To:	Rex Vaughn, Chair Cedar Lake Improvement Board	**Date:**	March 8, 2022
From:	John Jacobson, PE, Senior Engineer Mark Kieser, Senior Scientist Kieser & Associates, LLC	**cc:**	Mike Foster, Env. Engineer Kieser & Associates, LLC

RE: Findings for Stage 2 of Task 6 – Cedar Lake Phase III Augmentation Assessment

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Kieser & Associates, LLC (K&A) has been managing an ongoing water level monitoring program at Cedar Lake, Alcona and Iosco Counties, Michigan since 2005. Recognizing early the potential need to augment lake levels during low rainfall summer recreational seasons,[1,2] K&A assessed augmentation options in a 2011 report to the Cedar Lake Improvement Board (CLIB).[3] That 2011 Augmentation Feasibility Report provided long-term recommendations to sustain summer lake levels that included:

- Surface water hydrology modifications to reduce watershed losses from the King's Corner culvert
- Sherman and Jones Creek modifications to enhance summer discharges
- Use of the 12-inch augmentation test well at the Sherman Creek site for future groundwater augmentation
- Installation of additional groundwater augmentation wells as needed to maintain desired lake elevation goals

The first two of these recommendations have been largely completed to the extent possible to optimize surface and groundwater flows to Cedar Lake during summer months. These efforts have vastly improved stabilized and sustained lake levels, however, during exceptionally dry years (both winter and summer periods), the need for additional augmentation has become apparent as reflected in the latter two recommendations.

As part of the 2021 Task 6 (Stage 2) work scope under the CLIB, K&A was authorized to assess the next level of augmentation well use to help maintain recreationally desired water levels during summer months, particularly during years with limited precipitation. These current efforts included the following initial two stages of assessment:

1. Sample the existing augmentation well at the Sherman Creek site for PFAS contaminants, and then simulate future pumping conditions in the context of reported PFAS groundwater

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[1] Kieser & Associates, LLC (K&A). 2005. "PHASE I – Final Report for the Preliminary Hydrologic Evaluation of Cedar Lake with Reference to Lake Levels (Alcona & Iosco Counties, MI)" Prepared for the Alcona/Iosco Cedar Lake Association, Inc., Greenbush, MI 49738, July 15, 2005, 148 pp.
[2] K&A. 2006. "PHASE II – Final Report for Additional Hydrologic Evaluation of Cedar Lake with Reference to Lake Levels (Alcona & Iosco Counties, MI), Prepared for the Alcona/Iosco Cedar Lake Association, Inc., September 18, 2006, 89 pp.
[3] Kieser & Associates, LLC. 2011. "Cedar Lake Augmentation Feasibility." Prepared for the Cedar Lake Improvement Board, August 25, 2011, 118pp.

contamination associated with Wurtsmith Air Force Base contaminant plume to determine whether the CLIB Sherman Creek property was suitable for multiple augmentation wells.[4]

2. If no PFAS concerns were identified in Stage 1, proceed to Stage 2 for preliminary engineering and costing of equipment needs and operation of multiple augmentation wells necessary to maintain desired lake levels under a variety of conditions.

K&A has completed both to these initial two stages of augmentation well use assessment. Non-detect PFAS laboratory results were previously communicated to the CLIB from sampling of the existing 12-inch augmentation test well. This memorandum presents results from preliminary engineering and costing of equipment and operation for augmentation wells including capacity needs to maintain lake levels and considerations of regional groundwater contamination to the south of Cedar Lake.

For the augmentation well assessment, K&A studied several historic and current data sets including the following (supplemental information is provided for reference in appendices to this memorandum):

- Lake level and precipitation data between 2014 and 2021, particularly years 2020 and 2021 to identify augmentation needs for maintaining water levels between the legal lake level of 608.2 and one foot below legal lake level at 607.2 as a targeted range for suitable summer lake levels (see Appendix A for related graphs and data summaries used in this historic examination)
- Inflows to the lake from precipitation with direct measurements from Sherman Creek and Jones Creek (Appendix B)
- State of Michigan PFAS groundwater testing results for regional aquifer conditions (Appendix C)
- Publicly available well data for the sections west of Cedar Lake (Appendix D)
- Cedar Lake Augmentation Feasibility Study of August 2011 and particularly, the Williams & Works Groundwater Resource Evaluation Cedar Lake Wetlands Improvement Project aquifer testing (excerpted and included here as Appendix E)

The following sections provide results of historic data assessment and modeling efforts to assess groundwater augmentation well considerations for maintaining suitable summer-time Cedar Lake levels.

Modeling Lake Level and Augmentation Scenarios

Lake levels were simulated with a Microsoft Excel tool developed by K&A that uses equations derived from the Soil & Water Assessment Tool (SWAT).[5] SWAT is a widely used, river basin-scale model originally developed by the United States Department of Agriculture, Agricultural Research Service. The model utilizes temperature and precipitation data to predict soil moisture, stormwater runoff, evaporation, groundwater exchange, and lake volume. The tool was modified for Cedar Lake by adding a pump inflow element.

The K&A-derived model was used to simulate lake levels under current conditions (no pumping), and three groundwater well pumping rates of 1,000, 1,500 and 2,000 gallons per minute (gpm) for both 2020 and 2021. This provided the opportunity to simulate low precipitation recreational season conditions, though starting the season at or above legal lake level in 2020. The very dry, late winter/early spring of

[4] At the time of the 2011 K&A Feasibility Study, groundwater PFAS contamination was not a publicly identified issue in the region. Testing at Cedar Lake became necessary following discovery of Wurtsmith Air Force base groundwater contamination and a groundwater PFAS plume extending northward, which eventually impacted Van Etten Lake and local private water wells. Thus, testing was implemented by K&A at the 12-inch augmentation test well to determine whether the aquifer beneath the Sherman Creek CLIB property was contaminated, which if so, would negate the use of possible augmentation wells at this site.

[5] Neitsch, S. L., J. G. Arnold, J. R. Kiniry , and J. R. Williams. 2011. Soil and Water Assessment Tool Theoretical Documentation—Version 2009. TWRI Report TR-406. Texas Water Resources Institute, College Station, Texas.

2021 with lake levels beginning 0.8 feet below the legal lake level, but generally average summer precipitation, provided conditions to assess early season deficits. Importantly, measured 2021 conditions helped validate how summer precipitation critically influences lake levels. For example, during dry, high air temperature (i.e., high evaporation) periods between summer storms in 2021, the lake rapidly lost between 20.5 and 24.0 million gallons of water per day (see Appendix A). With precipitation events providing greater than one inch of rain, the lake responded with rapidly increasing lake levels of over 0.5 feet within 18 hours. This is attributed not only to direct rainfall onto the lake surface, but also the enhanced tributary flows from Sherman and Jones Creeks (see Appendix B). A volume mass balance and an assessment of increased tributary inflows were completed to validate these 2021 conditions for augmentation scenarios. These validation assessments are as follows.

Volume Mass Balance

A mass balance analysis of summer (July/August) 2021 conditions was developed for measured conditions and calculated gains/losses. This mass balance assumes:

Precipitation + Runoff + Pumping – (Evaporation + Seepage) = Changed Lake Level

Table 1 presents the mass balance results. For the months of July and August, it rained 10.01 inches and the lake level fell by 0.306 feet. With precipitation onto Cedar Lake plus the runoff measured from Sherman Creek and Jones Creek, subtracting lake evaporation and seepage (predicted by the model from lake levels), the resultant pumping rate that would have maintained the lake level was computed at 1,200 gpm. This rate would have made up the losses associated with the drop in lake level during this time period.

Table 1 – Mass Balance Calculations for July/August 2021 Lake Levels.

Month	Precipitation onto Lake Surface (inches)	Evaporation (mm)	Seepage (mm)	Changed Lake Level (ft)	Runoff	
					Jones Creek (MG)	Sherman Creek (MG)
July	6.74	195	129	607.022	237.25	67.44
August	3.27	169	165	606.716	147.03	27.83
Subtotals	10.01	364	294	-0.306	384.29	95.27
MG subtotals	*292.18*	*388.61*	*313.88*	*-107.18*	*384.29*	*95.27*
Total pumping offset volume		107.18	MG			
Days pumping		62	days			
Pumping rate		1,200.51	gpm			

Inflowing Streams to Cedar Lake

CLIB project enhancements to: 1) minimize watershed flow losses at the Kings Corner Culvert, and; 2) construct Sherman Creek instream grade structures have collectively enhanced surface and groundwater storage in this portion of the drainage to Cedar Lake. These have resulted in increased flow volumes (see Appendix B). Though somewhat inadvertent, Road Commission improvements to the Jones Creek culvert under West Cedar Lake Road appear to have effectively connected water storage in the upstream swamp to the lake. Summer rainfall onto these areas now directly translates to clean runoff rapidly discharging to Cedar Lake via Jones Creek. This is attributed to the larger diameter of the replaced culvert and lower invert elevation allowing almost four times more discharge of accumulated precipitation volumes than with the previous, smaller diameter/higher invert elevation culvert.

Precipitation in the summer of 2021 across nearly 600 acres of topographically level wetlands immediately upstream of West Cedar Lake Road, released rapidly to the lake through the larger culvert, resulted in peak lake level responses within about 18 hours. Previously, such runoff was not released into the lake, with a portion of this lost to evapotranspiration and seepage (which may have ultimately returned to the lake via groundwater, though greatly delayed compared to runoff). The 600 acres of Jones Creek swamp extends westward to, and beyond the railroad tracks traversing the northwestern cedar swamp watershed of the lake. Further defining controlling factors within the Jones Creek drainage will be necessary for determining benefits of groundwater augmentation to help stabilize and enhance lake levels.

Modeling Groundwater Pumping Scenarios

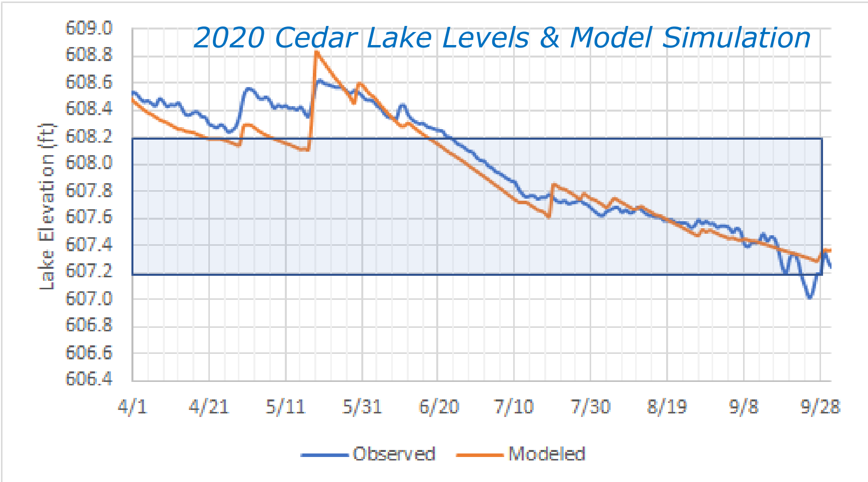
The mass balance and tributary flow assessment validated K&A model conditions for simulating lake level elevations in 2020 and 2021. Baseline conditions were then used to assess select groundwater well pumping rates for augmenting observed lake elevations necessary to sustain desired levels. Figures 1a-d show 2020 lake levels with augmentation well pumping at rates of: 0 gpm (i.e., observed conditions vs. model simulation of these measured baseline conditions); 1,000 gpm; 1,500 gpm, and; 2,000 gpm against the observed lake levels, respectively. Figures 2a-d illustrate similar information for 2021. For both years, the 0 gpm pumping scenarios show that modeled levels match well with observed lake levels providing confidence for predicted pumping conditions under various augmentation scenarios.

For 2020, observed lake levels remained at about 608.2 until late June (Figure 1a). When these passed below this legal lake level, pumping at 1,000 gpm beginning on June 24th (Figure 1b) would have kept the lake level at or above 607.7 (within six inches of the legal lake level) for the remainder of the recreational season. Pumping at 1,500 gpm (Figure 1c) or at 2,000 gpm (Figure 1d) would have provided only limited additional lake level benefits, and still not have achieved or sustained the 608.2 legal lake level. As will be noted later in this memorandum, the limited additional benefits of increased pumping beyond 1,000 gpm will have significant cost ramifications.

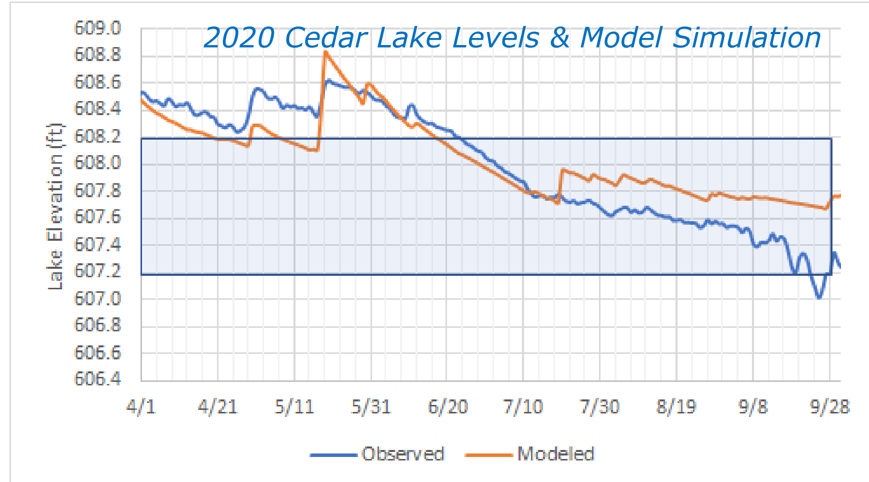
In April of 2021, observed lake level was 0.8 feet below the legal elevation (Figure 2a). By late June, water levels dropped another foot over these early April levels. July precipitation brought water levels to near the lower bound of target management goals (i.e., 607.2) before again dropping in August. Augmentation well pumping, if initiated on April 1, 2021, suggests that any of the three pumping scenarios (Figures 2b-d) might provide sufficient replacement volumes to meet or nearly meet the 607.2 level threshold for the majority of the recreational season. At 1,000 gpm, late June/early July levels would have dropped below this threshold for a few weeks, though would have otherwise largely provided lake levels in the target range. Pumping at 1,500 gpm would provide most of the recreational season levels within this range. At 2,000 gpm, pumping would have resulted in a few additional inches of lake level, approaching the legal lake elevation.

Given the dramatic increase in Jones Creek flows in 2021 under the typical average summer rainfall, an additional model simulation for seasonal pumping conditions was conducted to further assess ramifications of observed tributary runoff discharges. For the alternative pumping scenarios shown in Figures 3a-d, Jones Creek flows were artificially set at only 25% of the actual measured 2021 flows. The baseline (0 gpm) condition (Figure 3a) provides a sense of how important Jones Creek has become as a large source of inflow into Cedar Lake. With the now larger diameter culvert, this scenario suggests what the lake level response may have otherwise been with the restricted flows through the smaller culvert. The 1,000 gpm scenario in Figure 3b suggests that this level of pumping would likely have only roughly matched observed 2021 conditions, well short of the targeted lake level goals. Pumping at 1,500 gpm would still have missed these levels for a good portion of the recreational season (Figure 3c); while 2,000 gpm would achieve such goals (Figure 3d). The need for these higher (and costly) pumping rates in this last set of simulations highlights the critical hydrologic contributions of Jones Creek, now with the larger culvert (and at comparatively minimal road maintenance cost).

