Evaluation of Groundwater Pumping for Richfield Dairy, LLC Town of Richfield Adams County, Wisconsin

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Section 1
Introduction

I, Charles B. Andrews, was retained by Michael Best & Friedrich L.L.P. to evaluate the effects of groundwater production for water supply at the proposed Richfield Dairy in Town of Richfield, Adams County, Wisconsin on groundwater levels, lake levels and surface-water flows in the vicinity of the proposed dairy. The dairy is estimated to require approximately 72.5 million gallons per year. The water supply is proposed to be obtained from two new high capacity wells to be located at the dairy that will be completed in the Cambrian-age sandstone aquifer[1]. This report describes my evaluations of impacts of groundwater pumping for the dairy.

I am a Senior Principal at the groundwater consulting firm S.S. Papadopulos & Associates, Inc. (SSP&A) in Bethesda, Maryland. My expertise includes the evaluation and modeling of groundwater systems. I received a Ph.D. in geology from the University of Wisconsin, and I have over thirty years of professional experience in groundwater consulting. One component of this Ph.D. included the development of groundwater model code and structure to simulate groundwater flow near Portage, Wisconsin. In addition, I recently completed evaluations of the effects of groundwater pumping for the New Chester Dairy in Adams County and the effects of irrigation pumping in the Town of Saratoga that were submitted to the Wisconsin Department of Natural Resources in support of high capacity well permits. My qualifications are included in Attachment A.

In the preparation of this report, I have reviewed and/or relied on technical reports, site documents, and laboratory analytical reports that contain information on groundwater conditions in the area of interest. The list of documents I reviewed is contained in Section 6. The documents upon which I have relied are the types of documents typically used by hydrology experts to evaluate the effects of groundwater pumping. Finally, I have relied upon extensive education, training and experience in the field of hydrology in formulating the opinions expressed in this report.

[1] The high capacity wells will be located in the SW¼ of the NE¼ of Section 25 Township 18 North Range 7 East.

Section 2
Background

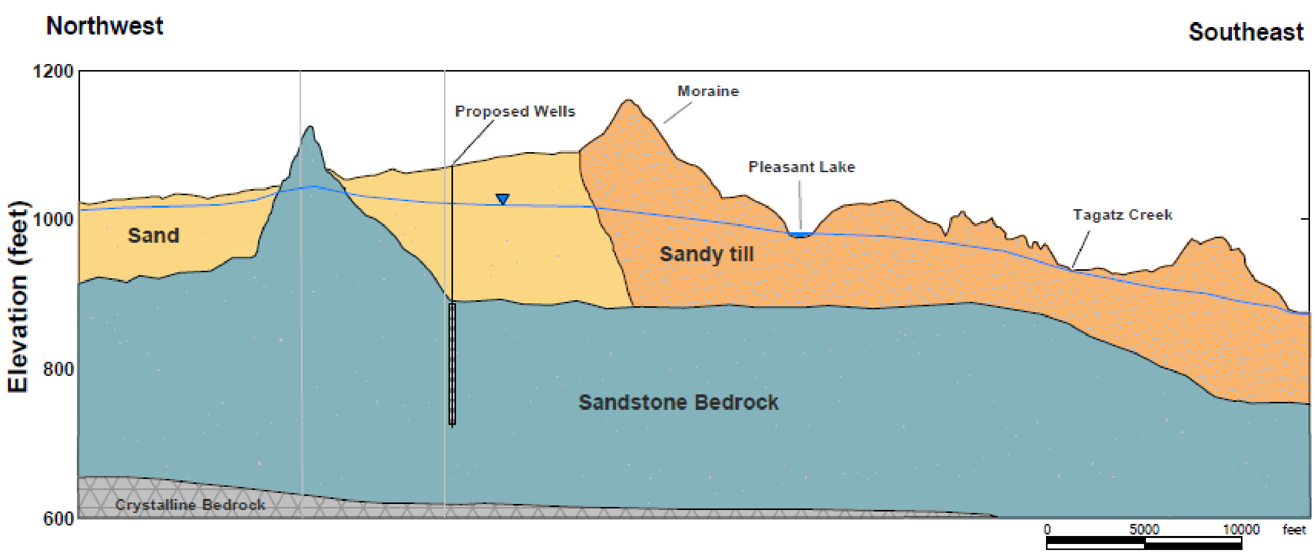
The Richfield Dairy is to be located on an 146-acre parcel in the NE¼ of Section 25 in the Town of Richfield[2], Adams County about 4 miles to the southwest of Coloma, Wisconsin (Figure 1). This parcel is used currently for irrigated agriculture. The dairy, following construction, will house a total of 4,300 milking and dry cows and 250 steers. Total water usage at the facility is estimated to be 72.5 million gallons per year, which is equivalent to an average rate of 138 gallons per minute (gpm).

The proposed Richfield Dairy is located in a region with very productive groundwater aquifers. The aquifers consist of glacial sands and gravels that are estimated to be up to 170 feet thick at the property and underlying Cambrian-age sandstones of the Mt. Simon Formation that are estimated to be about 300 feet thick at the property. The surface of the top of the sandstone is very irregular with a number of sandstone mounds extending to the surface in the area. The sandstone is mainly well-rounded medium grained sand. The sandstone overlies pre-Cambrian aged bedrock that is not a productive aquifer. This region is often referred to as the Central Sand region and/or the Central Sand Plain of Wisconsin.

The proposed dairy is located on the eastern edge of a relatively flat plain with coarse grained surface sediments deposited by glacial meltwater streams. Elevations at the site range from about 1,090 feet above mean sea level (MSL) in the southeast portion of the property to about 1,070 feet above MSL along the northern boundary of the property. The eastern edge of the dairy is less than one mile west of the Johnstown moraine, a north-south trending glacial feature that forms a narrow ridge rising as much as 120 feet above the plain. This ridge represents the westernmost extent of glaciation during the last phase of Wisconsin-age glaciation (Mickelson and others, 2011). East of the western edge of the moraine is hummocky terrain formed as the result of the collapse of sediments deposited on glacial ice, and west of the moraine are primarily deposits from glacial Lake Wisconsin and glacial meltwater. In the depressions in the hummocky terrain east of the terminal moraine are a number of lakes with no surface water outlet whose water levels are controlled to a large degree by the elevation of the water table. The nearest lake to the proposed dairy is the approximately 130-acre Pleasant Lake, which is located about 2.5 miles to the southeast of the proposed dairy. This lake is discussed in detail in the next section.

[2] Township 18 North, Range 7 East.

A schematic northwest-southeast trending geologic section of the area in the vicinity of the proposed Richfield Diary is shown below. This figure illustrates the hummocky terrain east of the dairy site, the location of Pleasant Lake, the thicknesses of the sand and gravel units, thickness of the sandstone and the relative depth to the pre-Cambrian bedrock. The sands located west of the Johnstown Moraine and the sand till to the east comprise what is referred to as the sand and gravel aquifer. The sandstone bedrock of the Mt. Simon Formation is referred to as the sandstone aquifer.



Recharge rates in the vicinity of the property are relatively high because of the coarse grained surficial sediments. Average annual precipitation based on the last 30-years of record at the Hancock Agricultural Research Station, located about 9 miles north-northeast of the dairy, is about 31 inches per year and about one-quarter to one-third of precipitation is estimated to infiltrate into the subsurface and recharge the groundwater aquifers (Mechenich and others, 2009; Bradbury and others, 1992).

Surface water runoff from the property is negligible as surface water drainage systems are poorly developed on the landscape. The nearest well-developed stream systems are the headwaters of Chaffee Creek and Tagatz Creek located about 3.3 miles to the east of the property, and the headwaters of Little Roche a Cri Creek located about 3 miles to the west of the property. Chaffee Creek, a tributary of the Mecan River, and Tagatz Creek, a tributary of the Montello River, are in the Fox River watershed. Little Roche a Cri Creek is a tributary of the Wisconsin River. The proposed high-capacity wells are within the Little Roche a Cri Creek watershed. A map showing the surface-water features in the vicinity of the proposed dairy is shown on Figure 2.

The headwater reaches of Chaffee Creek and Tagatz Creek to the east of the proposed dairy are designated Class I trout streams and are Outstanding Resource Waters. Fordham Creek, a tributary of Little Roche a Cri Creek, located to the west of the proposed dairy is also a designated Class I trout stream and an Exceptional Resource Water. Other headwater streams shown on Figure 2 that are designated Class I trout streams include Caves Creek, South Branch Wedde Creek, Mecan River, Schmudlack Creek, and the lower half of segment 0058 of Little Roche a Cri Creek.

The aquifers at the property are regionally extensive. The proposed dairy is located near a regional groundwater divide between the Wisconsin River and Fox River drainages. Groundwater flow at the property is toward the east-southeast toward the headwaters of Chaffee and Tagatz creeks. A regional water table map shown on Figure 3 provides information on general directions of groundwater flow.

Groundwater is extensively used in the Central Sands region for irrigated agriculture, and this use has expanded significantly within the last twenty years. Within five miles of the property are located more than 136 high capacity wells, most of which are used for irrigation water. The locations of these wells and average pumping rates from 2007 through 2011 are shown on Figure 4. Many of the high capacity wells are located in a narrow band on the relatively flat plain located just west of the terminal moraine. The amount of water applied to irrigated lands varies but is estimated to be as much as fourteen inches per year. Much of the applied irrigation water infiltrates back to the groundwater table as a result of the coarse-grained soils with the remainder evapotranspirated by crops. On-going research at the University of Wisconsin suggests, based on plant-soil-atmosphere models, that irrigation results in an average of 2 inches in recharge reduction compared with perennially vegetated lands (Kraft and others, 2012).

In Adams County, groundwater pumping for irrigation is estimated to have increased by about a factor of ten in the 26 year period from 1979 to 2005 (Lawrence and others, 1982; Ellefson and others, 1987, Ellefson and others, 1997; Ellefson and others, 2002; and Buchwald, 2009). Total groundwater pumping for irrigation in 1979 was estimated to be 1.5 billion gallons per year and by 2005 groundwater pumping for irrigation had increased to 17 billion gallons per year. For perspective, total groundwater recharge in Adams County is estimated to be about 100 billion gallons per year; therefore, at 2005 pumping rates about 17 percent of total recharge is being captured by the irrigation pumping[3]. A graph of the increase in irrigation pumping from 1979 through 2005 is shown below.

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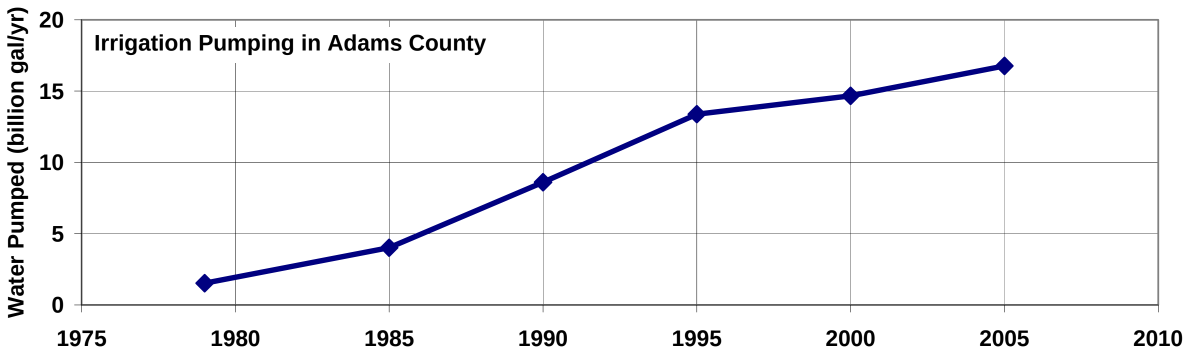
[3] The total amount of recharge calculated based on a land area in Adams County of 648 square miles and a recharge rate of 8.85 inches per year (Mechenich and others, 2009).

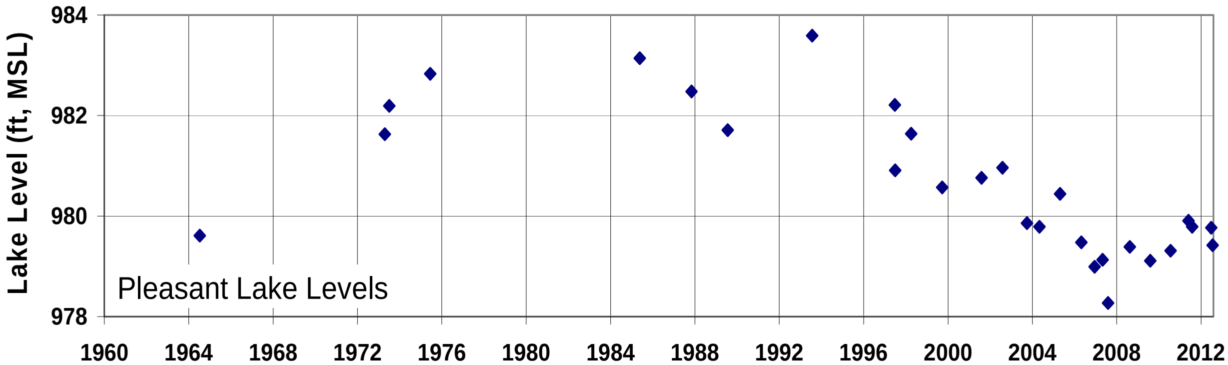


Recent studies by researchers at the University of Wisconsin Stevens Point (Kraft and others 2011; and Kraft and Mechenich 2010) have suggested that groundwater use for irrigated agriculture in the Central Sands region has resulted in observable declines in groundwater levels and lake levels and declines in base flow of headwater streams in the region. In the vicinity of the proposed dairy, the effect of irrigated agriculture on groundwater levels has been estimated to be about a two foot decline in groundwater levels relative to those that existed prior to 1980 (Kraft, 2010).

Section 3
Pleasant Lake

Pleasant Lake, located about 2.5 miles to the southeast of the proposed dairy, is situated in a closed depression in the hummocky terrain east of the Johnstown Moraine. This approximately 130-acre lake is about 3,000 feet long with an approximate east-west orientation, averages about 2,000 feet wide, and has a maximum reported depth of 23.7 feet and a mean depth of 15 feet. The lake is groundwater fed with groundwater entering the lake from the west and north and water flowing out of the lake into the groundwater system on the east and south sides of the lake. About 1,300 feet east of Pleasant Lake is a wetland that forms the headwaters of Chaffee Creek, and about 1,300 feet to the south of Pleasant Lake is a wetland that forms the headwaters of Tagatz Creek where groundwater from the lake discharges. The elevations of these wetlands are more than 10 feet lower than average lake level and their base levels have an influence on the level of Pleasant Lake.

Because the lake is in a closed depression, the water level in the lake closely reflects the position of the water table in the underlying sand and gravel aquifer. Thus, changes in the regional water table have an effect on lake levels. Water levels in Pleasant Lake have been measured irregularly since 1964. The available data, as maintained by the Waushara County[4], are shown on the graph below.



[4] Data obtained from Rick Ertl, Waushara County Department of Zoning & Land Conservation. The lake data through 2010 are described in the report "2010 Report on Lake Levels Observed in Waushara County", Waushara County Land Conservation & Zoning. In addition, as part of Richfield Dairy's evaluations, lake levels were measured on June 19 and July 17, 2012.

Measured water levels in the lake have ranged from a high of 983.59 feet MSL in July 1993 to a low of 978.27 in August 2007; a range of 5.32 feet. Within the past eight years, most water level measurements have been within the range of 979 to 980 feet MSL.

The lake level was measured on June 19, 2012, as part of Richfield Dairy's evaluations, at 979.77 feet MSL and again on July 17, 2012 at 979.42 feet MSL. The change in lake level of 0.35 feet observed between June 19 and July 17 is consistent with expected seasonal changes and occurred during a period of abnormally warm and dry weather. The lake levels measured recently are similar to the lake level of 979.61 feet MSL that was measured on July 9, 1964. Water levels in the lake are influenced by precipitation in addition to the level of the regional water table. The high water level that was recorded in July 1993 followed a very wet three month period in which there was 22 inches of precipitation and the low level in 1964 occurred in one of the driest years. Water levels are also influenced by agricultural pumping as described in a later section. An estimated water budget for Pleasant Lake, bathymetry, and available water-level data are described in Attachment B.

There are several lakes located along the terminal moraines in similar geologic settings to Pleasant Lake that also have long-term water level data. These lakes include Pine Lake located about 10 miles to the north-northeast of Pleasant Lake, and Long and Huron Lakes located about 16 miles to the north-northeast. Water-level declines in each of these lakes, on the order of three to five feet, were recorded from the mid-1990's to 2010. The lake level hydrographs for these lakes are shown in Attachment C.

Section 4
High Capacity Wells for the Richfield Dairy

An application for two high capacity wells for the Richfield Dairy was submitted to the Department of Natural Resources on April 28, 2011 and this application was conditionally approved on November 3, 2011[5]. Both wells are to be located in the SW¼ of the NE¼ of Section 25 Township 18 North Range 7 East. The wells are to be located just east of 1st Drive approximately 500 feet apart. In the well application, the wells were described as being cased to 185 feet below ground surface with an 11.75 inch borehole in the sandstone from 185 feet to 350 feet below ground surface. Five-hundred gallon per minute submersible pumps are to be installed in each well. The wells will be operated year around to meet the water needs of the dairy and annual average pumping is estimated to be no more than 72.5 million gallons per year.

There is an existing high capacity well on the property that has been used since 1976 for irrigation water for 115 acres[6]. Average total pumping from this well during the period 2007 through 2011 was approximately 46.5 million gallons per year. This well is 123 feet deep, has a 20 foot long screen in the sand and gravel aquifer and is outfitted with a 1,000 gpm pump. The well was tested when drilled; drawdown was 35 feet after four hours of pumping at 1,000 gpm. This well is proposed to be abandoned.

The nearest municipal well to the proposed high capacity wells is a well operated by the Coloma Waterworks. This well is approximately 3 miles to the northeast of the proposed high capacity wells. There are three domestic wells within one mile of the proposed high capacity wells.

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[5] The wells were assigned high capacity well numbers 71786 and 71787.

[6] This well has high capacity well #146 and Wisconsin Unique Well ID of BB432.

Section 5
Evaluation of Effects of Pumping

The best method available for estimating the potential effect of pumping groundwater on water levels and stream flows is numerical groundwater models. Numerical groundwater models can represent the spatial geometries of the groundwater system, such as thickness of geologic units and spatial locations of pumping wells and headwater streams, and the hydraulic properties of the aquifers. The appropriate representation of spatial geometries and hydraulic properties is essential for estimating the water level changes that have the potential to occur as the result of pumping and the potential rate of propagation of the water level changes to groundwater discharge areas. There are a number of computer programs that are used to develop numerical models of groundwater systems; the most commonly used program is MODFLOW developed by the U.S. Geological Survey.

A regional model of groundwater flow in the Central Sands region has been developed by Mechenich and others (2009) using the MODFLOW program (the model is referred to in this report as the "regional model" and "regional groundwater model")[7]. As this regional model was based on a comprehensive compilation of available groundwater data, and was consistent with available data, I developed a model similar in structure to the regional groundwater model with site-specific refinements to estimate the effects of groundwater pumping for the Richfield Dairy on groundwater levels, the level of Pleasant Lake and stream flows.

The regional model was used by Kraft to estimate the effects of the proposed pumping by the Richfield Dairy on the level of Pleasant Lake, groundwater levels and stream flows (2011a, 2011b). Kraft used the model to evaluate effects of pumping 52.5 million gallons per year and 131.2 million gallons per year by the dairy. The results of these model evaluations were presented in two letter reports by Kraft; one to the Department of Natural Resources and the other to the Pleasant Lake Management District (2011a, 2011b). The calculated changes in the level of Pleasant Lake based on these evaluations were stated by Kraft in the letter reports to be about 2 inches and 5.6 inches, respectively, for the two pumping scenarios. My evaluation of the water table drawdown maps presented in the letter reports by Kraft indicate that the stated lake level changes were overestimated; average calculated drawdowns at Pleasant Lake are about 1.5 inches and 4.6 inches for the two scenarios, respectively. Kraft did not evaluate a pumping rate of 72.5 million gallons per year, the anticipated water use by the dairy. Based on the results for the two scenarios that Kraft did evaluate, I estimate that the regional model would calculate a water level change at Pleasant Lake at a pumping rate of 72.5 million gallons per year of about 2

[7] Mechenich and others (2009) developed four similar regional groundwater models. The models differed in the number of model layers and in recharge and hydraulic conductivity distributions. The regional model version that is referred to as "Model C" in Mechenich and others (2009) is the regional model referred to in this report. Model C is a two layer model in which the sand and gravel aquifer is represented by model layer 1 and the sandstone aquifer is represented by model layer 2.

inches after long-term pumping. As is described below, my evaluations using the model I developed produced a similar estimate of the long-term change in the water level of Pleasant Lake as the result of pumping for the dairy.

The groundwater model that I developed for these analyses encompasses an area of approximately 469 square miles in the vicinity of the Richfield Dairy property (Figure 5). This model is referred to in this report as the "site-specific model". The site-specific model domain is much smaller than the model domain used in the regional model, but is sufficiently large to include all of the important factors and processes that are relevant to understanding the effects of pumping for the Richfield Dairy. The site-specific model domain includes headwater streams in the Wisconsin River and Fox River watersheds. Headwaters streams in the Wisconsin River watershed that are included in the site-specific model domain include Big Roche a Cri Creek, Little Roche a Cri Creek, Klein Creek, Duck Creek, Fairbanks Creek, Risk Creek, Campbell Creek and Neenah Creek, which are located in the western and southern portions of the site-specific model domain. Headwater streams in the Fox River watershed that are included within the eastern part of the site-specific model domain include Schmudlack Creek, Mecan River, south and north branches of Wedde Creek, Chaffee Creek, Tagatz Creek, Caves Creek, Lawrence Creek, and Klawitter Creek.

I used a modified version of the finite-difference computer program MODFLOW-2000 developed by the U.S. Geological Survey to develop the site-specific model. This version of MODFLOW (Bedekar et al. 2011) was developed by SSP&A for the U.S. Department of Energy (CHPRC-00258 Rev 2) to handle dry cells in a manner similar to MODFLOW-SURFACT and MODFLOW-NWT. The graphic-user-interface Groundwater Vistas was used to prepare groundwater model input files and to evaluate model results. The model finite-difference grid and model input parameters are described below.

The modeled effect of the long-term pumping of groundwater anywhere in the vicinity of the Richfield Dairy is to lower groundwater levels in the immediate vicinity of the pumped well and to decrease groundwater discharge to headwater streams. The modeled reductions that occur in groundwater discharge is a function of the length of time that the well is pumped. When a well is initially pumped, all of the water that is pumped comes from groundwater in storage in the aquifer as a result of a lowering of the water table in the vicinity of the well, and initially there is no reduction in groundwater discharge to headwater streams. As a well is pumped for a longer period of time, water-table declines eventually propagate to the groundwater discharge areas at the headwater streams, and a reduction in groundwater discharge occurs. It is well established that if a well is pumped at a constant rate for a very long period of time, water-table declines stabilize and the reduction in groundwater discharge equals the pumping rate.

Groundwater pumping currently occurs in the vicinity of the Richfield Dairy for irrigated agriculture. This pumping primarily occurs during the summer growing season of June through August. This pumping has resulted in a lowering of the water table, a decrease in groundwater discharge, and a decrease in stream flows relative to conditions that would have existed had no pumping occurred. The natural variability in groundwater levels and stream flows in the region due to seasonal and long-term variability in precipitation and climatic conditions is likely larger than the effects of pumping for irrigation. As a result, it is difficult to clearly separate the climatic effects on water levels and stream flows from effects due to pumping (Miller, 2012).

Finite-Difference Grid and Boundary Conditions

The site-specific model grid that I used in this analysis consists of 271 rows and 344 columns as shown on Figure 5. Grid spacing in the vicinity of the Richfield Dairy is 125 feet by 125 feet and grid spacing increases away from this area to a maximum size of 1,000 feet by 1,000 feet. Three layers are represented in the model: model layer 1 represents approximately the upper 15 feet of the saturated portion of the sand and gravel aquifer; model layer 2 represents the rest of the sand and gravel aquifer; and model layer 3 represents the sandstone aquifer. The sand and gravel aquifer was modeled as two layers so that the position of the water-table could be better represented and the MODFLOW lake package could be used to simulate the water budget of Pleasant Lake.

The base of model layer 2 was developed from an analysis of available data on the elevation of the top of the bedrock in the model domain. These data are described in Attachment D. The base of model layer 3 was derived from the contour map representing the thickness of sandstone on Figure 5 in Mechenich and others (2009), which is approximately consistent with the thickness of the sandstone unit as depicted in Olcott (1992). The base of the sand and gravel aquifer as represented in the site-specific model is shown on Figure 6 and the base of the sandstone aquifer as represented in the site-specific model is shown on Figure 7.

The boundary conditions on the site-specific model domain are drain and no-flow boundaries along the northern boundary and constant head boundaries along the eastern, southern and western boundaries. The drain boundary represents Dry Creek, a tributary of Big Roche a Cri Creek, while the no-flow boundary corresponds approximately with groundwater flow lines that trend east-west, away from the groundwater divide. The heads specified along the no-flow boundaries were derived from the regional water-level map developed by Lippelt and Hennings (1981); equal heads were specified for model layers 1, 2 and 3 at a given model cell.

The streams within the model domain were all modeled with the MODFLOW drain package. Drain elevations at each model cell were determined based on visual analysis of 1:24,000 USGS topographic maps. Drain conductances were specified consistent with the assumption of a well connected stream. Pleasant Lake, Burnita Lake, Patrick Lake, and McGinnis Lake were simulated with the MODFLOW lake package[8]. In the lake package for all lakes, it was specified that precipitation on the lake is equal to evaporation on an annual basis. Surface water runoff was estimated for each lake based on watershed contributing area; runoff

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[8] Patrick Lake and McGinnis Lake were modeled with the lake package as these lakes had previously been simulated in this matter for an analysis of pumping from the New Chester Dairy. Burnita Lake was simulated with the lake package due to proximity to Pleasant Lake. This lake is reported to have an area of 13 acres and a maximum depth of 8 feet.

equivalent to 100 gpm[9], 0 gpm, 52 gpm, and 98 gpm were specified for Pleasant Lake, Burnita Lake, Patrick Lake and McGinnis Lake, respectively.

Recharge

A uniform recharge rate of 8.85 inches on model layer 1 was used in the site-specific model. This recharge rate is identical to the recharge rate used in the regional model. As the recharge rate is correlated with aquifer hydraulic conductivities, the recharge rate was fixed in model calibration based upon the value used in the regional model and no attempt was made to vary it.

Model Parameters

The parameters in the groundwater model, the values of which are estimated as part of an automated procedure described below, are 1) the leakance, or resistance to groundwater flow, of the lakebed materials, and 2) the horizontal and vertical hydraulic conductivity in the different aquifers. The parameter values were calibrated using a combination of uniform zones and pilot-points as described below (Doherty, 2009).

Horizontal hydraulic conductivity in the sand and gravel aquifer was estimated using pilot-points (Figure 8). The horizontal hydraulic conductivity in the sand and gravel aquifer within the model domain is estimated to be between 15 and 205 feet per day, the distribution of which is shown in Figure 8. The horizontal hydraulic conductivity of the sandstone aquifer is represented by a single zone and estimated to be 7 feet per day. The vertical hydraulic conductivity of the sand and gravel aquifer was calibrated as 0.08 of the horizontal hydraulic conductivity west of the terminal moraine and 0.11 of the horizontal hydraulic conductivity east of the terminal moraine. Lakebed leakance for Pleasant Lake and Burnita Lake were calibrated to be 0.05 per day.

Model Calibration

The automated model calibration computer program "PEST - Model Independent Parameter Estimation" (*PEST*) was used to assist with model calibration (Doherty, 2009). A groundwater model is deemed calibrated when the difference between model outputs and field observations, referred to as calibration targets, has been reduced to a minimum in the weighted least squares sense [i.e., the sum of squared differences between model outputs and measurements, termed the objective function or PHI (Φ)]. Model calibration is an iterative process that seeks to reduce Φ by determining the sensitivity of the model parameters to the calibration data. When the calibration process can no longer reduce Φ (i.e., $\Phi = \Phi_{min}$), the parameters are considered optimal with respect to the measured data set and may be used to make predictions under conditions comparable to the calibration conditions. The computer program PEST automates the procedure of determining the minimum value of Φ.

[9] Surface water runoff was based on a contributing area of 510 acres and annual average runoff of 3.9 inches.

The first step in the model calibration process is the identification of measured hydrologic data that can be used as calibration targets. Two sets of calibration targets were identified: water levels in monitoring wells and measured stream flows. Water levels at 193 wells in the sand and gravel aquifer and 13 wells in the sandstone aquifer (as described in Attachment F), and base stream flows at 13 locations (as described in Attachment G) were used in the model calibration process.

It is important to note that the observed water levels and observed stream flows are data from multiple time periods over several decades. In the regional model analysis it was implicitly assumed that the observed water levels and stream flows represented conditions with no irrigation pumping and that the effects of pumping were smaller than the variability in water-level and stream flow data as the result of collection over long-time periods.

All calibration targets that were identified are intended to represent average, baseline hydrologic conditions. As a result, the calibration process consisted of the development of a groundwater model to simulate average, baseline conditions. This type of model is commonly referred to as a steady-state model. In this steady-state groundwater model, the only variable parameters are the distribution of hydraulic conductivity and the magnitude of hydraulic conductivities. In some circumstances, a steady-state model has other variable parameters (such as thickness of geologic units and recharge rate), but in this study, the thickness of the permeable glacial aquifer and the recharge rates were assumed to be known.

The second step in the model calibration process is the identification of conditioning information on model parameters. Conditioning information that was used were estimates of aquifer hydraulic conductivity from specific capacity tests on 60 high capacity wells within the model domain (refer to Attachment E). The hydraulic conductivity of the sand and gravel aquifer based on the specific capacity tests ranged between 6 feet per day and 805 feet per day and the hydraulic conductivity of the sandstone aquifer ranged between 5 and 25 feet per day[10]. These tests suggest hydraulic conductivity is variable in the sand and gravel. As such, pilot-points were used to calibrate hydraulic conductivity in this aquifer.

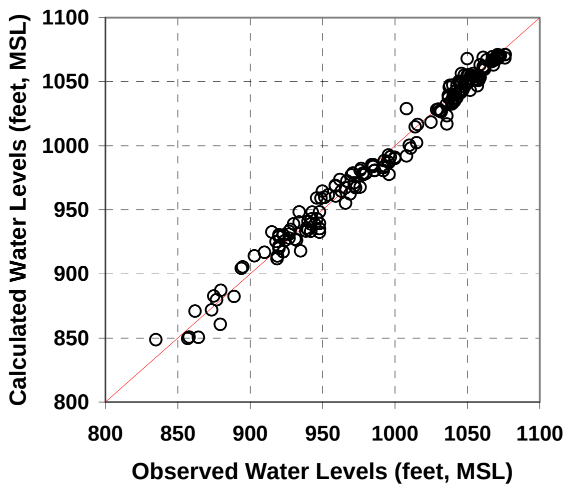
In using pilot-points, the parameter estimation program, PEST, estimates values for each pilot-point and these discrete estimates are then transformed (via kriging-interpolation) into a continuous hydraulic conductivity field that is used by the model. The starting value for a pilot-point is the respective median of the hydraulic conductivities that resulted from the specific capacity tests depending on whether the pilot-point is located west or east of the Johnstown Moraine. As such, the initial hydraulic conductivity condition in the sand and gravel aquifer was actually a two zone system. The calibration introduced variability or heterogeneity that was supported by the calibration data; the degree of heterogeneity introduced was controlled by using

[10] In an area to the north of the model domain in the Central Sand Region, Bradbury and others (1992) estimated based on 10 pumping tests that hydraulic conductivity of sand and gravel aquifer ranged from 70 feet per day to 200 feet per day in the region investigated. The hydraulic conductivity of the Mt. Simon Sandstone was estimated by Bradbury and others (1999) to the south of the model domain in Dane County to range between 6 and 31 feet per day based on 14 pumping tests.

preferred-value regularization (Doherty, 2009). The preferred-value scheme is used here because of the available specific capacity tests. By using a preferred-value scheme a calibrated pilot-point value differed from its initial value only if there was a marked improvement in the fit of the model to the calibration data (a reduction in Φ). While the specific capacity tests in the sandstone aquifer suggested some variability in the hydraulic conductivity, there is insufficient head data in this unit to warrant a pilot-point calibration, so a uniform zone is used.

The third step in the calibration process is automated calibration using the computer program PEST. The result of this step is the calibrated groundwater model. The distribution of hydraulic conductivities estimated by this process for the sand and gravel aquifer is shown on Figure 8. The calibrated hydraulic conductivity of the sandstone aquifer was 7 feet per day. The calculated steady-state water table in the calibrated model is shown on Figure 9. Also shown on these figures are the differences between model calculated water levels and observed water levels at locations included in the calibration process. The model calculated base stream flows are listed and compared to measured stream flows on Table 1. The modeled level in Pleasant Lake was 979.96 feet MSL.

Quantitative evaluation of the model calibration consisted of examining the residuals between the 206 measured water levels targets, and the residuals from the 13 base stream-flow targets. The residual is defined as the target minus the calculated water level or stream flow. The conventional way to qualitatively judge the goodness of a model calibration is to examine a plot of observed versus calculated water levels; if the match between observed and calculated water levels is excellent all of the data points plot on a straight line. Such a plot is shown to the right.



As a result of the favorable comparison of observed and calculated groundwater levels and stream flows, I concluded that the site-specific model appropriately represented the groundwater system in the vicinity of the Richfield Dairy. Thus, I concluded that the site-specific model was an appropriate method to use to evaluate the effects of pumping at the Richfield Dairy.

Irrigation Pumping

There are a total of 425 active high-capacity irrigation wells within the model domain. These wells and median pumping rates are listed in Attachment H[11]. The median average

[11] Irrigation pumping data obtained from the Wisconsin Department of Natural Resources database; http://prodoasext.dnr.wi.gov/inter1/hicap$.startup.

pumping rate from these wells during the period 2007 through 2011 was equivalent to about 22,873 gallons per minute (51 cubic feet per second or 12 billion gallons per year). As noted above, this pumping was not explicitly simulated in the baseline steady-state model analysis. The rationale for not simulating the pumping was that the effects of pumping are of the same order of magnitude as the variability in estimates of water levels and base stream flows. This approach is similar to that used by Kraft and others (2012).

I used the site-specific model to determine the magnitude of water level changes and stream flow changes that result from the irrigation pumping relative to baseline pre-pumping conditions. The effect of the existing pumping from high capacity wells on groundwater levels, lake levels and stream flows was simulated by explicitly simulating pumping from each of the active high capacity wells in the model domain. Each of the high capacity wells was pumped at a rate reflecting 20 percent consumptive use relative to baseline conditions[12]. This simulation was conducted as a steady-state analysis, and thus the calculated water level changes, lake level changes reflect changes that would occur from baseline conditions after long-term pumping.

The calculated long-term water-level drawdown from baseline conditions in the sand and gravel aquifer in the vicinity of Richfield Dairy is about 2.8 inches, and the long-term change in the water level in Pleasant Lake from baseline conditions is approximately 0.7 feet. The model calculated Pleasant Lake water level was 979.26 feet MSL. Refer to Attachment H for a graphic showing long-term drawdowns and a tabulation of stream flow reductions.

