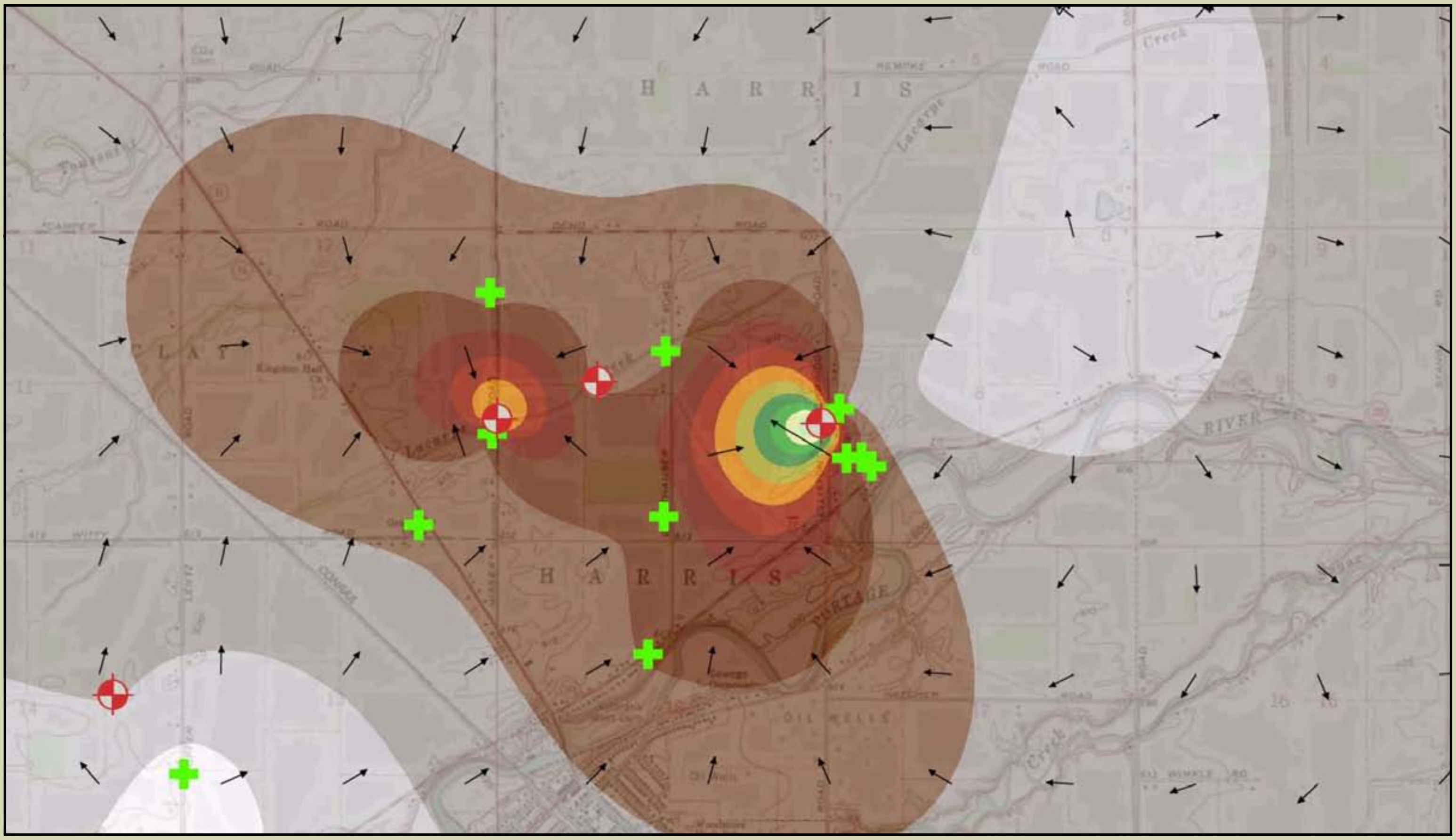
Ground Water Investigation of the Carbonate Bedrock Aquifer to Evaluate the Impact of Pumping High–Yielding Irrigation Wells on Local Water Supply Wells in Ottawa County, Harris Township, Ohio



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Technical Report of Investigations 2012-1

March 2012

GROUND WATER INVESTIGATION OF THE CARBONATE BEDROCK AQUIFER TO EVALUATE THE IMPACT OF PUMPING HIGH-YIELDING IRRIGATION WELLS ON LOCAL WATER SUPPLY WELLS IN OTTAWA COUNTY, HARRIS TOWNSHIP, OHIO

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Water Resources Technical Report of Investigations 2012-1

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ABSTRACT

A ground water investigation of the carbonate bedrock aquifer was initiated in May 2011 by the ODNR Division of Soil and Water Resources at the request of local home owners in Ottawa County, Harris Township Ohio. The purpose of the investigation was to evaluate the impact of high-yielding irrigation wells on ground water levels in the nearby domestic water supply wells.

Previous work completed in this area confirms that the carbonate bedrock aquifer of northwestern Ohio contains a number of flow zones. The well completion diagram for the Luckey homestead farm well shows the extent to which the flow zones occur in the subsurface. Drilling data shows that the carbonate bedrock aquifer is anisotropic and heterogeneous in its configuration. This gives rise to a number of concerns that need to be considered before long-term pumping rates can be accurately calculated and the data used to design water supply systems.

Pumping test data shows that the transmissivity of the aquifer is not uniform throughout the aquifer. It can vary both in the vertical and horizontal directions and may vary over short distances within the carbonate bedrock aquifer when there are significant variations in permeability as well as fracturing. This helps to explain major changes in yield over short distances in both the vertical and horizontal directions.

Field data obtained for this project shows that the pumping of the high-yielding water wells can have an impact on the local water supply wells. The degree of impact depends on the location of the water well relative to the pumping center and the pumping rate. It also depends on the flow zone from which the water well produces. A deeper high-yielding well can impact water supply wells completed in the upper flow zone in the carbonate bedrock aquifer.

To fully define the hydraulic conditions for each of the high-yielding wells, it is recommended that each high-yielding well owner undertake a hydrogeological assessment to evaluate the impacts from pumping these wells on the surrounding water supply wells.

Based on the results of the hydrogeological assessment, the owner of the high-yielding well should prepare a report that fully defines the aquifer characteristics along with a ground water pumping and monitoring plan to show how the operator will prevent dewatering of nearby domestic water supply wells. A mitigation plan should be developed in the event that local domestic water supply wells are affected by pumping of the high-yielding water well.

In accordance with 1521.16, each high-yielding water supply well owner must register their facility and report the ground water usage to the ODNR Division of Soil and Water Resources as appropriate.

1.0 Introduction

Over the past six year's (2005 to 2011) farmers in northwestern Ohio, and in particular Ottawa County, Harris Township, installed high-yielding water wells to provide water needed to irrigate their tomato crops. Shortly after the wells went into operation, the local homeowners began to complain that the water levels in their water wells were declining. In some cases the homeowners lowered their well pumps, deepened their water wells, or drilled a new well to insure an adequate water supply for their domestic water needs.

In response to the request of the local homeowners for assistance, the Ohio Department of Natural Resources – Division of Soil and Water Resources (ODNR-DSWR) met with the homeowners to discuss the possible impacts that the pumping of the high-yielding irrigation wells could have on regional or local ground water levels. As a result, the ODNR-DSWR agreed to conduct an investigation to determine the impact that the irrigation wells were having on local domestic water supply wells.

1.1 SITE LOCATION AND SETTING

Figure 1 is a general site location map that shows the location of the study area in northwestern Ohio. Figure 2 shows the location of the study area relative to important geographic features. Major communities in the area are the village of Elmore to the south, Genoa to the northwest and Woodville to the southwest.

Topographically, the area is characterized by a generally flat, gently rolling appearance. Surface elevation across the area ranges from 620 feet to 600 feet above mean sea level, giving the area a topographic relief of 20 feet.

Physiographically, the study area is located in the Huron-Erie Lake Plains Section of the Central Lowland Province (Brockman, 1998). Surface water drainage is part of the Cedar-Portage sub-basin of the Western Lake Erie sub-region of the Lake Erie watershed. Surface water drainage has a typical dendritic drainage pattern. The surface water runoff in the study area is controlled by the Portage River that flows from the southwest toward the northeast and discharges to Lake Erie.

Land use in the area is dominated by agricultural activity with some minor urban and industrial development. Domestic home development has occurred mostly along road frontage along farm roads that cross the area.

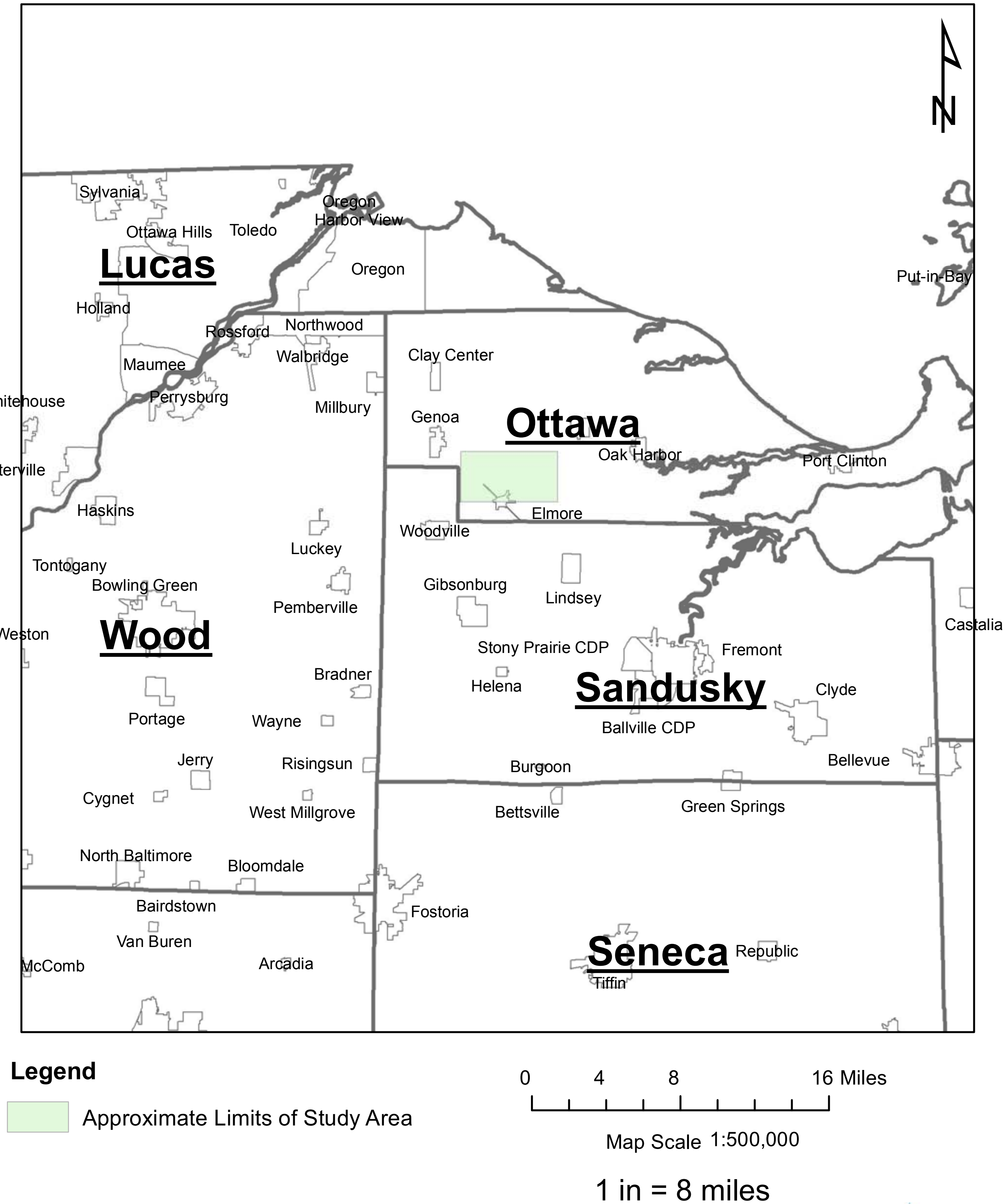
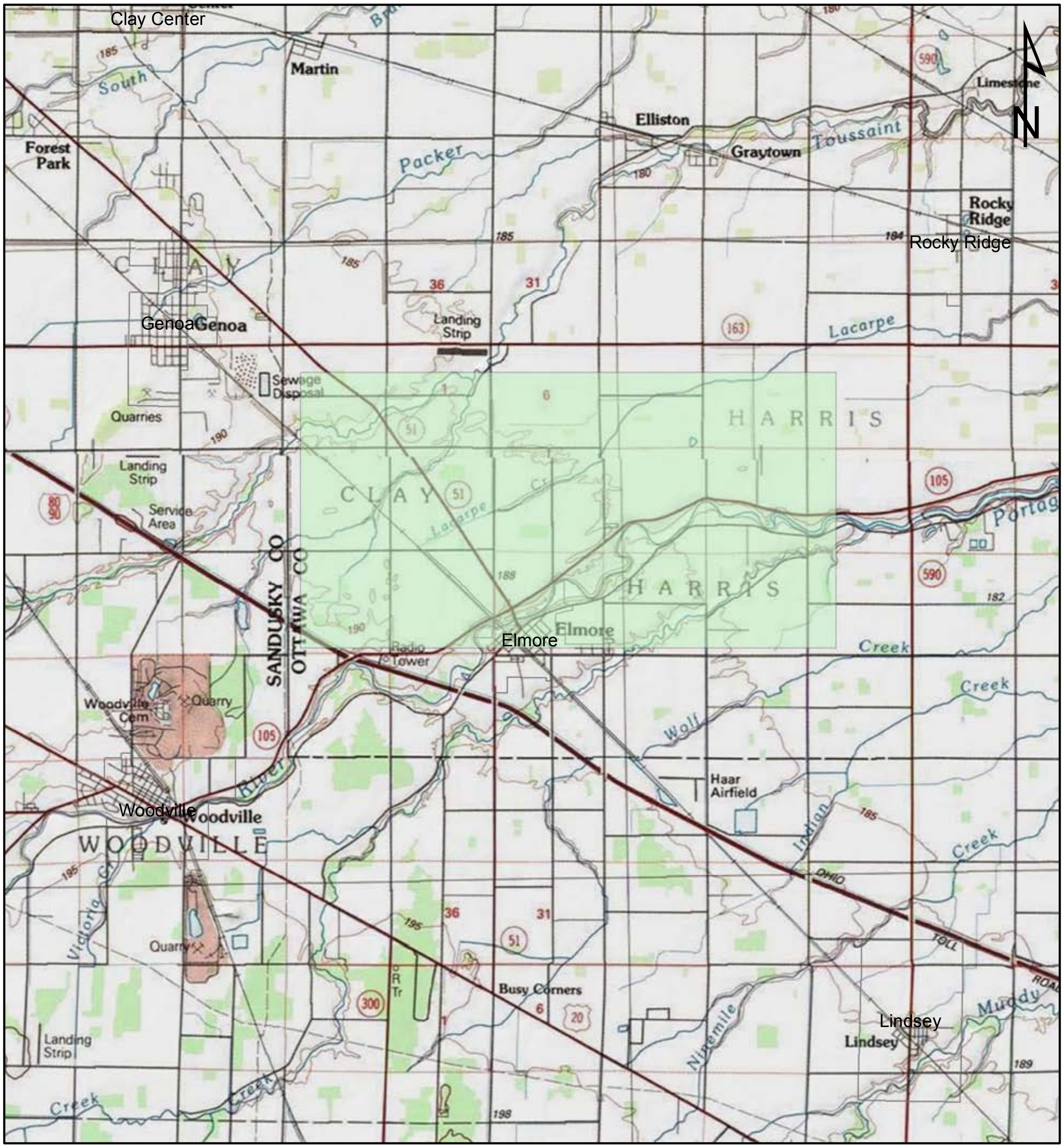


Figure 1. General Location Map for the Ottawa County High-Yield Irrigation Well Study Area



0 1 2 4 Miles

Map Scale 1:100,000

1 in = 2 miles

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Approximate Limit of Study Area

Figure 2. Topographic Map Ottawa County, Harris Township Study Area

1.2 PURPOSE AND SCOPE OF WORK

The ODNR-DSWR has the authority to collect data to help resolve conflicts between ground water users by conducting technical investigations and preparing related reports to help all ground water users understand the impacts to the resource.

In areas where ground water withdrawals are exceeding natural recharge, the Division can designate ground water stress areas with special reporting requirements for all ground water users. The Division can hold public meetings or hearings upon request from local governments and boards to help disseminate ground water information in conflict areas.

The purpose of this project is to investigate what impact the high-yielding irrigation wells may have on the ground water levels in nearby water supply wells. The ODNR-DSWR will assess the validity of allegations made by local homeowners that the irrigation wells are exceeding reasonable ground water withdrawal rates from the carbonate bedrock aquifer, resulting in the dewatering of the domestic water supply wells.

The scope of work for the project was as follows:

- Review the previous work regarding the hydrogeology of the carbonate aquifer in northwest Ohio near Ottawa County, Harris Township
- Review the well construction and well completion details for the high-yielding wells
- Review the well construction and well completion details for domestic water wells in Ottawa County, Harris Township
- Implement a field investigation to monitor water levels in the high-yielding water wells and select water wells in the area
- Analyze the data to determine the impact of pumping the high-yielding water wells may have on the ground water levels in the nearby domestic wells
- Write a report summarizing the conclusions and recommendations obtained from the study to assist with a resolution to the ground water conflict caused by the pumping of the irrigation wells

2.0 PREVIOUS WORK

2.1 HYDROGEOLOGY OF THE STUDY AREA

During the late 1960's, the ODNR- Division of Water implemented a ground water investigation to determine the hydraulic characteristics of the carbonate aquifer of northwestern Ohio (ODNR, 1970). The area of the study included the Portage, Sandusky and a large part of the Maumee River Basins. The objective of the study was to provide a comprehensive program for the development of the water resources that would give maximum support to the growth and development of the region. To define the subsurface hydraulic characteristics of the limestone and dolomites that compose the carbonate bedrock aquifer, 76 wells were drilled into the subsurface. The study of the carbonate bedrock aquifer system was done as follows:

(1) The lithology of each well was logged

(2) A 2-hour trial pump test was implemented

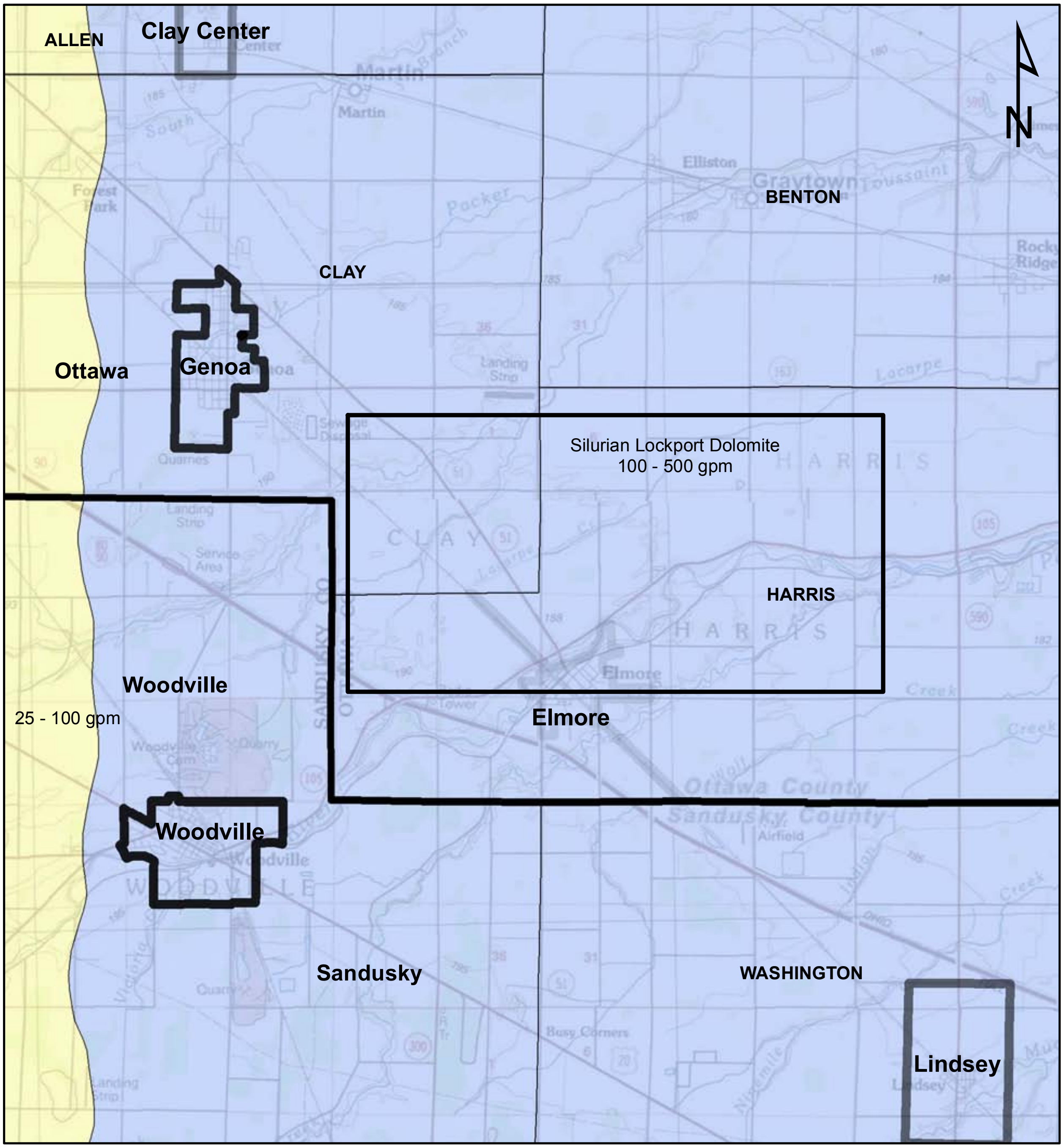
(3) A step test was run to determine well loss and depth of water yielding zones

(4) A constant rate 24-hour pumping test was implemented to determine carbonate aquifer hydraulic characteristics

Geologically, the bedrock stratigraphic sequence under the study area consists of the Silurian-age Lockport Dolomite and Tymochtee and Greenfield Dolomites (Slucher et al., 2006). The structure of the bedrock is controlled by the Findlay Arch which runs directly through the study area. The Findlay Arch separates the bedrock sediments of the Michigan Basin from the Appalachian Basin. Hydrogeologically, the ground water yields from the carbonate bedrock aquifer generally range from 25 to 500 gpm with some individual wells producing over 500 gpm (Figure 3).

The carbonate bedrock is overlain by unconsolidated glacial ground moraine and lake bed sediments of varying thickness as shown on Figure 4. These unconsolidated glacial and lake bed sediments yield less than 5 gpm to drilled wells; for that reason, glacial sediments are not generally used as a water source in the study area. Higher yields of 5-25 gpm can be obtained from the unconsolidated alluvial sediments along the Portage River.

Net ground water recharge rates through the glacial ground moraine and lake bed sediment are estimated to be in the range of 2 to 4 inches per year (Smith, 1994). The recharge occurs in areas where the glacial till is thin or where it contains sand and gravel deposits. Otherwise, the glacial till acts as a confining unit in areas that contain thick clay deposits.



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Silurian Lockport

YIELD

25 - 100 gpm

100 gpm - 500 gpm

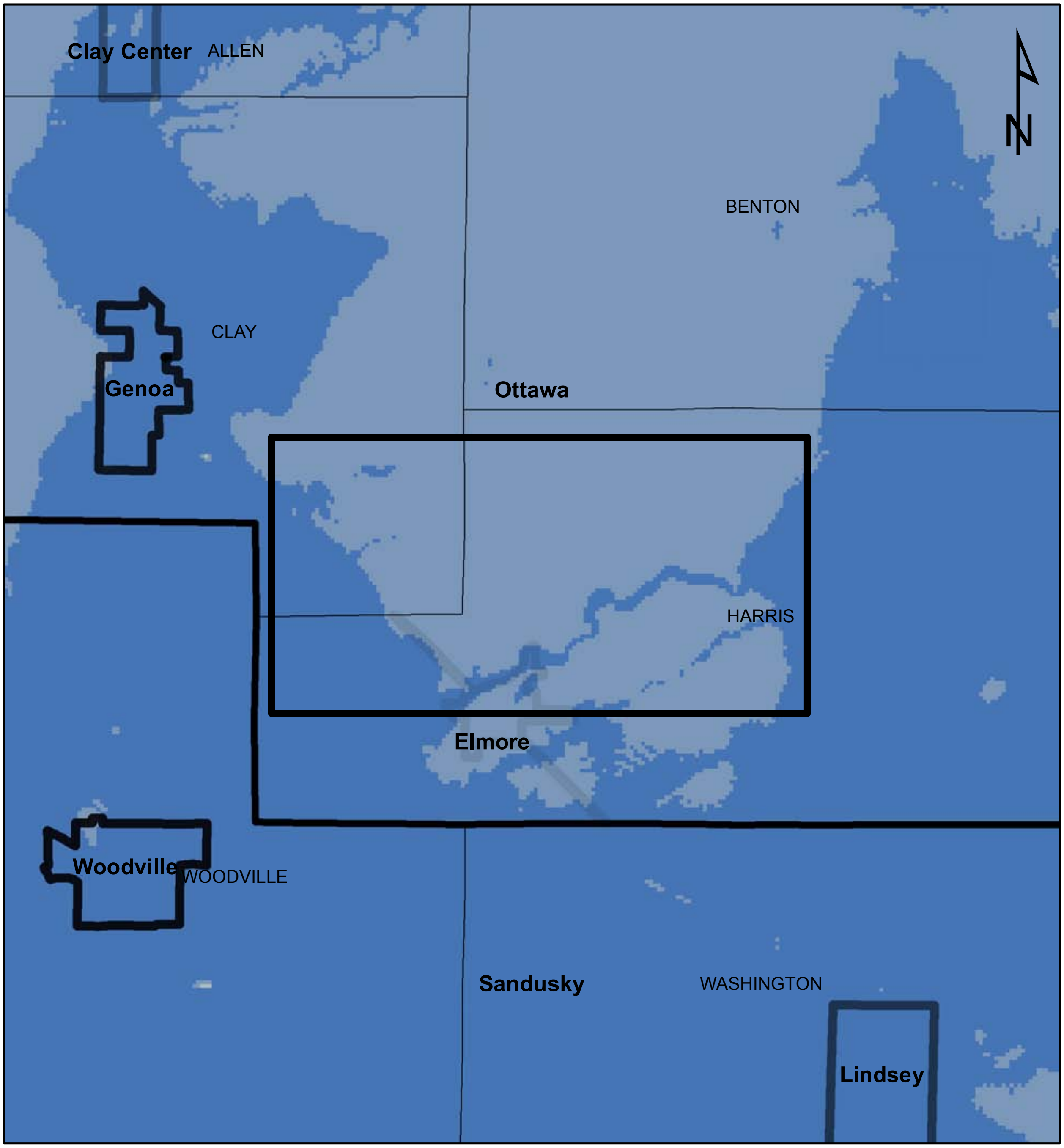
Approximate Limits of Study Area

0 1 2 4 Miles

Map Scale 1:100,000

1 in = 2 miles

Figure 3. Carbonate Bedrock Aquifer Yield in the Study Area (ODNR-DSWR)



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Drift Thickness

Value

- 0 - 30 Feet
- 30.1 - 65 Feet
- Approximate Limits of Study Area

0 1 2 4 Miles

Map Scale 1:100,000

1 in = 2 miles

Figure 4. Glacial Aquifer Thickness in feet in the Study Area (ODNR-DSWR)

It was further noted that the carbonate aquifers in karst terrain are seldom homogenous and need to be interpreted with caution (White and White, 1989 and Eagon and Johe, 1972). As a result, the following characteristics of the carbonate aquifer need to be considered:

(1) The permeability of carbonate aquifers are generally derived from secondary porosity and permeability associated with joints, fractures and solution channels in the bedrock

(2) The fractures can be connected both vertically and horizontally in ways that are hard to predict

(3) The occurrence and movement of ground water seldom approach that associated with homogeneous and isotropic aquifer systems

(4) The carbonate aquifer in Ohio is covered by a layer of glacial ground moraine of varying thickness containing a random mixture of boulder, cobble, gravel, sand, silt and clay-size sediments that were deposited as the glacial ice melted

(5) Much of the recharge to the underlying carbonate bedrock aquifer is derived from vertical leakage through the overlying unconsolidated glacial sediments

A number of flow zones in the carbonate bedrock were detected in each of the wells drilled during the northwest Ohio study. The flow zones were an indication of the degree of jointing, fracturing and solutioning in the carbonate sequence encountered in each drilled well. The number of fractures encountered in individual wells could vary from zero up to 10 or more. Ground water yields increased with depth as fracture zones were encountered while drilling the individual water wells (Eagon and Johe, 1972).

During individual pumping tests, it was discovered that the upper water-bearing zones could be dewatered, which affected the pumping test results. As the upper water-bearing flow zones were dewatered, the water level in the pumping well would drop substantially. Further, any additional water pumped from the well was obtained from the lower water-bearing flow zones. An erroneously optimistic prediction of ground water yield from individual wells resulted by not accounting for the drop in water level in the pumping well and the increased well loss due to dewatering of the upper flow zones.

Use of the step test and pumping test data provided valuable insight for predicting the safe pumping level and yield from the carbonate aquifer. When predicting the safe pumping level and yield where dewatering of the upper flow zones occurs, there is no substitute for good step test data. In addition, when regional flow concepts were applied with standard methods, it was possible to obtain reasonable values for hydraulic conductivity, pumping water levels, and safe yields for the carbonate aquifers (Eagon and Johe, 1972).

2.2 REGIONAL GROUND WATER OCCURRENCE AND MOVEMENT

Figure 5 was developed from the ODNR-DSWR well log database to show the regional ground water gradient in the subsurface. This figure shows that the regional ground water movement in the carbonate bedrock aquifer is from the southwest toward the northeast. The ground water elevations vary from 650 to 550 feet above mean sea level. The ground water discharge is toward Lake Erie (Haiker, 2009 and Crist, 2006).

2.3 PUMPING TEST ANALYSIS FOR WELL P-12 LOCATED IN OTTAWA COUNTY BENTON TOWNSHIP

A review of the 1970 ODNR-Division of Water report on the carbonate bedrock aquifer revealed that well P-12 was drilled in the study area near the high-yielding water wells. This well was used to evaluate the hydraulic characteristic of the carbonate aquifer in the study area because there was no long-term pumping test data available for any of the irrigation wells. Well P-12 was drilled to a depth of 360 feet below the land surface and had well construction and yield similar to the irrigation wells (ODNR unpublished data, 1969).

The location of well P-12 is shown on Figures 5 and 6. From the unpublished report on well P-12, a well log, step test, and 24-hour pumping test data were available for the well. From the well log, two flow zones were identified as follows:

- The upper flow zone was noted at 64 to 65 feet
- The lower flow zone was noted at 270 to 280 feet

The step test was run for 6 hours. Six steps were run at 60 minutes each. The initial step was run at 76 gallons per minute (gpm), with each step increased by approximately 10 gpm. The maximum pumping rate was 126 gpm. The maximum drawdown in the well was approximately145 feet.

From the step test as well as the pumping test, it was noted that the upper producing zone at 65 feet could easily be dewatered. An additional 40 feet of drawdown occurred in the pumping well once this zone was dewatered. If the pumping rate was maintained below 50 gpm, the upper water-bearing zone would not have been dewatered and the pumping level would have stayed above 65 feet. It was also noted that the specific capacity of the well declined from 2.04 gpm/foot of drawdown at a pumping rate of 76 gpm to 0.54 gpm/foot of drawdown when the pumping rate was increased to 126 gpm in the last step.

Based on the results of the step test, the constant rate test was run at 99 gpm for a period of 24 hours. The original static water level in the well was 23.94 feet below the land surface. The total drawdown in the well was measured at 99.75 feet. The specific capacity for the 24-hour pumping test was approximately 1.01 gpm/foot of drawdown.

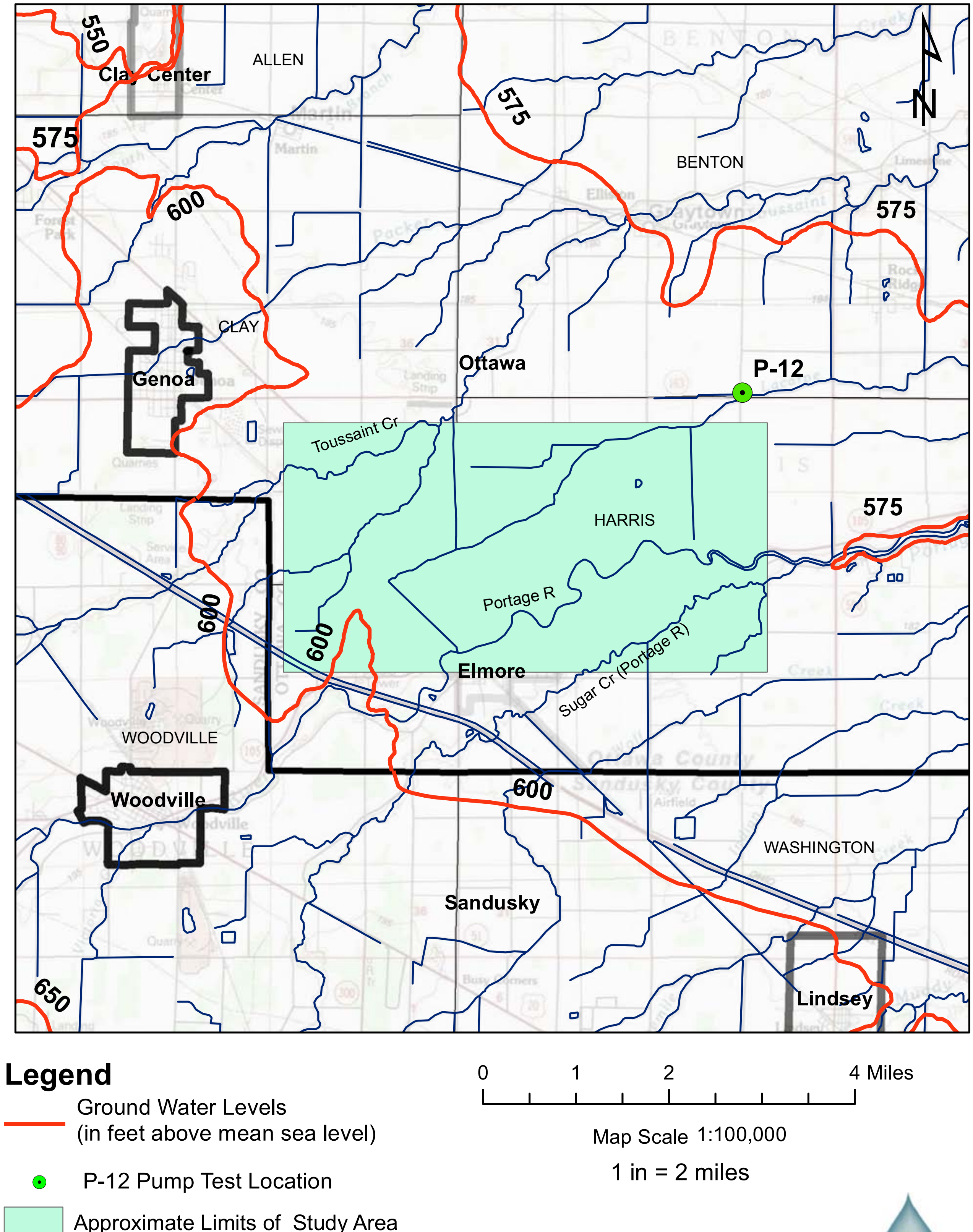


Figure 5. Regional Bedrock Ground Water Flow Gradient Map (Haiker, 2009 and Crist, 2006)

Legend

WELL TYPE

Observation

Pumping

0 500 1,000 2,000 Feet

Map Scale 1:12,000

1 inch = 1,000 feet

Figure 6. P-12 Pump Test Location Map
(ODNR-DSWR - Unpublished Report 48 September 1969 P-12 Pump Test)

Results from the pumping test indicated that the transmissivity was approximately 1600 gallons per day per foot. The storage coefficient for the well was estimated to be 1×10^{-4}. There were three observation wells (OW-1, OW-2 and OW-3) located at varying distances and directions from the pumping center that were measured over the 24-hour period to monitor the effects of pumping P-12. The location of the observation wells are also shown on Figure 6.

In general, it was noted that data from the P-12 pumping test were hard to interpret and the data showed very little agreement. Much of the disagreement in the data resulted from the dewatering of the aquifer at 65 feet; also, there was some on-going well development during the step test and pumping test. As a result, the well loss coefficient for the well was hard to determine.