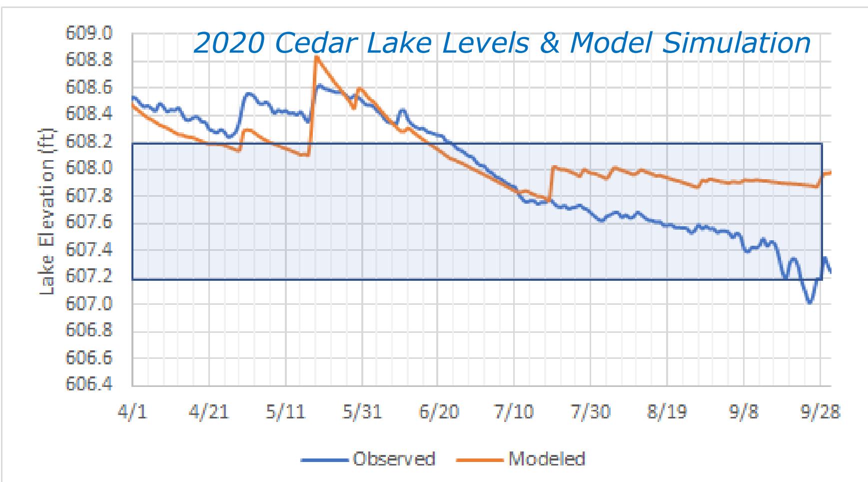
a) 0 gpm (2020)



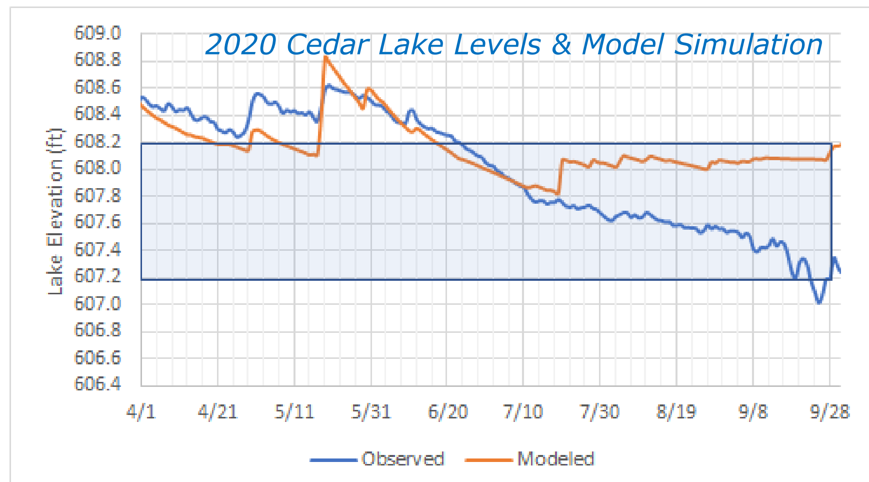
b) 1,000 gpm (2020)



c) 1,500 gpm (2020)

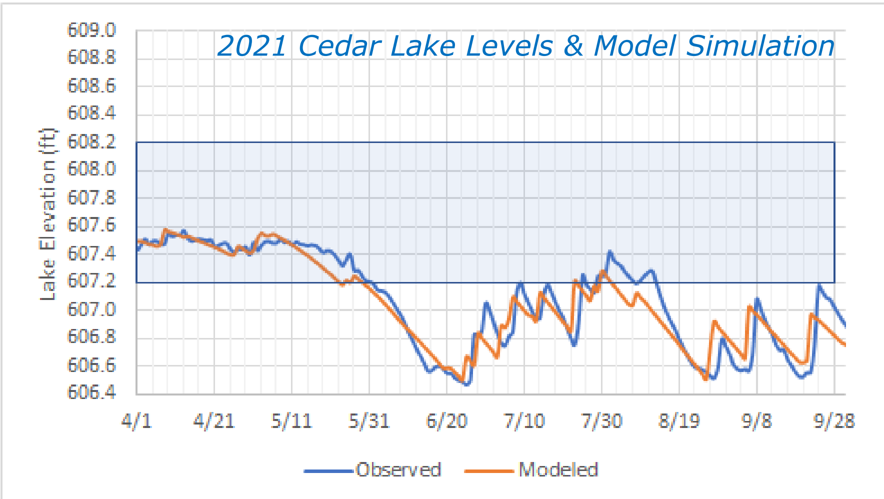


d) 2,000 gpm (2020)

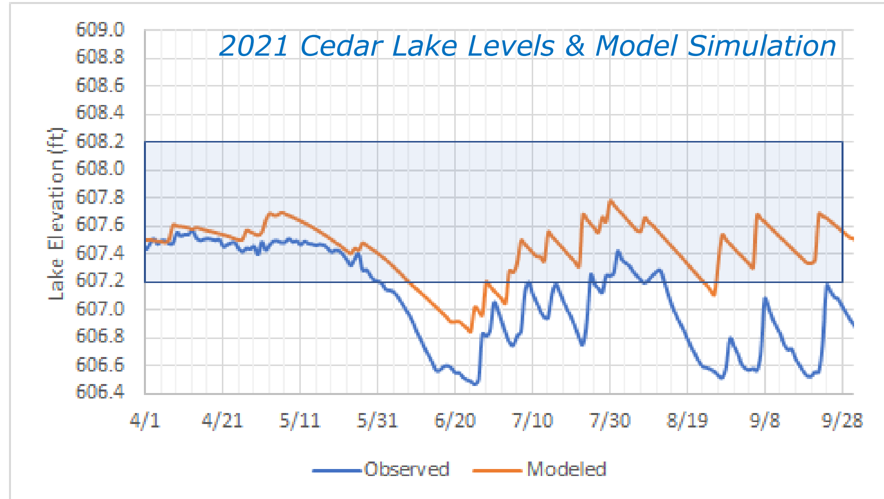


Figures 1a-d – Modeling results of groundwater pumping vs. baseline monitored lake elevations for 2020; a) 0 gpm pumping; b) 1,000 gpm; c) 1,500 gpm; d) 2,000 gpm (shaded area represents lake level management target from legal lake level at 608.2 to minus one foot at 607.2).

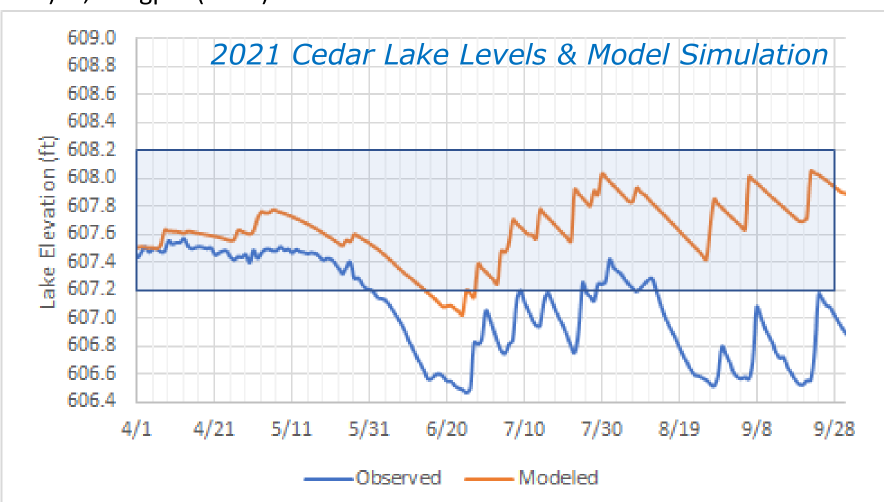
a) 0 gpm (2021)



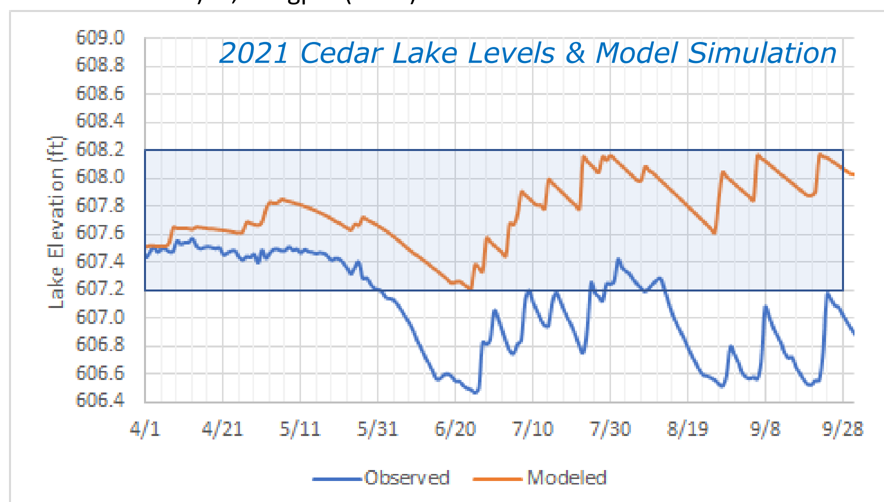
b) 1,000 gpm (2021)



c) 1,500 gpm (2021)

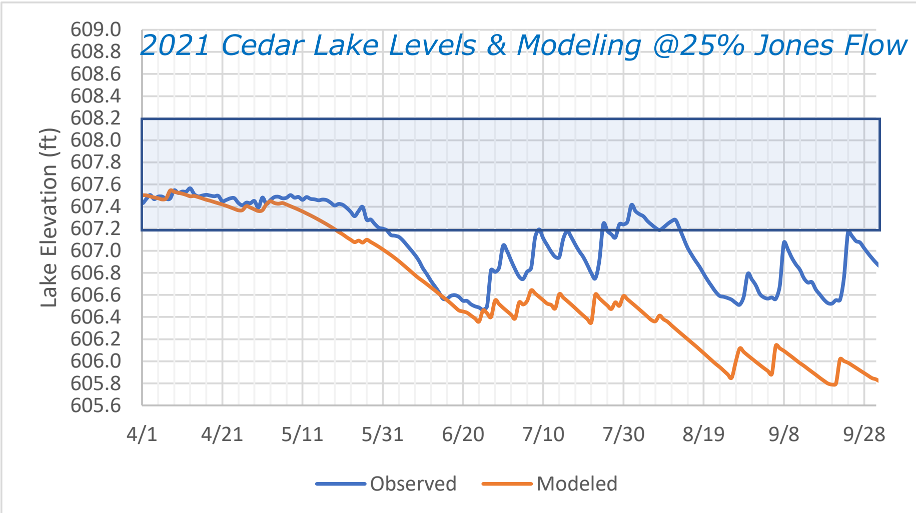


d) 2,000 gpm (2021)

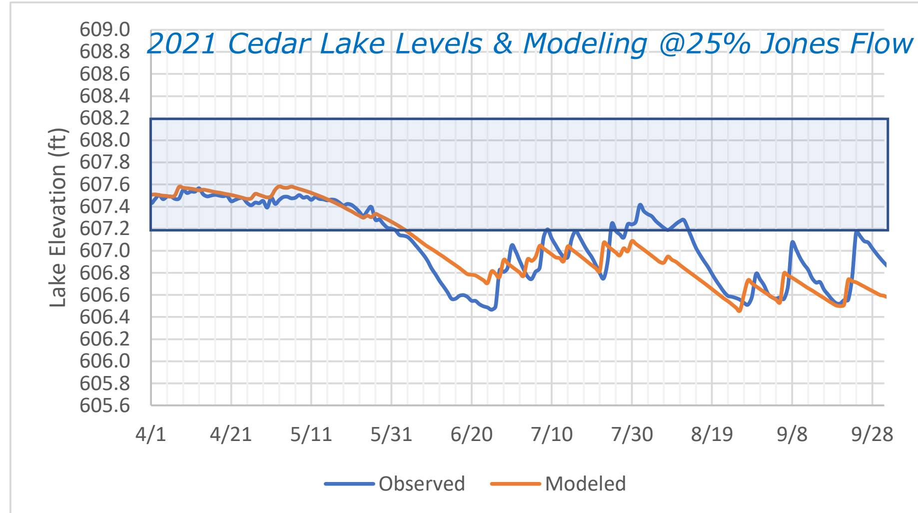


Figures 2a-d – Modeling results of groundwater pumping vs. baseline monitored lake elevations for 2021; a) 0 gpm pumping; b) 1,000 gpm; c) 1,500 gpm; d) 2,000 gpm (shaded area represents lake level management target from legal lake level at 608.2 to minus one foot at 607.2).

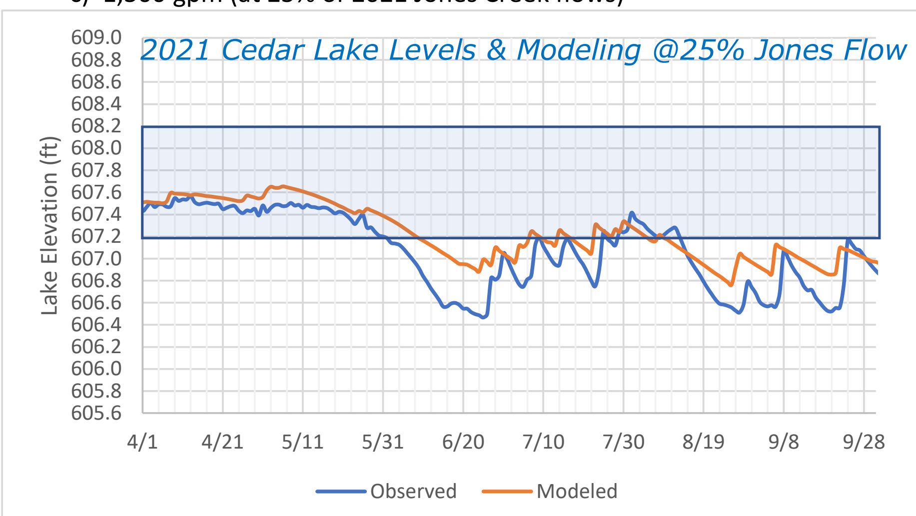
a) 0 gpm (at 25% of 2021 Jones Creek flows)



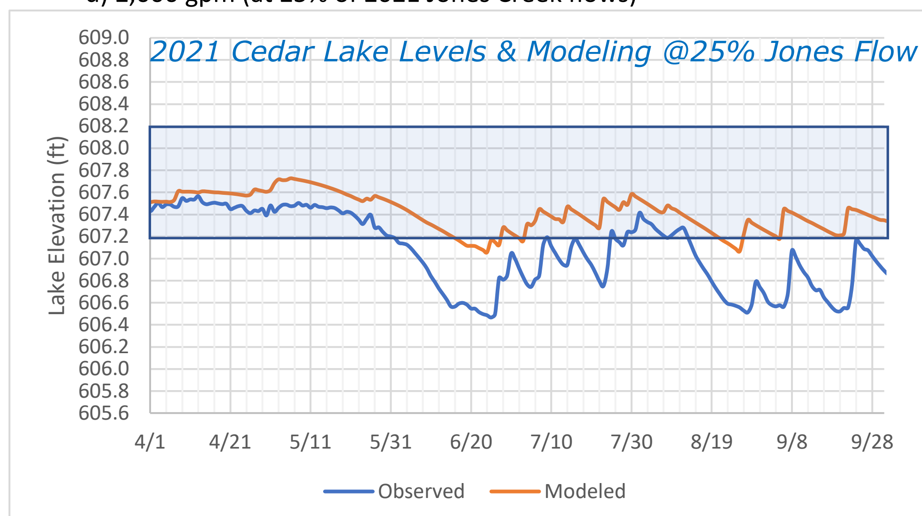
b) 1,000 gpm (at 25% of 2021 Jones Creek flows)



c) 1,500 gpm (at 25% of 2021 Jones Creek flows)



d) 2,000 gpm (at 25% of 2021 Jones Creek flows)



Figures 3a-d – Modeling results of groundwater pumping at 25% of 2021 measured Jones Creek flows vs. baseline monitored lake elevations for 2021; a) 0 gpm pumping; b) 1,000 gpm; c) 1,500 gpm; d) 2,000 gpm (shaded area represents lake level management target from legal lake level at 608.2 to minus one foot at 607.2).

Proposed Augmentation Capacity

Based on modeling of 2020 and 2021 recreational season lake levels, two separate well sites, each pumping 500 to 600 gpm are currently recommended to maintain sufficient water levels to within one foot of legal lake level in the months of June, July, August, and September. As identified in the K&A 2011 Augmentation Feasibility report, average rainfall for these four months between 2008 to 2010 was approximately 16 inches. In 2020, precipitation for this summer period was 8.57 inches, and in 2021, 16.5 inches. In 2020, the lake level started out high from a wet winter and early spring rains, then with only 54% of the summer average rainfall, observed lake levels dropped to one foot below legal lake level, remaining within the targeted range of suitable lake levels. With a pumping option at 1,000 gpm, late June augmentation well pumping would have kept summer levels to within about four to six inches of the legal lake elevation of 608.2.

In 2021, while the summer average rainfall kept the lake level relatively constant (between elevation 606.4 and 606.8), it remained below the targeted lower management threshold of 607.2 given unusually low springtime lake levels. As indicated in model discussions, a 1,000 gpm pumping rate starting in April of 2021 would have kept summer lake levels above this 607.2 threshold, except for approximately two weeks in June where it would have dropped to 606.8.

It would be difficult at this time to suggest that surplus augmentation well capacity to maintain summer water levels at 608.2 would be a reasonable goal. This is based on precipitation during summer months remaining the most significant controlling factor for recreation season lake levels, and modeling that shows even doubling the pumping capacity to 2,000 gpm still does not achieve or sustain levels at the legal lake elevation. Comparatively, moderate pumping capacity at 1,000 gpm appears sufficient to maintain summer levels within one foot of lake outlet discharge across a variety of observed conditions.

Augmentation Well Site Recommendations

Based on K&A evaluations noted above, there are two specific areas in the northwest contributing watershed of Cedar Lake both considered suitable for placement of five separate 100 gpm groundwater augmentation wells. These well site locations are shown in Figure 4. They are considered optimal as groundwater withdrawals can be discharged to wetlands that lead to either Sherman Creek in the south, or Jones Creek in the north. This minimizes the need for long-distance conveyance to the lake via artificial conduits. Lands surrounding Sherman Creek, west of West Cedar Lake Road, are also under the ownership and control of the CLIB (Figure 5). The potential pumping well influence zone of both areas does include select private water wells, particularly in the Jones Creek area (Figure 6). Further evaluations would be necessary to determine specific impacts with augmentation pumping and final well orientation in both areas.

No well sites are recommended south of Kings Corner Road. The risk of PFAS contamination from Van Etten Lake increases the risk of impact to the local aquifer, and potential discharge to the lake through augmentation well pumping. If requested in the next study phase, any sites south of Kings Corner Road would require additional testing both for PFAS and aquifer capacity (see Appendix C for EGLE PFAS monitoring well locations and recent sampling results).