It is useful to put the irrigation pumping in perspective relative to the total groundwater flow in the model domain to understand the magnitude of the effects of the irrigation pumping. Within the model domain, the total groundwater input from recharge is equivalent to approximately 133,500 gpm. Under no pumping conditions, this 133,500 gpm of groundwater flows toward and discharges into the headwater streams, and this groundwater discharge represents base flow conditions in the headwater streams. The effect of pumping is to reduce the amount of groundwater discharging into the headwater streams, and thus reduce the base flow of the streams. Total groundwater pumping for irrigation, as noted above, is equivalent to about 22,873 gpm, or about 17 percent of total recharge. Much of the water pumped for irrigation, though, infiltrates into the sandy soils within the model domain and recharges the groundwater table. The net effect of irrigation pumping, assuming that only 20 percent of the pumped water is consumptively used, is equivalent to a consumptive use of only 4,575 gpm, or about 3.4 percent of total groundwater recharge within the model domain. Under this consumptive use assumption, the effect of irrigation pumping is to reduce the total groundwater discharge to the headwater streams in the Fox River and Wisconsin River drainages by about 3.4 percent. Since there is slightly less groundwater flowing toward the headwater streams with the current irrigation pumping relative to no-pumping conditions, there is a slight reduction in groundwater levels relative to pre-pumping conditions.

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[12] Twenty percent consumptive use is consistent with the application of 10 inches of water to the fields and increased evapotranspiration of 2 inches.

Effects of Groundwater Pumping at Richfield Dairy

I estimated the effects of groundwater pumping at the Richfield Dairy by simulating, using the site-specific model as described above with the incorporation of the existing high capacity well pumping in the model domain, the additional pumping of 72.5 million gallons per year from the proposed high capacity wells and cessation of pumping for irrigation from the existing high capacity well at the dairy site.

The 146-acre parcel on which the proposed dairy is to be located is agricultural fields that are irrigated with water produced from an existing high capacity well.[13] The average pump rate from this well between 2007 and 2011 was equivalent to 88 gpm (46.5 million gallons per year). For purposes of this analysis, it was assumed consistent with the ongoing studies at the University of Wisconsin that net groundwater recharge is reduced by 2-inches per year as the result of irrigated agriculture. The implication of this assumption is that of the 88 gpm that was pumped for irrigation, the equivalent of 76 gpm infiltrated through the soils and recharged the groundwater, and only the equivalent of 12 gpm represented increased evapotranspiration by crops relative to baseline conditions[14].

With the site-specific model, the effects of groundwater use for the Richfield Dairy were simulated by including the proposed new high capacity well in model layer 3 (sandstone aquifer), and by removing the existing high capacity well at the dairy site from the simulation. The site-specific model was then run in a transient mode to estimate groundwater levels and base stream flows in the headwater streams with ongoing groundwater use at the dairy[15]. The effect of the groundwater use at the dairy was then subsequently estimated by comparing these groundwater levels and base stream flows to those calculated with the site-specific model simulation that included the existing high capacity wells. These differences are the effects due to water use at the dairy.

The calculated changes in the level of Pleasant Lake with time from start of pumping at the dairy are shown on the graph at the top of the next page. After 3 years of pumping the calculated decline in the level of Pleasant Lake from baseline conditions is about three-eights of an inch, after 5 years of pumping the calculated decline in level of Pleasant Lake is less than three quarters of an inch, and after twenty five years of constant pumping the calculated decline is less than two inches. The calculated water level change at Burnita Lake is less than 1.3 inches after 25 years.

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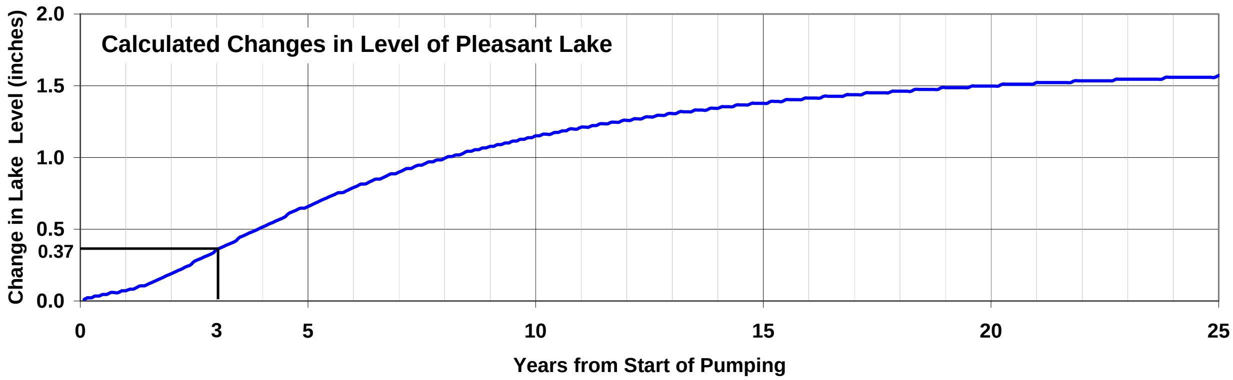
[13] High Capacity Well Number 00146; this well was completed April 1976 and has a reported capacity of 1,000 gpm from the sand and gravel aquifer. This well was used to irrigate 115 acres.

[14] In the model simulations that included pumping from existing high capacity wells, the pumping rate from high capacity well number 00146 was specified at an average rate of 12 gpm consistent with expected consumptive use of water from this well.

[15] A specific yield of 0.25 and specific storage of 10^{-6} per foot was assigned to all model units for the transient simulations.



The model calculated changes in the characteristics of Pleasant Lake are small. Under baseline conditions with the existing high capacity pumping, the model calculated groundwater inflow to the lake is approximately 610 gpm; this inflow declines by less than one and a half percent after twenty-five years of constant groundwater pumping for the dairy (declines by approximately 10 gpm). The calculated change in lake surface area as a result of a lake level lowering is less than one percent (about one acre) and the calculated change in lake volume is about one percent. These changes in lake level, lake area, and lake volume are very small relative to natural variability in lake level, lake area, and lake volume as described above[16]. For instance, as described in Section 3, the variability in summer lake levels was more than 5 feet between 1964 and 2012.

The calculated changes in water levels in the sand and gravel aquifer are very small. These calculated changes after 5 and 25 years of pumping are shown on Figure 10a and Figure 10b, respectively. The calculated changes in stream flows as the result of constant pumping for the dairy for twenty five years are also very small; the changes at each of the gaging locations in the model domain are listed on Table 1. The change in flow of Chaffee Creek at the gaging station at County CH, about one mile downstream of the headwater, is about 22 gpm, a change of about three percent relative to the estimated base flow of 1.8 cfs (808 gpm). Much smaller percentage changes are calculated at other stream gaging locations.

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[16] These percentage changes in lake area and lake volume are based on a lake level of about 980 feet MSL. At a low lake stage of 979 feet MSL, the percentage changes in lake volume and lake level would be larger. The calculated changes in lake area and lake volume at a lake stage of 979 feet MSL are approximately one percent and 1.3 percent, respectively.

Prediction Uncertainty

The predicted decline in the level of Pleasant Lake after 25 years of pumping at average rates of 72.5 million gallons per year is about 1.6 inches. The uncertainty in this estimate has been evaluated using a quantitative analysis of uncertainty based on a method developed by Moore and Doherty (2005)[17]. The results of this evaluation are briefly described below.

The method of Moore and Doherty (2005) is implemented in the PREDVAR utility in the parameter estimation program PEST and this utility was used for our analysis of predictive uncertainty. This method calculates predictive uncertainty as the result of the inability of the calibration process to capture all of the parameter detail necessary for making an accurate prediction and as the result of noise in the measurement data. The calculated standard deviation using this method for the drawdown at Pleasant Lake is about 10 percent. Thus, at a 90 percent level of confidence, the calculated drawdown at Pleasant Lake after 25 years of pumping at an average rate of 72.5 million gallons per year is 1.6 ± 0.26 inches.

I evaluated the uncertainty of the predicted drawdown at Pleasant Lake in a qualitative manner. For the qualitative evaluation, Pleasant Lake was not modeled explicitly with the MODFLOW lake package. Rather, the lake was only implicitly represented in the site-specific model[18], and the drawdowns after 25 years of dairy pumping were observed at the west and east ends of the lake. The calculated drawdowns ranged from 2.2 inches at the west end to 1.2 inches at the east end. This range of drawdowns in a qualitative manner indicates the uncertainty associated with the predicted average drawdown in the lake, based on the MODFLOW lake package, of 1.6 inches

The results of the uncertainty evaluation indicate that the predictive uncertainty in estimating the water-level change at Pleasant Lake is relatively small. Some may find it surprising that the predictive uncertainty is so small given the magnitude of the residuals in the calibrated groundwater model (refer to Figure 9). The magnitude of the residuals reflects primarily the fact that the observed water levels were not taken at a single point in time but rather represent water levels collected over many decades, and does not reflect inaccurate parameters in the model. The predictive uncertainty is small because the groundwater system in the vicinity of the proposed high capacity wells is relatively simple; a very productive sand and gravel aquifer overlying a productive sandstone aquifer. Since the groundwater system consists primarily of a thick sand and gravel aquifer, only a limited range of aquifer properties can reproduce the general shape of the water table in the vicinity of the proposed high-capacity wells and the observed stream flows. As a result, the predictive uncertainty in calculated drawdown is small.

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[17] C. Moore and J. Doherty, 2005. Role of the Calibration Process in Reducing Model Predictive Error, Water Resources Research, Vol. 41:W0520.

[18] In the regional model used by Kraft to estimated the effects of pumping at the Richfield Dairy, Pleasant Lake was also implicitly modeled (Kraft, 2011a, 2011b)

The water level in Pleasant Lake is a reflection of the water table in the sand and gravel aquifer as groundwater flows into the lake on the west side and flows out of the lake on the east and south sides. Since the lake water level is a reflection of the water table, water level changes calculated for the lake have a relatively low predictive error. The characteristics of the sediment in the lake influence how much groundwater flows into and out of the lake but have little effect on average lake level. As a result, the characteristics of these sediments have little influence on prediction uncertainty.

I evaluated the uncertainty or predictive error associated with calculated stream flow qualitatively. It is important to understand that in the modeling analyses that the total reduction in stream flow after long-term pumping at a constant rate is equal to the pumping rate. Since in the long term the total reduction in stream flow is equal to the pumping rate, there is no predictive uncertainty regarding the total change in stream flow. There is, though, predictive uncertainty in the distribution of the total stream flow reductions among the many streams within the model domain. Since the hydraulic conductivity of the sand and gravel aquifer falls within a relatively narrow range within the model domain, the predictive uncertainty relative to the distribution of stream flow reductions is expected to be small.

Section 6
References

Adams County Land & Water Conservation Department.2008. Lake Classification Report for McGinnis Lake, Adams County. May.

Bedekar, V., Niswonger, R. G., Kipp, K., Panday, S. and Tonkin, M. (2011), Approaches to the Simulation of Unconfined Flow and Perched Groundwater Flow in MODFLOW. Ground Water, 49: no. doi: 10.1111/j.1745-6584.2011.00829.

Bradbury, K., J. Faustini, and M. Stoertz, 1992. Groundwater Flow Systems and Recharge in the Buena Vista Basin, Portage and Wood Counties, Wisconsin. Wisconsin Geological and Natural History Survey, Information Circular 1992.

Bradbury, K.R., S.K. Swanson, J.T. Krohelski, and A.K. Fritz. 1999. *Hydrogeology of Dane County, Wisconsin*. Open-File Report. Wisconsin Geological and Natural History Survey. 1999-04. October 1.

Buchwald, C., 2009. Water Use in Wisconsin 2005.U.S. Geological Survey Open-File Report 2009-1076.

CHPRC-00258 Rev 2, MODFLOW and Related Codes Software Management Plan, 2010, CH2M Hill Plateau Remediation Company, Richland, Washington

Clancy, K., G.J. Kraft, and D.J. Mechenich. 2009. Knowledge Development for Groundwater Withdrawal Management Around the Little Plover River, Portage County Wisconsin - A Report to the Wisconsin Department of Natural Resources. January 14.

Clayton, L. 1987. Pleistocene Geology of Adams County, Wisconsin. Wisconsin Geological and Natural History Survey, Information Circular 59.

Doherty, J. 2009. PEST – Model-Independent Parameter Estimation & Uncertainty Analysis, Version 12.2.Watermark Computing. Brisbane, Australia.

Ellefson, B., K. Rury and J. Krohelski, 1987.Water Use in Wisconsin 1985.U.S. Geological Survey Open File Report 87-699.

Ellefson, B, C. Fan, and J. Ripley, 1997. Water Use in Wisconsin 1995.U.S. Geological Survey Open-File Report 97-356.

Ellefson, B, G. Mueller, and C. Buchwald, 2002.Water Use in Wisconsin 2000.U.S. Geological Survey Open-File Report 02-356.

Evans, R. 2008. Lake Classification Report for McGinnis Lake, Adams County, Wisconsin. Adams County Lake & Water Conservation Department, Friendship, Wisconsin, November.

Gebert, W.A. 1982. Low-Flow Characteristics of Streams in the Central Wisconsin River Basin, Wisconsin. U.S. Geological Survey Water Resources Investigations Open-File Report 81-495.

Harbaugh, A., E. Banta, M. Hill and M. McDonald, 2000.MODFLOW-2000, the Modular Three-Dimensional Fine-Difference Ground-Water Model. U.S. Geological Survey Open-File Report 00-92.

IPS Environmental and Analytical Services, 1996. Phase I Pleasant Lake Management Plan, Waushara County, Wisconsin. Report to Pleasant Lake Improvement Corporation. August.

Kraft, G., 2011a. Letter to Eric Ebersberger, Wisconsin Department of Natural Resources. October 7.

Kraft, G. 2011b. Letter to Jean McCubbin, President Pleasant Lake Management District. November 28.

Kraft, G.J., D.J. Mechenich, and K. Clancy. 2007. Technical Memorandum #1 - Exploring Daily Streamflow Records - Project for Understanding Groundwater Pumping Effects on Lake Levels and Streamflows in Central Wisconsin. August 1.

Kraft, G.J., D.J. Mechenich, and K. Clancy. 2007. Technical Memorandum # 2 - Exploring Long-Term Streamflow Records - Project for Understanding Groundwater Pumping Effects on Lake Levels and Streamflows in Central Wisconsin. August 5.

Kraft, G.J., D.J. Mechenich, and K. Clancy. 2007. Technical Memorandum # 4- Groundwater Level Trends in the Study Area - Project for Understanding Groundwater Pumping Effects on Lake Levels and Streamflows in Central Wisconsin. August 20.

Kraft, G. and D. Mechenich, 2010. Groundwater Pumping Effects on Groundwater levels, Lake Levels, and Streamflows in the Wisconsin Central Sands. A Report to the Wisconsin Department of Natural Resources. Center for Watershed Science and Education, College of Natural Resources, University of Wisconsin – Stevens Point/Extension. March 15.

Kraft, G., K. Clancy, and D. Mechenich, 2012. Irrigation Effects in the Northern Lake States: Wisconsin Central Sands Revisited. Ground Water Vol. 50 (2):308-318.

Lake and Pond Solutions Co., 2012. Lake Survey of Pleasant Lake, Waushara County, Wisconsin. June 20. Greenville, Wisconsin.

Lawrence, C.L., and B. Ellefson, 1982.Water Use in Wisconsin 1979.U.S. Geological Survey Water-Resources Investigation Report 82-444.

Lippelt, I. and R. Hennings, 1981. Irrigable Lands Inventory, Phase I. Wisconsin Geological and Natural History Survey Miscellaneous Paper 81-1.

Mechenich, D, G. Kraft, and K. Clancy, 2009.Technical Memorandum #11. Groundwater Flow Model for the Wisconsin Central Sands. University of Wisconsin – Stevens Point.

Mickelson, D., L. Maher, S. Simpson, 2011. Geology of the Ice Age National Scenic Trail. University of Wisconsin Press.

Miller, N. 2012. Vanishing Waters?:*Grow - Wisconsin's Magazine for the Life Sciences*: 11.

Mudrey, M.G., B.A. Brown, and J.K. Greenberg. 1982. Bedrock Geologic Map of Wisconsin. 1.

Olcott, P.G., 1992. Ground Water Atlas of the United States – Iowa, Michigan, Minnesota, Wisconsin. HA 730-J. U.S. Geological Survey.

U.S. Geological Survey.1987. *Adams County - Groundwater-Contamination Susceptibility Analysis*.PUBL-WR-177-87.U.S. Geological Survey.

University of Wisconsin-Stevens Point and University of Wisconsin - Extension. 2011. Letter from George J. Kraft to Eric Ebersberger, Wisconsin Department of Natural Resources, Regarding: Communications with Citizens in Regard to the Town of Richfield Wells Associated with a Proposed Dairy. October 7.

Waschbusch, R.J., D.L. Olson, and S.B. Marsh. 2005. *Water Resources Data Wisconsin Water Year 2005*. Water-Data Report WI-05-1.U.S. Geological Survey. Water-Data Report WI-05-1.

Waushara County Land Conservation & Zoning. 2010. Report on Lake Levels Observed in Waushara County.

Weeks, E.P., and H.G. Stangland. 1971. Effects of Irrigation on Streamflow in the Central Sand Plain of Wisconsin. Open-File Report.

Wisconsin Department of Natural Resources, 1985. Patrick Lake, Adams County, Feasibility Study Results and Management Alternatives. Prepared for the Patrick Lake Protection and Rehabilitation District by Bureau of Water Resources Management.

Wisconsin Department of Natural Resources. Well Construction Report - Wisconsin Unique Well Number -WT 595. 1.

Wisconsin Department of Natural Resources. 2012. Well Construction Report - Wisconsin Unique Well Number - WT 594. 2.

Wisconsin Department of Natural Resources. 2012. Well Data, CD 2102 Well Data.exe

Wisconsin Geological and Natural History Survey. WiscLITH. Open-File Report 2009-03.

Wisconsin Geological and Natural History Survey. 2011. Lexicon of Pleistocene Stratigraphic Units of Wisconsin. Technical Report 1.

FIGURES

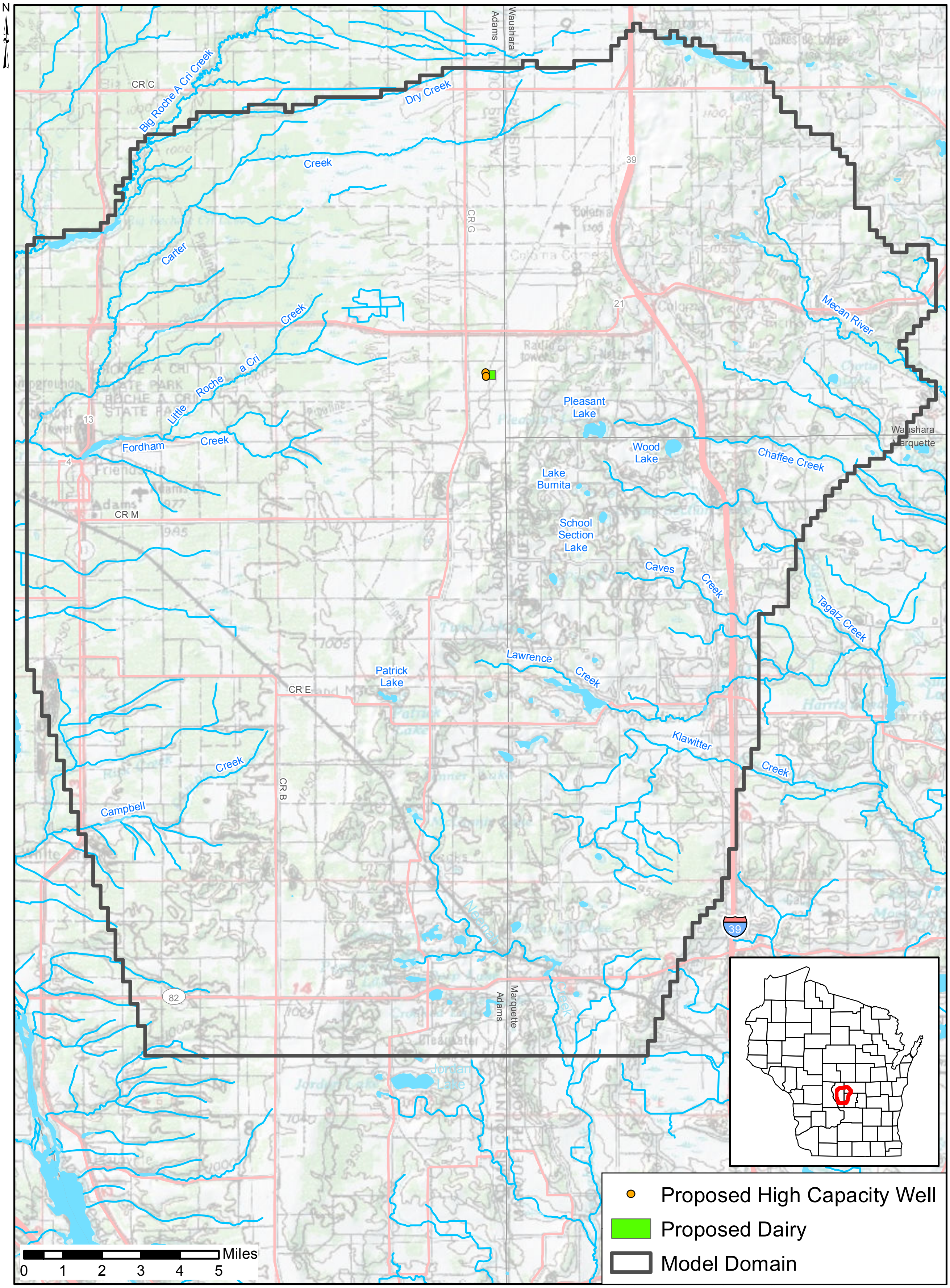


Figure 1 Location Map

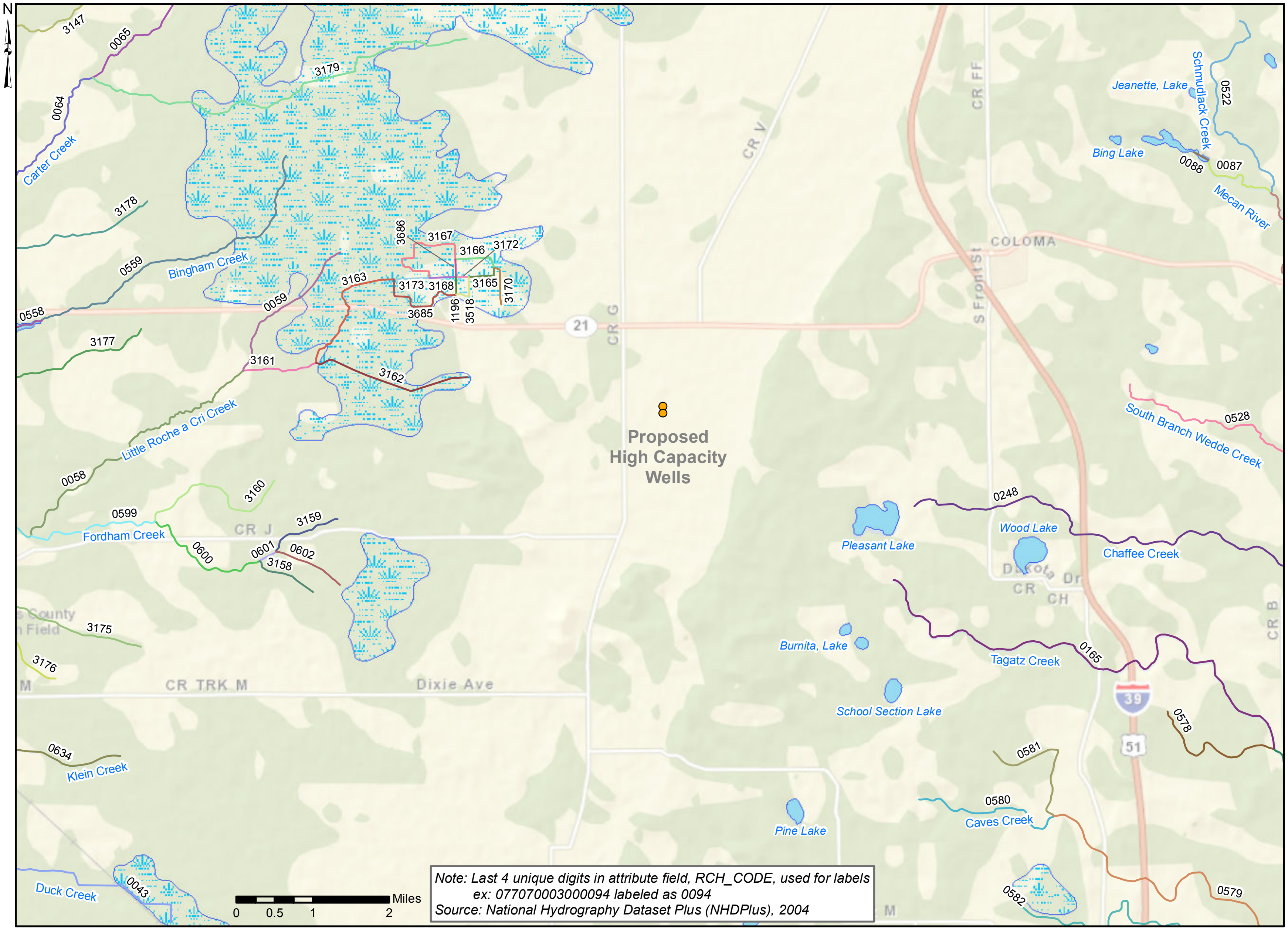
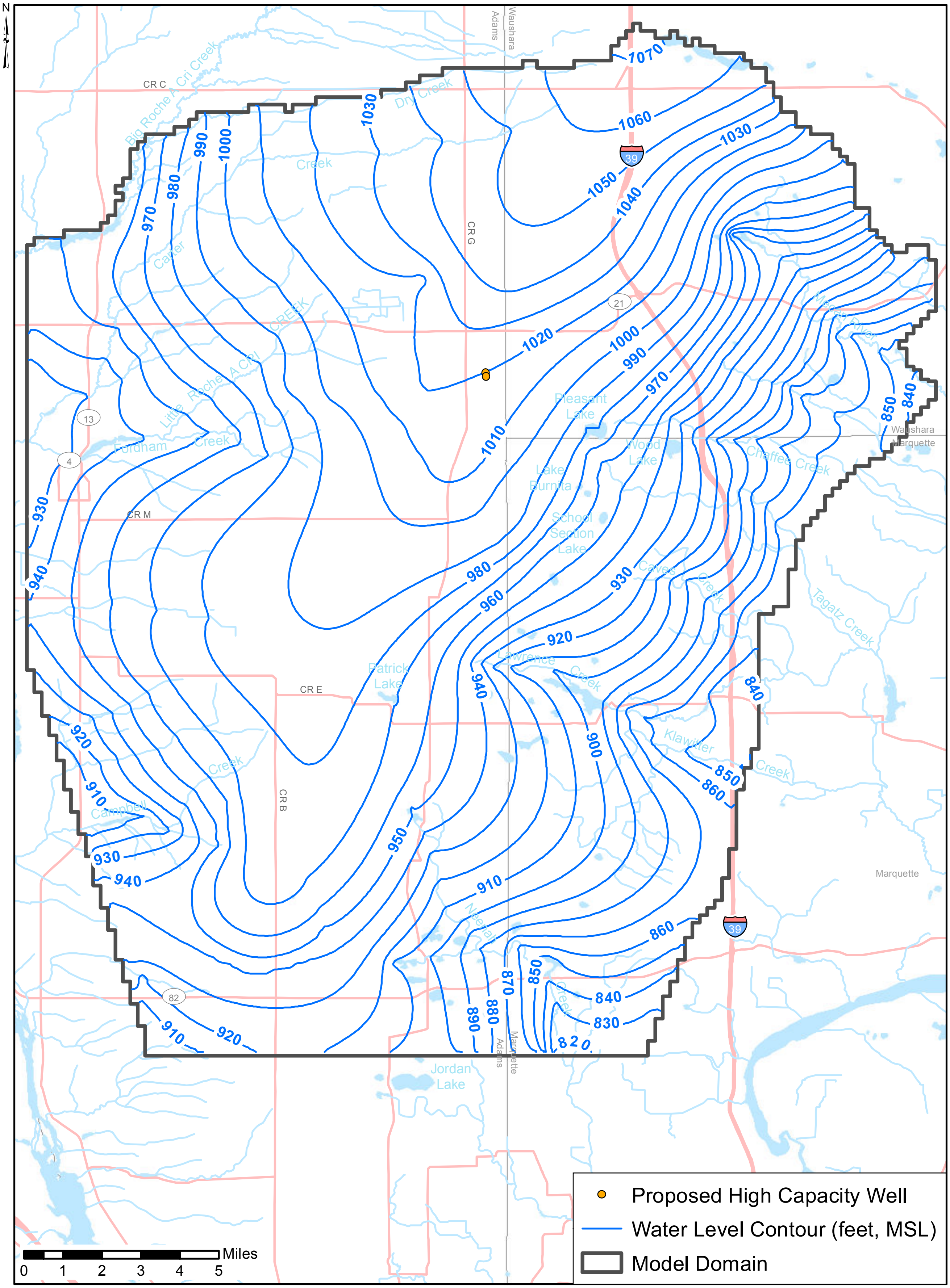


Figure 2 Surface Water Features



Note: Water levels calculated with groundwter model described in section 5.

