 S = 0.15
 T = 65,500 gpd/ft (adjusted for water temperature)
 r = 94 feet (estimated effective radius of collector,
80% of average lateral length)

Using the above equation and assumptions, it was estimated that equilibrium conditions would have been reached in 18.1 days after the start of pumping. Projecting the trend of the drawdown

versus time relation at the end of the constant-rate test pumping period to 18.1 days indicates that this would have resulted in an additional 1.2 feet of drawdown. This would give a total of 7.0 feet of drawdown under the test conditions and an estimated specific capacity of about 230 gpm/ft.

The following equation can be used to estimate the yield of a well under conditions that vary from the test conditions:

$$Q_2 = \frac{Q_1 \times m_2 \times s_2 \times v_1}{m_1 \times s_1 \times v_2}$$

Where: Q = yield (gpm) of collector well under test (Q₁) and design (Q₂) conditions;
s = drawdown (ft) in collector well under test (s₁) and design (s₂) conditions;
m = aquifer thickness (ft) corrected for dewatering under test (m₁) and design (m₂) conditions; and
v = viscosity coefficient under test (v₁) and design (v₂) temperature conditions.

Substituting the observed data from the performance test (test conditions) into the above equation and using the information presented below, it is possible to estimate the maximum yield of the collector well for the test conditions average conditions and low temperature, low water level conditions.

Yield conditions

Top of aquifer	1419 feet msl
Base of aquifer	1396 feet msl
Static Water Level	
test conditions	1426.3 feet msl
design conditions, low river level	1418.2 feet msl
design conditions, average river level	1425.0 feet msl

Pumping level

test conditions projected to equilibrium (1590 gpm)	1419.3 feet msl
recommended minimum pumping level	1403.0 feet msl

Water temperature / viscosity coefficient

test conditions	57 °F / 1.04
average conditions	55 °F / 0.93
low temperature conditions	45 °F / 1.26

Using the above equation and assumptions, the potential stabilized collector yield would be approximately 3440 gpm (4.95 MGD) under the test conditions, 3130 gpm (4.50 MGD) under average conditions and 1800 gpm (2.59 MGD) under the combination of low water levels and low water temperatures. Consequently, Well No. 46 should be capable of operating in excess of the original design capacity of 1800 gpm (2.59 MGD) under most conditions. Actual drawdown values in the collector will vary from the projected values with changes pumping rates and pumping patterns, static water level changes and changes in recharge conditions. Drawdown in the collector for a given pumping rate and pumping time will tend to increase as plugging of the well screen and adjacent aquifer occurs due to mineral and/or bacterial encrustation.

7.2 WELL NO. 47 YIELD PROJECTIONS

As with Well No. 46, the water levels in Well No. 47 during the constant-rate test did not completely stabilize. To estimate the time to equilibrium with the equation given in Section 7.1 the following assumptions were made based upon interpretation of data obtained from the initial hydrogeological investigation report of the collector well sites (Klaer & Associates, 1979). The values used to compute the time to reach equilibrium at Well No. 46 were as follows:

- a = 500 feet
- S = 0.15
- T = 63,600 gpd/ft (adjusted for water temperature)
- r = 74 feet (estimated effective radius of collector,
80% of average lateral length)

Using the above equation and assumptions, it was estimated that equilibrium conditions would have been reached in 17 days after the start of pumping. Projecting the trend of the drawdown versus time relation at the end of the constant-rate test pumping period to 17 days indicates that this would have resulted in an additional 0.9 feet of drawdown. This would give a total of 8.0 feet of drawdown under the test conditions and an estimated specific capacity of about 160 gpm/ft.

Using the equation given in Section 7.1 to estimate well yields under conditions that vary from the test conditions, the assumptions used to project the yields for Well No. 47 are as follows:

Yield conditions

Top of aquifer	1422 feet msl
Base of aquifer	1400 feet msl
Static Water Level	
test conditions	1426.3 feet msl
design conditions, low river level	1420.2 feet msl
design conditions, average river level	1427.0 feet msl

Pumping level

test conditions projected to equilibrium (gpm)	1418.3 feet msl
recommended minimum pumping level	1410.1 feet msl

Water temperature / viscosity coefficient

test conditions	53° F / 1.04
design, average conditions	55° F / 0.93
design, low temperature conditions	45° F / 1.26

Using the equation given in Section 7.1 and assumptions given above, the potential stabilized yield of Well No. 47 would be approximately 2010 gpm (2.89 MGD) under the test conditions, 2150 gpm (3.10 MGD) under average conditions, but only about 1040 gpm (1.50 MGD) under the combination of low water levels and low water temperatures. Consequently, Well No. 47 should be capable of operating in excess of the original design capacity of 1670 gpm (2.40 MGD) under most conditions but may not be capable of operating at this capacity under the combined conditions of low static levels and low water temperature.

8.0 SUMMARY

Collector Wells International, Inc. completed the rehabilitation of the City of Sioux Falls Collector Well No. 46 and Collector Well No. 47. The rehabilitation of the collector wells was accomplished during the period from August 2005 through January 2006. The rehabilitation included sealing the existing laterals, cleaning debris from the caisson, installation of new ports in the caisson walls, installation and development of new laterals and performance testing of the wells.

In Well No. 46, the three (3) new 12-inch diameter laterals have a lengths of 107 to 127 feet with each having 7 feet of blank pipe adjacent to the caisson wall. In Well No. 47, the four (4) new 12-inch diameter laterals have lengths ranging from 67 to 117 feet with each having 7 feet of blank pipe adjacent to the caisson wall.

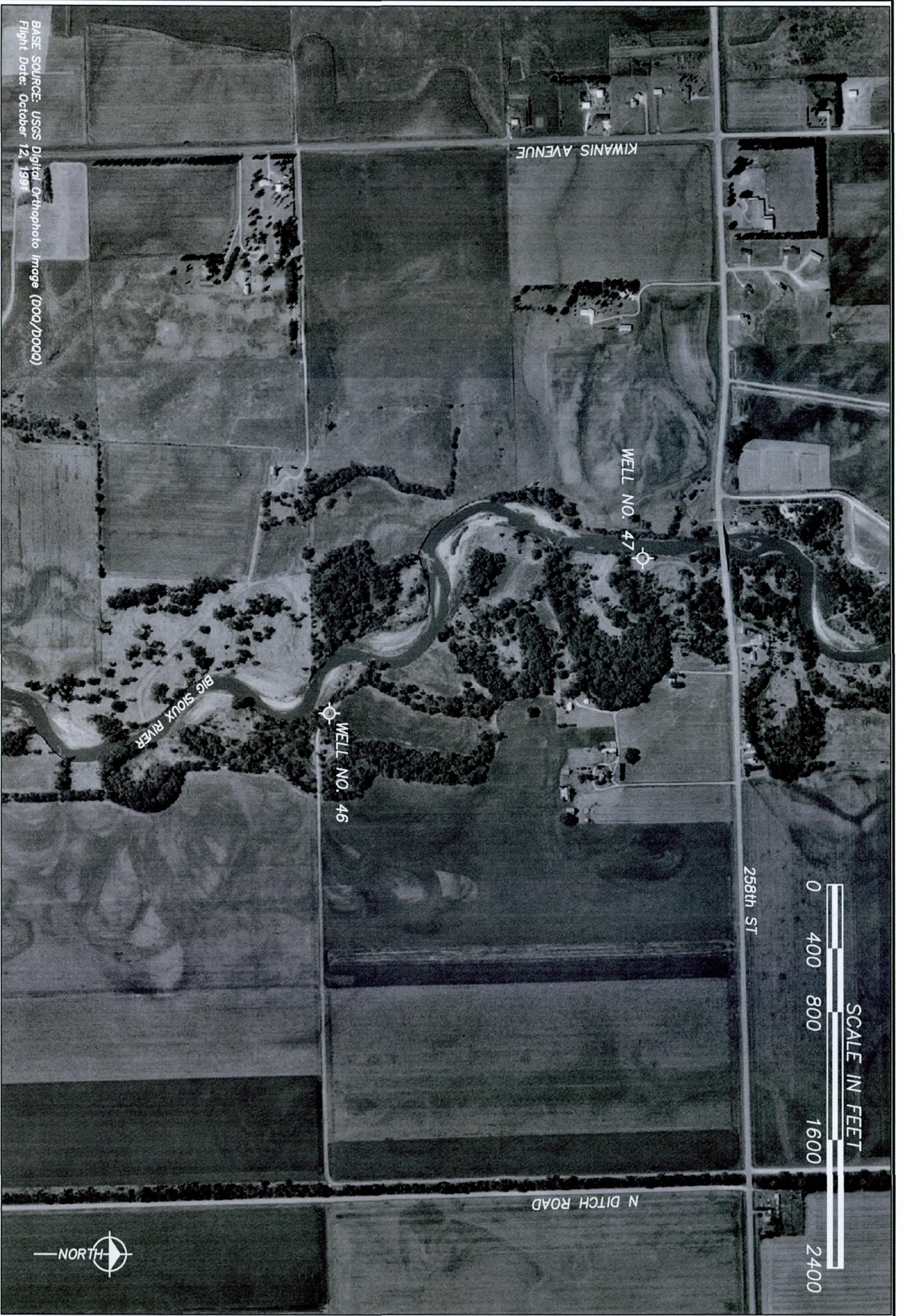
The testing results indicate that the rehabilitation efforts were successful in both Well No. 46 and Well No. 47. The observed specific capacity of Well No. 46 at the end of the post-maintenance constant-rate test was 275 gpm/ft based on the average pumping rate of 1590 gpm. In its current conditions, the Well No. 46 should be capable of pumping for extended periods at the design rate of 1800 gpm (2.59 MGD) with the pumping water levels above the minimum recommended elevation (5 feet above the centerline of the laterals) of 1403.2 feet. The observed specific capacity of Well No. 47 at the end of the post-maintenance constant-rate test was 178 gpm/ft based on the average pumping rate of 1245 gpm. In its current conditions, the Well No. 47 should be capable of pumping for extended periods at the design rate of 1630 gpm (2.40 MGD) with the pumping water levels above the minimum recommended elevation (5 feet above the centerline of the laterals) of 1410.1 feet. However, Well No. 47 might not be capable of pumping at this rate under conditions of low static level and low water temperature.