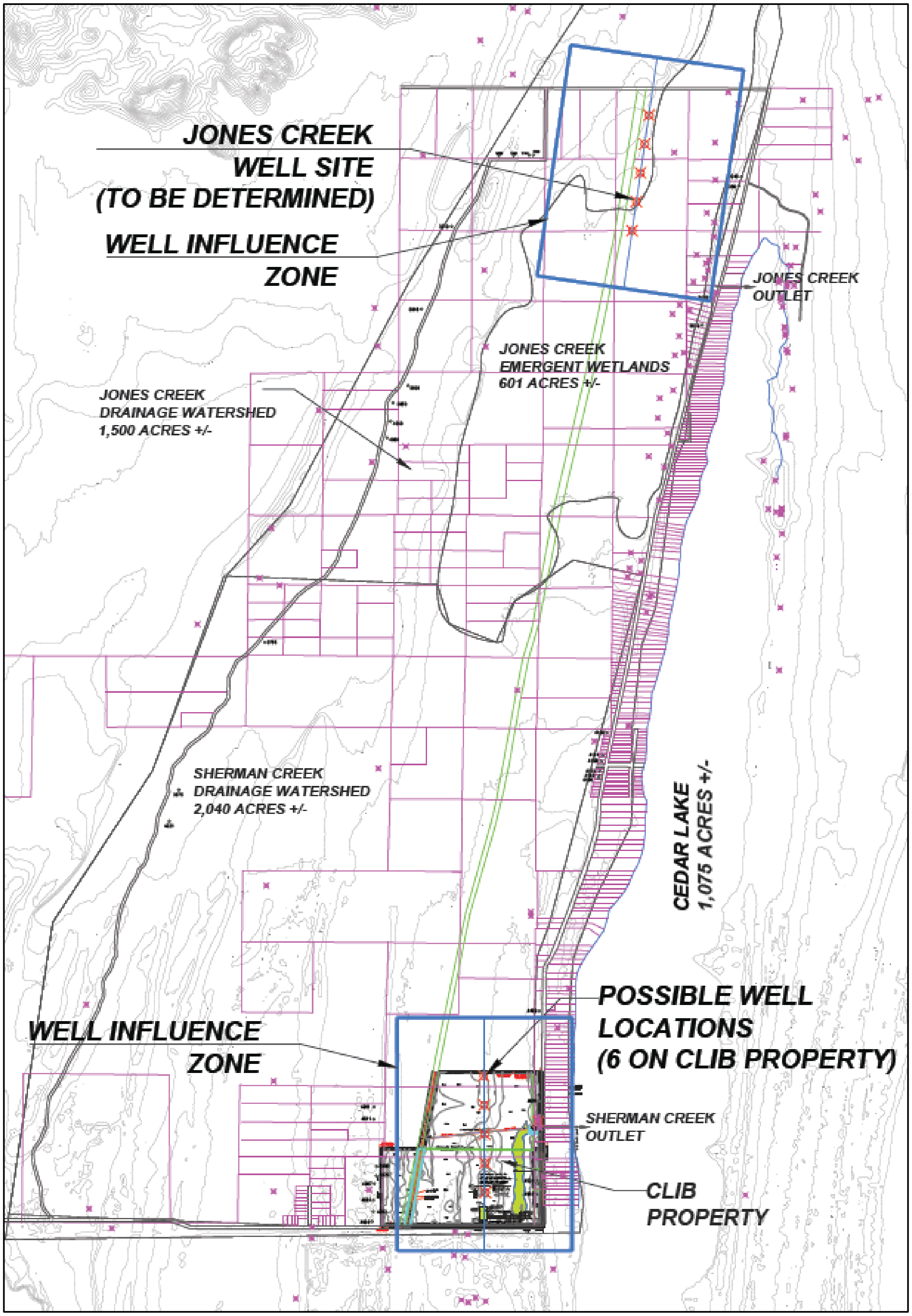


Figure 4 – Proposed well site locations at the Sherman Creek CLIB property (five new wells plus the existing 12-inch well), and Jones Creek (five new wells). Well influence zones are denoted for each area based on the layout of new wells illustrated by ☒ symbols.

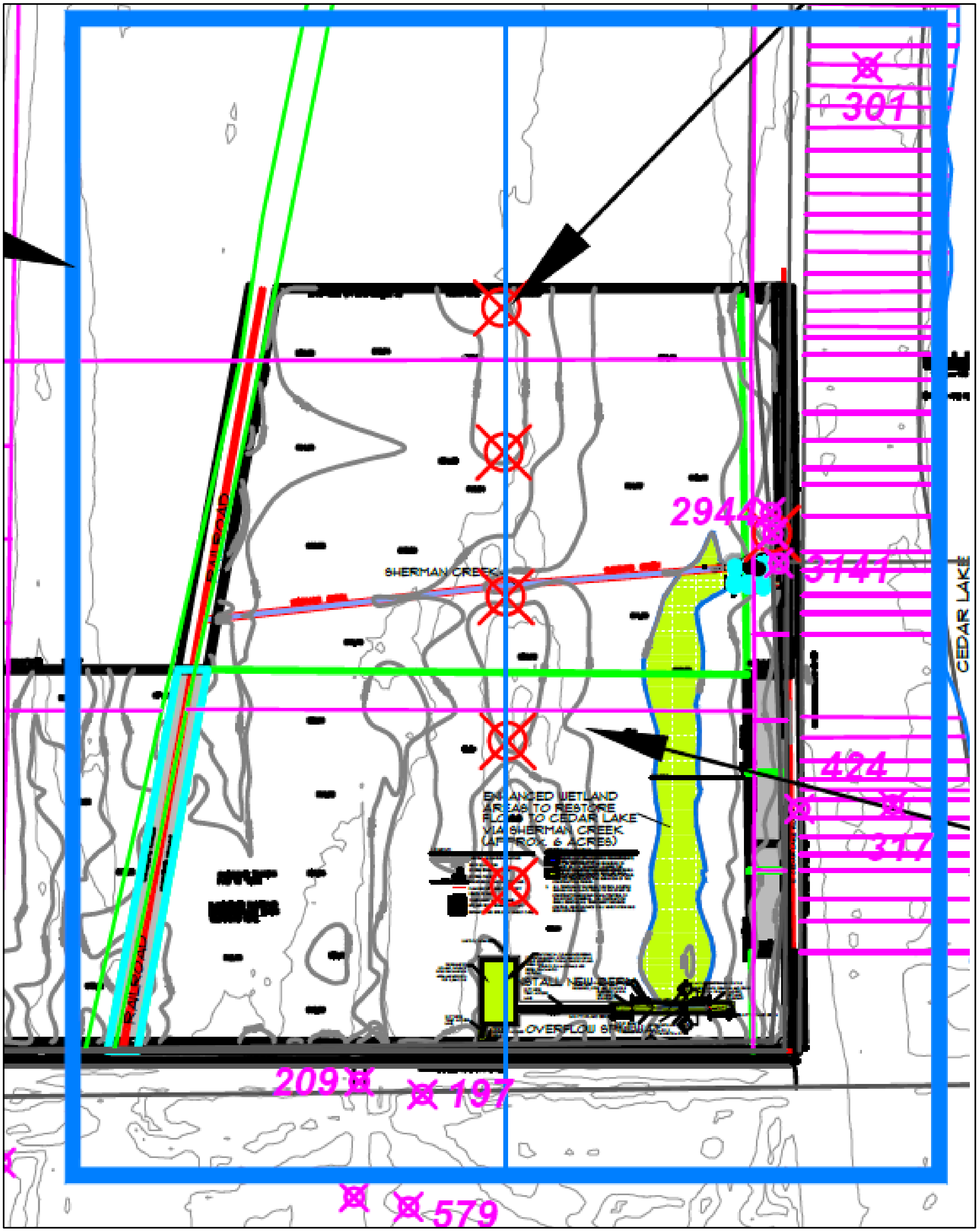


Figure 5 – Proposed well site locations at the Sherman Creek CLIB property (five new wells plus the existing 12-inch well). Well influence zones are denoted by blue borders based on the layout of new wells illustrated by ⊠ symbols. Private wells are numbered.

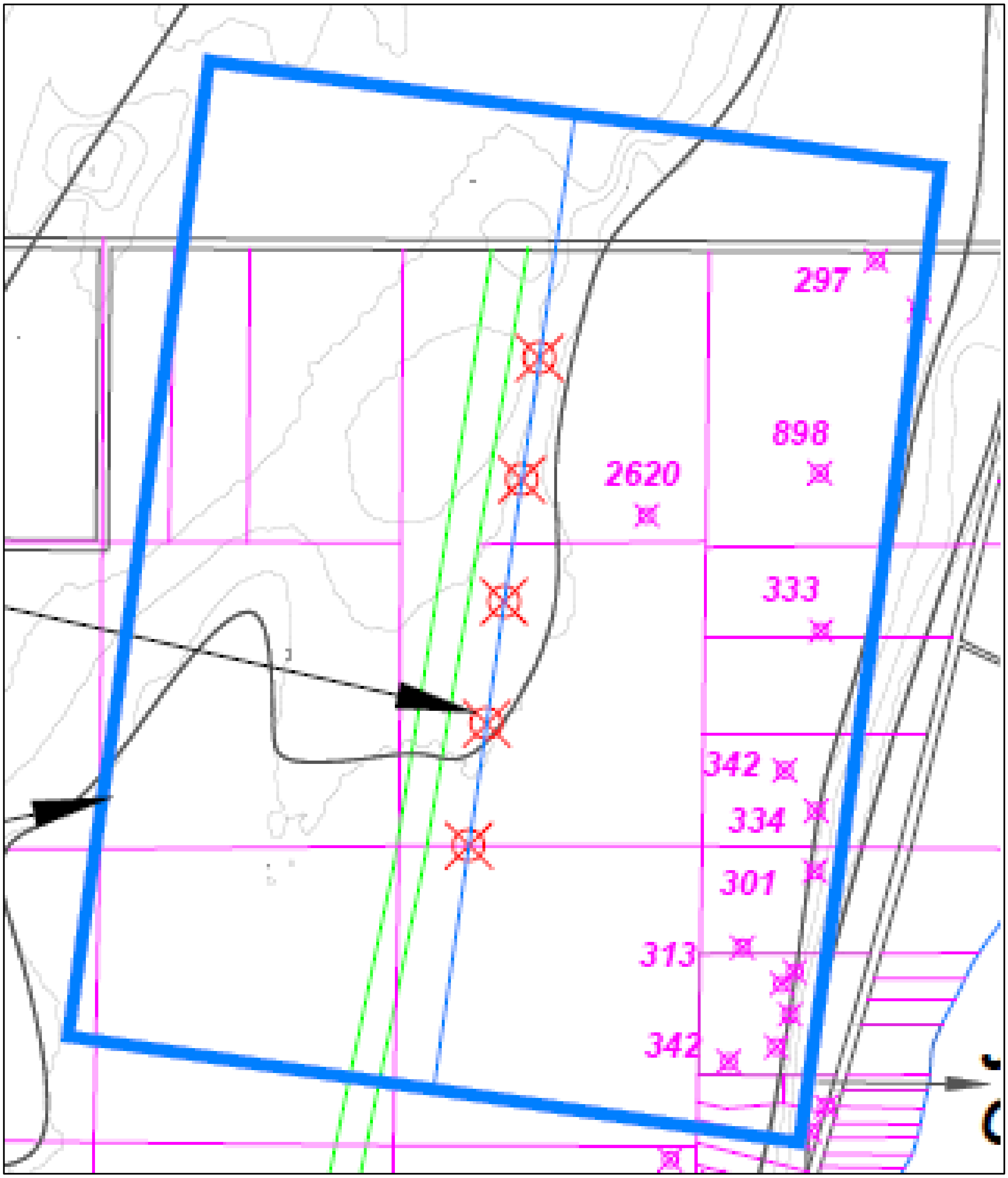


Figure 6 – Proposed well site locations at Jones Creek (five new wells). Well influence zones are denoted by blue borders based on the layout of new wells illustrated by ☒ symbols. Private wells are numbered.

<u>Augmentation Well Site Conditions</u>

K&A reviewed relevant well logs and well depths from Iosco and Alcona County Sections 24N 9E Sec's 4 and 10, and 25N 9E Sec's 15, 16, 22, 28, 32, and 33, respectively (see Appendix D for these data, including yellow-highlighted records for wells located in the influence zone of the proposed well fields). A confined aquifer was identified from these well logs that is similar to that observed during the aquifer testing of the 12-inch test well identified in the Williams and Works study of 2010 (see Appendix E of this memo for an excerpted copy of this assessment from the K&A, 2011 Augmentation Feasibility Study). The 2010 assessment identified glacial deposits in the area as "Lacustrine Sands and Gravels". Thus, K&A expects this aquifer to be generally homogenous as these were bottom deposits of Lake Huron when the water elevation was higher. This aquifer is most likely fed by the Pine River Basin to the northwest along with some possible leakage from shallow groundwater.

The Williams and Works study concluded that the aquifer would be able to provide 500 gpm from each well site pumping for 100 days or more with a well configuration of five wells, set 500 feet apart with the drawdown influence of 3,000 feet wide by 4,000 feet long depending on the axis orientation of the well set. The confined aquifer, if pumped at 500 gpm for 100 days or more would draw water from an area approximately 2,500 to 3,000 feet from the centroid of the well field.

A well assessment tool from the State of Michigan[6] was used by K&A in the 2011 Augmentation Feasibility Report to determine suitable locations of possible well sites in the northwest watershed area of Cedar Lake. Figure 7 is a snapshot of excerpted assessment results from that report. For all locations and depths where groundwater might be withdrawn at a 500 gpm flow rate, no likely Adverse Resource Impacts were identified for those area wells included in Appendix D or surface water features.

Results from MDEQ Groundwater Withdrawal Assessment Tool: Adverse Resource Impact (ARI) Zone at various locations surrounding Cedar Lake.

Pumping Rate (GPM)	Well Depth (ft)	Location				
		1	2	3	4	5
500	25-50	A	B	A	A	A
	51-75	A	B	A	A	A
	76-100	A	B	A	A	A
750	25-51				B	
	51-76				B	
	76-101				B	
1,000	25-51	A	D	A	D	A
	51-76	A	D	A	D	A
	76-101	A	D	A	D	A
1,300	25-51	A	D	A		A
	51-76	A	D	A		A
	76-101	A	D	A		A

Well Location	Latitude (N)	Longitude (W)
1	44.519395	83.350626
2	44.523774	83.355813
3	44.554309	83.338978
4	44.555944	83.348263
5	44.516674	83.342593
6	44.530294	83.344696
7	44.547135	83.342482

Location Descriptions:
Location 1: Sherman Creek Wetlands Area (Coastline)
Location 2: North of Birch Acres Road (just west of cedar lake watershed boundary) (Cool Stream)
Location 3: Jones Creek Area (Coastline)
Location 4: East of Poor Farm Road near Northern section of Cedar Lake (Cool Stream)
Location 5: Near Sherman Creek crossing at Cedar Lake road. Street address 4691
Locations 6 and 7 yielded results very similar to Locations 1 and 5, being categorized in ARI Zone A.

ARI = Adverse Resource Impact

Source:
http://www.miwwat.org/
Michigan Water Withdrawal Assessment Tool

Zone	A	Not Likely to Cause an Adverse Resource Impact
Zone	B	Not Likely to Cause an Adverse Resource Impact
Zone	D	Is likely to cause an adverse resource impact on a stream in an adjacent watershed (ID# 286). The withdrawal cannot be initiated without a site-specific review conducted by the Michigan Department of Environmental Quality.

Figure 7 – Michigan Water Withdrawal Assessment Tool results for areas of potential groundwater augmentation well site placement in the northwestern drainage areas to Cedar Lake from K&A, 2011 (see also Appendix D private water well logs for these areas).

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[6] Water Withdrawal Assessment Tool; see: https://www.egle.state.mi.us/wwat/(S(4qxmdnybjzijasn4cuknwt0a))/default.aspx.

Augmentation Well Installation and Operational Costs

The installation and operational costs of the two proposed well sites, and an optional third well set (absent a specifically identified watershed location) are presented in Table 2. Probable installation costs for the 1,000 gpm capacity are about $1.25M with yearly operational costs estimated at $114,000. For the 1,500 gpm scenario, probable installation costs are $1.95M with annual estimated operational costs at $164,000. The difference in the installation costs between the two is $699,855 and $50,000 for yearly operational costs. Notably, modeling suggests that the lake levels will increase by only 0.2 feet (lake level 606.8 to 607.0 at its low point) with the increased pumping at 1,500 gpm. (See Appendix F for additional details of this cost breakdown.)

Table 2. Augmentation well installation, design and permitting as well as operational costs for 1,000 gpm and 1,500 gpm scenarios.

1,000 gpm Proposed Pumping Installation Costs					
2 Well Sites (CLIB and Jones Creek)				$	1,050,238
Design Engineering/Permitting Fees (18%)		18%	18%	$	189,043
Stakeholder Coordination (Lump sum)		LS	LS	$	10,000
			Probable Installation Costs =	**$**	**1,249,280**
			Annual O&M Costs =	**$**	**114,000**
1,500 gpm Proposed Pumping Installation Costs					
3 Well Sites (CLIB, Jones Creek, plus one other)				$	1,642,488
Design Engineering/Permitting (18%)		18%		$	295,648
Stakeholder Coordination (Lump sum)		LS		$	10,000
			Probable Installation Costs =	**$**	**1,948,135**
			Annual O&M Costs =	**$**	**164,000**

Conclusions and Recommendations

Based on outcomes from these K&A Task 6, Stage 2 efforts, the following conclusions and recommendations are provided to guide next step CLIB considerations for advancing interests in groundwater augmentation wells for Cedar Lake.

- Cedar Lake responds to precipitation and lake losses rapidly during summer months. Water losses during summer dry periods are influenced by: air temperatures affecting lake surface evaporation rates, and; leakage to groundwater. Daily water losses from Cedar Lake were as high as 24 million gallons per day under warm summer temperatures in July/August of 2021. Rainfall frequency and amount, as well as standing water stored in the northwest drainage area along with soil moisture, otherwise influence recovery of lake levels. Rainfall events >1 inch per day yield water level increases of >one-half foot within 18 hours. This was noted in 2021 where the lake level dropped 0.5 to 0.6 feet within a 10-day period with no rain, and then rose the same amount with a single day rain event of >1 inch. CLIB drainage improvements in the northwest Cedar Lake swamp have radically increased clean runoff inflowing to the lake, dramatically improving natural recharge of the lake.
- A recent culvert replacement at Jones Creek beneath West Cedar Lake Road appears to have vastly increased surface water flows to the lake during summer precipitation events from this area. This relates to a larger culvert with a lower invert elevation seasonally providing anywhere between 10-40 times more water through the culvert and into the lake than over previous flows through the smaller diameter/higher invert elevation culvert.