Figure 3 Water Table Map

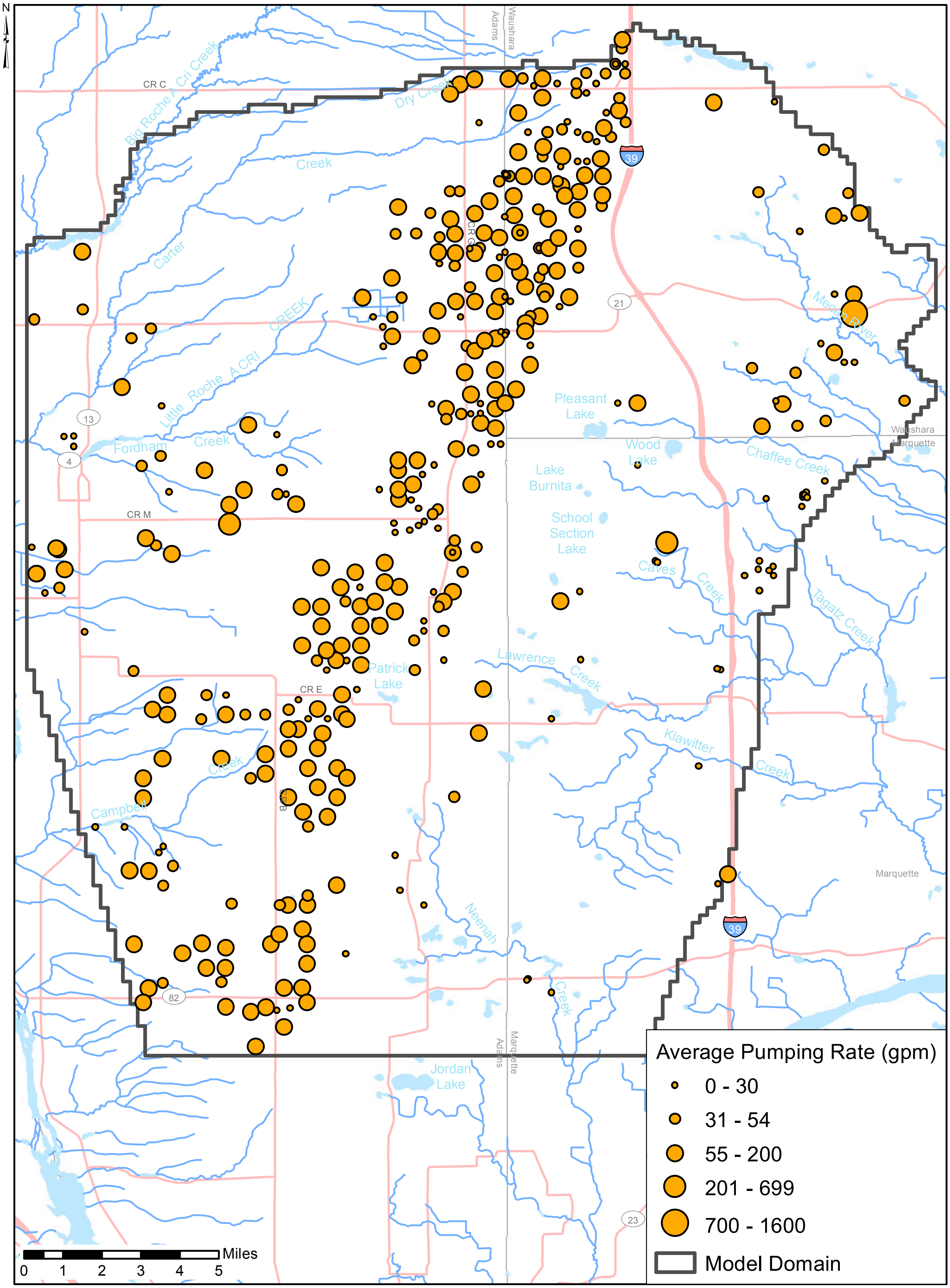


Figure 4 Average Pumping Rates at Existing High Capacity Well Locations

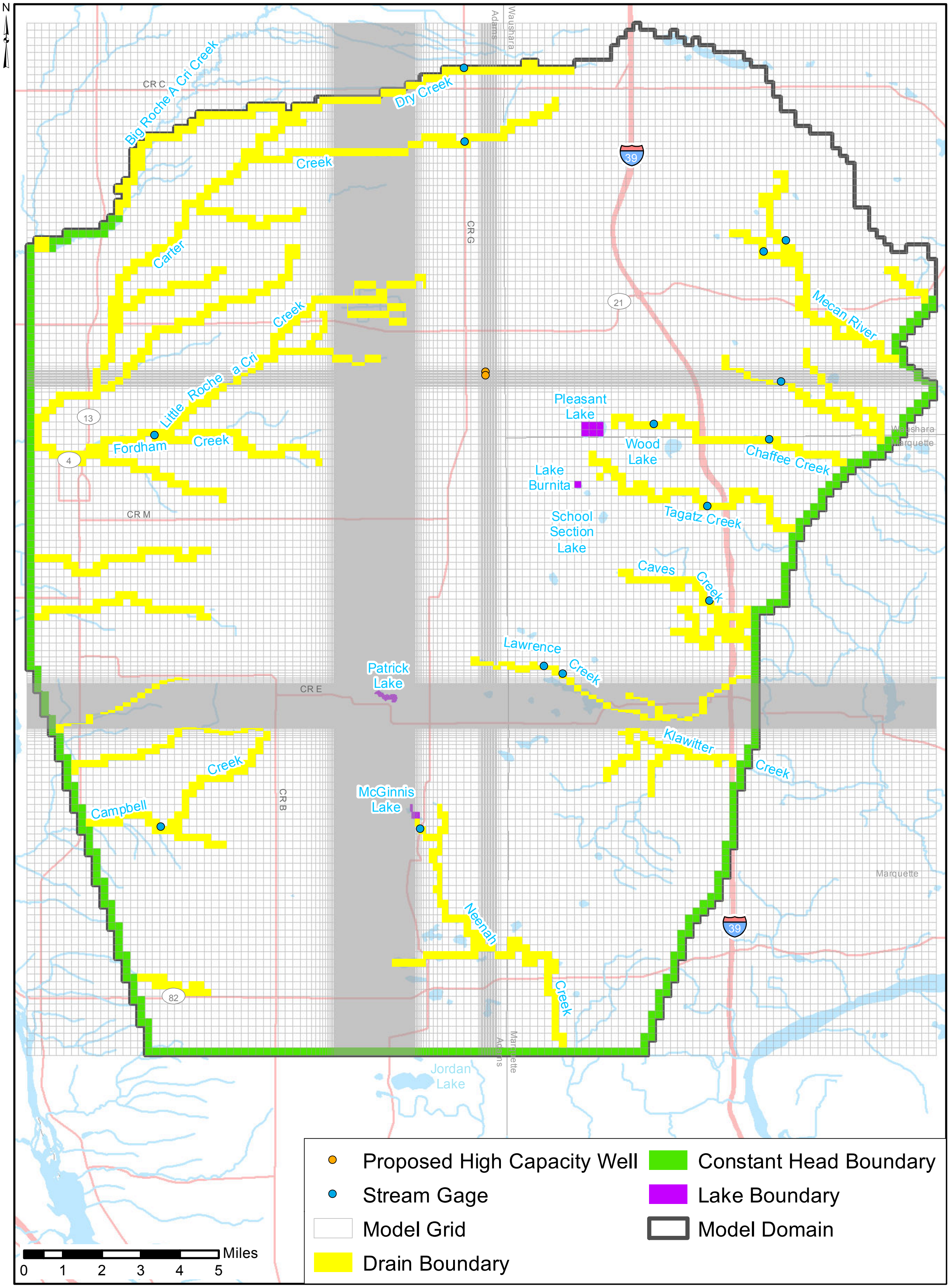


Figure 5 Model Domain and Boundary Conditions and Stream Gage Locations

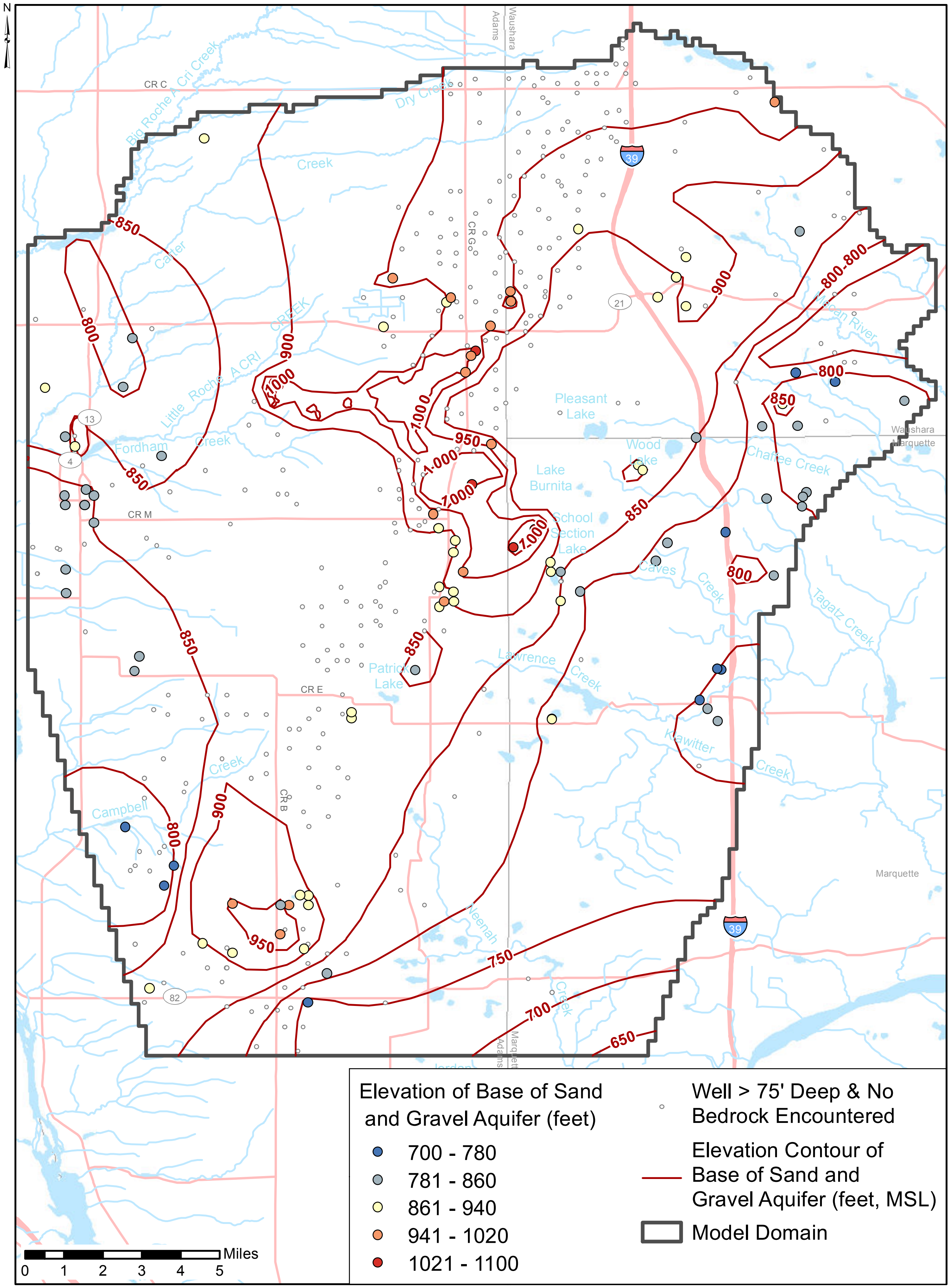


Figure 6 Elevation of Base of Sand and Gravel Aquifer (Model Layer 2)

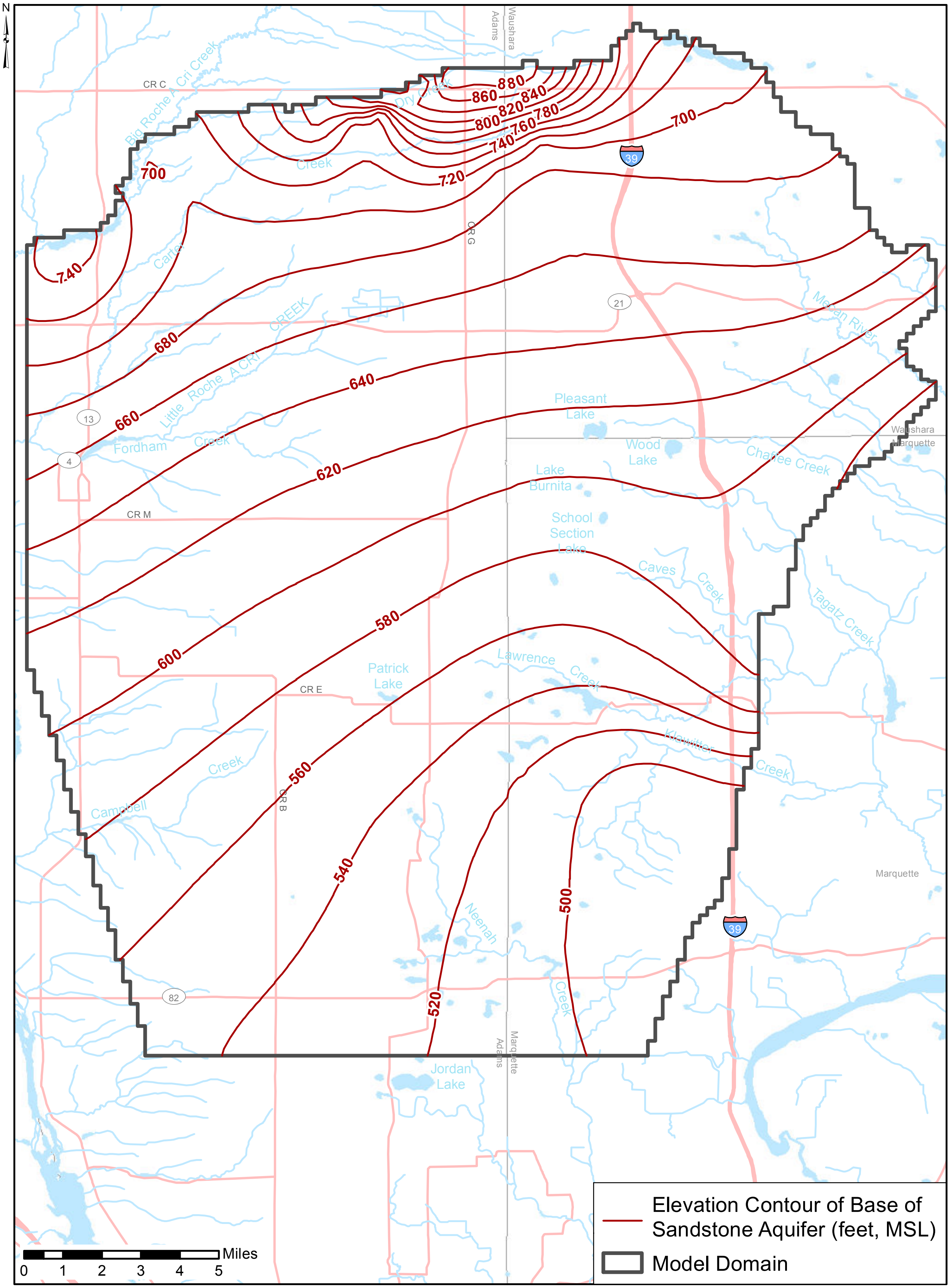


Figure 7 Elevation of Base of Sandstone Aquifer (Model Layer 3)

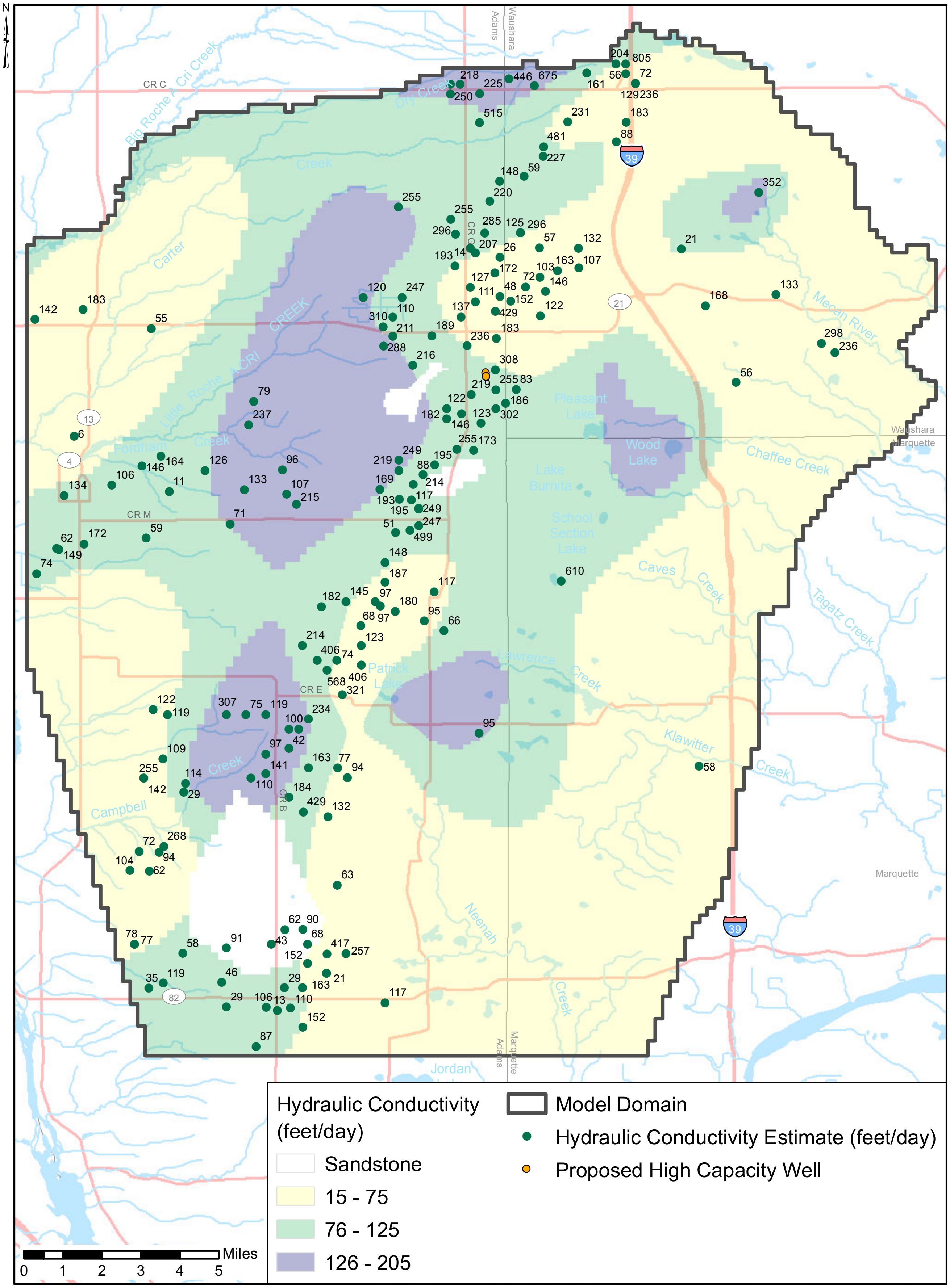


Figure 8 Hydraulic Conductivity of Sand and Gravel Aquifer

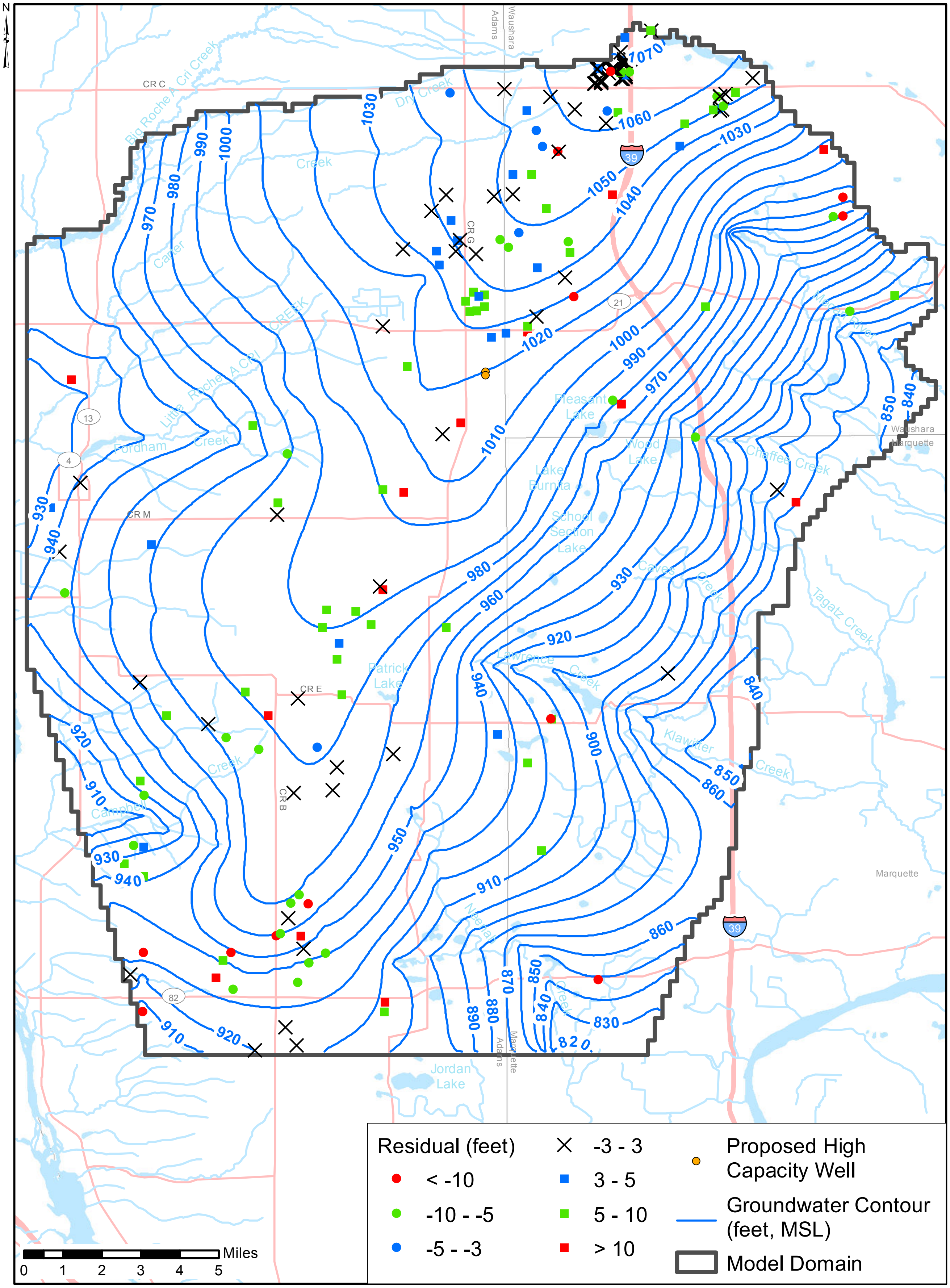


Figure 9 Calculated Steady State Water Table and Residuals

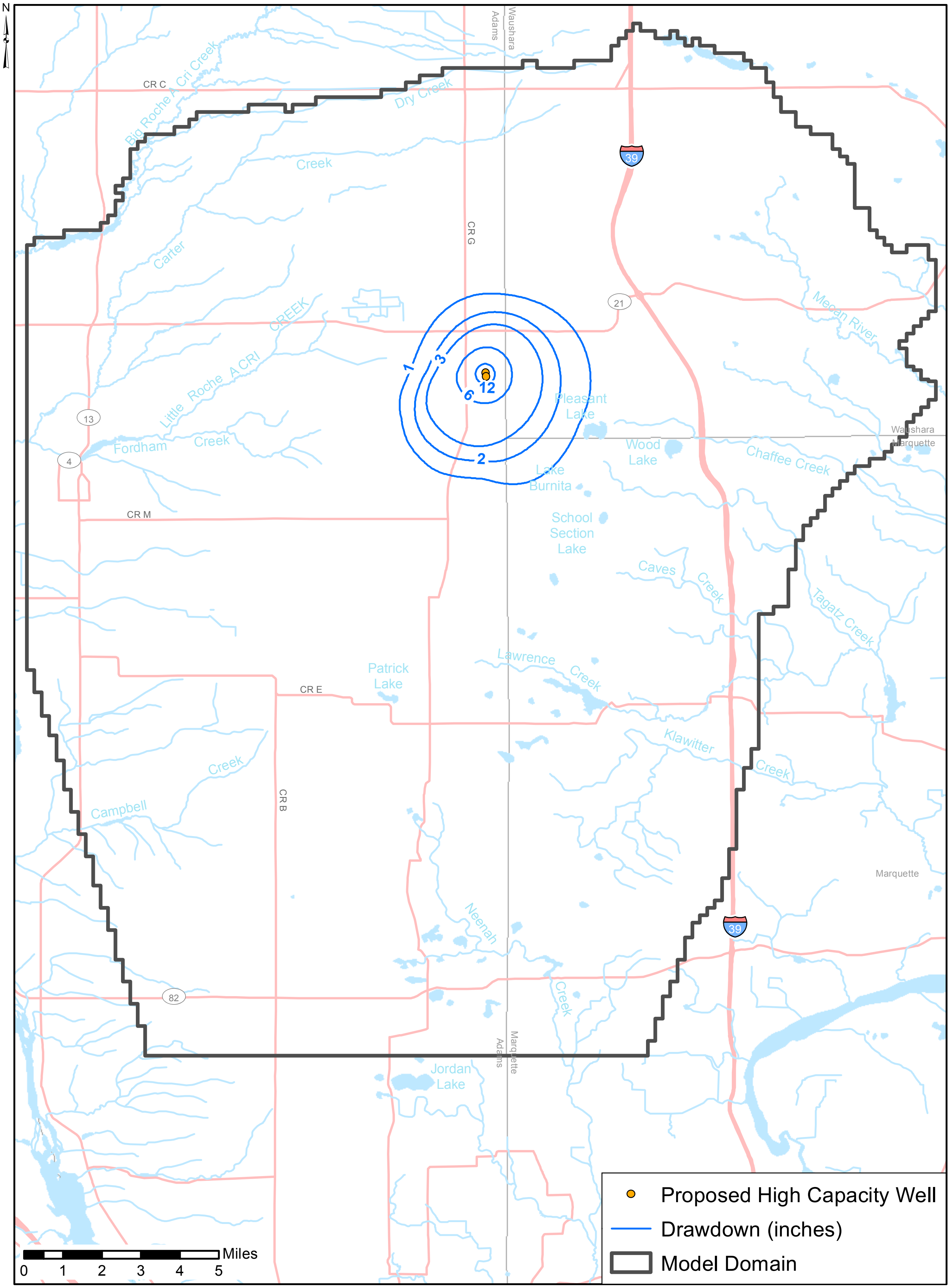


Figure 10a Calculated Drawdowns at the Water Table after 5 Years of Pumping

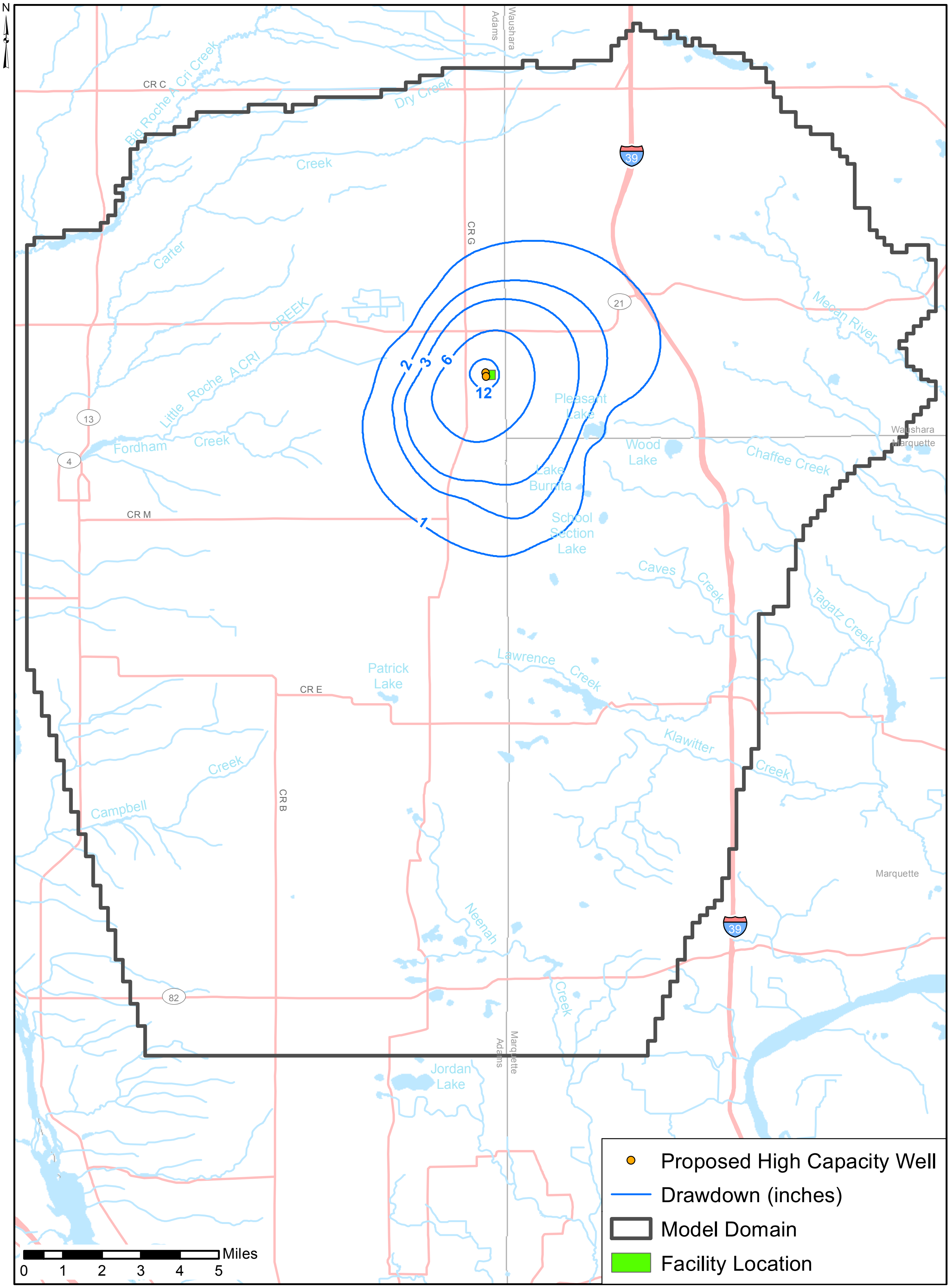


Figure 10b Calculated Drawdowns at the Water Table after 25 Years of Pumping

TABLES

Table 1
Stream Base Flows and Calculated Changes in Base Flow Due to Proposed High Capacity Wells for Richfield Dairy

Stream Name	Estimated Base Flow (cfs)	Model Calculated Base Flows (cfs)			Change in Base Flow due to Pumping of New High Capacity Wells (gpm)
		No Pumping	Pumping from Existing High Capacity Wells	Pumping from Existing High Capacity and Proposed Dairy Wells	
Little Roche-A-Cri Creek at 10th Ave	34	35.1	33.3	33.2	43
Campbell Creek at County A	2.4	2.3	2.1	2.1	0.4
Neenah Creek at County G	0.8	1.0	0.8	0.8	0.3
Neenah Creek at County A	>42	31.4	31.0	31.0	0.7
Chaffee Creek at County JJ	14	14.3	13.9	13.8	27
Chaffee Creek at County CH	1.8	1.7	1.4	1.4	22
Lawrence Creek at Eagle	20	17.5	17.0	17.0	5
Lawrence Creek nr Westfield	16	14.7	14.3	14.3	4
Carter Creek at County G	2.5	3.3	2.3	2.3	4
Mecan River at County GG	13	12.3	12.0	12.0	3
Schmudlack Creek at Cottonville Rd	1.2	2.0	1.8	1.8	1
Tagatz Creek near Westfield	7.6	6.0	5.6	5.5	27
South Branch Wedde Creek at JJ	7	2.2	2.1	2.1	3

Note: Refer to Attachment G for details on the stream gaging locations and stream gaging data.

Attachment A

Resume of Charles B. Andrews

CHARLES B. ANDREWS

Hydrologist

EDUCATION

PhD Geology, 1978, University of Wisconsin, Madison, Wisconsin
MS Geology, 1976, University of Wisconsin, Madison, Wisconsin
MS Water Resources, 1974, University of Wisconsin, Madison, Wisconsin
BA Geology, 1973, Carleton College, Northfield, Minnesota

American University of Beirut, Beirut, Lebanon, 1971-1972

REGISTRATIONS

Registered Geologist California No. 3853, Georgia PG001689, Alabama No. 1175, Washington No. 2841

PROFESSIONAL HISTORY

S.S. Papadopulos & Associates, Inc., Bethesda, Maryland
President, 1994-present , Principal Hydrogeologist, 1984-present
Beijing Water International, Beijing, China, Principal, 2007-present
Woodward-Clyde Consultants, San Francisco and Walnut Creek, California
Hydrogeologist and head of Groundwater Section, 1980-1984
Northern Cheyenne Indian Tribe, Lame Deer, MT Scientist, 1978-1980

SUMMARY OF QUALIFICATIONS

Dr. Andrews is nationally known for his creative solutions to difficult water resource problems. His areas of expertise include the assessment and remediation of contaminated sites, formulation of water resource projects, assessment of surface water and groundwater flow and quality conditions at hazardous waste sites, design of water remediation systems, and development of new and modification of off-the-shelf numerical simulation models for adaptation to specific field projects. He has provided technical guidance to significant water-rights litigation. Dr. Andrews is a frequently requested member of groundwater advisory panels for the evaluation of state-of-the-art hydrology and for pioneering research and evaluation of contaminant transport in the subsurface. He is the author and co-author of numerous publications on modeling of groundwater flow and transport of chemical constituents, and the use of analytical models in identifying appropriate remediation alternatives for a site.

As President of S.S. Papadopulos & Associates, Inc., Dr. Andrews overviews and serves as technical advisor on all projects. S.S. Papadopulos & Associates, Inc. is a 60-person environmental consulting firm that specializes in the assessment and remediation of contaminated sites and groundwater problem solving.

APPOINTMENTS

Trustee, Geological Society of America, 2007-present
Advisor to Editor, *Ground Water,* 1998-present
Board of Directors of the Association of Groundwater Scientists and Engineers Division of the National Ground Water Association, 1997-2001
National Research Council Committee on Groundwater Cleanup Alternatives, National Academy of Sciences, 1991-1994
National Research Council Committee on Groundwater Modeling Assessment, National Academy of Sciences, 1987-1988

REPRESENTATIVE RECENT PROJECT EXPERIENCE

- Leads the groundwater analysis effort for design of remedial alternatives for Onondaga Lake, Syracuse, New York. This lake is reputed to be the most contaminated lake in the United States and remediation is projected to cost several hundreds of millions of dollars. In this role he interacts frequently with and has

CHARLES B. ANDREWS

Hydrologist

made many presentations to the New York State DEP.

- Participated as a technical expert for a major pipeline company in year-long Consent Decree negotiations with the U.S. Department of Justice on soil and groundwater contamination issues at 30 compressor station sites. Developed a comprehensive framework, which was incorporated in the Consent Decree, for efficient, cost-effective investigation and remediation of compressor stations.

RESENTATIVE PROJECT EXPERIENCE *— continued*

- Provided groundwater consulting services for the identification and development of spring water sources for a major bottled water company in Michigan, Colorado, Ohio and Ontario. This work involved development of groundwater models to determine potential production rates, optimal pumping rates and locations, and environmental effects of water production. In addition, developed long-term monitoring plans and was an expert witness in litigation related to development and operation of spring water sources.
- Chair of external peer review panel for Frenchman Flat CAU at the Nevada Test Site, 2010. Also, served on a review panel for Hanford site-wide groundwater flow and transport model, 1989-2001; and developed a groundwater model of the A- and M- areas at the Savannah River Site, 1985-1986.
- Managed remediation activities, including remedial investigations, feasibility studies, remedial design and implementation, for industrial sites in California and New Jersey that are extensively contaminated with arsenic and associated heavy metals. Several of these investigations involved the evaluation of geochemical parameters that govern arsenic mobility in the subsurface and groundwater/surface-water interactions.
- Peer reviewer for investigation and development of major spring source in rural Guangdong Province, China.
- Peer reviewer for development of assessment guidelines for Ministry of Environmental Protection, China for initial phase of National Groundwater Plan

SELECTED RECENT PUBLICATIONS

Root, R.A., D. Vlassopoulos, N.A. Rivera, M.T. Rafferty, C. Andrews, and P.A. O'Day. 2009. Speciation and Attentuation of Arsenic and Iron in a Tidally Influenced Shallow Aquifer: *Geochimica et Cosmochimica Acta, ScienceDirect*: 26.

Barth, G., and C. Andrews. 2009. Practical Problems, Practical Solutions. National Groundwater Association's Annual Groundwater Summit, Tucson, Arizona April 19 - 23, 2009. Tucson. April 19 - 23.

Spiliotopoulos, A., and C.B. Andrews. 2007. Analysis of Aquifer Test Data – MODFLOW and PEST. In *Groundwater and Wells*.(3rd ed.). 812p.

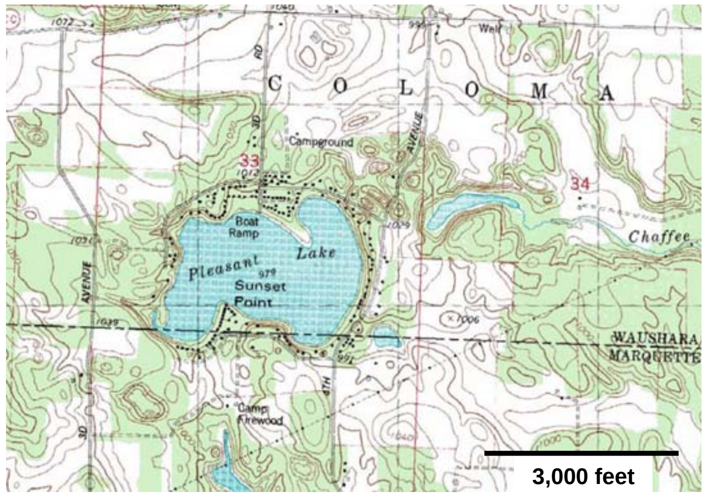
Andrews, Charles. 2008. One Hydrogeology A New Paradigm for Model Construction: Modeling with Google Earth. MODFLOW and More 2008: Ground Water and Public Policy Conference, May 18-21, 2008, Golden, Colorado.

Andrews, C.B., 2008. Review of "Effective Groundwater Model Calibration: With Analysis of Data, Sensitivities, Predictions, and Uncertainty": *Ground Water*. 46, no. 1: 5.

Attachment B

Pleasant Lake Data

Attachment B
Pleasant Lake



Pleasant Lake is located in an ice contact depression just east of western extent of the Johnstown Moraine. A topographic map of the lake vicinity is shown on the figure to the right. The lake elevation on the topographic map is 979 feet MSL[1]. The lake elevation on June 19, 2012 was 979.77 feet MSL. The small elongated water body to the east of the lake is the headwaters of Chaffee Creek, and the small water body to the south of Pleasant Lake is the headwaters of Tagatz Creek. The area from which surface water runoff drains directly into Pleasant Lake is calculated to be about 510 acres; most of this area is located to the west of the lake. A map of the contributing watershed for Pleasant Lake is attached as Figure B-1.

Pleasant Lake was characterized in a 1996 Lake Management Plan as a hard water seepage lake having good to very good water quality with littoral bottom materials comprised of primarily sand and marl (IPS, 1996). The plan also noted that the lake basin is fairly deep. The plan noted that fish species supported in the lake include northern pike, yellow perch, largemouth bass, rock bass, bluegill, black crappie, pumpkinseed, black bullhead, white sucker and warmouth bass.

A survey of Pleasant Lake was conducted on June 19, 2012 to determine current lake bathymetry[2]. A Lowrance sonar depth finder and GPS system were used for the survey. The maximum lake depth was determined to be 23.7 feet at a lake elevation of 979.77 feet MSL and the average depth was about 15 feet. The results of this lake survey are shown on Figure B-2. The lake area at the time of this survey is estimated to have been about 130.4 acres based on an air photo taken in the summer of 2011[3].

A previous lake survey was conducted in July 1964 using sonar by the Wisconsin Conservation Department. The lake area at the time of this survey is estimated to have

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[1] The topographic map shown is from the 1:24,000 quadrangle map for the Westfield West quadrangle dated 1981. The topographic map is based on air photos taken in 1959-1960 with revisions based on air photos taken in 1974 and field checked in 1976.

[2] This lake survey was conducted by Lake and Pond Solutions Company, Greenville, Wisconsin. The report of the lake survey is contained in Attachment I.