2.4 VILLAGE OF WOODVILLE OBSERVATION WELL S-2 GROUND WATER LEVEL FLUCTUATIONS

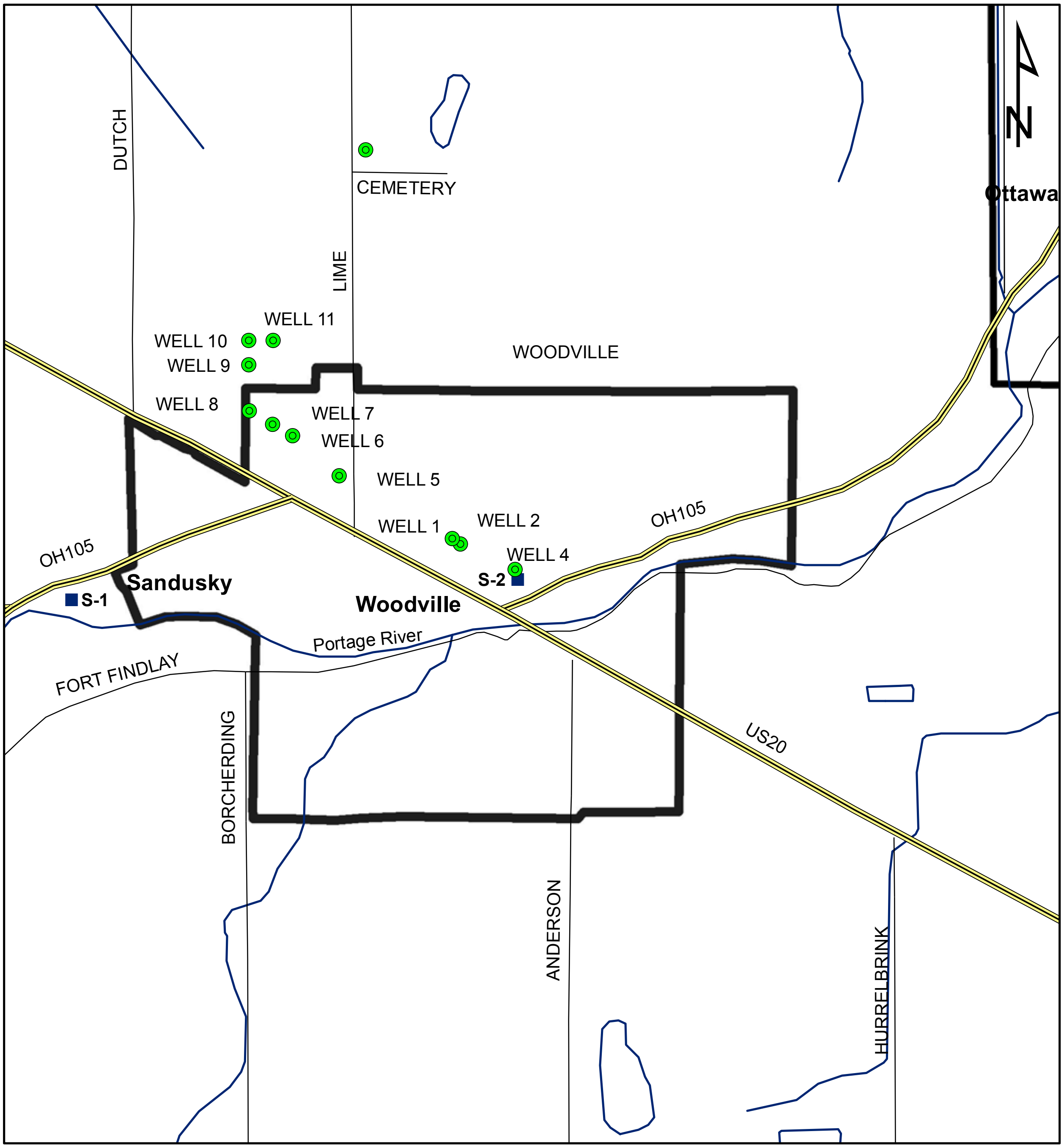
A review of the historic data for the region showed that the village of Woodville operates a well field southwest of the study area. The well field produces water from the carbonate bedrock aquifer. The ODNR-DSWR maintained an observation well (denoted as well S-2) near the Woodville water supply wells. The location of the village of Woodville production wells relative to observation well S-2 is shown on Figure 7. Observation well S-2 is located approximately 150 feet from the closest production well.

A study of the historic ground water levels from the S-2 observation well showed that ground water level data could be used to evaluate local ground water fluctuations in the carbonate bedrock caused by pumping the Woodville water supply wells. Ground water levels from the S-2 well would be similar to the effects caused by pumping high-yielding wells on nearby domestic water supply wells. Therefore, the ground water level data from well S-2 could be used to evaluate the influence of pumping on ground water levels in nearby water supply wells.

Figure 8 shows the water level fluctuation in observation well S-2. Water level data for the well are compared to precipitation data from 1990 to June 12, 2007. These data show that ground water levels can vary from approximately 18 to 59 feet below the land surface despite normal rain fall amounts. This indicates that the pumping associated with the Woodville water supply wells can have an impact on nearby water wells. The ground water fluctuation in well S-2 was 41 feet.

2.5 PUBLIC WATER SUPPLIES IN THE STUDY AREA

Public water systems (PWS) are regulated by the Ohio Environmental Protection Agency, Division of Drinking and Ground Waters (Ohio EPA DDAGW). A public water system is defined as a system that provides water for human consumption to at least 15 service connections or



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pws_wells

Obsevation Wells

Status

Active

Inactive

0 1,000 2,000 4,000 Feet

Map Scale 1:24,000

1 inch = 2,000 feet

Figure 7. Village of Woodville Water Supply Wells (Ohio EPA)

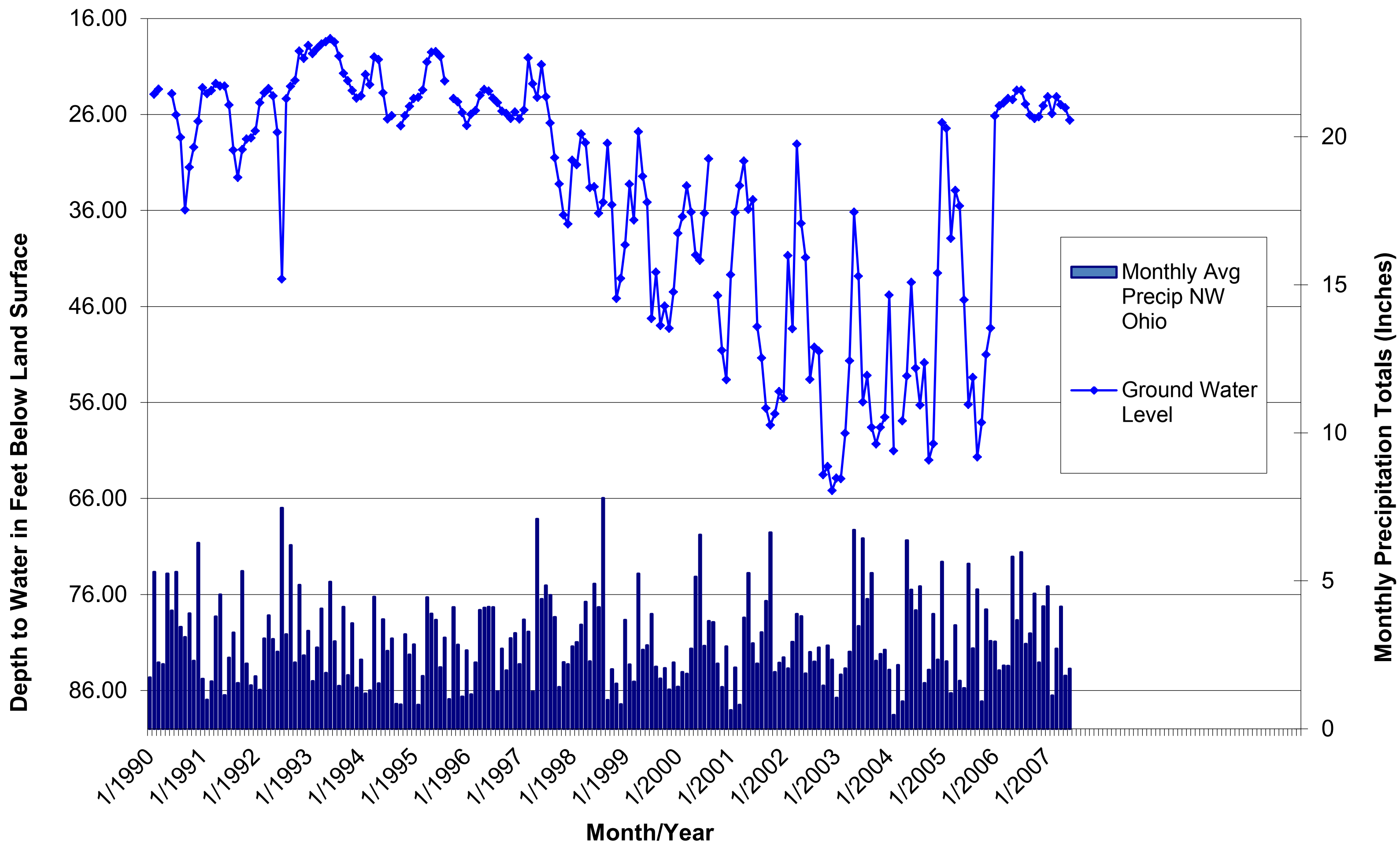


Figure 8. Monthly Average Depth to Water ODNR Observation Well S-2 Woodville, Plotted with Monthly PrecipitationTotals from NW Ohio Climate Region

serves an average of at least 25 people for at least 60 days each year. This includes water used for drinking, food preparation, bathing, showering, and washing dishes. Public water systems range in size from large municipalities to small churches and restaurants that rely on a single well. There are three types of public water systems:

Community water systems serve at least 15 service connections used by year-round residents or regularly serve at least 25 year-round residents. Examples include cities, mobile home parks, and nursing homes.

Nontransient noncommunity systems serve at least 25 of the same persons over six months per year. Examples include schools, hospitals, and factories.

Transient noncommunity systems serve at least 25 different persons over 60 days per year. Examples include campgrounds, restaurants and gas stations. Drinking water systems associated with agricultural migrant labor camps, as defined by the Ohio Department of Agriculture, are regulated even though they may not meet the minimum number of people or service connections.

Public water systems use either a ground water source or a surface water source, including ground water under the direct influence of surface water. In Ohio, approximately 5,340 public water systems serve approximately 11.1 million people daily.

Private water systems are regulated by the Ohio Department of Health. Private water systems are households and small businesses that serve fewer than 25 people per day 60 days out of the year.

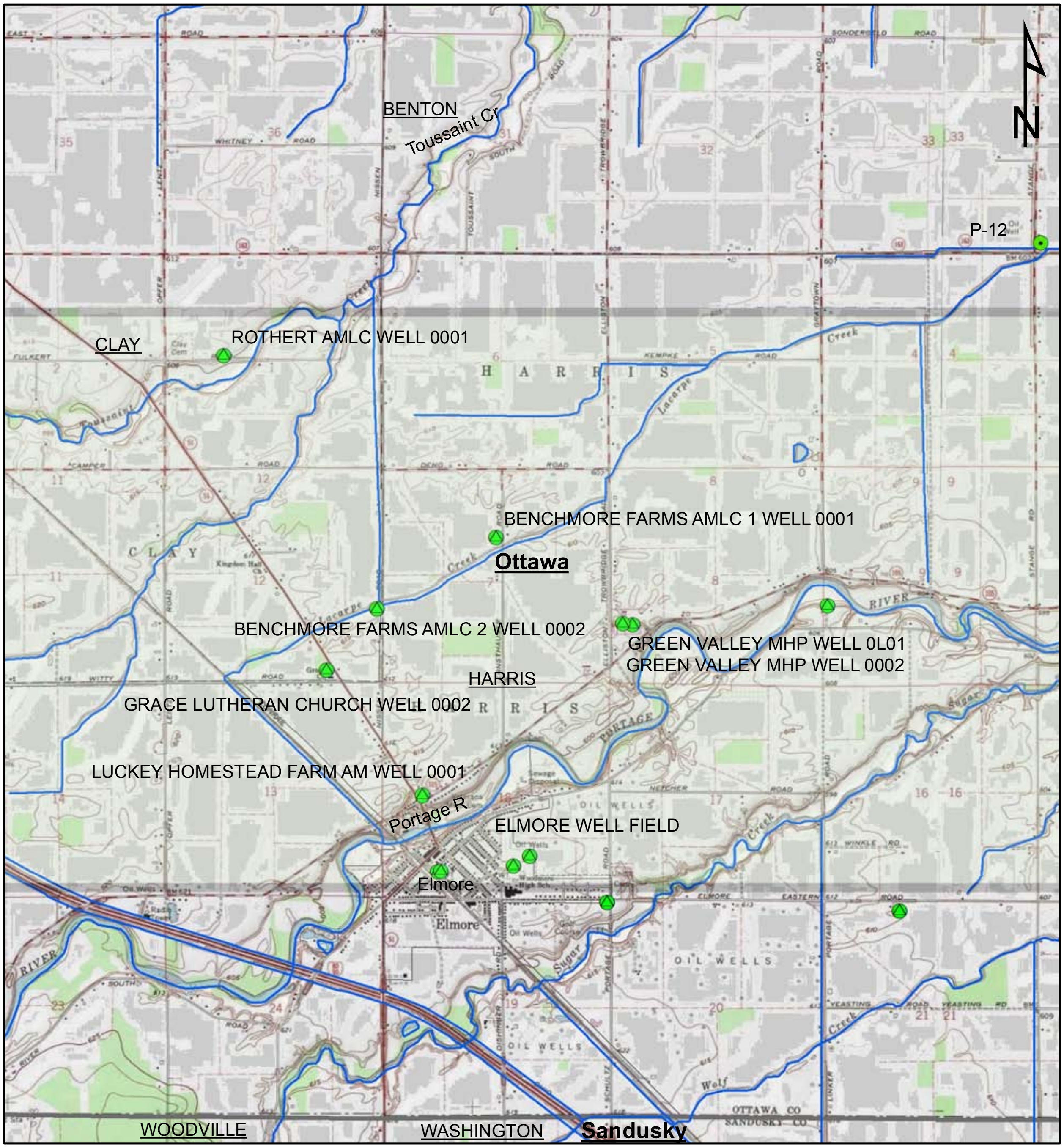
Figure 9 shows the location of the public water supply wells in the study area. These wells are as follows:

- Grace Lutheran Church 0002
- Green Valley Mobile Home Park Well 0001 and 0002
- Benchmore Farms AMLC Well 0001
- Luckey Homestead Farm Well 0001
- Elmore Village Community Water Supply Wells
- Rothert AMLC 0001

2.6 WATER WITHDRAWAL FACILITY REGISTRATION PROGRAM

The Water Withdrawal Facility Registration (WWFR) Program, as established in H.B. 662 by the Ohio General Assembly in 1988, implements one of the objectives of the Great Lakes Charter in Ohio. The Great Lakes Charter serves as a good-faith agreement among governors and premiers of the Great Lakes states and provinces to establish a regional approach to Great Lakes water resource management programs. The regional approach will strengthen the states' effort to protect and better manage such a vital resource in this water-rich Great Lakes Region.

The Charter recognized the need for good water resource data as fundamental to water resource planning, management, and protection. The recommendation to create a water



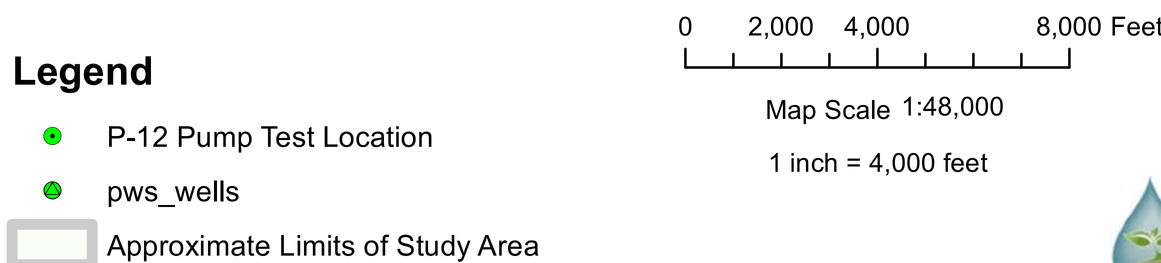


Figure 9. Public Water Supply Well Locations (Ohio EPA)

withdrawal facility registration program resulted because many states and provinces did not have the necessary authority to collect such data.

The drought of 1988 raised many concerns about water use and management in Ohio. Many communities and businesses sought alternative water sources to supplement depleted supplies. Also, conflicts and questions arose in the competition for a limited water resource. The state did not have adequate information to assist everyone seeking additional water. Without the knowledge of water withdrawals in an area, state officials risked referring water withdrawers to a source of water already limited by current demands.

Section 1521.16 of the Ohio Revised Code requires any owner of a facility, or combination of facilities, with the capacity to withdraw water at a quantity greater than 100,000 gallons per day (gpd) to register such facilities with the ODNR Division of Soil and Water Resources. The WWFR Program will provide information of great importance to the citizens of the state. Water, one of our most basic and precious natural resources, needs to be studied more intensely and water resource planners need reliable information to plan for the future. The state's economy depends on water and economic development will continue to place increased demands on this critical resource (ODNR-DSWR website).

The ground water stress area legislation, signed in April of 1990, gave the Chief of the Division of Water (now the Division of Soil and Water Resources) the authority to designate an area as a ground water stress area and establish a threshold withdrawal capacity lower than 100,000 gpd for the area in terms of water withdrawal registration. Any person who withdraws water at a rate greater than a specified threshold (for example, 10,000 gpd) in a ground water stress area would be required to register the facility with the Chief. Registration is not intended to regulate use of ground water, but only to gather additional information for resolving conflicts and guiding or advising new users. Annual reports must also be submitted for these facilities. There are currently no ground water stress areas designated in Ohio.

The ground water facilities registration forms can be found on the ODNR-Division of Soil and Water Resources website at:

http://www.dnr.state.oh.us/water/tabid/20441/Default.aspx#WWFR%20Forms

3.0 Methods of the Investigation

Prior to implementing this project, the ODNR-DSWR reviewed the Ohio Revised Code concerning ground water supply development in Ohio. Standard hydrogeological as well as engineering practices were used to carry out all fieldwork and data analysis (Bair and Lahm, 2006; Driscoll, 1986; Fetter, 2001; Kruseman and deRidder, 1990; Merritt, 1983).

A partial glossary has been attached at the end of this report for those who are not familiar with the subject matter. The reader can refer to the Encyclopedic Dictionary of Hydrogeology by Poehls and Smith (2009) for further reference.

3.1 ODNR WEBSITE SEARCH

As part of the investigation, the ODNR-DSWR conducted a search of the water well record database for Ottawa County, Harris Township to identify the number of domestic water wells within the study area (ODNR-DSWR website, 2011). The records show that approximately 600 wells have been drilled in Harris Township since the late 1940’s. Items identified in the database are the ODNR well log number, original owner of the well, well depth, test rate, static water level and aquifer type. Figure 10 shows the location of 155 wells with known coordinates within the study area.

Data for the 155 wells are as follows:

(1) All of the wells drilled in the area are completed in the carbonate bedrock aquifer

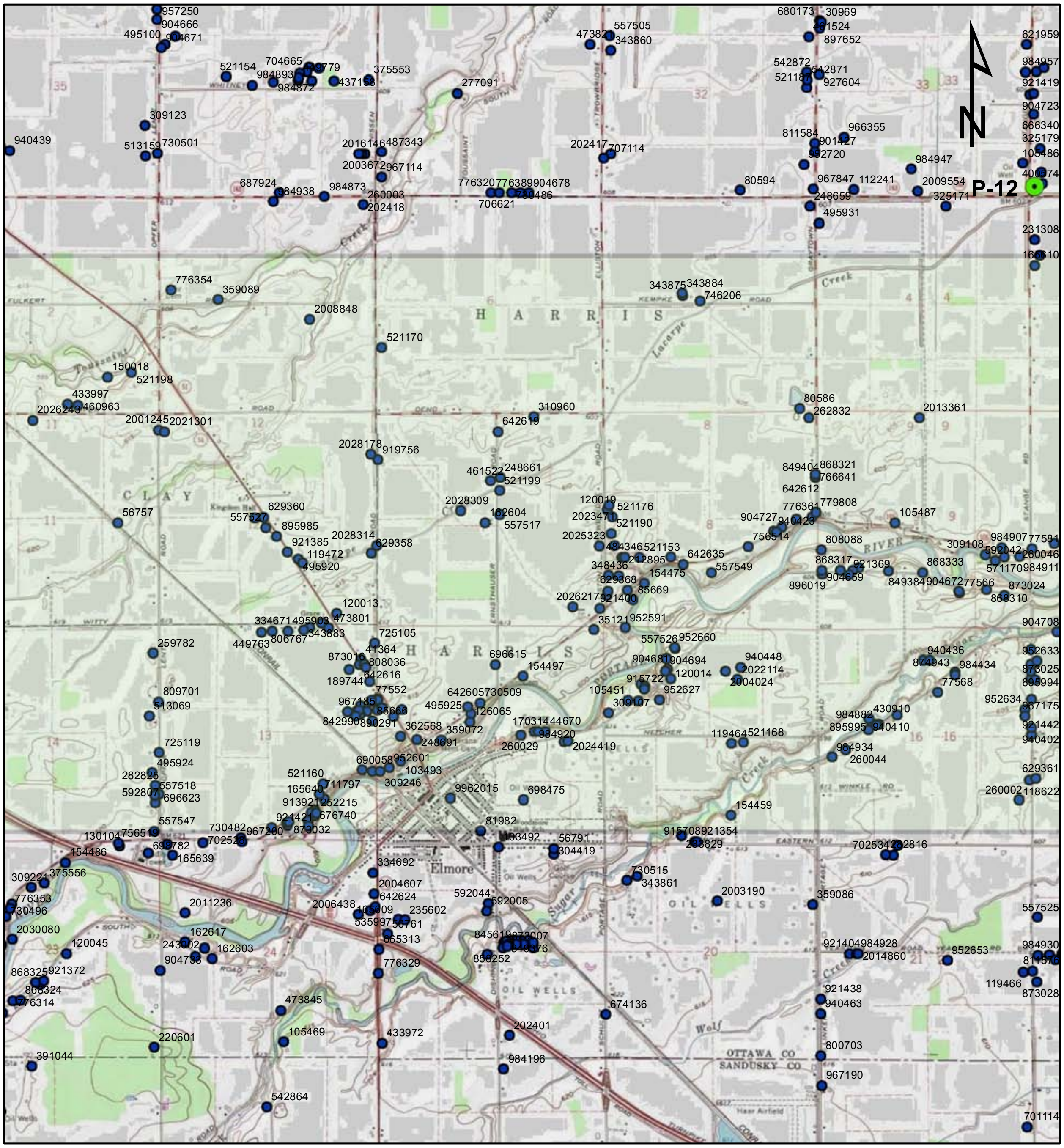
(2) Well depths range from 34 to 276 feet below the land surface with an average well depth of 84 feet

(3) Pumping rates vary from 1 to 60 gpm with an average pumping rate of 18 gpm

(4) Static water levels in the wells vary from 8 to 50 feet below the land surface with an average static water level of 27 feet

Ground water recharge and movement in the subsurface typically occur through the glacial till and migrate to deeper levels in the carbonate bedrock aquifer along fracture patterns within the bedrock.

All database water wells were evaluated to select the most appropriate data points for use in the study. A print-out of the ODNR well log database for the 155 wells in the study area is presented in Appendix A.



USGS: Genoa, Oak Harbor, Elmore, Lindsey

0 2,000 4,000 8,000 Feet

Map Scale 1:48,000

1 inch = 4,000 feet

Legend

Approximate Limit of Study Area

Water Well Locations

P-12 Pump Test Location

Figure 10. Water Supply Well Locations in the Ottawa County Study Area (ODNR-DSWR)

3.2 HIGH-YIELDING WATER WELL COMPLETION DETAILS

The first step in the study was to define the limits of the study area using the location of the irrigation wells. Figure 11 shows the location of the five high-yielding water wells identified in the Ottawa County, Harris Township study area. Information about each well is listed in Table 1. These wells are located north of the Portage River. The study area is defined between State Route 163 to the north, the Portage River to the south, Martin-Williston Road to the west, and State Route 590 to the east.

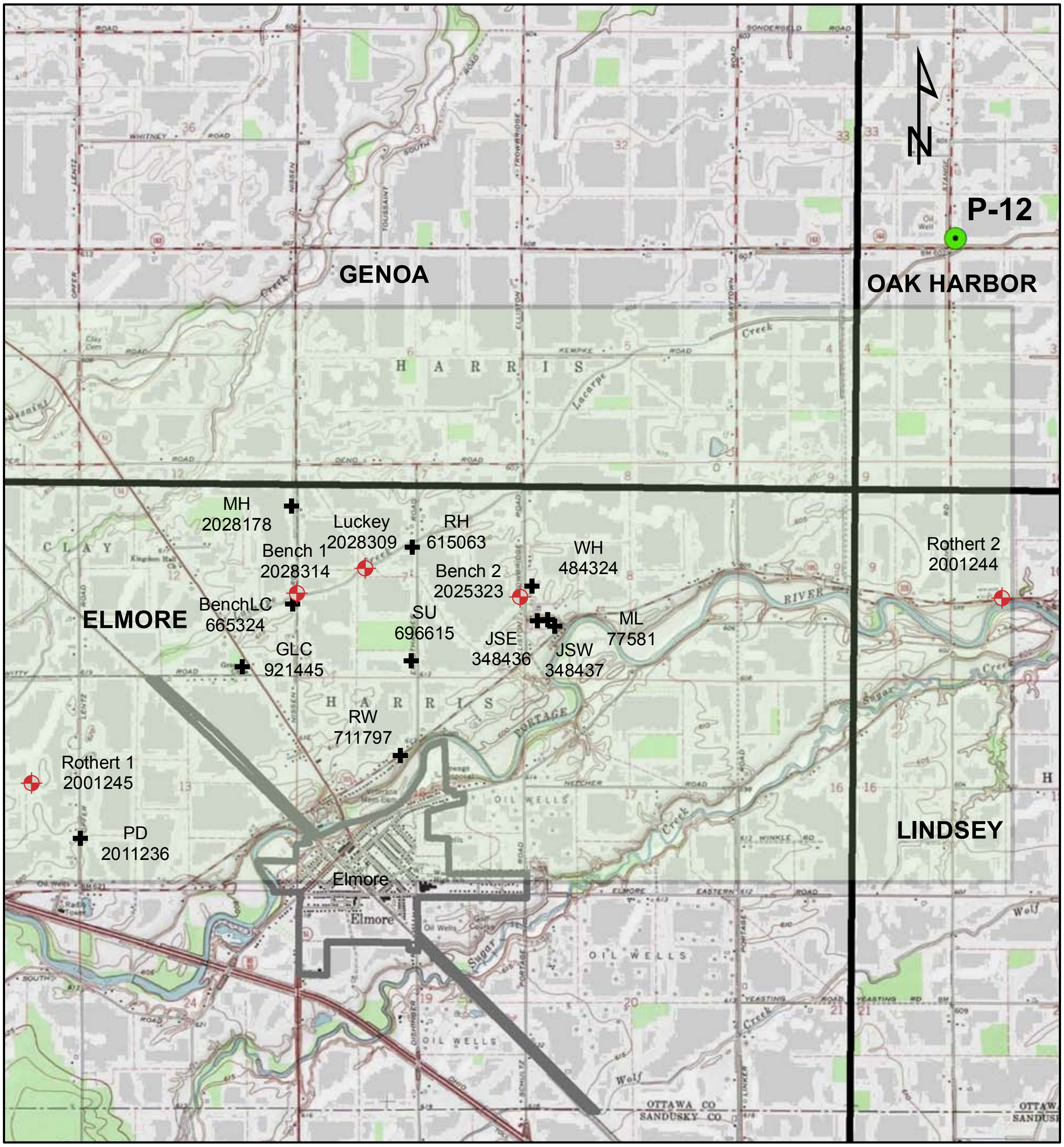
Individual well completion diagrams for the irrigation wells are shown on Figures 12 through 16. These data show the individual well completion for each of the five high-yielding wells identified in the study area. The original well logs can be found in Appendix B.

Table 1. High-yielding farm irrigation wells, Ottawa County, Harris Township

Well-Log No.	Well Symbol	Latitude	Longitude	Well Depth (feet)	Test Rate (gpm)	Casing Length (feet)	Pump Capacity (gpm)	Surface Elevation (feet amsl)	Static Water Level (feet)
2028314	Bench1	41.49241	-83.30023	400	300	100	225	609	37
2025323	Bench2	41.49258	-83.28003	420	300	100	225	609	34
2028309	Luckey	41.49443	-83.29392	350	300	54	150	610	36
2001245	Rothert1	41.47969	-83.32365	345	240	98	225	618	30
2001244	Rothert2	41.49278	-83.23667	365	280	100	225	597	31

3.3 WATER WELLS USED TO MEASURE THE EFFECTS OF PUMPING THE HIGH-YIELDING WATER WELLS

Once the study area was defined, observation wells were selected from the available water wells. Each homeowner was approached to gain permission to monitor the water level in their well. Water well records used for this investigation are presented in Appendix C. Figure 11 also shows the locations of water wells in the study area that were used for monitoring purposes. Data regarding these water wells is shown in Table 2.



USGS: Genoa, Oak Harbor, Elmore, Lindsey

0 2,500 5,000 10,000 Feet

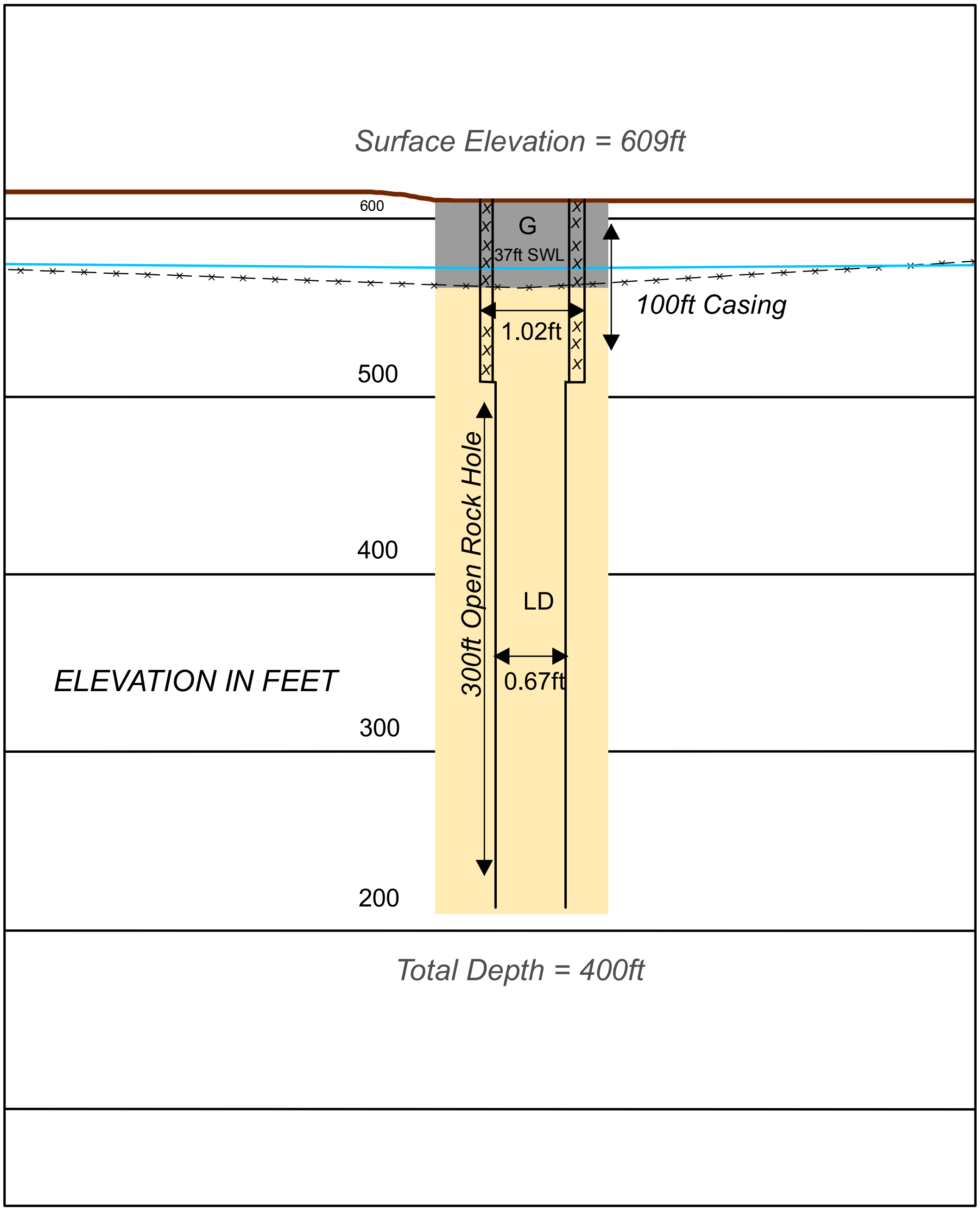
Map Scale 1:48,000

1 inch = 4,000 feet

Legend

- Domestic Well
- Irrigation Well
- Approximate Limit of Study Area
- P-12 Pump Test Location

Figure 11. Irrigation and Water Supply Wells Locations Used to Monitor Ground Water Levels in the Carbonate Bedrock Aquifer



Legend

Geology

G: Glacial Till

LD: Lockport Limestone and Dolomite

Bentonite Grout

Original Static Water Level (SWL)

Top of Rock

500 Elevation Gridline

Surface

Scale

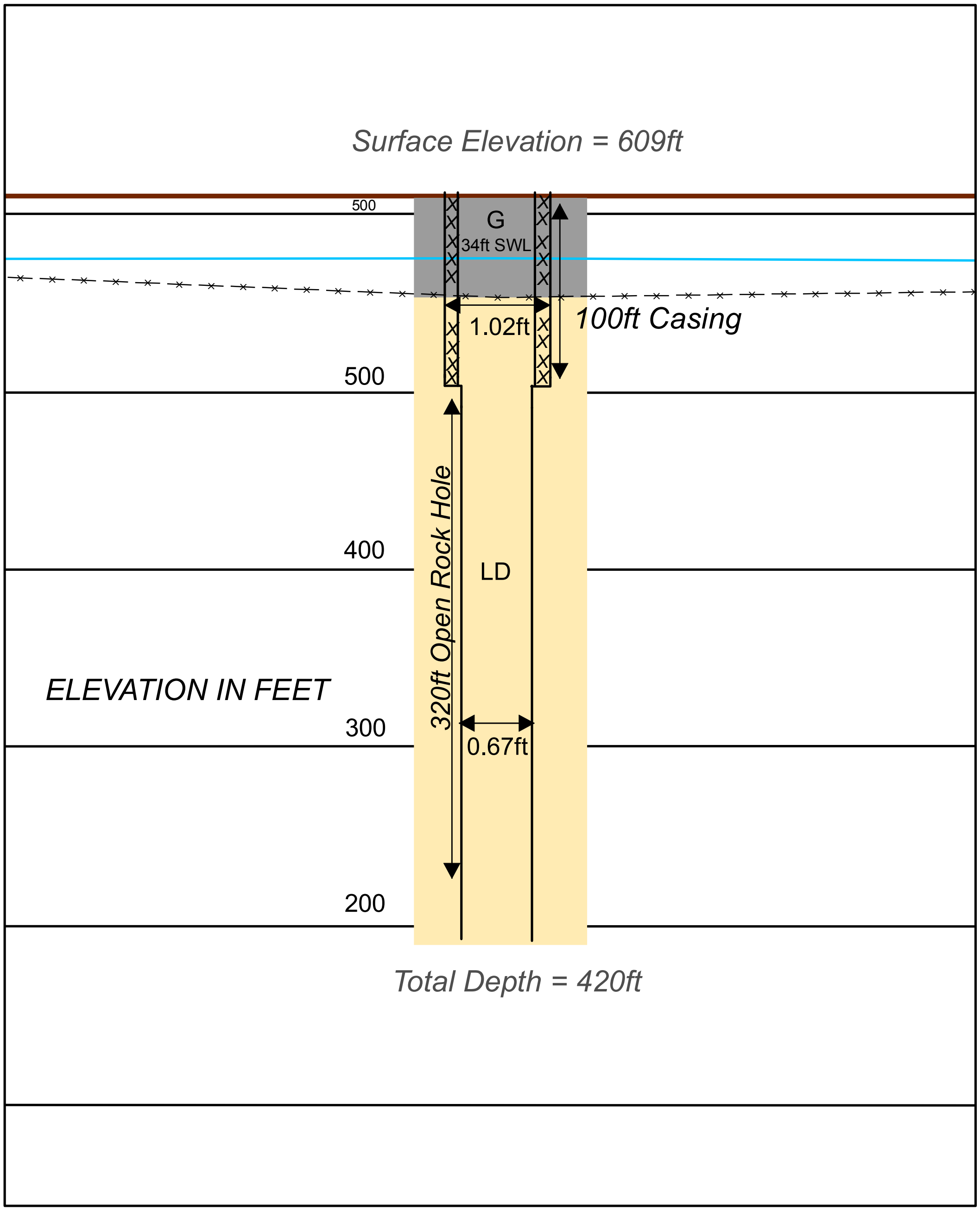
Verticle: 1in = 100ft

Horizontal: None

Well diagram exaggerated

Figure 12. Bench 1 Irrigation Well Completion Diagram
ODNR Well Log Number 2028314

Cartography by:
Bobby Baker
December, 2011



Legend

Geology

G: Glacial Till

LD: Lockport Limestone and Dolomite

Bentonite Grout

Original Static Water Level (SWL)