- Modeling of lake levels indicates that a groundwater pumping rate of 1,000 gallons per minute would economically augment lake levels to be maintained between the legal lake elevation and approximately one foot below this level during a range of conditions seen in 2020 and 2021, with some minor exceptions.
- Based on 2010 testing of the aquifer in the northwest Cedar Lake watershed, two well sites should provide the recommended 1,000 gallons per minute groundwater volumes necessary to economically augment flows to Cedar Lake. One well site is recommended on the CLIB existing property at the corner of Cedar Lake Road and Kings Corner Road. Pumped groundwater would be discharged into the swamp surrounding Sherman Creek, then flow through the creek to Cedar Lake. This would include the existing 12-inch well and five new 100 gpm wells. A second well site is proposed along the railroad tracks in the Jones Creek marsh where well discharges would similarly pass through Jones Creek to Cedar Lake.
- A review of well site locations on the northwest portion of Cedar Lake watershed using a State of Michigan assessment tool indicates that both sites identified for augmentation wells are appropriate for well development in the areas of Sherman Creek and Jones Creek. These well clusters may have some limited influence on a few private water wells requiring additional verification.
- No well sites are recommended south of Kings Corner Road. The risk of PFAS contamination from Van Etten Lake increases the risk of impact to the local aquifer, and potential discharge to the lake through augmentation well pumping.
- The economics of the number of well sites is driven by the limitations of the regional aquifer. Previous testing indicated that the aquifer would be able to produce 500 gallons per minute with five wells located 500 feet apart at selected well sites. A cluster of five wells at each site would influence an area of 3,000 feet wide by 4,000 feet long. Given previous pump testing results, the well sites would need to be far enough apart to not influence each other or other private wells to the point of hampering production.
- The probable costs of developing two well sites to produce 1,000 gallons per minute is estimated at $1.25M with an operating cost of $114,000 per year for 120 days of operation per year. If three well sites were required, costs to produce 1,500 gallons per minute would be $1,95M with annual operational costs of $164,000 per year for 120 days of operation. K&A modeling indicates that the additional 500 gallons per minute of augmentation above the recommended 1,000 gpm would not have increased 2021 summer lake levels by more than 0.2 foot (2.4 inches) at an additional capital cost of $700,000 and additional annual operating costs of $50,000.

APPENDIX A

CEDAR LAKE - LAKE LEVEL AND PRECIPITATION DATA FOR ASSESSING VOLUMES AND RATES OF LAKE VOLUME LOSSES AND GAINS IN 2021

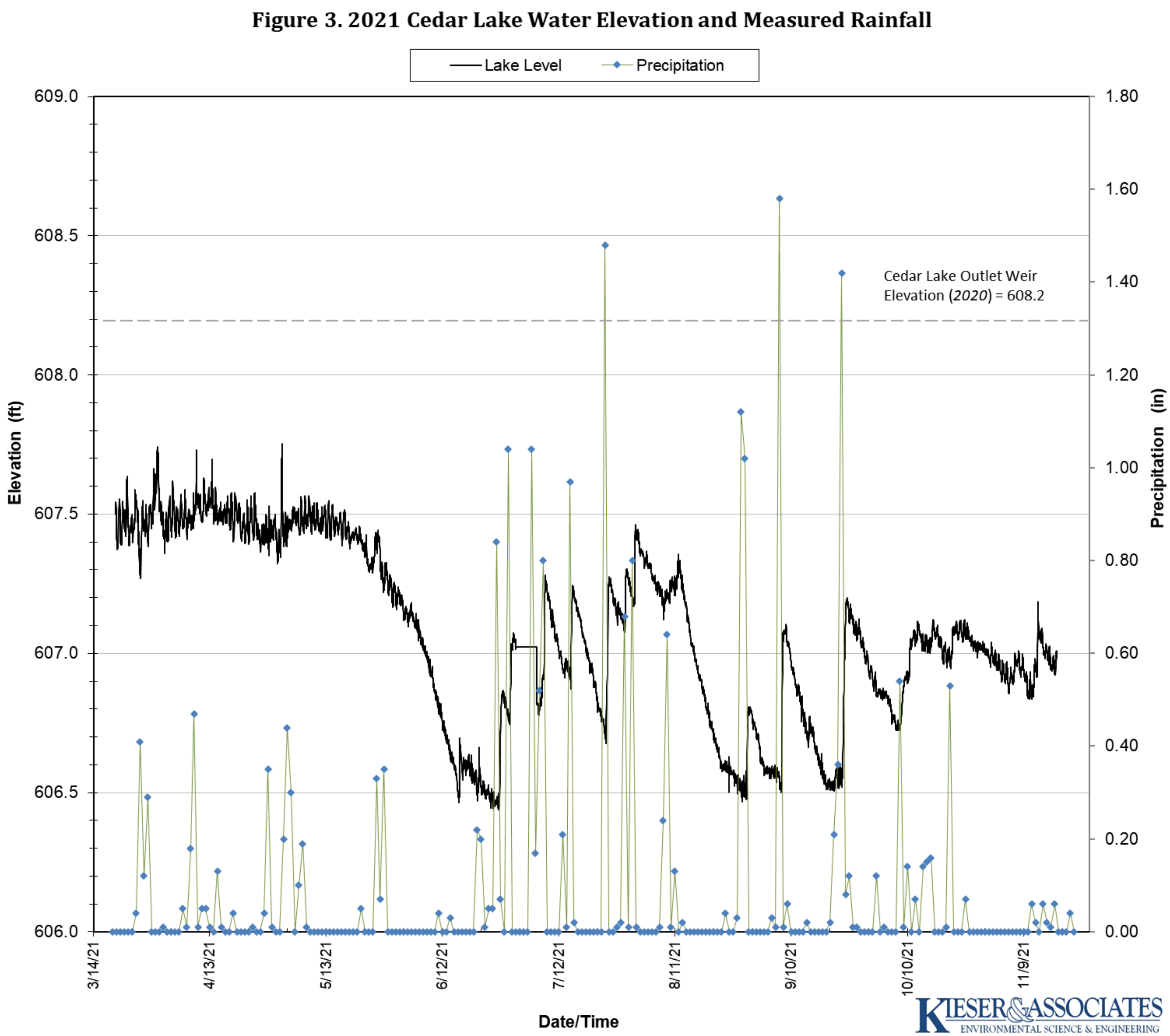


Figure 3. 2021 Cedar Lake Water Elevation and Measured Rainfall
Lake Level
Precipitation
Cedar Lake Outlet Weir Elevation (2020) = 608.2
Elevation (ft)
Precipitation (in)
Date/Time
609.0
608.5
608.0
607.5
607.0
606.5
606.0
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
3/14/21
4/13/21
5/13/21
6/12/21
7/12/21
8/11/21
9/10/21
10/10/21
11/9/21
KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING

Computations of Volume Losses from 2021 Lake Level Data

slope #	June Slope			
1	6/6/2021	607.072		
	6/16/2021	606.502		
	9.71	0.57	0.06	ft/day
			0.70	in/day
			20,564,971	gallons/day
			199,651,597	gallons
slope #	July Slope			
2	7/15/2021	607.225		
	7/24/2021	606.702		
	8.29	0.523	0.06	ft/day
			0.76	in/day
			22,093,157	gallons/day
			183,189,097	gallons
slope #	August Slope			
3	8/11/2021	607.357		
	8/23/2021	606.577		
	11.29166667	0.78	0.07	ft/day
			0.83	in/day
			24,195,494	gallons/day
			273,207,449	gallons
slope #	September Slope			
4	9/8/21 0:00	607.079		
	9/18/21 6:00	606.570		
	10.25	0.509	0.050	ft/day
			0.596	in/day
			17,393,695	gallons/day
			178,285,374	gallons
slope #	October Slope Slope			
5	10/22/2021	607.065		
	11/5/2021	606.872		
	14.25	0.193	0.01	ft/day
			0.16	in/day
			4,743,953	gallons/day
			67,601,330	gallons

APPENDIX B

CEDAR LAKE INFLOW DATA TO ASSESS

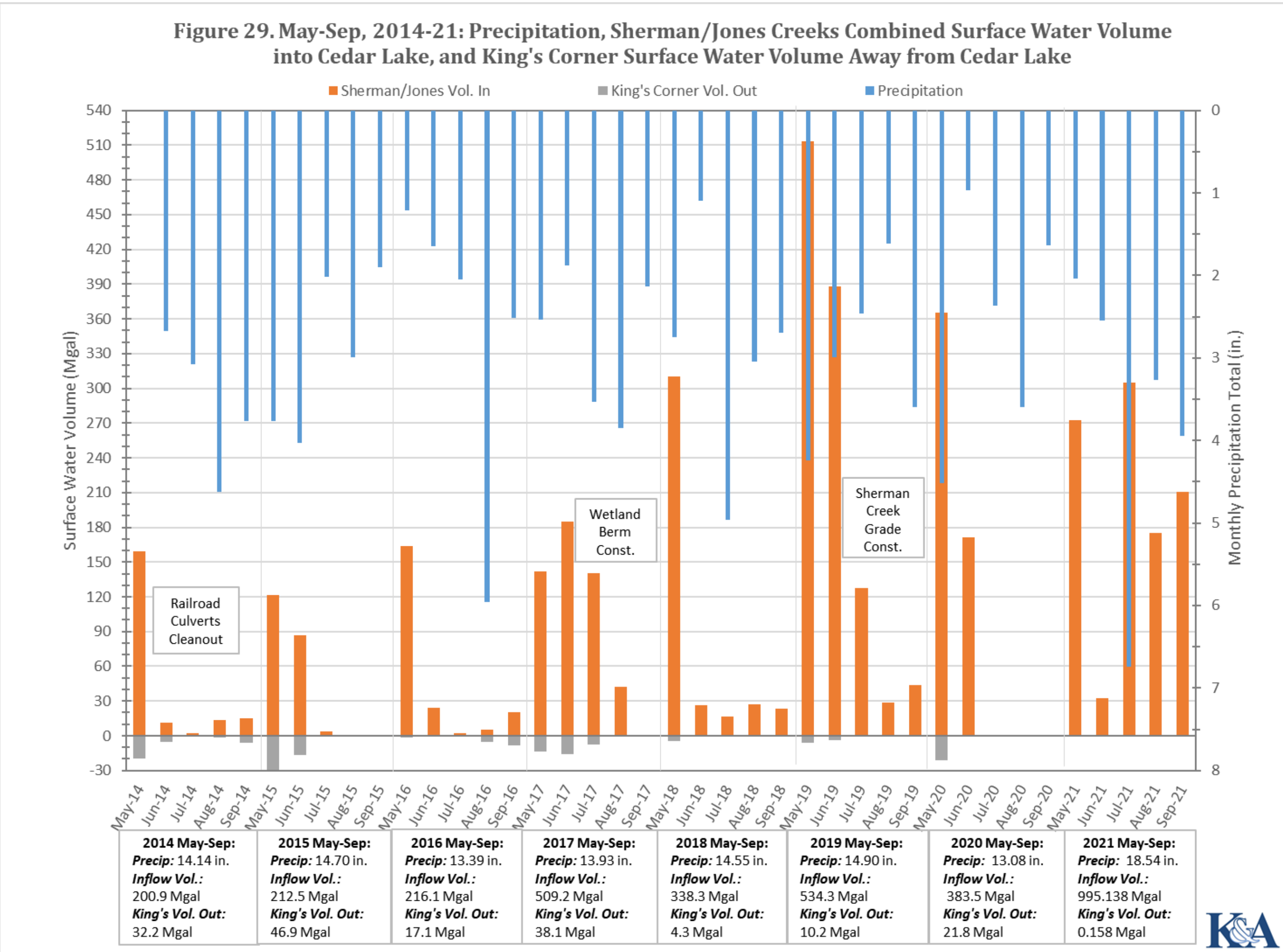
RAINFALL/RUNOFF CONTRIBUTIONS

Table 3. Comparison of Surface Water Volumes from May 1 to Sep 30, 2014 to 2021.

Site	Volume (Mgal)							
	2014	2015	2016	2017	2018	2019	2020	2021
Sherman Creek (inflow to CL)	136.04	190.929	198.126	449.441	328.134	446.753	359.857	195.171
Jones Creek (inflow to CL)	64.817	21.587	17.964	59.784*	75.712	654.691	177.250	799.967
Cedar Lake Outlet (outflow from CL)	13.003	109.5	0.162**	26.123**	51.975	143.156	21.560	0.000
Kings Corner (outflow away from CL)	32.208	46.862	17.049	38.053	4.384	10.161	21.819	0.158

*Jones Creek 2017 flows from 5/1/17 to 9/1/17 only.

**Affected by presence of beaver dam upstream of Cedar Lake outlet, mechanically removed in fall 2017.



APPENDIX C

EGLE WURTSMITH PFAS GRUNDWATER INVESTIGATION

MONITORING WELL DATA 1/10/2022

1/10/2022

Legend

GSU Monitoring Well

Wurtsmith PFAS Groundwater Investigation Monitoring Well

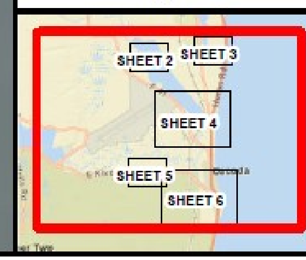
Well ID	
Well Screen Depth Interval	
Analyte	Total PFAS
Result (ppt)	Result (ppt)

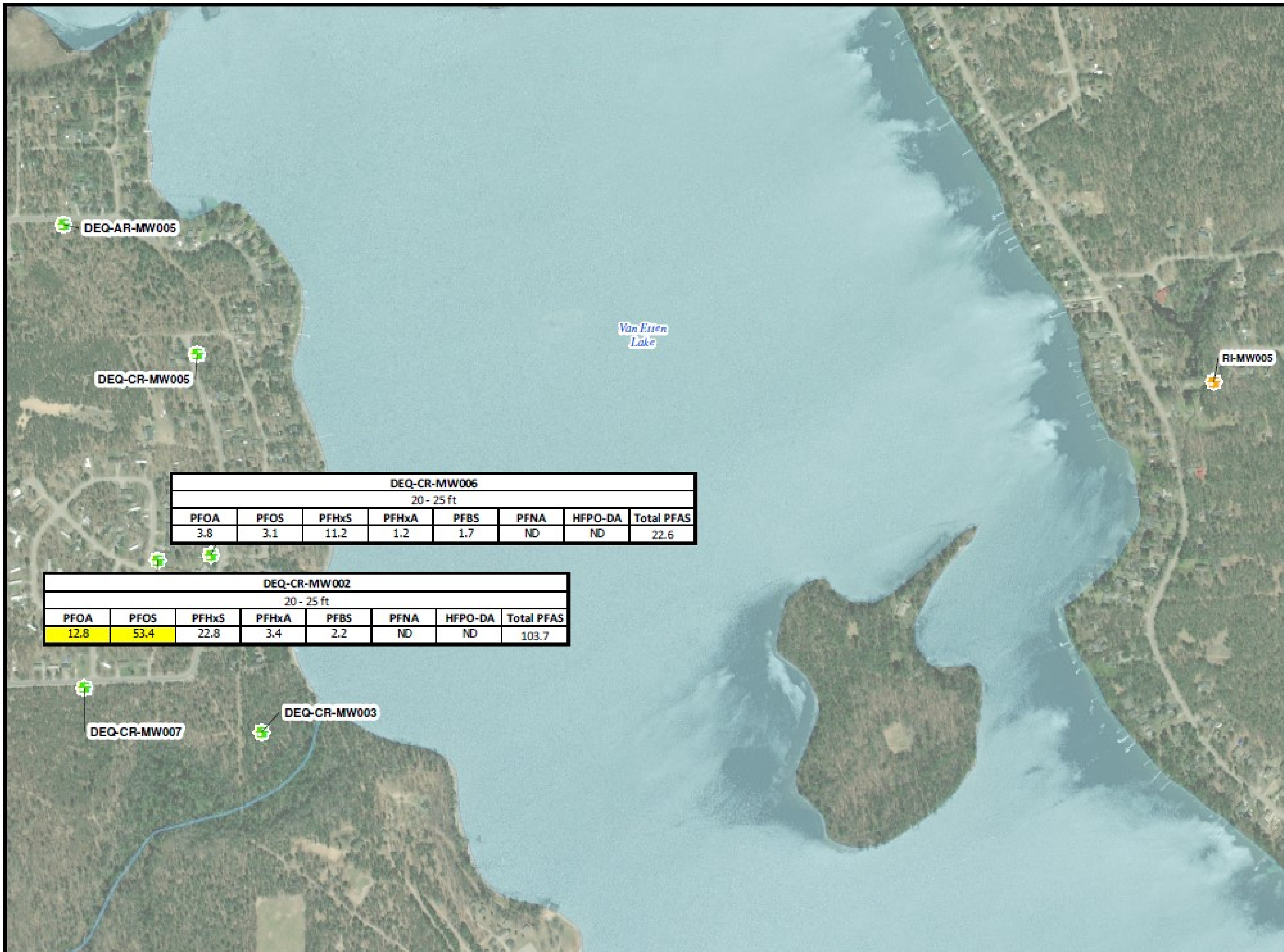
ND = non-detect
Yellow highlight = Exceedance of Michigan Part 201 criteria
* No results = Well not sampled

GSU YEAR 3 QUARTER 1
GROUNDWATER SAMPLING
OCTOBER 2021
SHEET 1 OF 6

OSCODA AREA
IOSCO COUNTY,
MICHIGAN

0 3,800 7,600
Feet





DEQ-CR-MW006							
20 - 25 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
3.8	3.1	11.2	1.2	1.7	ND	ND	22.6