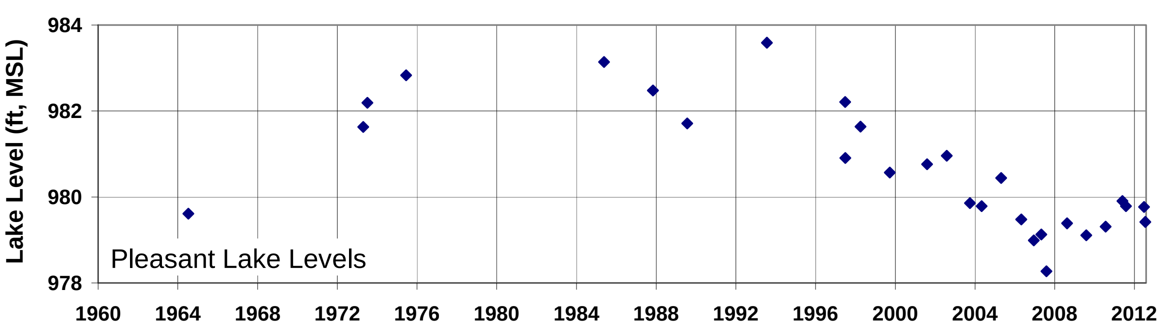
[3] The lake area is reported in Attachment I to be 131.5 acres. This lake area is based an undated lake image used by the program ciBIOBASE to interpret the survey data. A more accurate estimate of lake area was obtained from an air photo from Digital Globe taken in summer of 2011 when the lake level was similar to the level in June 2012.

been 129.5 acres at a lake elevation of 979.61 feet MSL[4]. The maximum depth was determined to be 24 feet, the average depth was determined to be about 14 feet and the volume was determined to be 1,850 acre feet. The results of this lake survey are shown on Figure B-3.

The lake areas in 1964 and 2012 were similar consistent with lake elevations on the dates of the surveys. Differences in lake volume and average depth between the two survey is likely due to differences in number of survey points in each of the surveys and not the result of significant differences in the lake between the two periods.

Lake area was also estimated from air photos taken in 1992, 2005, 2010, and 2011; estimated areas on these dates are 136.7 acres, 130.5 acres, 130.5 acres, 130.4 acres, respectively[5]. Unfortunately, exact lake levels on the dates of the air photos are not known; however, based on long-term lake level trends shown below, it is likely that lake levels in 1992 were about 3 feet to 4 higher than between 2005 and 2011. From these data, it would appear that lake acreage increases about 2 acres for each foot increase in water level.

Lake level elevations were measured on 28 occasions at irregular intervals between 1965 and July 2012; since 1997 at least one measurement is available for most years. A lake level database is maintained by Waushara County Department of Zoning & Land Conservation[6]. The available lake level data are shown on the plot below.



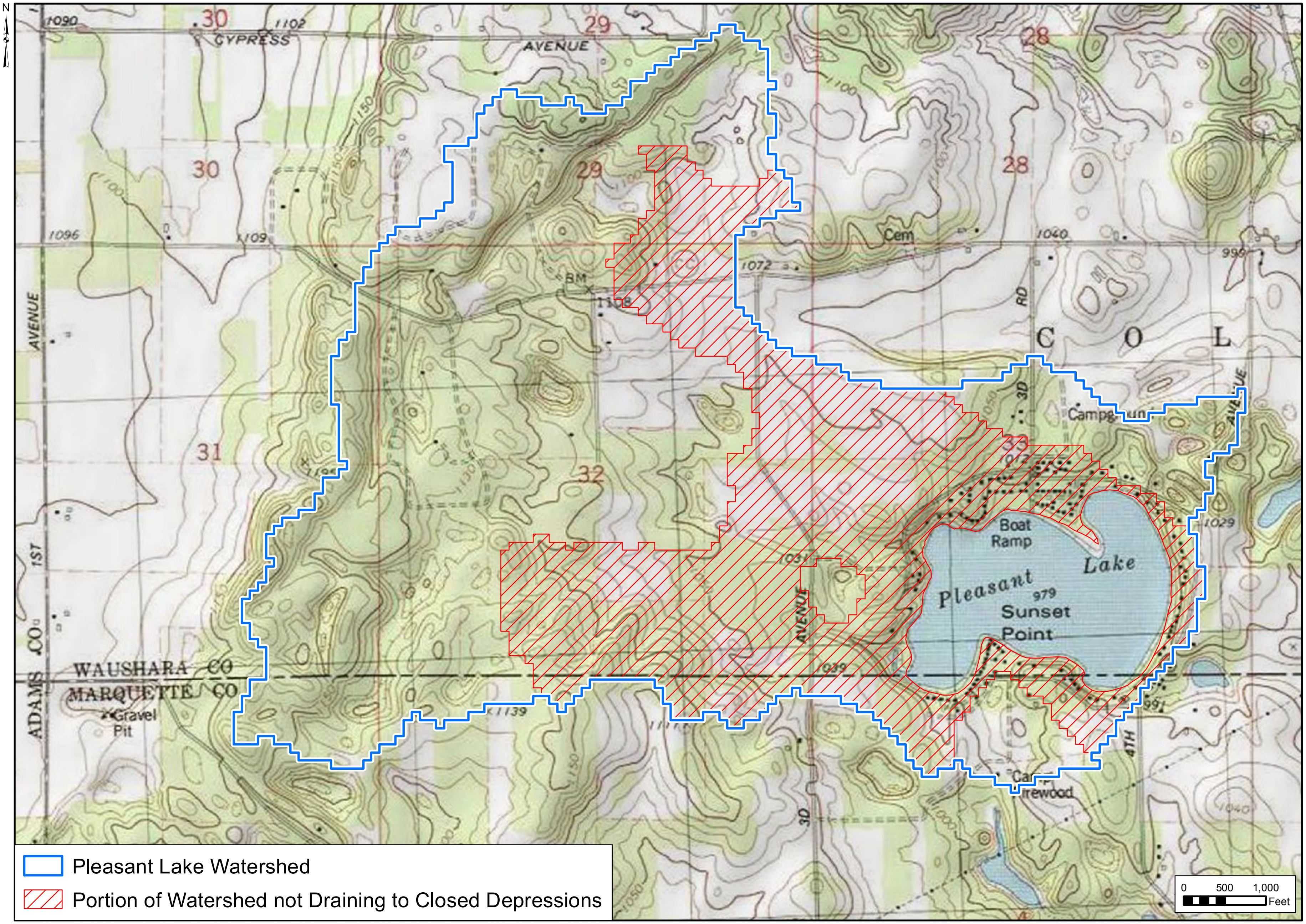
These lake levels are based on a reference that is a brass cap cast in a 6" diameter concrete post at ground level. The brass cap is located 21 feet south of the centerline of 3rd Lane and 26 feet east of the public access centerline and approximately 127 feet north of the OHWM (Near the north end of the retaining wall on the east side of the landing). There is a small survey marker sign next to the brass cap.

[4] The lake area reported for the 1964 survey was 126.5 acres. This lake area was determined to be incorrect based on a re-evaluation of the map provided with the survey. The shoreline depicted on this figure encloses as an area of 129.5 acres as determined by georeferencing the figure.
[5] Copies of these air photos are shown on Figure B-4, B-5, B-6 and B-7.
[6] As part of the lake survey conducted for this study, lake level elevations of 979.77 feet MSL and 979.42 feet MSL were measured on June 19, 2012 and July 17, 2012, respectively.

The density of vegetation in the lake was determined from the sonar survey conducted in June 2012. The sonar data were interpreted to provide an estimate of percent biovolume (also known as percent of lake volume inhabited by vegetation). Percent biovolume is the percent of the water column occupied by plant matter. Biovolume percents range from zero percent for bare bottom to 100 percent where vegetation extends from the bottom of the lake to the surface. Percent biovolume is near zero over much of the lake where depths are greater than 15 feet and as would be expected percent biovolume greater than 50 percent only occurs in near shore area. The spatial distribution of percent biovolume in Pleasant Lake is shown on Figure B-8.

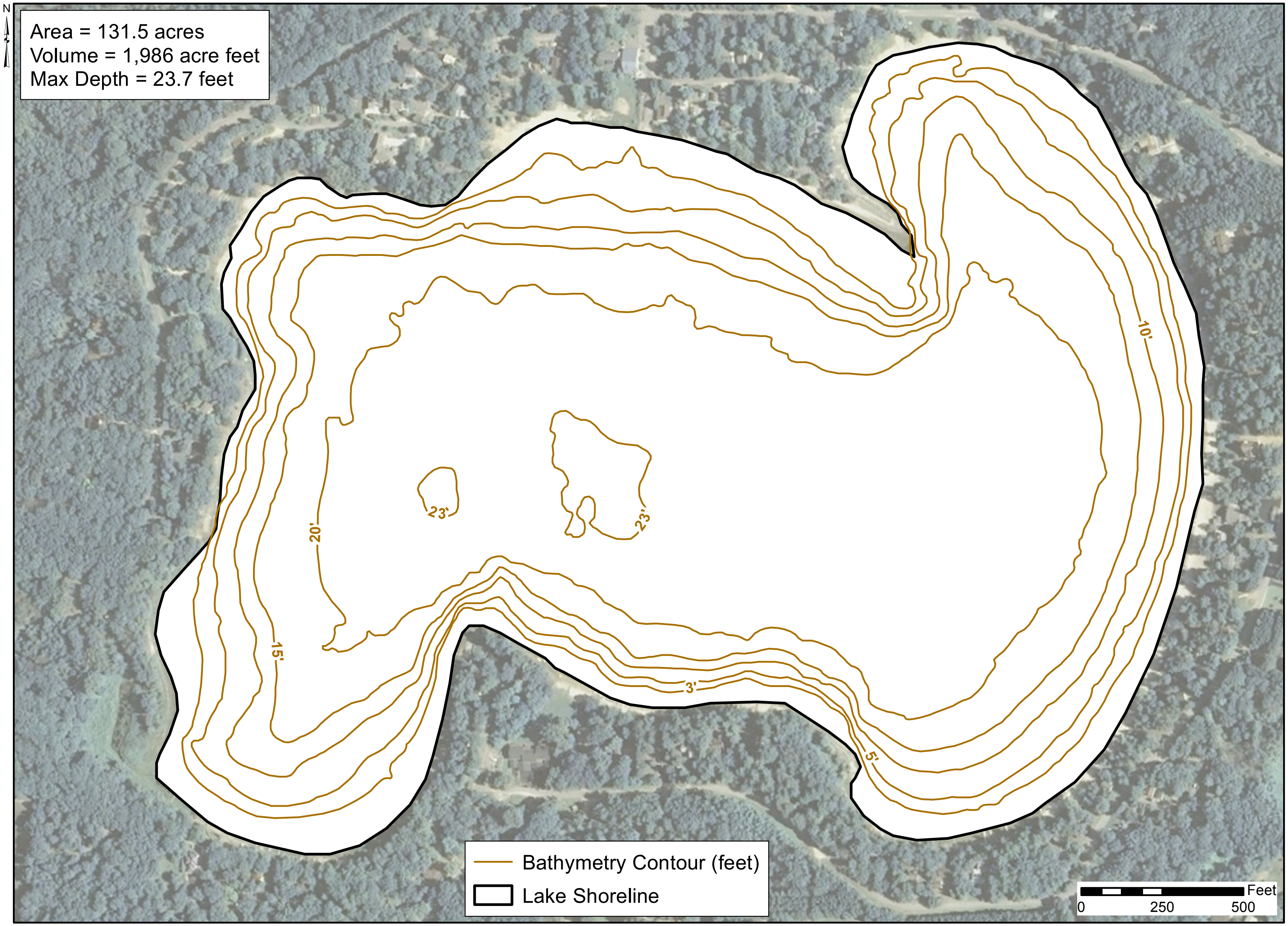
The water budget for the lake consists of inflows from groundwater, precipitation and surface runoff and consists of outflows from evaporation and groundwater discharge. An estimated water budget for the lake is shown to the right. The surface water runoff is calculated on the basis of 3.9 inches per year of runoff from the contributing area to the lake. The groundwater component of the budget is estimated from the groundwater model described in this report. Based on this water budget, the average residence time of water in the lake is greater than one year.

Source	**Inflow (gpm)**	**Outflow (gpm)**
Precipitation	210	
Evaporation		210
Surface Runoff	100	
Groundwater	610	710
Total	920	920



Note: Pleasant Lake watershed is 1,443.3 acres. Area of water not draining to closed depressions is 509 acres.

Figure B-1 Pleasant Lake Watershed



Note: Source of map is Lake and Pond Solutions, 2012. Survey Conducted on June 19, 2012

Figure B-2 Pleasant Lake Bathymetric Contours 2012

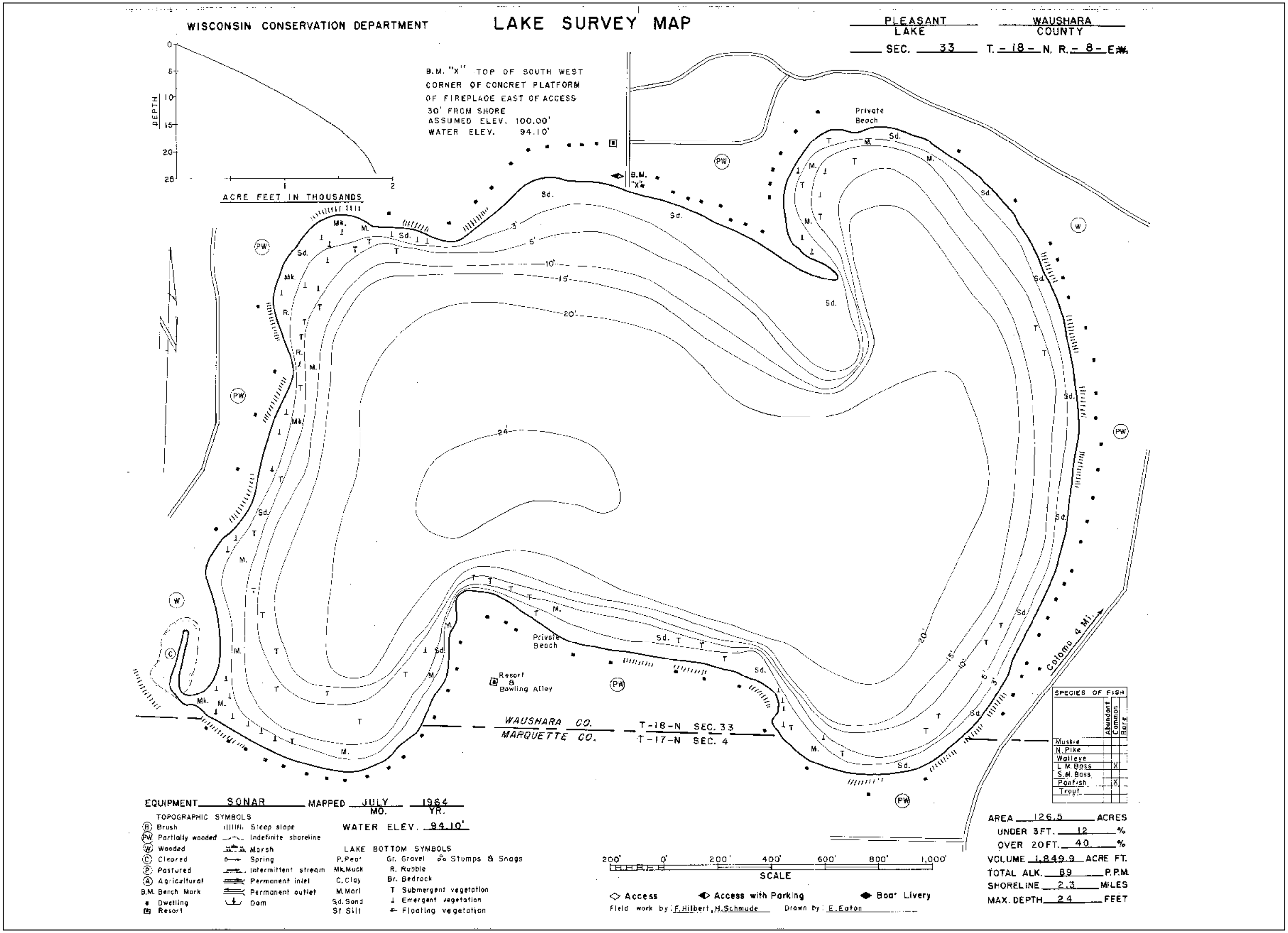


Figure B-3 Pleasant Lake Bathymetric Contours 1964

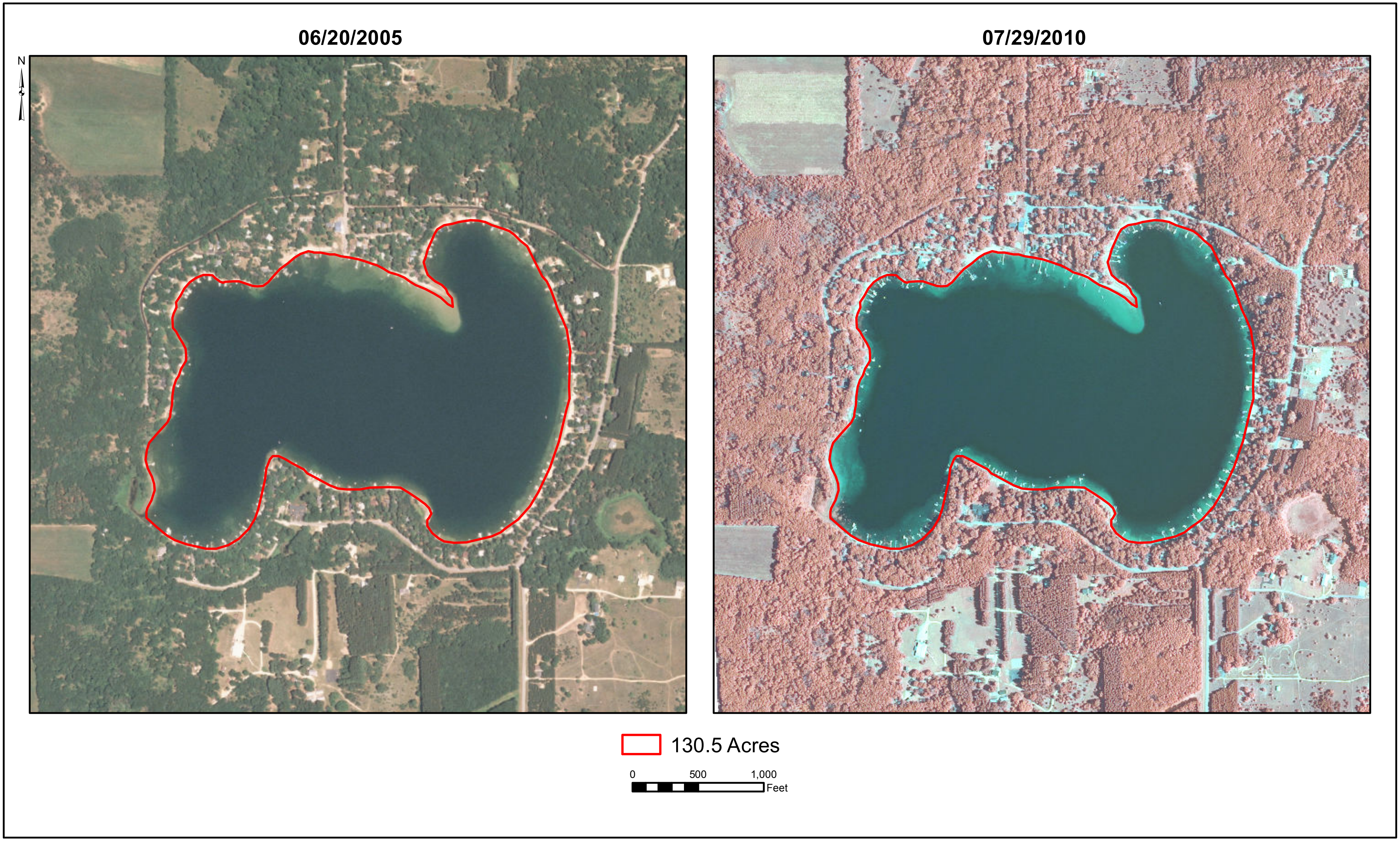


Figure B-4 Pleasant Lake in 2005 and 2010

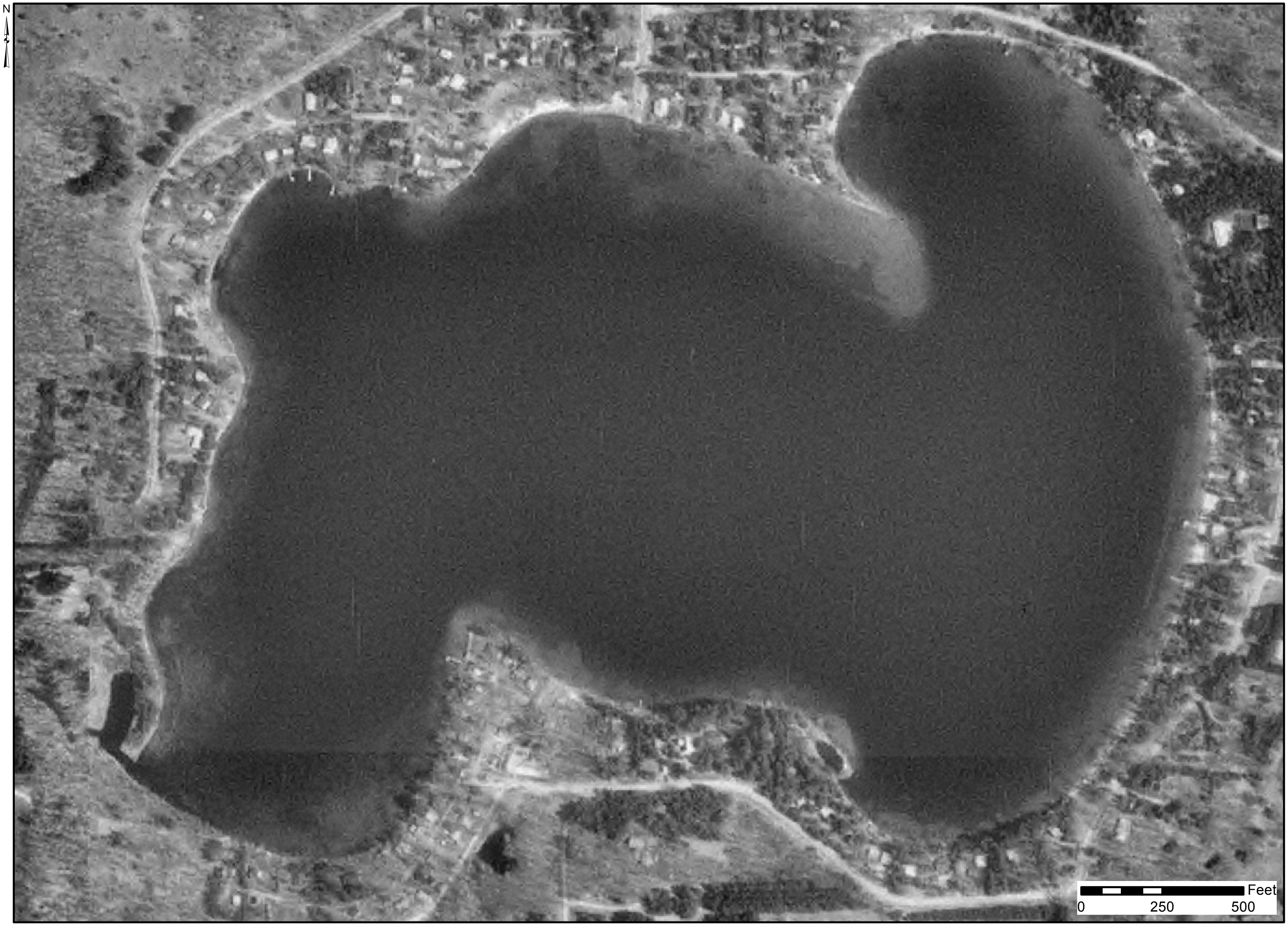


Figure B-5 Pleasant Lake 1992

Figure B-6 Comparisons of Pleasant Lake Shorelines in 1992 and 2010

Figure B-7 Pleasant Lake Summer 2011

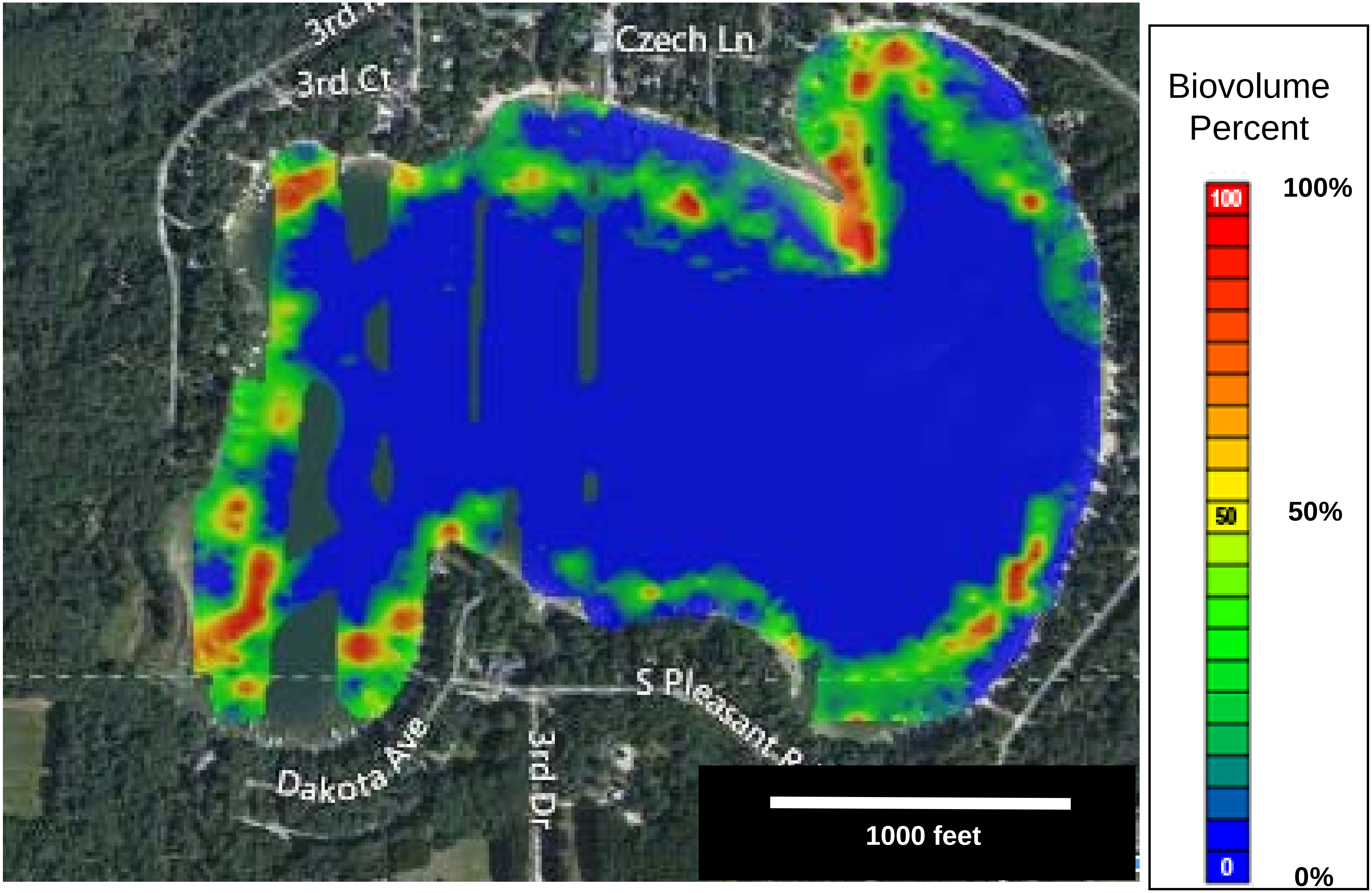
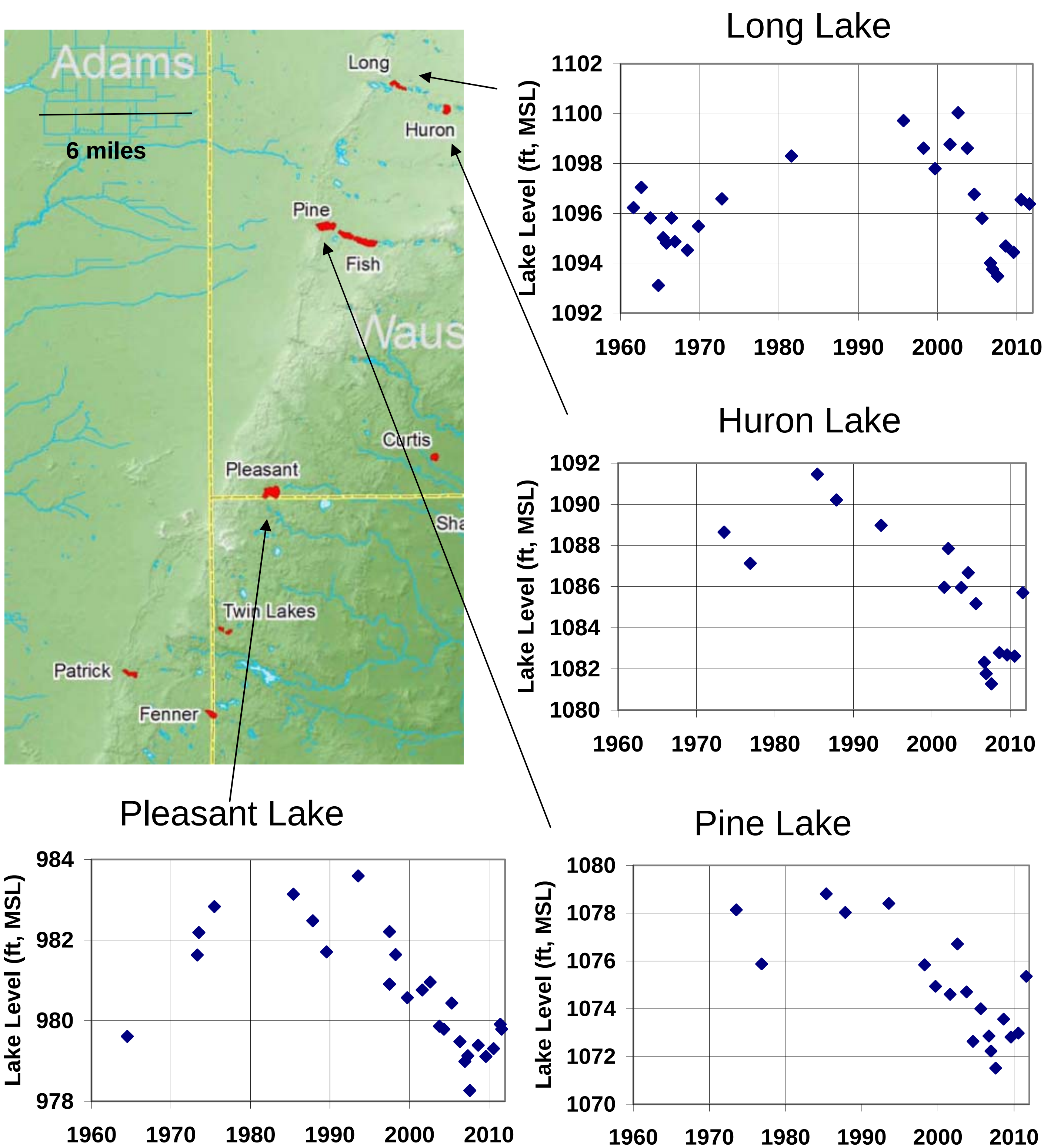


Figure B-8 Pleasant Lake – Biovolume Percent June 2012

Attachment C

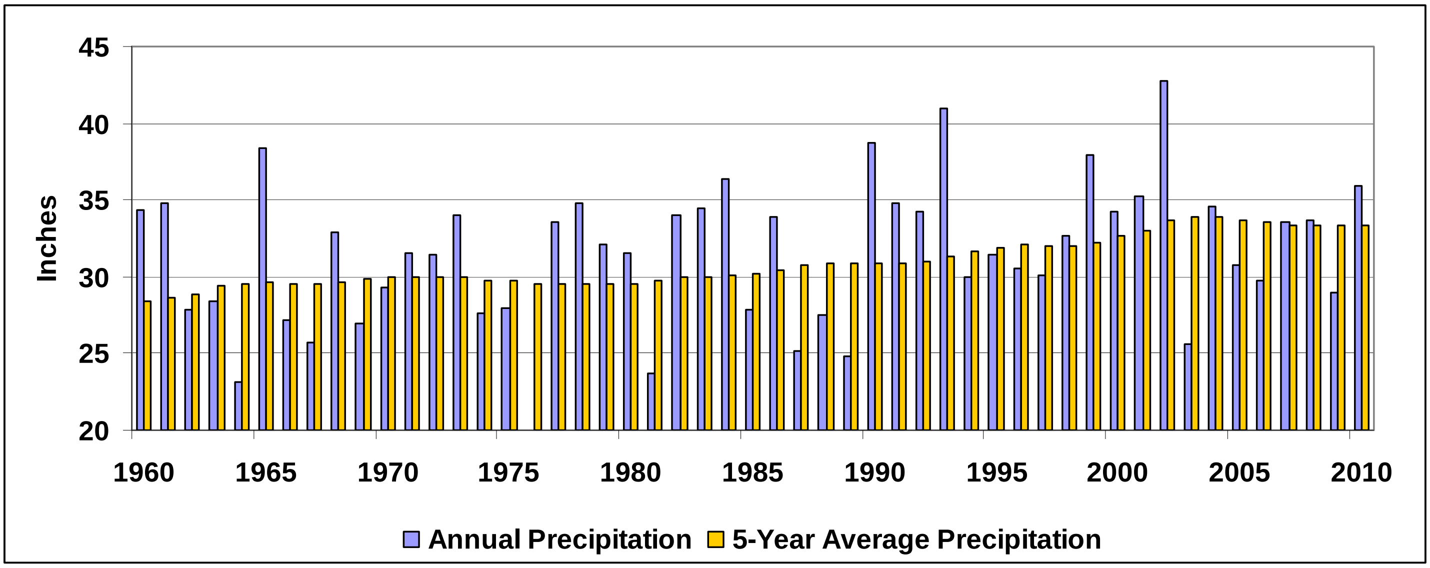
Water Levels in Lakes along the Terminal Moraine and Precipitation Data from Hancock

Attachment C
Levels in Lakes Along the Terminal Moraine



Sources: 2010 Report on Lake Levels Observed in Waushara County, Waushara County Land Conservation & Zoning Dept and personal communication with Rick Ertl, Waushara County, June 2012.

Attachment C
(continued)



Annual precipitation data from the University Hancock Experimental Farm

Attachment D

Elevation of Base of Sand and Gravel Unit

Attachment D
Elevation of Base of Sand and Gravel Unit (Top of Rock)

The base of the sand and gravel unit (equivalent to the top of the bedrock surface) was estimated based on the top of rock as reported for individual wells in the DNR 2012 Well Information database and the WiscLith database. Additional top of rock data were obtained through the review of DNR well construction reports on high-capacity wells (downloaded from the DNR database website). These data were kriged to develop a structure contour map of the top of the bedrock surface. The contoured surface was adjusted in some areas of the model domain based on the depth of wells completed in the sand and gravel aquifer where the bottom elevation of the well could provide a maximum elevation of the bedrock surface. In addition, the elevation of the top of rock was adjusted based on land surface elevation in areas where bedrock is exposed at ground surface (from Clayton, L. 1987). The top of rock data used in kriging are summarized in the table below and shown in Figure 6.