Top of Rock

500 Elevation Gridline

Surface

Scale

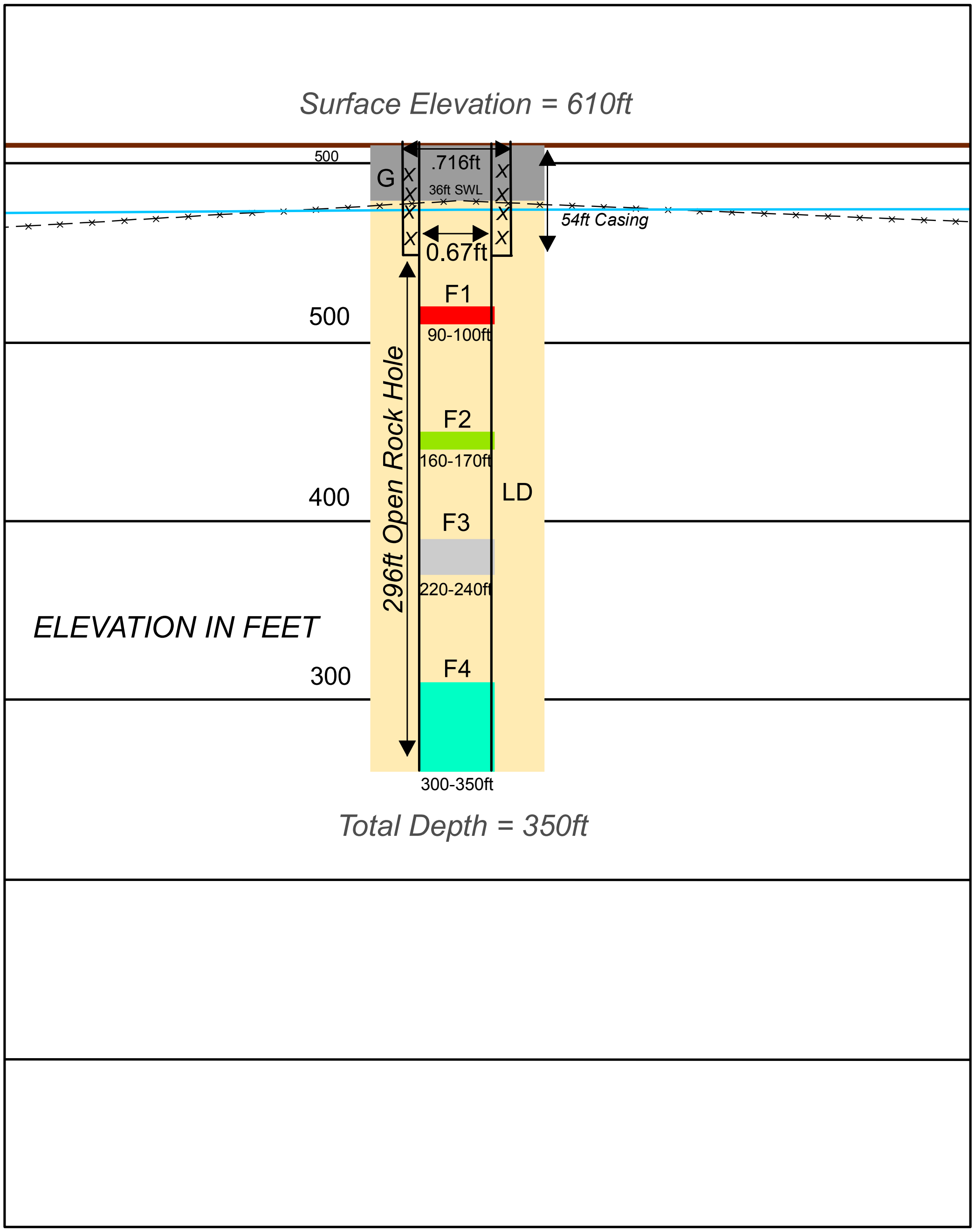
Verticle: 1in = 100ft

Horizontal: None

Well diameter exaggerated

Figure 13. Bench 2 Irrigation Well Completion Diagram
ODNR Well Log Number 2025323

Cartography by:
Bobby Baker
December, 2011



Legend

Geology
- G: Glacial Till
- LD: Lockport Limestone and Dolomite
- Bentonite Grout
- F1: Flowzone 1, 25 GPM
- F2: Flowzone 2, 50 GPM
- F3: Flowzone 3, 75 GPM
- F4: Flowzone 4, 150 GPM

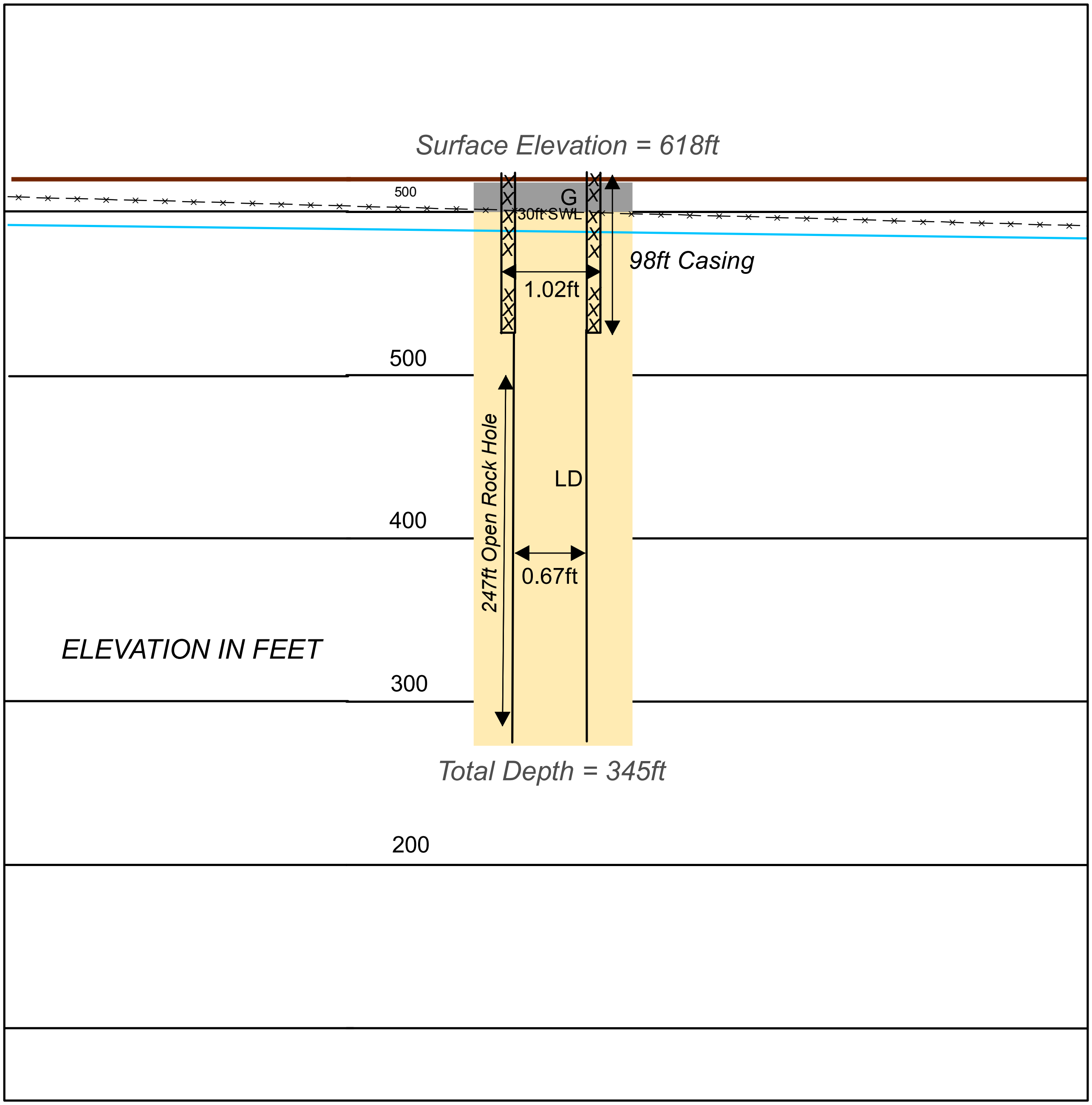
- Original Static Water Level (SWL)
- Top of Rock
- 500 Elevation Gridline
- Surface

Scale
Verticle: 1in = 100ft
Horizontal: None

Well diameter exaggerated

Figure 14. Luckey Irrigation Well Completion Diagram
ODNR Well Log Number 2028309

Cartography by:
Bobby Baker
December, 2011



Legend

Geology

G: Glacial Till

LD: Lockport Limestone and Dolomite

Bentonite Grout

Original Static Water Level (SWL)

Top of Rock

500 Elevation Gridline

Surface

Scale

Verticle: 1in = 100ft

Horizontal: None

Well diameter exaggerated

Figure 15. Rothert 1 Irrigation Well Completion Diagram
ODNR Well Log Number 2001245

Cartography by:
Bobby Baker
December, 2011

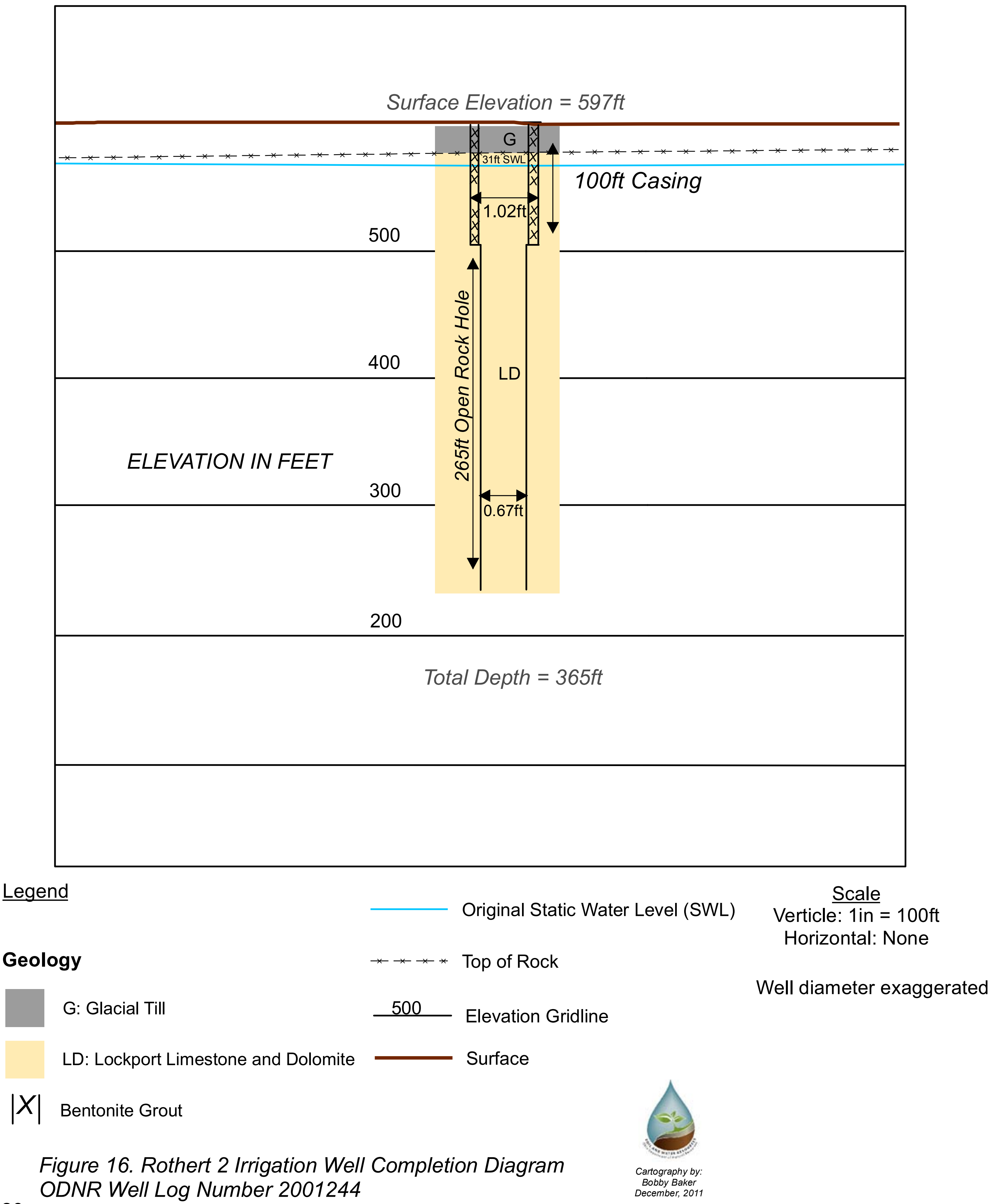


Figure 16. Rothert 2 Irrigation Well Completion Diagram
ODNR Well Log Number 2001244

Table 2. Water supply wells monitored during this study, Ottawa County, Harris Township

Well-Log No.	Well Symbol	Latitude	Longitude	Well Depth (feet)	Test Rate (gpm)	Casing Length (feet)	Pump Capacity (gpm)	Surface Elevation (feet amsl)	Static Water Level (feet)
665324	BLC	41.49196	-83.30043	125	20	59	-	609	27
921445	GLC	41.4877	-83.30492	165	45	47	-	615	40
348436	JSE	41.49105	-83.27746	55	20	48	-	603	28
348437	JSW	41.49098	-83.27843	67	20	48	-	602	28
2028178	MH	41.49857	-83.3006	142	15	61.9	12	614	46
77581	ML	41.49067	-83.27689	50	0	30	-	605	13
2011236	PD	41.475997	-83.31934	102	12	27	12	619	26
615063	RH	41.49588	-83.28972	55	12	53	-	609	26
711797	RW	41.481776	-83.29059	99	10	49	-	611	46
696615	SU	41.48819	-83.28965	62	20	51	-	606	35
484324	WH	41.49329	-83.27894	73	16	57	-	609	20

3.4 FIELD MEASURMENTS FOR 6-MONTH OBSERVATIONS

Base line ground water data on each of the high-yielding and selected water supply wells was obtained prior to irrigation season. A monitoring well network was set up (Sanders, 1998). The *State of Ohio Technical Guidance for Well Construction and Ground Water Protection Manual* was consulted along with the *Midwest Planning Service Private Water System Handbook*. Ground water level measurements were obtained on a monthly basis from May through September 2011. Field data showing the water level measurements are presented in Appendix D.

3.5 PUMP TEST P-12 DATA ANALYSIS METHODS

The previous work on the carbonate bedrock aquifer was done by the ODNR-Division of Water during the late 1960s and early 1970s. Based on a study, it was found that well P-12 was located within the Ottawa County study area. The locations of the pumping and observation wells are shown on Figure 6. The well completion diagram is shown on Figure 17.

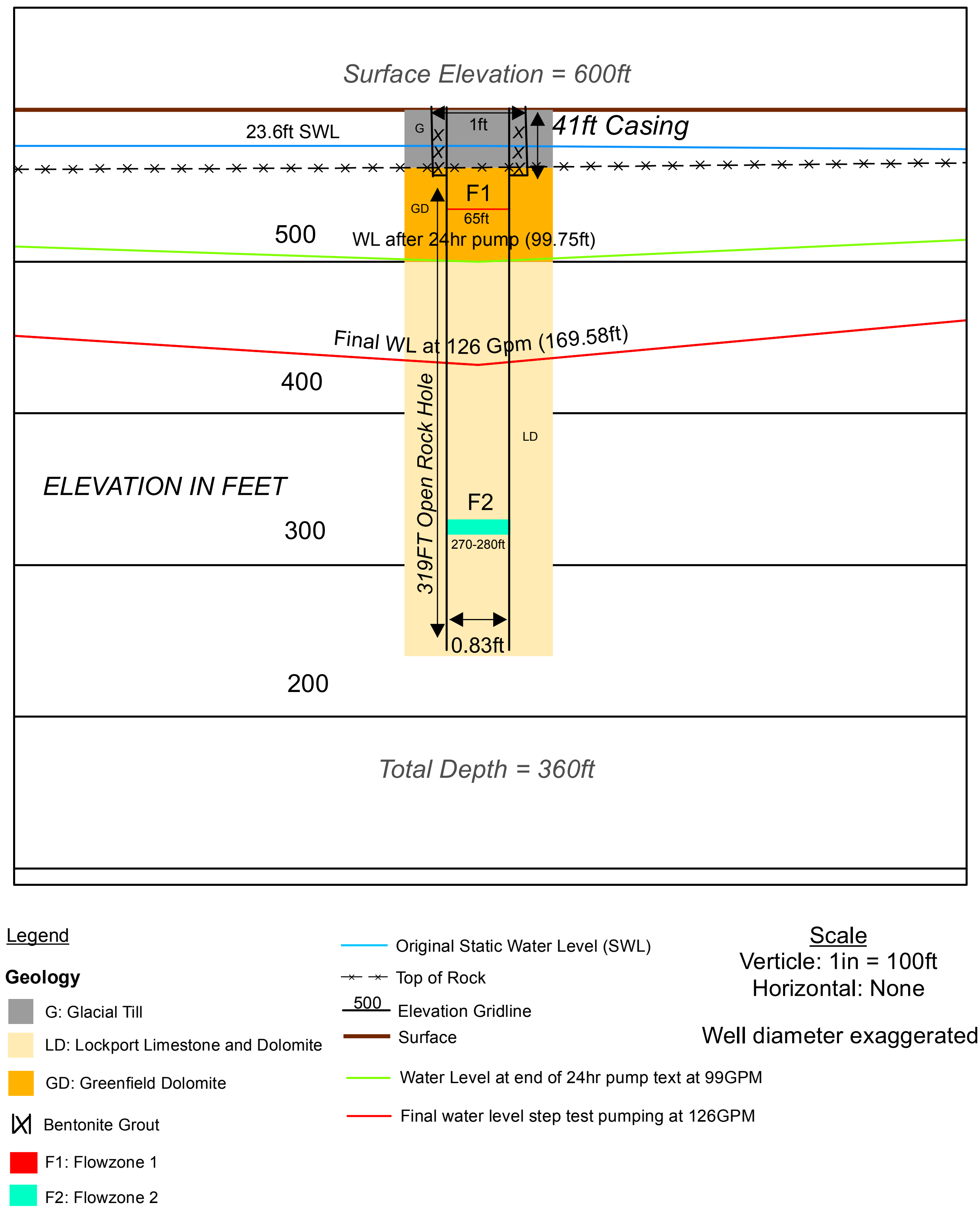


Figure 17. P-12 Well Completion Diagram

Cartography by:
Bobby Baker
December, 2011

Modified from:
ODNR unpublished report number 48
October, 1969

The ground water hydraulics calculations for well P-12 were originally done manually. A new analysis of these data was performed by using the latest analysis methods and computer technology. AQTESOLV version 4.5 was selected as the aquifer analysis method of choice (Duffield, 2007). AQTESOLV pump test data analyses are available upon request.

3.6 IMPACT ASSESSMENT

Once the field data was obtained, an impact assessment was done to evaluate the impact that the irrigation wells were having on the local water supply wells. This was done by using the field data as a guideline for calibration of the **WellZ** computer model (Schwartz and Zhang, 2002). This computer model was used to assess the well interference effect that the irrigation wells would have over a period of time on the nearby domestic water wells. An interval of 14-days was used for the **WellZ** computer model because that was the length of time that Bench 1 and Bench 2 irrigation wells were in operation during early July. The data results from the **WellZ** computer modeling can be found in Appendix E.

4.0 FIELD INVESTIGATION RESULTS

To evaluate the subsurface conditions under the study area, cross sections, ground water gradient maps, and hydrographs were drawn to represent the data. The important trends in the data are presented for review.

4.1 SITE HYDROGEOLOGY OF THE STUDY AREA

Figure 18 represents a hydrogeological cross section drawn through the study area. Shown on the cross section is the stratigraphic section for each well relative to sea level. Shown on the cross section for each well is the:

- Top of bedrock
- Thickness of the glacial till over the bedrock
- Depth to water in each well that was measured on July 14, 2011

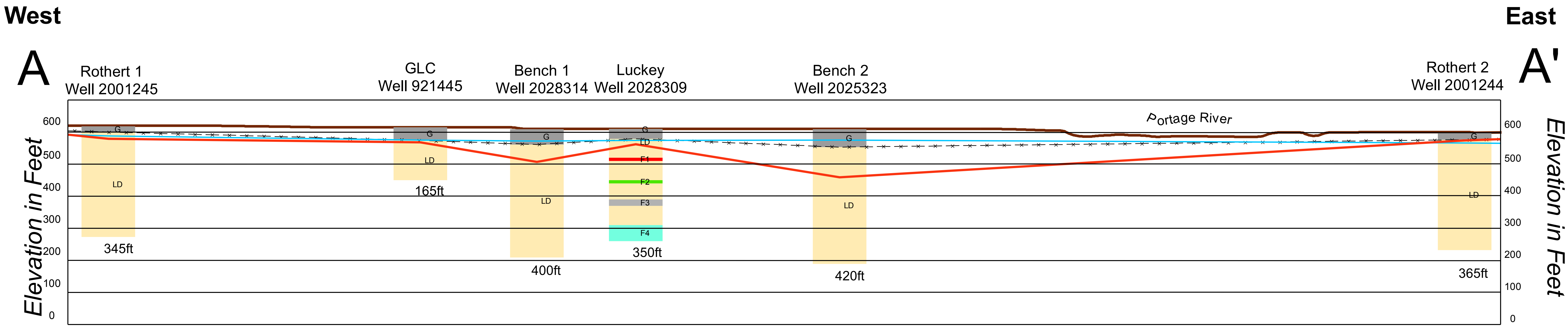
It is important to note that in the Luckey well, four flow zones were noted by the well driller at the time the well was drilled (Figure 14). These flow zones are important because they show precisely from where in the well the subsurface water is produced. Both the thickness and flow rate for each flow zone as estimated and measured by the driller are as follows;

- Uppermost flow zone occurred at a depth between 90 to 100 feet and produced 25 gpm
- Second flow zone occurred at a depth 160 to 170 feet and produced 50 gpm
- Third flow zone occurred at a depth of 220 to 240 feet and produced 75 gpm
- Fourth flow zone occurred at 300 to 350 feet and produced 150 gpm

The flow rate for the entire well was estimated to be 300 gpm. It is also important to note that these flow zones were not noted on the drilling logs for the Bench 1 and 2 wells or the Rothert 1 and 2 wells.

The cross section shows the carbonate bedrock aquifer is actually one hydrogeologic unit from the base of the glacial till to the top of the Rochester Shale. The cross section also reveals the importance of measuring the thickness and flow rate from each zone encountered in the well bore during drilling. Ground water recharge, as well as ground water yield, is controlled by ground water flow through both the vertical and horizontal fracture flow system.

Hydrogeological Cross Section A-A'



Legend

Geology

G: Glacial Till

LD: Lockport Limestone and Dolomite

Ground Water Level: July 14th 2011

Original Static Water Level

Top of Rock

500 Elevation in Feet

Surface

Luckey Well

Flow Zones

F1: 25 GPM

F2: 50 GPM

F3: 75 GMP

F4: 150 GPM

Scale

Vertical: 1in = 300ft
Horizontal: 1in ≈1800ft

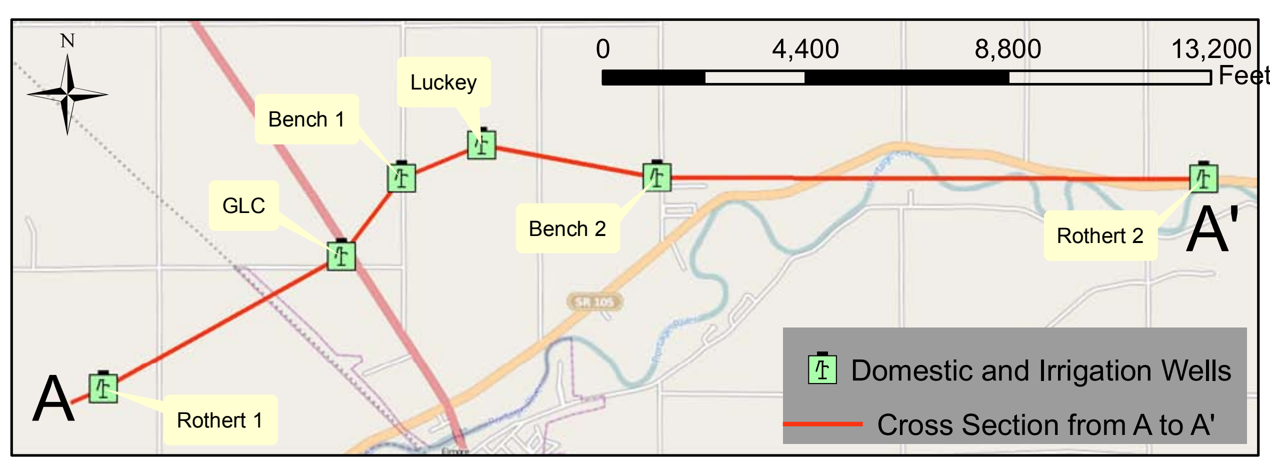


Figure 18
Hydrogeological Cross Section
A-A'
West -East

Cartography by:
Bobby Baker
December, 2011

4.2 RESULTS OF THE GROUND WATER LEVEL MEASUREMENTS FOR MAY THROUGH SEPTEMBER 2011

Figure 11 shows locations of the irrigation wells and the water supply wells used to evaluate ground water levels in the subsurface during these investigations. The field work to set up the monitoring locations for the wells was completed during May 2011. Field measurements were obtained on June 15, July 14, July 20, August 9, and September 9, 2011.

4.2.1 Ground Water Elevation Levels for June 15, 2011

Figure 19 represents a map showing the ground water elevations measured on June 15, 2011. These data were obtained prior to the pumping of the wells for irrigation purposes. As a result, these data represent background conditions prior to pumping the high-yielding wells for irrigation purposes. The only active pumping wells were the domestic water wells.

These data are consistent with the regional ground water flow gradient mapped by Haiker, 2009 and Crist, 2006 and shown in Figure 5. The ground water flow gradient is generally to the northeast in the direction of Lake Erie. In the study area, the one notable exception is that locally the ground water discharges to the Portage River. Only minor changes to the natural ground water flow patterns are noticeable near the domestic water supply wells designated as RW, SU, JSE, and JSW in Table 2. Any change in ground water levels from pumping the water supply wells does not noticeably alter the natural regional ground water flow gradient.

4.2.2 Ground Water Elevation Levels for July 14, 2011

Figure 20 represents a map showing ground water elevations as measured on July 14, 2011. These data were obtained when both the Bench 1 and Bench 2 irrigation wells were pumping at a rate of approximately 200 gpm each. The Luckey and Rothert 1 and 2 wells were turned off and not pumping at the time the water level measurements were taken. The Luckey well had been on earlier in the month but had been off for four days prior to these measurements.

The cone of depression for both the Bench 1 and 2 wells is shown on the map along with the regional ground water flow pattern. The general ground water flow gradient in the region is similar to the ground water flow for June 15, 2011. However, it should be noted that the ground water discharge to the Portage River has been reversed and the new ground water flow gradient is now toward the Bench 1 and 2 irrigation wells.

4.2.3 Ground Water Elevation Levels for July 20, 2011

Figure 21 represents a map showing the ground water elevation as measured on July 20, 2011. The irrigation wells were not in use. As a result, the ground water levels had recovered. The ground water flow patterns had almost recovered and returned to their pre-

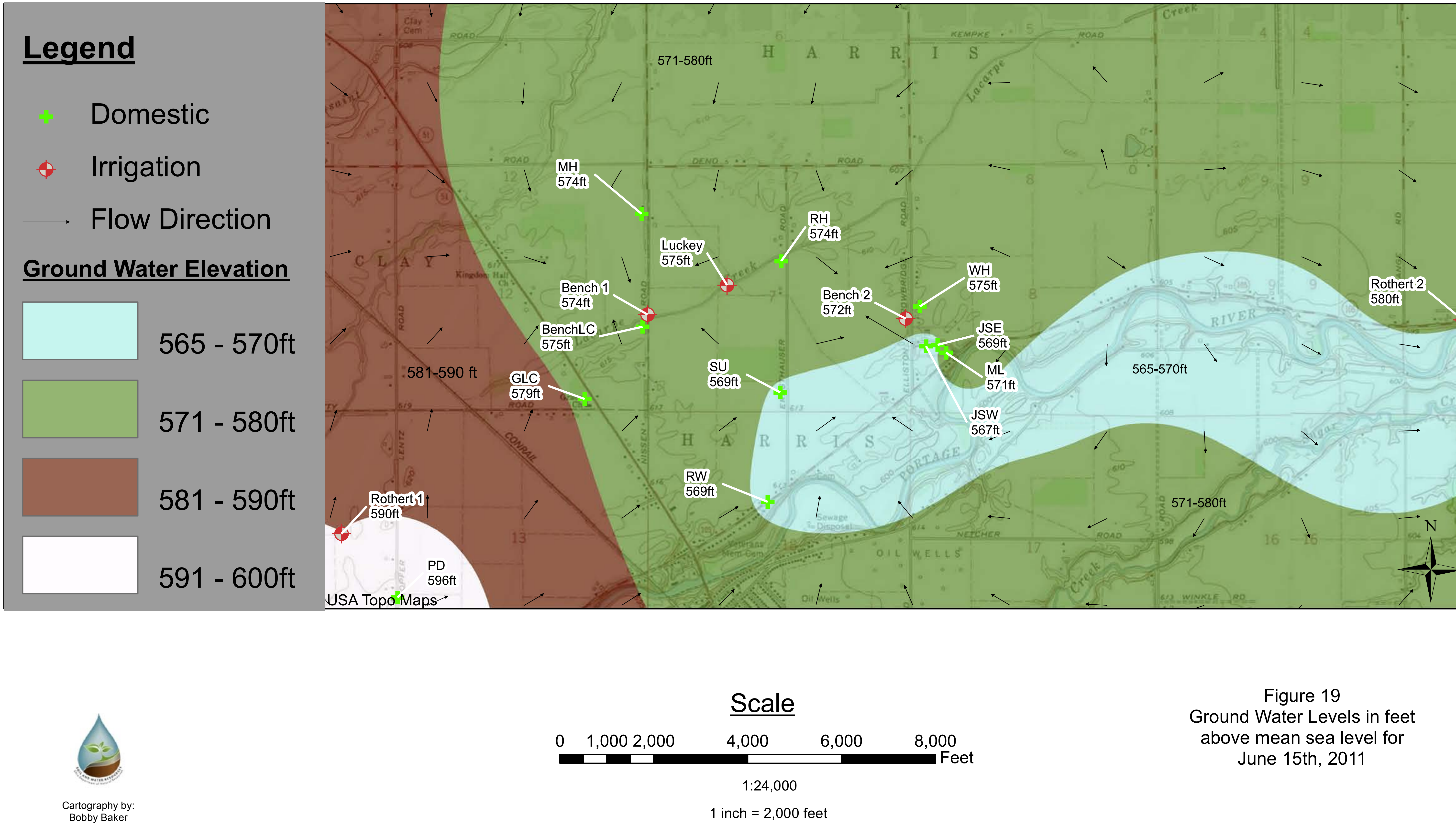
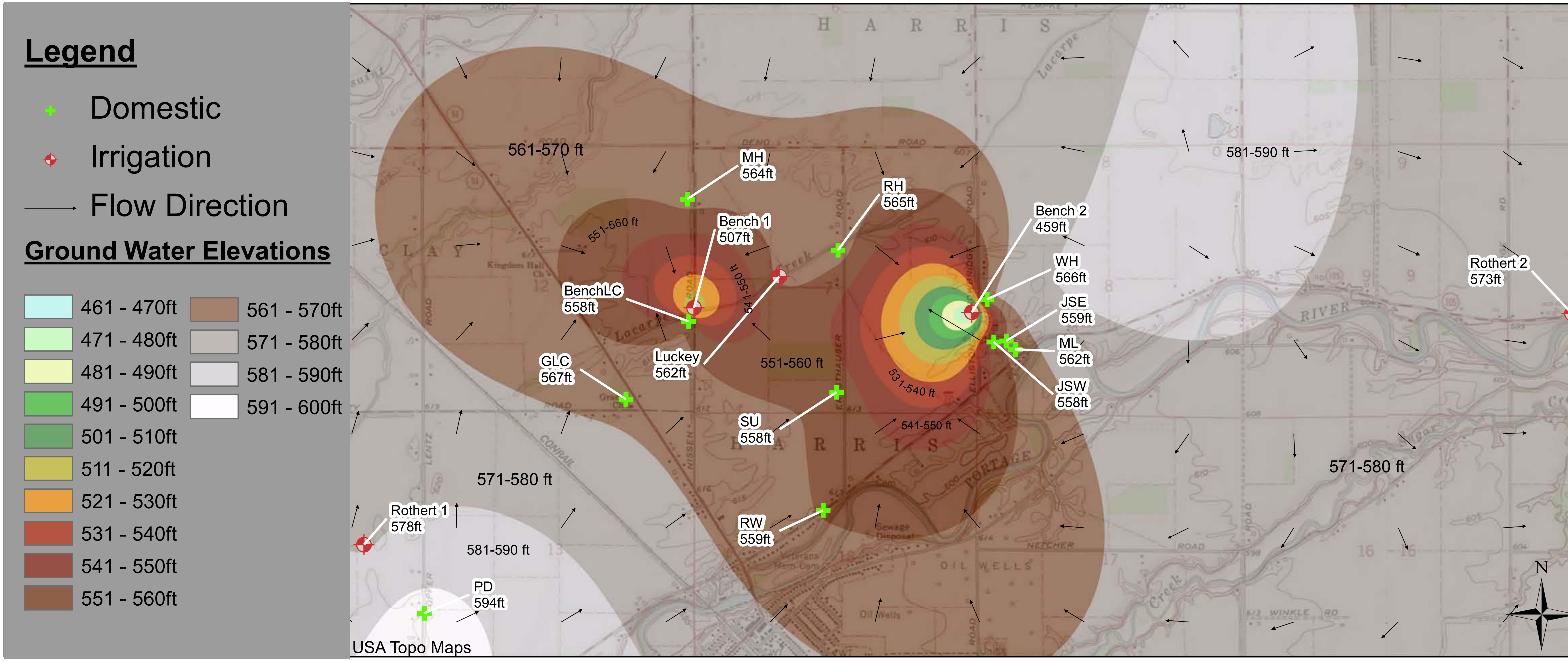


Figure 19
Ground Water Levels in feet above mean sea level for June 15th, 2011

Cartography by:
Bobby Baker
March, 2012



Scale

0 1,000 2,000 4,000 6,000 8,000 Feet

1:24,000

1 inch = 2,000 feet

Figure 20
Ground Water Levels in feet above mean sea level for July 14, 2011

Cartography by:
Bobby Baker
March, 2012

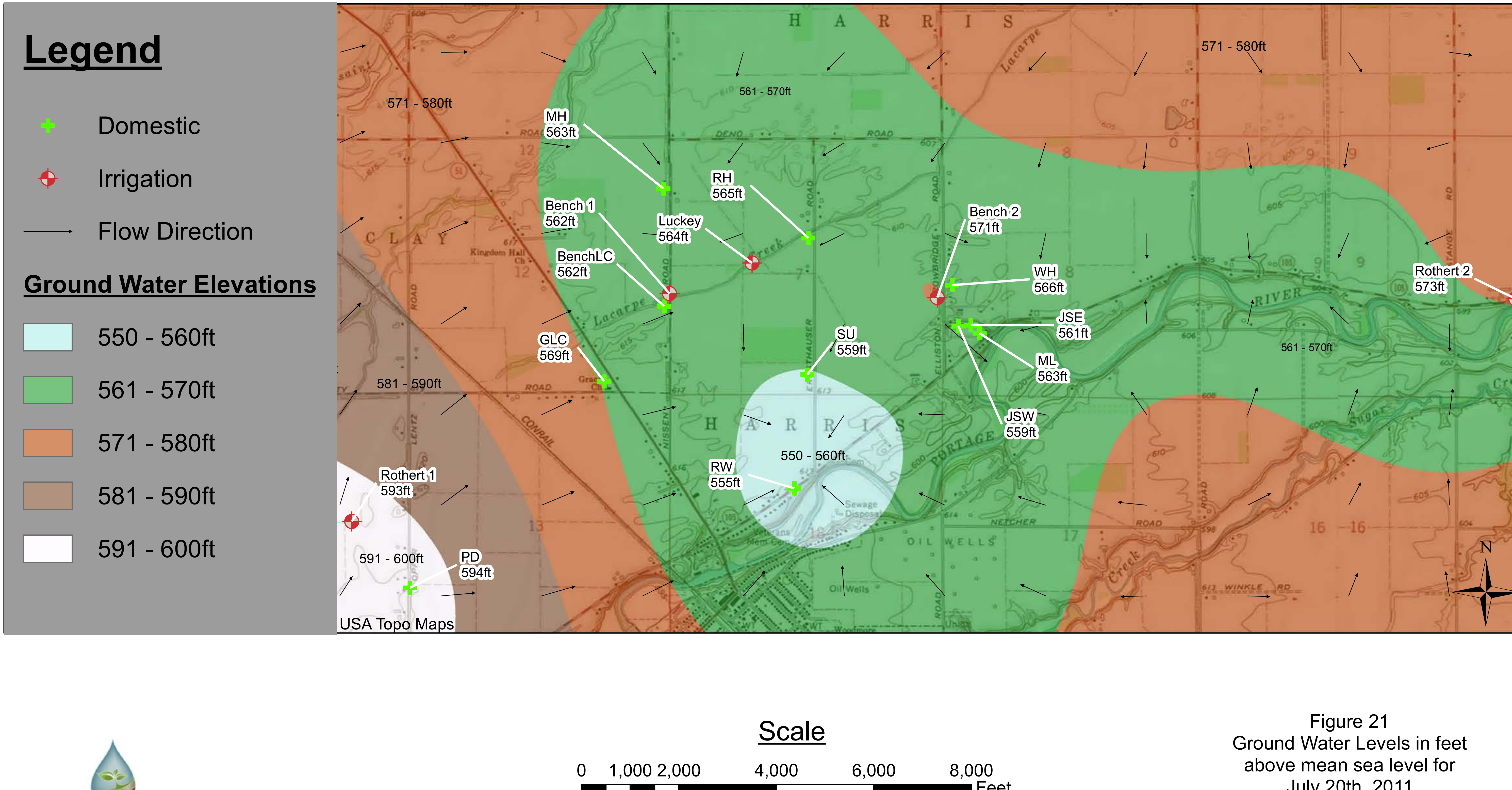


Figure 21
Ground Water Levels in feet
above mean sea level for
July 20th, 2011

Cartography by:
Bobby Baker
March, 2012

pumping water levels established on June 15, 2011. The only well having an influence on the ground water pattern appears to be well RW.