Routine monitoring of both collector wells is recommended to determine the point at which additional maintenance will be needed. At a minimum, this monitoring should include measurements of the static and pumping water levels in the caisson, pumping rate, and water levels in at least one of the observation wells at each site (preferably the observation well closest to the caisson). Measurements from the observation wells help distinguish between pumping

water level changes that are due to changes in well efficiency and those that are due to changes in aquifer conditions. These measurements should be made at least every other month. Ideally, the collector well monitoring should be done at a time when the well has been running long enough for the pumping level to become relatively stable.

9.0 REFERENCES

- Bruin, J. and H. E. Hudson, Jr., 1955.** Selected Methods for Pump Test Analysis, Illinois State Water Survey, Report of Investigations, No. 25.
- Driscoll, F. G., 1986.** *Groundwater and Wells, 2nd Edition.* Johnson Division, St. Paul, MN.
- Howard R. Green Company, 2005.** Rehabilitation of Collector Wells 46 and 47 in the City of Sioux Falls, South Dakota - Bid Request No. 05-1063, Bid Request Documents Prepared by the Howard R. Green Company, Sioux Falls South Dakota.
- Fred H. Klaer, Jr. & Associates, February 1979.** Hydrogeological Survey for Proposed Wells No. 46 and 47 Sioux Falls, South Dakota, Report Prepared by Fred H. Klaer, Jr. & Associates, Consulting Hydrogeologists, Prepared for Ground Water Associates, Inc., Westerville, Ohio.
- Walton, W. C., 1970.** *Ground Water Resource Evaluation,* McGraw Hill Book Company, New York, NY.



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PROJECT LOCATION MAP
 COLLECTOR WELLS 46 AND 47 REHABILITATION
 SIOUX FALLS, SOUTH DAKOTA

PROJECT NUMBER
 105-270

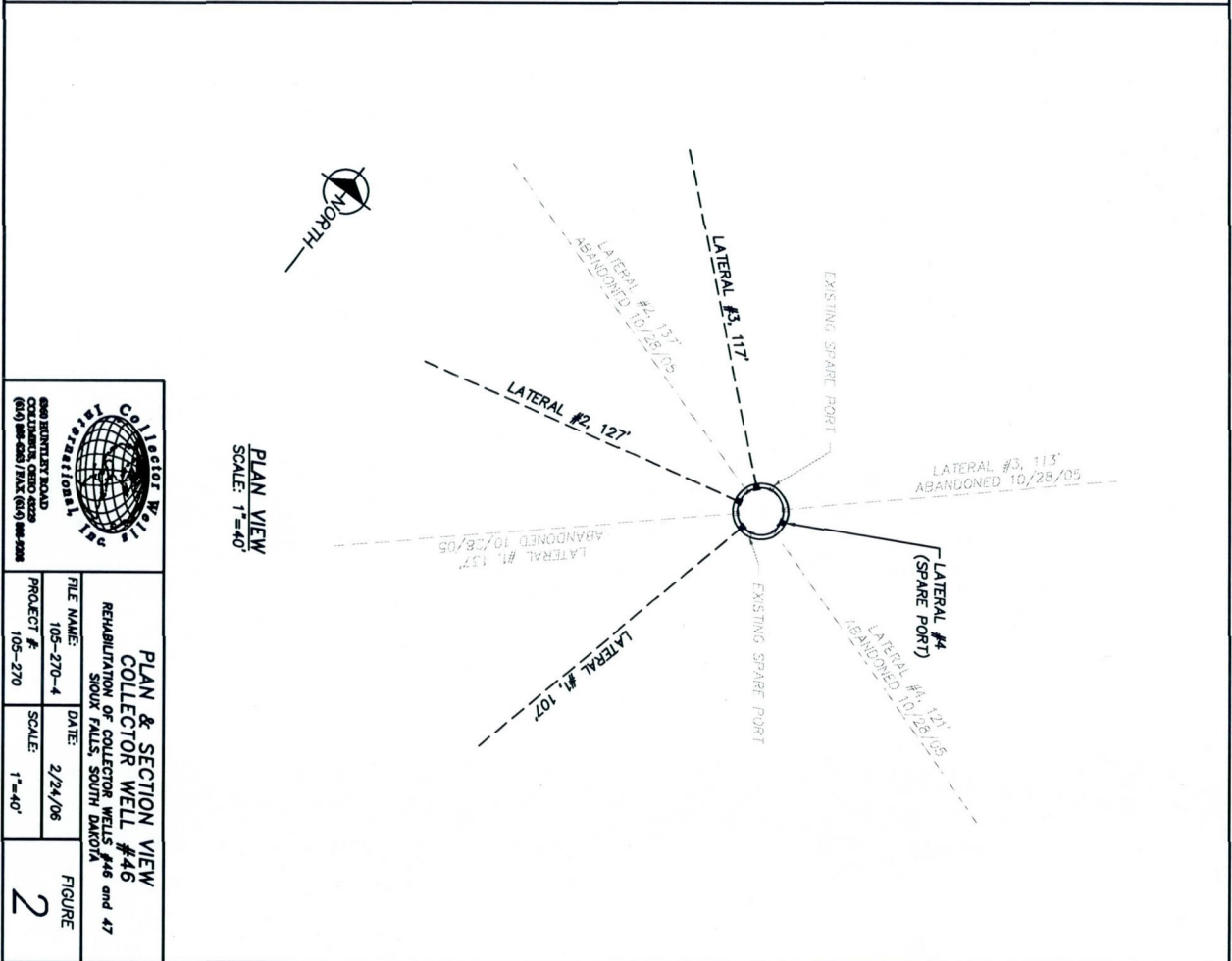
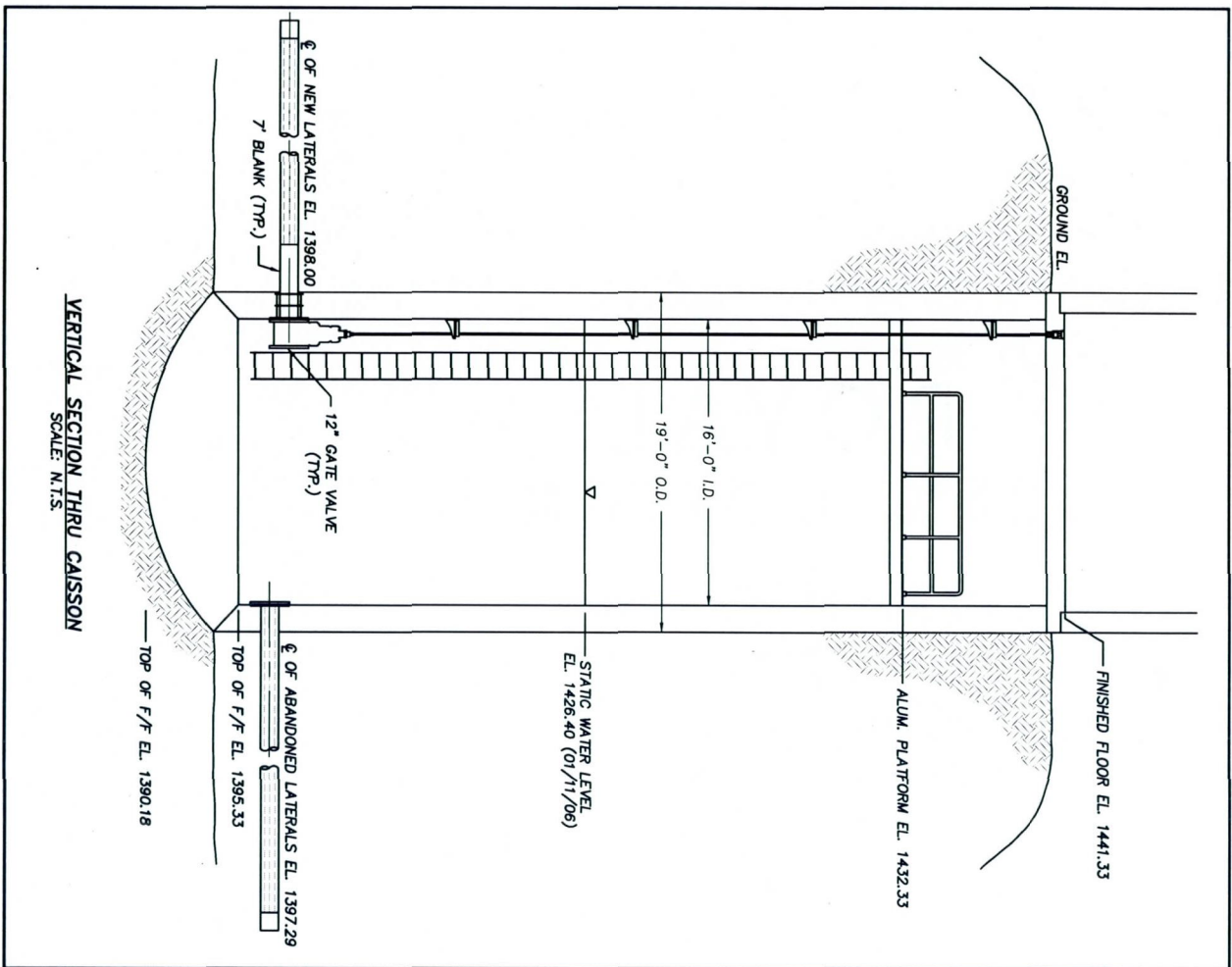
DATE
 2/28/06