Table D-1

Summary of Top of Rock Elevation Data

Well ID	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Depth to Rock (feet)	Elevation of Top of Rock (feet MSL)	Ground Surface Elevation (feet MSL, estimated from DEM)	Data Source
200	2014617.683	704850.899	146	815	961	DNR- Hi Cap well summary
204	2017412.117	715744.251	119	841	960	DNR- Hi Cap well summary
278	2068855.351	731608.227	57	1008	1065	DNR- Hi Cap well summary
358	2070201.251	734524.680	40	1022	1062	DNR- Hi Cap well summary
1487	2018471.277	711196.068	112	853	965	DNR- Hi Cap well summary
2077	2103486.817	691304.264	150	715	865	DNR 2012 Well Data
36376	2111862.766	727282.404	35	874	909	DNR 2012 Well Data
36435	2113873.526	724348.912	88	801	889	DNR 2012 Well Data
36688	2109105.461	724293.545	112	797	909	DNR 2012 Well Data
36704	2074964.693	741216.604	45	1016	1061	DNR 2012 Well Data
68204	2067483.814	708804.485	157	881	1038	DNR 2012 Well Data
68717	2065332.958	699809.209	155	893	1048	DNR 2012 Well Data
69416	2100589.692	687234.316	112	751	863	DNR 2012 Well Data
69486	2094676.850	706064.054	142	797	939	DNR 2012 Well Data
69588	2106741.379	704016.293	76	810	886	DNR 2012 Well Data
69589	2110657.717	704059.514	86	797	883	DNR 2012 Well Data
69914	2114185.197	750719.882	153	860	1013	DNR 2012 Well Data
70192	2115074.693	715336.340	55	835	890	DNR 2012 Well Data
70193	2114604.242	714742.043	60	824	884	DNR 2012 Well Data
70194	2109646.673	714484.816	100	784	884	DNR 2012 Well Data
70200	2114503.457	713398.655	95	790	885	DNR 2012 Well Data
70817	2128399.754	727749.066	55	840	895	DNR 2012 Well Data
71378	2033429.137	763261.235	112	898	1010	DNR 2012 Well Data
71423	2053389.224	684680.586	171	870	1041	DNR 2012 Well Data
71424	2053385.940	685531.129	136	894	1030	DNR 2012 Well Data
71526	2098704.353	747207.848	134	916	1050	DNR 2012 Well Data
22	2047544.799	659390.833	125	912	1037	DNR- Hi Cap well summary
33	2044904.441	659381.493	45	983	1028	DNR- Hi Cap well summary
76	2025981.940	648152.415	98	882	980	DNR- Hi Cap well summary
137	2047561.192	660710.936	140	902	1042	DNR- Hi Cap well summary
166	2067230.135	701858.184	156	891	1047	DNR- Hi Cap well summary
172	2065187.656	710429.765	133	887	1020	DNR- Hi Cap well summary
185	2022729.933	670010.527	152	776	928	DNR- Hi Cap well summary
1708	2072329.999	721888.435	145	944	1089	DNR- Hi Cap well summary
352	2014557.250	722917.930	110	839	949	DNR- Hi Cap well summary
356	2062041.134	691257.752	200	839	1039	DNR- Hi Cap well summary
652	2065925.409	700527.087	60	980	1040	DNR- Hi Cap well summary
830	2069739.856	716429.168	21	1052	1073	DNR- Hi Cap well summary
985	2023666.056	736201.419	172	798	970	DNR- Hi Cap well summary
1031	2043726.666	655429.296	8	1013	1021	DNR- Hi Cap well summary
1301	2028024.002	662056.533	230	746	976	DNR- Hi Cap well summary
1866	2058955.064	744391.248	78	952	1030	DNR- Hi Cap well summary
1887	2064506.063	712411.196	101	951	1052	DNR- Hi Cap well summary
2004	2022425.234	729604.769	170	790	960	DNR 2012 Well Data
2008	2043753.612	659379.104	176	848	1024	DNR 2012 Well Data
2247	2033245.664	654236.458	135	868	1003	DNR 2012 Well Data
2253	2037238.495	659547.281	13	980	993	DNR- Hi Cap well summary
18940	2092255.476	719065.282	100	908	1008	DNR- Hi Cap well summary
18947	2081797.995	700606.644	143	862	1005	DNR 2012 Well Data
36549	2084137.735	751024.725	189	913	1102	DNR 2012 Well Data
36661	2110784.577	768260.247	160	990	1150	DNR 2012 Well Data

Table D-1

Summary of Top of Rock Elevation Data

Well ID	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Depth to Rock (feet)	Elevation of Top of Rock (feet MSL)	Ground Surface Elevation (feet MSL, estimated from DEM)	Data Source
40003	2050088.623	650170.316	225	813	1038	DNR 2012 Well Data
54001	2101712.027	686027.662	160	705	865	DNR 2012 Well Data
54002	2101712.027	686027.662	65	800	865	DNR 2012 Well Data
75003	2015864.941	721564.691	70	897	967	DNR 2012 Well Data
75061	2017178.793	713583.759	146	818	964	DNR 2012 Well Data
75062	2017178.793	713583.759	165	799	964	DNR 2012 Well Data
75063	2014540.128	713574.628	135	818	953	DNR 2012 Well Data
82207	2080607.673	684642.423	202	770	972	DNR 2012 Well Data
82212	2096237.339	708530.634	140	781	921	DNR 2012 Well Data
82213	2084419.471	701937.155	195	801	996	DNR 2012 Well Data
88499	2098738.424	740564.614	100	937	1037	DNR 2012 Well Data
90534	2102989.745	691446.562	95	774	869	DNR- Hi Cap well summary
2332	2097429.771	744526.649	158	867	1025	DNR- Hi Cap well summary
3334	2023968.365	691110.704	142	832	974	DNR- Hi Cap well summary
3514	2067195.780	707158.137	150	901	1051	DNR- Hi Cap well summary
3710	2080412.727	705886.254	100	875	975	DNR- Hi Cap well summary
3711	2080429.583	704563.305	80	891	971	DNR- Hi Cap well summary
3717	2081752.101	704563.182	177	833	1010	DNR- Hi Cap well summary
90847	2102989.745	691446.562	92	777	869	DNR 2012 Well Data
71389	2047459.187	646189.007	296	732	1028	DNR 2012 Well Data
1000175	2065187.739	710429.783	140	880	1020	WiscLith
1000176	2065321.477	702541.316	157	889	1046	WiscLith
1000362	2068532.263	704526.700	115	956	1071	WiscLith
1000401	2067240.217	700534.566	145	904	1049	WiscLith
1000418	2064505.983	712411.149	80	972	1052	WiscLith
13000883	2078236.379	710298.023	4	1062	1066	WiscLith
13000927	2075394.923	707853.671	4	1046	1050	WiscLith
39000051	2080562.042	684590.052	65	907	972	WiscLith
39000086	2081798.004	700606.624	115	890	1005	WiscLith
39000091	2084419.381	701937.151	195	800	995	WiscLith
1000003	2018478.868	714919.287	150	818	968	WiscLith
1000170	2014680.621	701667.851	145	809	954	WiscLith
1000199	2037227.588	652921.657	135	872	1007	WiscLith
1000202	2014519.276	714907.462	125	828	953	WiscLith
1000241	2046441.779	660748.927	135	899	1034	WiscLith
1000244	2046980.892	653460.563	100	929	1029	WiscLith
1000256	2066237.830	741106.063	112	926	1038	WiscLith
1000294	2057716.741	737774.538	115	910	1025	WiscLith
1000320	2072246.957	737872.991	87	976	1063	WiscLith
1000367	2024611.498	693113.466	180	800	980	WiscLith
1000379	2069613.468	733842.545	45	1020	1065	WiscLith
1000394	2029341.494	664728.625	220	750	970	WiscLith
1000412	2066891.394	741762.217	98	947	1045	WiscLith
1000437	2027665.762	720246.151	108	859	967	WiscLith
1000486	2011880.369	729506.334	75	875	950	WiscLith
39000040	2103049.855	684311.174	125	805	930	WiscLith
39000053	2100109.136	722771.645	85	835	920	WiscLith
39000076	2092918.880	718398.573	115	884	999	WiscLith
39000089	2104163.769	709931.109	190	761	951	WiscLith
70000011	2094881.518	741778.438	100	928	1028	WiscLith
70000891	2074959.855	742541.404	45	1019	1064	WiscLith

Table D-1

Summary of Top of Rock Elevation Data

Well ID	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Depth to Rock (feet)	Elevation of Top of Rock (feet MSL)	Ground Surface Elevation (feet MSL, estimated from DEM)	Data Source
70000953	2118958.644	730301.345	158	714	872	WiscLith
70001032	2097429.664	744526.664	150	875	1025	WiscLith
70001043	2113638.774	731578.647	160	748	908	WiscLith
70001044	2097429.664	744526.664	130	895	1025	WiscLith

[1] Datum: NAD83, Stateplane, Wisconsin South, FIPS 4803

Attachment E

Estimates of Hydraulic Conductivity

Attachment E
Estimates of Hydraulic Conductivity

Hydraulic conductivity (K) was estimated at high capacity well locations using measured specific capacity data (as reported in the Wisconsin DNR database) using the TGUESS model (Bradbury and Rothschild, 1985). The hydraulic conductivity estimates are listed in Table E-1[1]. In the sand and gravel unit, hydraulic conductivities were estimated between 6 and 805 feet per day, with an average of 169 feet per day. East of the moraine there are 16 estimates of hydraulic conductivity in the sand and gravel aquifer, while west of the moraine there are 176 estimates in the sand and gravel aquifer. East of the moraine the estimates range between 21 and 610 feet per day in the sand and gravel with an average of 171 feet per day and a median of 117 feet per day. West of the moraine, estimates range between 6 and 805 feet per day in the sand and gravel aquifer with an average of 169 feet per day and a median of 144 feet per day. In the sandstone aquifer, 5 estimates of hydraulic conductivity were made, ranging between 5 and 25 feet per day, with an average of 12 feet per day.

[1] Hydraulic conductivity values shown in Table E-1 of this attachment have been updated from those previously presented by SSP&A in the report titled "Evaluation of Groundwater Pumping, New Chester Township, Adams County, Wisconsin" dated April 12, 2012. In the previous report the hydraulic conductivity values were associated with wrong well numbers due to a transcription error.

Table E-1

Estimates of Hydraulic Conductivity

Well ID	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Hydraulic Conductivity (feet/day)	Well Depth (feet, bgs)	Aquifer
4	2067437.4	746026.2	193	65	Sand/Gravel
5	2068153.5	770651.2	207	72	Sand/Gravel
6	2066802.4	770650.3	218	71	Sand/Gravel
9	2066810.0	769328.9	250	80	Sand/Gravel
16	2066866.8	752332.5	255	60	Sand/Gravel
17	2072159.7	754820.9	220	66	Sand/Gravel
18	2051462.9	692579.4	74	78	Sand/Gravel
23	2044391.1	656088.9	62	130	Sand/Gravel
24	2046846.5	656096.7	90	155	Sand/Gravel
25	2047486.5	654132.0	68	195	Sand/Gravel
28	2073077.3	736231.5	183	130	Sand/Gravel
35	2061723.0	732538.9	216	86	Sand/Gravel
44	2068344.4	725981.6	182	85	Sand/Gravel
50	2050230.0	671389.8	132	140	Sand/Gravel
53	2046799.5	648179.3	143	195	Sand/Gravel
55	2026042.9	664067.5	62	180	Sand/Gravel
65	2059832.4	718316.0	219	124	Sand/Gravel
80	2057948.7	705818.6	148	80	Sand/Gravel
87	2036518.9	645620.2	29	211	Sand/Gravel
89	2047587.1	684608.6	234	120	Sand/Gravel
93	2039526.4	724457.4	237	80	Sand/Gravel
94	2045994.5	713744.6	215	90	Sand/Gravel
96	2059927.5	714434.1	193	126	Sand/Gravel
97	2061811.0	716390.1	214	109	Sand/Gravel
98	2065956.5	696569.0	66	192	Sand/Gravel
100	2041827.5	679892.9	97	100	Sand/Gravel
101	2047465.4	651500.4	152	180	Sand/Gravel
103	2049395.9	699861.2	182	115	Sand/Gravel
108	2023411.2	664075.7	104	155	Sand/Gravel
109	2062525.8	713072.8	195	80	Sand/Gravel
113	2070858.0	748430.4	147	105	Sand/Gravel
116	2044069.1	718388.6	96	94	Sand/Gravel
117	2044660.9	715081.9	107	120	Sand/Gravel
118	2069057.8	735176.2	236	106	Sand/Gravel
120	2054758.5	694580.9	123	113	Sand/Gravel
121	2025306.7	676575.1	142	110	Sand/Gravel
122	2072850.4	745034.2	172	106	Sand/Gravel
124	2070209.0	741175.8	111	100	Sand/Gravel
126	2042572.7	654130.7	43	147	Sand/Gravel
127	2054729.5	697234.0	68	126	Sand/Gravel
129	2051578.6	677997.7	77	175	Sand/Gravel
136	2052902.0	676665.8	94	140	Sand/Gravel
146	2072931.1	731965.1	308	123	Sand/Gravel
154	2059826.7	719670.9	249	120	Sand/Gravel
156	2067711.1	721192.9	255	110	Sand/Gravel
157	2046269.1	683272.7	188	140	Sand/Gravel
158	2059044.8	736464.4	211	88	Sand/Gravel
171	2044360.4	648181.4	29	133	Sand/Gravel

Table E-1

Estimates of Hydraulic Conductivity

Well ID	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Hydraulic Conductivity (feet/day)	Well Depth (feet, bgs)	Aquifer
174	2064304.8	736508.2	189	111	Sand/Gravel
188	2066328.7	726655.5	122	104	Sand/Gravel
190	2024026.9	654102.7	78	250	Sand/Gravel
233	2070193.2	747748.0	207	105	Sand/Gravel
236	2059775.2	753971.6	255	74	Sand/Gravel
238	2057945.2	646168.2	117	164	Sand/Gravel
240	2070718.0	682705.9	95	150	Sand/Gravel
241	2057336.3	699872.3	97	142	Sand/Gravel
243	2036483.0	685196.1	307	105	Sand/Gravel
247	2067529.8	750354.0	296	89	Sand/Gravel
249	2013835.0	707565.0	149	120	Sand/Gravel
254	2036519.8	653583.6	91	138	Sand/Gravel
263	2035851.5	648941.1	46	218	Sand/Gravel
272	2048805.1	692577.7	406	85	Sand/Gravel
273	2050149.6	691245.5	568	62	Sand/Gravel
279	2038915.2	715667.8	133	122	Sand/Gravel
280	2027944.2	648825.2	119	230	Sand/Gravel
289	2044949.0	683255.8	100	123	Sand/Gravel
291	2072911.0	739864.0	429	80	Sand/Gravel
293	2044947.1	673996.6	184	136	Sand/Gravel
294	2041890.1	645550.8	106	215	Sand/Gravel
299	2062563.0	710824.2	247	130	Sand/Gravel
301	2061367.2	710223.7	499	113	Sand/Gravel
307	2025981.9	648152.4	35	231	Sand/Gravel
308	2070799.2	765380.3	515	76	Sand/Gravel
311	2028528.5	685210.6	119	123	Sand/Gravel
312	2041849.5	685209.9	119	123	Sand/Gravel
313	2052206.1	687912.9	321	123	Sand/Gravel
318	2068253.7	739113.7	137	77	Sand/Gravel
320	2052696.7	700530.1	145	123	Sand/Gravel
321	2052720.3	652817.1	257	158	Sand/Gravel
323	2073009.1	726631.6	302	136	Sand/Gravel
327	2072961.5	729256.1	255	132	Sand/Gravel
329	2050236.9	684607.9	290	93	Sand/Gravel
333	2054178.9	688586.9	171	105	Sand/Gravel
338	2029132.5	707007.2	81	126	Sand/Gravel
339	2059958.8	702508.7	27	171	Sand/Gravel
343	2046925.7	672043.1	429	135	Sand/Gravel
349	2046792.6	694576.8	214	115	Sand/Gravel
351	2054777.5	691913.5	406	100	Sand/Gravel
353	2044954.0	680598.1	42	170	Sand/Gravel
357	2056666.3	700531.7	97	142	Sand/Gravel
359	2039156.1	685195.7	75	120	Sand/Gravel
362	2063111.2	717722.5	88	85	Sand/Gravel
575	2059328.6	699210.5	180	137	Sand/Gravel
576	2063308.4	697881.1	95	173	Sand/Gravel
689	2073556.6	741869.1	48	148	Sand/Gravel
806	2025639.9	709135.7	59	140	Sand/Gravel

Table E-1

Estimates of Hydraulic Conductivity

Well ID	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Hydraulic Conductivity (feet/day)	Well Depth (feet, bgs)	Aquifer
1025	2078211.1	770408.8	675	80	Sand/Gravel
1169	2071484.6	750489.8	285	90	Sand/Gravel
1202	2078973.6	744509.4	103	167	Sand/Gravel
1247	2073477.2	757471.0	148	78	Sand/Gravel
1389	2024026.9	654102.7	77	197	Sand/Gravel
1397	2085313.5	772101.4	161	102	Sand/Gravel
1417	2064599.8	701839.5	117	141	Sand/Gravel
1446	2069648.2	728631.8	219	113	Sand/Gravel
1447	2070986.4	724685.3	123	145	Sand/Gravel
1448	2074316.4	727390.7	186	146	Sand/Gravel
1479	2017090.6	740079.6	183	116	Sand/Gravel
1578	2026561.6	685865.8	122	132	Sand/Gravel
1603	2010555.5	738757.2	142	92	Sand/Gravel
1649	2069534.2	743088.7	127	98	Sand/Gravel
1651	2066352.5	725252.1	146	103	Sand/Gravel
1698	2057254.0	715729.4	169	111	Sand/Gravel
1744	2014519.2	714907.5	134	126	Sand/Gravel
1913	2055046.5	741743.7	120	92	Sand/Gravel
1928	2079678.8	742546.3	146	131	Sand/Gravel
1994	2047596.3	678002.9	163	131	Sand/Gravel
1995	2051516.4	662084.2	63	235	Sand/Gravel
2071	2036986.4	711043.0	71	128	Sand/Gravel
2121	2025031.6	718918.4	146	111	Sand/Gravel
2133	2027772.5	727011.0	128	80	Sand/Gravel
2149	2026295.7	737536.2	55	147	Sand/Gravel
2155	2039844.5	676580.8	110	119	Sand/Gravel
2219	2033605.6	718305.4	126	98	Sand/Gravel
2251	2057967.6	703174.1	187	126	Sand/Gravel
2554	2090597.0	772087.4	56	54	Sand/Gravel
2566	2062539.9	713145.0	249	121	Sand/Gravel
2674	2059016.4	739098.9	110	91	Sand/Gravel
2701	2030589.0	652851.1	58	192	Sand/Gravel
2985	2091918.0	770761.1	129	63	Sand/Gravel
3026	2059437.3	709869.4	51	100	Sand/Gravel
3132	2027665.7	720246.2	164	110	Sand/Gravel
3422	2089278.2	773416.6	204	81	Sand/Gravel
3471	2060295.6	741756.6	247	97	Sand/Gravel
4179	2070800.2	769345.9	225	84	Sand/Gravel
4469	2089320.9	762819.9	88	135	Sand/Gravel
4597	2027907.1	679210.6	109	117	Sand/Gravel
36313	2077023.9	743170.9	72	120	Sand/Gravel
36314	2079030.8	739210.9	122	120	Sand/Gravel
36408	2081336.2	745404.9	163	155	Sand/Gravel
36468	2078899.9	748478.9	57	105	Sand/Gravel
36491	2076339.2	750495.0	125	86	Sand/Gravel
36492	2076339.1	750525.3	296	88	Sand/Gravel
36577	2101374.5	740619.6	168	120	Sand/Gravel
36629	2079382.3	760859.7	227	138	Sand/Gravel

Table E-1

Estimates of Hydraulic Conductivity

Well ID	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Hydraulic Conductivity (feet/day)	Well Depth (feet, bgs)	Aquifer
36654	2079449.4	762142.7	481	103	Sand/Gravel
36690	2090627.1	765450.1	183	92	Sand/Gravel
36704	2074964.7	741216.6	152	46	Sand/Gravel
36715	2082693.0	765510.2	231	72	Sand/Gravel
36720	2074712.0	771363.0	446	73	Sand/Gravel
36721	2084184.2	748384.3	132	165	Sand/Gravel
36731	2091918.0	770761.1	72	80	Sand/Gravel
36735	2108572.5	755996.0	352	122	Sand/Gravel
36741	2118907.1	734241.8	236	174	Sand/Gravel
36746	2075719.8	729305.8	83	150	Sand/Gravel
40001	2050088.6	650170.3	163	162	Sand/Gravel
40002	2050099.2	652820.7	417	160	Sand/Gravel
40003	2050088.6	650170.3	21	360	Sand/Gravel
67300	2069527.0	748394.8	14	100	Sand/Gravel
67322	2025306.7	676575.1	255	110	Sand/Gravel
67409	2090599.8	773414.4	805	63	Sand/Gravel
67430	2084235.1	745742.2	107	168	Sand/Gravel
67457	2091918.0	770761.1	236	82	Sand/Gravel
67460	2020947.8	716305.3	106	107	Sand/Gravel
67718	2081849.3	703302.7	610	177	Sand/Gravel
67907	2073528.0	747172.6	26	104	Sand/Gravel
68062	2057767.4	735155.3	288	87	Sand/Gravel
68066	2064677.8	719041.5	195	87	Sand/Gravel
68305	2100507.4	678250.1	58	255	Sand/Gravel
68512	2041840.1	677237.4	141	118	Sand/Gravel
68728	2069992.4	720991.4	173	108	Sand/Gravel
69534	2076806.5	758177.1	59	122	Sand/Gravel
69776	2027369.2	666539.7	94	166	Sand/Gravel
69778	2027993.9	667372.1	268	78	Sand/Gravel
69981	2061543.2	714289.0	117	79	Sand/Gravel
70270	2117044.0	735537.4	298	60	Sand/Gravel
70635	2028756.8	715438.3	11	74	Sand/Gravel
70744	2013522.8	707783.1	62	151	Sand/Gravel
70759	2010781.5	704296.4	74	141	Sand/Gravel
70779	2040509.0	640242.6	87	220	Sand/Gravel
70926	2105532.8	730206.9	56	180	Sand/Gravel
70944	2017207.2	708325.5	172	145	Sand/Gravel
71093	2045180.4	645477.0	110	173	Sand/Gravel
71128	2043411.7	645161.1	13	139	Sand/Gravel
71419	2046827.4	642858.3	152	198	Sand/Gravel
71508	2040210.0	727678.6	79	110	Sand/Gravel
71525	2098107.6	748298.0	21	140	Sand/Gravel
71529	2030741.5	674720.2	29	74	Sand/Gravel
71530	2030993.1	675917.8	114	122	Sand/Gravel
71658	2024685.9	666707.0	72	162	Sand/Gravel
75004	2015877.4	722924.8	6	108	Sand/Gravel
75010	2057716.7	737774.5	310	101	Sand/Gravel
90290	2110923.9	742120.9	133	104	Sand/Gravel

Table E-1

Estimates of Hydraulic Conductivity

Well ID	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Hydraulic Conductivity (feet/day)	Well Depth (feet, bgs)	Aquifer
22	2047544.8	659390.8	5	400	Sandstone
33	2044904.4	659381.5	6	400	Sandstone
3481	2104474.9	663606.1	8	320	Sandstone
71423	2053389.2	684680.6	25	345	Sandstone
71424	2053385.9	685531.1	15	195	Sandstone

[1] Datum: NAD83, Stateplane, Wisconsin South, FIPS 4803

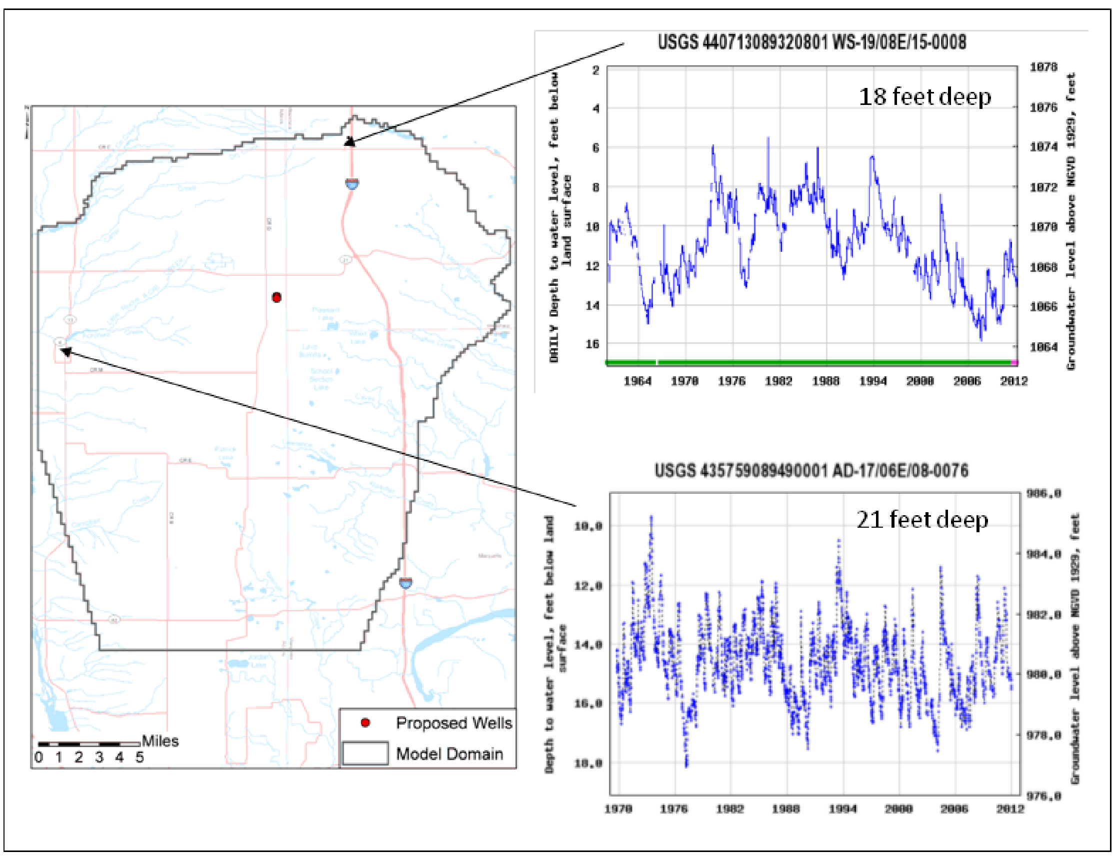
Attachment F

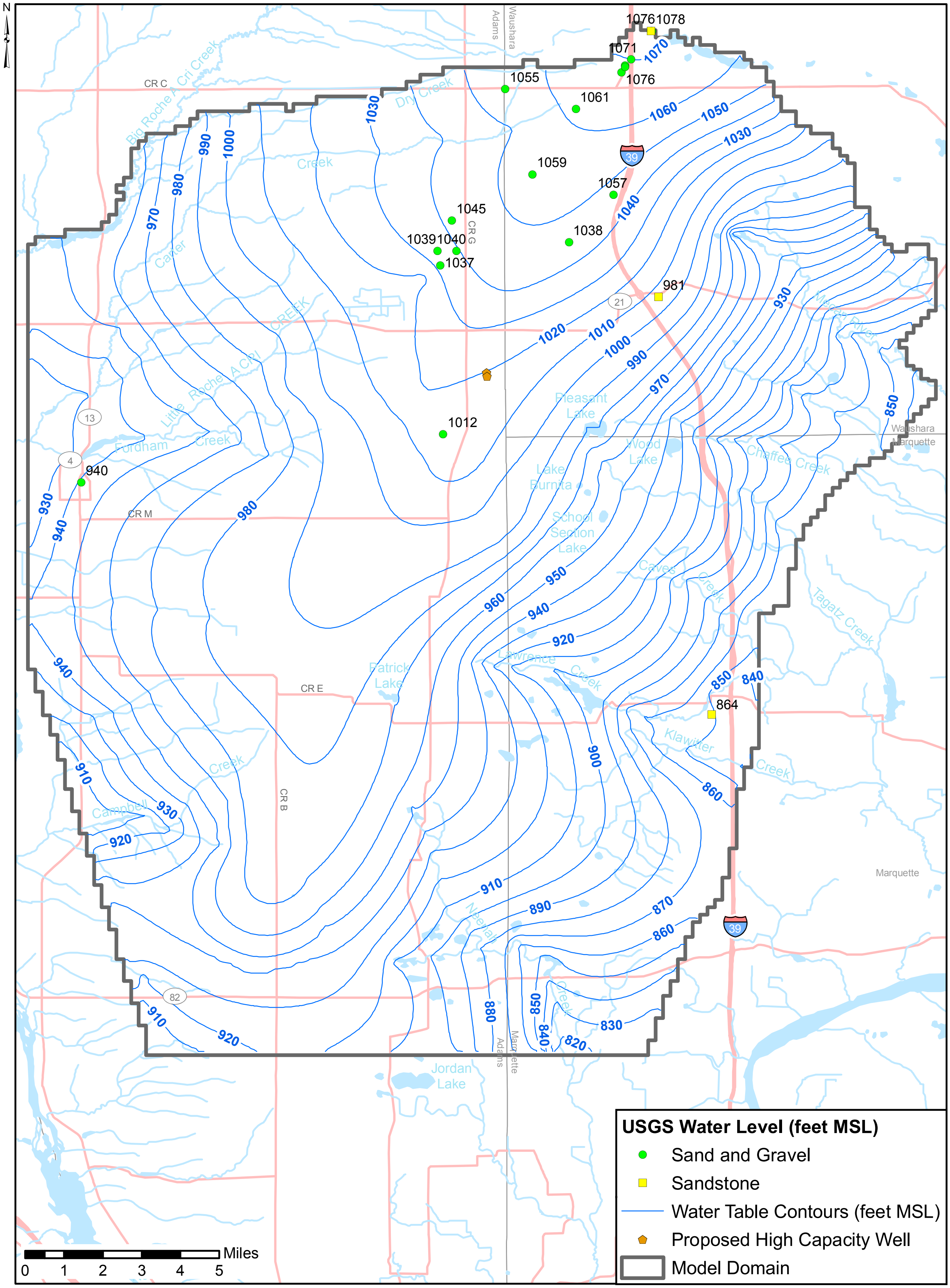
Water-Level Data

Attachment F
Water-Level Data

A total of 225 water-level targets were identified in the model domain, 210 in the sand and gravel unit and 15 in the sandstone. These water-level data were obtained from the USGS database (http://waterdata.usgs.gov/nwis/gw). Most of the wells have only one measurement, but if historical data were available, the average was used as the target value. Each of these targets is included in the PEST calibration dataset; however, several were assigned weights of 0 after a preliminary review of the data looking for unusually high or low values. In the sand and gravel unit 17 targets were ignored in this way, and in the sandstone, 2 were. The water-level targets are listed in Table F-1. Figures F-1 through F-6 show the locations of the targets with posted water levels measured during each of the last six decades. For wells with multiple measurements during a given time period, the average water level for that time period is posted.

The USGS has two long-term groundwater monitoring wells in the model domain. The locations of these wells and long-term hydrographs are shown below. Both wells are relatively shallow (18 feet deep and 21 feet deep) but both are reported to be completed in the sand and gravel aquifer. The water-level in the well near Friendship in the western portion of the model domain does not appear to reflect water-levels in deeper portions of the sand and gravel or sandstone aquifers. The other monitoring well located in the northern portion of the model domain has water levels that appear to reflect conditions in the sand and gravel aquifer. The well shows a significant decline in levels since the mid-1990's.





Note: Water table contours from steady-state groundwater model.