4.2.4 Ground Water Elevation Levels for September 9, 2011

Figure 22 presents a map showing the ground water elevation as measured on September 9, 2011. These data confirm the regional ground water flow pattern that was measured on June 15, 2011 as well as July 20, 2011 with the general flow pattern of discharge to the Portage River. The ground water data show some minor influences from the pumping of the mobile home park (JSE and JSW) and the domestic water supply wells RW and SU.

4.3 HYDROGRAPHS OF THE IRRIGATION AND WATER SUPPLY WELLS

Hydrographs were developed for each of the wells to depict the ground water levels in the irrigation and domestic water wells with time. For reasons of clarity, the irrigation water levels were separated from the other water wells. Ground water levels measured in the irrigation wells are shown in Figure 23 and data for the domestic water wells are shown in Figure 24. Individual hydrographs for each well can be found in Appendix D.

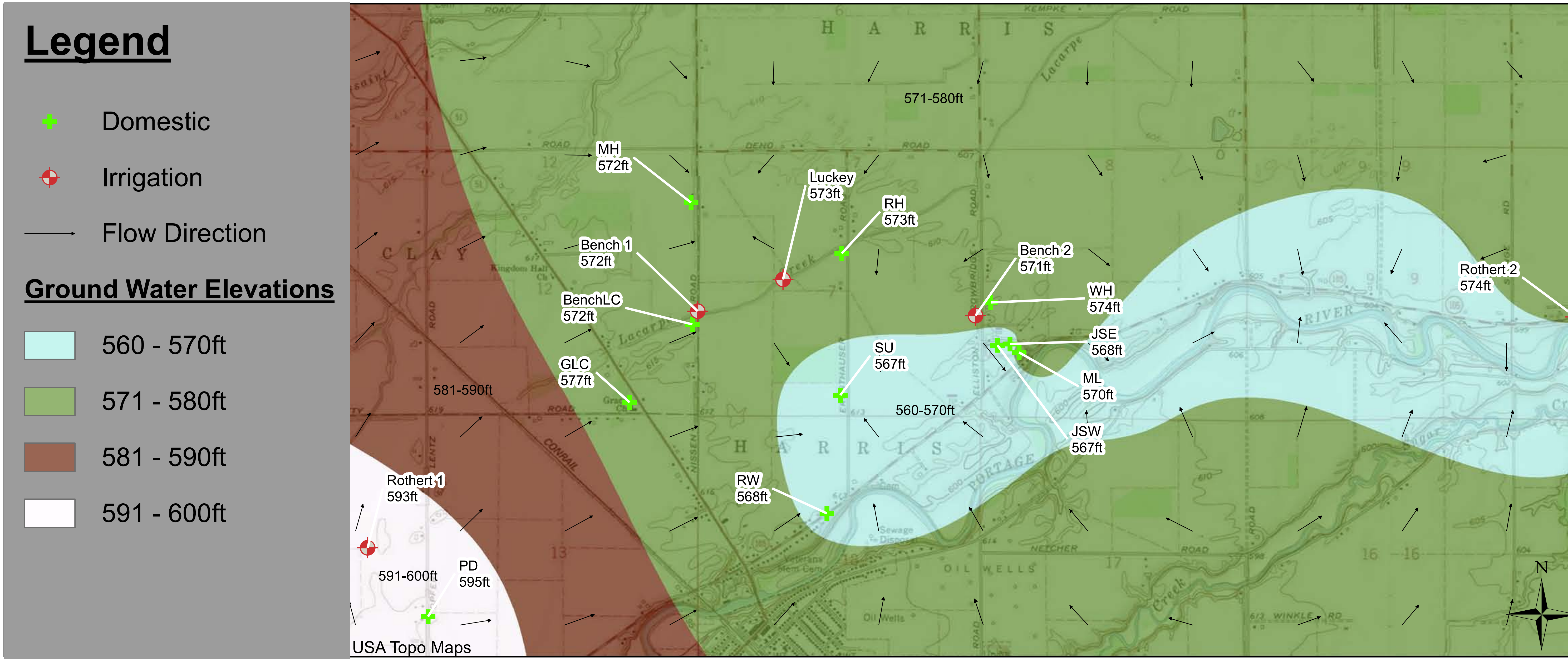
4.3.1 Hydrographs for High-Yielding Wells May through September 2011

Table 3 was developed to show ground water levels that were measured in the irrigation wells. It is important to note that only the Bench 1 and 2 wells were actively pumping when these measurements were made. The Luckey well was periodically pumped but was off during the time that the measurements were taken. The Rothert wells were not used for irrigation purposes during the summer because of crop rotation. Thus, the Rothert wells were used as background wells for observation only.

Table 3. Static water levels measured in high-yielding irrigation wells (feet)

Date	Bench 1	Bench 2	Luckey	Rothert 1	Rothert 2
5/19/2011	34.48	33.58	33.45	22.5	-------*
6/15/2011	34.59	36.41	34.5	27.91	17
7/14/2011	102	150	47.97	39.13	23.1
7/20/2011	46.08	46.08	45.18	25	23.17
8/9/2011	39.8	38.79	38.7	24.2	22.35
9/9/2011	36.62	37.22	36.44	24.32	22.24

*Parameter not measured



Cartography by:
Bobby Baker
March, 2012

Scale

0 1,000 2,000 4,000 6,000 8,000 Feet

1:24,000

1 inch = 2,000 feet

Figure 22
Ground Water Levels in feet above mean sea level for September 9th, 2011

The field data shows that the ground water level in the Bench 1 well during pumping was approximately 150 feet below the land surface on July 14, 2011. It was difficult to get an accurate measurement in this well because of an obstruction down in the well. The pumping water level in the Bench 2 well was 102 feet below the land surface. The water level in the Luckey well, which is located between the Bench 1 and 2 wells, declined to 47.97 feet below the land surface on July 14. These data show that the water level in the Luckey well was affected by the overlapping cones of depression caused by the pumping of the Bench 1 and 2 wells.

Figure 23 is a hydrograph of the data showing the depth to ground water in the Bench 1, Bench 2 and Luckey wells. Since the Luckey well is located between the Bench 1 and 2 wells, the ground water level in the well reflect the depth to water and additional drawdown as a result of the overlapping cones of depression. The total drawdown in the Luckey well from June 15 to July 14 was 13.37 feet.

4.3.2 Hydrographs for Domestic Water Wells May through September 2011

Table 4 was developed to show the impact and effect on depth to water in the water supply wells as a result of the ground water pumping from the Bench 1 and 2 wells. This data shows that the pumping of the irrigation wells had an impact on the ground water levels in the nearby domestic water wells. The deepest water levels measured in the domestic wells during the study occurred on July 14 during the time that the Bench 1 and 2 irrigation wells were in use.

Table 4. Static water levels measured in water supply wells (feet below top of casing)

Date	SU	B LC	GLC	WH	JS E	JS W	MH	RH	ML
5/19/2011	35.33	32.03	31.89	32.03	31.89	32.47	33.4	32.97	31.58
6/15/2011	36.51	33.2	33.68	34	33.68	34.2	34.86	34.45	33.34
7/14/2011	47.76	50.2	47.25	43	43.03	43.6	45.0	43.98	42.72
7/20/2011	46.28	46.58	45.23	42.583	41.81	42.45	45.08	43.15	41.59
8/9/2011	40.55	41.18	39.76	37.65	37.17	37.77	39.42	38.0	36.81
9/9/2011	38.35	36.4	37.98	34.92	34.35	34.91	36.88	35.96	34.06

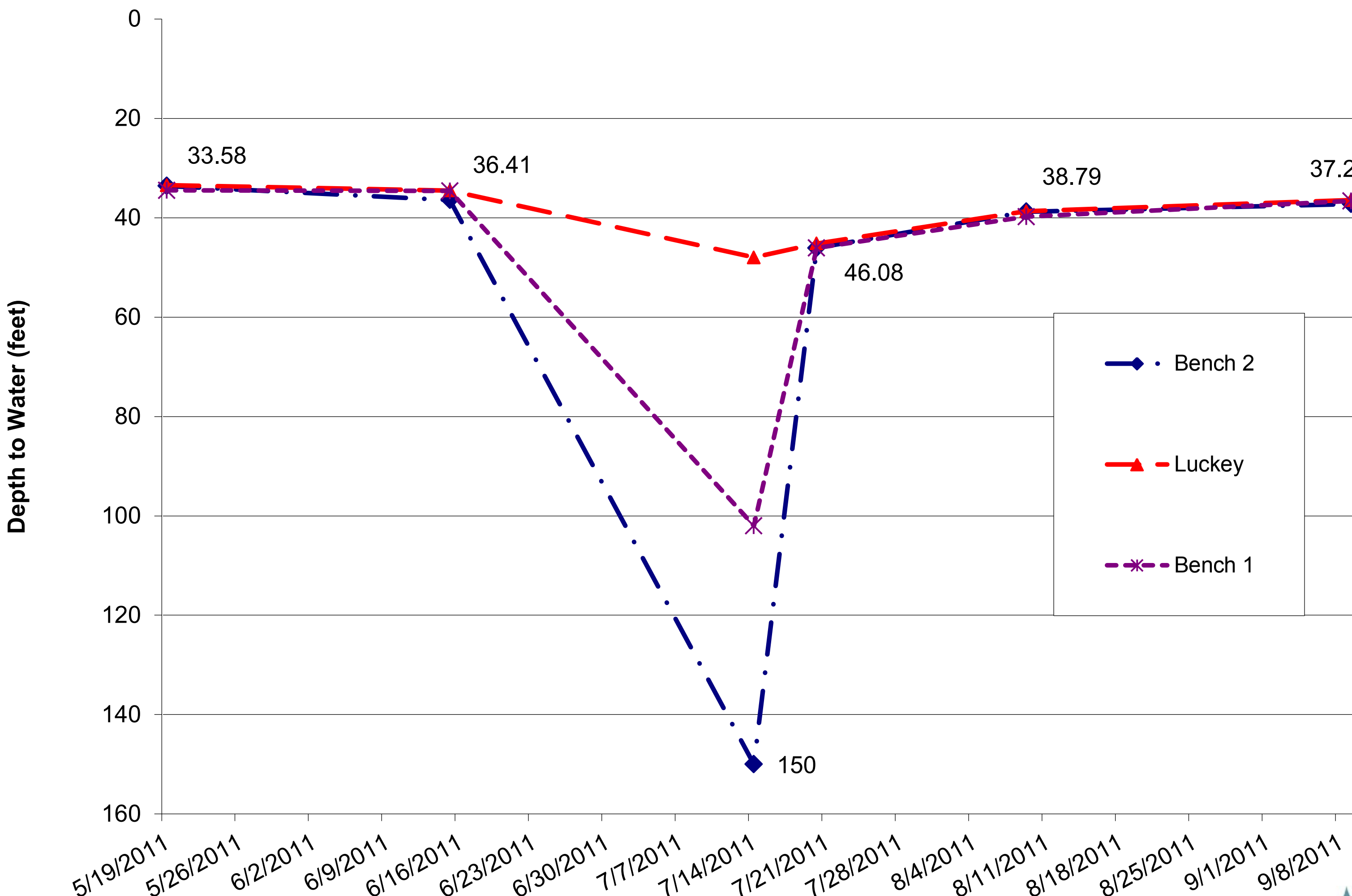


Figure 23. Ground Water Levels in the Three Active Irrigation Wells.
*** Bench 2 data set labled for reference**

Figure 24 represents a hydrograph of the water levels measured in some of the wells from May through September 2011. All the wells measured show a similar trend; the major decline in the ground water levels occurred during the pumping of the Bench 1 and 2 wells on July 14, 2011. By September, the ground water levels had recovered. Individual hydrographs for each well measured can be found in Appendix D.

4.4 EVALUATION OF THE IRRIGATION AND WATER SUPPLY WELL HYDRAULIC CHARACTERISTICS BASED ON ODNR WELL LOG DATA

In addition to the ground water level measurements, the ODNR-DSWR made an attempt to evaluate the well hydraulics of both the water supply and irrigation water wells that were monitored in this study. This was done by analyzing the data supplied by the well drillers in the ODNR-DSWR well log reports. The drillers' pumping/bail-down test data was used to calculate the specific capacity of the wells.

As part of the work, the driller estimated the pumping capacity for the well by conducting a short term pumping/bail-down test on the well. These tests are generally done by pumping, bailing, or blowing air into the well to extract water at a known rate in gallons per minute (gpm). Prior to conducting the test, the driller measured the static water level in the well. Near the end of the test, the driller measured the pumping water level in the well. The driller then determined the total drawdown in the well during pumping. These tests are generally done to estimate a sustainable yield of the well and to determine the depth at which to set the pump.

It should be noted that the driller did not report conducting a pumping test for the Luckey well.

4.4.1 Domestic Well Hydraulics Based on Driller Pumping/Bail-Down Test

Table 5 shows the results of the pumping/bail-down tests done by the well driller at the time that the well was drilled. Based on the analysis, the specific capacity of the well in terms of gallon per minute per foot of drawdown (gpm/ft) was estimated. This data is used to determine how much water is flowing into the well for every foot of drawdown based on the pumping rate. Analysis of the data shows that the shallow domestic water wells that did not encounter a fracture in the subsurface have a specific capacity that varies from 0.26 to 0.62 gpm/foot of drawdown. However, other wells (such as JSE and JSW) that did encounter a fracture or void in the limestone have a specific capacity in the range of 10 to 20 gpm/foot of drawdown.

4.4.2 Irrigation Well Hydraulics Based on Driller Pumping Test

Table 6 shows the results of the pumping test for the irrigation wells. These data show a similar trend that was observed in the other water wells. In the Bench 1 and 2 wells, the specific capacity of the wells varies from 1.81 to 2.0 gpm/ foot of drawdown. In the Rothert 1 and 2 wells, the specific capacity of the wells range from 6 to 6.2 gpm/foot. These data suggest the Bench wells did not encounter significant fracture flow in the subsurface. However, the Rothert wells encountered a higher number of flow zones over the length of aquifer penetrated.

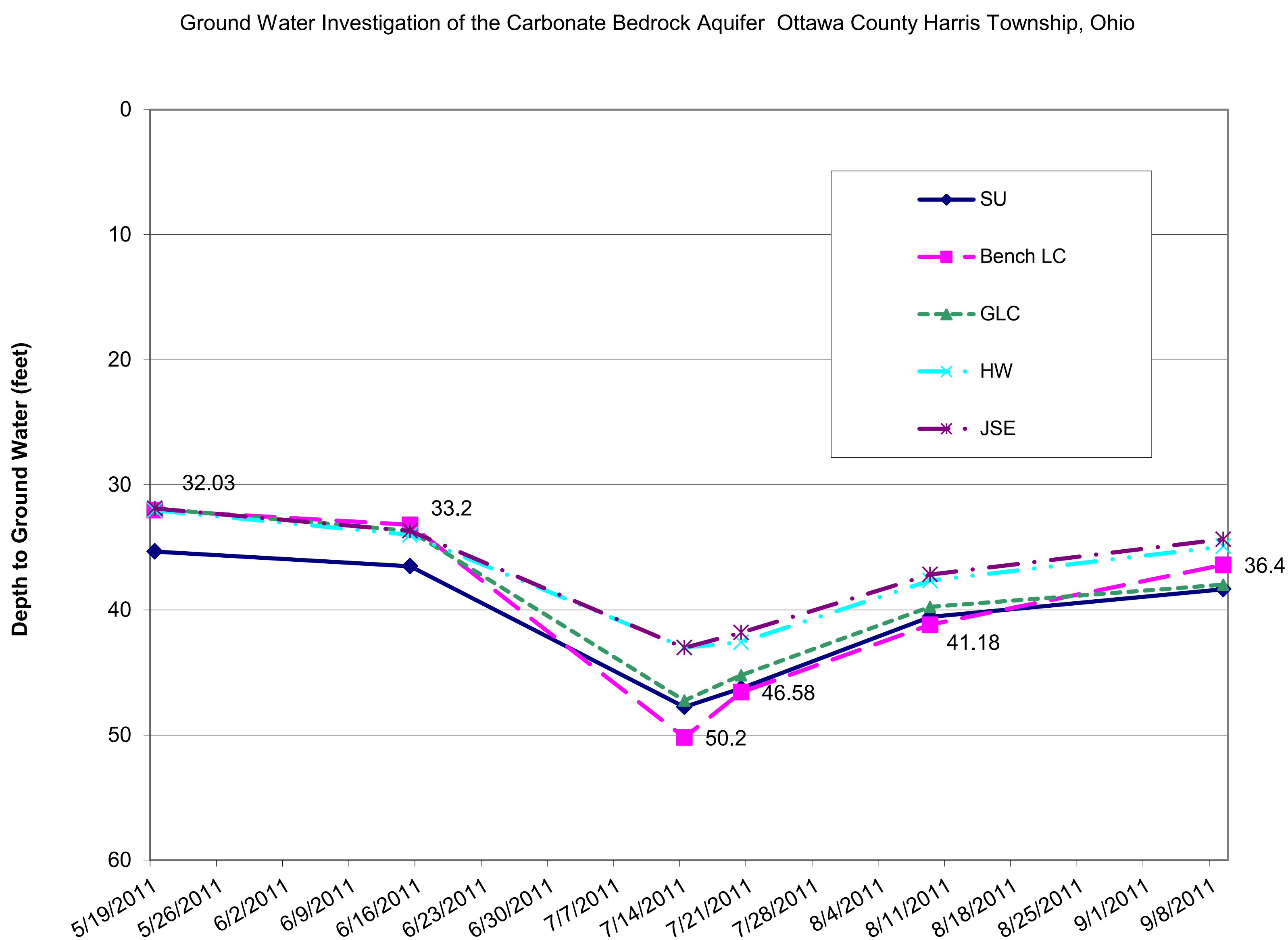


Figure 24. Ground Water Levels in the Non-Irrigation Wells.
*** Bench LC well labled for reference**

Table 5. Domestic well hydraulics based on driller bail-down test data

Well Log Number.	Well ID	Pumping Rate (gpm)	Pumping Level (feet)	Pumping* Level (feet)	Drawdown (feet)	Specific Capacity* (gpm/foot)
665324	BLC	20	27	60	33	0.61
921445	GLC	45	40	113	73	0.62
348436	JSE	20	28	30	2	10
348437	JSW	20	28	28	0	20+
2028178	MH	15	46	102	56	0.26
77581	ML	-	13	-	-	-
2011236	PD	12	26	70	44	0.26
615063	RH	12	26	-	-	-
711797	RW	8-10	46	-	-	-
696615	SU	10-20	35	-	-	-
484324	WH	16	30	35	5	3.2

*Calculated value from well log data - parameter not provided by driller

Table 6. Irrigation well water well hydraulics based on the driller pumping test data

Well Log Number	Well ID	Pumping Rate (gpm)	Pre-Pumping Level (feet)	Pumping* Level (feet)	Drawdown (feet)	Specific Capacity* (gpm/foot)
2028314	Bench 1	230	37	151	114	2.0
2025323	Bench 2	300	34	200	166	1.81
2028309	Luckey	300	36	-	-	-
2001245	Rothert 1	240	30	70	40	6
2001244	Rothert 2	280	31	76	45	6.2

*Calculated value from well log data - Parameter not provided by driller

4.4.3 Bench 1 and 2 Well Irrigation Well Hydraulics Based on June 15 to July 14 Field Measurements

Table 7 was developed based on the drawdown measured over the 14-day irrigation pumping cycle. Both the Bench 1 and 2 wells were assumed to be pumping at a rate of 200 gpm. The pumping rate was estimated based on the pump capacity and the irrigation system design characteristics. The specific capacity of the Bench 1 well was calculated to be 2.97 gpm/foot of drawdown in the well. This compares well with the specific capacity from the original test of 2 gpm/foot of drawdown estimated from the pumping/bail down test. The specific capacity of the Bench 2 well was calculated to be 1.76 gpm/ foot of drawdown. This also agrees well with the original pumping test derived value of 1.81 gpm/foot of drawdown estimated from the pumping/bail down test.

The Lucky and Rothert 1 and 2 wells were turned off during the field measurements and used only for background water level measurements.

Table 7. Bench 1 and 2 Well evaluation based on the June 15 to July 14 field measurements

Well ID	Pumping Rate (gpm)	Pre-Pumping Water Level (feet)	Pumping Water Level (feet)	Drawdown (feet)	Specific Capacity (gpm/foot)
Bench 1	200	34.59	102	67.41	2.97
Bench 2	200	36.41	150	113.59	1.76

4.4.4 Luckey and Bench 1 Evaluation Pumping Tests

As part of this study, an attempt was made to evaluate the hydraulic characteristics of the Luckey and Bench 1 irrigations wells. This was done by having the well owner pump the well after a round of water level measurements were obtained throughout the study area. The well evaluations were conducted on the Luckey and Bench 1 wells independently of each other. The Rothert 1 and 2 wells were not used for irrigation this season so they were used only for observation and ground water monitoring. The results of the ODNR-DSWR pump test evaluation is presented in Table 8.

4.4.4.1 Luckey Well Hydraulics Based on July 14, 2011 Pumping Test

An attempt was made to evaluate the hydraulic characteristics of the Luckey well on July 14, 2011. The Luckey well was turned on after the initial round of static water level measurements was taken. The pump capacity for the Luckey well is 150 gpm. It was estimated that the well pumped at a rate of 130 gpm. The initial static water level in the Luckey well was 48.38 feet below the ground surface. Water level measurements were taken for approximately 2 1/2 hours. The initial static water level was affected by the overlapping cones of depression from the pumping associated with the Bench 1 and 2 wells.

After 2 1/2 hours, the water level in the well had declined from the initial 48.38 feet to 53.17 feet below the land surface and had stabilized at that level. The total drawdown in the well was 4.79 feet. The specific capacity of the well was calculated to be 27.14 gpm/foot of drawdown.

During the pumping of the Luckey well, water level measurements were also obtained from the RH well located approximately 1300 feet from the Luckey well. The initial static water level in the well prior to pumping was 43.98 feet below the land surface. The final static water level was 44.29 feet below the land surface. Thus, the total drawdown in the well was 0.31 feet.

4.4.4.2 Bench -1 Well Hydraulics on July 20, 2011 Pump Test

An attempt was made to evaluate the hydraulic characteristics of the Bench 1 well on July 20, 2011. This well had not been used for a few days prior to this test. The well was turned on after the initial round of static water levels was obtained for the area. The initial static water level in the Bench 1 well was 45.95 feet below the land surface. Measurements on the well were taken for 50 minutes. The pumping water level was measured at 102 feet below the land surface. During the evaluation, it was difficult to measure the water level in the Bench well due to an obstruction in the well so the test was ended. To obtain the best data it would be necessary to install a 1-inch diameter stilling tube and a transducer down the well bore. The pump capacity in the well was 225 gpm. It was estimated that the well was pumping at a rate of approximately 200 gpm. The total drawdown in the well was estimated to be 56.05 feet. Thus, the specific capacity of the well was estimated to be 3.56 gpm/foot of drawdown. This result is higher than the results from the original pumping test completed by the well driller of 2 gpm/foot of drawdown. During the pumping of the Bench 1 well, water level measurements were also obtained from the Bench labor camp (Bench LC) well located 325 feet from the Bench 1 well. The initial static water level in the well prior to pumping was 46.41 feet below the land surface. The final static water level was 52 feet below the land surface. Thus, the total drawdown in the well was 5.59 feet.

Table 8. ODNR-DSWR well evaluation for Bench1 and Luckey irrigation wells

Well ID	Pumping Rate (gpm)	Pre-Pumping Water Level (feet)	Pumping Water Level (feet)	Drawdown (feet)	Specific Capacity (gpm/foot)
Bench 1	200	45.9	102*	56.1	3.56
Bench LC Observation	------	46.41	52	5.59	------
Luckey	130	48.38	53.17	4.79	27.14
RH Observation	-------	43.93	44.29	0.31	----

*It should be noted that it was difficult to measure water levels below 102 feet because of obstruction in the well

5.0 RESULTS OF P-12 PUMPING TEST ANALYSIS

Because there was no long term pumping test data for the irrigation wells, it was necessary to turn to literature for the data. The ODNR, Division of Water study *Ground Water for Planning in Northwest Ohio* (1970) provided a wealth of data. The P-12 well characteristics closely matched those of the irrigation wells. Well P-12 was drilled in Ottawa County, Benton Township just north of the Harris Township line (Figure 5). The location of P-12 and the observation wells are shown on Figure 6 in Section 2.0. The well construction details are presented in Figure 17, Section 3.0.

The pumping test on P-12 was completed as follows:

- A trial pre-pump test was run to estimate the pumping capacity of the well
- A variable-rate step test with six (6) steps was run to estimate the well efficiency
- A 24-hour constant-rate pumping test was run to estimate aquifer characteristics

Three (3) observation wells were used to evaluate the drawdown in the carbonate aquifer at varying distances from the pumping well P-12 in the northern, southern and eastern directions. The location of these wells is also shown on Figure 6.

Data input for the pumping test taken from the unpublished ODNR report are as follows:

- Pumping rate: 99 gpm
- Well Depth (b): 360 feet
- Original Static Water Level: 23.94 feet
- Specific Capacity: 1.01 gpm/ft
- Glacial Till Thickness (b'): 38 ft
- Radius of the Well (rw): 0.42 feet
- Radius of the Casing (rc): 0.50 feet

P-12 pumping test analysis was done using the confined model with the Cooper-Jacob solution. Based on the Cooper-Jacob solution, the original transmissivity was estimated to be 1,600 gallons/day/foot. The original storage coefficient of the aquifer was estimated to be 0.0001. These data were used as a starting point for estimating the hydraulic properties of the aquifer by using the AQTESOLV computer program. AQTESOLV 4.5 version was used to estimate the hydraulic properties of the aquifer (Duffield, 2007). As with all ground water pumping test analyses, the Cooper-Jacob solutions use the following assumptions:

- Aquifer has an infinite areal extent
- Aquifer is homogeneous and isotropic with a uniform thickness
- Pumping well is fully or partially penetrating
- Flow to the pumping well is horizontal
- Flow is unsteady
- Water is released instantaneously from storage

In addition, its was assumed that the hydraulic conductivity are the same in the horizontal and vertical directions, thus Kh/Kr = 1

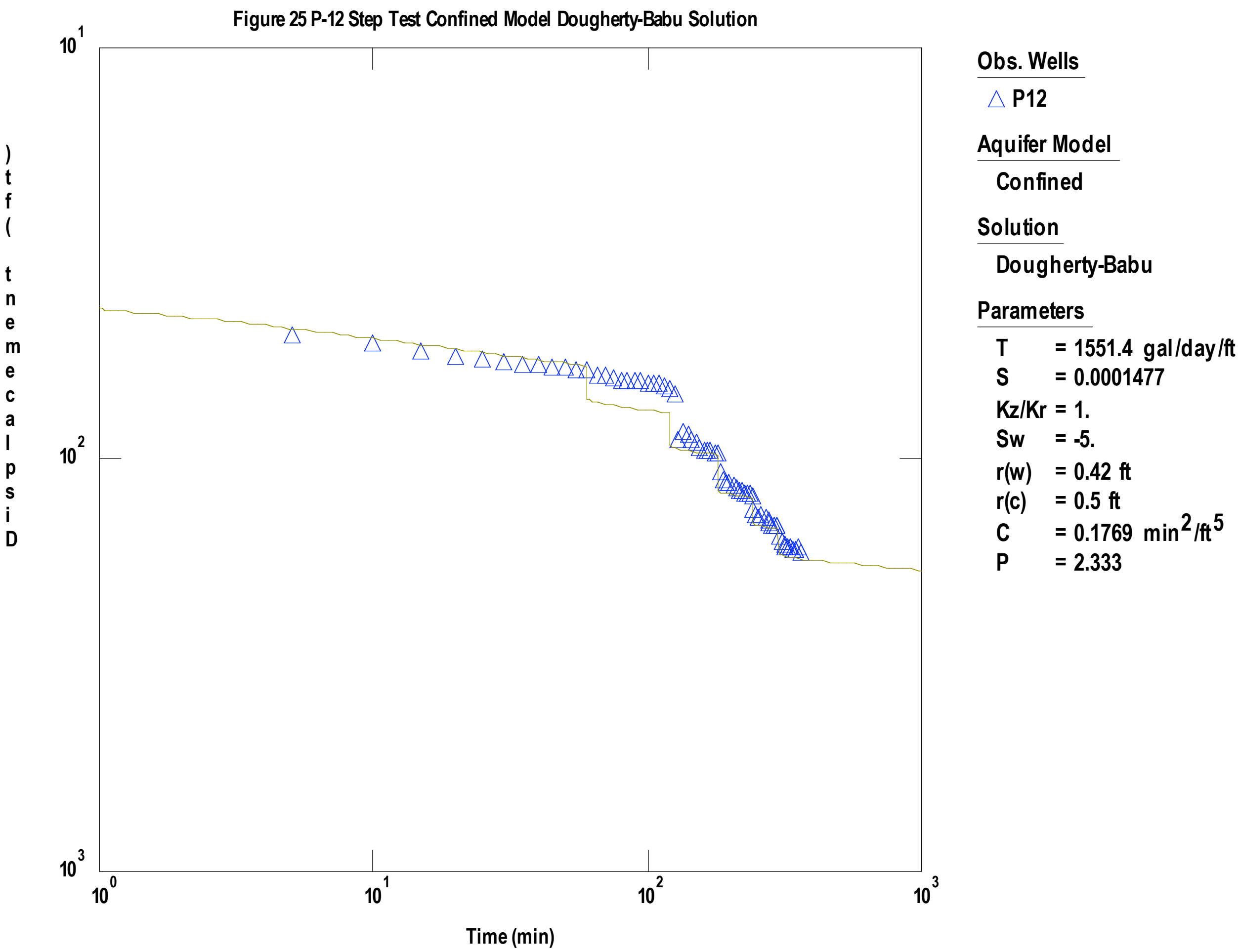
5.1 STEP TEST RESULTS CONFINED MODEL DOUGHERTY-BABU SOLUTION

The step test is a procedure for determining the performance of a well under conditions of turbulent flow. It is used to determine well efficiency, optimum pumping rate, and to separate laminar and turbulent components caused by the pumping of the well. In a step-drawdown test, a well is pumped at several successively higher pumping rates and the drawdown for each rate or step is recorded. In the case of well P-12, six (6) steps were run for one hour each. The well was initially pumped at a rate of 76 gpm. The successive steps were run at 85, 95, 107, 116 and 126 gpm. The step test was analyzed using a confined model with the Dougherty-Babu solution (Figure 25).

Based on the step test data, the transmissivity of the well was estimated to be 1551.4 gallons/day/foot (207.4 ft^2/day). The storage coefficient (S) was estimated to be 0.0001477. The well was found to have a well efficiency of 73.8 percent based on the last step.

5.2 RESULTS OF THE P-12 PUMPING TEST ANALYSIS

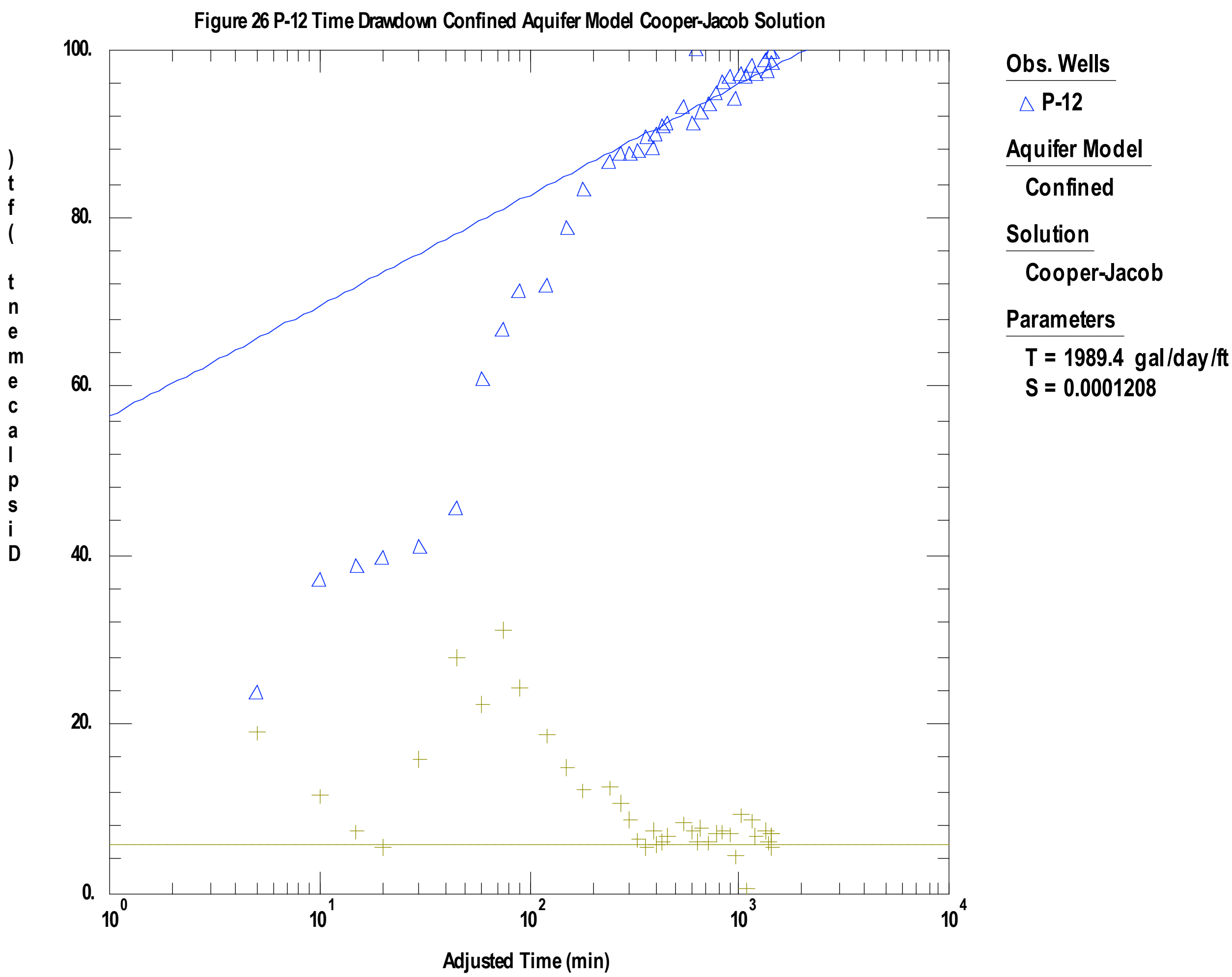
Based on the step test, it was decided to run the test at a constant rate of 99 gpm for 24 hours. To be consistent with the historic work, it was decided to use the confined model using the Cooper-Jacob solution for the pumping test. In addition, it was decided to evaluate the historic data using the leaky aquifer model and the Hantush-Jacob solution. The distance-drawdown plot was analyzed using the confined aquifer model using the Dougherty-Babu solution.



5.2.1 Time-Drawdown Confined Model Cooper-Jacob Solution Results

Based on the well completion data (Figure 17), two flow zones were identified in the well. The upper flow zone occurred at 64 to 65 feet and the lower flow zone occurred at 270 to 280 feet. The pumping test data confirms that the majority of the water produced from the well came from these two flow zones. During the pump test, water was initially produced from the upper flow zone at 65 feet. As the pumping test progressed, the upper flow zone was dewatered. There was a steep drop in the water level of approximately 40 feet when this occurred. With time the majority of the water was produced from the deeper flow zone at 270 to 280 feet below the land surface.

Figure 26 shows the results of the time-drawdown plot for the confined aquifer model using the Cooper-Jacob solution. These data show that the transmissivity of the well was estimated to be 1989.4 gallons/day/foot (265.9 ft^2/day). The storage coefficient was estimated to be on the order of 0.0001208. The derivative data for the water produced from the well also confirms that the water is initially produced from the upper flow zone but over time the upper flow zone is dewatered and the majority of the water is obtained from the lower flow zone.