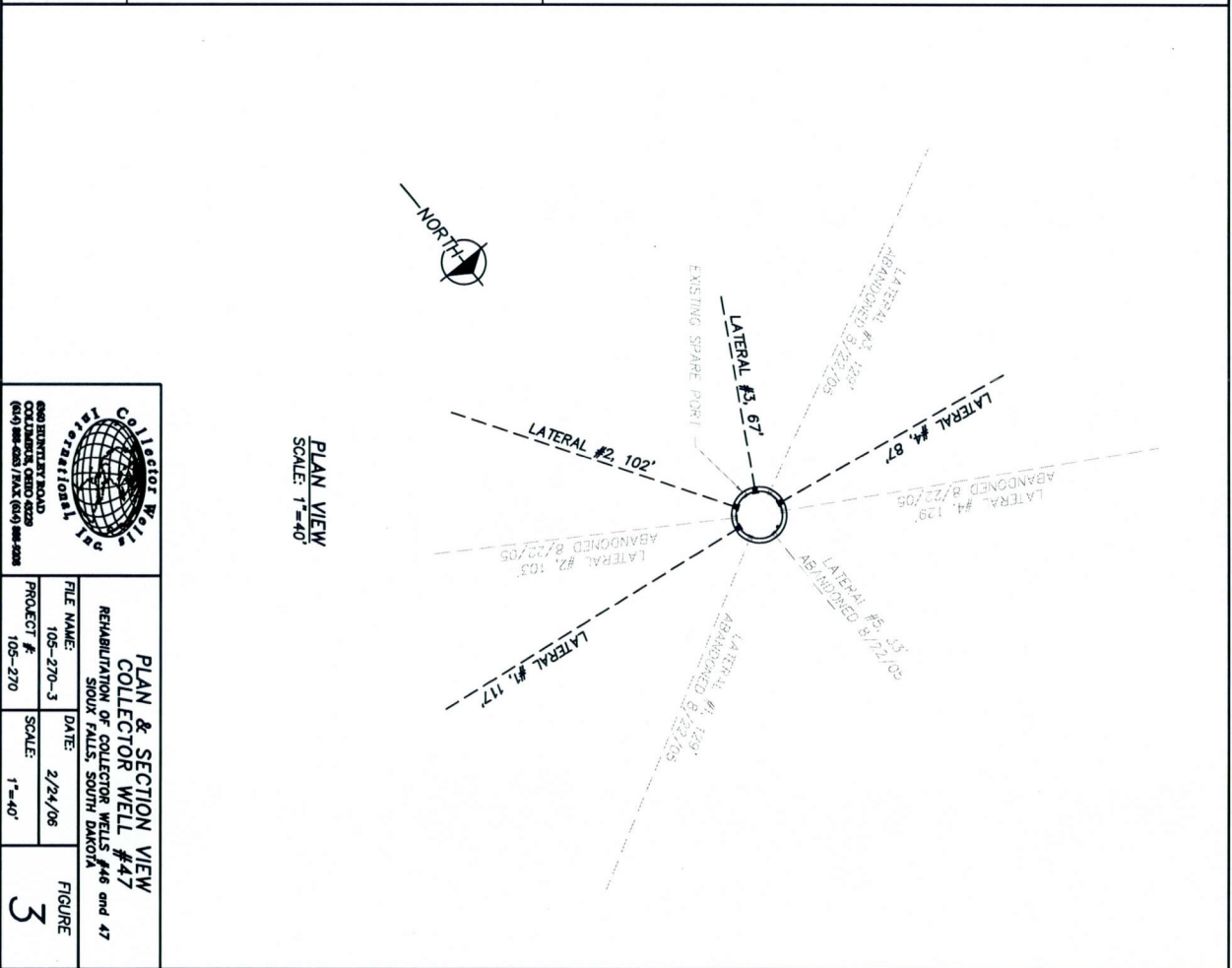
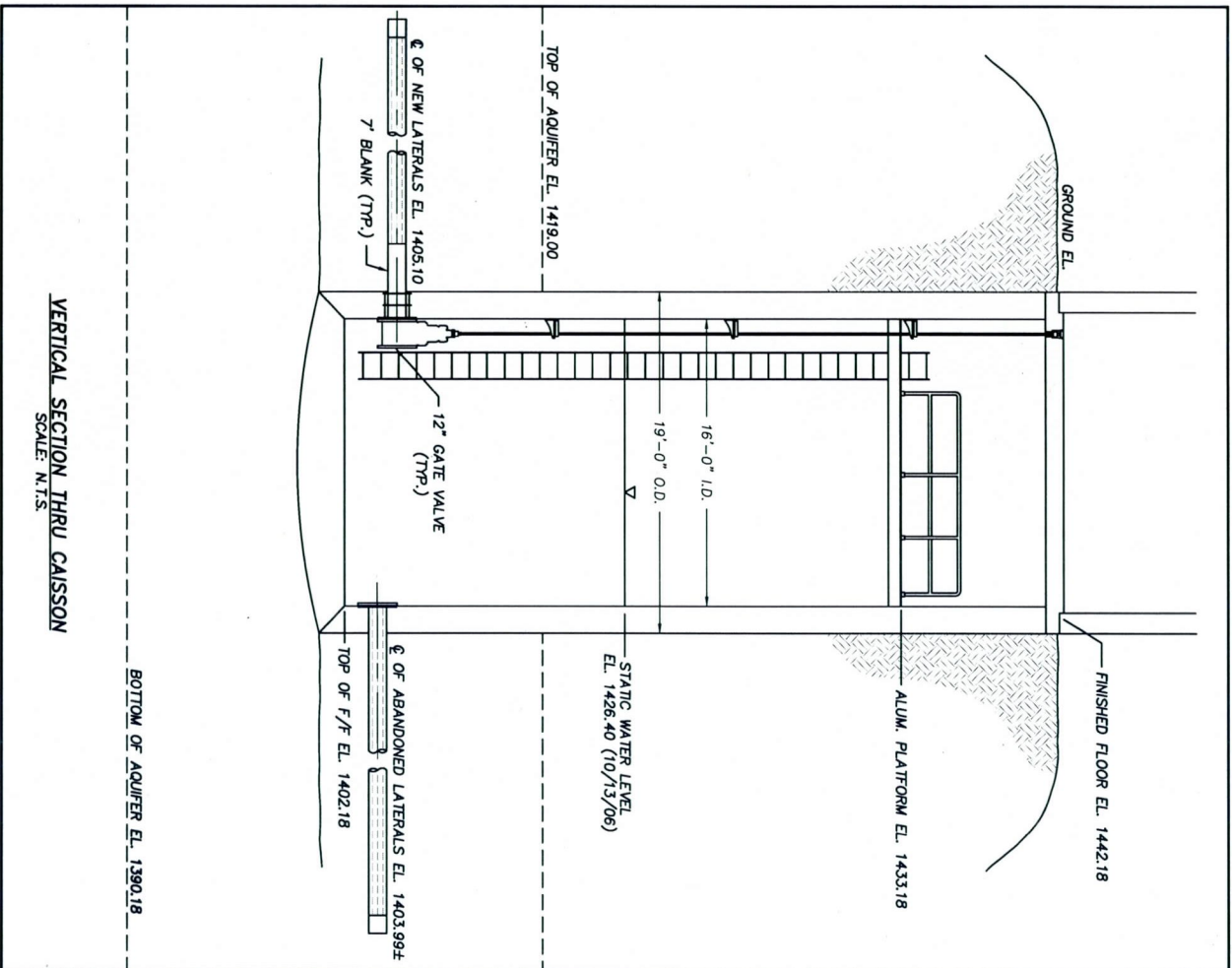
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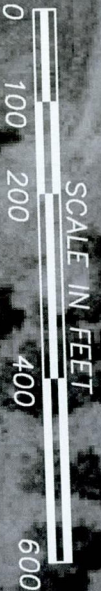
SCALE
 1" = 800'

FIGURE

1







BASE SOURCE: USGS Digital Orthophoto Image (DOQ/D0000)
Flight Date: October 12, 1991



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WELL NO. 46 WELL LOCATION MAP

COLLECTOR WELLS 46 AND 47 REHABILITATION
SIOUX FALLS, SOUTH DAKOTA

PROJECT NUMBER	DATE	FILE NAME	SCALE
105-270	2/28/06	105-270-07	1" = 200'



BASE SOURCE: USGS Digital Orthophoto Image (D00/D000)
Flight Date: October 12, 1991

SCALE IN FEET
0 100 200 400 600



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WELL NO. 47 WELL LOCATION MAP
COLLECTOR WELLS 46 AND 47 REHABILITATION
SIOUX FALLS, SOUTH DAKOTA

PROJECT NUMBER
105-270

DATE
2/28/06

FILE NAME
105-270-06

SCALE
1" = 200'

FIGURE

5

FIGURE 6
Well No. 46 Post-Maintenance Multiple-Rate Step Test Hydrographs
Sioux Falls, South Dakota

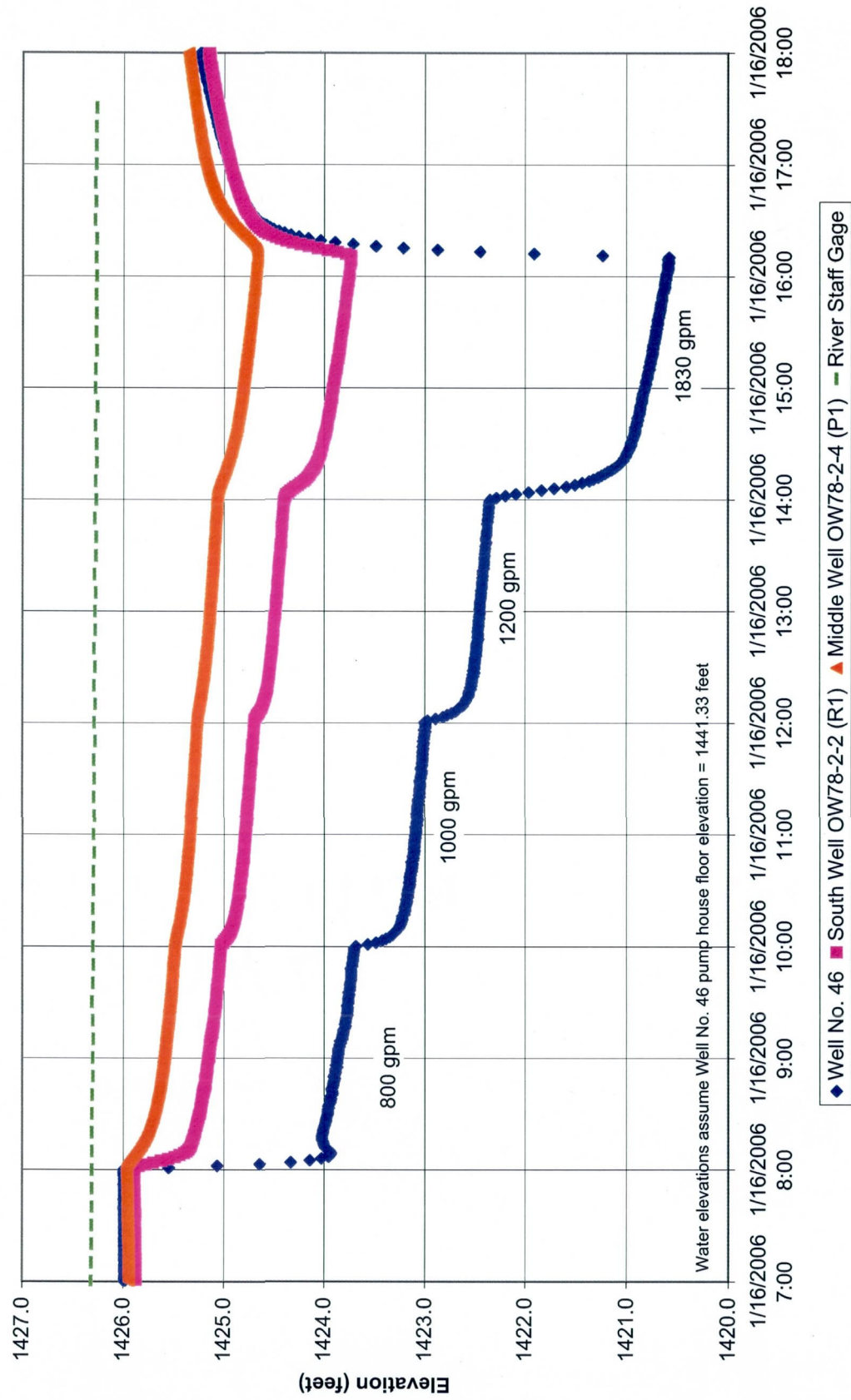


FIGURE 7
Well No. 46 Post-Maintenance Multiple-Rate Step Test Drawdown Versus Time Plots
Sioux Falls, South Dakota