Figure F-1 Groundwater Levels: 1947-1959

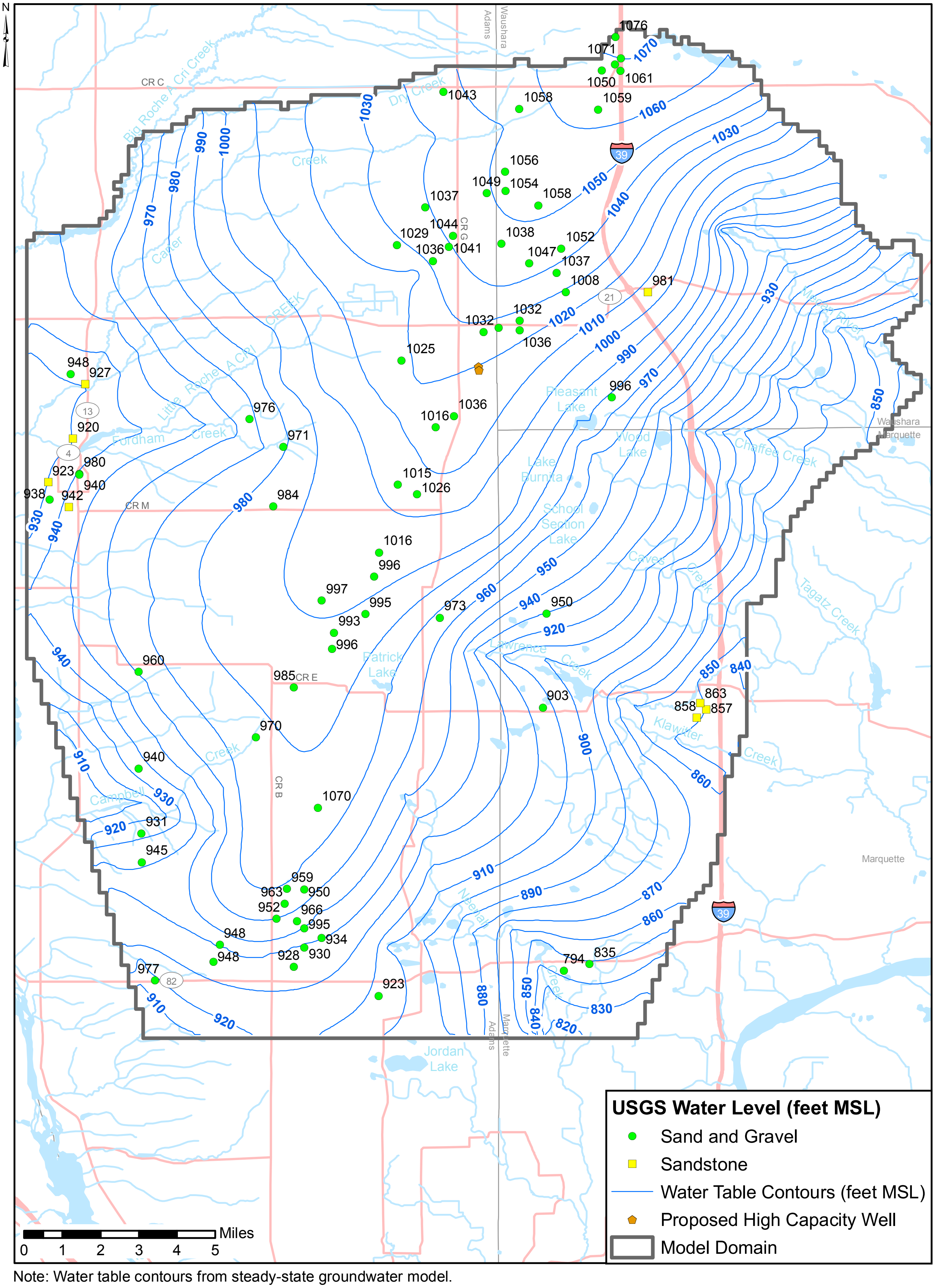
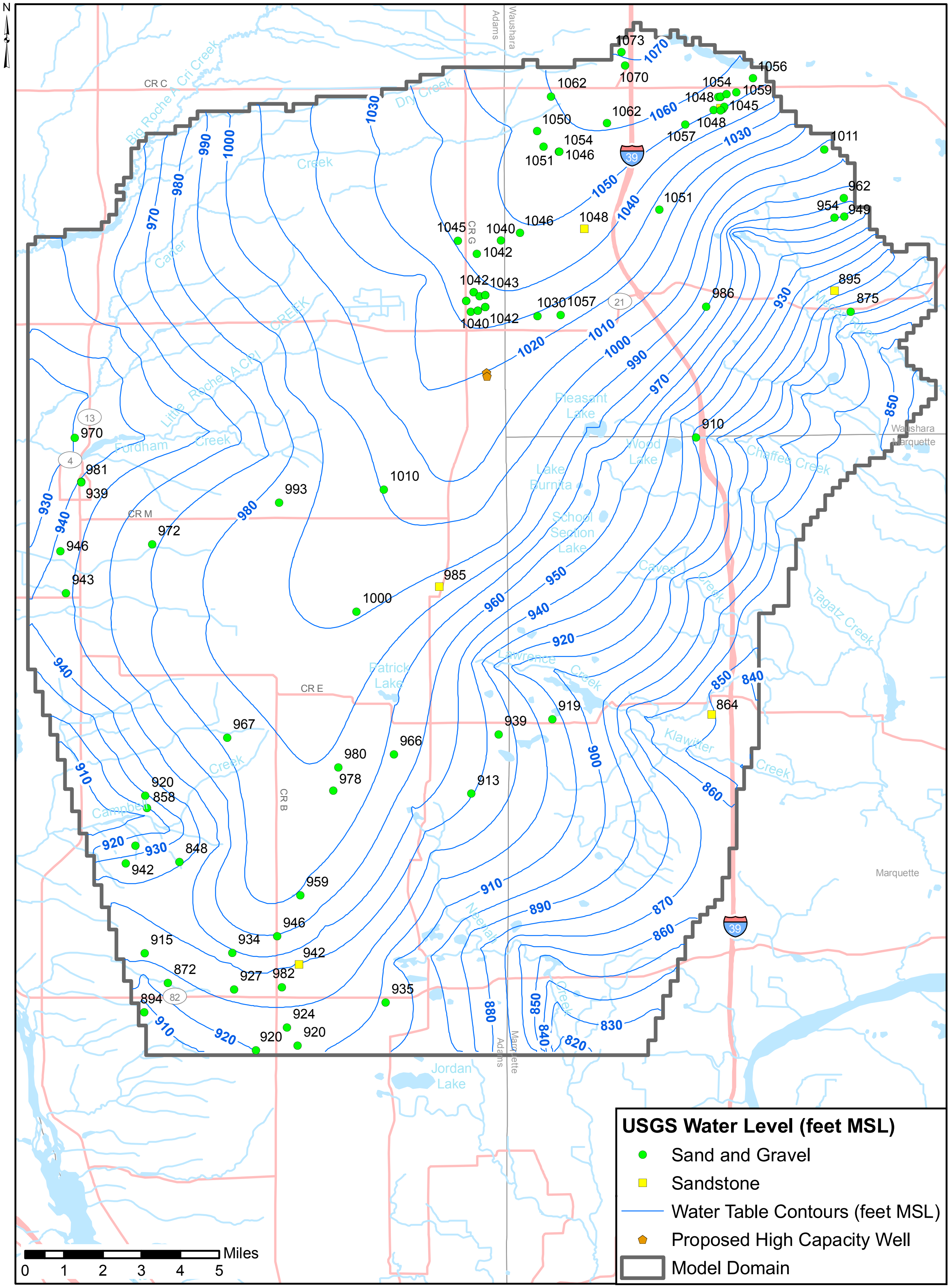
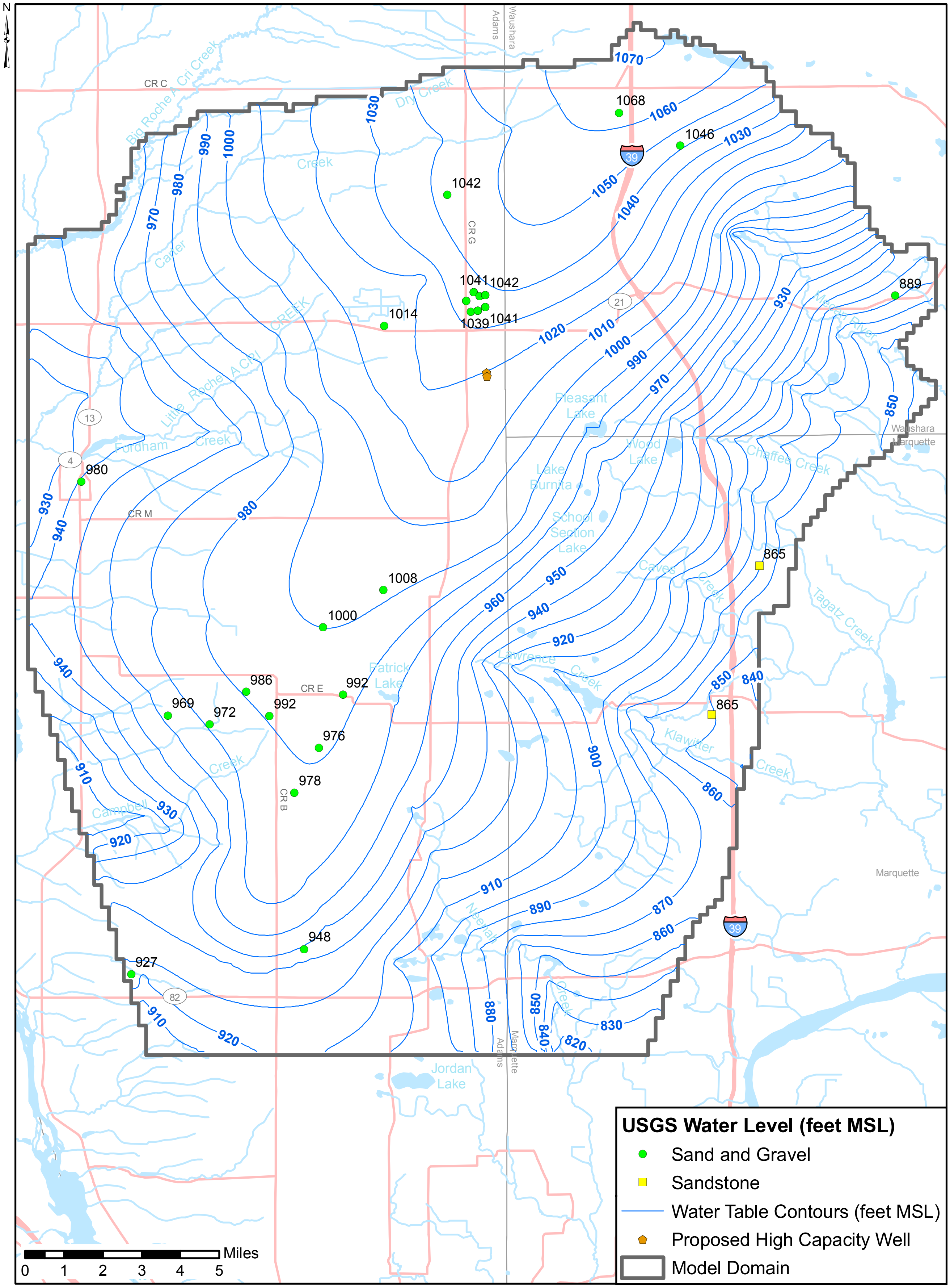


Figure F-2 Groundwater Levels: 1960-1969



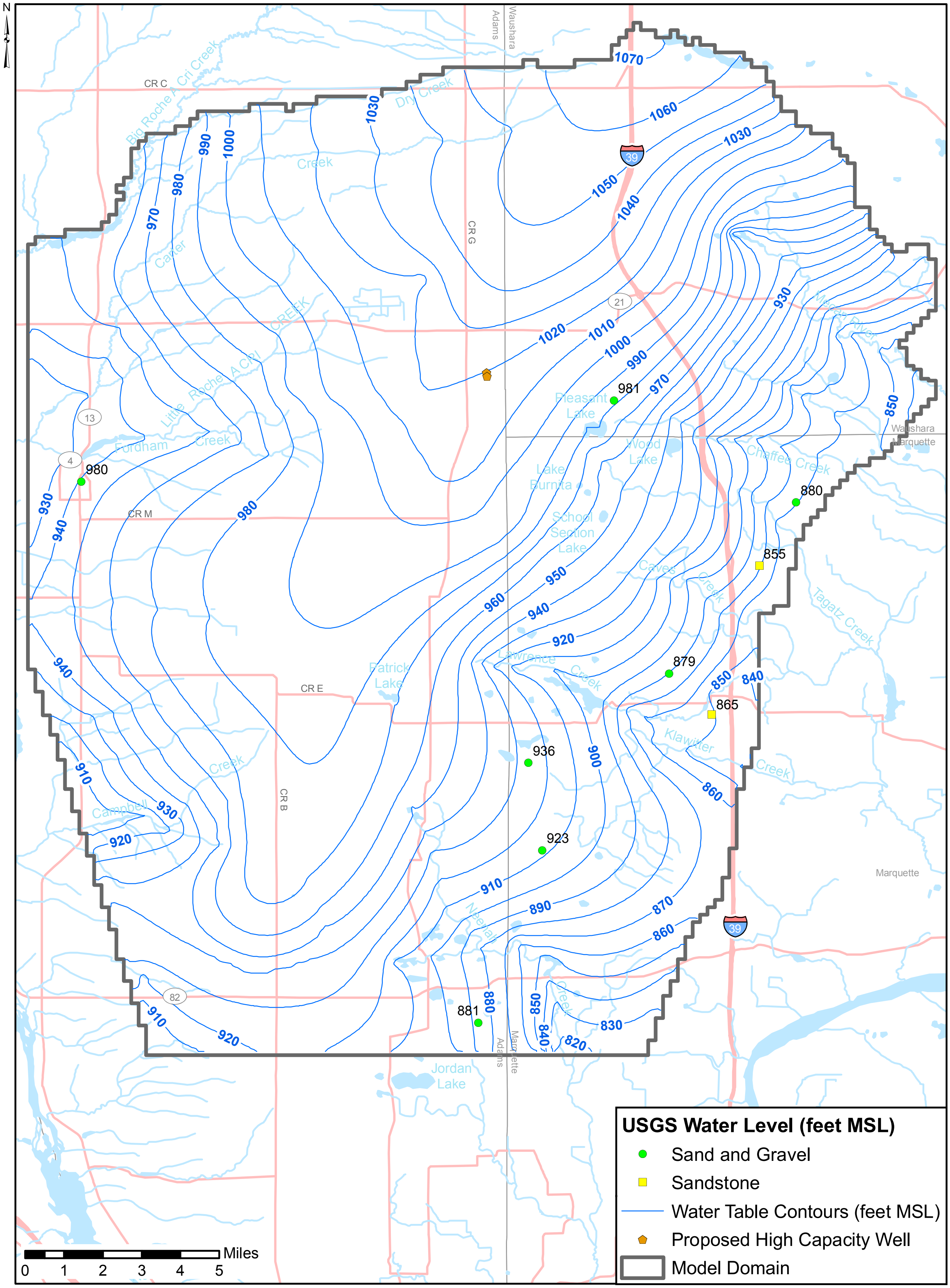
Note: Water table contours from steady-state groundwater model.

Figure F-3 Groundwater Levels: 1970-1979



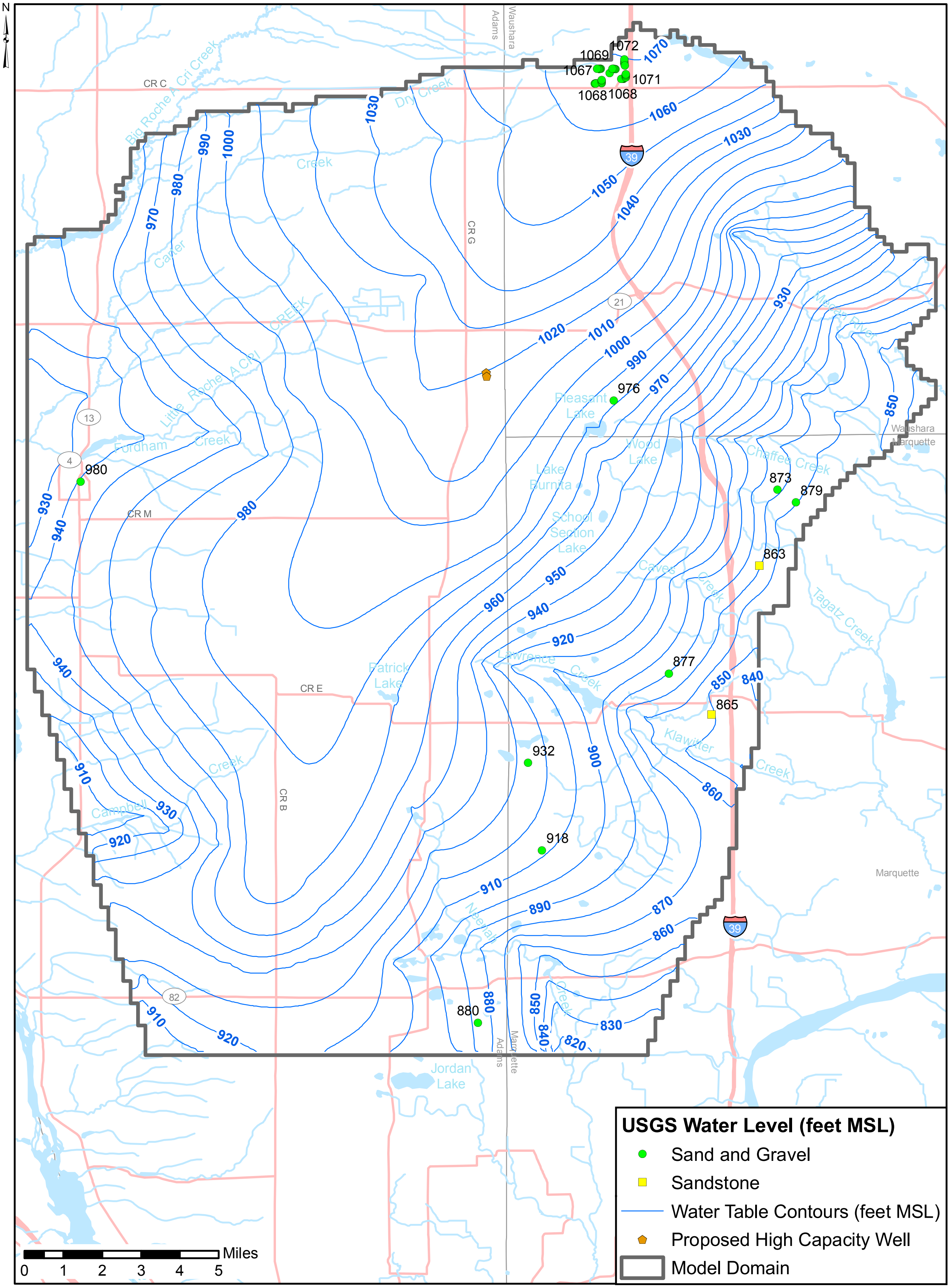
Note: Water table contours from steady-state groundwater model.

Figure F-4 Groundwater Levels: 1980-1989



Note: Water table contours from steady-state groundwater model.

Figure F-5 Groundwater Levels: 1990-1999



Note: Water table contours from steady-state groundwater model.

Figure F-6 Groundwater Levels: 2000-present

Table F-1

Water Level Data

Well ID	X-Coordinate (feet)[1]	Y-Coordinate (feet)[1]	Source	Unit	Target Value (feet)	Date of First Measurement	Date of Last Measurement	Count	Included as Target
434518089434001	2040391.042	639759.908	USGS	Sand and Gravel	920	6/7/1976			Yes
434524089422301	2046040.077	640386.593	USGS	Sand and Gravel	920	6/20/1977			Yes
434548089424301	2044563.886	642811.454	USGS	Sand and Gravel	924	11/4/1974			Yes
434551089365001	2070563.836	643461.775	USGS	Sand and Gravel	880	9/20/1994	8/25/2011	8	Yes
434608089394101	2057911.174	644886.738	USGS	Sand and Gravel	923	7/15/1965			Yes
434609089470601	2025258.941	644879.330	USGS	Sand and Gravel	894	1/7/1978			Yes
434621089394001	2057979.207	646203.304	USGS	Sand and Gravel	935	6/12/1978			Yes
434639089442001	2037429.662	647951.708	USGS	Sand and Gravel	927	3/13/1979			Yes
434648089422001	2046230.218	648892.364	USGS	Sand and Gravel	928	6/7/1965			Yes
434650089330501	2086944.783	649276.630	USGS	Sand and Gravel	835	7/29/1968			Yes
434655089445101	2035150.418	649564.655	USGS	Sand and Gravel	948	5/15/1965			Yes
434700089473001	2023485.026	650038.563	USGS	Sand and Gravel	927	4/5/1984			Yes
434714089420001	2047687.984	651530.105	USGS	Sand and Gravel	930	3/3/1966			Yes
434718089443901	2036023.601	651896.111	USGS	Sand and Gravel	948	5/18/1969			Yes
434727089412801	2050030.413	652854.948	USGS	Sand and Gravel	934	11/1/1963			Yes
434728089442301	2037194.074	652912.275	USGS	Sand and Gravel	934	4/12/1979			Yes
434728089470501	2025311.631	652878.265	USGS	Sand and Gravel	915	8/12/1977			Yes
434733089421001	2046947.601	653451.211	USGS	Sand and Gravel	948	5/5/1980			Yes
434750089421401	2046648.084	655171.417	USGS	Sand and Gravel	966	4/12/1962			Yes
434750089430001	2043274.403	655159.664	USGS	Sand and Gravel	946	10/28/1971			Yes
434753089425201	2043860.106	655465.410	USGS	Sand and Gravel	952	4/1/1962	3/6/1965	10	Yes
434814089423701	2044952.791	657595.500	USGS	Sand and Gravel	963	6/1/1964			Yes
434833089420001	2047659.193	659528.867	USGS	Sand and Gravel	950	5/1/1962			Yes
434834089423201	2045312.388	659621.779	USGS	Sand and Gravel	959	10/15/1964			Yes
434845089421701	2046408.335	660739.444	USGS	Sand and Gravel	959	6/18/1975			Yes
434911089470501	2025284.697	663307.085	USGS	Sand and Gravel	945	12/23/1964			Yes
434928089474001	2022714.478	665021.847	USGS	Sand and Gravel	942	5/30/1972			Yes
434944089345001	2079230.027	666812.419	USGS	Sand and Gravel	919	9/20/1994	8/25/2011	8	Yes
434950089470501	2025274.508	667255.899	USGS	Sand and Gravel	931	7/30/1966			Yes
434952089472201	2024027.878	667455.207	USGS	Sand and Gravel	918	5/25/1972			Yes
435059089470301	2025403.021	674242.652	USGS	Sand and Gravel	920	4/16/1979			Yes
435102089422701	2045626.450	674608.273	USGS	Sand and Gravel	978	9/3/1982			Yes
435105089411501	2050901.193	674931.264	USGS	Sand and Gravel	978	8/21/1976			Yes
435118089471001	2024885.138	676165.105	USGS	Sand and Gravel	940	6/25/1968			Yes
435136089410601	2051548.810	678072.553	USGS	Sand and Gravel	980	4/2/1974			Yes
435140089351301	2077338.826	678660.070	USGS	Sand and Gravel	932	9/20/1994	8/25/2011	9	Yes
435153089392301	2059087.971	679823.734	USGS	Sand and Gravel	966	7/1/1970			Yes
435200089433001	2040990.659	680465.154	USGS	Sand and Gravel	970	5/7/1966			Yes
435202089414201	2048901.632	680695.292	USGS	Sand and Gravel	976	4/3/1985			Yes
435216089443101	2036516.994	682070.869	USGS	Sand and Gravel	967	7/7/1978			Yes
435219089360901	2073287.603	682519.656	USGS	Sand and Gravel	939	5/17/1978			Yes
435234089450401	2034094.253	683886.046	USGS	Sand and Gravel	972	11/11/1981			Yes
435239089342901	2080602.238	684580.924	USGS	Sand and Gravel	919	10/24/1979			Yes
435239089343001	2080528.990	684580.550	USGS	Sand and Gravel	903	7/9/1969			Yes
435245089431301	2042220.752	685025.700	USGS	Sand and Gravel	992	5/18/1984			Yes
435246089462101	2028451.080	685084.888	USGS	Sand and Gravel	969	5/16/1984			Yes
435308089421801	2046240.788	687368.453	USGS	Sand and Gravel	985	8/21/1965			Yes
435313089405701	2052170.777	687896.584	USGS	Sand and Gravel	992	5/2/1984			Yes
435317089435601	2039060.959	688255.400	USGS	Sand and Gravel	986	5/16/1980			Yes
435330089471001	2024850.823	689530.494	USGS	Sand and Gravel	959	7/12/1963	9/21/1964	3	Yes
435339089305001	2096383.008	690761.554	USGS	Sand and Gravel	877	9/20/1994	4/17/2012	22	Yes
435400089410601	2051493.701	692652.969	USGS	Sand and Gravel	996	6/7/1960			Yes
435422089410201	2051778.118	694881.666	USGS	Sand and Gravel	993	9/5/1963	10/15/1964	10	Yes
435442089374301	2066337.616	696967.016	USGS	Sand and Gravel	973	12/22/1965			Yes
435443089413301	2049500.811	696999.478	USGS	Sand and Gravel	1000	5/8/1984			Yes
435447089400301	2056087.347	697429.880	USGS	Sand and Gravel	995	9/5/1963	10/15/1964	2	Yes
435504089403101	2054031.031	699143.118	USGS	Sand and Gravel	1000	3/29/1978			Yes
435506089412501	2050077.765	699330.508	USGS	Sand and Gravel	997	5/24/1966			Yes
435530089492901	2014646.792	701657.063	USGS	Sand and Gravel	943	6/6/1978			Yes
435533089394101	2057678.825	702094.085	USGS	Sand and Gravel	1008	4/9/1985			Yes
435538089394601	2057310.856	702598.890	USGS	Sand and Gravel	996	11/1/1962	10/15/1964	2	Yes
435626089493901	2013903.185	707325.825	USGS	Sand and Gravel	946	6/20/1978			Yes
435635089464901	2026339.171	708266.559	USGS	Sand and Gravel	972	3/8/1979			Yes
435714089425601	2043372.916	712267.321	USGS	Sand and Gravel	984	5/27/1966			Yes
435724089495601	2012647.527	713196.066	USGS	Sand and Gravel	938	6/1/1960			Yes
435729089265401	2113642.517	713945.831	USGS	Sand and Gravel	879	9/21/1994	4/1/2010	5	Yes
435730089425401	2043513.667	713887.893	USGS	Sand and Gravel	993	10/2/1970			Yes
435743089390101	2060550.989	715269.369	USGS	Sand and Gravel	1015	10/10/1965			Yes

Table F-1

Water Level Data

Well ID	X-Coordinate (feet)[1]	Y-Coordinate (feet)[1]	Source	Unit	Target Value (feet)	Date of First Measurement	Date of Last Measurement	Count	Included as Target
435744089273001	2111137.049	715660.971	USGS	Sand and Gravel	873	8/17/2010	8/25/2011	4	Yes
435747089394001	2057696.866	715662.586	USGS	Sand and Gravel	1010	4/10/1979			Yes
435758089490001	2016736.200	716647.452	USGS	Sand and Gravel	940	7/21/1952	8/10/1970	917	Yes
435835089423601	2044807.390	720474.087	USGS	Sand and Gravel	971	9/12/1966			Yes
435855089300001	2100076.267	722762.091	USGS	Sand and Gravel	910	7/27/1973			Yes
435901089374901	2065782.111	723190.182	USGS	Sand and Gravel	1016	6/15/1959	10/16/1964	8	Yes
435913089434001	2040114.925	724305.986	USGS	Sand and Gravel	976	4/1/1966			Yes
435916089371501	2068261.083	724720.229	USGS	Sand and Gravel	1036	7/1/1964			Yes
435940089321701	2090034.144	727260.648	USGS	Sand and Gravel	996	5/2/1961			Yes
435946089323001	2088930.836	727750.122	USGS	Sand and Gravel	977	9/20/1994	8/25/2011	9	Yes
440015089491601	2015536.254	730517.081	USGS	Sand and Gravel	948	5/1/1963			Yes
440032089385301	2061063.930	732384.260	USGS	Sand and Gravel	1025	4/1/1963	10/16/1964	3	Yes
440110089361801	2072373.698	736283.035	USGS	Sand and Gravel	1032	6/15/1962	10/16/1964	10	Yes
440112089351001	2077341.505	736509.735	USGS	Sand and Gravel	1036	5/1/1964			Yes
440116089355001	2074416.756	736900.388	USGS	Sand and Gravel	1031	9/6/1963			Yes
440125089351001	2077334.999	737826.106	USGS	Sand and Gravel	1032	5/1/1961	9/6/1963	2	Yes
440126089393801	2057752.945	737838.513	USGS	Sand and Gravel	1014	6/16/1983			Yes
440138089345301	2078570.515	739148.676	USGS	Sand and Gravel	1030	6/29/1971			Yes
440142089251201	2121016.104	739808.730	USGS	Sand and Gravel	875	6/9/1978			Yes
440145089365701	2069507.655	739813.702	USGS	Sand and Gravel	1039	6/6/1979	9/5/1985	26	Yes
440146089364401	2070456.964	739919.365	USGS	Sand and Gravel	1040	6/6/1979	9/5/1985	24	Yes
440146089364402	2070456.964	739919.365	USGS	Sand and Gravel	1040	6/6/1979	8/25/1981	17	Yes
440150089294001	2101431.277	740490.974	USGS	Sand and Gravel	986	6/15/1976			Yes
440151089363001	2071477.400	740430.484	USGS	Sand and Gravel	1041	6/6/1979	9/5/1985	25	Yes
440151089363002	2071477.400	740430.484	USGS	Sand and Gravel	1041	6/6/1979	9/5/1985	25	Yes
440159089370501	2068916.704	741228.627	USGS	Sand and Gravel	1040	6/5/1979	9/5/1985	26	Yes
440159089370502	2068916.704	741228.627	USGS	Sand and Gravel	1040	6/5/1979	9/5/1985	26	Yes
440203089234901	2127064.644	741978.289	USGS	Sand and Gravel	889	8/1/1981			Yes
440204089334301	2083671.009	741807.794	USGS	Sand and Gravel	1008	7/15/1963			Yes
440207089363001	2071469.819	742050.630	USGS	Sand and Gravel	1043	6/6/1979	9/5/1985	25	Yes
440207089363002	2071469.819	742050.630	USGS	Sand and Gravel	1043	6/6/1979	9/5/1985	25	Yes
440211089365101	2069933.861	742448.480	USGS	Sand and Gravel	1042	6/6/1979	9/5/1985	25	Yes
440211089365102	2069933.861	742448.480	USGS	Sand and Gravel	1042	6/6/1979	9/5/1985	24	Yes
440230089340001	2082415.460	744434.024	USGS	Sand and Gravel	1037	4/27/1961			Yes
440243089345201	2078610.580	745730.891	USGS	Sand and Gravel	1047	7/21/1969			Yes
440247089375301	2065388.665	746073.233	USGS	Sand and Gravel	1036	7/31/1958	9/12/1963	2	Yes
440302089364501	2070348.202	747614.739	USGS	Sand and Gravel	1042	4/16/1978			Yes
440303089335101	2083055.412	747779.005	USGS	Sand and Gravel	1052	5/1/1968			Yes
440306089372301	2067571.135	748007.018	USGS	Sand and Gravel	1040	7/18/1958	9/12/1963	2	Yes
440306089375801	2065015.032	747995.550	USGS	Sand and Gravel	1039	7/2/1958			Yes
440309089390101	2060412.753	748279.465	USGS	Sand and Gravel	1029	8/1/1964			Yes
440310089354401	2074799.308	748446.075	USGS	Sand and Gravel	1038	12/14/1966			Yes
440320089372001	2067783.825	749425.637	USGS	Sand and Gravel	1045	11/18/1978			Yes
440321089371501	2068148.498	749528.563	USGS	Sand and Gravel	1044	9/12/1963	8/27/1964	8	Yes
440347089373101	2066968.269	752156.030	USGS	Sand and Gravel	1045	8/1/1959			Yes
440400089380701	2064333.871	753460.701	USGS	Sand and Gravel	1037	7/16/1964			Yes
440402089343401	2079884.725	753737.084	USGS	Sand and Gravel	1058	6/20/1964			Yes
440419089361101	2072794.313	755423.517	USGS	Sand and Gravel	1049	9/13/1963			Yes
440420089323101	2088855.275	755607.444	USGS	Sand and Gravel	1057	8/4/1953			Yes
440421089374001	2066295.778	755595.927	USGS	Sand and Gravel	1042	5/20/1981			Yes
440422089353601	2075348.069	755739.664	USGS	Sand and Gravel	1054	6/18/1965			Yes
440448089350101	2077890.153	758385.101	USGS	Sand and Gravel	1059	4/30/1956	7/6/1956	2	Yes
440518089341201	2081451.387	761441.146	USGS	Sand and Gravel	1046	6/18/1972			Yes
440519089255901	2117433.145	761758.263	USGS	Sand and Gravel	1011	7/29/1976			Yes
440525089302601	2097942.256	762241.593	USGS	Sand and Gravel	1046	5/22/1980			Yes
440525089344001	2079404.180	762139.488	USGS	Sand and Gravel	1051	12/4/1978			Yes
440614089290701	2103677.420	767238.326	USGS	Sand and Gravel	1051	7/12/1972			Yes
440614089291102	2103385.556	767236.523	USGS	Sand and Gravel	1046	12/5/1972			Yes
440615089334001	2083756.655	767225.266	USGS	Sand and Gravel	1061	8/8/1958			Yes
440630089291101	2103375.605	768856.705	USGS	Sand and Gravel	1053	5/24/1971			Yes
440632089342601	2080391.376	768929.229	USGS	Sand and Gravel	1062	5/1/1978			Yes
440634089290001	2104175.684	769266.725	USGS	Sand and Gravel	1054	6/15/1973	7/27/1973	2	Yes
440636089284201	2105487.725	769477.455	USGS	Sand and Gravel	1059	6/29/1976			Yes
440637089373201	2066818.129	769370.118	USGS	Sand and Gravel	1043	5/7/1965			Yes
440642089355101	2074184.706	769910.914	USGS	Sand and Gravel	1055	8/11/1954			Yes
440648089330301	2086434.250	770686.467	USGS	Sand and Gravel	1067	10/18/2011			Yes
440648089330401	2086386.212	770661.907	USGS	Sand and Gravel	1067	10/18/2011			Yes
440649089325101	2087310.111	770751.958	USGS	Sand and Gravel	1068	10/17/2011			Yes