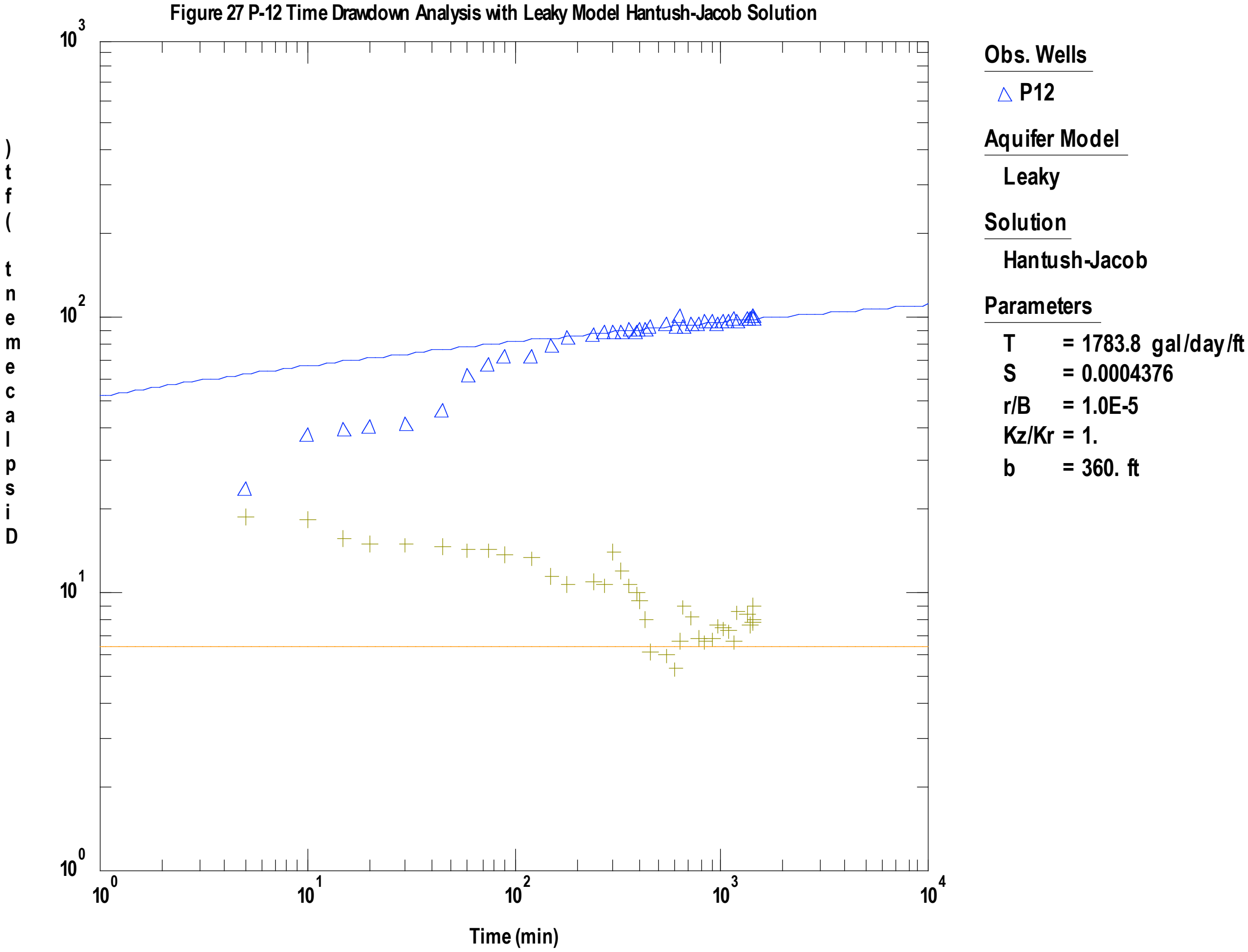


5.2.2 Time-Drawdown Leaky Model Hantush-Jacob Solution Results

Figure 27 shows the results of the time-drawdown plot for the leaky aquifer model using the Hantush-Jacob Solution. These data show that the transmissivity of the well was estimated to be on the order of 1783.8 gallons/day/foot (238.4 ft^2/day). The storage coefficient was estimated to be on the order of 0.0004376. This is higher than the coefficient of storage obtained using the Cooper-Jacob Solution.

The leakage coefficient (r/B) for the leaky model is on the order of 1 x 10^{-5} which suggests that the glacial material surrounding P-12 does not leak much water through the confining layer into the carbonate aquifer below. Essentially, these data suggest that the confined model provides an accurate representation for the carbonate bedrock aquifer.

Figure 27 P-12 Time Drawdown Analysis with Leaky Model Hantush-Jacob Solution



5.2.3 Distance-Drawdown Confined Model Dougherty-Babu Solution Results

Table 9 shows the observation well data used for the distance-drawdown plot. Shown in the table are the distance each observation well was from the pumping well P-12, the original static water level, the final water level, and the total drawdown in each well. Wells OW-1 and OW-3 were located in the north-south direction and OW-2 was located east of P-12 (see Figure 6 for well locations).

Figure 28 shows the results of the distance-drawdown plot for the confined aquifer model using the Dougherty-Babu Solution. These data show that the transmissivity of the aquifer was estimated to be 4177.5 gallons/day/foot (558.4 ft^2/day). The storage coefficient was estimated to be 0.000421. This storage coefficient is consistent with the leaky model but is slightly higher than estimated by the confined model.

Table 9. P-12 observation well data.

Well ID	Distance (Feet)	Direction	Initial Water Level (Feet)	Final Water Level (Feet)	Drawdown (Feet)
P-12	----	------	23.94	123.69	99.79
OW-1	1500	South	26.11	27.07	1.04
OW-2	3500	East	22.1	23.07	0.97
OW-3	800	North	23.12	27.19	4.07

Figure 28 P-12 Distance Drawdown Confined Aquifer Model Dougherty-Babu Solution

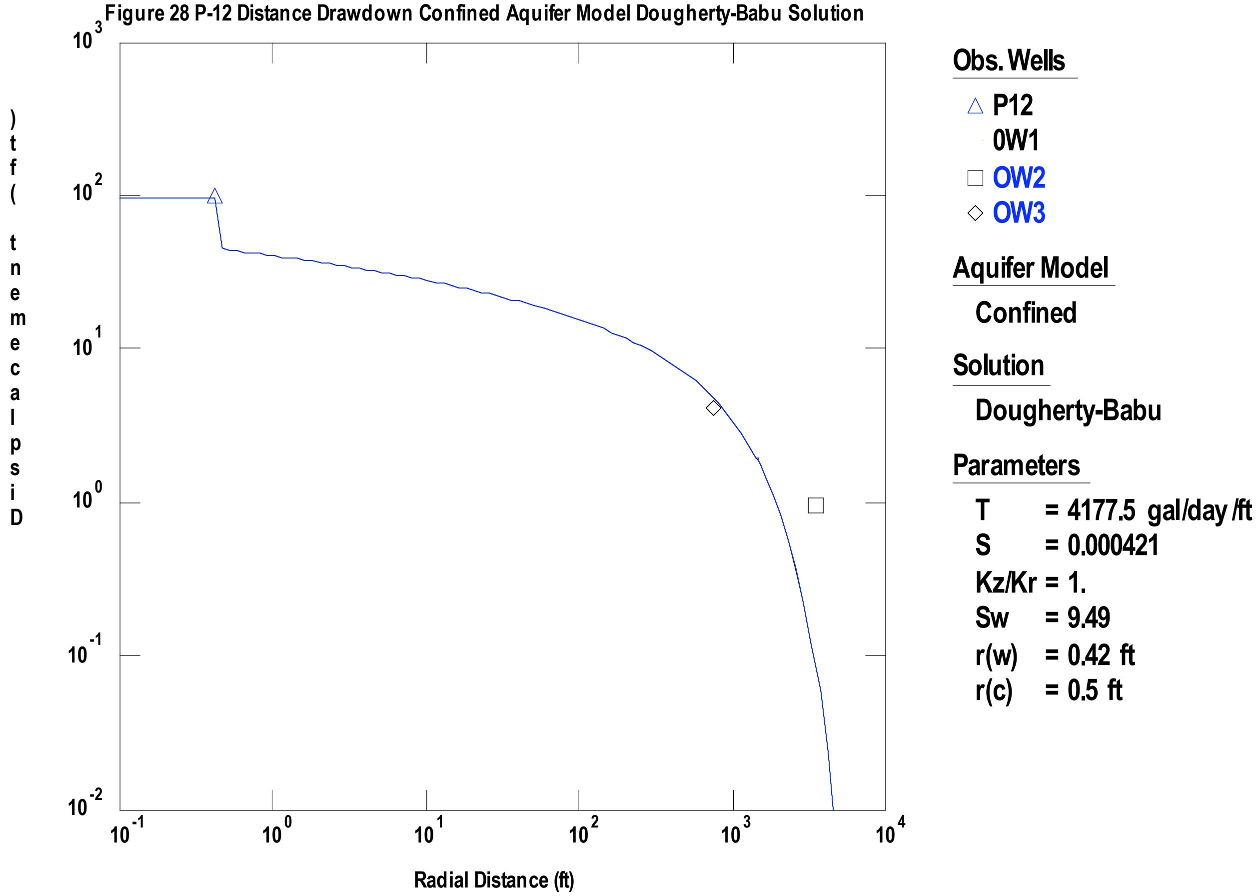


Figure 29 is a drawdown plot for the observation well data OW-1, 2 and 3 generated from the confined model Daugherty-Babu distance-drawdown solution for the P-12 pumping test. This model assumes that the water table is horizontal and the aquifer is homogeneous, infinite in extent, and uniform in thickness; yet observation shows that the carbonate bedrock aquifer is heterogeneous and anisotropic. As a result, the drawdown data predicted by the computer model does not always agree with the observed field data.

In the case of well P-12, the predicted drawdown data agrees in the north-south direction for OW-3 and OW-1 respectively. In OW-3, located 800 feet north of P-12, the drawdown measured in the field was 4.07 feet. This agrees well with the predicted drawdown of 3 to 4 feet. In OW-1, located 1500 feet south of P-12, the drawdown measured in the field was 1.04 feet, which agrees with the predicted drawdown of 0 to 2 feet. However, the drawdown measured in the field for OW-2, located 3500 east of pumping well P-12, was 0.97 foot, which is greater than predicted by the computer model.

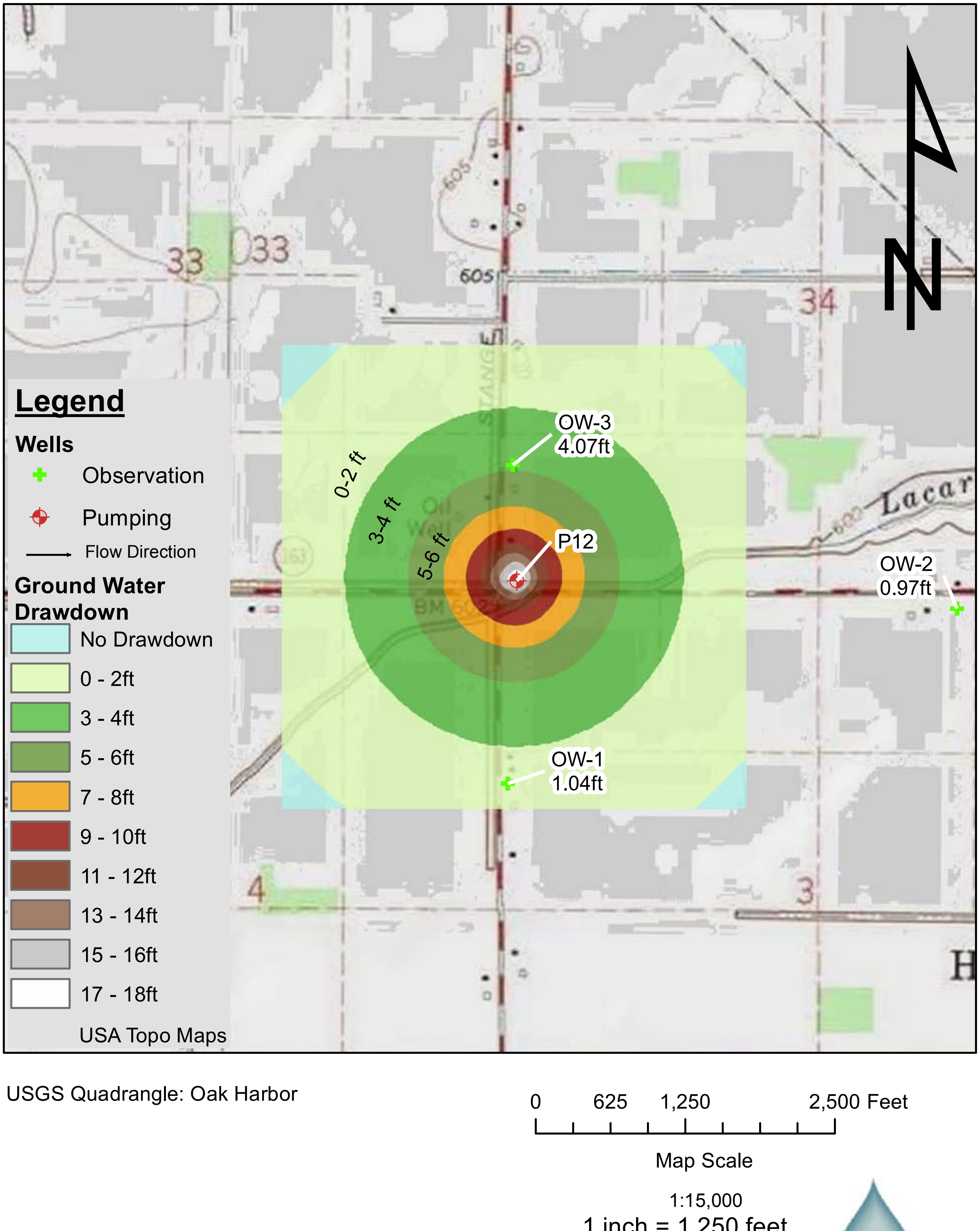


Figure 29 Plot P-12 Showing Changes in Ground Water Levels with Distance from Pumping Center.

6.0 IMPACT ASSESSMENT

Ground water models can be used to predict the changes in ground water levels in response to different pumping scenarios. Before a model can be run, aquifer characteristics like transmissivity and storativity must be known. These values were obtained from the pumping test data from well P-12. The next step is to calibrate the model to the known field observations or measurements. After the model is calibrated, it can be used to simulate the effects of pumping the high-yielding well at different pumping rates and over different time periods.

6.1 ACTUAL FIELD MEASUREMENTS:

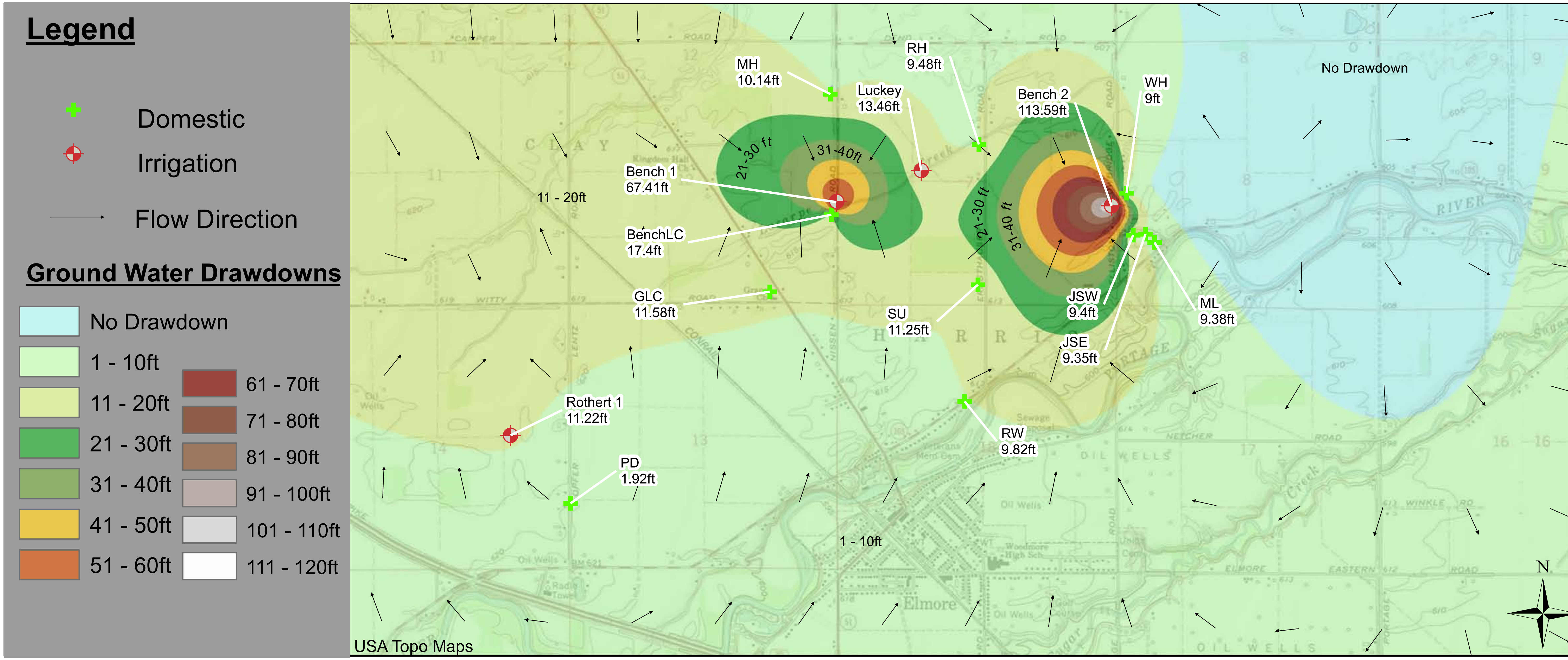
Static water levels were measured in all of the study wells during May and June 2011. Pumping of the irrigation wells began on July 2. On July 14, the ODNR-DSWR measured the water level in all of the wells. To determine the impact of pumping, the water level difference was computed by subtracting the June 15 reading from the July 14 measurement. Figure 30 shows the amount of drawdown or decline in the ground water level. During the time of these measurements, only the Bench 1 and Bench 2 wells were in operation, while the Luckey and Rothert wells were turned off and used for monitoring ground water levels only.

6.2 MODEL CALIBRATION WITH WELLZ AT 14-DAYS:

The computer model **WellZ** (Schwartz and Zhang 2002) was used to evaluate the impact from pumping the high-yielding water wells on the water supply wells. The actual measured drawdown in the water wells from June 15, 2011 through July 14, 2011 was evaluated against the predicted drawdown in the monitored water supply wells using the **WellZ** computer model. This computer program utilizes either a confined or leaky computer model and is based on the Theis solution. The Theis solution calculates the well interference affects or drawdown in individual wells with distance from the pumping well. The Theis solution assumes:

- Aquifer is homogeneous and isotropic
- Well will pump without stopping for 14 days
- There is leakage through the glacial till.

To evaluate the effectiveness of using the **WellZ** computer model to predict the measured drawdown observed in the field, these data were compared to the observed field measurements. Two computer simulations were run pumping only the Bench 1 and 2 irrigation wells because those were the only wells in operation during the time of data collection on July 14. The first simulation was run with the Bench 1 and 2 wells pumping at a rate of 200 gpm each. The second computer simulation was run pumping the Bench 1 and 2 wells at a rate of 250 gpm each. The Luckey and Rothert 1 and 2 wells were turned off and used as observation wells.



Scale

0 1,100 2,200 4,400 6,600 8,800 Feet

1:24,000

1 inch = 2,000 feet

Cartography by:
Bobby Baker
March, 2012

Figure 30
Actual Ground Water Level Drawdown
Measured Between
June 15th 2011 and July 14th, 2011

The **WellZ** computer model was analyzed using a leaky model with the following parameters:

- Transmissivity =265 ft^2 /day
- Storativity = 0.0001 (dimensionless)
- Vertical Hydraulic Conductivity (leakage) through the glacial till =0.03 ft/day assumed

The actual field measurements and the calculated values for interference for the two simulations are presented in Table10.

Table 10. Measured vs. calculated drawdown effects on water supply wells caused by pumping Bench 1 and Bench 2 irrigation wells

Well Log ID	Drawdown measured from June 15 – July 14	Model Calibration 14-Days 200GPM	Model Calibration 14-Days 250 GPM
BLC	17.4	47.836	59.795
GLC	11.58	7.376	9.219
JSE	9.35	14.054	17.567
JSW	9.40	16.663	20.829
MH	10.14	8.087	10.109
ML	9.38	19.298	24.122
PD	1.92	0.168	0.209
RH	9.48	9.588	11.985
RW	9.82	2.47	3.087
SU	11.25	7.732	9.667
WH	9.00	23.406	29.258
LUCKEY	13.46	12.098	15.123
ROTHERT1	11.22	0.168	0.21
ROTHERT2	6.10	0.011	0.014

Based on the data in Table 10, the following observations were made:

1. Actual drawdowns in the Luckey well and well SU were more than the predicted drawdowns for the 200 gpm calibration run. Both of these wells are located between the two Bench irrigation wells.

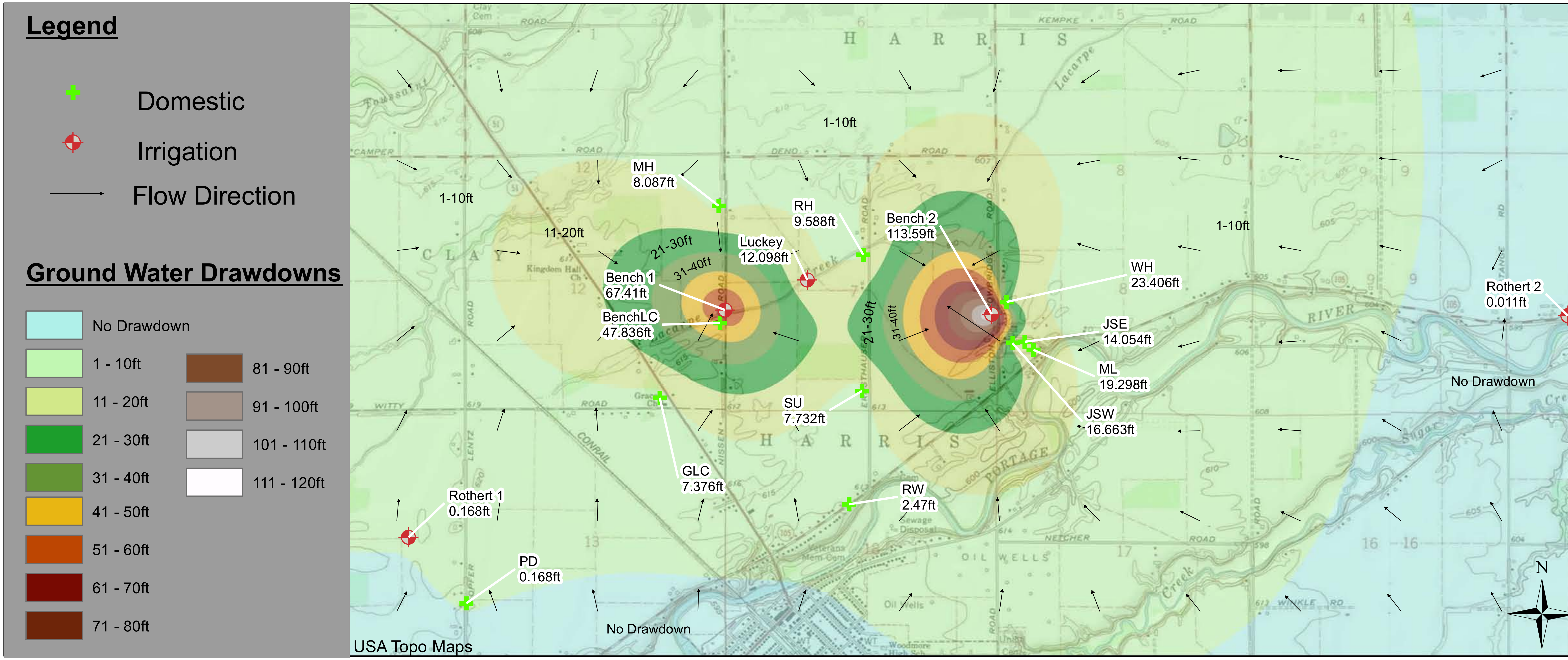
2. Actual drawdowns in the wells located along Elliston-Trowbridge Road were less than anticipated by the computer model. These include wells WH, JSW, JSE and ML. Ground water drawdowns on the order of 9 to 9.4 feet were measured. Predicted drawdowns ranged from 14 to 23 feet. This could be due to the fact that 100 feet of casing was installed in an attempt to isolate the upper flow zone(s).

3. Drawdown in well BLC, located adjacent to the Bench 1 pumping well, was predicted to be 47.83 feet. However, the actual measured drawdown was 17.4 feet. This too could be due to the fact that 100 feet of casing was installed in the Bench 1 well.

4. These data show that the actual ground water level drawdown across the area can vary significantly from the predicted ground water levels depending on distance and location relative to the pumping center.

When the actual ground water level measurements are compared to the 14-day model calibration, it was observed that these data do not show a good match to the **WellZ** predicted drawdowns. As a result, it was not possible to calibrate the **WellZ** model to the actual field conditions (Figure 31). The most likely reason for the lack of correlation between the actual field measurements and the predicted decline in the ground water levels is because of the anisotropic conditions in the aquifer in both the horizontal and vertical directions. Consequently, it was not possible to accurately simulate the decline in the ground water levels with time and with all the irrigation wells pumping.

Table 10 shows the differences in the measured and calculated drawdown values. The model cannot be calibrated to match all of the data; it only provides an indication of what might happen. In reality, the carbonate aquifer shows good correlation in the northern, southern, and western directions but shows poor correlation in the eastern direction. The **WellZ** model exhibits somewhat less drawdown and interference than the measured values would indicate. Also, the maximum interference shown would take place only in wells which are completed in the same flow zone within the aquifer. Because the model could not be calibrated, it was not possible to run a pumping simulation to predict a worst case scenario with all five irrigation wells pumping simultaneously.



Scale

0 1,125 2,250 4,500 6,750 9,000 Feet

1:24,000

1 inch = 2,000 feet

Cartography by:
Bobby Baker
March, 2012

Figure 31
Predicted Ground Water Levels
after Pumping Bench 1 and Bench 2
for 14 Days at 200 Gallons Per Minute.
The numbers by each monitoring point
represent the drawdown predicted in the well.

7.0 Conclusions

7.1 SITE HYDROGEOLOGY CONCLUSIONS

Ground water occurrence and movement in the carbonate bedrock aquifer of northwestern Ohio is complex and poorly understood. Previous work documents show that there are a number of flow zones in the subsurface. The well completion diagram for the Luckey well shows the extent to which the flow zones occur in the subsurface (Figures 14 and 18). Drilling data shows that the carbonate bedrock aquifer is anisotropic and heterogeneous in its configuration. This gives rise to a number of concerns that need to be considered before long-term pumping rates can be accurately calculated and the data used to design water supply systems.

The overall porosity and permeability within the carbonate bedrock aquifer in north-central Ohio is composed of three (3) types:

1. Primary porosity and permeability resulting from the three-dimensional interconnection of the micro-fractures that compose the matrix of the bedrock

2. Secondary permeability resulting from the three-dimensional network of joints, fractures and bedding planes

3. Secondary permeability also resulting from the three-dimensional cavernous nature of the openings

This helps explain major changes in yield within short distances. Field data results confirm that diffuse, laminar, and turbulent conduit flow are present within the carbonate bedrock aquifer of northwestern Ohio. The hydraulic characteristics of the aquifer are not uniform; there are significant variations in permeability that need to be accounted for within the carbonate bedrock aquifer (i.e. degree of fracturing as well as variation in cementation). This helps to explain major changes in yield over short distances in both the vertical and horizontal directions.

Overall, because of the degree of interconnectedness of the fractures and conduits in both the vertical and horizontal directions, it must be assumed that the carbonate bedrock aquifer acts as a continuous water bearing unit from the surface to the top of the Rochester Shale at a depth of over 400 feet below the land surface.

7.2 P-12 PUMP TEST CONCLUSIONS

Previous work confirmed that well P-12 intercepted two flow zones. At the time it was noted that the upper water-bearing zone could be dewatered, which affected the pumping test results. As the upper water-bearing flow zone was dewatered, the water level in the pumping well dropped an additional 40 feet. Any subsequent water pumped from the well was obtained from the lower water-bearing flow zone. Thus, an erroneously optimistic prediction of ground water yield from individual wells resulted by not accounting for the drop in water level in the pumping well and not accounting for the increased well loss due to dewatering of the upper flow zone. Review of these data during this study confirms the results obtained during the original study of well P-12.

The 1969 data was analyzed using step test, time-drawdown and distance-drawdown analytical techniques. The step test data suggests that the transmissivity of the carbonate aquifer is approximately 1551 gallons/day/foot (207.4 ft^2/day). The storage coefficient for the aquifer was 0.0001.

The time-drawdown data using the Cooper-Jacob confined model solution confirmed a transmissivity of 1989.4 gallons/day/foot (265 ft^2/day). These data agreed well with the Dougherty-Babu leaky model solution transmissivity of 1783.8 gallons/day/foot (238.4 ft^2/day) with a storage coefficient of 0.0004 for the aquifer.

The distance-drawdown plot for the P-12 data using the Dougherty-Babu confined model solution indicated that the transmissivity of the aquifer could be as high as 4177 gallons/day/foot (558.4 ft^2/day). The storage coefficient of the aquifer was approximately 0.0004. Data from the distance-drawdown plot for the P-12 well show that the transmissivity of the carbonate bedrock aquifer in not uniform in the vertical and horizontal direction. These data also show that the storage coefficient is not uniform as well.

7.3 FIELD DATA MEASUMENTS CONCLUSIONS

The regional direction of ground water flow across the study area is from the southwest to the northeast in the direction of Lake Erie. However, the local ground water flow direction in the study area is toward the Portage River, which acts as a natural ground water discharge point.

Hydrographs of the ground water level data show that the greatest changes in water levels occurred during the pumping of the irrigation wells between June 15, 2011 and July 14, 2011.

As shown on Figures 20 and 30, the pumping of the Bench 1 and 2 irrigation wells can have a major impact on the regional ground water flow direction. The major impact occurs between the two pumping wells where the individual cones of depression overlap. Ground water level declines of up to 17.4 feet can be attributed to this pumping. Drawdown values of 10 feet were observed approximately 4000 feet way from the Bench 2 well. It appears that installing 100 feet of casing was only partially successful in isolating the irrigation wells from the neighboring wells.

Ground water level measurements made on September 9, 2011 indicated that the water table had recovered and that no long term impacts had occurred once the irrigation wells were turned off.

7.4 IMPACT ASSESSMENT CONCLUSIONS

Water well records for the S-2 observation well completed in the Village of Woodville show that ground water levels can vary from about 18 to 59 feet below the land surface in response to nearby pumping despite normal rain fall amounts. This indicates that the pumping associated with the Woodville water supply wells can have an impact on nearby water wells. The ground water fluctuation can be as much as 41 feet.

Field data obtained for this project show that the pumping of the high-yielding water wells can have an impact on the local water supply wells. The degree of impact depends on the location of the water well relative to the pumping center and the pumping rate. It also depends on the flow zone from which the water well produces. Based on the data result, it is possible for a deeper high-yielding well to dewater the upper flow zone in the carbonate bedrock aquifer.

In the case of P-12, the model-predicted drawdown data agrees in the north-south direction for OW-3 and OW-1 respectively. In OW-3, located 800 feet north of P-12, the drawdown measured in the field was 4.07 feet. This agrees well with the predicted drawdown of 3 to 4 feet. In OW-1, located 1500 feet south of P-12, the drawdown measured in the field was 1.04 feet, which agrees with the predicted drawdown of 0 to 2 feet. However, the drawdown measured in the field for OW-2, located 3500 east of pumping well P-12, was 0.97 foot, which is greater than predicted by the computer model.

An attempt was made to model the carbonate aquifer using the **WellZ** computer model. It was not possible to calibrate the **WellZ** computer model to the actual field data because of the anisotropic and heterogeneous nature of the carbonate bedrock aquifer system. The **WellZ** data consistently either over- or under-estimated the predicted drawdown in the domestic water wells. The reason for the lack of agreement is due to the anisotropic characteristics of the aquifer in the horizontal and vertical direction. Additional study and data collection would be necessary to more fully define the aquifer so that accurate model predictions can be made.

It has been concluded that it would not be beneficial to do any additional computer modeling of the carbonate bedrock aquifer at this time because the model cannot be calibrated to match all of the actual field measurements. The carbonate aquifer shows good correlation in some of the wells but shows poor correlation in other wells.

Even though it was decided not to pursue additional computer modeling, the field data results clearly show the impact of pumping the irrigation wells. Field measurements from pumping the Bench 1 and 2 wells show the impacts on ground water levels in the neighboring water wells (Figures 20, 24 and 30). In the event of drought conditions in the area, pumping all five irrigation wells at one time could cause the ground water levels in the upper flow zones to be dewatered or drop lower than what was measured on July 14, 2011.

The specific capacity data for the Rothert 1 and Rothert 2 wells would indicate that the impacts to the water level from pumping these wells would be less than what was observed from the

Bench 1 and 2 wells. Pumping the Luckey well at 130 gpm caused less than 1 foot of drawdown in the closest domestic well located approximately 1300 feet from the irrigation well.

8.0 Recommendations

Within the context of the results and conclusions for this study, pumping the Bench 1 and 2 irrigation wells had an impact on ground water levels in the water wells completed in the shallow flow zones (Figures 20, 24 and 30). In the event of drought conditions in the area, pumping all five deep irrigation wells simultaneously has the potential to exceed the safe yield of the carbonate bedrock aquifer. If the safe yield of the aquifer is exceeded, the upper flow zones in the carbonate bedrock aquifer system will most likely become dewatered.

Accordingly, it is recommended that a best management plan be put in place to control the pumping from these deep high-yielding water wells. Any depletion of the ground water supplies in the shallow flow zones could cause dewatering of the shallow wells in the area. Recommendations are as follows:

- To fully define the hydraulic conditions for each of the high-yielding wells, each well owner should identify the flow zones present in each well with depth. Geophysical well logging of the well using caliper and gamma logs or the use of a downhole camera are recommended to identify the number and thickness of each flow zone present in the wells. Other geophysical well logs could also be used as appropriate.

- A step test should be conducted on each well to determine the well efficiency. This would be done by pumping the well between 4 to 8 different pumping rates (or steps).

- A 24-hour pumping test should be conducted on each well independently to determine the long-term sustainable yield of the well. Both drawdown and recovery data should be obtained during the 24-hour pumping test. A ground water level monitoring program should also be designed and implemented to determine the effects of pumping the high-yielding water well on individual nearby water supply wells.

- The owner of the high-yielding well should prepare a report that fully defines the aquifer characteristics, a ground water level monitoring plan, and a best management plan for protecting the ground water supplies in the carbonate bedrock aquifer. The plan should show how the operator of the high-yielding well will prevent dewatering of nearby water supply wells. A mitigation plan should be developed in the event that local domestic water supply wells are affected by pumping of the high-yielding water well.

- To allow for accurate measurements when the Bench irrigation wells are being pumped, at least 200 feet of one-inch diameter pipe should be installed in the wells to provide access for the monitoring equipment. Obstructions in the well made it difficult to obtain accurate measurements. The pipe should be centered under the access port in the well cap. If accurate measurements cannot be obtained in the Rothert wells, one-inch monitoring piping should be installed in these wells also.

- Each high-yielding water supply well owner must complete the ODNR-DSWR Water Withdrawal Facility Registration form and report the ground water usage each year to the ODNR-Division of Soil and Water Resources per ORC 1521.16.

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10.0 Partial Glossary of Terms used in the Report

Anisotropic: A material that changes in its physical properties with direction as well as having non-uniform spatial distribution of properties throughout the substance. An anisotropic medium displays directional differences in hydraulic conductivity with direction. A property of a material in which spatial characteristic can change with both the distance and the direction between two locations.

Aquifer: a consolidated or unconsolidated geologic formation or series of formations that have the ability to receive, store or transmit water.

Aquifer (artesian): An aquifer that is bounded above and below by impermeable rock or sediment layers. The water in the aquifer is also under enough pressure that, when the aquifer is tapped by a well, the water rises up the well bore to a level that is above the top of the aquifer. The water may or may not flow onto the land surface.

Bedrock: Solid rock present beneath any soil, sediment or other surface cover. In some locations it may be exposed at Earth's surface.

Carbonate Rock: A rock made up primarily of carbonate minerals (minerals containing the CO3 anionic structure). Limestone (made up primarily of calcite (CaCO3) and dolomite (CaMg CO3)2 are the most common examples.

Confined Aquifer : An aquifer that is bounded above and below by impermeable rock or sediment layers. There may or may not be enough pressure in the aquifer to make it an "artesian aquifer".

Contour Line: A line on a map that traces locations where the value of a variable is constant. For example, contour lines of elevation trace points of equal elevation across the map. All points on the "ten foot" contour line are ten feet above sea level.

Discharge: The volume of water in a flowing stream that passes a given location in a unit of time. It is frequently expressed in cubic feet per minute or gallons per minute (gpm). Calculated by the formula Q = A x V where Q is the discharge, A is the cross sectional area of the channel and V is the average velocity of the stream.

Datum: A reference location or elevation which is used as a starting point for subsequent measurements. Sea level is a datum for elevation measurements. Datums can also be arbitrary such as the starting point for stream stage measurements or based upon a physical feature such as the base of a rock unit.

Drawdown: A lowering of the water table around a producing well. The drawdown at any given location will be the vertical change between the original water table and the level of the water table reduced by pumping.

Heterogeneous: A material consisting of dissimilar or diverse ingredients or constituents.

Homogeneous: A material consisting of uniform structure or composition throughout.

Hydraulic Conductivity (K): The ability of a porous material to transmit a fluid. It is usually expressed as gallons/day/foot squared or feet per day.

Hydrogeology: The study of the interrelationship of geologic material and processes with water that control the distribution and character of water bodies.

Hydrograph: A graph that shows the change of a water-related variable over time. Example: A stream discharge hydrograph shows the change in discharge of a stream over time.

Impermeable Layer: A layer of rock, sediment or soil that does not allow water to pass through. This could be caused by a lack of pore space or pore spaces that are so small that water molecules have difficulty passing through.

Infiltration: The movement of surface water into porous soil.

Isotropic: A material that is uniform in its physical properties with direction as well as having uniform spatial distribution throughout the substance. An isotropic medium displays uniform hydraulic conductivity in all direction. A property of a material in which spatial characteristic do not change with the direction between two locations.