DEQ-CR-MW002							
20 - 25 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
12.8	53.4	22.8	3.4	2.2	ND	ND	103.7

EGLE

1/10/2022

Legend

GSU Monitoring Well

Wurtsmith PFAS Groundwater Investigation Monitoring Well

Well ID	
Well Screen Depth Interval	
Analyte	Total PFAS
Result (ppt)	Result (ppt)

ND = non-detect

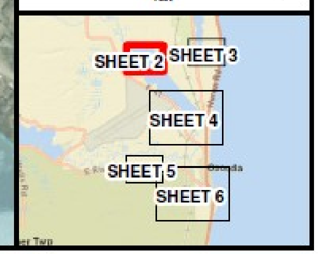
Yellow highlight = Exceedance of Michigan Part 201 criteria

* No results = Well not sampled

GSU YEAR 3 QUARTER 1
GROUNDWATER SAMPLING
OCTOBER 2021
SHEET 2 OF 6

OSCODA AREA
IOSCO COUNTY, MICHIGAN

0 550 1,100
Feet



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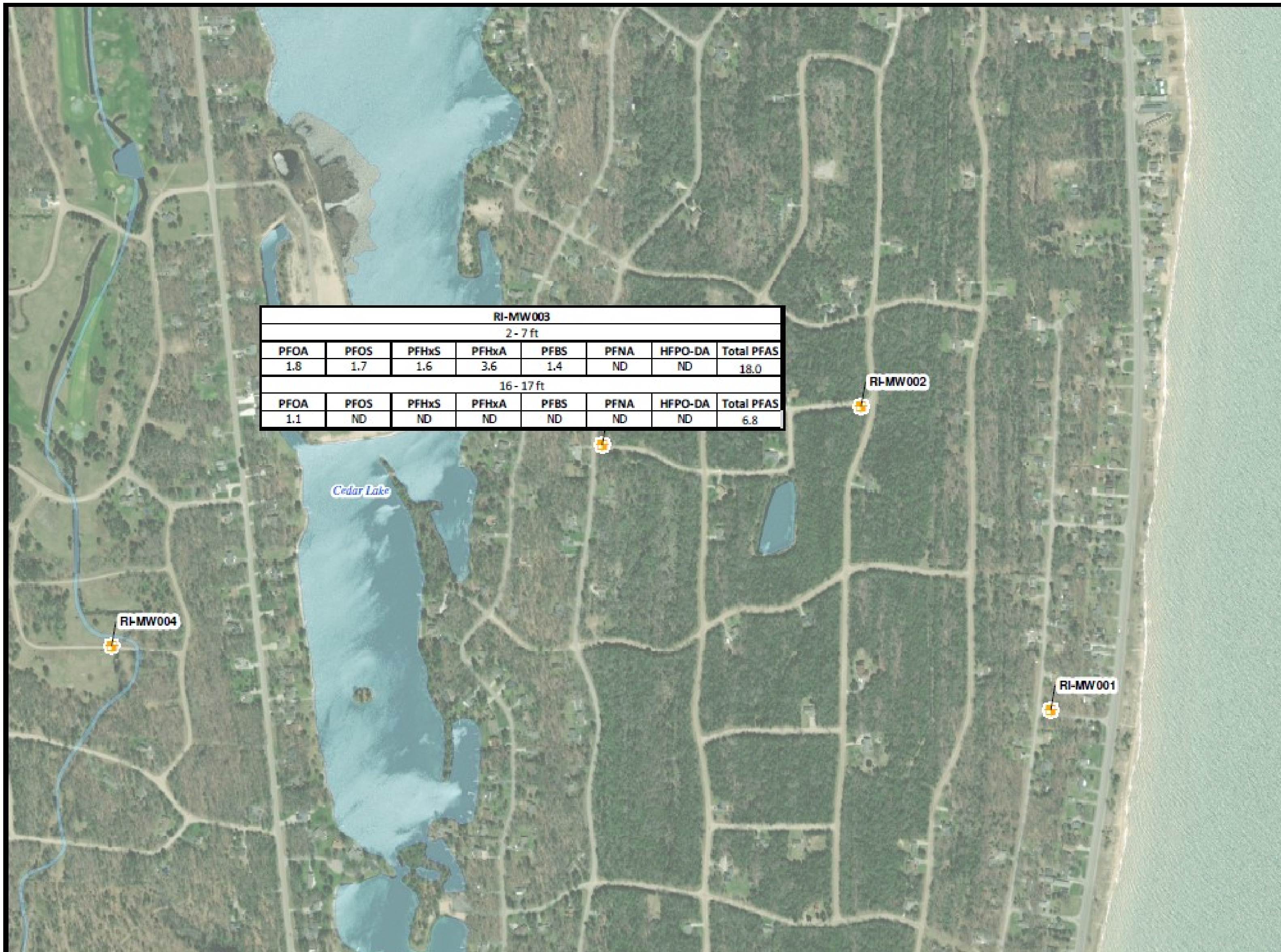


RI-MW003							
2 - 7 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
1.8	1.7	1.6	3.6	1.4	ND	ND	18.0
16 - 17 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
1.1	ND	ND	ND	ND	ND	ND	6.8

1/10/2022

Legend

GSU Monitoring Well

Wurtsmith PFAS Groundwater Investigation Monitoring Well

Well ID	
Well Screen Depth Interval	
Analyte	**Total PFAS**
Result (ppt)	Result (ppt)

ND = non-detect

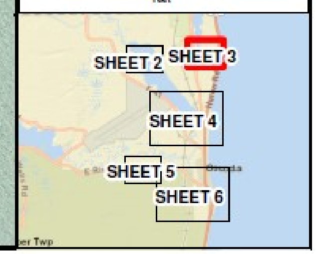
Yellow highlight = Exceedance of Michigan Part 201 criteria

* No results = Well not sampled

GSU YEAR 3 QUARTER 1
GROUNDWATER SAMPLING
OCTOBER 2021
SHEET 3 OF 6

OSCODA AREA
IOSCO COUNTY,
MICHIGAN

0 550 1,100
Feet



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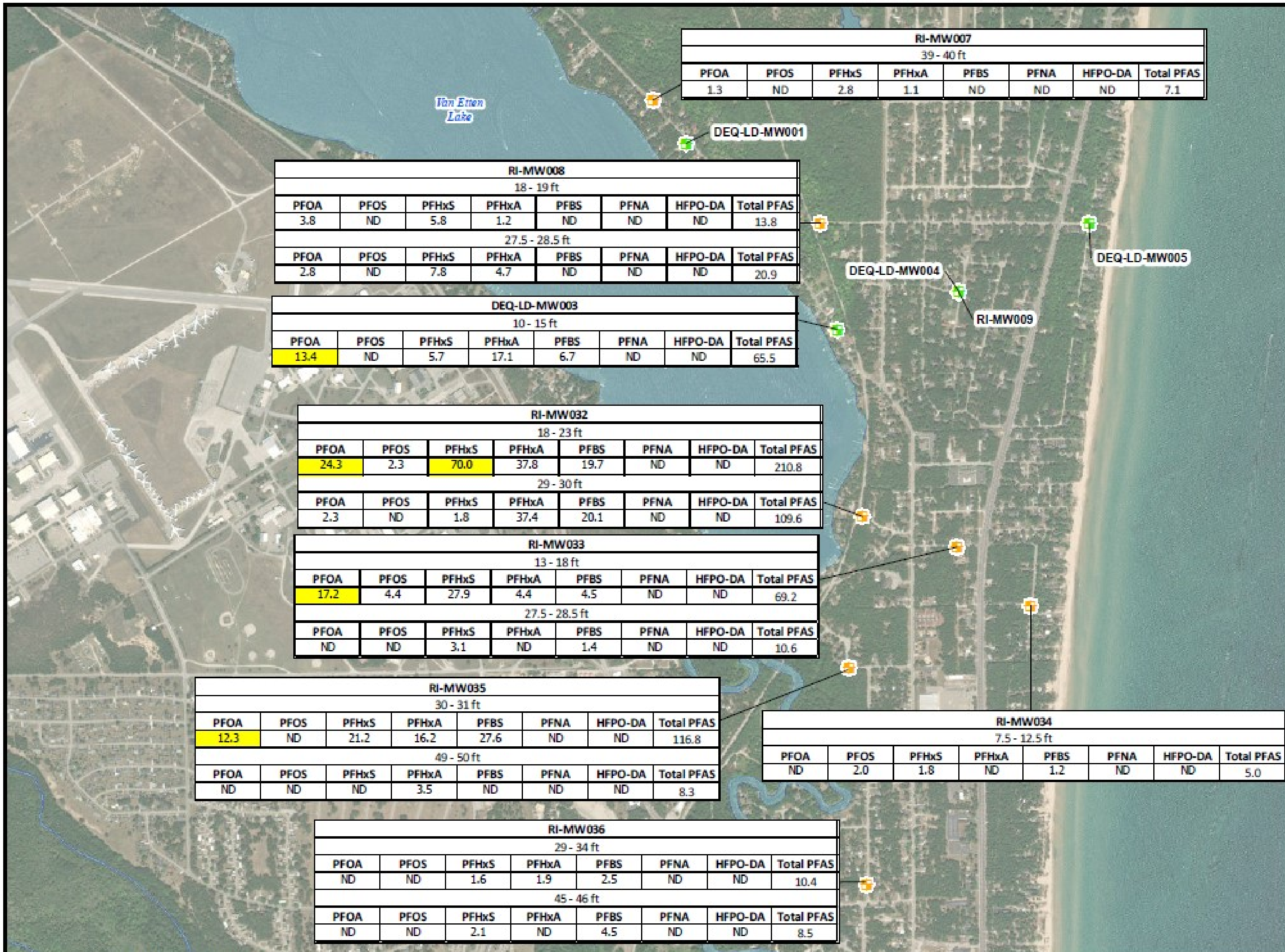


RI-MW007

39 - 40 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
1.3	ND	2.8	1.1	ND	ND	ND	7.1

RI-MW008

18 - 19 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
3.8	ND	5.8	1.2	ND	ND	ND	13.8
27.5 - 28.5 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
2.8	ND	7.8	4.7	ND	ND	ND	20.9

DEQ-LD-MW003

10 - 15 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
13.4	ND	5.7	17.1	6.7	ND	ND	65.5

RI-MW032

18 - 23 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
24.3	2.3	70.0	37.8	19.7	ND	ND	210.8
29 - 30 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
2.3	ND	1.8	37.4	20.1	ND	ND	109.6

RI-MW033

13 - 18 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
17.2	4.4	27.9	4.4	4.5	ND	ND	69.2
27.5 - 28.5 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
ND	ND	3.1	ND	1.4	ND	ND	10.6

RI-MW035

30 - 31 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
12.3	ND	21.2	16.2	27.6	ND	ND	116.8
49 - 50 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
ND	ND	ND	3.5	ND	ND	ND	8.3

RI-MW034

7.5 - 12.5 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
ND	2.0	1.8	ND	1.2	ND	ND	5.0

RI-MW036

29 - 34 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
ND	ND	1.6	1.9	2.5	ND	ND	10.4
45 - 46 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
ND	ND	2.1	ND	4.5	ND	ND	8.5

EGLE

1/30/2022

Legend

- GSU Monitoring Well
- Wurtsmith PFAS Groundwater Investigation Monitoring Well

Well ID	
Well Screen Depth Interval	
Analyte	Total PFAS
Result (ppt)	Result (ppt)

ND = non-detect

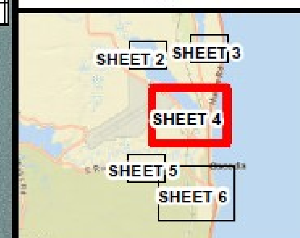
Yellow highlight = Exceedance of Michigan Part 201 criteria

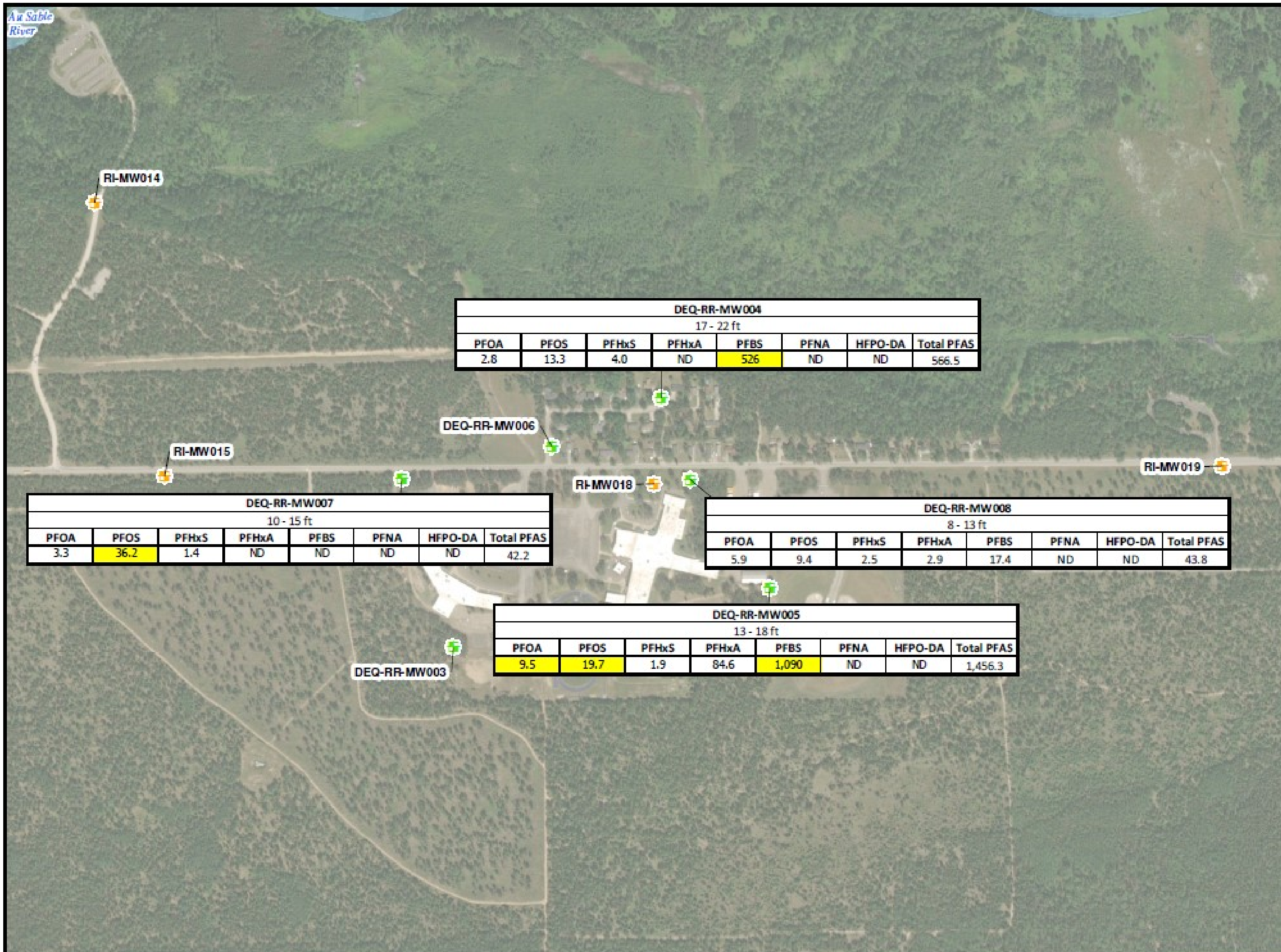
* No results = Well not sampled

GSU YEAR 3 QUARTER 1
GROUNDWATER SAMPLING
OCTOBER 2021
SHEET 4 OF 6

OSCODA AREA
IOSCO COUNTY,
MICHIGAN

0 1,100 2,200
Feet





DEQ-RR-MW004							
17 - 22 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
2.8	13.3	4.0	ND	526	ND	ND	566.5

DEQ-RR-MW007							
10 - 15 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
3.3	36.2	1.4	ND	ND	ND	ND	42.2

DEQ-RR-MW008							
8 - 13 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
5.9	9.4	2.5	2.9	17.4	ND	ND	43.8

DEQ-RR-MW005							
13 - 18 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
9.5	19.7	1.9	84.6	1,090	ND	ND	1,456.3

EGLE

1/10/2022

Legend

GSU Monitoring Well

Wurtsmith PFAS Groundwater Investigation Monitoring Well

Well ID	
Well Screen Depth Interval	
Analyte	Total PFAS
Result (ppt)	Result (ppt)

ND = non-detect

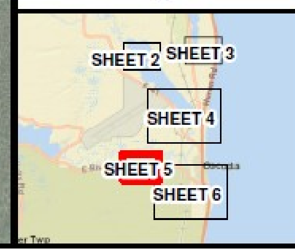
Yellow highlight = Exceedance of Michigan Part 201 criteria