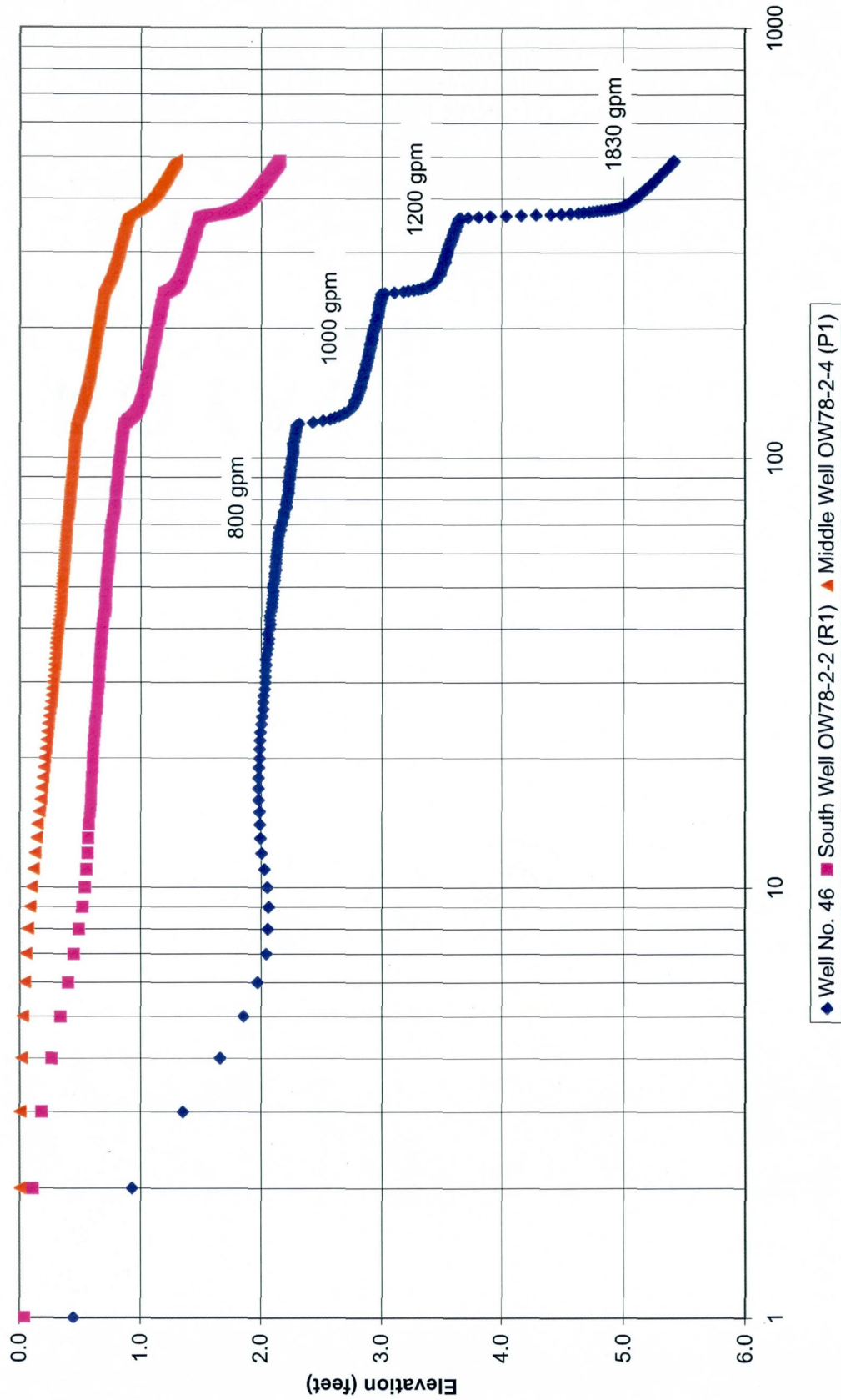


FIGURE 8
Well No. 46 Post-Maintenance Constant-Rate Test Hydrographs
Sioux Falls, South Dakota

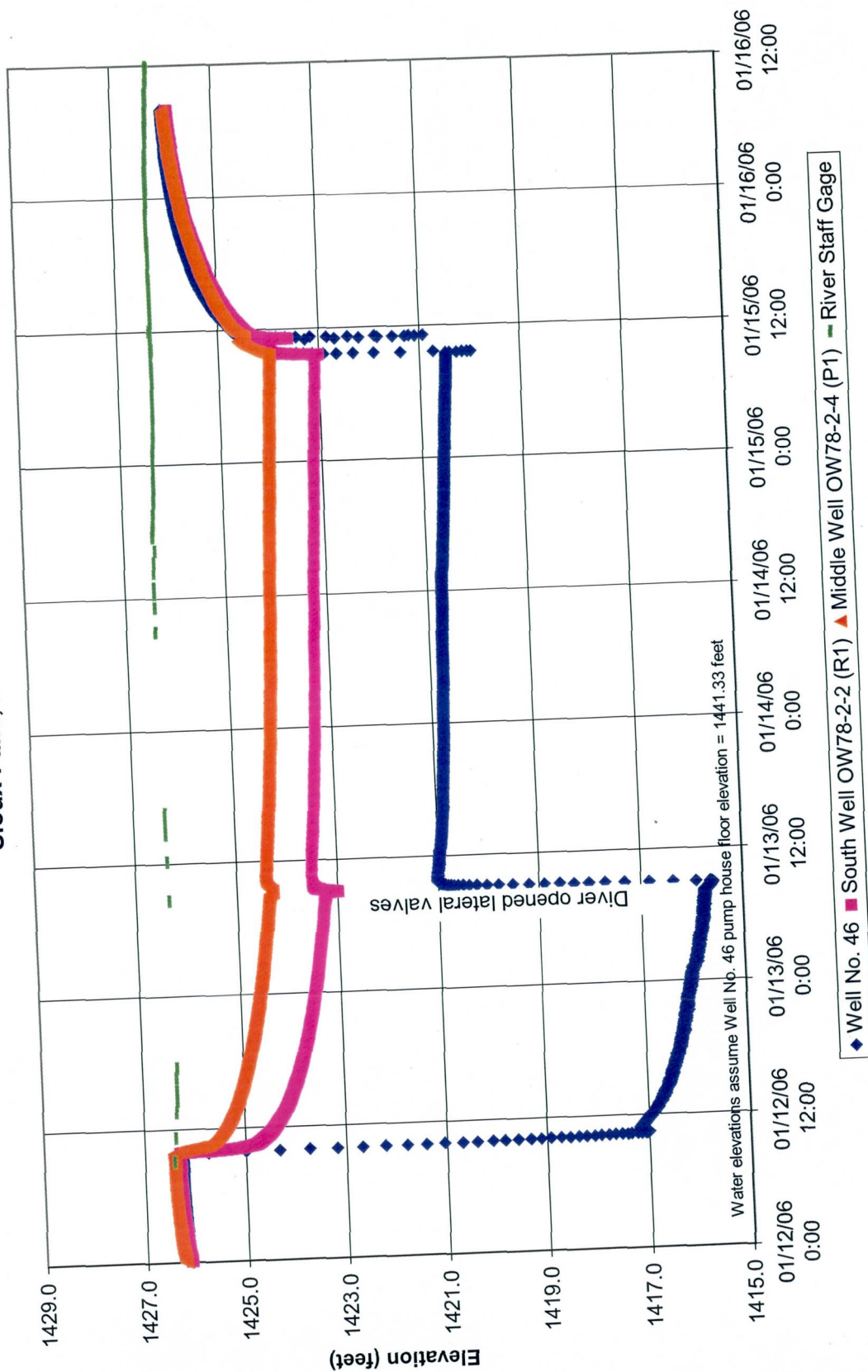


FIGURE 9
Well No. 46 Post-Maintenance Constant-Rate Test Drawdown Versus Time Plots
Sioux Falls, South Dakota