Joint: A fracture in rock along which there has been no displacement.

Karst: A landscape that is characterized by the features of solution weathering and erosion in the subsurface. These features include caves, sinkholes, disappearing streams, and subsurface drainage.

Porosity: The volume of pore space in a rock, sediment, or soil usually expressed as a percentage of pore space that containing water. This pore space can include openings between grains, fracture openings and caverns.

Recharge: Water added to an aquifer or other water body. An aquifer is recharged by precipitation in an area where the aquifer has a porous connection to the surface.

Recharge Area: The geographic area where water infiltrates into the ground and enters an aquifer.

Seepage: The slow movement of water through the pore spaces of a solid material. This term is also applied to a loss of water by infiltration through the bottom of a stream, canal, irrigation ditch, reservoir or other body of water.

Specific Capacity: The quantity of water produced in a well per unit foot of drawdown. Specific capacity is commonly expressed as gallons per minute per foot of drawdown (gpm/foot) over a specific time interval.

Storativity (S): A dimensionless quantity also called the storage coefficient. It is the volume of water that an aquifer released from storage or takes into storage per unit surface area of the aquifer per unit change in head

Stratification: A layered structure of sedimentary rocks in which the individual layers can be traced a considerable distance. The layers can be caused by many differences which include materials of different composition, color, grain size or orientation.

Stratigraphic Sequence: The sequence of sedimentary rock layers found in a specific geographic area, arranged in the order of their deposition.

Topographic Map: A map that shows the change in elevation over a geographic area through the use of contour lines. The contour lines trace points of equal elevation across the map. See also: contour line and contour map.

Transmissivity (T): The rate of movement of water at a prevailing viscosity through an aquifer of unit width under a unit hydraulic gradient. It is usually defined a gallons/day/foot or feet squared per day.

Water Table: A level beneath the Earth's surface, below which all pore spaces are filled with water and above which the pore spaces are filled with air. It is the top of the zone of saturation in a subsurface rock, soil or sediment unit.

Withdrawal: A removal of water from a surface or ground water source for use.

Yield (Q): The quantity of water that can be produced from an aquifer. It is generally express as gpm.

Zone of Saturation: The zone beneath the water table where all pore spaces are completely filled with water. Water that exists within this zone is known as "ground water".

11.0 Appendix A - Water Wells in the Ottawa County, Harris Township Study Area

WELL LOG NUMBER	STREET NUMBER	STREET NAME	STREET TYPE	ORIGINAL OWNER FIRST NAME	ORIGINAL OWNER LAST NAME	TOTAL DEPTH	TEST RATE	DEPTH TO WATER	AQUIFER_TYPE
120048	0	51	SR	RAYMOND	DRUSE	102		50	LIMESTONE
189744	0	51	SR	HOWEL	BRUNTY	125	16	24	LIMESTONE
120025	0	51	SR	JOHN	IMGERSOLL	97		20	ROCK
120039	0	51	SR	HENRY	WILKINS	102		35	ROCK
873016	19135	51	SR	TERRY	PARKINS	125	8	38	LIMESTONE
248691	0	51	SR	J	LUCKEY	147		35	LIMESTONE
118646	0	51	SR	DONALD	DANESCHRODER	90		25	LIMESTONE
642616	19150	51	SR	BERNARD	BRUNTZ	102	11	33	LIMESTONE
776371	19010	51	SR	DONALD	FLICK	97	15	40	LIMESTONE
808036	19145	51	SR	MICHAEL	CAMPBELL	93	15	37	LIMESTONE
85666	0	51	SR	KENNETH	SNIDER	125	7	26	LIMESTONE
362568	0	51	SR		TOLEDO EDISON	122	25	20	LIMESTONE
260016	0	51	SR	JOHN	HOVIS	140	8	44	LIMESTONE
1012298	19020	51	SR	JACK	BRADSHAW	103	14	42	LIMESTONE
484331	0	105	SR	BILL	MERCE	65	16	26	LIMESTONE
2004887	15959	105	SR	DANIEL AND JE	NEAL	59	20	21	LIMESTONE
2012772	16580	105	SR	DENNIS	STINEBAUGH	82	15	27	LIMESTONE
154497	0	105	SR	JAMES	RYMERA	100		22	LIMESTONE
592019	0	105	SR	JOHN	CAMP	50	16	13	LIMESTONE
162604	0	105	SR	HARMON	ARERS	156	6	22	LIMESTONE
154475	0	105	SR	GEO	LUBECK	62		25	LIMESTONE
2026217	18063	105	SR	DONALD	BENCH	162	35	38	LIMESTONE
605539	15227	105	SR	BILL	STOIBER	52	20	15	LIMESTONE
730509	18263	105	SR		BENCHMORE FARMS	81	16	34	LIMESTONE
741380	15189	105	SR	SCOTT	SHEPPARD	78	30	17	LIMESTONE
756514	17314	105	SR	BRUCE	CARD	62	10	26	LIMESTONE
776361	17017	105	SR	ESTHER	JAMES	52	15	31	LIMESTONE
67660	0	105	SR	LESTER	GATES	96		9	LIMESTONE
44670	0	105	SR	FRED	BRINGE	134			LIMESTONE
105476	0	105	SR	MYRLE	BRINGE	125			LIMESTONE
56792	0	105	SR	LEWIS	GELDINE	58		20	LIMESTONE

WELL LOG NUMBER	STREET NUMBER	STREET NAME	STREET TYPE	ORIGINAL OWNER FIRST NAME	ORIGINAL OWNER LAST NAME	TOTAL DEPTH	TEST RATE	DEPTH TO WATER	AQUIFER_TYPE
126071	0	105	SR	DON	BENNIER	54		12	CREVICE
120005	0	105	SR		MASTRU BROS	68		40	LIMESTONE
77581	0	105	SR	MYRON	LOHR	50		13	LIMESTONE
118635	0	105	SR	L	TOOPS	34		25	
495925	0	105	SR	ROBERT	WAX	90	7	43	LIMESTONE
359072	0	105	SR	M	HARDER	83	16	41	LIMESTONE
85669	0	105	SR	RICHARD	AMES	90	15	22	LIMESTONE
212895	0	105	SR	STANLEY	KERBEL	80	15	23	LIMESTONE
557549	0	105	SR	DAN	JAMES	60	16	28	LIMESTONE
309108	0	105	SR	BILL	DOUGLAS	66	14	17	LIMESTONE
592042	0	105	SR	ROBERT	MCMASTER	75	16	20	LIMESTONE
571170	16104	105	SR	GARY	AMELING	75	24	9	LIMESTONE
260046	0	105	SR	K	GEISLER	60		32	LIMESTONE
542884	0	105	SR	GEORGE	SHAW	60	16	29	LIMESTONE
557515	0	105	SR	DAVID	SCREPTOCK	58	16	29	CREVICE
514324	15151	105	SR		GOLDSHY CONSTRUCTION	60	21	13	LIMESTONE
484330	0	105	SR	MIKE	PAVLICA	59	16	26	LIMESTONE
557548	15146	105	SR	DANIEL	YOUNG	40	16	8	LIMESTONE
642605	18263	105	SR		BENCH FARMS	89	28	33	LIMESTONE
642635	17600	105	SR	MARTIN	WYPYHOWSKI	64	30	34	LIMESTONE
629368	17880	105	SR	STANLEY	SLATES	61	8	30	LIMESTONE
659807	15474	105	SR	CALVIN	GAHN	85	37	12	LIMESTONE
904727	17151	105	SR	NANCY	BENAVIDES	105	10	31	LIMESTONE
921400	18063	105	SR	FARMS	BENCHMORE	145	30	40	LIMESTONE
940423	17189	105	SR	BONNIE	RHODA	123	12	42	LIMESTONE
952591	17958	105	SR	MARY ANN	AMES	125	15	34	LIMESTONE
984911	16064	105	SR	DAVID	GREER	52	25	13	
984907	16027	105	SR	ROBERT	KRANTZ	62	30	18	
105487	0	105	SR	ROBERT	WEIDNER	140			
521153	0	105	SR	DENNIS	DOLPH	70	16	30	LIMESTONE
154477	0	105	SR	CARL	SAMPSEN	63		20	LIMESTONE & ROCK

WELL LOG NUMBER	STREET NUMBER	STREET NAME	STREET TYPE	ORIGINAL OWNER FIRST NAME	ORIGINAL OWNER LAST NAME	TOTAL DEPTH	TEST RATE	DEPTH TO WATER	AQUIFER_TYPE
126065	0	105	SR	ALVIN	HENFERLICH	125			LIMESTONE
120531	0	590	SR	FRED	WEIS	47	21	15	ROCK
260029	0			MAYNARD	YEASTING	88	16	35	LIMESTONE
77568	0			HEILMAN		61		20	LIMESTONE
77552	0			WILLARD	WAIS	95		40	LIMESTONE
35121	0	105/ELLISTON-TROWBRID	SR	ANDREW	HELMECI	89			LIMESTONE
334671	0	COOK	RD	PAUL	GROVER	97	16	44	LIMESTONE
309107	0	EAST RIVER	RD	MAYAMARD	YEASTING	106	16	35	LIMESTONE
521190	0	ELLISTON-TROWBRIDGE	RD	ROBERT	ROTH	70	16	27	LIMESTONE
542883	1591	ELLISTON-TROWBRIDGE	RD	WILLIAM	DUNLAP	70	16	34	LIMESTONE
484346	1685	ELLISTON-TROWBRIDGE	RD	CLIFFORD	MILLER	78	16	30	LIMESTONE
484325	1685	ELLISTON-TROWBRIDGE	RD	CLIFFORD	MILLER	73	16	30	LIMESTONE
521176	0	ELLISTON-TROWBRIDGE	RD	LYN	STACEY	70	16	35	LIMESTONE
2004024	1853	ELLISTON-TROWBRIDGE	RD	TRINIDAD	CUEVAS	102	12	33	LIMESTONE
343883	0	ELMORE		PAUL	JOHNSON	110	16	35	LIMESTONE
779808	1440	GRAYTOWN	RD	EUGENE	DUNHAM	100	15	30	LIMESTONE
878439	2128	HESSVILLE	RD	DOULAS	MOYER	48	20	15	ROCK
868348	2060	HESSVILLE	RD	JIM	HILLABRAND	83	12	22	LIMESTONE
896020	2300	HESSVILLE	RD	DEBORAH	FREIMARK	64	15	23	LIMESTONE
904745	2125	HESSVILLE	RD	NORBERT	BLISS	50	30	23	LIMESTONE
900892	2200	HESSVILLE	RD	DONALD	PHILLIPS	55	18	29	LIMESTONE
895994	2164	HESSVILLE	RD	GARY	MOHRMAN	64	30	23	LIMESTONE
901446	2128	HESSVILLE	RD	DOUG	MOYER	60	18	15	ROCK
873025	2205	HESSVILLE	RD	TODD	BRINGMAN	45	30	24	LIMESTONE
921442	2478	HESSVILLE	RD	NICHOLAS	SNEATH	63	20	20	LIMESTONE
940402	2444	HESSVILLE	RD	DAN	SLATES	58	25	23	LIMESTONE
952633	2155	HESSVILLE	RD	CHARLES	ALMROTH	62	20	21	LIMESTONE
952634	2376	HESSVILLE	RD	WILLIAM	SHULER	65	15	22	LIMESTONE
967175	2410	HESSVILLE	RD	JENNI	PFISTER	82	10	21	LIMESTONE
2007818	2175	HESSVILLE	RD	MELISSA	HERRIG	70	20	18	LIMESTONE
119464	0	NETCHER	RD		HARLAND	80		20	ROCK

WELL LOG NUMBER	STREET NUMBER	STREET NAME	STREET TYPE	ORIGINAL OWNER FIRST NAME	ORIGINAL OWNER LAST NAME	TOTAL DEPTH	TEST RATE	DEPTH TO WATER	AQUIFER_TYPE
521168	0	NETCHER	RD	DONALD	NETCHER	64	16	30	LIMESTONE
41364	0	NISSEN	RD	HARVEY	JOHNS	110		22	LIMESTONE
629358	0	NISSEN	RD	DONALD	BENCH	104	15	33	CREVICE
725105	2010	NISSEN	RD	STEPHEN	PENSION	61	5		LIMESTONE
259782	0	OPFER-LENTZ	RD	WM	SHIFFERT	128	7	21	LIMESTONE
513069	2426	OPFER-LENTZ	RD	LAWRENCE	ALBRIGHT	67	10	15	LIMESTONE
809701	2354	OPFER-LENTZ	RD		GORDON LUMBER CO	52	15	27	LIMESTONE
495926	0	ORCHARD	DR	JIM	DOLPH	112	16	36	LIMESTONE
756510	19080	ORCHARD	DR	JOHN	BECK	116	10	35	LIMESTONE
811552	19167	ORCHARD	DR	DAVID	ECERT	84	20	12	ROCK
842990	19145	ORCHARD	DR	RODOLFO	CRUZ	67	15	40	ROCK
890291	19190	ORCHARD	DR	WILLIAM	GROSS	83	30	35	ROCK
967185	19124	ORCHARD	DR	JERSEY	BECK	102	15	37	LIMESTONE
105451	0	PORTAGE RIVER SOUTH	RD	JOE	SANDWICH	100			LIMESTONE
120014	0	PORTAGE RIVER SOUTH	RD	LAURIE	DOLPH	44		25	LIMESTONE
120040	0	PORTAGE RIVER SOUTH	RD	WALTER	SCHAFF	65		35	ROCK
211680	0	PORTAGE RIVER SOUTH	RD	SCOTT	WODRICH	52	1	14	LIMESTONE
391206	0	PORTAGE RIVER SOUTH	RD	CLARKE	SUMMERS	50	16	21	LIMESTONE
359074	0	PORTAGE RIVER SOUTH	RD	RICHARD	HOOVER	58	16	26	LIMESTONE
542865	15187	PORTAGE RIVER SOUTH	RD	JOHN	HAAR	52	16	25	LIMESTONE
742190	15550	PORTAGE RIVER SOUTH	RD		ELMORE CONSERVATION	43	60	11	LIMESTONE
808088	16985	PORTAGE RIVER SOUTH	RD		HILLIE-KLICKMAN CAMP	276	55	25	LIMESTONE
849384	16119	PORTAGE RIVER SOUTH	RD	SCOTT	HENDERLY	69	10	21	LIMESTONE
904672	16056	PORTAGE RIVER SOUTH	RD	CHARLES	STELLA	83	30	22	LIMESTONE
868333	16087	PORTAGE RIVER SOUTH	RD	DANIEL	KRALL	56	20	20	LIMESTONE
868326	16165	PORTAGE RIVER SOUTH	RD	DAVE	GERRARD	76	50	20	LIMESTONE
896019	16236	PORTAGE RIVER SOUTH	RD	SCOTT	GAVORSKI	64	20	25	LIMESTONE
904659	16200	PORTAGE RIVER SOUTH	RD	MICHELLE	MELCHER	73	20	24	LIMESTONE
873024	16020	PORTAGE RIVER SOUTH	RD	KEITH	HUIZENGA	84	12	24	LIMESTONE
868318	17800	PORTAGE RIVER SOUTH	RD	JOHN	WATERS	125	15	36	LIMESTONE
868317	16241	PORTAGE RIVER SOUTH	RD	BALDWIN	WILLIAM	63	25	22	LIMESTONE

WELL LOG NUMBER	STREET NUMBER	STREET NAME	STREET TYPE	ORIGINAL OWNER FIRST NAME	ORIGINAL OWNER LAST NAME	TOTAL DEPTH	TEST RATE	DEPTH TO WATER	AQUIFER_TYPE
921369	16170	PORTAGE RIVER SOUTH	RD	WILLIAM	BALDWIN	65	25	28	LIMESTONE
984920	18305	PORTAGE RIVER SOUTH	RD	SUSAN	HANNENAN	120		35	
2003593	18190	PORTAGE RIVER SOUTH	RD	DANIEL AND AN	LAITY	128	40	15	LIMESTONE
80587	0	PORTAGE RIVER SOUTH	RD	OLIVER	ANDERSON	55			LIMESTONE
2024419	18160	PORTAGE RIVER SOUTH	RD	RYAN	BEAM	130	12	41	LIMESTONE
542866	15189	PORTAGE RIVER SOUTH	RD	JEFF	HARR	52	16	19	LIMESTONE
904681	17729	RAVINE	DR	BOB	RECKER	146	10	46	LIMESTONE
904694	17659	RAVINE	DR	BILL	ZIMMERMAN	124	12	32	LIMESTONE
952660	17639	RAVINE	DR	JAMES	KAMAN	85	20	34	LIMESTONE
2022114	17610	RAVINE	DR	RYAN & ASHLEY	TRAVIS	82	22	34	LIMESTONE
170314	0	RICE	ST	MORTON	HANNEMAN	109	16	27	LIMESTONE
592040	17781	RIVERSIDE	DR	JOHN	WATERS	72	16	34	LIMESTONE
557526	17761	RIVERSIDE	DR	HANS	GROB	70	16	34	LIMESTONE
629392	17749	RIVERSIDE	DR	MARGARET	SHAFFER	68	15	34	LIMESTONE
665335	17749	RIVERSIDE	DR	JOHN	FLETCHER	75	12	30	LIMESTONE
776348	17750	RIVERSIDE	DR	RICK	WATSON	70	15	33	LIMESTONE
915722	17785	RIVERSIDE	DR	MATTHEW	WEGERT	60	25	21	LIMESTONE
895995	16351	SMITH	RD	JOHN	WEIDNER	60	20	23	LIMESTONE
904708	15900	SMITH	RD	SHIRLEY	MACINLSKI	50	15	20	LIMESTONE
873002	16100	SMITH	RD	JIM	WEDDELL	64	20	22	LIMESTONE
940403	16290	SMITH	RD	DONALD	GOLDSBY	70	20	24	LIMESTONE
940410	16412	SMITH	RD	RAYMOND	HEILMAN	65	20	30	LIMESTONE
940454	15720	SMITH	RD	JL	OVERMYER	63	20	13	LIMESTONE
984882	16320	SMITH	RD	TIM	PERRY	81	13	21	
984434	16380	SMITH	RD	JOHN	RIFFLE	90	20	30	LIMESTONE
430910	0	SMITH	RD	LESLIE	WILLEY	138	18	12	LIMESTONE
626329	0	WEIS	RD	JOHN	ZIMMERMAN	60	3	11	LIMESTONE
449763	0	WITTY	RD		KOCIS	75	16	29	LIMESTONE
806767	19274	WITTY	RD	CAROLYN	HEMINGER	110	12	41	LIMESTONE
473801	0	WITTY	RD	DENNIS	FLICK	105	16	35	LIMESTONE
495903	19430	WITTY	RD	PAUL	GROVER	82	16	29	LIMESTONE

WELL LOG NUMBER	STREET NUMBER	STREET NAME	STREET TYPE	ORIGINAL OWNER FIRST NAME	ORIGINAL OWNER LAST NAME	TOTAL DEPTH	TEST RATE	DEPTH TO WATER	AQUIFER_TYPE
					MAXIMUM	276	60	50	
					MINIMUM	34	1	8	
					AVERAGE	83	18	27	
* Note a zero (0) means that the address was not reported to the ODNR-DSWR									
** Note a blank space means that the data was not reported to the ODNR									

12.0 Appendix B – High-Yielding Irrigation Well Logs

Bench -1

DNR 7802.05e

WELL LOG AND DRILLING REPORT

Ohio Department of Natural Resources
Division of Water, 2045 Morse Road, Columbus, Ohio 43229-6605
Voice (614) 265-6740 Fax (614) 265-6767

Well Log Number: 2028314

Page 1 of 1 for this record.

WELL LOCATION

County: OTTAWA   Township: CLAY

Owner/Builder: DON BENCH

Address of Well Location: S NISSEN RD

City: ELMORE   Zip Code +4: 43416

Permit No.: ___ Section: ___ and/or Lot No.: ___

Use of Well: AGRIC/IRRIG

Coordinates of Well (Use only one of the below coordinate systems)

State Plane Coordinates

N ☐ X ___ +/- ___ ft.

S ☐ Y ___ +/- ___ ft.

Latitude, Longitude Coordinates

Latitude: 41.492433   Longitude: -83.300004

Elevation of Well in feet: ___ +/- ___ ft.

Datum Plane: ☐ NAD27 ☒ NAD83   Elevation Source: GPS

Source of Coordinates: GPS

Well location written description:

Comments on water quality/quantity and well construction:

Surface Elevation
615 ft amsl

WELL TEST *

Pre-Pumping Static Level: 37 ft.   Date: 7/1/2010

Measured from: GROUND LEVEL

Pumping test method: PUMPING

Test Rate: 230 gpm   Duration of Test: 1 hrs.

Feet of Drawdown: 114 ft.   Sustainable Yield: 300 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☐ Yes ☒ No   Flowing Well? ☐ Yes ☒ No

PUMP/PITLESS

Type of pump: SUBMERSIBLE   Capacity: 225 gpm

Pump set at: 245 ft.   Pitless Type: WELL SEAL

Pump installed by: SHIDLER & WILDER

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm: SHIDLER & WILDER

Address: 17333 IDA CENTER RD

City, State, Zip: PETERSBURG MI 49270

Signed: ALLEN SHIDLER (Filed Electronically)   Date: 8/12/2010

ODH Registration Number: 2023

CONSTRUCTION DETAILS

Drilling Method: ROTARY

BOREHOLE/CASING (Measured from ground surface)

1 { Borehole Diameter 12 inches   Depth 100 ft.
  { Casing Diameter 8 in. Length 100 ft. Thickness 0.265 in.

2 { Borehole Diameter ___ inches   Depth ___ ft.
  { Casing Diameter ___ in. Length ___ ft. Thickness ___ in.

Casing Height Above Ground: 1 ft.

Type { 1: PVC
     { 2:

Joints { 1: Solvent
       { 2:

SCREEN

Diameter ___ in. Slot Size ___ in. Screen Length ___ ft.

Type ___ Material ___

Set Between ___ ft. and ___ ft.

GRAVEL PACK (Filter Pack)

Material/Size ___ Vol/Wt. Used ___

Method of Installation ___

Depth: Placed From: ___ ft. To: ___ ft.

GROUT

Material: Bentonite slurry   Vol/Wt. Used: 20

Method of Installation: Pumped w/Tremie pipe

Depth: Placed From: 0 ft. To: 100 ft.

DRILLING LOG*

FORMATIONS INCLUDE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Color	Texture	Formation	From	To
BROWN		CLAY	0	20
BLUE		CLAY	20	48
		GRAVEL	48	51
		LIMESTONE	51	400

Aquifer Type (Formation producing the most water.): LIMESTONE

Date of Well Completion: 7/1/2010   Total Depth of Well: 400 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
Distribute copies of this record to Customer, and Local Health Deptartment.

Bench -2

DNR 7802.05e

WELL LOG AND DRILLING REPORT

Ohio Department of Natural Resources
Division of Water, 2045 Morse Road, Columbus, Ohio 43229-6605
Voice (614) 265-6740 Fax (614) 265-6767

Well Log Number: 2025323

Page 1 of 1 for this record.

WELL LOCATION

County: OTTAWA Township: HARRIS

Owner/Builder: DON BENCH

Address of Well Location: ELLISTON TROWBRIDGE RD

City: ELMORE Zip Code +4: 43416

Permit No. ______ Section; ______ and/or Lot No. ______

Use of Well: AGRIC/IRRIG

Coordinates of Well (Use only one of the below coordinate systems)

State Plane Coordinates

N ☐ X ______ +/- ______ ft.

S ☐ Y ______ +/- ______ ft.

Latitude, Longitude Coordinates

Latitude: 41.49254 Longitude: -83.28003

Elevation of Well in feet: ______ +/- ______ ft.

Datum Plane: ☐ NAD27 ☒ NAD83 Elevation Source: GPS

Source of Coordinates: GPS

Well location written description:

Comments on water quality/quantity and well construction:

Surface Elevation
~610 ft amsl

WELL TEST *

Pre-Pumping Static Level: 34 ft. Date: 7/7/2009

Measured from: GROUND LEVEL

Pumping test method: PUMPING

Test Rate: 300 gpm Duration of Test: 1 hrs.

Feet of Drawdown: 166 ft. Sustainable Yield: 300 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☐ Yes ☒ No Flowing Well? ☐ Yes ☒ No

PUMP/PITLESS

Type of pump: SUBMERSIBLE Capacity: 25 gpm

Pump set at: 168 ft. Pitless Type: WELL SEAL

Pump installed by: ______

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm: SHIDLER & WILDER

Address: 17333 IDA CENTER RD

City, State, Zip: PETERSBURG MI 49270

Signed: ALLEN SHIDLER (Filed Electronically) Date: 12/10/2009

ODH Registration Number: 2023

CONSTRUCTION DETAILS

Drilling Method: ROTARY

BOREHOLE/CASING (Measured from ground surface)

1. Borehole Diameter: 12 inches Depth: 100 ft.
   Casing Diameter: 8 in. Length: 100 ft. Thickness: 0.265 in.
2. Borehole Diameter: ______ inches Depth: ______ ft.
   Casing Diameter: ______ in. Length: ______ ft. Thickness: ______ in.

Casing Height Above Ground: 1 ft.

Type: 1: PVC 2: ______

Joints: 1: Solvent 2: ______

SCREEN

Diameter ______ in. Slot Size ______ in. Screen Length ______ ft.

Type ______ Material ______

Set Between ______ ft. and ______ ft.

GRAVEL PACK (Filter Pack)

Material/Size ______ Vol/Wt. Used ______

Method of Installation ______

Depth: Placed From: ______ ft. To: ______ ft.

GROUT

Material: Bentonite slurry Vol/Wt. Used: 20

Method of Installation: Pumped w/Tremie pipe

Depth: Placed From: 0 ft. To: 100 ft.

DRILLING LOG*

FORMATIONS INCLUDE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Color	Texture	Formation	From	To
		SOIL	0	2
YELLOW		CLAY	2	12
BROWN		CLAY	12	52
BLACK		GRAVEL	52	56
		SHALE	56	60
		LIMESTONE	60	420

Aquifer Type (Formation producing the most water.): LIMESTONE

Date of Well Completion: 7/7/2009 Total Depth of Well: 420 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
Distribute copies of this record to Customer, and Local Health Deptartment.

Luckey

WELL LOG AND DRILLING REPORT

DNR 7802.05e

Ohio Department of Natural Resources
Division of Water, 2045 Morse Road, Columbus, Ohio 43229-6605
Voice (614) 265-6740 Fax (614) 265-6767

Well Log Number: 2028309

Page 1 of 1 for this record.

WELL LOCATION

County OTTAWA Township HARRIS

LUCKY HOMESTEAD FARMS
Owner/Builder

TR ERNSTHAUSEN
Address of Well Location

City ELMORE Zip Code +4 43416

Permit No. ______ Section: ______ and/or Lot No. ______

Use of Well AGRIC/IRRIG

Coordinates of Well (Use only one of the below coordinate systems)

State Plane Coordinates

N ☐ X ______ +/- ______ ft.

S ☐ Y ______ +/- ______ ft.

Latitude, Longitude Coordinates

Latitude: 41.494839 Longitude: -83.292503

Elevation of Well in feet: ______ +/- ______ ft.

Datum Plane: ☐ NAD27 ☒ NAD83 Elevation Source ______

Source of Coordinates: GPS

Well location written description:

Comments on water quality/quantity and well construction:

HIT 25 GPM @ 90'-100'
HIT 50 GPM @ 160'-170'
HIT 75 GPM @ 220'-240'
HIT 150 GPM @ 300'-350'

HIT 300+ GPM TOTAL

S E ≈ 612 amsl

WELL TEST *

Pre-Pumping Static Level 36 ft. Date 4/22/2010

Measured from TOP OF CASING

Pumping test method AIR

Test Rate ______ gpm Duration of Test ______ hrs.

Feet of Drawdown ______ ft. Sustainable Yield 300 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☐ Yes ☒ No Flowing Well? ☐ Yes ☒ No

PUMP/PITLESS

Type of pump Grundfoss Capacity 150 gpm

Pump set at 200 ft. Pitless Type ______

Pump installed by ______

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm STOEPFEL DRILLING, LLC

Address 12245 SR 115

City, State, Zip OTTAWA OH 45875

Signed ROGER WINKLE/GARY VONDER EMBSE Date 8/11/2010

(Filed Electronically)

ODH Registration Number 0115

CONSTRUCTION DETAILS

Drilling Method: ROTARY/AIRHAMR

BOREHOLE/CASING (Measured from ground surface)

1 { Borehole Diameter 12 inches Depth 54 ft.
Casing Diameter 8.625 in. Length 55 ft. Thickness 0.32 in. }

2 { Borehole Diameter 7.75 inches Depth 350 ft.
Casing Diameter ______ in. Length ______ ft. Thickness ______ in. }

Casing Height Above Ground 1 ft.

Type { 1: Steel
2: ______ }

Joints { 1: Threaded
2: ______ }

SCREEN

Diameter ______ in. Slot Size ______ in. Screen Length ______ ft.

Type ______ Material ______

Set Between ______ ft. and ______ ft.

GRAVEL PACK (Filter Pack)

Material/Size ______ Vol/Wt. Used ______

Method of Installation ______

Depth: Placed From: ______ ft. To: ______ ft.

GROUT

Material Bentonite/polymer slurry Vol/Wt. Used 75 GALLONS/150 LBS.

Method of Installation Pumped w/Tremie pipe

Depth: Placed From: 0 ft. To: 54 ft.

DRILLING LOG*

FORMATIONS INCLUDE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Color	Texture	Formation	From	To
LT. BROWN	MOIST	CLAY	0	12
BROWN	GUMMEY	CLAY	12	31
LT. GRAY	PACKED	HARDPAN	31	48
LT. BROWN	BROKEN	LIMESTONE	48	51
LT. GRAY	MEDIUM	LIMESTONE	51	70
LT. BROWN	MEDIUM	LIMESTONE	70	115
WHITE	SOFT	LIMESTONE	115	175
LT. BROWN	SOFT	LIMESTONE	175	280
WHITE	SOFT	LIMESTONE	280	350
		Water Encountered At	90	100
			160	170
			220	240
			300	350

Aquifer Type (Formation producing the most water.) LIMESTONE

Date of Well Completion 4/22/2010 Total Depth of Well 350 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
Distribute copies of this record to Customer, and Local Health Deptartment.

Rothert-1

DNR 7802.05e

WELL LOG AND DRILLING REPORT

Ohio Department of Natural Resources
Division of Water, 2045 Morse Road, Columbus, Ohio 43229-6605
Voice (614) 265-6740 Fax (614) 265-6767

Well Log Number: 2001245

Page 1 of 1 for this record.

WELL LOCATION

County: OTTAWA Township: HARRIS

Owner/Builder: ROTHERT FARMS

Address of Well Location: 1084 S OPFER-LENTZ RD

City: ELMORE Zip Code +4: 43416

Permit No. ____ Section: ____ and/or Lot No. ____

Use of Well: AGRIC/IRRIG

Coordinates of Well (Use only one of the below coordinate systems)

State Plane Coordinates

N ☐ X ____ +/- ____ ft.

S ☐ Y ____ +/- ____ ft.

Latitude, Longitude Coordinates

Latitude: 41.28779 Longitude: 83.19403

Elevation of Well in feet: ____ +/- ____ ft.

Datum Plane: ☐ NAD27 ☒ NAD83 Elevation Source ____

Source of Coordinates: GPS

Well location written description:

41.47965
83.323383

Comments on water quality/quantity and well construction:

Surface Elevation
~620 ft amsl

WELL TEST *

Pre-Pumping Static Level: 30 ft. Date: 4/6/2005

Measured from: TOP OF CASING

Pumping test method: PUMPING

Test Rate: 240 gpm Duration of Test: 4 hrs.

Feet of Drawdown: 40 ft. Sustainable Yield: 240 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☐ Yes ☒ No Flowing Well? ☐ Yes ☒ No

PUMP/PITLESS

Type of pump: SUBMERSIBLE Capacity: 225 gpm

Pump set at: 145 ft. Pitless Type: WELL SEAL

Pump installed by: SHIDLER & WILDER WELLS & PUMPS, INC

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm: SHIDLER & WILDER

Address: 17333 IDA CENTER RD

City, State, Zip: PETERSBURG MI 49270

Signed: ALLEN SHIDLER (Filed Electronically) Date: 2/15/2006

ODH Registration Number: 2023ODH

CONSTRUCTION DETAILS

Drilling Method: MUD ROTARY

BOREHOLE/CASING (Measured from ground surface)

1 { Borehole Diameter 12.25 inches Depth 98 ft.
  { Casing Diameter 8 in. Length 98 ft. Thickness 0.41 in.

2 { Borehole Diameter ____ inches Depth ____ ft.
  { Casing Diameter ____ in. Length ____ ft. Thickness ____ in.

Casing Height Above Ground ____ ft.

Type { 1: PVC
     { 2:

Joints { 1: Solvent
       { 2:

SCREEN

Diameter ____ in. Slot Size ____ in. Screen Length ____ ft.

Type ____ Material ____

Set Between ____ ft. and ____ ft.

GRAVEL PACK (Filter Pack)

Material/Size ____ Vol/Wt. Used ____

Method of Installation ____

Depth: Placed From: ____ ft. To: ____ ft.

GROUT

Material: Bentonite slurry Vol/Wt. Used: 8

Method of Installation: Pumped w/Tremie pipe

Depth: Placed From: 0 ft. To: 98 ft.

DRILLING LOG*

FORMATIONS INCLUDE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Color	Texture	Formation	From	To
BROWN		SILT AND CLAY	0	14
GRAY		CLAY & GRAVEL	14	18
		LIMESTONE	18	345

Aquifer Type (Formation producing the most water.): LIMESTONE

Date of Well Completion: 4/6/2005 Total Depth of Well: 345 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
Distribute copies of this record to Customer, and Local Health Deptartment.

Rothert 2

DNR 7802.05e

WELL LOG AND DRILLING REPORT

Ohio Department of Natural Resources
Division of Water, 2045 Morse Road, Columbus, Ohio 43229-6605
Voice (614) 265-6740 Fax (614) 265-6767

Well Log Number: 2001244

Page 1 of 1 for this record.

WELL LOCATION

County: OTTAWA Township: HARRIS

Owner/Builder: ROTHERT FARMS

Address of Well Location: HGWY 105

City: ELMORE Zip Code +4: 43416

Permit No. ______ Section: ______ and/or Lot No. ______

Use of Well: AGRIC/IRRIG

Coordinates of Well (Use only one of the below coordinate systems)

State Plane Coordinates

N ☐ X ______ +/- ______ ft.

S ☐ Y ______ +/- ______ ft.

Latitude, Longitude Coordinates

Latitude: 41.2957 Longitude: 83.14191

Elevation of Well in feet: ______ +/- ______ ft.

Datum Plane: ☐ NAD27 ☒ NAD83 Elevation Source ______

Source of Coordinates: GPS

Well location written description:

41.492833 83.236517

Comments on water quality/quantity and well construction:

Surface Elevation ~ 600' amsl

5

WELL TEST *

Pre-Pumping Static Level: 31 ft. Date: 6/21/2005

Measured from: TOP OF CASING

Pumping test method: PUMPING

Test Rate: 280 gpm Duration of Test: 6 hrs.

Feet of Drawdown: 45 ft. Sustainable Yield: 280 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☐ Yes ☒ No Flowing Well? ☐ Yes ☒ No

PUMP/PITLESS

Type of pump: SUBMERSIBLE Capacity: 225 gpm

Pump set at: 166 ft. Pitless Type: WELL SEAL

Pump installed by: SHIDLER & WILDER WELLS & PUMPS INC.

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm: SHIDLER & WILDER

Address: 17333 RD IDA CENTER

City, State, Zip: PETERSBURG MI 49270

Signed: ALLEN SHIDLER (Filed Electronically) Date: 2/15/2006

ODH Registration Number: 2023ODH

CONSTRUCTION DETAILS

Drilling Method: MUD ROTARY

BOREHOLE/CASING (Measured from ground surface)

1 { Borehole Diameter 12.25 inches Depth 100 ft.
Casing Diameter 8 in. Length 100 ft. Thickness 0.41 in. }

2 { Borehole Diameter ______ inches Depth ______ ft.
Casing Diameter ______ in. Length ______ ft. Thickness ______ in. }

Casing Height Above Ground: 2 ft.

Type { 1: PVC 2: ______ }

Joints { 1: Solvent 2: ______ }

SCREEN

Diameter ______ in. Slot Size ______ in. Screen Length ______ ft.

Type ______ Material ______

Set Between ______ ft. and ______ ft.

GRAVEL PACK (Filter Pack)

Material/Size ______ Vol/Wt. Used ______

Method of Installation ______

Depth: Placed From: ______ ft. To: ______ ft.

GROUT

Material: Bentonite slurry Vol/Wt. Used: 8

Method of Installation: Pumped w/Tremie pipe

Depth: Placed From: 0 ft. To: 100 ft.

DRILLING LOG*

FORMATIONS INCLUDE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Color	Texture	Formation	From	To
BROWN	SMALL	CLAY & GRAVEL	0	18
GRAY	SMALL	CLAY & GRAVEL	18	21
		LIMESTONE	21	365

Aquifer Type (Formation producing the most water.): LIMESTONE

Date of Well Completion: 6/21/2005 Total Depth of Well: 365 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
Distribute copies of this record to Customer, and Local Health Deptartment.