* No results = Well not sampled

GSU YEAR 3 QUARTER 1
GROUNDWATER SAMPLING
OCTOBER 2021
SHEET 5 OF 6

OSCODA AREA
IOSCO COUNTY,
MICHIGAN

0 550 1,100
Feet



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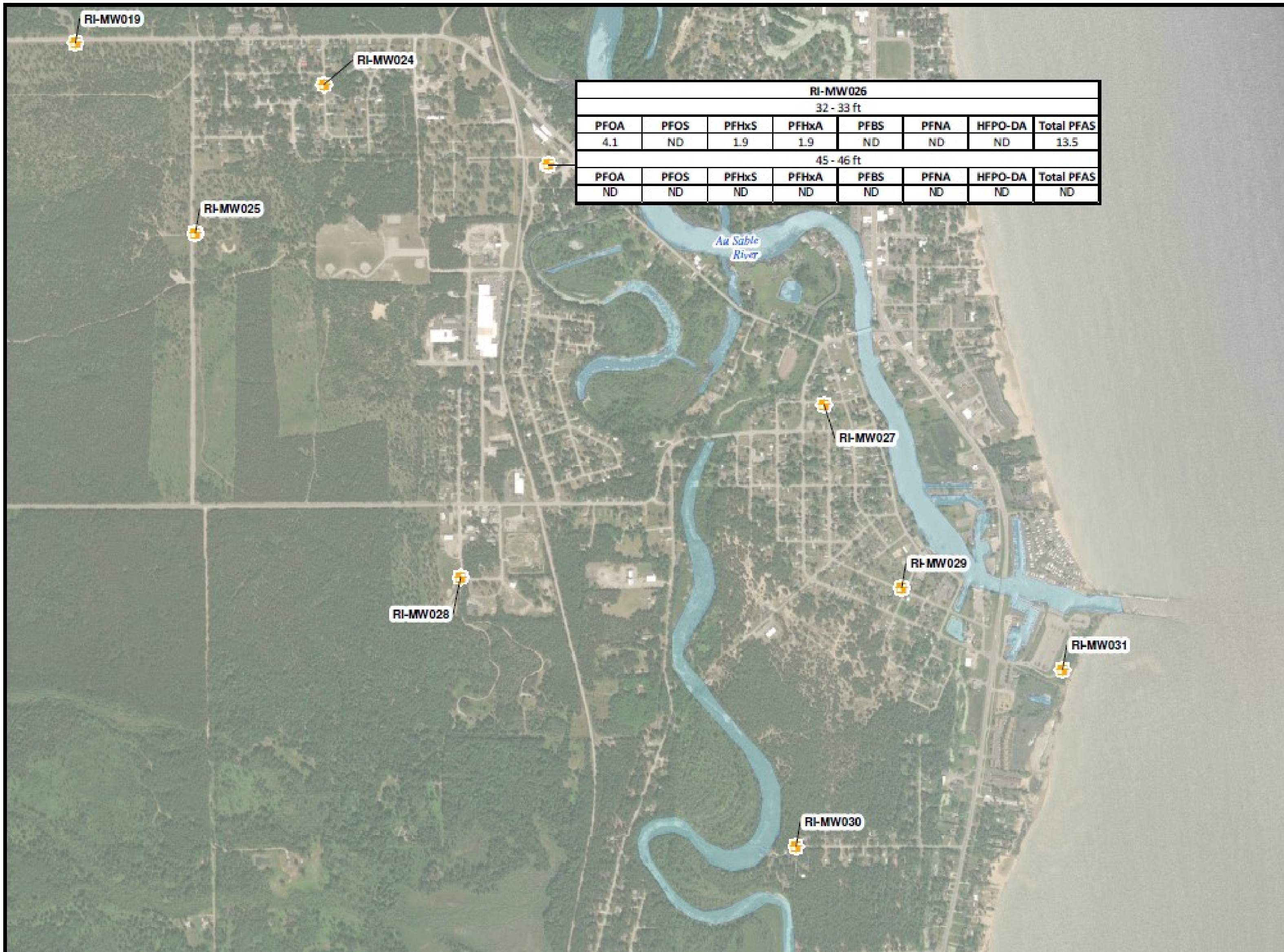
EGLE

1/10/2022



RI-MW026							
32 - 33 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
4.1	ND	1.9	1.9	ND	ND	ND	13.5
45 - 46 ft							
PFOA	PFOS	PFHxS	PFHxA	PFBS	PFNA	HFPO-DA	Total PFAS
ND	ND	ND	ND	ND	ND	ND	ND

Legend

GSU Monitoring Well

Wurtsmith PFAS Groundwater Investigation Monitoring Well

Well ID	
Well Screen Depth Interval	
Analyte	Total PFAS
Result (ppt)	Result (ppt)

ND = non-detect

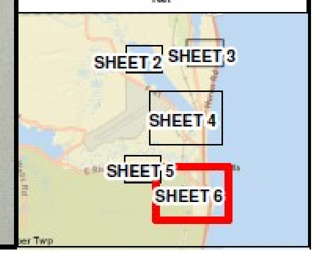
Yellow highlight = Exceedance of Michigan Part 201 criteria

* No results = Well not sampled

GSU YEAR 3 QUARTER 1
GROUNDWATER SAMPLING
OCTOBER 2021
SHEET 6 OF 6

OSCODA AREA
IOSCO COUNTY,
MICHIGAN

0 1,100 2,200
Feet



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APPENDIX D

PUBLICLY AVAILABLE WATER WELL DATA

ID	County	Township	Section	Fraction	Twn #	Rng #	Well Location	Well Depth	Date Completed	Static Water Level (ft)	Pumping Level (ft)	Pumping Duration (hrs)	Pumping Rate (gpm)	Min Screen Depth	Max Screen Depth	Well Diameter (in)	latitude	longtitude	
293	Alcona	Greenbush	15		25 N	9 E	Timber Lakes Estates, Lot #224	41	7/10/1967	4			17.5	37	41		44.564695	-83.317843	
	Alcona	Greenbush	15		25 N	9 E	Timber Lakes Estates, Lot #88	63	7/11/1967	4			14	59	63		44.561741	-83.319233	
298	Alcona	Greenbush	15		25 N	9 E	Timber Lakes Estates, Lot #82	42	7/13/1967	6			14	38	42		44.564601	-83.318545	
294	Alcona	Greenbush	15		25 N	9 E	Timber Lakes Estates, Lot #6	42	7/21/1967	7			14	38	42		44.562841	-83.320064	
335	Alcona	Greenbush	22		25 N	9 E	3829 W Cedar Lake Rd.	28	11/2/1967	4	4	1		25	28		44.54589	-83.33263	
323	Alcona	Greenbush	22		25 N	9 E	3868 E Cedar Lake Dr	37	5/7/1968	1				34	37		44.54516	-83.32463	
330	Alcona	Greenbush	22		25 N	9 E	3861 Cedar Lake Dr.	18	5/23/1968	7			10	14	18		44.54532	-83.32443	
322	Alcona	Greenbush	22		25 N	9 E	3787 W Cedar Lake Rd.	25	11/1/1968	3				22	25		44.54744	-83.33228	
324	Alcona	Greenbush	22		25 N	9 E	3578 Cedar Lake Dr.	26	6/6/1969	3			15	22	26		44.55356	-83.32420	
332	Alcona	Greenbush	22	NW SE SW	25 N	9 E	3868 Cedar lake Rd.	68	6/13/1969	12			15	60	68		44.54795	-83.33329	
339	Alcona	Greenbush	22		25 N	9 E	3899 S. Cedar Lake Rd.	38	6/18/1969	3				34	38		44.54343	-83.33455	
319	Alcona	Greenbush	22		25 N	9 E	3566 E Cedar Lake Dr.	29	7/5/1969	3			15	25	29		44.55397	-83.32424	
329	Alcona	Greenbush	22	NW SE SE	25 N	9 E	3828 W Cedar Lake Rd.	28	7/22/1969	6				24	28		44.54976	-83.33266	
87	Alcona	Greenbush	10		25 N	9 E	120 ft East 140 ft S of intersection of Ridley and Stevens, Lot #27 Alcan Ac	51	5/20/1970	35			360	47	51		44.58336	-83.33885	
216	Iosco	Oscoda	4		24 N	9 E	Lakewood Shores Resort	60	6/8/1970	10	25	2	25	56	60		44.50001	-83.34327	
61	Alcona	Greenbush	9		25 N	9 E	1200 ft N of Wissemiller, 300 ft W of Prince Rd	24	6/8/1970	9			700	19	24		44.57289	-83.35544	
203	Iosco	Oscoda	4	NE NE NW	24 N	9 E	1/2 mile W Cedar Lake Road, 1/8 mile S of County Line Rd	80	6/17/1970	5	20	5	25	76	80		44.50987	-83.35113	
320	Alcona	Greenbush	22	NW SE SE	25 N	9 E	3859 Cedar Lake Dr.	23	6/27/1970	7			5	19	23		44.54541	-83.32459	
326	Alcona	Greenbush	22	NW SE SE	25 N	9 E	3867 Cedar Lake Dr.	24	6/27/1970	9			11	20	24		44.54523	-83.32461	
341	Alcona	Greenbush	22		25 N	9 E	Lot #3-4, Cedar Lake Dr.	23	6/27/1970	7			5	18	22				
215	Iosco	Oscoda	4		24 N	9 E	Lakewood Shores lot 798	100	9/24/1970								44.50831	-83.34473	
424	Alcona	Greenbush	33	SE SE SE	25 N	9 E	4851 Cedar Lake Rd.	26	5/17/1971	4				23	26		44.51413	-83.34080	SC
327	Alcona	Greenbush	22		25 N	9 E	2.5 miles S of Wissmiller Rd., on Cedar Lake Rd.	28	5/19/1971	8				24	28		44.53459	-83.33710	
331	Alcona	Greenbush	22		25 N	9 E	Lot 595 Cedar Lake Rd.	26	7/20/1971	8									
325	Alcona	Greenbush	22	SE SE NW	25 N	9 E	2 and 3/4 miles N of County Line Rd. on Cedar Lake Rd.	39	11/4/1971	10			19	35	39		44.55105	-83.33163	
342	Alcona	Greenbush	22	NE NE NE	25 N	9 E	2.5 miles S of Mikado Rd., 75 ft W of Cedar Lake Rd	42	12/3/1971	9	6	0.5	12	38	42		44.55506	-83.33113	JC
205	Iosco	Oscoda	4		24 N	9 E	Lot 58, Lakewood Shores Golf and Country Club	48	12/8/1972	10	30	2	15	44	48		44.50849	-83.34539	
422	Alcona	Greenbush	33	SE NE NE	25 N	9 E	3/4 miles N of County Line, on Cedar Lake	58	12/27/1972	4							44.52297	-83.33898	
67	Alcona	Greenbush	10	SE SE NE	25 N	9 E	8.5 miles N of Oscoda on US-23 on lake side of Rd.	34	1/24/1973	4	22	1	13	31	34		44.54981	-83.31117	
213	Iosco	Oscoda	4		24 N	9 E	Lakewood Shores, lot 80	63	3/10/1973	12	14	1	12	59	63		44.49909	-83.34677	
57	Alcona	Greenbush	9		25 N	9 E	4141 Wissmiller	52	10/3/1973	27	28	1	18	47	52		44.56962	-83.35289	
89	Alcona	Greenbush	10		25 N	9 E	Lot #63 Alcove Acres	63	10/5/1973	48	51	1	3	56	63		44.57930	-83.33914	
88	Alcona	Greenbush	10		25 N	9 E	1/2 mile S of Greenbush on Cedar Lake Rd	42	10/26/1973	18	31	1	4	37	42		44.56504	-83.32774	JC
86	Alcona	Greenbush	10	SW SW SE	25 N	9 E	2573 S. Scott Rd.	442	4/30/1974	18	19	0.5	14	42	34		44.58165	-83.33710	
300	Alcona	Greenbush	15		25 N	9 E	3468 Cedar Lake Dr	25	5/29/1974	2							44.55606	-83.32459	
66	Alcona	Greenbush	9	NE NE NE	25 N	9 E	40 ft W of Poor Farm Rd, 60 ft S of Ridley Rd	84	6/11/1974	61	61	1	18	76	84		44.56912	-83.34186	
307	Alcona	Greenbush	21	SW SW SV	25 N	9 E	2 miles S of Wissmiller Rd., 200 ft W of Poor Farm Rd.	32	6/12/1974	18	18	1	14	28	32		44.54033	-83.36314	
299	Alcona	Greenbush	15		25 N	9 E	3431 Cedar Lake Rd.	25	7/25/1974	6							44.55771	-83.32343	
308	Alcona	Greenbush	22	NW NW NI	25 N	9 E	4945 Cedar Lake Rd.	25	4/1/1975	6							44.51316	-83.32755	
71	Alcona	Greenbush	10	NE NW NV	25 N	9 E	1 mi W of intersection of Cedar Lake Rd and Ridley, lot #53, Alcan Acres S	46	6/5/1975	26	31	0.5	8	39	46		44.58368	-83.33963	
55	Alcona	Greenbush	9	SE SE SW	25 N	9 E	2955 Prince Rd	42	8/4/1975	19	28	0.5	8	36	42		44.58181	-83.35388	
316	Alcona	Greenbush	22	SE SE NW	25 N	9 E	3745 Cedar Lake Rd.	27	8/28/1975	8							44.54875	-83.32425	
317	Alcona	Greenbush	22	SW SE SW	25 N	9 E	4851 Cedar Lake Rd.	54	10/22/1975	4			11				44.51416	-83.33956	SC
217	Iosco	Oscoda	4		24 N	9 E	7949 Cedar Lake Rd	29	12/11/1975	3			10				44.50978	-83.34026	SC
343	Alcona	Greenbush	22	NE SE NE	25 N	9 E	3485 Cedar Lake, 1 mile S of E. Cedar Lake, 800 ft E of W. Cedar Lake	39	11/12/1976	10	20	1	10	35	39		44.55825	-83.32881	
310	Alcona	Greenbush	22		25 N	9 E	3071 Cedar Lake Rd	47	4/17/1977	8							44.56450	-83.32709	
76	Alcona	Greenbush	10		25 N	9 E	2 mi SW of intersection of US-23 and F-30, Lot #18, Alcan Acres Sub	42	5/7/1977	14	14	1	12	38	42		44.58045	-83.33991	
63	Alcona	Greenbush	9	SE NE NE	25 N	9 E	2611 S Poor Farm Rd	55	8/15/1977	28			55				44.59120	-83.34114	
421	Alcona	Greenbush	33		25 N	9 E	1 mile N of County Line Rd., On Cedar Lk Rd.	26	4/20/1978	5							44.52641	-83.34142	
74	Alcona	Greenbush	10	NW NW N\	25 N	9 E	150 ft E of Poor Farm Rd, 1/4 mile N of Wissmiller Rd	69	6/19/1979	4	4	1	15	61	69		44.57317	-83.34108	
209	Iosco	Oscoda	4		24 N	9 E	1/4 mile W of Cedar Lake Rd, 1/4 mile S of County Line Rd	60	8/1/1979	6							44.50828	-83.34587	
210	Iosco	Oscoda	4	NW NE SW	24 N	9 E	1/4 mile W of Cedar Lake Rd, off King Corner Rd. Lakewood Golf Country (	54	9/5/1979	7	25	0.5	350	51	54		44.51147	-83.34585	
312	Alcona	Greenbush	22		25 N	9 E	3911 Cedar Dr.	32	8/18/1981	8				25	32		44.55563	-83.32868	
70	Alcona	Greenbush	10		25 N	9 E	2 mi SW of intersection of F-30 and US-23, Lot #36, alcan Acres Sub.	63	8/30/1982	21	23	1	12	59	63		44.57928	-83.34033	
419	Alcona	Greenbush	28		25 N	9 E	1 mile NE of intersection of Cedar Lake Rd. and County Line Rd.	40	9/7/1982	18	20	1	14	36	40		44.52659	-83.34143	
77	Alcona	Greenbush	10		25 N	9 E	1/4 mile W of intersection of Cedar Lake Rd and Gruff St.	42	8/18/1984	11	14	1	16	37	42		44.58489	-83.32390	
69	Alcona	Greenbush	10	NW NW N\	25 N	9 E	600 ft S of Riddley, 100 ft W of Scott	67	9/17/1985	41	41	1	7				44.58211	-83.33806	
292	Alcona	Greenbush	15	SW SE SE	25 N	9 E	1 mile S of Wissmiller Rd, 500 ft E of Cedar Lake Rd	38	11/5/1985	10	10	1	11	34	38		44.55536	-83.32894	JC
311	Alcona	Greenbush	22	NE SE SE	25 N	9 E	4264 E Cedar Lake	25	5/22/1986	3	3	1	6				44.53782	-83.32488	
85	Alcona	Greenbush	10	NW NW N\	25 N	9 E	100 yds E of Poor Farm Rd, 150 ft S of Riddley Rd	68	4/3/1987	41	41	1	12	64	68		44.58348	-83.34031	
328	Alcona	Greenbush	22	NE SW SW	25 N	9 E	2 miles N of Kings Corner Rd. , 400 ft E of Cedar Lake Rd.	55	5/20/1987	2	2	1	13	51	55		44.54063	-83.33357	
75	Alcona	Greenbush	10	NW SW N\	25 N	9 E	1/2 mile S of Ridley Rd., Lot 32 Alcan Acres Sub	62	12/12/1987	15	45	1	33	56	62		44.57653	-83.33904	
306	Alcona	Greenbush	21	NW NE NE	25 N	9 E	70 ft W of Poor Farm Rd., 1/4 mile S of Wissmiller	72	3/9/1988	18	18	1	9	68	72		44.56601	-83.34192	
202	Iosco	Oscoda	4	SW SE SE	24 N	9 E	3/4 mile S of Kings Corner Rd., 1/2 mile W of Cedar Lake Rd	63	4/30/1988	4	4	1	18	57	63		44.50107	-83.34963	
291	Alcona	Greenbush	15	SW SE SE	25 N	9 E	3481 Cedar Lake Rd	31	5/23/1988	11	11	1	8				44.56763	-83.34403	
303	Alcona	Greenbush	16	NE SE SE	25 N	9 E	400 ft E of Poor Farm Rd., 3/4 mile S of Wissmiller Rd	83	6/6/1988	13	13	1	19	77	83		44.55681	-83.34395	
201	Iosco	Oscoda	4	NW SE SE	24 N	9 E	3/4 mile S of Kings Corner Rd., 1/2 mile W of Cedar Lake Rd.	54	6/26/1989	10	10	1	13	50	54		44.54785	-83.35151	
309	Alcona	Greenbush	22	NE SW SW	25 N	9 E	1/2 mile S of Wissmiller, 400 ft E of Cedar Lake Dr.	36	9/13/1989	8	8	1	11	32	36		44.55321	-83.34392	
56	Alcona	Greenbush	9	SE NE NE	25 N	9 E	300 ft W of Poor Farm Rd, 1/2 mile N of Wissmiller	46	5/22/1990		35	1	8	42	46		44.54247	-83.35901	