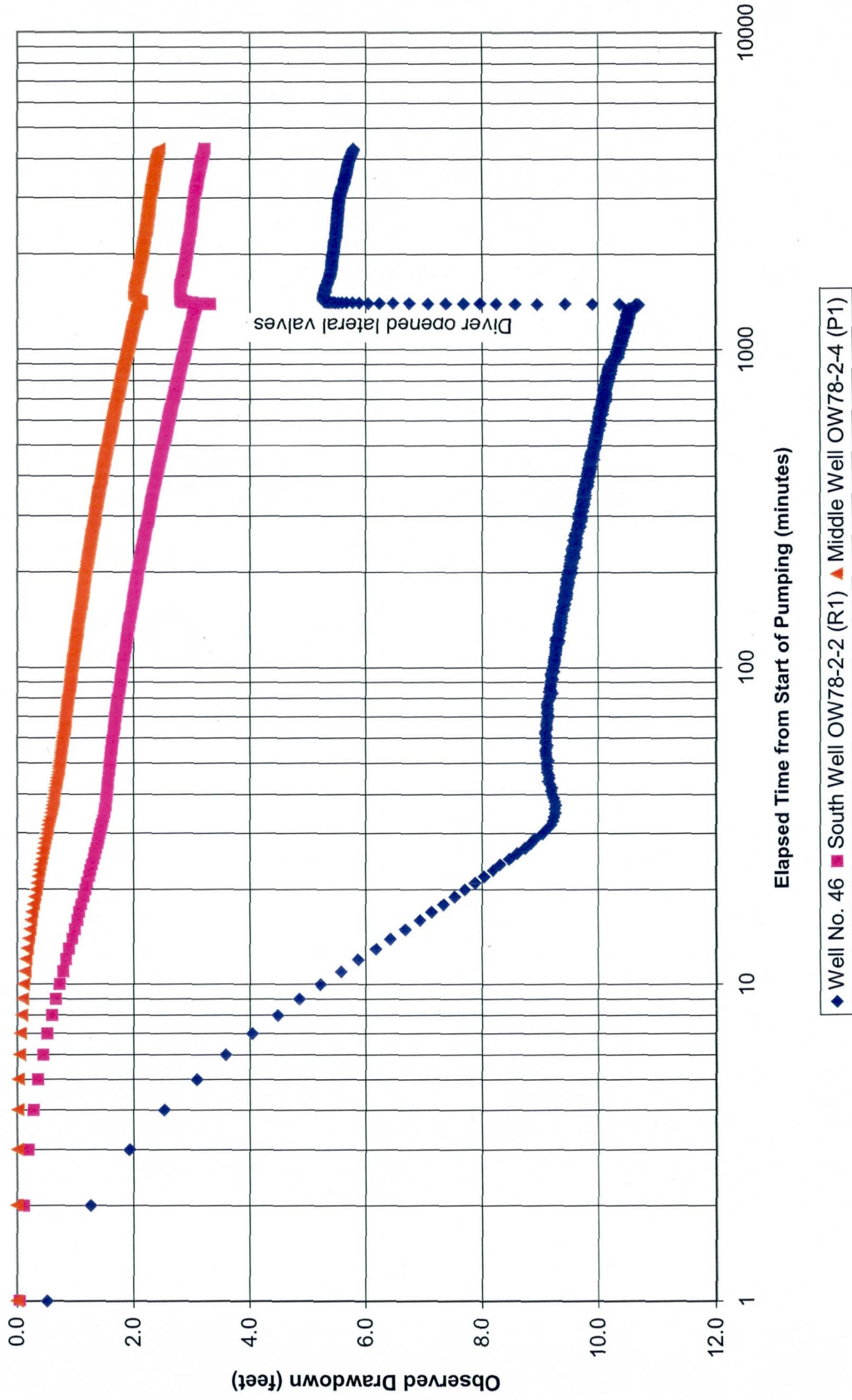


FIGURE 10
Well No. 47 Post-Maintenance Multiple-Rate Step Test Hydrographs
Sioux Falls, South Dakota

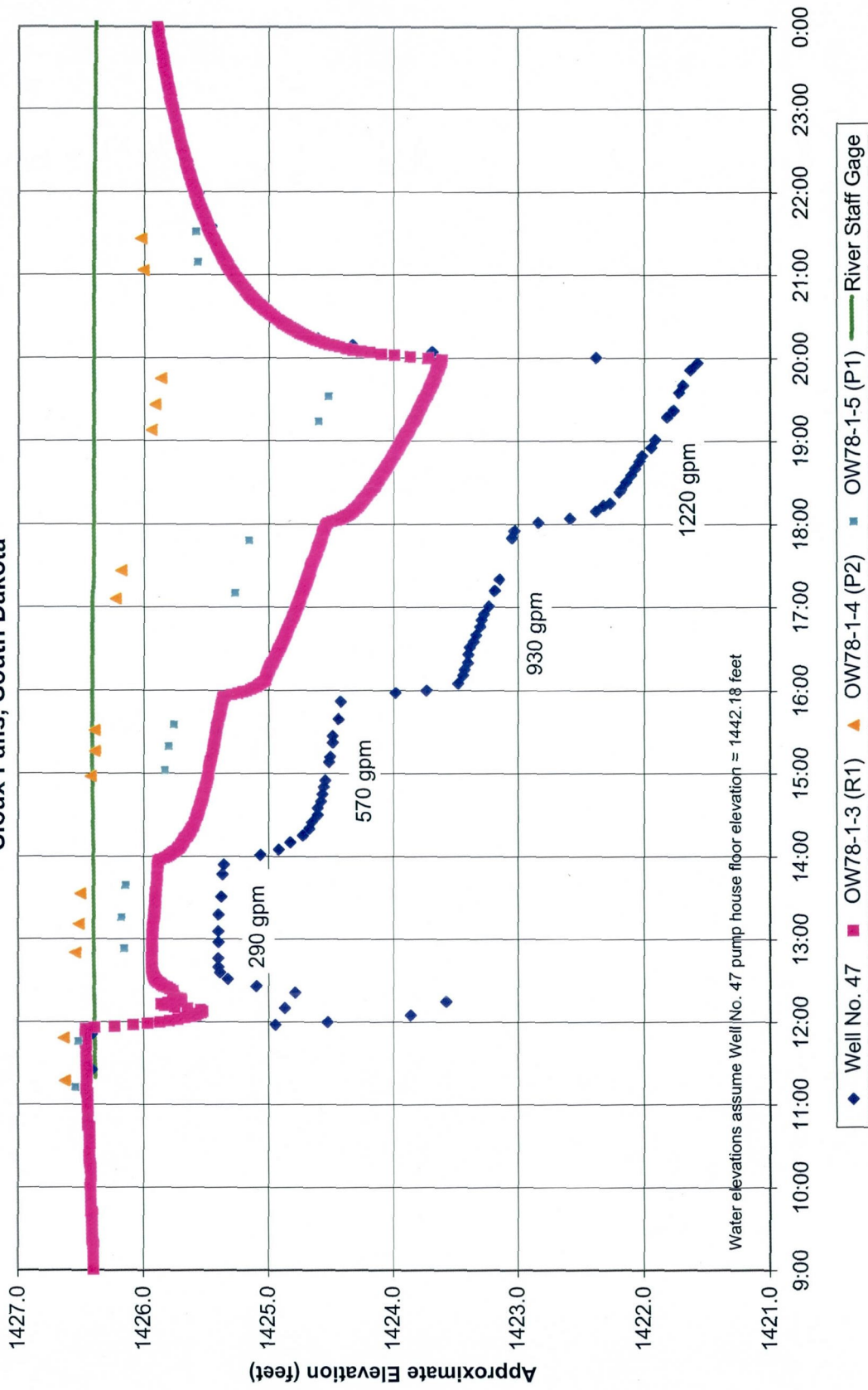


FIGURE 11
Well No. 47 Post-Maintenance Multiple-Rate Step Test Drawdown Versus Time Plots
Sioux Falls, South Dakota

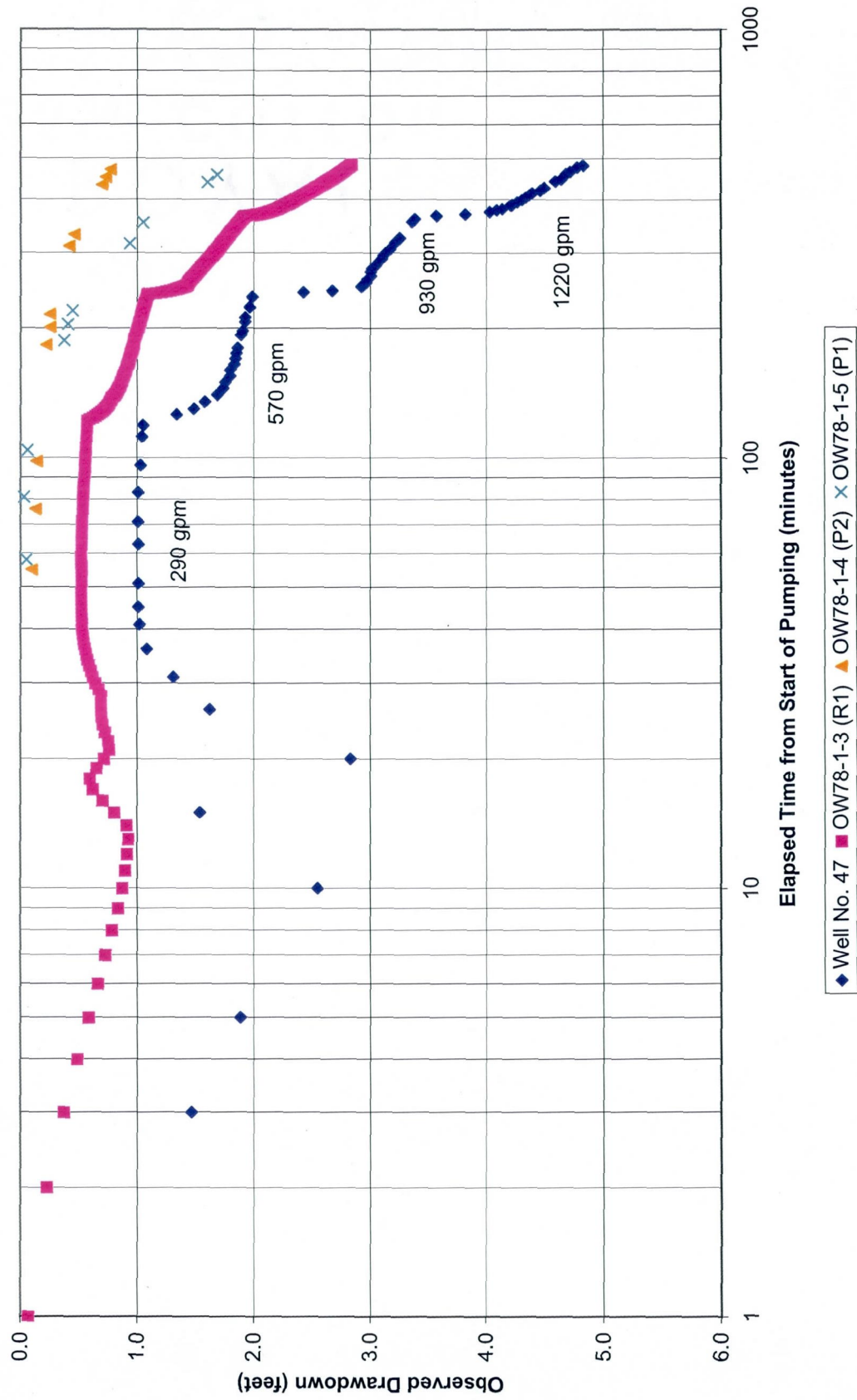


FIGURE 12

Well No. 47 Post-Maintenance Constant-Rate Test Hydrographs
 Sioux Falls, South Dakota - Average Pumping Rate 1245 gpm