13.0 Appendix C –Well Logs Used for Observation

WELL LOG AND DRILLING REPORT

665324

BLG

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Fountain Square
Columbus, Ohio 43224

NO CARBON PAPER NECESSARY— SELF-TRANSCRIBING

Permit Number ____________

COUNTY Ottawa TOWNSHIP Harris SECTION OF TOWNSHIP ____________

OWNER Donald Bench ADDRESS RT 105, Elmore, Ohio

LOCATION OF PROPERTY Labor Camp 1709 on Nissen Rd 1/4 mi N of RT 51

CONSTRUCTION DETAILS

Casing diameter 5 5/8" Length of casing 59 1/2'

Type of screen ____ Length of screen ____

Type of pump ____

Capacity of pump ____

Depth of pump setting ____

Date of completion ____
Rotary ☐ or Cable ☐

BAILING OR PUMPING TEST
(specify one by circling)

Test rate 20 gpm Duration of test 24 hrs

Drawdown 33 ft Date 6/20/88

Static level (depth to water) 27' ft

Quality (clear, cloudy, taste, odor) ____

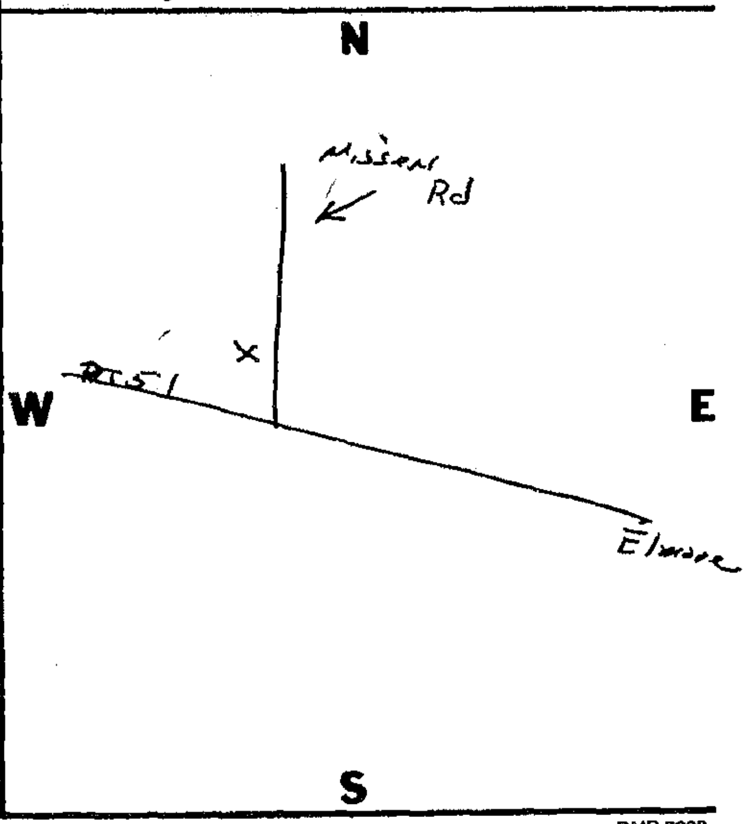
Pump installed by ____

WELL LOG*

Formations: sandstone, shale, limestone, gravel, clay	From	To
Clay	0 ft	48 ft
Soft Limestone	48	51
Soft + Broken Formation	51	55
Limestone	55	125
Crevice @ 57 1/2'		
This well replaces		
well drilled well		
Log #629358		
6/20/86		

SKETCH SHOWING LOCATION

Locate in reference to numbered state highways, street intersections, county roads, etc.



* If additional space is needed to complete well log, use next consecutively numbered form.

DNR 7802

DRILLING FIRM KIMBALL WELL DRILLING ~~5709 WOODVILLE ROAD~~ REGISTRATION NUMBER 57 DATE 6/20/88

ADDRESS NORTHWOOD, OHIO 43619 SIGNED P. Kimball

Completion of this form is required by 1521.05, Ohio Revised Code - file within 30 days after completion.

WHITE ORIGINAL COPY - ODNR, DIVISION OF WATER, FOUNTAIN SQ., COLS., OHIO 43224 / Blue - Customer's Copy / Pink - Driller's Copy / Green - Local Health Dept. Copy

DNR 7802.96

TYPE OR USE PEN
SELF TRANSCRIBING
PRESS HARD

WELL LOG AND DRILLING REPORT

Ohio Department of Natural Resources
Divison of Water, 1939 Fountain Square Drive
Columbus, Ohio 43224-9971 Voice (614) 265-6739 Fax (614) 447-9503

Page 921445

WELL LOCATION

County OTTAWA Township Clay

Owner/Builder (Circle One or Both) GRACE LUTHERAN CHURCH
First Last

Address of Well Location 19225 W WITTY RD
Number Street Name

City ELMORE Zip Code +4 43416

Permit No. EPA Section/Lot No. (Circle One or Both) 12 Section

Location of Well in State Plane coordinates, if available: Use of Well PUBLIC-EPA

N ☐ X 0.00 +/- ft. or m

S ☐ Y 0.00 +/- ft. or m

Elevation of Well 0.00 +/- ft. or m

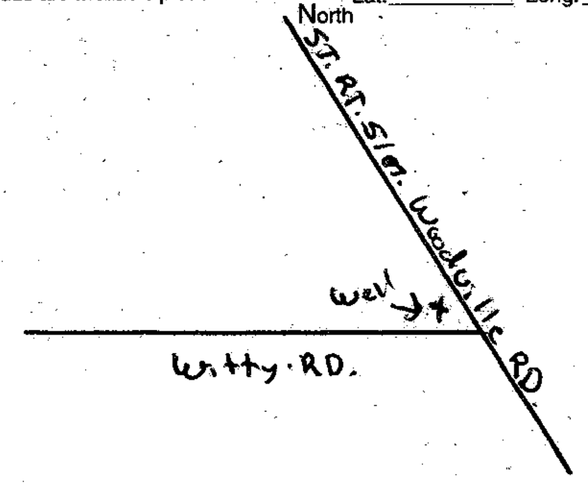
Datum Plain: ☐ NAD27 ☐ NAD83 Elevation Source

Source of Coordinates: ☐ GPS ☐ Survey ☒ Other

Sketch a map showing distance well lies from numbered state highways, street intersections, county roads, buildings or other notable landmarks. If latitude and longitude are available please include here: Lat: ° ' " Long: ° ' "

North

W



E
a
s
t

South

WELL TEST*

Pre-Pumping Static Level 40 ft. Date 09/14/01

Measured from: ☐ Top of Casing ☐ Ground Level ☒ Other TOG

☒ Air ☐ Bailing ☐ Pumping* ☐ Other

Test Rate 45 gpm Duration of Test 24 hrs.

Feet of Drawdown 73 ft. Sustainable Yield 45 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☒ Yes ☐ No Flowing Well? ☐ Yes ☒ No

Quality

PUMP/PITLESS

Type of pump Capacity 0 gpm

Pump set at 0 ft. Pitless Type

Pump installed by

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm KIMBALL WELL DRILLING

Address 2320 N. Billman Road

City, State, Zip Genoa, OH 43430

Signed Curtis E Kimball Date 11/08/01

ODH Registration Number 57

CONSTRUCTION DETAILS

☒ Rotary ☐ Cable ☐ Augered ☐ Driven ☐ Other

BOREHOLE/CASING (measured from ground surface)

1 ☒ Borehole Diameter 9 inches Depth 46 ft.

Casing Diameter 6 in. Length 47 ft. Thickness in.

2 ☒ Borehole Diameter inches Depth ft.

Casing Diameter in. Length ft. Thickness in.

Casing Height Above Ground 12 ft.

Type: Steel 1 ☐ 2 ☐; Galv. 1 ☐ 2 ☐; PVC 1 ☐ 2 ☐; 1 ☒ GALVINIZED; 2 ☒ Other

Joints: Threaded 1 ☒ 2 ☐; Welded 1 ☐ 2 ☐; Solvent 1 ☐ 2 ☐; 1 ☐; 2 ☒ Other

SCREEN

Diameter Slot Size Screen Length ft.

Type Material

Set Between ft. and ft.

GRAVEL PACK (Filter Pack)

Material/Size Volume/Weight Used

Method of Installation

Depth: Placed FROM ft. TO ft.

GROUT

Material BENSEAL Volume/Weight Used 450#

Method of Installation TREME PIPE

Depth: Placed FROM 46 ft. TO TOG ft.

DRILLING LOG*

INDICATE DEPTH(S) AT WHICH WATER IS ENCOUNTERED. Show color, texture, hardness, and formation: sandstone, shale, limestone, gravel, clay, sand, etc.	From	To
SANDY SOIL	0	5
CLAY	5	30
CLAY AND GRAVEL	30	32
SAND	32	35
CLAY	35	39
CLAY AND GRAVEL	39	41
LIMESTONE	41	165

*(If more space is needed to complete drilling log, use next consecutively numbered form.)

Date of Well Completion 09/14/01 Total Depth of Well 165 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.

ORIGINAL COPY TO - ODNR, DIVISION OF WATER, 1939 FOUNTAIN SQ. DRIVE, COLS., OHIO 43224-9971

Blue - Customer's copy Pink - Driller's copy Green - Local Health Dept. copy

Trailer Park

WELL-LOG AND DRILLING REPORT

ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
1562 W. First Avenue
Columbus, Ohio 43212

PLEASE USE PENCIL OR TYPEWRITER
DO NOT USE INK.

No 348436

County OTTAWA Township HARRIS Section of Township 8

Owner MR CLIFFORD MILLER Address ELMORE

Location of property 1795 ELLISTON RD. NEAR ST RT 105

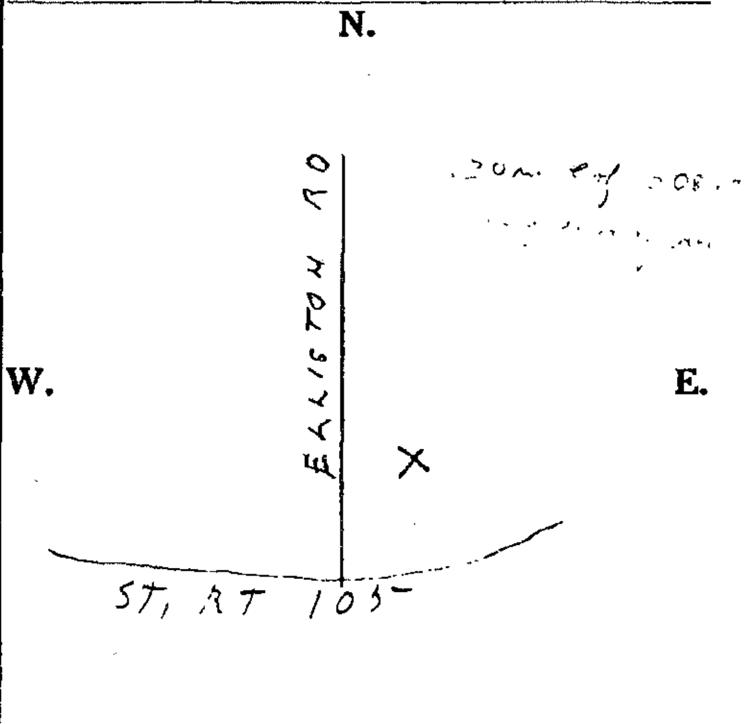
CONSTRUCTION DETAILS	BAILING OR PUMPING TEST
Casing diameter 5" Length of casing 48	Pumping Rate 20 G.P.M. Duration of test ___ hrs.
Type of screen ___ Length of screen ___	Drawdown 2 ft. Date ___
Type of pump ___	Static level-depth to water 28 ft.
Capacity of pump ___	Quality (clear, cloudy, taste, odor) CLEAR
Depth of pump setting ___	
Date of completion ___	Pump installed by ___

WELL LOG*

Formations Sandstone, shale, limestone, gravel and clay	From	To
	0 Feet	Ft.
CLAY	—	43
LIMESTONE	43	65

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm DEWEY [illegible] Date 8-4-64

Address [illegible] Signed [illegible]

*If additional space is needed to complete well log, use next consecutive numbered form.

A

Trailor Park

WELL LOG AND DRILLING REPORT

ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
1562 W. First Avenue
Columbus, Ohio 43212

PLEASE USE PENCIL OR TYPEWRITER
DO NOT USE INK.

Nº 348437
JSW

County OTTAWA Township HARRIS Section of Township 8

Owner MR. CLIFFORD MILLER Address ELMORE O

Location of property 1795 ELLISTON RD NEAR 105

CONSTRUCTION DETAILS

Casing diameter 5 5/8 Length of casing 48

Type of screen ______ Length of screen ______

Type of pump ______

Capacity of pump ______

Depth of pump setting ______

Date of completion ______

BAILING OR PUMPING TEST

Pumping Rate 20 G.P.M. Duration of test ______ hrs.

Drawdown NONE ft. Date ______

Static level-depth to water 28 ft.

Quality (clear, cloudy, taste, odor) CLEAR

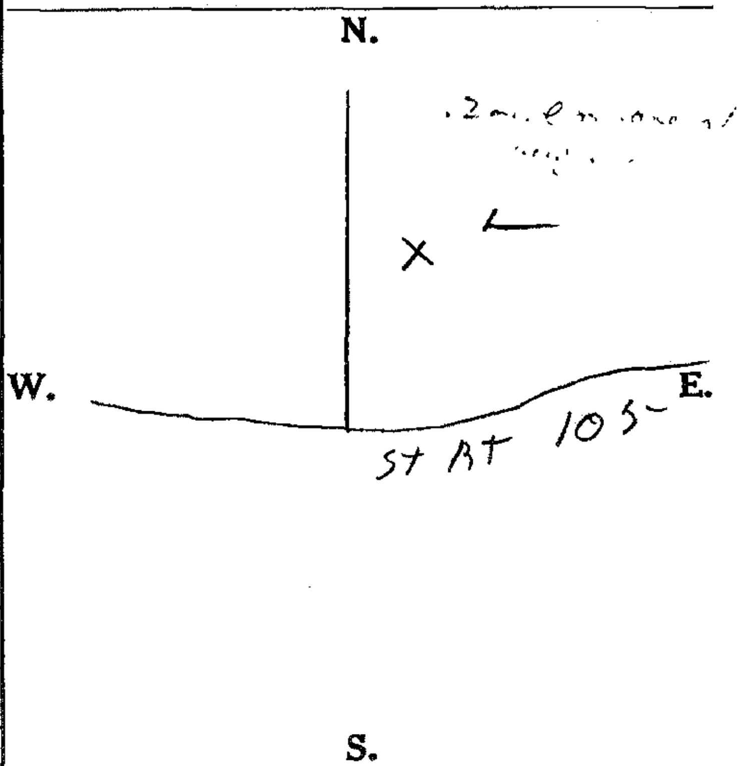
Pump installed by ______

WELL LOG*

Formations Sandstone, shale, limestone, gravel and clay	From	To
	0 Feet	Ft.
CLAY	—	44
LIMESTONE	44	67

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm DEWEY WIDMER Date 9-13-69

Address MILLBURY O Signed [illegible]

*If additional space is needed to complete well log, use next consecutive numbered form.

A

mH

DNR 7802.05e

WELL LOG AND DRILLING REPORT

Ohio Department of Natural Resources
Division of Water, 2045 Morse Road, Columbus, Ohio 43229-6605
Voice (614) 265-6740 Fax (614) 265-6767

Well Log Number: 2028178

Page 1 of 1 for this record.

WELL LOCATION

County: OTTAWA Township: HARRIS

Owner/Builder: MARTIN HALICEK

Address of Well Location: 1196 S NISSEN RD

City: ELMORE Zip Code +4: 43416

Permit No.: 400398 Section: 12 and/or Lot No.:

Use of Well: DOMESTIC

Coordinates of Well (Use only one of the below coordinate systems)

State Plane Coordinates

N ☐ X ______ +/- ______ ft.

S ☐ Y ______ +/- ______ ft.

Latitude, Longitude Coordinates

Latitude: 41.4986 Longitude: -83.300633

Elevation of Well in feet: 658 +/- ______ ft.

Datum Plane: ☐ NAD27 ☒ NAD83 Elevation Source: GPS

Source of Coordinates: GPS

Well location written description:

Comments on water quality/quantity and well construction:

WELL TEST *

Pre-Pumping Static Level: 46 ft. Date: 7/13/2010

Measured from: GROUND LEVEL

Pumping test method: AIR

Test Rate: 15 gpm Duration of Test: 1 hrs.

Feet of Drawdown: 56 ft. Sustainable Yield: 12 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☐ Yes ☒ No Flowing Well? ☐ Yes ☒ No

PUMP/PITLESS

Type of pump: SUBMERSIBLE Capacity: 12 gpm

Pump set at: 110 ft. Pitless Type:

Pump installed by: KIMBALL WELL DRILLING

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm: KIMBALL WELL DRILLING

Address: 2320 N BILLMAN RD

City, State, Zip: GENOA OH 43430

Signed: CURTIS KIMBALL (Filed Electronically) Date: 8/3/2010

ODH Registration Number: 0057

CONSTRUCTION DETAILS

Drilling Method: ROTARY/AIRHAMR

BOREHOLE/CASING (Measured from ground surface)

1 { Borehole Diameter 9.5 inches Depth 60.9 ft.
Casing Diameter 6 in. Length 61.9 ft. Thickness 0.316 in.

2 { Borehole Diameter 5.5 inches Depth 142 ft.
Casing Diameter ______ in. Length ______ ft. Thickness ______ in.

Casing Height Above Ground: 1 ft.

Type { 1: PVC
2:

Joints { 1: O-ring
2:

SCREEN

Diameter ______ in. Slot Size ______ in. Screen Length ______ ft.

Type ______ Material ______

Set Between ______ ft. and ______ ft.

GRAVEL PACK (Filter Pack)

Material/Size ______ Vol/Wt. Used ______

Method of Installation ______

Depth: Placed From: ______ ft. To: ______ ft.

GROUT

Material: Bentonite/polymer slurry Vol/Wt. Used: #250

Method of Installation: Pumped w/Tremie pipe

Depth: Placed From: 60 ft. To: 0 ft.

DRILLING LOG*

FORMATIONS INCLUDE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Color	Texture	Formation	From	To
		CLAY	0	57
		LIMESTONE	57	142
		Water Encountered At	77	77
			96	96
			116	116
			136	136

Aquifer Type (Formation producing the most water.): LIMESTONE

Date of Well Completion: 7/15/2010 Total Depth of Well: 142 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
Distribute copies of this record to Customer, and Local Health Deptartment.

LOCATED

WELL LOG AND DRILLING REPORT

ORIGINAL

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Columbus, Ohio

No 77581

51 25/55

51

ML

1,796,900
666,100N

County Ottawa Township Allen Section of Township or Lot Number 3

Owner [illegible] Address [illegible]

Location of property on Route #105 - Cor #105 & Stange Rd - 2mi E of Elmore

CONSTRUCTION DETAILS

Casing diameter 4 1/4" Length of casing 30'

Type of screen Length of screen

Type of pump

Capacity of pump

Depth of pump setting

PUMPING TEST

Pumping rate G.P.M. Duration of test hrs.

Drawdown ft. Date

Developed capacity

Static level—depth to water 13 ft.

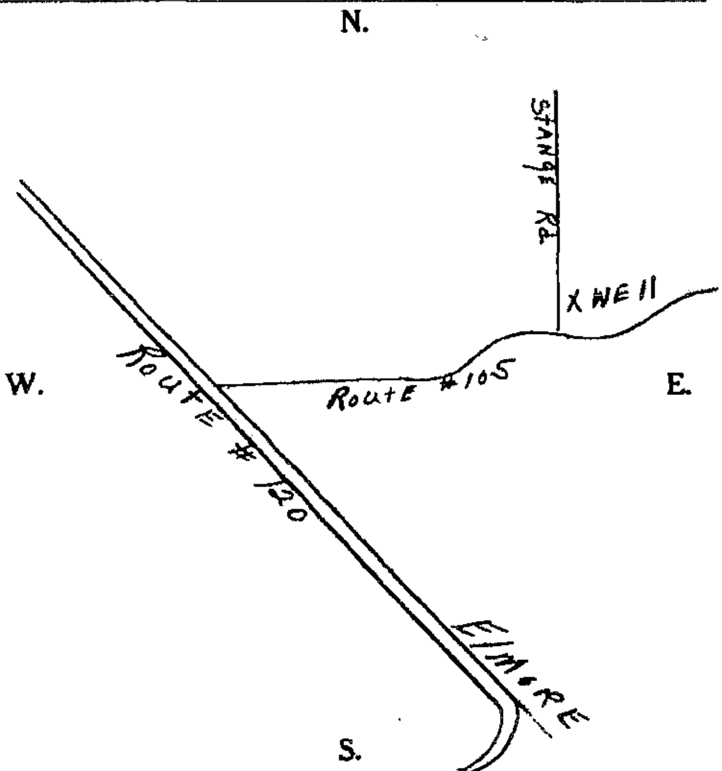
Pump installed by

WELL LOG

Formations Sandstone, shale, limestone, gravel and clay	From	To
Surface	0 Feet	3 Ft.
Red Clay	3	13
Blue Clay	13	25
Limestone	25	50
Water at 45'		

SKETCH SHOWING LOCATION

Locate in reference to numbered State Highways, St. Intersections, County roads, etc.



See reverse side for instructions

Drilling Firm Robert [illegible] Date 8-4-51

Address [illegible] Signed Robert [illegible]

51

PD

DNR 7802.05e

WELL LOG AND DRILLING REPORT

Ohio Department of Natural Resources
Division of Water, 2045 Morse Road, Columbus, Ohio 43229-6605
Voice (614) 265-6740 Fax (614) 265-6767

Well Log Number: 2011236

Page 1 of 1 for this record.

WELL LOCATION

County: OTTAWA Township: HARRIS

Owner/Builder: PAUL AND LAURIE DUPLER

Address of Well Location: 2756 S OPFER LENTZ RD

City: ELMORE Zip Code +4: 43416

Permit No.: 379452 Section: 14 and/or Lot No.:

Use of Well: DOMESTIC

Coordinates of Well (Use only one of the below coordinate systems)

State Plane Coordinates

N ☐ X ______ +/- ______ ft.

S ☐ Y ______ +/- ______ ft.

Latitude, Longitude Coordinates

Latitude: 41.4675 Longitude: 83.316944

Elevation of Well in feet: ______ +/- ______ ft.

Datum Plane: ☐ NAD27 ☐ NAD83 Elevation Source: ______

Source of Coordinates: GPS

Well location written description:

Comments on water quality/quantity and well construction:

WELL TEST *

Pre-Pumping Static Level: 26 ft. Date: 7/16/2007

Measured from: GROUND LEVEL

Pumping test method: AIR

Test Rate: 12 gpm Duration of Test: 1 hrs.

Feet of Drawdown: 44 ft. Sustainable Yield: 10 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☐ Yes ☒ No Flowing Well? ☐ Yes ☒ No

PUMP/PITLESS

Type of pump: SUBMERSIBLE Capacity: 12 gpm

Pump set at: 90 ft. Pitless Type: MERRILL PULL THRU

Pump installed by: KIMBALL WELL DRILLING

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm: KIMBALL WELL DRILLING

Address: 2320 N BILLMAN RD

City, State, Zip: GENOA OH 43430

Signed: CURTIS KIMBALL Date: 7/24/2007

(Filed Electronically)

ODH Registration Number: 0057

CONSTRUCTION DETAILS

Drilling Method: ROTARY/AIRHAMR

BOREHOLE/CASING (Measured from ground surface)

1 { Borehole Diameter 9 inches Depth 26 ft.
  Casing Diameter 6 in. Length 27 ft. Thickness 0.316 in.

2 { Borehole Diameter ______ inches Depth ______ ft.
  Casing Diameter ______ in. Length ______ ft. Thickness ______ in.

Casing Height Above Ground: 12 ft.

Type { 1: PVC
  2:

Joints { 1: splinelock
  2:

SCREEN

Diameter ______ in. Slot Size ______ in. Screen Length ______ ft.

Type ______ Material ______

Set Between ______ ft. and ______ ft.

GRAVEL PACK (Filter Pack)

Material/Size ______ Vol/Wt. Used ______

Method of Installation ______

Depth: Placed From: ______ ft. To: ______ ft.

GROUT

Material: Bentonite/polymer slurry Vol/Wt. Used: 125#

Method of Installation: Pumped w/Tremie pipe

Depth: Placed From: 26 ft. To: 0 ft.

DRILLING LOG*

FORMATIONS INCLUDE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Color	Texture	Formation	From	To
	SANDY	SOIL	0	3
		CLAY	3	18
		LIMESTONE	18	102
		Water Encountered At	82	102

Aquifer Type (Formation producing the most water.): LIMESTONE

Date of Well Completion: 7/18/2007 Total Depth of Well: 102 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
Distribute copies of this record to Customer, and Local Health Deptartment.

WELL LOG AND DRILLING REPORT

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
Fountain Square
Columbus, Ohio 43224

NO CARBON PAPER NECESSARY– SELF-TRANSCRIBING

615063
RH
83-47

COUNTY Ottawa TOWNSHIP Harris SECTION OF TOWNSHIP 02658

OWNER Larry Kontak ADDRESS 1400 S. Ernsthausen Rd, Elmore

LOCATION OF PROPERTY Same as above

CONSTRUCTION DETAILS

Casing diameter 5 5/8 Length of casing 53'

Type of screen ____ Length of screen ____

Type of pump ____

Capacity of pump ____

Depth of pump setting ____

Date of completion ____

BAILING OR PUMPING TEST
(specify one by circling) — PUMPING circled

Test rate 12 gpm Duration of test 1 hrs

Drawdown – ft Date 17 June 83

Static level (depth to water) 36 ft

Quality (clear, cloudy, taste, odor) ____

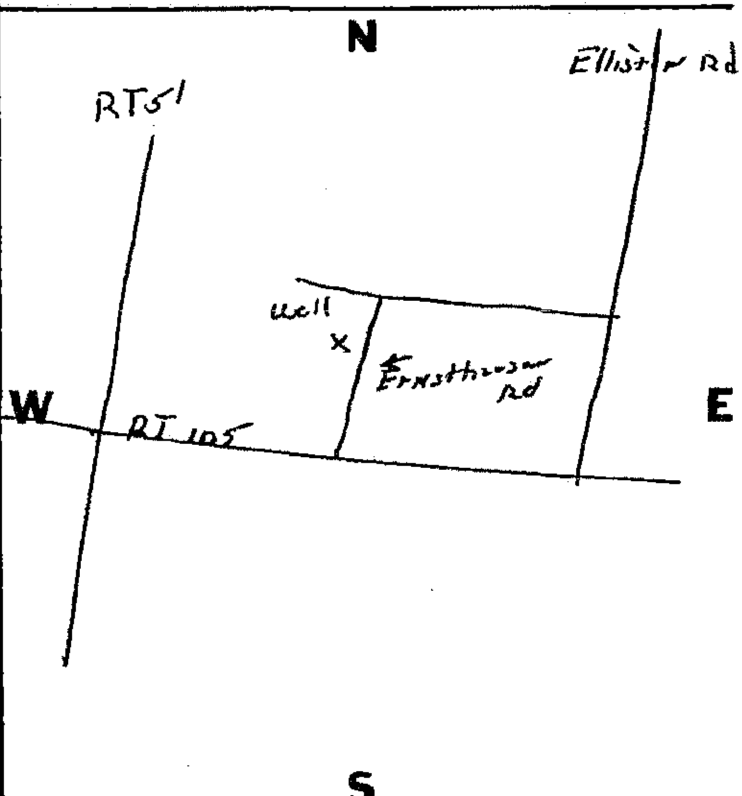
Pump installed by ____

WELL LOG*

Formations: sandstone, shale, limestone, gravel, clay	From	To
Clay	0 ft	42 ft
Shale lime	42	52
limestone	52	55

SKETCH SHOWING LOCATION

Locate in reference to numbered state highways, street intersections, county roads, etc.



DRILLING FIRM Kimball Well Drilling
ADDRESS 5709 Woodville Road Toledo, Ohio 43616

DATE 17 June 83

SIGNED [signature]

*If additional space is needed to complete well log, use next consecutive numbered form.

ORIGINAL COPY – ODNR, DIVISION OF WATER, FOUNTAIN SQ., COLS., OHIO 43224

WELL LOG AND DRILLING REPORT

711797
90-129

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
1939 Fountain Square Drive
Columbus, Ohio 43224
(614) 265-6739

TYPE OR USE PEN
SELF-TRANSCRIBING
PRESS HARD!

Permit Number 103381
RW

COUNTY Ottawa TOWNSHIP Harris SECTION/LOT NO. ____
(CIRCLE ONE)

OWNER/BUILDER (CIRCLE ONE OR BOTH) Robert Weidner PROPERTY ADDRESS 18587 W. ST. RT 105, Elmore, O (ADDRESS OF WELL LOCATION)

LOCATION OF PROPERTY 1/2 mi E of RT 51 N side of RT 105

CONSTRUCTION DETAILS

CASING
Diameter 5 5/8 in. Length 49 ft. Wall Thickness ____ in.
Type: ☒ Steel ☒ Galv. ☐ PVC ☐ Other ____
Joints: ☒ Threaded ☐ Welded ☐ Solvent ☐ Other ____

SCREEN
Type (wire wrapped, louvered, etc.) ____ Material ____
Length ____ ft. Diameter ____ in.
Set between ____ ft. and ____ ft. Slot ____

☒ Rotary ☐ Cable ☐ Augered ☐ Driven ☐ Dug ☐ Other ____
Date of completion 9/17/90

GROUT
Material Benseal Volume used ____
Method of installation Pumped Thru Tremie Pipe
Depth: placed from 49 ft. to TOG ft.

GRAVEL PACK
Material ____ Volume used ____
Method of installation ____
Depth: placed from ____ ft. to ____ ft.

Pitless Device ☒ Adapter ☐ Preassembled unit
Use of Well Home

PUMP

Type of pump ____ Capacity ____ gpm
Pump set at ____ ft.
Pump installed by ____

WELL TEST

Bailing ☐ or Pumping ☐ Air
Test rate 8-10 gpm Duration of test ____ hrs.
Drawdown ? ft.
Measured from: ☒ top of casing ☐ ground level ☐ Other ____
Static Level (depth to water) 46 ft. Date: 9/17/90
Quality (clear, cloudy, taste, odor) ____
(Attach a copy of the pumping test record, per 1521.05, ORC)

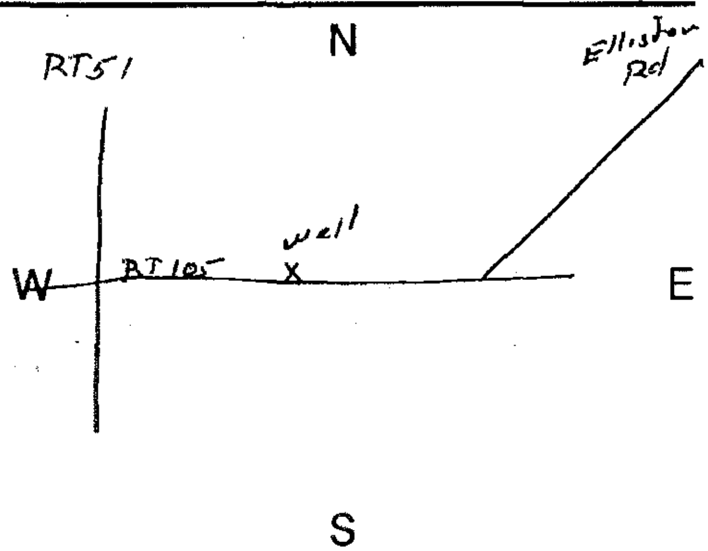
WELL LOG*

INDICATE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Show color, texture, hardness, and formation: sandstone, shale, limestone, gravel, clay, sand, etc.	From	To
Sand & Sandy Clay	0 ft.	12 ft.
Clay	12	41
Shale Lime	41	47
Limestone	47	99

SKETCH SHOWING LOCATION

Show distances well lies from numbered state highways, street intersections, county roads, etc.



* If additional space is needed to complete well log, use next consecutively numbered form

DNR 7802.88

DRILLING FIRM KIMBALL WELL DRILLING
ADDRESS 2320 N. Billman Road
CITY, STATE, ZIP Genoa, Ohio 43430

SIGNED R. Kimball
DATE 9/17/90
ODH REGISTRATION NUMBER 57

Completion of this form is required by 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.

ORIGINAL COPY - ODNR, DIVISION OF WATER, 1939 FOUNTAIN SQ. DRIVE, COLS., OHIO 43224

Blue - Customer's Copy Pink - Driller's Copy Green - Local Health Dept. Copy

WELL LOG AND DRILLING REPORT

696615 SU
89-88

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Water
1939 Fountain Square Drive
Columbus, Ohio 43224
(614) 265-6739

TYPE OR USE PEN
SELF-TRANSCRIBING
PRESS HARD!

Permit Number 87912

COUNTY Ottawa TOWNSHIP Harris SECTION/LOT NO. ____ (CIRCLE ONE)

OWNER/BUILDER (CIRCLE ONE OR BOTH) Steven Lowry PROPERTY ADDRESS (ADDRESS OF WELL LOCATION) 1920 S. Ernsthausen, Elmore

LOCATION OF PROPERTY 1/4 mi E of RT 51 on RT105 1/4 N. on W side Ernsthausen Rd

CONSTRUCTION DETAILS

CASING
Diameter 5 5/8 in. Length 51 ft. Wall Thickness ____ in.
Type: ☒ Steel ☒ Galv. ☐ PVC ☐ Other ____
Joints: ☒ Threaded ☐ Welded ☐ Solvent ☐ Other ____

SCREEN
Type (wire wrapped, louvered, etc.) ____ Material ____
Length ____ ft. Diameter ____ in.
Set between ____ ft. and ____ ft. Slot ____
☒ Rotary ☐ Cable ☐ Augered ☐ Driven ☐ Dug ☐ Other ____
Date of completion 7/18/89

GROUT
Material Benseal Volume used 100 #
Method of installation Pumped Tremie pipe
Depth: placed from 0 ft. to 51 ft.

GRAVEL PACK
Material ____ Volume used ____
Method of installation ____
Depth: placed from ____ ft. to ____ ft.
Pitless Device ☐ Adapter ☐ Preassembled unit
Use of Well Home

PUMP
Type of pump ____ Capacity ____ gpm
Pump set at ____ ft.
Pump installed by ____

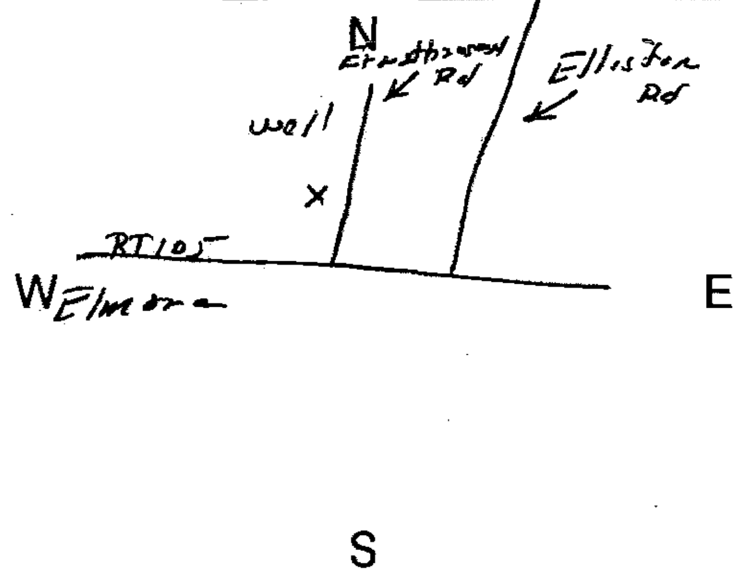
WELL TEST
Bailing ☒ or Pumping ☐
Test rate 10-20 gpm Duration of test ____ hrs.
Drawdown ? ft.
Measured from: ☐ top of casing ☒ ground level ☐ Other ____
Static Level (depth to water) 35 ft. Date: 7/18/89
Quality (clear, cloudy, taste, odor) ____
(Attach a copy of the pumping test record, per 1521.05, ORC)

WELL LOG*

INDICATE DEPTH(S) AT WHICH WATER IS ENCOUNTERED. Show color, texture, hardness, and formation: sandstone, shale, limestone, gravel, clay, sand, etc.	From	To
Clay	0 ft.	47 ft.
Soft limestone	47	49
Limestone	49	62

SKETCH SHOWING LOCATION

Show distances well lies from numbered state highways, street intersections, county roads, etc.



* If additional space is needed to complete well log, use next consecutively numbered form

DNR 7802.88

DRILLING FIRM KIMBALL WELL DRILLING
ADDRESS 5709 WOODVILLE ROAD
CITY, STATE, ZIP NORTHWOOD, OHIO 43619

SIGNED P. Kimball
DATE 7/19/89
ODH REGISTRATION NUMBER 57

Completion of this form is required by 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.