Table F-1

Water Level Data

Well ID	X-Coordinate (feet)[1]	Y-Coordinate (feet)[1]	Source	Unit	Target Value (feet)	Date of First Measurement	Date of Last Measurement	Count	Included as Target
440649089330101	2086571.018	770758.092	USGS	Sand and Gravel	1067	10/18/2011			Yes
440649089330201	2086481.520	770712.040	USGS	Sand and Gravel	1067	10/18/2011			Yes
440650089325101	2087310.842	770883.603	USGS	Sand and Gravel	1068	10/17/2011			Yes
440652089325101	2087312.922	771037.545	USGS	Sand and Gravel	1068	10/17/2011			Yes
440653089325101	2087313.601	771183.372	USGS	Sand and Gravel	1068	10/17/2011			Yes
440655089321101	2090242.011	771322.989	USGS	Sand and Gravel	1071	10/12/2011			Yes
440655089321201	2090156.667	771320.502	USGS	Sand and Gravel	1071	10/11/2011			Yes
440655089321301	2090042.843	771319.870	USGS	Sand and Gravel	1071	10/11/2011			Yes
440655089321501	2089925.388	771320.232	USGS	Sand and Gravel	1071	10/11/2011			Yes
440657089320601	2090577.929	771525.365	USGS	Sand and Gravel	1071	10/12/2011			Yes
440658089320601	2090578.327	771717.781	USGS	Sand and Gravel	1071	10/13/2011			Yes
440700089320601	2090578.302	771849.423	USGS	Sand and Gravel	1071	10/13/2011			Yes
440701089320601	2090578.406	771962.837	USGS	Sand and Gravel	1071	10/13/2011			Yes
440703089323701	2088359.036	772120.717	USGS	Sand and Gravel	1069	9/30/2009			Yes
440704089321501	2089931.452	772220.738	USGS	Sand and Gravel	1076	10/15/1959			Yes
440708089322501	2089183.344	772660.940	USGS	Sand and Gravel	1071	10/16/2011			Yes
440708089322701	2089050.548	772663.249	USGS	Sand and Gravel	1071	10/16/2011			Yes
440708089322901	2088918.504	772667.586	USGS	Sand and Gravel	1071	10/16/2011			Yes
440708089323101	2088760.918	772669.757	USGS	Sand and Gravel	1070	10/17/2011			Yes
440708089325301	2087186.564	772680.409	USGS	Sand and Gravel	1069	10/19/2011			Yes
440708089325401	2087063.996	772680.759	USGS	Sand and Gravel	1069	10/19/2011			Yes
440708089325601	2086970.229	772619.490	USGS	Sand and Gravel	1063	9/29/2009			Yes
440708089325701	2086856.834	772681.658	USGS	Sand and Gravel	1067	10/19/2011			Yes
440708089325901	2086691.953	772682.798	USGS	Sand and Gravel	1069	10/19/2011			Yes
440713089320801	2090437.044	773134.942	USGS	Sand and Gravel	1067	12/15/1954	4/12/2012	52	Yes
440715089320901	2090377.967	773373.384	USGS	Sand and Gravel	1072	10/16/2011			Yes
440716089320901	2090382.165	773534.411	USGS	Sand and Gravel	1072	10/16/2011			Yes
440718089320901	2090387.716	773716.721	USGS	Sand and Gravel	1072	10/16/2011			Yes
440721089320901	2090389.250	773964.841	USGS	Sand and Gravel	1072	10/16/2011			Yes
440759089311801	2094057.773	777813.708	USGS	Sand and Gravel	1071	1/1/1954			Yes
440759089311902	2093984.833	777813.290	USGS	Sand and Gravel	1076	2/21/1958			Yes
450158089364701	2070740.223	741844.675	USGS	Sand and Gravel	1040	6/3/1971	9/5/1985	21	Yes
440317089335401	2082828.932	749195.488	USGS	Sand and Gravel	1038	11/16/1949	10/24/1957	47	Yes
440320089360001	2073625.963	749453.017	USGS	Sand and Gravel	1040	4/1/1977			Yes
440330089352501	2076176.949	750478.076	USGS	Sand and Gravel	1046	10/10/1977			Yes
440348089254101	2118810.014	752552.629	USGS	Sand and Gravel	954	4/18/1979			Yes
440349089252301	2120123.623	752662.979	USGS	Sand and Gravel	949	4/16/1979			Yes
440414089252301	2120106.111	755194.461	USGS	Sand and Gravel	962	9/21/1978			Yes
440448089353601	2075335.259	758372.441	USGS	Sand and Gravel	1056	6/15/1964			Yes
440518089341101	2081524.379	761441.523	USGS	Sand and Gravel	1054	6/23/1978			Yes
440546089345201	2078517.704	764261.549	USGS	Sand and Gravel	1050	5/22/1976			Yes
440554089301701	2098581.696	765182.066	USGS	Sand and Gravel	1057	10/23/1977			Yes
440556089324201	2087999.252	765324.074	USGS	Sand and Gravel	1062	9/13/1978			Yes
440610089322001	2089596.875	766750.571	USGS	Sand and Gravel	1068	11/30/1980			Yes
440612089291101	2103386.806	767033.986	USGS	Sand and Gravel	1048	7/24/1972	9/27/1972	2	Yes
440612089324001	2088136.387	766945.056	USGS	Sand and Gravel	1059	7/2/1965			Yes
440613089292401	2102437.609	767129.421	USGS	Sand and Gravel	1058	7/28/1973			Yes
440613089350901	2077263.531	766989.388	USGS	Sand and Gravel	1058	4/27/1961			Yes
440617089290401	2103894.461	767543.470	USGS	Sand and Gravel	1045	10/7/1971			Yes
440630089291501	2103083.762	768854.902	USGS	Sand and Gravel	1048	7/20/1972			Yes
440631089291101	2103374.982	768957.968	USGS	Sand and Gravel	1052	5/7/1971	5/12/1971	2	Yes
440655089281001	2107810.215	771416.202	USGS	Sand and Gravel	1056	9/14/1979			Yes
440704089315801	2091171.627	772227.686	USGS	Sand and Gravel	1061	11/1/1965			Yes
440705089323301	2088617.765	772314.730	USGS	Sand and Gravel	1050	5/15/1965			Yes
440721089315701	2091234.937	773949.551	USGS	Sand and Gravel	1071	5/1/1951	7/21/1966	4798	Yes
440731089321501	2089916.318	774954.827	USGS	Sand and Gravel	1073	5/6/1970			Yes
440750089320701	2090489.148	776882.060	USGS	Sand and Gravel	1076	6/5/1962			Yes
434630089464001	2027161.008	647010.576	USGS	Sand and Gravel	977	9/21/1964			No
434641089335301	2083428.222	648346.674	USGS	Sand and Gravel	794	7/19/1968			No
434642089425201	2043884.712	648276.678	USGS	Sand and Gravel	982	5/10/1977			No
434648089462201	2028476.657	648836.639	USGS	Sand and Gravel	872	6/15/1978			No
434740089420001	2047678.517	654162.588	USGS	Sand and Gravel	995	4/26/1968			No
434930089460001	2030044.703	665243.725	USGS	Sand and Gravel	848	4/11/1977			No
435024089413401	2049524.263	670774.743	USGS	Sand and Gravel	1070	11/10/1964			No
435042089470001	2025627.312	672521.940	USGS	Sand and Gravel	858	6/21/1979			No
435100089370001	2069588.623	674503.178	USGS	Sand and Gravel	913	4/15/1977			No
435447089342201	2081048.539	697543.989	USGS	Sand and Gravel	950	6/1/1962			No
435611089393701	2057955.887	705942.975	USGS	Sand and Gravel	1016	7/4/1965			No

Table F-1

Water Level Data

Well ID	X-Coordinate (feet)[1]	Y-Coordinate (feet)[1]	Source	Unit	Target Value (feet)	Date of First Measurement	Date of Last Measurement	Count	Included as Target
435730089382501	2063189.731	713964.293	USGS	Sand and Gravel	1026	5/25/1966			No
435759089490001	2016735.978	716748.719	USGS	Sand and Gravel	980	9/15/1969	4/13/2012	1988	No
435858089491201	2015845.426	722720.903	USGS	Sand and Gravel	970	1/12/1970			No
440140089341001	2081711.108	739367.276	USGS	Sand and Gravel	1057	9/16/1977			No
440711089320801	2090438.171	772932.429	USGS	Sand and Gravel	1081	6/14/1947	9/18/1956	182	No
440400089310601	2095072.491	753617.342	USGS	Sand and Gravel	1051	3/3/1977			No
435602089165401	2108657.417	705367.089	USGS	Sandstone	862	11/28/1987	6/7/2011	9	Yes
440615089291103	2103384.932	767337.786	USGS	Sandstone	1044	10/1/1971			Yes
434712089422001	2046221.641	651322.357	USGS	Sandstone	942	7/21/1975			Yes
435224089294102	2101705.375	683180.136	USGS	Sandstone	858	10/1/1962			Yes
435235089292301	2103017.031	684301.971	USGS	Sandstone	857	5/25/1966			Yes
435244089293401	2102205.803	685208.306	USGS	Sandstone	864	10/17/1949	4/12/2012	658	Yes
435537089375701	2065288.239	702531.467	USGS	Sandstone	985	6/15/1977			Yes
435714089492001	2015282.999	712189.001	USGS	Sandstone	942	10/7/1964			Yes
435748089495901	2012423.208	715625.766	USGS	Sandstone	923	12/4/1969			Yes
435847089491201	2015847.855	721607.073	USGS	Sandstone	920	9/1/1964			Yes
440001089484901	2017512.829	729103.832	USGS	Sandstone	927	5/1/1963			Yes
440210089254201	2118804.930	742628.780	USGS	Sandstone	895	5/17/1977			Yes
440335089332501	2084937.070	751029.361	USGS	Sandstone	1048	5/5/1971			Yes
440203089311001	2094994.687	741769.172	USGS	Sandstone	981	1/1/1939	11/21/1963	25	No
440759089311901	2093984.833	777813.290	USGS	Sandstone	1078	8/6/1957			No

[1] Datum: NAD83, Stateplane, Wisconsin South, FIPS 4803

Attachment G

Stream Flow Observations

Attachment G
Stream Flow Observations

Limited stream flow data are available for the model domain. The USGS has historically only maintained one continuous stream flow gage within the model domain. This gage was located on Lawrence Creek (station 04072750) just upstream of Lawrence Lake (about three miles east of Patrick Lake). Daily stream flow records are available for this location for the period November 1967 through September 1973. The Center for Watershed Science and Education at the University of Stevens Point/Extension has been monitoring a number of the streams in the model domain since the mid-2000's, including Little Roche a Cri, Mecan River, Lawrence Creek, Chaffee Creek, Campbell Creek, Neenah Creek at both an upstream and downstream location, Schmudlack Creek, Dry Creek and Carter Creek. In addition, some miscellaneous stream flow measurements are available from South Branch of Wedde Creek as described in Mechenich and others (2009) and from USGS peak flow station on Tagatz Creek. Available stream flow data are summarized on the table below. Hydrographs of the stream flow data and are shown on the attached figure and attached table lists the stream flow data collected by the Center for Watershed Science and Education.

Stream Name	County	Latitude	Longitude	Estimated Base Flow (cfs)	Number of Measurements	Source
Little Roche-A-Cri @ 10th Ave	Adams	43º 59' 01"	89° 46' 42"	34	9	UW Stevens Point
Campbell Creek at County A	Adams	43º 50' 21"	89° 46' 01"	2.4	30	UW Stevens Point
Neenah Creek at County G	Adams	43º 50' 13"	89° 38' 33"	0.8	44	UW Stevens Point
Neenah Creek at County A	Marquette	43º 43' 58"	89° 33' 42"	42	39	UW Stevens Point
Chaffee Creek at County JJ	Marquette	43º 58' 51"	89° 27' 43"	14	15	UW Stevens Point
Chaffee Creek at County CH	Waushara	43º 59' 13"	89° 31' 17"	1.8	39	UW Stevens Point
Lawrence Creek at Eagle	Marquette	43º 53' 39"	89° 34' 09"	20	31	UW Stevens Point
Lawrence Creek nr Westfield	Marquette	43º 53' 52"	89° 34' 43"	16	2161	USGS 0472750
Carter Creek at County G	Adams	44º 05' 33"	89° 35' 06"	2.5	22	UW Stevens Point
Dry Creek at County G	Adams	44º 07' 10"	89° 37' 05"	1.4	22	UW Stevens Point
Mecan River at County GG	Waushara	44º 03' 03"	89° 27' 51"	13	32	UW Stevens Point
Schmudlack Creek at Cottonville Rd	Waushara	44º 03' 17"	89° 27' 10"	1.2	15	UW Stevens Point
Tagatz Creek near Westfield	Marquette	43º 57' 22"	89° 29' 38"	7.6	1	USGS 04072792
South Branch Wedde Creek at JJ	Washara	44º 00' 09"	89° 27' 19"	7		USGS 04073260

Notes: Data for South Branch Wedde Creek from Mechenich and others (2009) and is based on data from August 1970 to August 1988.

USGS maintains peak flow gage on Tagatz Creek and has conducted manual gaging on 7 occassions. Base flow based on gaged flow at time when base flow observed in nearby streams (3/29/2006).

Estimated base flow for USGS gage on Lawerence Creek based on median flow for period of record of 16 cfs and average flow of 16.9 cfs.

Table G-1
Measured Steamflow Data
in Model Domain

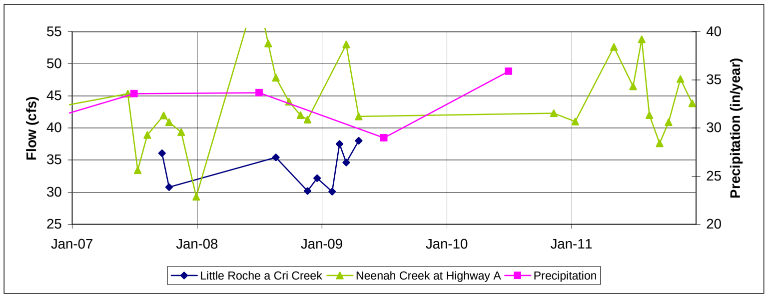
Lawrence Creek near Eagle		Chaffee Creek at County JJ		Campbell Creek at County A		Neenah Creek at County G		Neenah Creek at County A		Little Roche a Cri Creek at 10th Avenue	
	flow (cfs)		flow (cfs)		flow (cfs)		flow (cfs)		flow (cfs)		flow (cfs)
6/13/2007	18.7	7/5/2005	14.3	7/19/1971	2.6	8/9/2005	1.3	8/24/2005	41.4	9/21/2007	36.1
7/12/2007	17.3	8/24/2005	15.1	6/13/2007	1.7	8/24/2005	0.2	9/23/2005	44.8	10/12/2007	30.8
8/9/2007	18.3	9/23/2005	14.7	7/12/2007	1.0	9/23/2005	0.6	10/21/2005	39.9	8/19/2008	35.4
9/28/2007	17.5	10/21/2005	15.0	8/9/2007	1.3	10/21/2005	0.5	12/3/2005	44.1	11/20/2008	30.2
10/12/2007	17.2	12/3/2005	14.5	9/26/2007	2.5	12/3/2005	0.9	1/11/2006	43.9	12/18/2008	32.2
11/16/2007	18.4	1/11/2006	14.9	10/12/2007	1.9	1/11/2006	0.6	2/25/2006	33.6	1/31/2009	30.1
12/30/2007	14.7	2/25/2006	13.9	11/16/2007	1.7	2/25/2006	0.5	3/12/2006	50.3	2/21/2009	37.5
1/25/2008	19.2	3/12/2006	14.1	12/30/2007	1.5	3/12/2006	0.6	4/1/2006	49.0	3/13/2009	34.6
2/23/2008	17.8	4/1/2006	14.5	1/25/2008	2.0	4/1/2006	0.8	4/23/2006	46.0	4/19/2009	38.0
3/28/2008	20.4	4/23/2006	16.1	2/23/2008	2.7	4/23/2006	0.9	5/31/2006	60.5		
6/25/2008	16.8	5/31/2006	14.2	6/25/2008	4.3	5/31/2006	0.8	6/28/2006	33.8		
7/28/2008	20.7	6/28/2006	13.4	7/28/2008	4.0	6/28/2006	0.3	7/27/2006	33.0		
8/19/2008	22.7	7/27/2006	12.7	8/19/2008	3.4	7/27/2006	0.5	8/22/2006	34.1		
9/27/2008	20.8	8/22/2006	12.7	10/3/2008	3.3	8/22/2006	0.3	10/7/2006	42.8		
10/30/2008	19.9	10/7/2006	12.8	10/30/2008	2.5	10/7/2006	0.9	6/13/2007	45.4		
11/20/2008	20.5			11/20/2008	2.5	6/13/2007	0.3	7/12/2007	33.4		
12/18/2008	20.5			12/18/2008	2.6	7/12/2007	0.1	8/9/2007	38.9		
1/30/2009	19.7			1/30/2009	2.3	8/9/2007	0.3	9/26/2007	41.9		
2/21/2009	19.6			2/21/2009	2.5	9/26/2007	0.4	10/12/2007	40.9		
3/13/2009	19.1			3/13/2009	2.4	10/12/2007	0.4	11/16/2007	39.4		
4/19/2009	18.5			4/19/2009	2.3	11/16/2007	0.4	12/30/2007	29.3		
11/10/2010	20.1			11/10/2010	2.3	12/30/2007	0.5	6/25/2008	61.5		
1/12/2011	21.6			1/12/2011	1.9	3/28/2008	0.7	7/28/2008	53.2		
5/5/2011	20.3			5/5/2011	3.2	6/25/2008	1.2	8/19/2008	47.8		
6/30/2011	21.8			6/30/2011	2.3	7/28/2008	1.0	9/27/2008	44.1		
7/25/2011	20.3			7/25/2011	1.9	8/19/2008	0.8	10/30/2008	42.0		
8/18/2011	21.1			8/17/2011	1.8	9/27/2008	0.8	11/20/2008	41.3		
9/16/2011	20.7			9/16/2011	2.1	10/30/2008	0.7	3/13/2009	53.0		
10/12/2011	21.0			10/12/2011	2.1	11/20/2008	0.9	4/19/2009	41.8		
11/16/2011	22.5			11/16/2011	2.8	12/18/2008	1.0	11/10/2010	42.3		
12/20/2011	20.8					1/30/2009	1.0	1/12/2011	41.0		
						2/21/2009	1.0	5/5/2011	52.6		
						3/13/2009	1.0	6/30/2011	46.5		
						4/19/2009	0.7	7/25/2011	53.8		
						11/10/2010	0.7	8/17/2011	42.0		
						1/12/2011	0.8	9/16/2011	37.6		
						5/5/2011	1.1	10/12/2011	40.9		
						6/30/2011	1.1	11/16/2011	47.6		
						7/25/2011	0.9	12/20/2011	43.9		
						8/17/2011	0.9				
						9/16/2011	0.6				
						10/12/2011	0.9				
						11/16/2011	1.2				
						12/20/2011	1.1				
Count	31		15		30		44		39		9
Average	19.6		14.2		2.4		0.7		43.6		33.9
Median	20.1		14.3		2.3		0.8		42.3		34.6
Minimum	14.7		12.7		1.0		0.1		29.3		30.1
Maximum	22.7		16.1		4.3		1.3		61.5		38.0

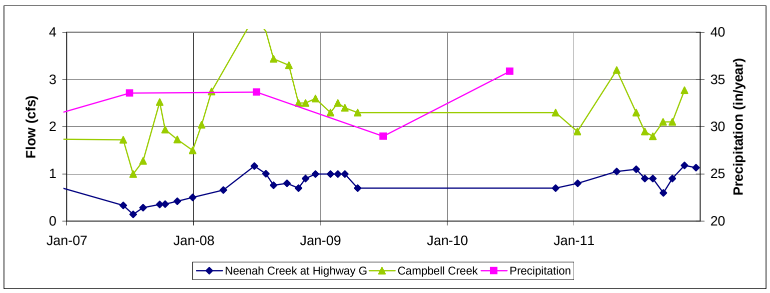
Note: Sources of data are Center for Watershed Science and Education, University of Wisconsin - Stevens Point/Extension and USGS Water Resource Investigations Open-File Report 81-495, "Low-Flow Characteristics of Streams in the Central Wisconsin River Basin, Wisconsin".

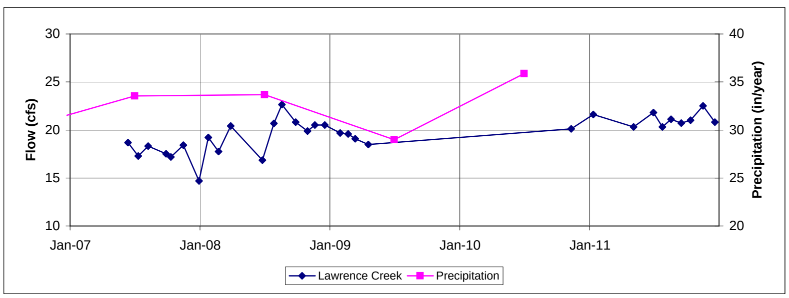
Table G-1
Measured Streamflow Data
in Model Domain (continued)

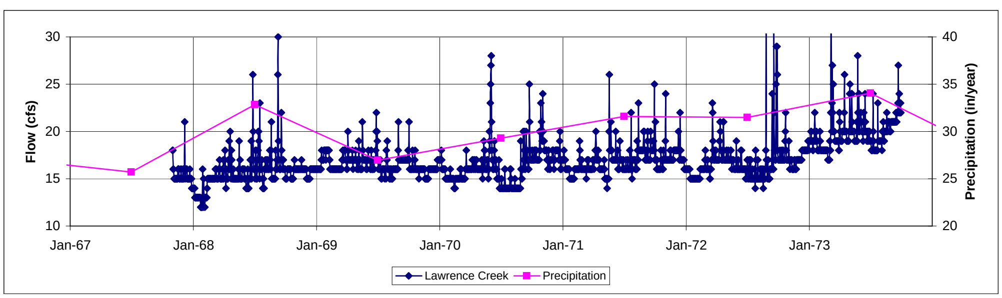
Carter Creek at County G		Dry Creek at County G		Mecan River at County GG		Schmudlack Creek		Chaffee Creek at County CH	
			flow (cfs)		flow (cfs)		flow (cfs)		flow (cfs)
07/11/07	0.5	06/13/07	1.2	07/05/05	13.9	07/05/05	1.3	07/05/05	1.7
08/09/07	0.2	09/28/07	0.7	06/13/07	12.1	08/24/05	1.2	08/24/05	2.0
09/28/07	2.9	10/13/07	2.5	07/13/07	10.7	09/23/05	1.2	09/23/05	1.8
10/13/07	2.5	11/16/07	0.4	08/10/07	15.2	10/21/05	1.5	10/21/05	2.1
11/16/07	2.2	12/31/07	0.5	09/28/07	12.6	12/03/05	1.7	12/03/05	2.6
07/01/08	3.2	03/28/08	2.7	10/12/07	12.5	01/11/06	1.4	01/11/06	1.3
07/28/08	3.5	07/01/08	3.6	11/15/07	12.8	02/25/06	1.1	02/25/06	0.9
08/19/08	3.3	07/28/08	1.8	12/31/07	12.9	03/12/06	1.3	03/12/06	1.6
10/03/08	2.4	08/19/08	1.8	01/25/08	13.4	04/01/06	1.1	04/01/06	1.5
10/30/08	0.0	10/03/08	1.1	02/23/08	12.8	04/23/06	1.3	04/23/06	2.1
11/20/08	0.2	10/30/08	0.0	03/28/08	11.8	05/31/06	1.1	05/31/06	1.7
03/14/09	2.6	11/20/08	0.0	06/25/08	13.5	06/28/06	0.8	06/28/06	1.8
04/17/09	2.2	04/17/09	2.3	07/28/08	13.7	07/27/06	0.7	07/27/06	1.5
11/10/10	3.8	11/10/10	4.0	08/19/08	14.2	08/22/06	0.6	08/22/06	1.3
05/05/11	9.7	05/05/11	8.3	09/27/08	13.5	10/07/06	0.8	10/07/06	1.2
07/01/11	4.3	07/01/11	4.6	10/30/08	14.0			06/13/07	1.2
07/25/11	2.2	07/25/11	1.4	11/20/08	13.9			07/12/07	0.9
08/17/11	1.7	08/17/11	0.7	12/17/08	14.4			08/09/07	0.5
09/16/11	1.0	09/16/11	0.1	01/31/09	13.5			09/28/07	1.1
10/12/11	1.9	10/12/11	0.4	02/21/09	14.0			10/12/07	1.2
11/16/11	3.9	11/16/11	1.5	03/13/09	12.5			11/16/07	0.3
12/20/11	3.5	12/20/11	2.6	04/19/09	12.3			03/28/08	1.1
				11/11/10	14.1			06/25/08	2.7
				01/12/11	14.5			07/28/08	3.0
				05/06/11	14.3			08/19/08	2.8
				06/30/11	14.5			09/27/08	2.6
				07/25/11	14.5			10/30/08	1.9
				08/18/11	13.2			11/20/08	1.9
				09/15/11	13.7			03/13/09	1.7
				10/11/11	14.6			04/19/09	1.7
				11/15/11	14.3			11/11/10	2.1
				12/21/11	14.5			05/05/11	2.4
								06/30/11	2.6
								07/25/11	2.3
								08/18/11	2.2
								09/15/11	2.0
								10/11/11	2.1
								11/15/11	1.9
								12/20/11	2.0
Count	22		22		32		15		39
Average	2.6		1.9		13.5		1.1		1.8
Median	2.5		1.4		13.7		1.2		1.8
Minimum	0.0		0.0		10.7		0.6		0.3
Maximum	9.7		8.3		15.2		1.7		3.0

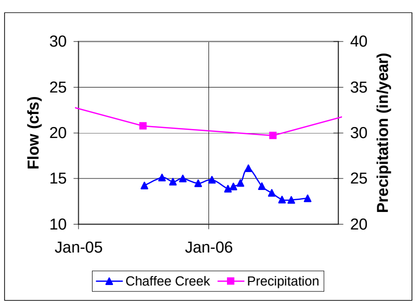
Hydrographs of Steam-Flow Data from the Model Domain





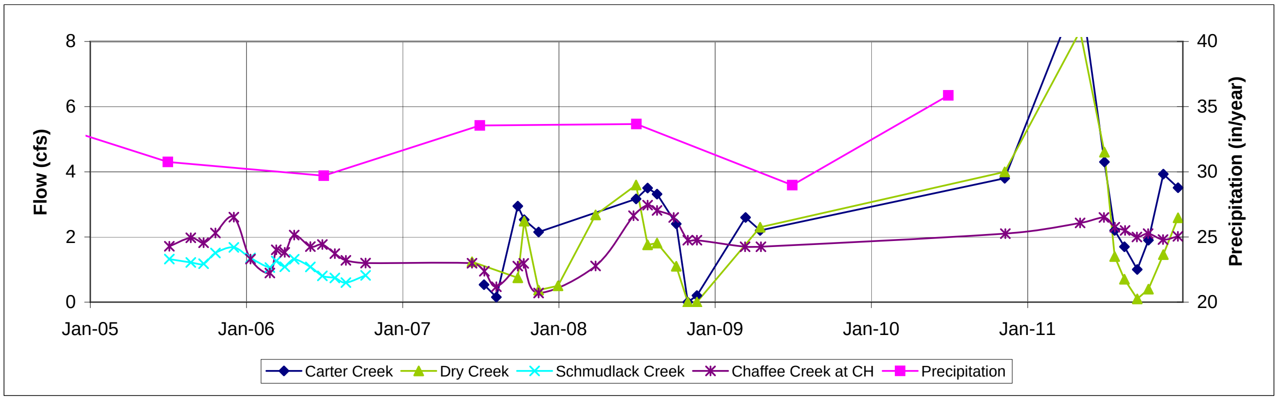


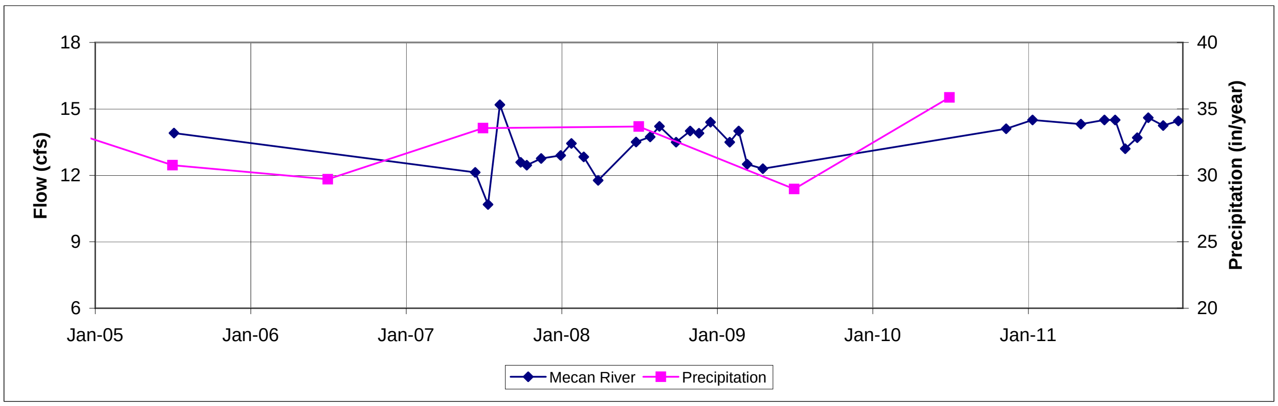




Note: Source of data are USGS data for Station 04071750 Lawrence Creek near Westfield and Center for Watershed Science and Education, University of Wisconsin, Stevens Point/Extension.

Hydrographs of Stream-Flow Data From Model Domain (continued)





Attachment H

Existing High Capacity Wells and Pumping Rates

Attachment H

Pumping Data in the Model Domain

Pumping rates for existing high capacity wells located in the model domain are summarized in Table H-1. Listed on the table are well number, well coordinates and average pumping rates for the period 2007 through 2011. These data were obtained from the Wisconsin Department of Natural Resources database on High Capacity wells. The location of the wells and the average pumping rate during the period 2007 to 2011 is shown in Figure 4 of the report.

The groundwater model described in the main body of this report was used to calculate the effect of the existing pumping from high capacity wells. The long term effect of this pumping was calculated assuming that consumptive use of the pumped water was equal to 20 percent of the average annual pumping during the period 2007 through 2011. A consumptive use of 20 percent was based on an average application rate of 10 inches per year for all high capacity wells and two inches per year of consumptive use.

The drawdowns and stream flow reductions attributable to long term use of the existing high capacity wells was calculated as the difference between water levels calculated with a groundwater simulation with no pumping in the model domain and a groundwater simulation with the existing high capacity wells pumping in the model domain. The calculated long-term drawdowns are shown on Figure H-1. The calculated changes in stream flow calculated as a result of the long-term use of the existing high capacity wells are listed on the table below.

Stream Base Flows and Calculated Changes in Base Flow due to Pumping from Existing High Capacity Wells

Stream Name	Estimated Base Flow (cfs)	Model Calculated Base Flows (cfs)		Change in Base Flow due to Pumping of Existing High Capacity Wells (gpm)
		No Pumping	Pumping from Existing High Capacity Wells	
Little Roche-A-Cri Creek at 10th Ave	34	35.1	33.3	812
Campbell Creek at County A	2.4	2.3	2.1	121
Neenah Creek at County G	0.8	1.0	0.8	63
Neenah Creek at County A	>42	31.4	30.9	216
Chaffee Creek at County JJ	14	14.3	13.9	212
Chaffee Creek at County CH	1.8	1.7	1.4	147
Lawrence Creek at Eagle	20	17.5	16.9	237
Lawrence Creek nr Westfield	16	14.7	14.2	216
Carter Creek at County G	2.5	3.3	2.3	458
Mecan River at County GG	13	12.3	12.0	111
Schmudlack Creek at Cottonville Rd	1.2	2.0	1.8	101
Tagatz Creek near Westfield	7.6	6.0	5.5	213
South Branch Wedde Creek at JJ	7	2.2	2.1	51

Note: Refer to Attachment G for details on the stream gaging locations and stream gaging data.

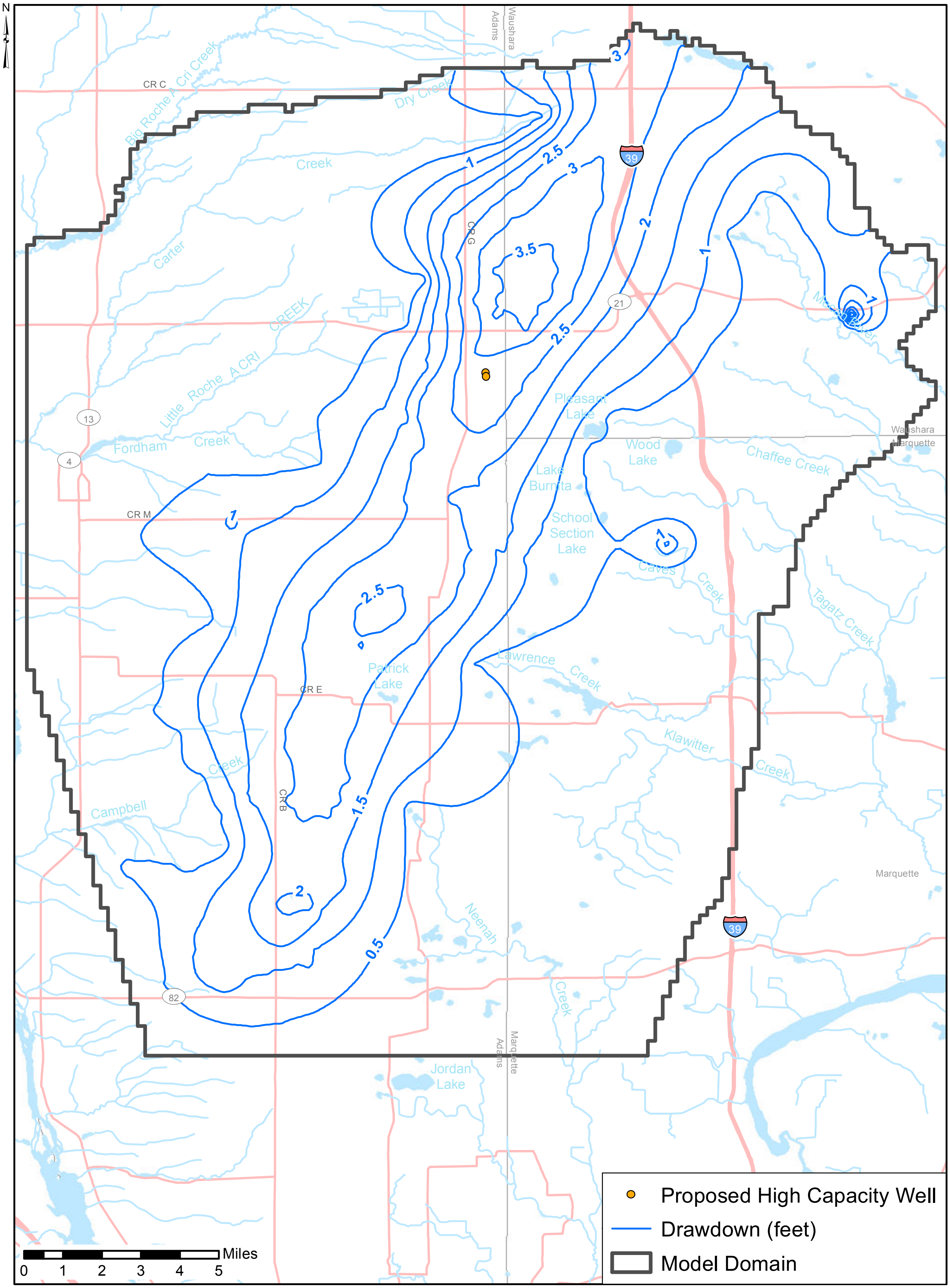


Figure H-1 Calculated Steady-State Drawdown at the Water Table From Existing High Capacity Wells

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
1	2065248.2	747878.0	36	69
2	2067587.1	747731.7	68	129
3	2065404.8	746345.8	15	28
4	2067437.4	746026.2	22	43
5	2068153.5	770651.2	44	83
6	2066802.4	770650.3	7	13
9	2066810.0	769328.9	48	92
16	2066866.8	752332.5	57	108
17	2072159.7	754820.9	37	71
18	2051462.9	692579.4	38	72
19	2052108.7	694580.3	42	81
20	2052791.8	692580.3	2	3
22	2047544.8	659390.8	49	92
24	2046846.5	656096.7	43	81
25	2047486.5	654132.0	48	91
28	2073077.3	736231.5	46	87
29	2056701.1	697893.4	1	3
33	2044904.4	659381.5	38	73
35	2061723.0	732538.9	36	69
36	2063031.1	733865.5	20	38
38	2064170.8	753176.8	24	46
39	2065474.5	749912.6	22	42
44	2068344.4	725981.6	19	35
50	2050230.0	671389.8	42	80
51	2052223.0	685262.1	22	43
53	2046799.5	648179.3	42	80
55	2026042.9	664067.5	52	100
65	2059832.4	718316.0	32	60
69	2062450.4	719688.0	41	77
70	2049578.5	682630.9	47	89
72	2039869.2	644913.0	51	97
76	2025981.9	648152.4	24	46
80	2057948.7	705818.6	29	55
85	2049344.1	705139.8	33	62
88	2033873.5	650927.5	45	86
89	2047587.1	684608.6	7	14

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
93	2039526.4	724457.4	55	105
94	2045994.5	713744.6	36	68
95	2072999.6	724006.9	32	61
96	2059927.5	714434.1	39	74
97	2061811.0	716390.1	41	79
98	2065956.5	696569.0	26	49
100	2041827.5	679892.9	31	59
101	2047465.4	651500.4	33	63
103	2049395.9	699861.2	43	81
111	2023411.2	664075.7	60	114
113	2070858.0	748430.4	21	41
116	2044069.1	718388.6	20	39
117	2044660.9	715081.9	13	26
118	2069057.8	735176.2	22	42
120	2054758.5	694580.9	42	79
122	2072850.4	745034.2	59	113
123	2067073.4	721014.6	8	14
124	2070209.0	741175.8	44	84
126	2042572.7	654130.7	34	64
127	2054729.5	697234.0	43	82
129	2051578.6	677997.7	30	57
130	2068172.5	756125.9	27	51
132	2043383.3	723162.9	4	8
136	2052902.0	676665.8	38	71
137	2047561.2	660710.9	19	36
145	2070131.0	771306.7	58	111
146	2072931.1	731965.1	47	88
149	2046751.3	699859.0	59	111
151	2067195.8	707158.1	35	66
154	2059826.7	719670.9	29	56
156	2067711.1	721192.9	30	57
157	2046269.1	683272.7	41	79
158	2059044.8	736464.4	48	92
165	2048913.7	675367.1	41	79
166	2067230.1	701858.2	39	75
167	2052016.1	702504.3	40	76