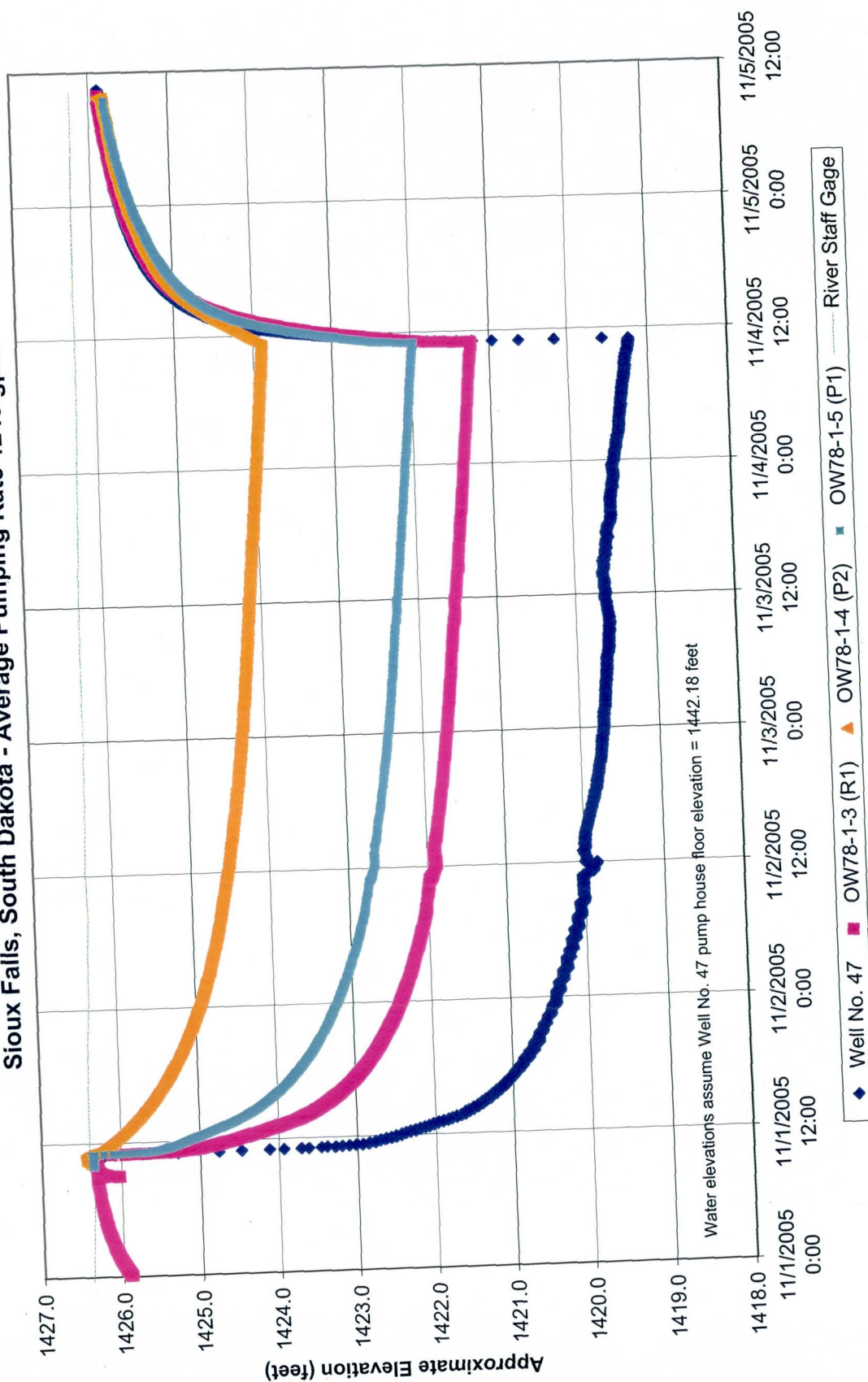


FIGURE 13
Well No. 47 Post-Maintenance Constant-Rate Test Drawdown Versus Time Plots
Sioux Falls, South Dakota - Average Pumping Rate 1245 gpm