ORIGINAL COPY - ODNR, DIVISION OF WATER, 1939 FOUNTAIN SQ. DRIVE, COLS., OHIO 43224

Blue - Customer's Copy Pink - Driller's Copy Green - Local Health Dept. Copy

Welsleman
Hoffman ✓
"Reck"

ORIGINAL

484324

HW
WH

WEL'' LOG AND DRILLING REP'RT

State of Ohio
DEPARTMENT OF NATURAL RESOURCES
Division of Geological Survey
Fountain Square
Columbus, Ohio 43224 Phone (614) 466-5344

NO CARBON PAPER NECESSARY–SELF-TRANSCRIBING

COUNTY OTTAWA TOWNSHIP HARRIS SECTION OF TOWNSHIP OR LOT NUMBER 8

OWNER HARRY CORDELL #3 ADDRESS OAK HARBOR, OHIO

LOCATION OF PROPERTY 1581 ELLISTON RD. 1 mi NORTH OF RT. # 105

CONSTRUCTION DETAILS

Casing diameter 4 1/4" Length of casing 57'

Type of screen ______ Length of screen ______

Type of pump ______

Capacity of pump ______

Depth of pump setting ______

Date of completion ______

BAILING OR PUMPING TEST

(specify one by circling)

Test rate 16 gpm Duration of test ______ hrs

Drawdown 5 ft Date 9/10/75

Static level (depth to water) 30 ft

Quality (clear, cloudy, taste, odor) CLEAR

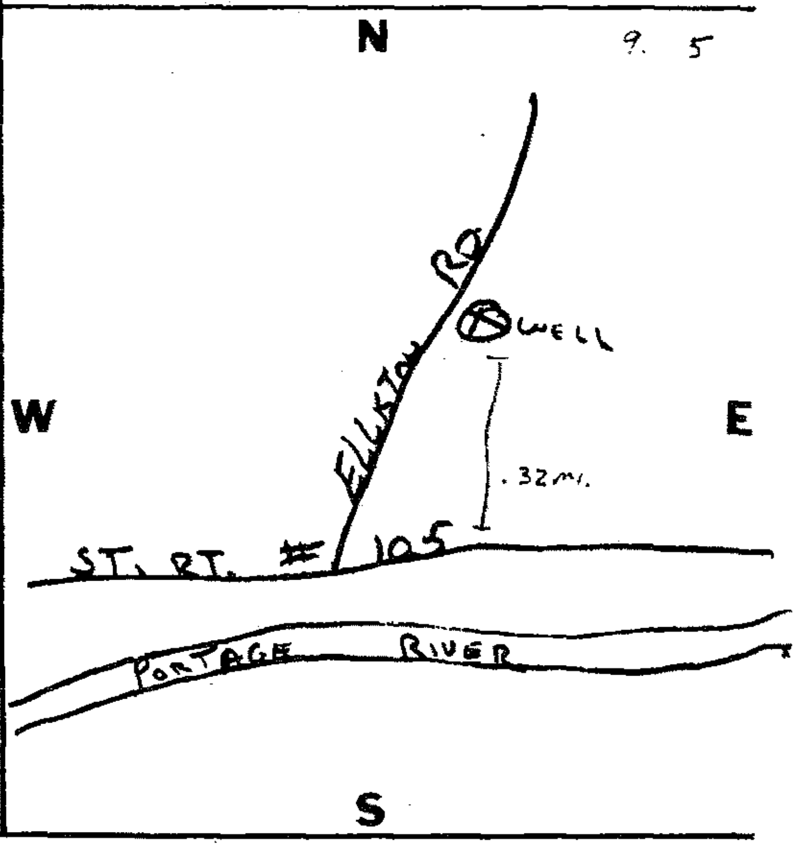
Pump installed by ______

WELL LOG*

Formations: sandstone, shale, limestone, gravel, clay	From	To
CLAY	0 ft	53 ft
LIMESTONE	53'	73'

SKETCH SHOWING LOCATION

Locate in reference to numbered state highways, street intersections, county roads, etc.



DRILLING FIRM Kimball Well Drilling
~~5709 Woodville Road~~

ADDRESS Toledo, Ohio 43616

DATE SEPT. 10, 1975

SIGNED Bob Kimball

*If additional space is needed to complete well log, use next consecutive numbered form.

A

14.0 Appendix D - Ground Water Level Measurements From May 2011 to September 2011

Well_Log	Address	WellSymbc	Latitude	Longitude	X2	Y2	WellYield	SurfEle
665324	1709 Nisse	BenchLC	41.49196	-83.3004	1749073	1273131	20	609
921445	Witty/SR 5	GLC	41.4877	-83.3049	1747834	1271589	45	615
348436	1795 Ellistc	JSE	41.49105	-83.2775	1755356	1272744	12	603
348437	1795 Ellistc	JSW	41.49098	-83.2784	1755109	1272721	20	602
2028178	1196 Nisse	MH	41.49857	-83.3006	1749048	1275541	15	609
77581	17821 SR 1	ML	41.4906	-83.2768	1755536	1272578	null	605
2011236	2756 Opfer	PD	41.476	-83.3193	1743847	1267359	12	619
615063	1400 S. Ern	RH	41.49588	-83.2897	1752027	1274534	12	609
711797	18587 SR 1	RW	41.48178	-83.2906	1751735	1269396	10	611
696615	1920 S Erns	SU	41.48819	-83.2897	1752002	1271731	20	606
484324	1581 Ellistc	WH	41.49329	-83.2789	1754979	1273564	16	609
2028314	Nissen	Bench 1	41.49241	-83.3002	1749096	1273399	300	609
2025323	Elliston-Trc	Bench 2	41.49258	-83.28	1754162	1273436	300	609
2028309	S. Ernsthau	Luckey	41.49443	-83.2939	1750871	1274016	300	610
2001245	Opfer-Lent	Rothert 1	41.47969	-83.3237	1742653	1268715	240	618
2001244	SR 105	Rothert 2	41.49278	-83.2367	1766546	1273281	280	597

SWL51911	SWL61511	SWL71411	SWL72011	SWL8911	SWL9911	GWE51911	GWE6511	GWE71411
32.03	33.2	50.6	46.58	41.18	36.4	576.97	575.8	558.4
0	35.67	47.25	45.23	39.76	37.98	0	579.33	567.75
31.89	33.68	43.03	41.88	37.17	34.35	571.11	569.32	559.97
32.47	34.2	43.6	42.45	37.77	34.91	569.53	567.8	558.4
33.4	34.86	45	45.08	39.42	36.88	575.6	574.14	564
31.58	33.34	42.72	41.59	36.81	34.06	573.42	571.66	562.28
22.5	22.78	24.7	24.86	23.5	23.18	596.5	596.22	594.3
32.97	34.5	43.98	43.15	38	35.96	576.03	574.5	565.02
0	41.96	51.78	55.6	44.04	42.42	0	569.04	559.22
35.33	36.51	47.76	46.28	40.55	38.35	570.67	569.49	558.24
0	34	43	42.03	37.65	34.92	0	575	566
34.48	34.59	102	46.08	39.8	36.62	574.52	574.41	507
33.58	36.41	150	37.62	38.79	37.22	575.42	572.59	459
33.45	34.5	47.96	45.18	38.7	36.44	576.55	575.5	562.04
22.5	27.91	39.13	25	24.2	24.32	595.5	590.09	578.87
0	17	23.1	23.17	22.35	22.24	597	580	573.9

GWE72011	GWE8911	GWE9911	DD615714	DD200PUM	DD250PUM	DDB1B2LUCKY
562.42	567.82	572.6	-17.4	47.836	59.795	51.926
569.77	575.24	577.02	-11.58	7.376	9.219	8.485
561.12	565.83	568.65	-9.35	14.054	17.567	14.71
559.55	564.23	567.09	-9.4	16.663	20.829	17.429
563.92	569.58	572.12	-10.14	8.087	10.109	11.165
563.41	568.19	570.94	-9.38	19.298	24.122	12.079
594.14	595.5	595.82	-1.92	0.168	0.209	0.195
565.85	571	573.04	-9.48	9.588	11.985	17.1
555.4	566.96	568.58	-9.82	2.47	3.087	3.109
559.72	565.45	567.65	-11.25	7.732	9.667	10.442
566.97	571.35	574.08	-9	23.406	29.258	24.344
562.92	569.2	572.38	-67.41	67.41	67.41	67.41
571.38	570.21	571.78	-113.59	113.59	113.59	113.59
564.82	571.3	573.56	-13.46	12.098	15.123	15.123
593	593.8	593.68	-11.22	0.168	0.21	0.193
573.83	574.65	574.76	-6.1	0.011	0.014	0.012

Figure 1 Hydrograph for Bench 1 Irrigation Well Nissen Road Static Water Levels

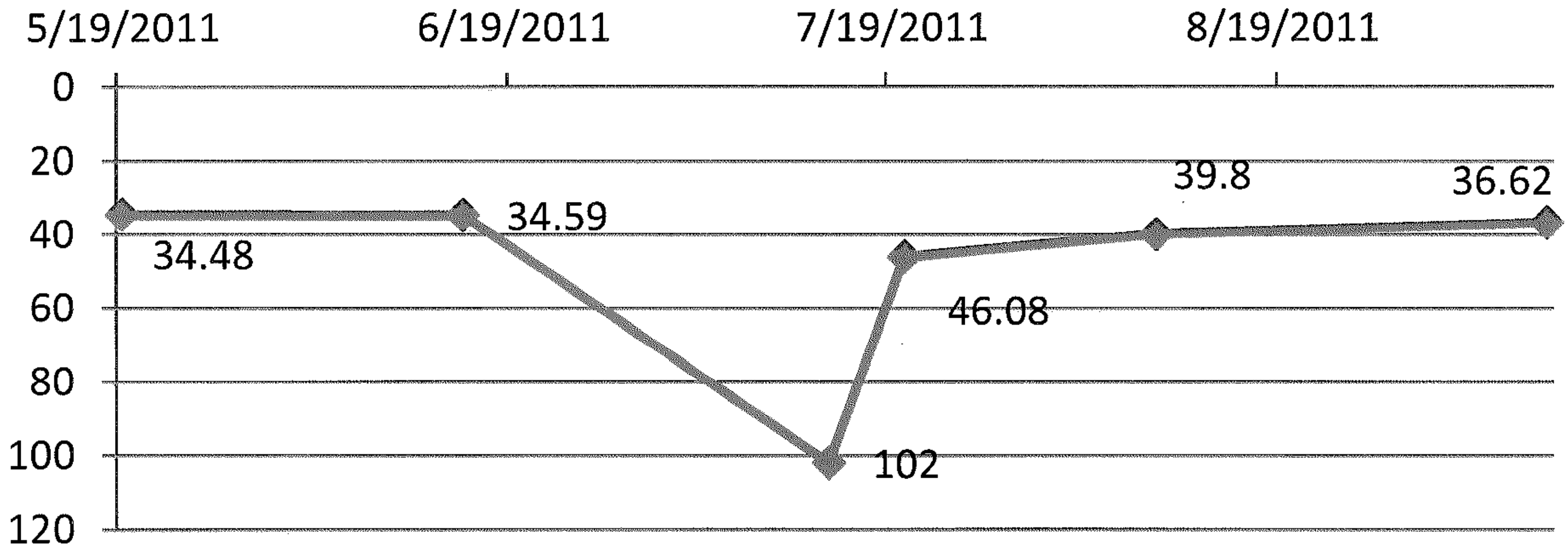


Figure 1 Hydrograph for Bench 2 Inrigation Well Elliston Trowbrige Static Water Levels

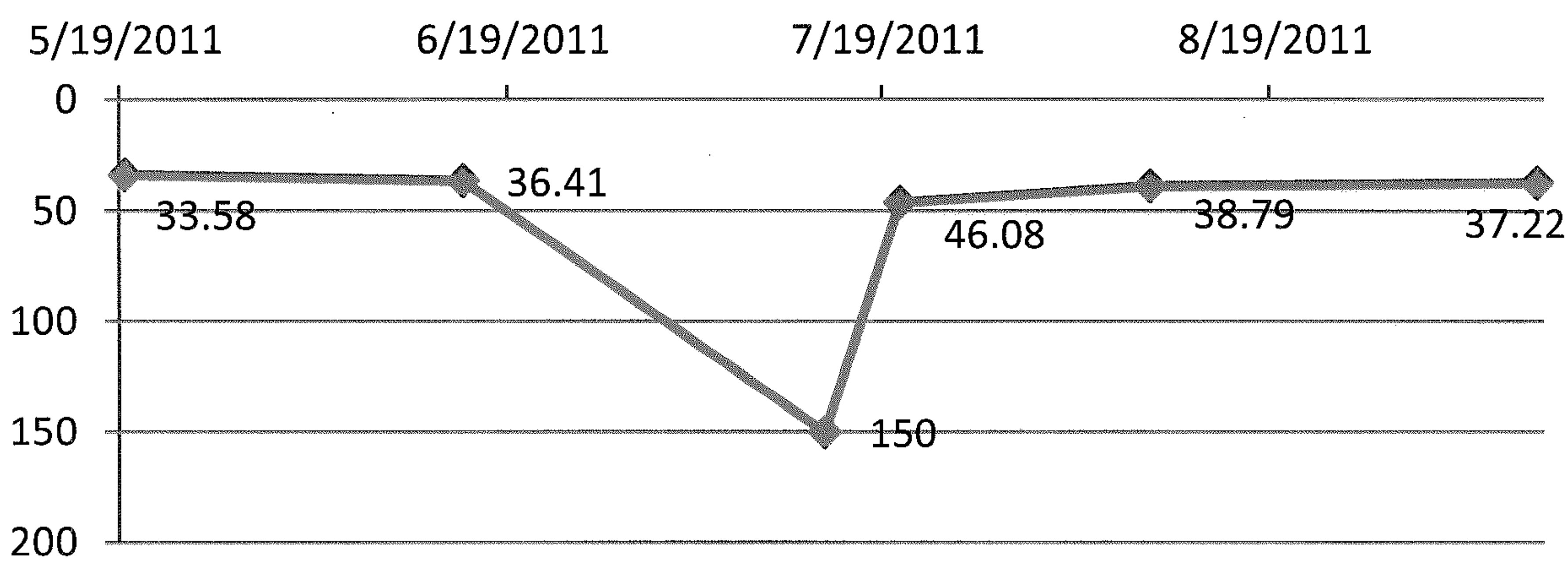


Figure 1 Hydrograph for Lucky Irrigation Well South Ernsthausen Static Water Levels

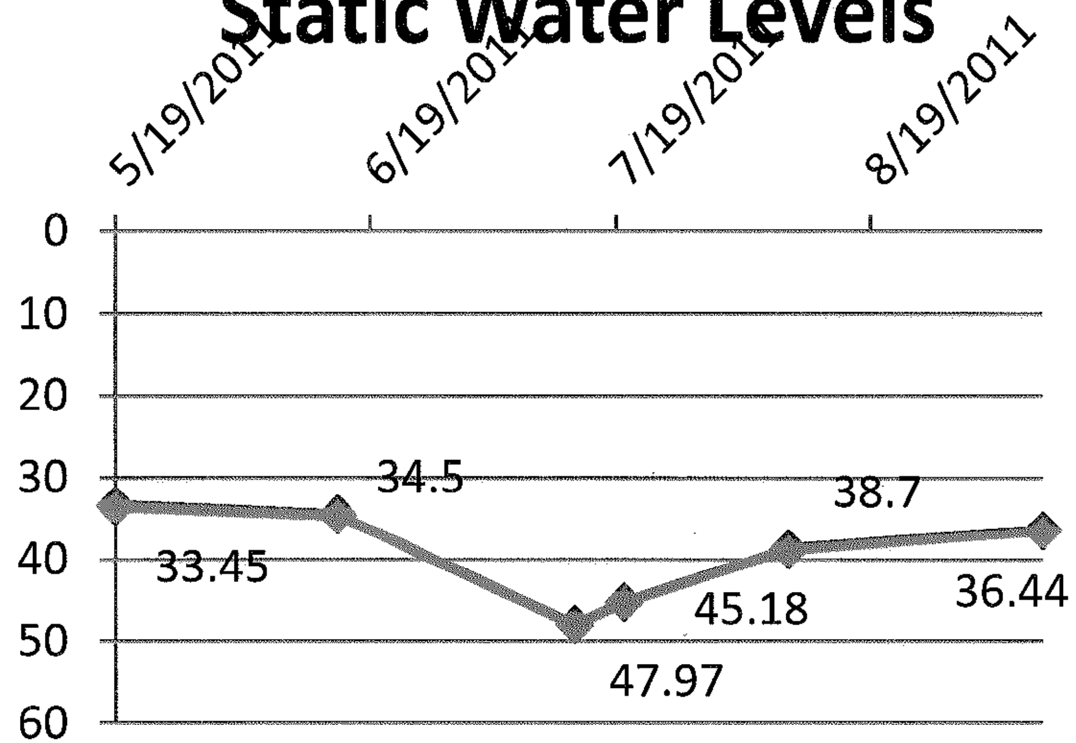


Figure 1 Rothert 1 Irrigation Well

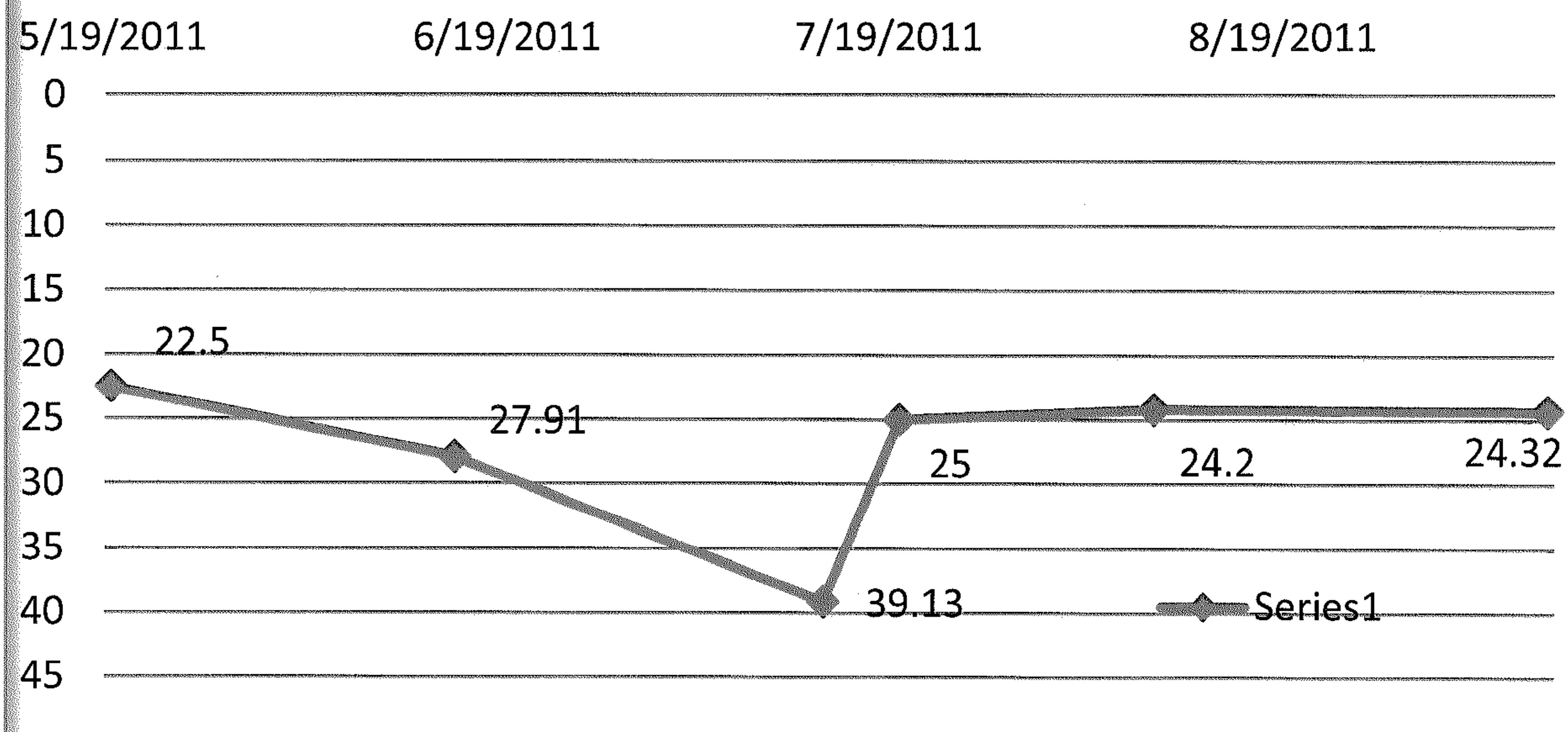
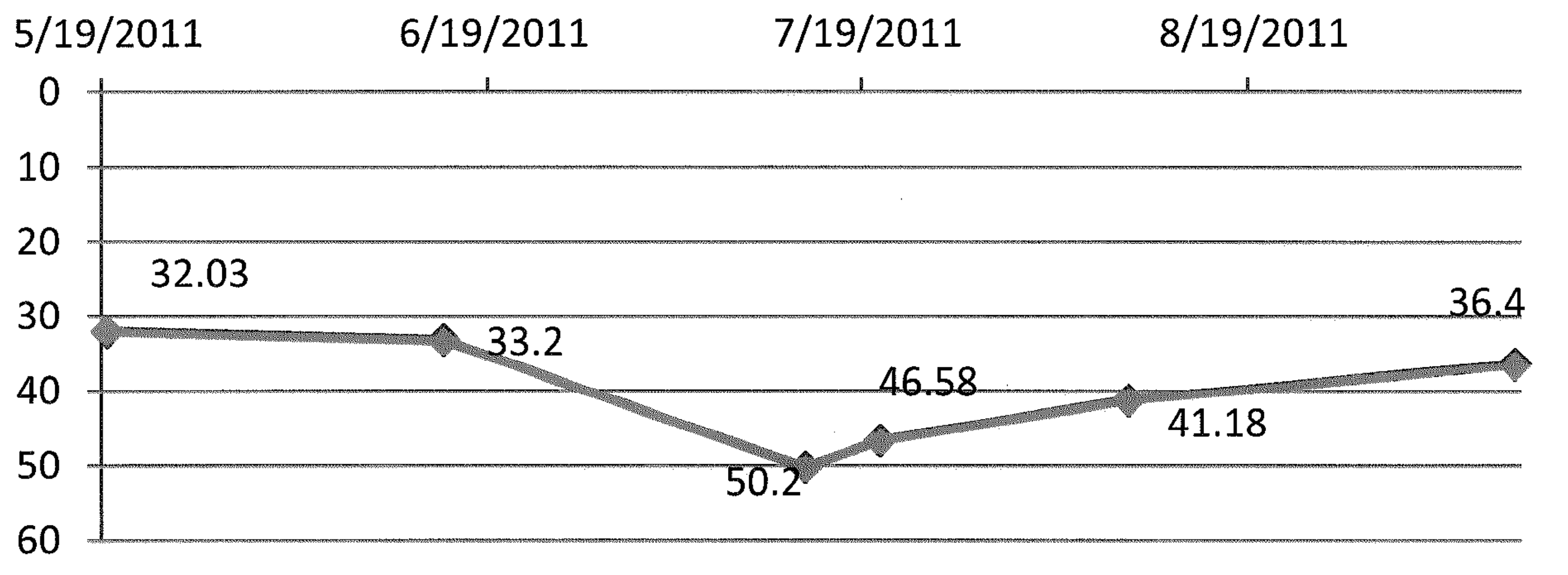


Figure 1 Hydrograph for Bench Labor Camp PWS Well 1709 Nissen Road Static Water Levels



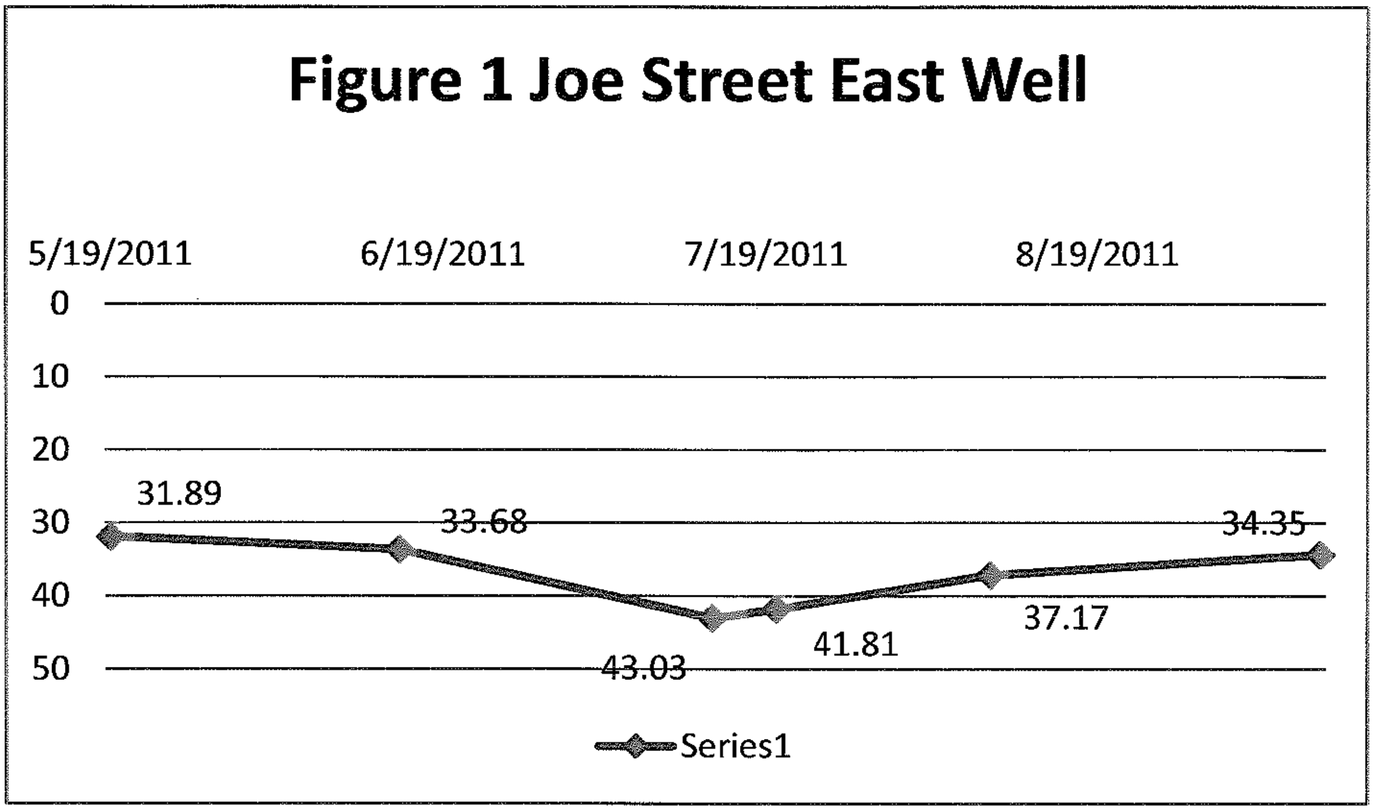


Figure 1 Joe Street East Well
5/19/2011
6/19/2011
7/19/2011
8/19/2011
0
10
20
30
40
50
31.89
33.68
43.03
41.81
37.17
34.35
Series1

Figure 1 Hydrograph for Steve Ulinski Domestic Water Well 1920 Ernsthausen Static Water Levels

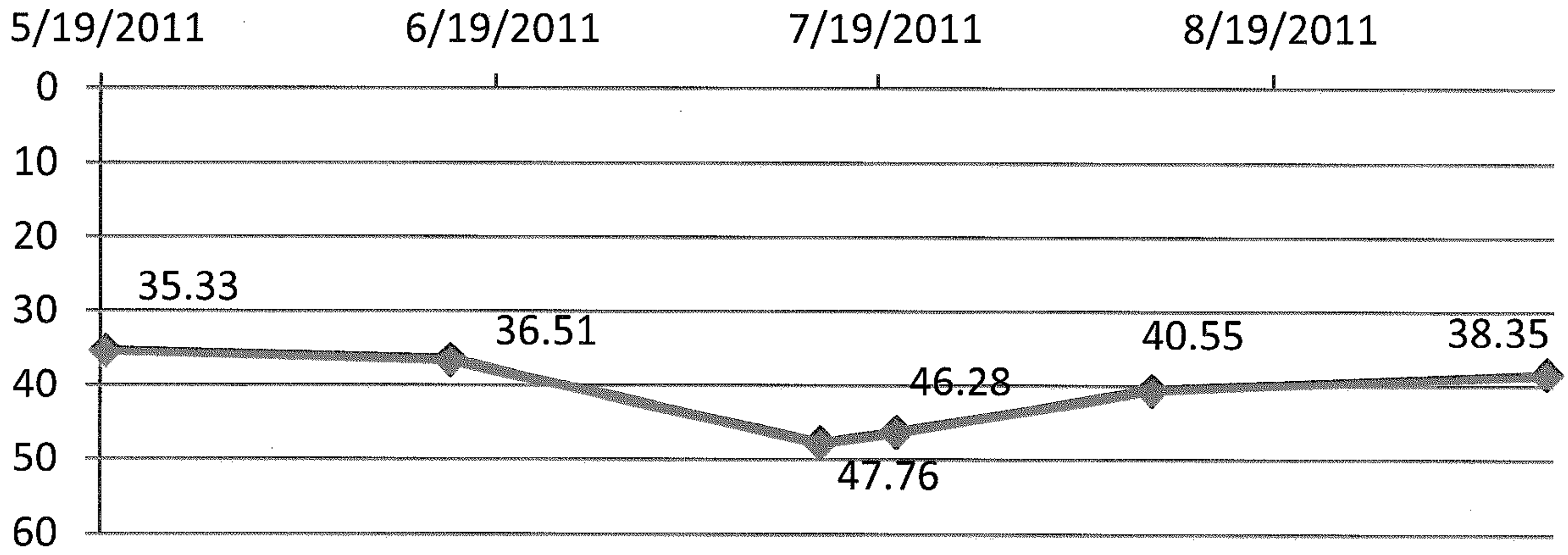


Figure 1 Hydrograph for Weldemar Hoffman Domestic Well 1581 S Elliston Trowbridge Road Static Water Levels

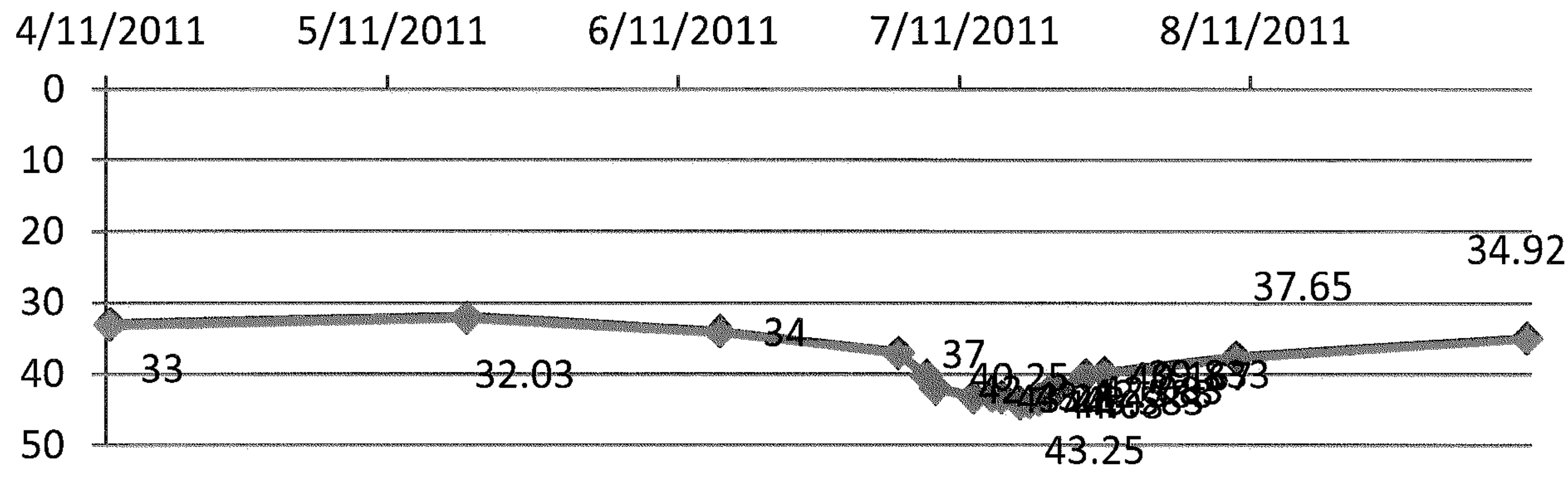
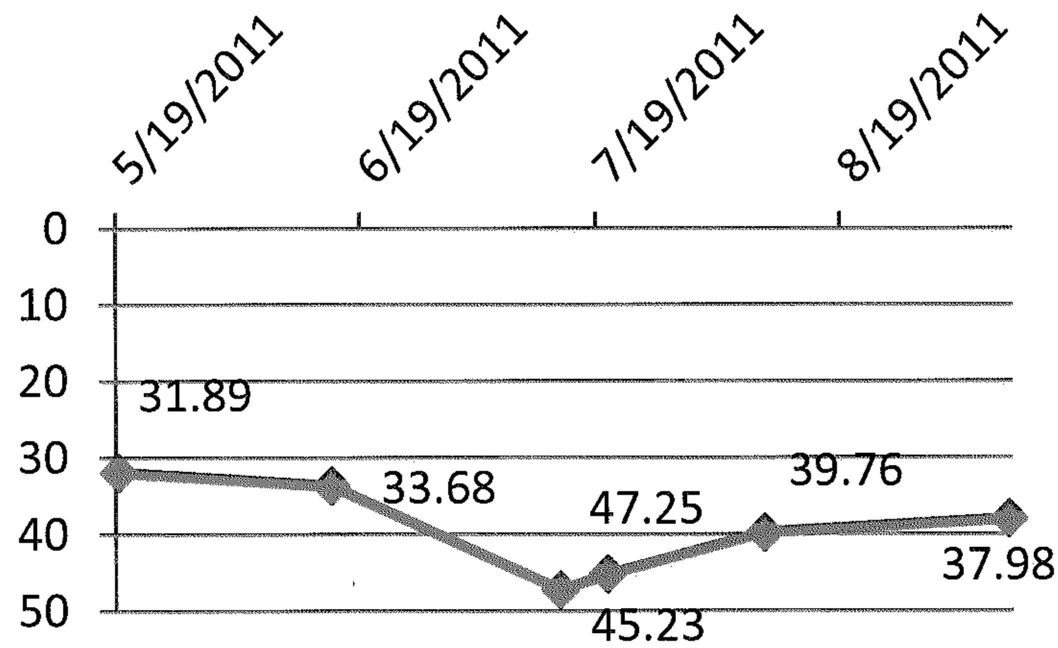


Figure 1 Hydrograph Grace Luthern Church Public Water Supply Well Static Water Levels



15.0 Appendix E - WellZ Ground Water Model Well Interference Calculations for 14 Days

Groundwater investigation of the carbonate bedrock aquifer to evaluate the impact of pumping high yielding irrigation wells on local and domestic water supply wells in Ottowa County, Harris Township, Ohio

Report for the Calculation of Drawdowns for 14 Days at 250 GPM

No. of Interval in X: 10
No. of Interval in Y: 10

Minimum X: 1739000.00 ft
Maximum X: 1774000.000000 ft
Minimum Y: 126000.00 ft
Maximum Y:1283000.000000 ft

Pumping Time: 14.000 Days
Number of Pumping Wells: 2

Solution Aquifer Model	Leaky-Theis
Transmissivity	265.0 ft2/day
Storativity Parameter for the Leaky-Confining Layer	0.0001
Hydraulic Conductivity	0.03 ft/day
Thickness of Aquifer	360.00 ft

Unit Used in the calculation:
Pumping Rate: 250 GPM
Length and Drawdowns: Feet

Well No.	Well Name	Pumping Rate
	Bench 1	250.000
	Bench 2	250.000

Number of Monitoring Wells: 14

Type	Well Name	Drawdown	
Monitoring Wells	GLC	9.219	
Monitoring Wells	JSE	17.567	
Monitoring Wells	JSW	20.829	
Monitoring Wells	MH	10.109	
Monitoring Wells	ML	24.122	
Monitoring Wells	PD	0.209	
Monitoring Wells	RH	11.985	
Monitoring Wells	RW	3.087	
Monitoring Wells	SU	9.667	
Monitoring Wells	WH	29.258	
Monitoring Wells	Luckey	15.123	
Monitoring Wells	Rothert 1	0.21	
Monitoring Wells	Rothert 2	0.014	
Monitering Wells	BLC	59.795	

Drawdowns in :SURFER grid format
Cut the following output to be used in SURFER
DSAA

Groundwater investigation of the carbonate bedrock aquifer to evaluate the impact of pumping high yielding irrigation wells on local and domestic water supply wells in Ottowa County, Harris Township, Ohio

Report for the Calculation of Drawdowns for 14 Days at 200 GPM

No. of Interval in X: 10
No. of Interval in Y: 10

Minimum X: 1739000.00 ft
Maximum X: 1774000.000000 ft
Minimum Y: 126000.00 ft
Maximum Y:1283000.000000 ft

Pumping Time: 14.000 Days
Number of Pumping Wells: 2

Solution Aquifer Model	Leaky-Theis
Transmissivity	265.0 ft2/day
Storativity Parameter for the Leaky-Confining Layer	0.0001
Hydraulic Conductivity	0.03 ft/day
Thickness of Aquifer	360.00 ft

Unit Used in the calculation:
Pumping Rate: 200 GPM
Length and Drawdowns: Feet

Well No.	Well Name	Pumping Rate
	Bench 1	200.000
	Bench 2	200.000

Number of Monitoring Wells: 14

Type	Well Name	Drawdown	
Monitoring Wells	GLC	7.376	
Monitoring Wells	JSE	14.054	
Monitoring Wells	JSW	16.663	
Monitoring Wells	MH	8.087	
Monitoring Wells	ML	19.298	
Monitoring Wells	PD	0.168	
Monitoring Wells	RH	9.588	
Monitoring Wells	RW	2.47	
Monitoring Wells	SU	7.732	
Monitoring Wells	WH	23.406	
Monitoring Wells	Luckey	12.098	
Monitoring Wells	Rothert 1	0.168	
Monitoring Wells	Rothert 2	0.011	
Monitering Wells	BLC	47.836	

Drawdowns in :SURFER grid format
Cut the following output to be used in SURFER
DSAA

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Division of Soil and Water Resources
2045 Morse Road
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March 2012

John Kasich, *Governor*   James Zehringer, *Director*   Karl Gebhardt, *Chief*