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
168	2054690.9	699872.7	48	91
170	2067366.5	674097.1	24	46
171	2044360.4	648181.4	39	73
172	2065187.7	710429.8	12	22
174	2064304.8	736508.2	34	64
179	2073512.8	749826.3	32	60
182	2063291.8	659377.2	0	0
183	2060050.0	661427.4	0	0
185	2022729.9	670010.5	14	26
188	2066328.7	726655.5	34	64
190	2024026.9	654102.7	16	31
200	2014617.7	704850.9	56	106
201	2013915.9	702394.9	20	37
213	2059439.8	666143.7	0	0
217	2048907.5	685931.1	47	90
233	2070193.2	747748.0	36	68
236	2059775.2	753971.6	41	78
240	2070718.0	682705.9	38	73
243	2036483.0	685196.1	45	85
244	2036500.6	687837.2	10	19
245	2033852.7	687851.8	24	46
247	2067529.8	750354.0	64	122
248	2059887.0	715734.1	34	65
249	2013835.0	707565.0	45	86
251	2026981.5	708106.4	17	32
253	2033159.7	684555.9	23	44
254	2036519.8	653583.6	40	76
263	2035851.5	648941.1	26	50
264	2025318.8	673929.6	49	94
265	2050118.5	693911.6	39	74
272	2048805.1	692577.7	21	40
273	2050149.6	691245.5	15	29
278	2068855.4	731608.2	30	57
279	2038915.2	715667.8	43	82
280	2027944.2	648825.2	24	46
283	2051563.8	674026.3	44	84

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
284	2065179.1	739899.0	55	105
286	2057370.0	697234.1	49	93
287	2047584.1	670062.5	14	26
289	2044949.0	683255.8	45	85
291	2072911.0	739864.0	48	92
292	2066854.8	756119.2	16	30
293	2044947.1	673996.6	55	105
294	2041890.1	645550.8	35	67
297	2062231.9	750383.9	21	40
299	2062563.0	710824.2	15	28
300	2059216.9	711168.6	14	26
301	2061367.2	710223.7	10	18
303	2059473.5	750340.7	26	49
305	2036509.8	650928.1	25	48
308	2070799.2	765380.3	8	15
309	2049417.7	697226.8	41	78
311	2028528.5	685210.6	45	85
312	2041849.5	685209.9	28	53
313	2052206.1	687912.9	47	90
318	2068253.7	739113.7	11	21
319	2066002.5	692607.1	0	0
320	2052696.7	700530.1	20	37
321	2052720.3	652817.1	14	27
323	2073009.1	726631.6	52	99
324	2070498.7	707852.3	17	33
325	2054663.9	702507.8	12	22
327	2072961.5	729256.1	37	71
328	2048918.4	680654.5	38	73
329	2050236.9	684607.9	14	27
332	2070968.3	727335.0	0	0
333	2054178.9	688586.9	8	16
336	2047459.2	646189.0	29	56
338	2029132.5	707007.2	34	65
339	2059958.8	702508.7	43	81
340	2028566.8	687844.2	37	70
341	2010834.1	704320.8	39	74

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
342	2010195.1	707891.9	2	5
343	2046925.7	672043.1	43	83
344	2068532.3	704526.7	21	40
348	2011996.0	701716.7	15	28
349	2046792.6	694576.8	30	58
350	2070136.3	771327.4	56	106
351	2054777.5	691913.5	41	78
352	2014557.2	722917.9	0	1
353	2044954.0	680598.1	62	117
356	2062041.1	691257.8	18	34
357	2056666.3	700531.7	38	72
358	2070201.3	734524.7	50	96
359	2039156.1	685195.7	24	46
362	2063111.2	717722.5	12	24
363	2035841.5	679223.3	39	73
364	2052889.6	684597.3	39	75
366	2071355.4	688660.5	40	76
368	2025981.9	648152.4	38	71
370	2062008.3	695242.3	27	52
430	2096237.3	708530.6	169	321
456	2077669.3	732610.7	35	67
468	2036518.9	645620.2	45	85
476	2078899.9	748478.9	23	45
482	2044944.9	685895.1	23	44
562	2046262.9	687226.6	0	0
575	2059328.6	699210.5	144	274
576	2063308.4	697881.1	0	0
645	2025330.2	646175.4	57	108
652	2065925.4	700527.1	41	79
666	2029341.5	664728.6	20	38
689	2073556.6	741869.1	33	63
766	2079382.3	760859.7	9	16
806	2025639.9	709135.7	48	92
816	2067637.9	741145.8	36	69
830	2069739.9	716429.2	35	67
892	2074303.8	741879.2	0	0

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
934	2044362.9	642875.9	39	74
985	2023666.1	736201.4	26	49
1025	2078211.1	770408.8	0	0
1031	2043726.7	655429.3	42	80
1169	2071484.6	750489.8	30	58
1195	2084072.1	760169.4	0	0
1202	2078973.6	744509.4	17	33
1241	2065173.8	713028.9	19	36
1247	2073477.2	757471.0	24	46
1301	2028024.0	662056.5	18	34
1307	2053989.1	704479.5	48	92
1386	2080556.1	647566.9	3	5
1387	2080556.1	647566.9	11	20
1388	2080556.1	647566.9	26	50
1389	2024026.9	654102.7	42	80
1397	2085313.5	772101.4	24	45
1417	2064599.8	701839.5	9	18
1445	2071540.1	735871.8	37	70
1446	2069648.2	728631.8	34	65
1447	2070986.4	724685.3	53	102
1448	2074316.4	727390.7	50	95
1479	2017090.6	740079.6	13	25
1490	2063317.3	696562.6	8	15
1498	2017005.4	747947.0	35	67
1577	2086631.6	770768.1	10	19
1578	2026561.6	685865.8	41	78
1603	2010555.5	738757.2	21	39
1649	2069534.2	743088.7	22	42
1651	2066352.5	725252.1	27	52
1698	2057254.0	715729.4	6	11
1708	2072330.0	721888.4	0	0
1866	2058955.1	744391.2	34	64
1887	2064506.1	712411.2	19	37
1890	2043434.3	715099.5	16	31
1913	2055046.5	741743.7	32	61
1928	2079678.8	742546.3	40	76

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
1994	2047596.3	678002.9	41	79
1995	2051516.4	662084.2	79	151
2004	2022425.2	729604.8	55	104
2008	2043753.6	659379.1	24	46
2071	2036986.4	711043.0	124	235
2077	2103486.8	691304.3	0	0
2121	2025031.6	718918.4	25	48
2133	2027772.5	727011.0	15	29
2149	2026295.7	737536.2	20	38
2155	2039844.5	676580.8	28	54
2196	2073744.0	737097.4	0	1
2219	2033605.6	718305.4	37	71
2247	2033245.7	654236.5	33	63
2251	2057967.6	703174.1	46	88
2253	2037238.5	659547.3	27	51
2542	2018774.2	670027.8	1	2
2543	2018774.2	670027.8	0	1
2554	2090597.0	772087.4	1	2
2566	2062539.9	713145.0	0	1
2674	2059016.4	739098.9	19	35
2701	2030589.0	652851.1	35	67
2751	2113638.7	731578.7	19	37
2762	2036960.8	713669.8	53	102
3026	2059437.3	709869.4	8	16
3122	2084533.7	692699.9	0	0
3132	2027665.7	720246.2	28	54
3334	2023968.4	691110.7	23	44
3422	2089278.2	773416.6	20	37
3471	2060295.6	741756.6	17	32
3480	2103156.9	662249.2	1	1
3481	2104474.9	663606.1	98	186
3514	2067195.8	707158.1	11	21
4597	2027907.1	679210.6	66	126
18901	2077359.1	649387.1	0	0
18940	2092255.5	719065.3	6	12
18947	2081798.0	700606.6	41	78

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
36310	2074843.0	758161.4	18	34
36311	2075460.4	755509.3	57	108
36312	2079664.8	741841.4	22	42
36313	2077023.9	743170.9	50	96
36314	2079030.8	739210.9	32	61
36315	2077712.1	739222.4	17	32
36316	2089278.2	773416.6	9	17
36317	2090597.0	772087.4	25	48
36318	2087953.2	772091.4	27	51
36320	2121574.2	732958.4	8	16
36321	2120245.1	732939.8	8	15
36323	2084001.5	769451.0	24	46
36342	2081327.2	770774.0	16	30
36355	2083995.2	770779.0	19	36
36365	2087559.9	758203.7	40	76
36366	2087264.9	760517.6	63	120
36367	2085085.9	758331.4	48	91
36370	2076031.6	766758.1	35	66
36371	2079296.0	771416.8	39	73
36375	2107690.4	732171.4	17	33
36376	2111862.8	727282.4	30	58
36406	2077039.4	738274.0	48	92
36408	2081336.2	745404.9	35	66
36415	2089585.6	727393.0	0	0
36418	2090087.7	775458.7	27	51
36419	2090222.1	776632.7	43	82
36435	2113873.5	724348.9	28	53
36461	2082967.3	741803.0	36	68
36468	2078899.9	748478.9	0	0
36476	2077031.8	737162.1	63	120
36484	2078785.5	753642.6	20	37
36491	2076339.2	750495.0	30	57
36492	2076339.1	750525.3	0	0
36497	2089713.0	767086.3	46	88
36498	2088627.3	763474.3	28	53
36499	2082410.3	755540.7	31	59

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
36500	2084272.8	756043.2	50	95
36501	2087392.7	754162.4	25	47
36508	2079417.4	758158.5	55	104
36519	2087976.2	766787.2	12	23
36537	2074302.1	747904.0	15	29
36546	2081877.4	756843.6	33	63
36549	2084137.7	751024.7	12	22
36560	2080221.0	748450.6	33	62
36568	2076287.8	745176.0	31	59
36570	2085483.3	763468.8	28	54
36574	2082041.3	764528.6	28	54
36575	2084070.6	764150.4	8	16
36576	2077377.6	764130.6	13	24
36592	2117456.3	761744.4	24	46
36596	2118893.4	742163.5	0	0
36608	2084093.9	753604.2	30	57
36623	2080137.1	752411.7	33	64
36626	2076079.1	761455.0	44	84
36629	2079382.3	760859.7	25	47
36633	2117683.4	725004.7	25	47
36634	2121539.6	742162.5	39	75
36635	2121546.0	739522.8	675	1284
36636	2081655.3	740505.4	9	17
36646	2081420.4	757506.1	18	34
36648	2082038.6	760904.9	51	98
36649	2087659.8	764728.6	29	56
36650	2120770.1	755838.0	14	27
36651	2122269.3	753193.3	47	89
36652	2120171.5	752449.6	15	28
36653	2118806.9	752756.1	50	95
36654	2079449.4	762142.7	50	95
36655	2079331.5	768779.4	62	117
36656	2079454.5	745551.4	22	41
36658	2077685.9	735251.1	14	28
36661	2110784.6	768260.2	8	16
36676	2092231.5	727393.6	45	85

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
36688	2109105.5	724293.5	35	66
36689	2080043.4	764140.6	17	33
36690	2090627.1	765450.1	27	52
36694	2085385.4	760174.0	12	22
36703	2075482.0	752872.5	40	76
36704	2074964.7	741216.6	11	21
36705	2076660.7	771452.2	17	33
36715	2082693.0	765510.2	14	26
36720	2074712.0	771363.0	40	76
36721	2084184.2	748384.3	41	78
36723	2087484.2	755614.4	31	59
36724	2075496.2	746564.6	60	113
36733	2089730.1	768744.6	21	41
36734	2070228.3	753072.3	32	60
36735	2108572.5	755996.0	18	35
36741	2118907.1	734241.8	52	99
36744	2082410.3	755540.7	49	93
36746	2075719.8	729305.8	49	93
36752	2081856.1	759448.8	15	29
36754	2081516.2	749743.2	29	56
36764	2102557.6	768181.5	79	149
67300	2069527.0	748394.8	0	0
67322	2025306.7	676575.1	58	111
67409	2090599.8	773414.4	0	0
67430	2084235.1	745742.2	18	34
67474	2063111.2	717722.5	0	0
67907	2073528.0	747172.6	5	10
68062	2057767.4	735155.3	16	30
68066	2064677.8	719041.5	8	15
68204	2067483.8	708804.5	21	40
68305	2100507.4	678250.1	0	0
68512	2041840.1	677237.4	38	73
68717	2065333.0	699809.2	20	37
68728	2069992.4	720991.4	19	36
68916	2074481.2	736955.2	0	0
69051	2074437.0	737033.9	0	0

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
69052	2074319.6	736618.8	0	0
69075	2090599.8	773414.4	0	1
69076	2090599.8	773414.4	0	0
69082	2086685.7	762820.0	0	0
69214	2085318.8	769445.9	0	0
69215	2085318.8	769445.9	0	0
69270	2073651.6	721899.1	7	12
69271	2071044.3	717757.0	4	7
69272	2064379.7	727294.1	2	4
69273	2070977.4	726010.1	4	8
69274	2070968.3	727335.0	0	1
69275	2069662.0	725993.1	6	12
69283	2077242.3	649244.9	0	0
69310	2056387.0	739099.3	0	1
69462	2074227.8	758589.8	0	0
69463	2074649.7	758282.0	0	0
69464	2074399.5	758390.1	0	0
69465	2074265.1	752672.1	0	0
69486	2094676.9	706064.1	1	2
69534	2076806.5	758177.1	39	73
69587	2108566.6	704921.0	8	15
69588	2106741.4	704016.3	8	16
69589	2110657.7	704059.5	9	18
69590	2110604.3	705318.6	8	16
69699	2033859.0	650883.9	45	85
69776	2027369.2	666539.7	6	12
69778	2027993.9	667372.1	0	0
69914	2114185.2	750719.9	9	17
69980	2063355.1	711380.5	0	0
69981	2061543.2	714289.0	0	0
70192	2115074.7	715336.3	1	1
70193	2114604.2	714742.0	0	0
70194	2109646.7	714484.8	7	14
70195	2114624.2	715039.9	0	0
70196	2114857.2	714986.8	1	2
70197	2117569.9	716839.9	0	0

Table H-1

Irrigation Pumping Average Rates 2007 to 2011

High Capacity Well No.	X-Coordinate[1] (feet)	Y-Coordinate[1] (feet)	Mean Pumping Rate 2007-2011	
			MG/year	gpm
70198	2115175.2	714685.1	0	0
70200	2114503.5	713398.7	13	25
70270	2117044.0	735537.4	13	24
70405	2110017.8	704725.1	0	0
70406	2108709.9	702063.0	0	0
70407	2108709.9	702063.0	0	0
70408	2108698.3	706033.2	0	0
70635	2028756.8	715438.3	0	0
70744	2013522.8	707783.1	61	117
70759	2010781.5	704296.4	62	119
70779	2040509.0	640242.6	32	60
70817	2128399.8	727749.1	20	39
70848	2110982.4	727756.7	0	0
70856	2036433.7	650915.9	50	95
70878	2094899.7	705881.4	0	0
70879	2094899.7	705881.4	0	0
71093	2045180.4	645477.0	0	0
71128	2043411.7	645161.1	0	0
75003	2015864.9	721564.7	0	0
75004	2015877.4	722924.8	0	0
75010	2057716.7	737774.5	4	8
75020	2017304.4	696437.1	0	1
82207	2080607.7	684642.4	2	5
82208	2080607.7	684642.4	1	1
82209	2080607.7	684642.4	0	1
82212	2096237.3	708530.6	192	366
82213	2084419.5	701937.2	0	0
90534	2102989.7	691446.6	1	3
90847	2102989.7	691446.6	0	0

[1] Datum: NAD83, Stateplane, Wisconsin South, FIPS 4803

Note: Irrigation pumping data obtained from the Wisconsin Department of Natural Resources database at http://dnr.wi.gov/org/water/dwg/hicap.html

Attachment I

Lake Survey of Pleasant Lake, Waushara County, Wisconsin

Prepared by:

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Greenville, WI 54942

LAKE SURVEY
of
PLEASANT LAKE
WAUSHARA COUNTY, WISCONSIN

July 25, 2012

Prepared by:
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Summary

Pleasant Lake is located in Waushara County, Wisconsin, about 5 miles southwest of Coloma, Wisconsin. The lake was surveyed for water level and lake bathymetry; the lake's area was estimated based on a historical aerial photo.

The water level was referenced to a benchmark used and maintained by Waushara County; the benchmark is positioned at an elevation of 991.63 feet. The water level was determined to be 979.79 feet on June 19, 2012 and 979.42 feet on July 17, 2012.

Lake bathymetry showed Pleasant Lake to have a maximum depth of 23.7 feet on June 19 and 23.3 feet on July 17, 2012. Volume was estimated from the survey data at 2,449,893 cubic meters (1,986 acre-feet).

Aquatic plant growth characteristics near the current water level appear well established.

Introduction

Pleasant Lake (T18N, R8E, Section 23) is located in Waushara County, Wisconsin about 5 miles southwest of Coloma, Wisconsin.

The lake is listed as a seepage lake with Northern Pike, Largemouth Bass, and Panfish present (1).

In July, 1964 the Wisconsin Conservation Department (Figure 1) surveyed Pleasant Lake using sonar. Measurements from the 1964 survey showed an area of 126.5 acres and a maximum depth of 24 feet (2); lake volume was estimated to be 1,849.9 acre-feet (2,281,892 cubic meters).

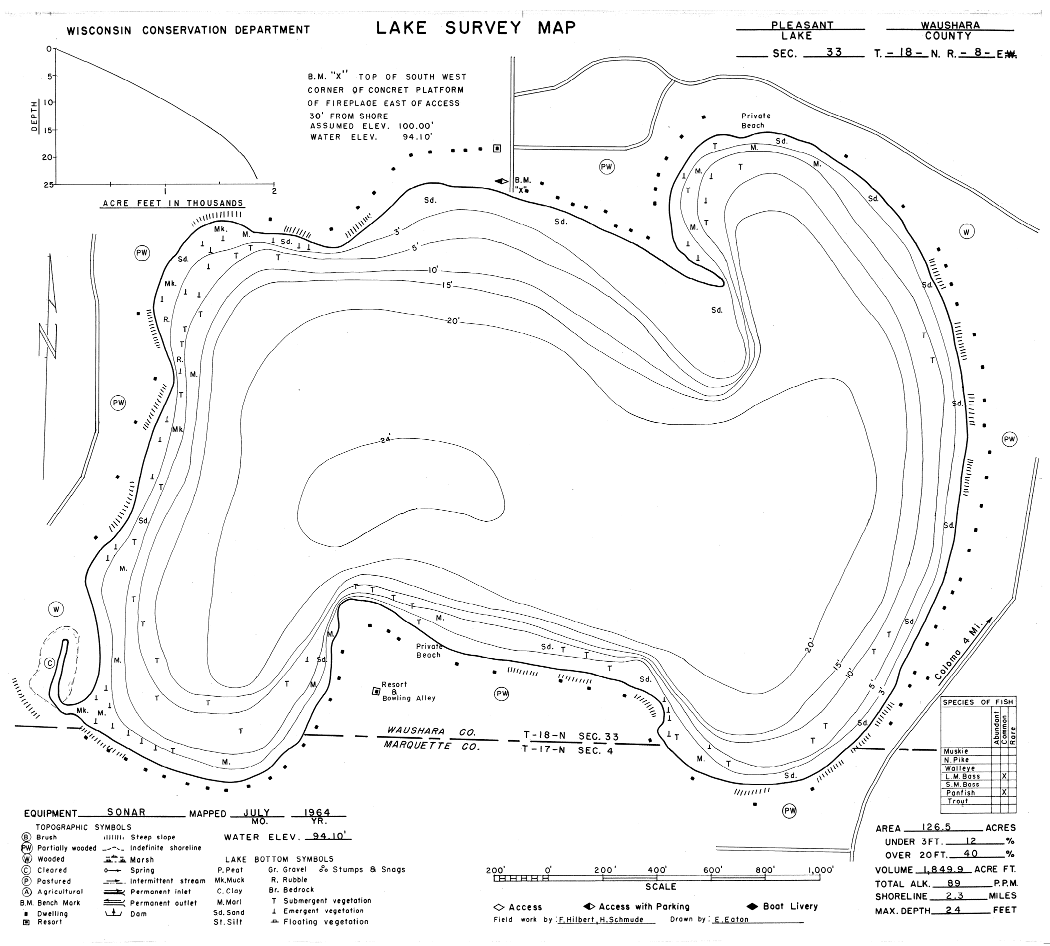

Figure 1. Wisconsin Conservation Department Lake Map, Pleasant Lake, Waushara County, Wisconsin, 1964.

On June 19th, 2012, Pleasant Lake was surveyed for lake bathymetry and area. On July 17, 2012, water levels were observed compared to a benchmark maintained by Waushara County. The balance of this report describes the methods and results from the 2012 Pleasant Lake survey.

Methods

Water Level

Water level was determined by measuring off of an established benchmark with a known elevation of 991.63 feet above mean sea level. The benchmark is located 21 feet south of the center line of 3rd Lane and 26 feet east of the public access centerline. The benchmark is a brass cap cast in a 6" concrete post at ground level. Water levels were measured on July 17, 2012 utilizing a surveyor's level and a 16-foot rod. The level was set up at a position approximately mid-way between the benchmark and the lake edge. Levels were measured at the benchmark and at the water's edge (both June 19, 2012 and July 17, 2012 water edges), and water levels were calculated based on the known benchmark elevation of 991.63 feet.

Lake Bathymetry and Area

Lake bathymetry was performed using a Lowrance HDS5 (Generation 2) GPS / Sonar Depth Locator. Transects were run mainly in a north-south orientation at about 75-foot increments across the Pleasant Lake area (Figure 2) at an average speed of about 5 miles per hour.

Data was logged onto a Lexar 4 gigabyte multi-use SDHC for later data upload. Data was then uploaded to the ciBioBase website portal where the lake area, bathymetry, volume, and plant information was calculated from the Lowrance HDS5 raw data.

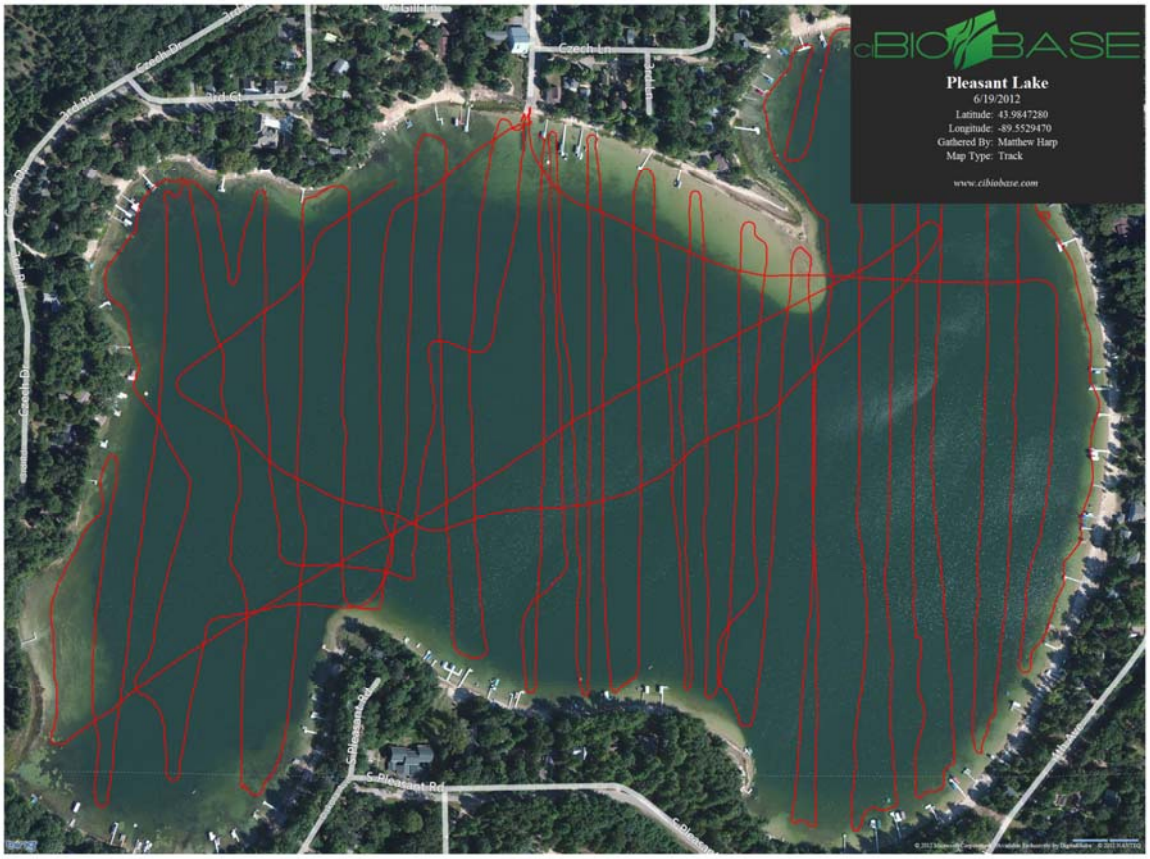

Figure 2. Sonar Survey Track Log, Pleasant Lake, Waushara County, Wisconsin, June 19, 2012.

Results and Discussion

<u>Water Level</u>

On June 17, 2012, Pleasant Lake water level was determined to be 979.42 feet above sea level as measured from the benchmark which has a recorded elevation of 991.63 feet.

Photographs were taken on June 19, 2012 which provided the ability to clearly identify the edge of the water on the concrete boat ramp. Based on these photos and observations made on July 17, 2012, the water level on June 19, 2012 was determined to be 979.79 feet.

<u>Lake Bathymetry and Area</u>

The June 19, 2012 sonar survey of Pleasant Lake yielded a depth contour map (Figure 3). Based on the June 19, 2012 survey, the maximum depth recorded was 23.7 feet, and the area of Pleasant Lake was determined to be 131.45 acres. Other results are shown in Table 1. Vegetation information was also surveyed with sonar readings and results are included on Figure 4. Vegetation density is depicted on Figure 4, with the color red representing the most dense vegetation and the color blue representing the least dense vegetation.

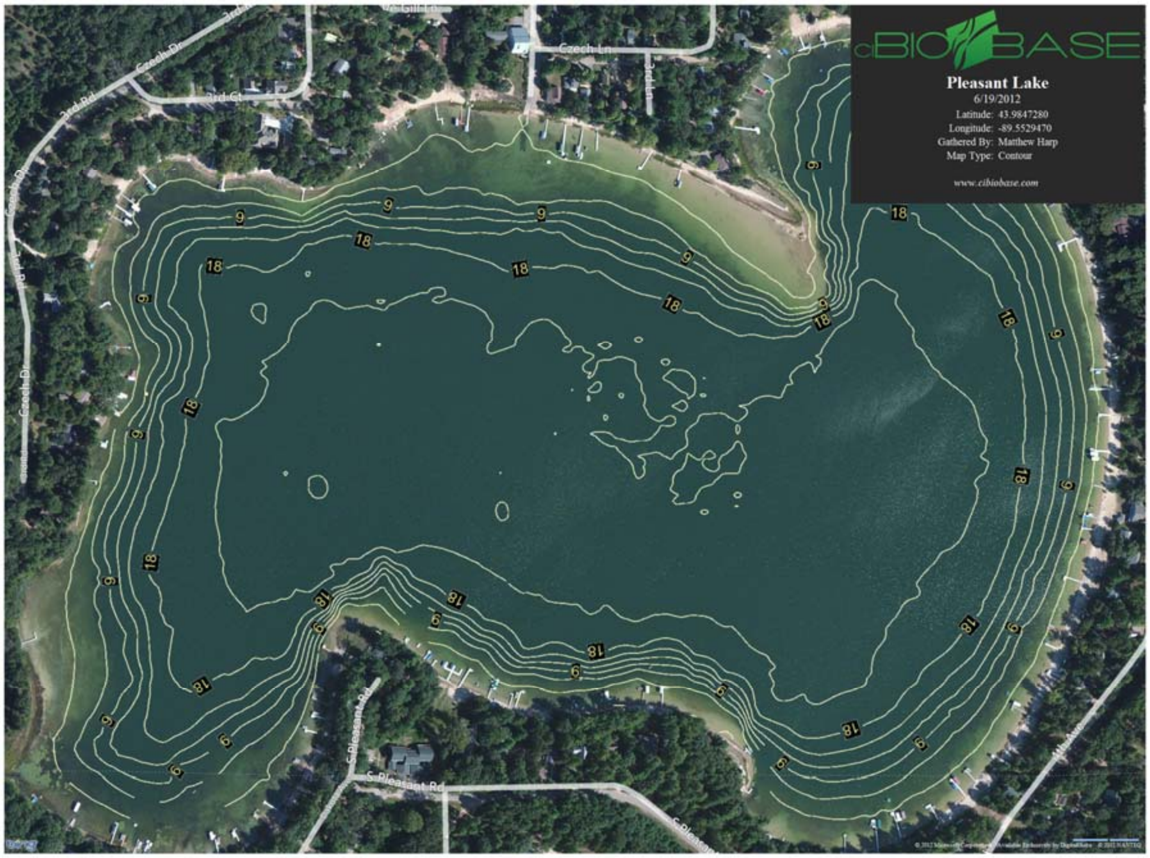

Figure 3. Depth Contour Map, Pleasant Lake, Waushara County, Wisconsin, June 19, 2012.

Table 1. Pleasant Lake Data Compilation, Pleasant Lake, Waushara County, Wisconsin, June 19, 2012.

Pleasant Lake
Marquette County
Wisconsin

Gathered On:	6/19/2012 7:27:16 AM
Gathered By:	Matthew Harp
Report Generated On:	6/20/2012 9:27:39 AM
High Water Temp:	78.75° F
Low Water Temp:	76.04° F
Actual Area Covered:	120.74 acres
Actual Percent Covered:	91.85%
Actual Volume Covered:	2250243.38 cu. m
Total Waterbody Acreage:	131.45 acres
* Total Lake Volume:	2449893.52 cu. m

Report URL:
http://files1.contourinnovations.com/ReportOutput/70060b78-296a-4ebc-9dd5-210f26d53116/report.htm

** Total Lake Volume is an estimation based on this data set only*

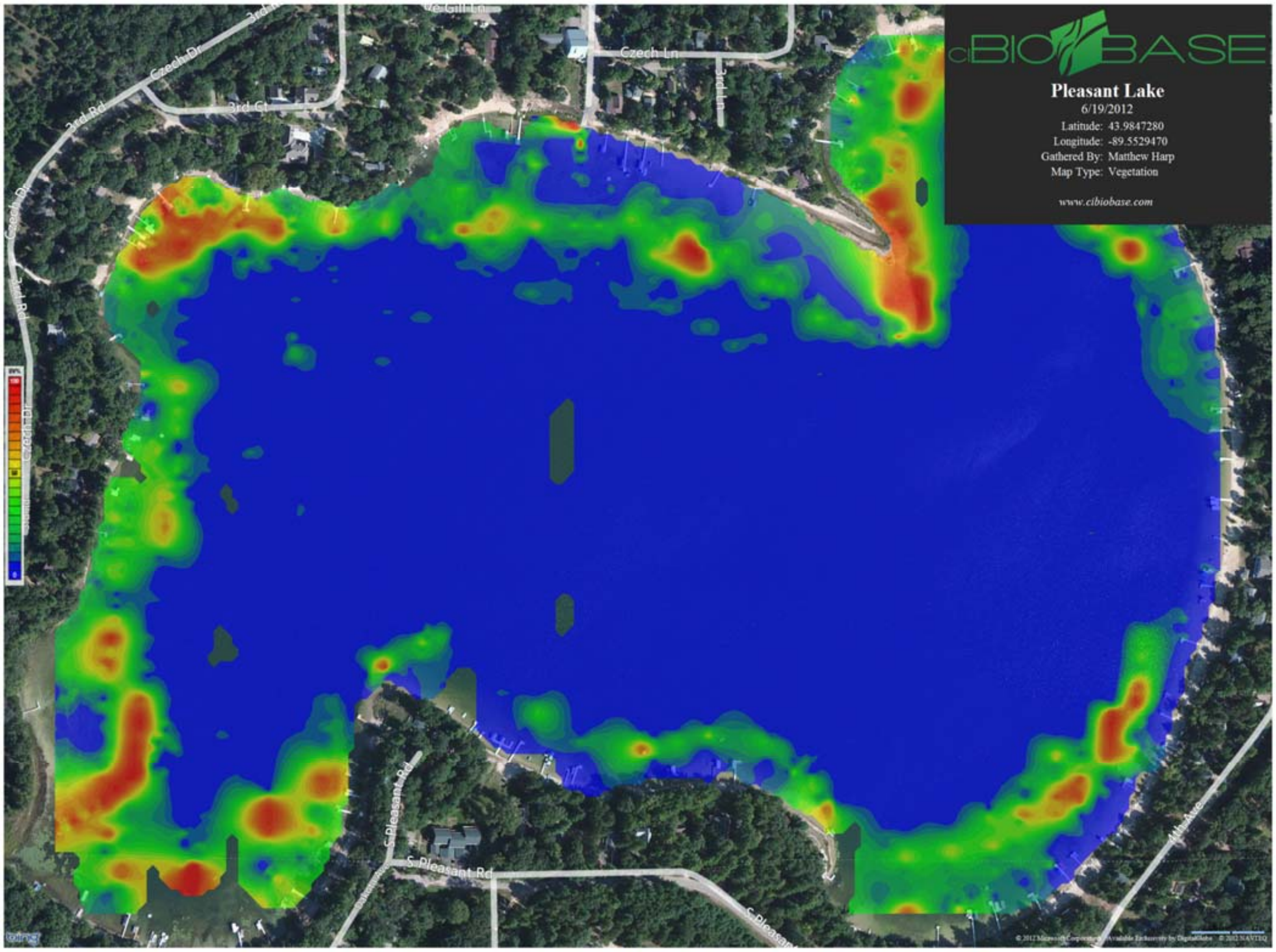

Figure 4: Vegetation Map, Pleasant Lake, Waushara County, Wisconsin, June 19, 2012.

Percent biovolume (otherwise known as Percent Volume Inhabited or PVI) represents the percent of the water column occupied by plant matter at each GPS location. It's a simply plant height divided by water depth multiplied by 100 for the collection of pings bound to each GPS location along a traveled path. Biovolume ranges from 0% (bare bottom) to 100% (vegetation growth to the surface). In addition to being visually intuitive, biovolume is an indicator of recreation nuisance conditions (e.g., surface growth), changes due to invasive species introductions (which typically grow closer to the surface than native species), and fish habitat conditions. Numerous research studies have demonstrated that fish feeding success and prey availability depends on how much visual barriers are present in the water column. Some biovolume is needed to support prey communities and water quality (50% is a good rule of thumb), but too much (>80%) can promote overly abundant and stunted fish communities and create recreational nuisances. ciBioBase produces a visually intuitive map and data that can help manage lakes for multiple uses. On the above figure, biovolume ranges from 0% (blue) to 100% (red).

References

1. Wisconsin Department of Natural Resources. 1991. *Wisconsin Lakes*. PUBL-FM-800 91. Bureau of Water Resources Management (Lakes Section) and Bureau of Fisheries Management (Aquatic Education). Madison, Wisconsin.

2. Wisconsin Conservation Department. *Lake Survey Map for Pleasant Lake. http://dnr.wi.gov/lakes/maps/dnr/0106900a.pdf*.