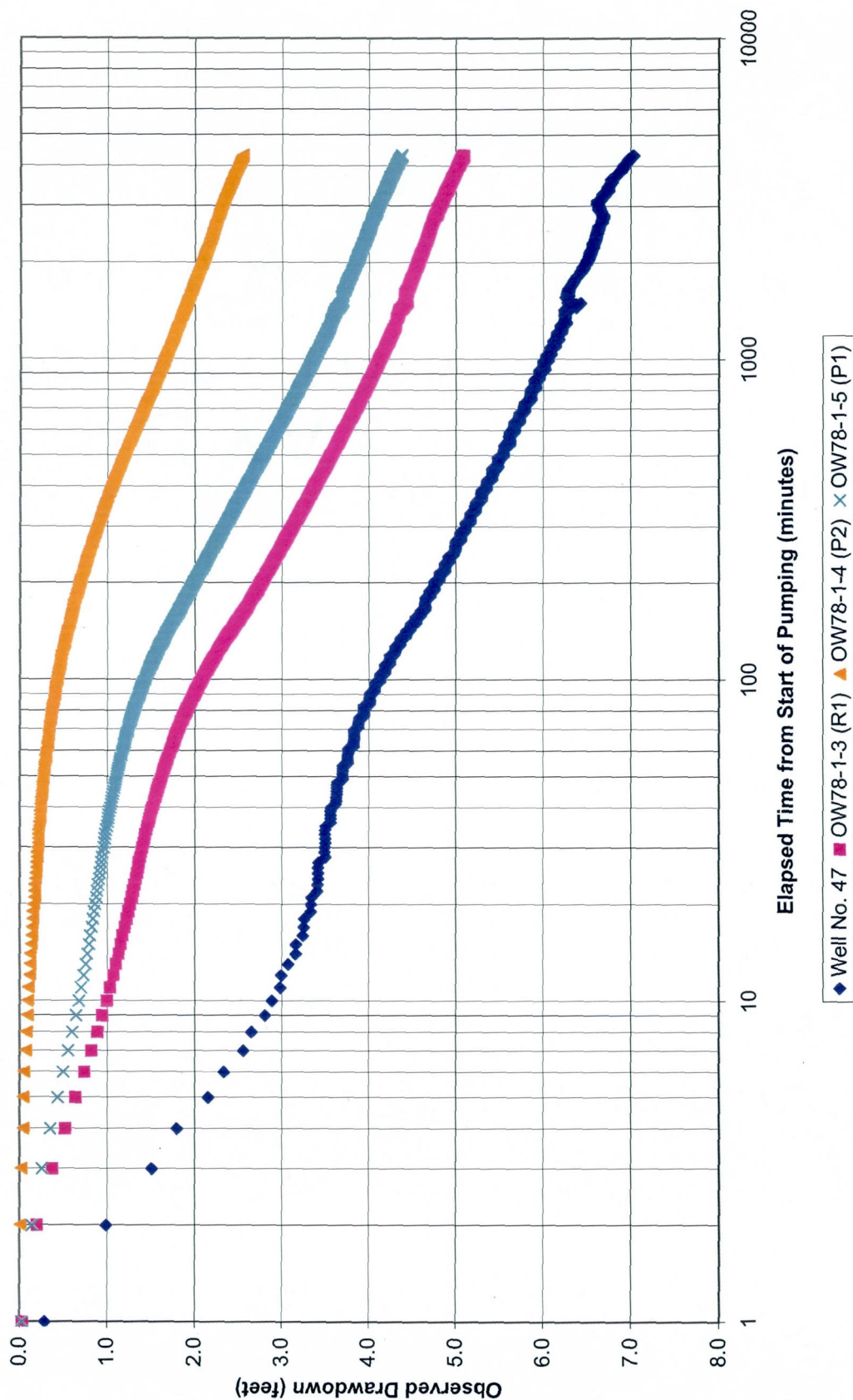


Figure 14
Well No. 46 Operation Data
City of Sioux Falls, South Dakota

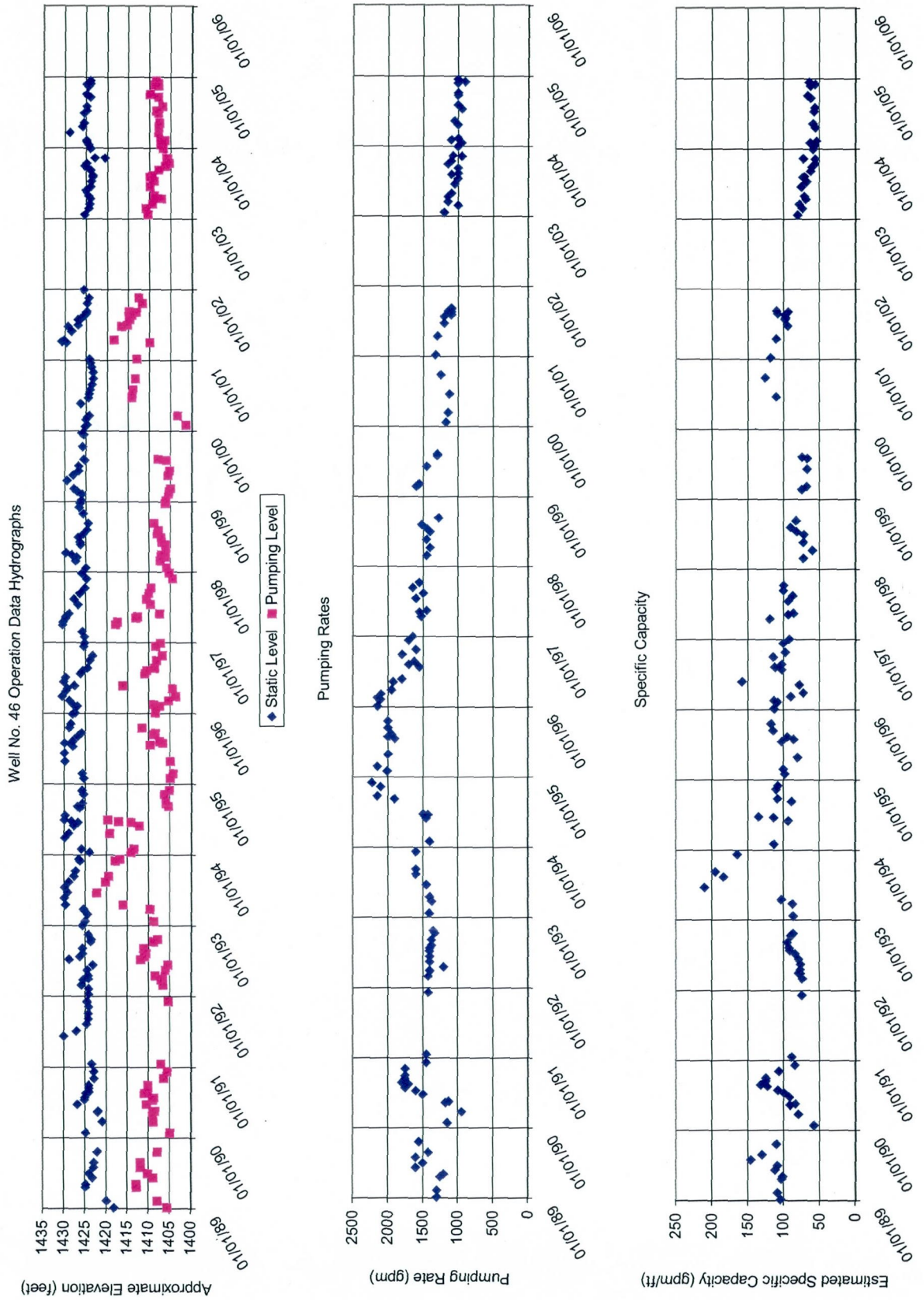


Figure 15
Well No. 47 Operation Data
City of Sioux Falls, South Dakota

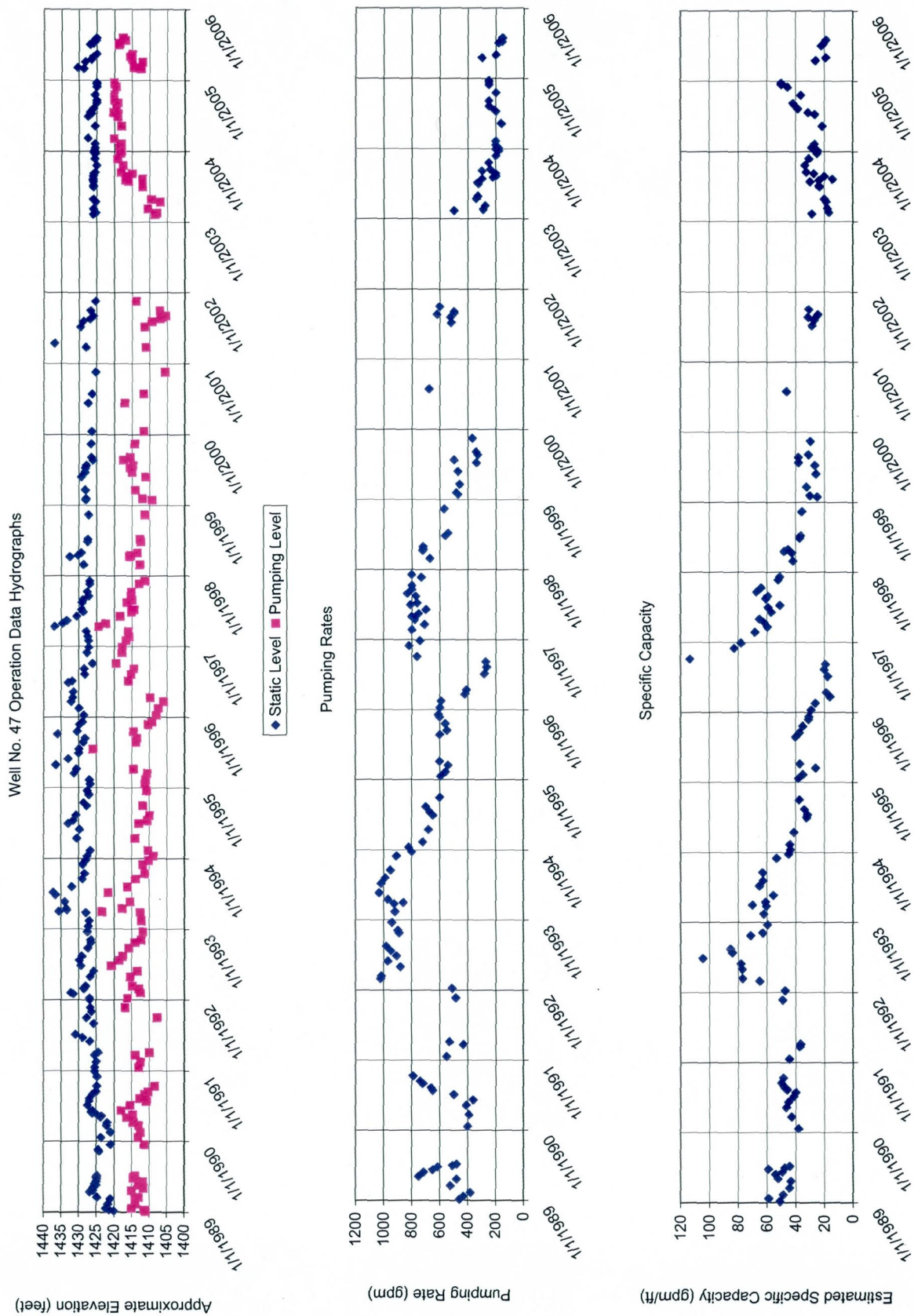


TABLE 1
Collector Well No. 46 Design Summary ⁽¹⁾
City of Sioux Falls, South Dakota

CAISSON AND LATERAL DESIGN

CAISSON INSIDE DIAMETER	16 feet
CAISSON OUTSIDE DIAMETER	19 feet
TOP OF PUMP HOUSE FLOOR ELEVATION	1441.33 feet, msl.
TOP OF PLUG (caisson floor) ELEVATION	1395.3 feet, msl.
INTERMEDIATE FLOOR ELEVATION	1432.3 feet, msl.
CAISSON DEPTH (top of finish floor to top of plug)	46.0 feet
CENTER LINE OF OLD LATERALS (abandoned) ELEV.	1397.3 feet, msl.
CENTER LINE OF NEW LATERALS ELEVATION	1398.0 feet, msl.
MINIMUM RECOMMENDED PUMPING ELEVATION	1403.0 feet, msl.
TOP OF AQUIFER ELEVATION (2)	1419 feet, msl.
BASE OF AQUIFER ELEVATION (2)	1396 feet, msl.
LATERAL DIAMETER (new laterals)	12.0 inches

LATERAL LENGTH

LATERAL NUMBER	BLANK LENGTH (feet)	LATERAL SCREEN LENGTH (feet)	TOTAL LATERAL LENGTH (feet)
1	7	100	107
2	7	120	127
3	7	110	117
TOTAL	21	330	351

LATERAL SCREEN SLOT SIZE AND PLACEMENT

LATERAL	SCREEN SLOT SIZE (inches)				
	0.040	0.060	0.080	0.100	0.125
1		57-67	7-27, 47-57, 67-77	27-47, 77-87	87-107
2	37-47	7-37, 47-57	57-67	67-107	107-127
3		7-17, 57-77	17-57, 77-87	87-97	97-117

1) Information on this table is in part based on information provided in the Project 05-1063 Bid Documents (H.R. Green Co., 2005), which reference The Ranney Company revised as-built drawings dated 1/25/80.

TABLE 2
Collector Well No. 47 Design Summary (1)
City of Sioux Falls, South Dakota

CAISSON AND LATERAL DESIGN

CAISSON INSIDE DIAMETER	16 feet
CAISSON OUTSIDE DIAMETER	19 feet
TOP OF PUMP HOUSE FLOOR ELEVATION	1442.18 feet, msl.
TOP OF PLUG (caisson floor) ELEVATION	1402.2 feet, msl.
INTERMEDIATE FLOOR ELEVATION	1433.2 feet, msl.
CAISSON DEPTH (top of finish floor to top of plug)	40.0 feet
CENTER LINE OF OLD LATERALS (abandoned) ELEV.	1404.2 feet, msl.
CENTER LINE OF NEW LATERALS ELEVATION	1405.1 feet, msl.
MINIMUM RECOMMENDED PUMPING ELEVATION	1410.1 feet, msl.
TOP OF AQUIFER ELEVATION (2)	1422 feet, msl.
BASE OF AQUIFER ELEVATION (2)	1400 feet, msl.
LATERAL DIAMETER (new laterals)	12.0 inches

LATERAL LENGTH

LATERAL NUMBER	BLANK LENGTH (feet)	LATERAL SCREEN LENGTH (feet)	TOTAL LATERAL LENGTH (feet)
1	7	110	117
2	7	95	102
3	7	60	67
4	7	80	87
TOTAL	28	345	373

LATERAL SCREEN SLOT SIZE AND PLACEMENT

LATERAL	SCREEN SLOT SIZE (inches)						
	0.030	0.040	0.600	0.080	0.100	0.125	0.150
1	97-117		7-27 87-97	27-37 77-87	37-67	67-77	
2			7-17	17-27	27-37	37-77 97-102	77-97
3	37-67	7-37					
4	7-17	17-27	27-37	37-47 67-87	47-67		

1) Information on this table is in part based on information provided in the Project 05-1063 Bid Documents (H.R. Green Co., 2005), which reference The Ranney Company revised as-built drawings dated 1/25/80.

2) Top and Bottom of Aquifer Elevations from Klaer & Associates (1979)

TABLE 3
Well No. 46 Post-Maintenance Multiple-Rate Step Test Summary
 City of Sioux Falls, South Dakota

Well No. 46 Step Test Conducted on 01/16/06

Step	Step Start Time	Step End Time	Step Duration (minutes)	Pumping Rate (gpm)	Depth to Water at End of Step (1)	Observed Drawdown at End of Step (feet)	Observed Specific Capacity (gpm/feet)	Laminar Flow Loss Percent %
Static	---	---	---	0	16.38	---	---	---
1	8:00	10:00	120	800	18.67	2.29	349.3	98.7%
2	10:00	12:00	120	1,000	19.39	3.01	332.2	93.8%
3	12:00	14:00	120	1,200	20.03	3.65	328.8	92.9%
4	14:00	16:10	130	1,830	21.85	5.47	334.6	93.0%

1) Depth to water measured from top of PVC water level meter access pipe
 1.1 feet above pump house floor.