ID	County	Township	Section	Fraction	Twn #	Rng #	Well Location	Well Depth	Date Completed	Static Water Level (ft)	Pumping Level (ft)	Pumping Duration (hrs)	Pumping Rate (gpm)	Min Screen Depth	Max Screen Depth	Well Diameter (in)	latitude	longtitude	
423	Alcona	Greenbush	33	NE SW SW	25 N	9 E	3/4 mile N of Kings Corner Rd, on Poor Farm Rd.	63	7/11/1990	16	16	1	22				44.52250	-83.37076	
72	Alcona	Greenbush	10	NE SE SE	25 N	9 E	3084 S. US-23	40	4/18/1991	6	31	1	60	33	40		44.56738	-83.31549	
290	Alcona	Greenbush	15	SW SW SW	25 N	9 E	600 ft N of Cedar Rd., 150 t W of US-23	48	6/17/1991	11	11	1	7	44	48		44.56463	-83.32284	
296	Alcona	Greenbush	15	NW SE SE	25 N	9 E	100 yds S of Huron Cedar Rd., on W side of Cedar Lake Dr	30	3/21/1992	2	10	1	7	26	30		44.55618	-83.32455	
199	Iosco	Oscoda	4	NW NE NW	24 N	9 E	3/4 mile W of Cedar Lake Rd, on S side of County Line Rd.	29.5	6/25/1992	8.5	13	1	5	25.5	29.5		44.51140	-83.35611	
302	Alcona	Greenbush	16	SW NE NE	25 N	9 E	1/2 mile S of Wissmiller Rd, 50 ft W of Poor Farm Rd.	43	6/26/1993	7	7	1	13	39	43		44.56225	-83.34790	
334	Alcona	Greenbush	22	NW NW NE	25 N	9 E	3521 Cedar Lake Rd.	34	9/25/1993	11	25	1	20	30	34		44.55713	-83.32915	JC
60	Alcona	Greenbush	9	SW NW NE	25 N	9 E	4266 Wilcox Rd	112	11/22/1993	97	96	0.5	5	108	112		44.58189	-83.35080	
62	Alcona	Greenbush	9	SE SE SE	25 N	9 E	300 ft N of Wissmiller Rd, 400 ft W of Poor Farm Rd	68	8/11/1995	5	5	1	19	64	68		44.57035	-83.34328	
301	Alcona	Greenbush	15		25 N	9 E	4671 W Cedar Lake Rd	61	8/15/1995	4	4	1	19	57	61		44.52115	-83.33977	SC
90	Alcona	Greenbush	10		25 N	9 E	500 ft S of Riddley, 100 ft E of Scott Rd.	62	9/5/1995	22	22	1	9	56	62		44.58232	-83.33706	
78	Alcona	Greenbush	10	SE NW NW	25 N	9 E	1/4 mile S of Riddley Rd, 100 ft E of Scott Rd	101	9/24/1995	11	11	1	13	93	101		44.58008	-83.33724	
64	Alcona	Greenbush	9	NE SE NE	25 N	9 E	1/4 mile S of Ridley Rd on W side of Poor Farm Rd	55	9/25/1995	20	30	1	10	51	55		44.58010	-83.34172	
207	Iosco	Oscoda	4	NW NE NE	24 N	9 E	1/4 mile West of Cedar Lake Rd., 150 yds, S of Kings Corner Rd.	63	10/5/1995		3	1	16	59	63		44.51040	-83.34605	
333	Alcona	Greenbush	22	NW SW SE	25 N	9 E	3457 W Cedar Lake Rd.	42	4/20/1996	10	12	1	15	38	42		44.55938	-83.32926	JC
289	Alcona	Greenbush	15	NW NE SE	25 N	9 E	3332 East Cedar Lake Rd.	52	5/20/1996	3				46	52		44.55774	-83.32407	
68	Alcona	Greenbush	10	NE NW NW	25 N	9 E	100 yds SW of scott and Ridley Rds.	58	5/29/1996	20	27	1	12	54	58		44.58306	-83.33846	
79	Alcona	Greenbush	10	SE NW SE	25 N	9 E	2 mi S of intersection of F-30 and Cedar Lake Rd.	29	7/19/1996	7	15	1	10	25	29		44.56268	-83.32866	
208	Iosco	Oscoda	4	SE SE NW	24 N	9 E	Kings Corner and Westwood	57	10/4/1996	4	17	3	25	53	57		44.51159	-83.34668	
297	Alcona	Greenbush	15	SE SW NE	25 N	9 E	3229 Cedar Lake Rd	37	5/8/1997	2	35	1	30	32	37		44.56449	-83.32708	JC
318	Alcona	Greenbush	22		25 N	9 E	4129 Buena Vista	30	6/13/1997	3	20	1	12	26	30		44.53530	-83.33486	
81	Alcona	Greenbush	10	SW NW NW	25 N	9 E	2611 S Poor Farm Rd	58	8/5/1997	43	43	1	12	54	58		44.59120	-83.34114	
304	Alcona	Greenbush	21		25 N	9 E	4080 S. Poorfarm Rd	41	9/17/1997	14	25	2	12	31	41		44.59095	-83.34169	
80	Alcona	Greenbush	10		25 N	9 E	2895 US-23	30	9/30/1997	8	10	1	14	26	30		44.57189	-83.31501	
83	Alcona	Greenbush	10	NE SE NE	25 N	9 E	2685 State Rd	31	6/23/1998	9	9	1	15	27	31		44.57800	-83.31543	
340	Alcona	Greenbush	22	SW NE NE	25 N	9 E	3578 Cedar Lake Dr.	35	7/1/1998	4	4	1	15	28	32		44.55365	-83.32419	
82	Alcona	Greenbush	10		25 N	9 E	1/4 mile S of Riddley Rd, 100ft E of Scott Rd	54	8/10/1998	13	13	1	17				44.58017	-83.33724	
315	Alcona	Greenbush	22		25 N	9 E	3744 E Cedar Lake Dr.	39.5	9/17/1998	3	30	1	7	35.5	39.5		44.54887	-83.32423	
198	Iosco	Oscoda	4	NE SW SW	24 N	9 E	7403 Devonshire Rd.	30	9/28/1998	15	17	1	14	26	30		44.49831	-83.35200	
59	Alcona	Greenbush	9	SE SE NE	25 N	9 E	2711 Scott	70	10/1/1998	12							44.58230	-83.33760	
338	Alcona	Greenbush	22	NW NE NE	25 N	9 E	3566 E. Cedar Lake Dr.	30	10/22/1998	5	25	1	30	25	30		44.55393	-83.32423	
65	Alcona	Greenbush	9	NW NW NW	25 N	9 E	1/2 mile S of F-30, 1/4 mile W of Yukon Dr.	136	10/24/1998	113	113	1	16	128	136		44.58372	-83.35055	
84	Alcona	Greenbush	10	SW NW NW	25 N	9 E	1/4 mile S of Riddley, 100 ft W of Stevens Rd	57	11/19/1998	36	31	1	14	49	57		44.58004	-83.34007	
337	Alcona	Greenbush	22		25 N	9 E	3609 Cedar Lake Dr	31	11/25/1998	10	20	1	10	27	31		44.55276	-83.32406	
197	Iosco	Oscoda	4	NW SW NE	24 N	9 E	7891 Gulf View	57	3/23/1999	4	10	0.5	10	53	57		44.51050	-83.34677	SC
420	Alcona	Greenbush	33	SW SW SW	25 N	9 E	80 ft W of Poor Farm Rd., 1/4 mile N of Kings Corner Rd.	66	6/1/1999	6	6	1	20	58	66		44.53344	-83.35134	
314	Alcona	Greenbush	22		25 N	9 E	4171 E Cedar Lake Dr.	27	6/12/1999	3	18	1	5	25	27		44.51361	-83.35859	
313	Alcona	Greenbush	22	NE NE SW	25 N	9 E	3625 Cedar St.	43	7/14/1999	11	35	1	25	38	43		44.55481	-83.33046	
561	Iosco	Oscoda	10		24 N	9 E	480 BROOKWOOD	35	7/5/2000	12	12	1	24	37	35		44.48616	-83.33735	
73	Alcona	Greenbush	10	SE NW NW	25 N	9 E	1/4 mile S of Ridley Rd, 200 ft E of Scott Rd	63	7/12/2000	32	32	1	13	59	63		44.51880	-83.35849	
452	Alcona	Greenbush	32		25 N	9 E	7751 CEDAR LAKE ROAD OSCODA, MI 48750	68	7/19/2000	5	60	1	400	38	68		44.51290	-83.37074	
397	Alcona	Greenbush	28		25 N	9 E	4480 BIRCH ACRES OSCODA, MI	76	9/19/2000	7	13	1	12	68	76	4.0	44.51087	-83.35145	
533	Alcona	Greenbush	22		25 N	9 E	3675 W CEDAR LAKE RD GREENBUSH, MI 48738	44	12/5/2000	9	20	1	15	39	44	5	44.49848	-83.34967	
765	Iosco	Oscoda	9		24 N	9 E	4531 OAK RIDGE	57	5/8/2001	8	40	1	20	52	57	5	44.50855	-83.35722	
579	Alcona	Greenbush	32		25 N	9 E	7751 CEDAR LAKE RD OSCODA , MI 48750	68	5/16/2001	11	57	1	40	58	68	5	44.50839	-83.34631	SC
833	Iosco	Oscoda	10		24 N	9 E	7725 Cedar Lane	32	6/24/2001	4	9	1	8	28	32	5	44.50447	-83.35133	
678	Alcona	Greenbush	22		25 N	9 E	4093 E. CEDAR LAKE DR GREENBUSH, MI	29	7/18/2001	10	19	1	11	26	29	5	44.50220	-83.35040	
898	Iosco	Oscoda	10		24 N	9 E	7245 HUNTINGTON	43	7/20/2001	7	35	1	40	33	43	5	44.56092	-83.32867	JC
290	Alcona	Greenbush	15		25 N	9 E	3389 W. Cedar Lake Rd. Greenbush, MI 48738	40	9/10/2001	8	30	2	25	30	40	5	44.52800	-83.35882	
844	Alcona	Greenbush	22		25 N	9 E	3939 W CEDAR LAKE RD	57	5/1/2002	above	57	1	100	51	57	8	44.51290	-83.37074	
841	Alcona	Greenbush	15		25 N	9 E	3300 SUNSET DRIVE GREENBUSH, MI	38	6/1/2002	3	25	1	6	26	38	5	44.55068	-83.33252	
850	Alcona	Greenbush	15		25 N	9 E	3585 CEDAR LAKE RD GREENBUSH, MI	36	7/1/2002	14	21	1	25	30	36	5	44.51197	-83.36926	
1098	Iosco	Oscoda	10		24 N	9 E	7378 LAKEWOOD DRIVE	42	7/30/2002	7	19	1	25	35	42	4	44.55104	-83.32377	
928	Alcona	Greenbush	15		25 N	9 E	CEDAR LK RD GREENBUSH, MI	33	11/13/2002	12	18	1	12	26	33	5	44.56016	-83.32208	
1169	Iosco	Oscoda	10		24 N	9 E	7109 CEDAR LAKE ROAD	35	11/14/2002	8	35	1	30	29	35	5	44.54423	-83.32458	
1239	Iosco	Oscoda	16		24 N	9 E	6881 Loud Dr.	42	6/7/2003	9	30	2	20	37	42	5	44.55585	-83.32406	
1091	Alcona	Greenbush	22		25 N	9 E	3991 WEST CEDA LAKE ROAD MI	57	8/19/2003	above				50	57	5	44.55684	-83.32378	
1471	Iosco	Oscoda	10		24 N	9 E	4718 WILLOWBEND	36	9/6/2003	13	21	1	23	32	36	5	44.54246	-83.33391	
1160	Alcona	Greenbush	22		25 N	9 E	3871 WEST CEDAR LAKE ROAD MI	32	9/11/2003	11	18	1	12	28	32	4	44.54270	-83.33464	
1794	Iosco	Oscoda	4		24 N	9 E	7589 WESTWOOD	56	12/2/2003	4	14	1	15	50	56	5	44.54314	-83.32495	
1559	Iosco	Oscoda	16		24 N	9 E	7068 Loud Drive	45	1/21/2004	15	30	1	30	35	45	5	44.55270	-83.33148	
1870	Alcona	Greenbush	22		25 N	9 E	4924 E. Cedar Lake Greenbush, MI 48738	59	2/18/2004	7	15	2	20	55	59	5	44.55330	-83.35104	
1890	Alcona	Greenbush	22		25 N	9 E	3563 CEDAR LAKE DRIVE GREENBUSH, MI	36	4/19/2004	7	7	19	15	30	36	5	44.55360	-83.33119	
1891	Alcona	Greenbush	21		25 N	9 E	3491 POORFARM ROAD GREENBUSH, MI	53	5/3/2004	12	26	1	12	47	53	5	44.55614	-83.33020	
1915	Alcona	Greenbush	22		25 N	9 E	3742 CEDAR LAKE RD MI 48738	46	5/18/2004	6	14	1	14	40	46	4	44.55521	-83.32447	
1929	Alcona	Greenbush	15		25 N	9 E	3453 Cedar Lake Rd. Greenbush, MI 48738	38	6/14/2004	9	30	2	18	33	38	5	44.55464	-83.33161	
1988	Alcona	Greenbush	15		25 N	9 E	3652 CEDAR LAKE DR GREENBUSH, MI 48738	33	7/9/2004	8	14	1	12	29	33	5	44.55590	-83.32358	
2575	Iosco	Oscoda	10		24 N	9 E	7212 CEDAR BROOK	29	10/6/2004	12	21	1	14	25	29	5	44.54674	-83.32497	
2303	Alcona	Greenbush	15		25 N	9 E	4968 HURON CEDAR GREENBUSH, MI 48738	32	10/11/2004	4	18	1	14	32		5	44.54231	-83.33477	