TABLE 4
Well No. 46 Post-Maintenance Constant-Rate Test Summary
City of Sioux Falls, South Dakota

Test Dates: 1,590 gpm
Average Pumping Rate for Pumping Period 57 degrees F
Water Temperature in Caisson:

Water Temperature in Caisson.								
Observed Static Water Level			Observed 72-hr Pumping Water Level		Observed 72-hr Well Performance			
Well ID	Approximate Reference Elevation (feet)	Depth to Water (feet)	Approximate Water Elevation (feet)	Depth to Water (feet)	Approximate Water Elevation (feet)	Observed Drawdown (feet)	Observed Specific Capacity (gpm/ft)	Drawdown Differential (feet/1000 gpm)
Well No. 46	1442.39	16.12	1426.27	21.91	1420.48	5.79	274.6	
South Well								1.65
OW78-2-2 (R1)	1432.72	6.41	1426.31	9.62	1423.10	3.21		
Middle Well								2.15
OW78-2-4 (P1)	1431.81	5.43	1426.38	7.91	1423.90	2.48		

TABLE 5

Well No. 46 Post-Maintenance Lateral Flow Analysis
City of Sioux Falls, South Dakota

Lateral No.	Lateral Orientation (° East of North)	Total As-Built Lateral Length, feet from inside wall	Lateral Screen Length (feet)	Lateral Diameter (inches)	Relative Lateral Velocity (kilometers/hr)	Water Temperature (° F)	Per Cent of Total Flow	Average Flow, per length of screen (gpm per foot)
1	193	107	100	12	1.19	55.7	27.8	4.4
2	257	127	120	12	1.46	58.7	34.0	4.5
3	312	117	110	12	1.63	56.3	38.1	5.5
Average		117	110			56.9		4.8
Total		351	330					

Average Collector Pumping Rate During Flow Analysis: 1580 gpm

Relative Lateral Water Velocity and Water Temperature values are averages of two measurements on each lateral.
Average temperature is the mean weighted by percent of flow from each lateral.

Lateral Flow Analysis Performed on 1/13/06

Approximate Elevation of centerline of laterals = 1398.2 feet

TABLE 6
Well No. 46 Post-Maintenance Sand Testing Results
City of Sioux Falls, South Dakota

Start Time of Sand Test	Time of Reading	Pumping Rate at Reading (gpm)	Elapsed Time of Reading from Start of Sand Test (minutes)	Elapsed Time from Start of Pumping to Reading (hours)	Sand Volume in Sample Tube (ml)	Sand Content (ppm) *
Constant-Rate Test						
1/12/06 10:54	1/12/06 11:25	1510	31	1.6	0.03	0.5
	1/12/06 12:33	1520	99	2.7	0.08	0.4
	1/12/06 13:06	1510	132	3.3	0.09	0.4
	1/12/06 14:04	1510	190	4.2	0.1	0.3
	1/12/06 16:19	1510	325	6.5	0.12	0.2
	1/12/06 17:11	1510	377	7.4	0.16	0.2
	1/12/06 17:50	1510	416	8.0	0.2	0.3
	1/13/06 8:27	1560	1293	22.6	0.3	0.1
	1/13/06 11:40	1580	1486	25.8	0.35	0.1
1/13/06 11:44	1/13/06 13:05	1580	81	27.3	0.03	0.2
	1/13/06 14:20	1590	156	28.5	0.03	0.1
	1/13/06 15:12	1590	208	29.4	0.03	0.1
	1/13/06 17:18	1590	334	31.5	0.04	0.1
	1/14/06 8:30	1590	1246	46.7	0.05	< 0.1
	1/14/06 9:25	1590	1301	47.6	0.05	< 0.1
1/14/06 9:30	1/14/06 9:50	1590	20	48.0	0	0
	1/14/06 10:50	1590	80	49.0	< 0.01	< 0.1
	1/14/06 14:03	1590	273	52.2	< 0.01	< 0.1
	1/14/06 15:00	1590	330	53.2	< 0.01	< 0.1
	1/14/06 16:05	1590	395	54.3	0.01	< 0.1
	1/14/06 17:21	1600	471	55.5	0.01	< 0.1
	1/15/06 8:40	1610	1390	70.8	0.02	< 0.1
1/15/06 8:43	1/15/06 9:09	1610	26	71.3	< 0.01	< 0.1
	1/15/06 9:28	1610	45	71.6	< 0.01	< 0.1
Multiple-Rate Step Test - 1/16/06						
1/16/06 8:21	1/16/06 9:44	800	83	1.7	< 0.01	< 0.1
	1/16/06 10:14	1000	113	2.2	< 0.01	< 0.1
	1/16/06 10:26	1000	125	2.4	< 0.01	< 0.1
	1/16/06 11:59	1000	218	4.0	< 0.01	< 0.1
	1/16/06 12:49	1200	268	4.8	< 0.01	< 0.1
	1/16/06 14:11	1770	350	6.2	< 0.01	< 0.1
	1/16/06 15:04	1820	403	7.1	0.01	< 0.1
	1/16/06 15:55	1830	454	7.9	0.01	< 0.1

* Sand Content = [Sand Volume] / [Elapsed Time] x 528

TABLE 7

Well No. 47 Post-Maintenance Multiple-Rate Step Test Summary
City of Sioux Falls, South Dakota

Well No. 47 Step Test Conducted on October 31, 2005

Step	Step Start Time	Step End Time	Step Duration (minutes)	Pumping Rate (gpm)	Depth to Water at End of Step (1)	Observed Drawdown at End of Step (feet)	Observed Specific Capacity (gpm/feet)	Estimated Laminar Flow Loss %
Static	---	---	---	0	15.99	---	---	---
1	11:55	13:55	120	290	17.04	1.05	275.6	97.7%
2	13:55	15:55	120	570	17.98	1.99	286.4	96.0%
3	15:55	17:55	120	930	19.38	3.39	274.3	93.7%
4	17:55	19:59	124	1,220	20.82	4.83	252.6	91.3%

1) Depth to water measured from top of 2-inch PVC access pipe for water level chart recorder weight 0.22 feet above pump house floor.

TABLE 8
Well No. 47 Post-Maintenance Constant-Rate Test Summary
City of Sioux Falls, South Dakota

Test Dates: 11/01/2005 to 11/04/2005
Average Pumping Rate for Pumping Period 1,245 gpm
Water Temperature in Caisson: 52 degrees F

Well ID	Observed Static Water Level		Observed 72-hr Pumping Water Level		Observed 72-hr Well Performance			
	Approximate Reference Elevation (feet)	Depth to Water (feet)	Approximate Water Elevation (feet)	Depth to Water (feet)	Approximate Water Elevation (feet)	Observed	Drawdown Differential (feet/1000 gpm)	
						Observed Drawdown (feet)		Observed Specific Capacity (gpm/ft)
Well No. 47	1442.4	16.13	1426.27	23.12	1419.28	6.99	178.1	
North Well								
OW78-1-4 (P2)	1440.22	13.77	1426.45	16.33	1423.89	2.56		3.70
Middle Well								
OW78-1-3 (R1)	1439.83	13.49	1426.34	18.63	1421.20	5.14		1.54
South Well								
OW78-1-5 (P1)	1439.50	13.15	1426.35	17.54	1421.96	4.39		2.15

TABLE 9

Well No. 47 Post-Maintenance Lateral Flow Analysis
City of Sioux Falls, South Dakota

Lateral No.	Lateral Orientation (° East of North)	Total As-Built Lateral Length, feet from inside wall	Lateral Screen Length (feet)	Lateral Diameter (inches)	Relative Lateral Velocity (kilometers/hr)	Water Temperature (° F)	Per Cent of Total Flow	Average Flow, per length of screen (gpm per foot)
1	97	117	110	12	0.34	51.5	15.8	1.8
2	147	102	95	12	0.61	51.7	28.9	3.8
3	209	67	60	12	0.24	55.9	11.3	2.3
4	279	87	80	12	0.94	50.9	44.1	6.8
Average		93	86			51.8		3.7
Total		373	345					

Average Collector Pumping Rate During Flow Analysis: 1240 gpm

Relative Lateral Water Velocity and Water Temperature values are averages of two measurements on each lateral.
Average temperature is the mean weighted by percent of flow from each lateral.

Lateral Flow Analysis Performed on 11/03/05

Approximate Elevation of centerline of laterals = 1395.8 feet

TABLE 10
Well No. 47 Post-Maintenance Sand Testing Results
City of Sioux Falls, South Dakota

Start Time of Sand Test	Time of Reading	Pumping Rate at Reading (gpm)	Elapsed Time of Reading from Start of Sand Test (minutes)	Elapsed Time from Start of Pumping to Reading (hours)	Sand Volume in Sample Tube (ml)	Sand Content (ppm) *
Constant-Rate Test						
11/01/05 11:55	11/01/05 12:05	1240	10	0.2	< 0.01	<0.5
	11/01/05 12:26	1240	31	0.5	0.02	0.3
	11/01/05 12:51	1240	56	0.9	0.02	0.2
	11/01/05 14:06	1240	131	2.2	0.02	0.1
	11/02/05 7:03	1250	1148	19.1	0.02	< 0.1
	11/02/05 11:08	1250	1393	23.2	0.04	< 0.1
11/02/05 11:09	11/02/05 12:09	1250	60	24.2	0.03	0.3
	11/02/05 13:09	1250	120	25.2	0.03	0.1
	11/02/05 14:11	1250	182	26.3	0.03	0.1
	11/02/05 15:10	1250	241	27.2	0.03	0.1
	11/02/05 17:09	1250	360	29.2	0.03	< 0.1
	11/03/05 6:31	1250	1162	42.6	0.03	< 0.1
11/03/05 10:35	11/03/05 11:02	1250	27	47.1	0.01	0.2
	11/03/05 12:12	1250	97	48.3	0.01	0.1
	11/03/05 15:07	1250	272	51.2	0.01	< 0.1
	11/04/05 7:11	1250	1236	67.3	0.01	< 0.1
	11/04/05 10:08	1250	1413	70.2	0.01	< 0.1
11/04/05 10:11	11/04/05 10:41	1250	30	70.8	0	0.0
	11/04/05 11:00	1250	49	71.1	0	0.0

* Sand Content = [Sand Volume] / [Elapsed Time] x 528