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2542	Iosco	Oscoda	4		24 N	9 E	4320 CUSTWOOD DRIVE OSCODA, MI 48750	52	10/22/2004	5	18	1	18	44	52	5	44.54276	-83.32494	
2302	Alcona	Greenbush	22		25 N	9 E	3617 CEDAR STREET GREENBUSH, MI 48738	48	10/25/2004	11	18	1	14	42	48	5	44.54144	-83.33321	
2394	Alcona	Greenbush	22		25 N	9 E	4548 E Cedar Lake Dr Greenbush, MI 48738	159	1/17/2005	10	0	1	20	151	159	5	44.54211	-83.35770	
2450	Alcona	Greenbush	22		25 N	9 E	3547 W. CEDAR LAKE RD. GREENBUSH , MI 48738	42	6/22/2005	11	19	1	15	36	42	5	44.55220	-83.33058	
2508	Alcona	Greenbush	22		25 N	9 E	4964 EAST CEDAR LAKE DRIVE GREENBUSH, MI 48738	56	6/27/2005	11	23	1	15	50	56	5	44.56896	-83.34089	
2604	Alcona	Greenbush	22		25 N	9 E	3950 CEDAR LAKE ROAD GREENBUSH, MI 48738	31	9/21/2005	9	22	1	14	25	31	5	44.55538	-83.32446	
2623	Alcona	Greenbush	15		25 N	9 E	3569 EAST CEDAR LAKE DRIVE GREENBUSH, MI 48738	33	9/23/2005	12	21	1	11	27	22	5	44.55601	-83.32405	
2899	Iosco	Oscoda	4		24 N	9 E	4568 WEST WOOD DRIVE OSCODA, MI 48750	61	9/29/2005	6	19	1	14	55	61	5	44.54257	-83.32494	
2562	Alcona	Greenbush	22		25 N	9 E	3983 Cedar Lake Rd. Greenbush, MI 48738	56	10/5/2005	0	50	2	50	51	56	5	44.54540	-83.32545	
2576	Alcona	Greenbush	21		25 N	9 E	3950 Summers Trail Greenbush, MI 48738	43	10/10/2005	11	35	2	15	38	43	5	44.56866	-83.33464	
2620	Alcona	Greenbush	15		25 N	9 E	3400 EAST CEDAR LAKE DRIVE GREENBUSH, MI 48730	33	10/28/2005	5	18	1	14	27	33	5	44.56223	-83.33136	JC
2618	Alcona	Greenbush	15		25 N	9 E	3007 SOUTH POORFARM GREENBUSH, MI 48738	47	11/3/2005	10	19	1	12	41	47	5	44.54526	-83.32496	
2673	Alcona	Greenbush	22		25 N	9 E	4986 E. CEDAR LAKE DRIVE GREENBUSH , MI 48738	57	5/9/2006	11	19	1	15	51	57	5	44.54135	-83.33337	
2689	Alcona	Greenbush	15		25 N	9 E	4680 Wissmiller Greenbush, MI 48738	107	6/12/2006	7	105	3	8	97	107	5	44.55510	-83.35121	
2686	Alcona	Greenbush	22		25 N	9 E	3794 E. Cedar Lake Rd. Greenbush, MI 48738	49	6/20/2006	7	49	1	20	43	49	5	44.54479	-83.35818	
2757	Alcona	Greenbush	15		25 N	9 E	3443 U.S. 23 Greenbush, MI 48738	47	9/5/2006	10	30	2	35	36	46	5	44.54767	-83.32573	
3020	Alcona	Greenbush	21		25 N	9 E	3875 S POORFARM RD GREENBUSH, MI 48738	51	5/30/2007	18	31	1	14	41	51	5	44.51191	-83.35608	
3828	Iosco	Oscoda	4		24 N	9 E	4013 RALPH SCOTT DRIVE OSCODA, MI 48750	47	5/31/2007	12	29	1	20	37	47	5	44.55937	-83.32178	
2910	Alcona	Greenbush	22		25 N	9 E	3796 E CEDAR LK DR GREENBUSH, MI 48738	50	7/16/2007	5	19	1	14	44	50		44.55937	-83.32180	
2985	Alcona	Greenbush	16		25 N	9 E	3490 POORFARM GREENBUSH, MI 48738	48	8/6/2007	8	29	0	20	42	48	5	44.54542	-83.32457	
3593	Iosco	Oscoda	4		24 N	9 E	7883 GOLFVIEW DR OSCODA, MI 48750	71	10/17/2007	5	25	1	10	58	71	12	44.51674	-83.34111	
2944	Alcona	Greenbush	22		25 N	9 E	3989 W. Cedar Lk. Rd. Greenbush, MI 48738	56	10/19/2007	3	56	1	50	50	56	5	44.51694	-83.34113	SC
3141	Alcona	Greenbush	22		25 N	9 E	3746 CEDAR LK DR GREENBUSH, MI 48088	57	7/29/2008	12	16	0.5	20	51	57	5	44.51646	-83.34103	SC
3175	Alcona	Greenbush	15		25 N	9 E	5025 WOODLAND GREENBUSH, MI 48738	90	9/12/2008							5	44.55492	-83.32435	
3174	Alcona	Greenbush	15		25 N	9 E	5025 WOODLAND DR GREENBUSH, MI 48738	98	9/22/2008	18	30	1	10	92	98	5	44.54857	-83.34927	
3156	Alcona	Greenbush	33		25 N	9 E	4999 Birch Acres Oscoda, MI 48750	66	5/4/2009	4	40	1	35	61	66	5	44.55741	-83.32996	
3280	Alcona	Greenbush	22		25 N	9 E	3793 E CEDAR LAKE DR GREENBUSH, MI 48738	48.5	8/15/2009	19	25	0.5	20	42	48.5	5	44.51363	-83.35256	
3365	Alcona	Greenbush	22		25 N	9 E	3494 CEDAR LAKE DR GREENBUSH, MI 48738	35	7/7/2010	6	20	1	10	31	35	5	44.54071	-83.32479	
3336	Alcona	Greenbush	33		25 N	9 E	CEDAR LAKE RD. OSCODA , MI 48750	70	10/18/2010	3.5	36.25	2	94	60	70	5	44.54076	-83.32475	SC
3337	Alcona	Greenbush	33		25 N	9 E	CEDAR LAKE RD. OSCODA, MI 48750	70	10/19/2010	3.5	20	2	20	65	70	5	44.54843	-83.33177	SC
3335	Alcona	Greenbush	33		25 N	9 E	CEDAR LAKE RD. OSCODA, MI 48750	70	10/26/2010	3.6	70	8	200	60	70	5	44.55700	-83.32935	SC
3580	Alcona	Greenbush	21		25 N	9 E	3600 DOE TRL GREENBUSH, MI 48738	81	7/16/2011	12	20	1	20	75	81	5	44.55282	-83.33090	
3671	Alcona	Greenbush	15		25 N	9 E	3519 CEDAR LK RD GREENBUSH, MI 48738	35	8/21/2013	10	20	1	20	30	35	5	44.55032	-83.35497	
3762	Alcona	Greenbush	33		25 N	9 E	4982 BIRCH ACRES ROAD OSCODA, MI 48750	66	3/4/2015	5	45	3	30	56	66	5	44.55286	-83.32415	
3785	Alcona	Greenbush	22		25 N	9 E	4005 E. CEDAR LAKE DRIVE GREENBUSH, MI 48738	30	5/15/2015	10	25	2	15	25	30	5	44.54305	-83.33387	
3786	Alcona	Greenbush	22		25 N	9 E	4005 E. CEDAR LAKE DRIVE GREENBUSH, MI 48728	72	5/15/2015	0	0	0	0	32	42	5	44.56923	-83.35082	
3965	Alcona	Greenbush	15		25 N	9 E	3431 CEDAR LK RD GREENBUSH, MI 48738	42	10/13/2015	10	22	1	30	33	42	5	44.55892	-83.32878	
4228	Alcona	Greenbush	15		25 N	9 E	3377 W. CEDAR LK RD GREENBUSH, MI 48738	41	7/15/2016	7.5	25	1	15	31	41	5	44.55666	-83.32923	
4229	Alcona	Greenbush	15		25 N	9 E	3451 W. CEDAR LK RD GREENBUSH, MI 48738	40	9/12/2016	9	20	1	30	30	40	5	44.55630	-83.32945	
3932	Alcona	Greenbush	22		25 N	9 E	3741 W. CEDAR LAKE ROAD GREENBUSH, MI 48728	48	10/20/2016	10	40	3	10	40	45	5	44.53704	-83.34213	
4226	Alcona	Greenbush	22		25 N	9 E	3927 CEDAR LK RD GREENBUSH, MI 48738	33	5/9/2017	5	20	1	15	28	33	5	44.54904	-83.33203	
4230	Alcona	Greenbush	15		25 N	9 E	3463 W. CEDAR LK RD GREENBUSH, MI 48738	45	6/2/2017	12	30	0.5	15	40	45	4	44.48616	-83.33735	
4225	Alcona	Greenbush	22		25 N	9 E	3601 E. CEDAR LK DR GREENBUSH, MI 48738	29	8/25/2017	10	20	0.5	15	25	29	5	44.48502	-83.34400	
4227	Alcona	Greenbush	16		25 N	9 E	4266 E. WISSMILLER RD GREENBUSH, MI 48738	55	9/15/2017	16	30	1	40	50	55	2	44.49382	-83.33157	
4042	Alcona	Greenbush	22		25 N	9 E	3579 Cedar St. Greenbush, MI 48738	44	5/18/2018	8	36	1	20	38	44	5	44.48911	-83.33000	
4778	Iosco	Oscoda	4		24 N	9 E	7592 Westwood Dr. Oscoda, MI 48750	60	8/20/2018	4	25	1	20	50	60	4	44.49343	-83.33057	
4113	Alcona	Greenbush	21		25 N	9 E	3628 POOR FARM ROAD GREENBUSH, MI 48740	50	11/8/2018	7	35	3	15	40	50	5	44.50027	-83.33587	
4281	Alcona	Greenbush	28		25 N	9 E	4102 W Cedar Lake Rd GREENBUSH, MI 48738	57	9/17/2019	0.5	15	1	30	52	57	5	44.47987	-83.36144	
4327	Alcona	Greenbush	22		25 N	9 E	3703 W. Cedar Lk Rd. Greenbush, MI 48738	41	9/1/2020	7	41	1	20	28	34	4	44.48351	-83.32881	
200	Iosco	Oscoda	4		24 N	9 E	1/2 mile E of Cedar Lake Rd, 1 mile S of Kings Corner Rd,	105								5	44.48545	-83.36407	
321	Alcona	Greenbush	22	NE SW SW	25 N	9 E	3944 Cedar lake Dr	20		5			10	16	20	5	44.50309	-83.35003	
336	Alcona	Greenbush	22		25 N	9 E	1.5 miles S of Wissmiller, 400 ft E of Cedar Lake Rd.	32								4	44.49084	-83.33533	

APPENDIX E

EXCERPTED 2010 WILLIAMS & WORKS GROUNDWATER RESOURCE EVALUATION FOR CEDAR LAKE WETLANDS IMPROVEMENT PROJECT AQUIFER TESTING (AS REPORTED IN K&A, 2011)

Williams & Works
engineers . planners . surveyors
a tradition of service

November 29, 2010

Mr. Gerry Neubecker, III, President
Raymer Company
1357 Comstock Street
Marne, Michigan 49435

COPY

Reference: Groundwater Resource Evaluation Cedar lake Wetlands Improvement Project, Alcona County, Michigan

Dear Mr. Neubecker:

As you are aware, a new test pumping well was recently completed and an aquifer test was performed near Cedar Lake in Greenbush Township, Alcona County. A new system of wetland rehabilitation wells is proposed to provide water for the nearby wetland areas west of Cedar Lake. The purpose of this report, therefore, is to summarize the results of an aquifer test which will provide the basis of design for a proposed array of wells to be used for this purpose. The proposed withdrawal rate for this system (as determined by others) is 500 gpm.

Geologic Background

The surface topography in this area is relatively flat lying between about 600 and 620 feet. Much of the east half of Greenbush Township is marshland and associated with the Cedar Lake Swamp. The regional drainage in this area trends toward the southwest into the Pine River Drainageway and Van Etton Lake (see Figure 1).

Cedar Lake is located at the southeastern edge of Greenbush Township in Alcona County. Although most of southeast Alcona County is drained by the Pine River Basin and its wide network of tributaries, Cedar Lake appears to be somewhat isolated from the Pine River Basin. Compared to the average water level of Lake Huron at 579 feet, the average water level of Cedar Lake is considerably higher at about 607 feet (as taken directly from the USGS map), yet the edge to edge distance between the two water bodies is within ½ mile from each other. Localized mapping of Cedar Lake shows this lake to be within its own relatively small and enclosed watershed.

Groundwater flow in the local area is assumed to flow southward toward Van Etton Lake from the west side of the divide (west of Cedar Lake), or eastward directly toward Lake Huron within the Cedar Lake catchment area (see again Figure 1). A localized map of the local groundwater flow gradient is not possible to depict due to the layout of test wells (shown further below).

616.224.1500 phone . 800.224.1590 toll free . 616.224.1501 facsimile
549 Ottawa Avenue NW . Grand Rapids, MI 49503
williams-works.com

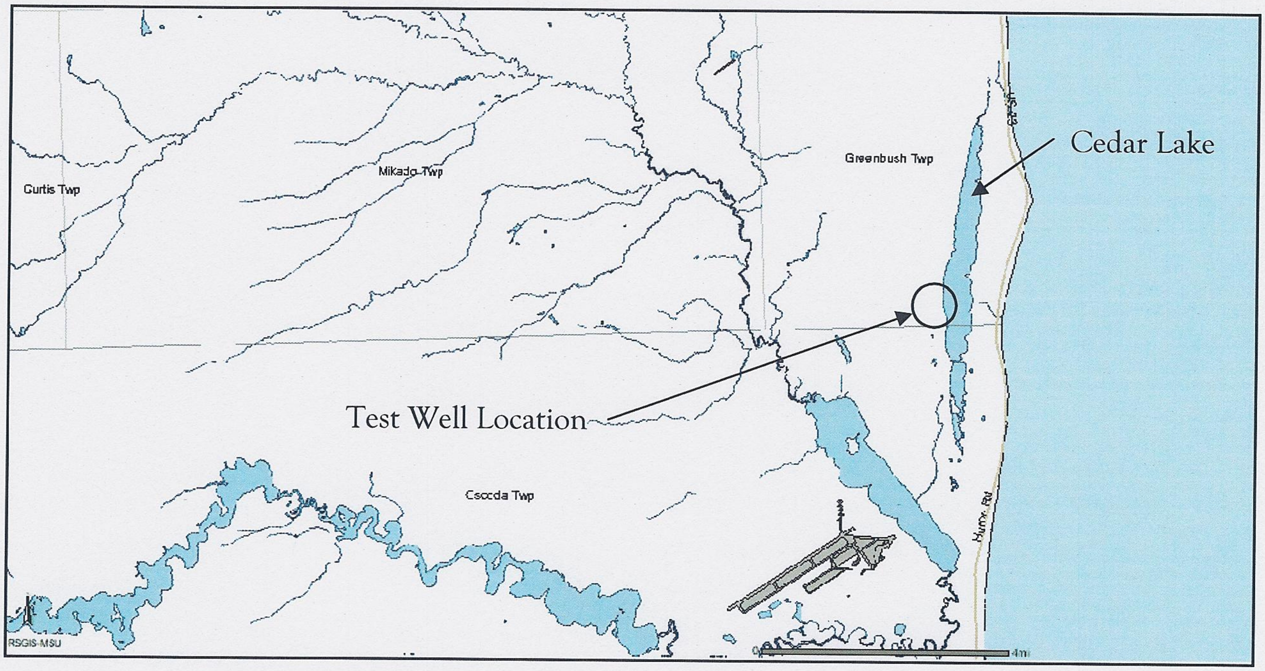

Figure 1. **Location Map of Cedar Lake and the Surrounding Areas of Southeast Alcona County and Northeast Iosco County**

The glacial deposits in this area consist mainly of lacustrine sands and gravels, with dune deposits east of the Lake, and broad fine textured till plains west of the area (see Figure 2).

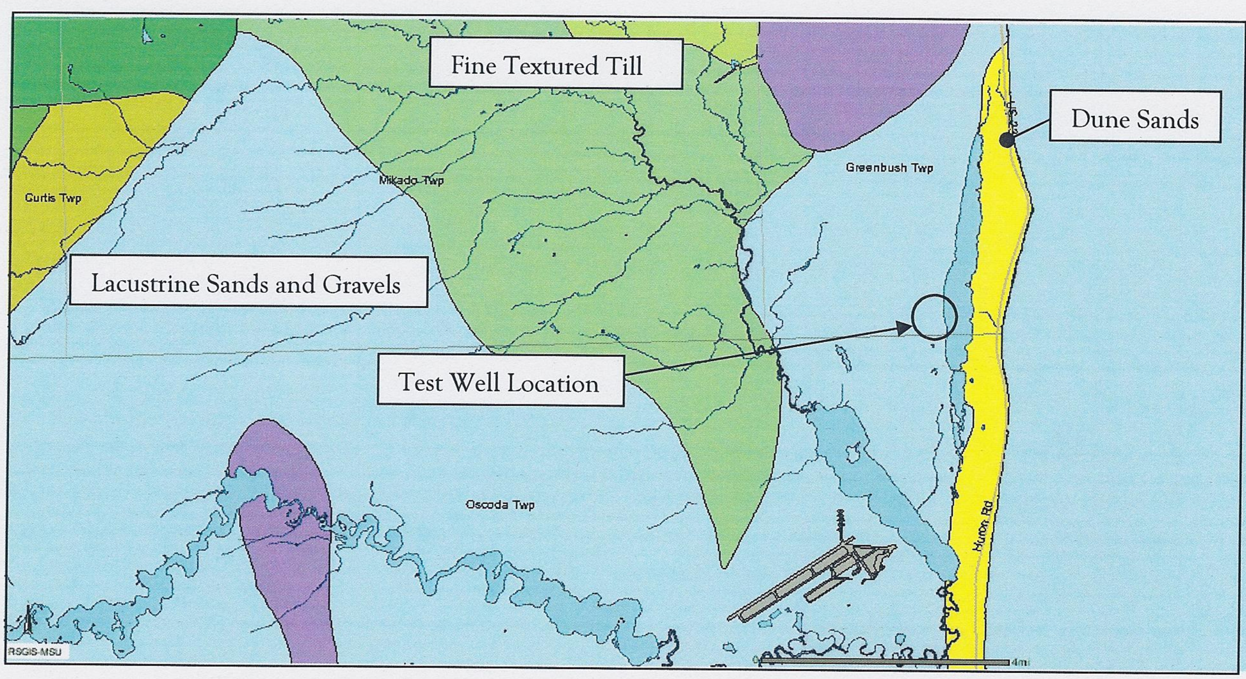

Figure 2. **Glacial Deposits in Southeast Alcona County and Northeast Iosco County**

Test Well and Observation Well Construction

A 12-inch test well and two observation wells were constructed to characterize the hydraulics of the aquifer in this area. A summary of these wells is as follows (well logs are attached to this report for reference);

12-inch Test Well (pumping well) has the following characteristics:

1. Drilled to a depth of 70 feet.
2. 60 feet of 12-inch PVC casing.
3. 10 feet of 12-inch diameter, 0.040 slot SSWW gravel packed screen set at a depth of 70 feet. The screen has a unit entrance capacity of 32.39 gpm/ft (at 0.1 ft/sec entrance velocity), or a total capacity of at least 324 gpm. Therefore, for the purpose of this aquifer test, we should not be concerned with entrance losses contributing to pumping well drawdowns.
4. The annular space filled from 50 feet to the surface with bentonite slurry.

5-inch Observation Well (OW-1) has the following characteristics:

1. Drilled to a depth of 70 feet.
2. 60 feet of 5-inch PVC casing.
3. 10 feet of 4.5-inch diameter, 0.012 slot PVC gravel packed screen set at a depth of 70 feet.
4. The annular space filled from 50 feet to the surface with bentonite slurry.

2-inch Observation Well (OW-2) has the following characteristics:

1. Drilled to a depth of 70 feet.
2. 65 feet of 2-inch PVC casing.
3. 5 feet of 2-inch diameter, 0.010 slot PVC gravel packed screen set at a depth of 70 feet.
4. The annular space filled from 60 feet to the surface with bentonite slurry.

The associated state plane and geographic coordinates, and top of casing elevations for each well are as follows:

Well Name	xcoord	ycoord	latitude	longitude	SWL	TOC elev	SWL elev
TPW-1	19952491.88	439199.59	44.51674	83.34111	4.6	616.20	611.60
OW-1 (5-inch)	19952485.23	439285.92	44.51698	83.34113	4.5	615.20	610.70
OW-2 (5-inch)	19952524.94	439098.74	44.51646	83.34099	4.5	616.14	611.64

A local map of the wellsite is shown below in Figure 3.

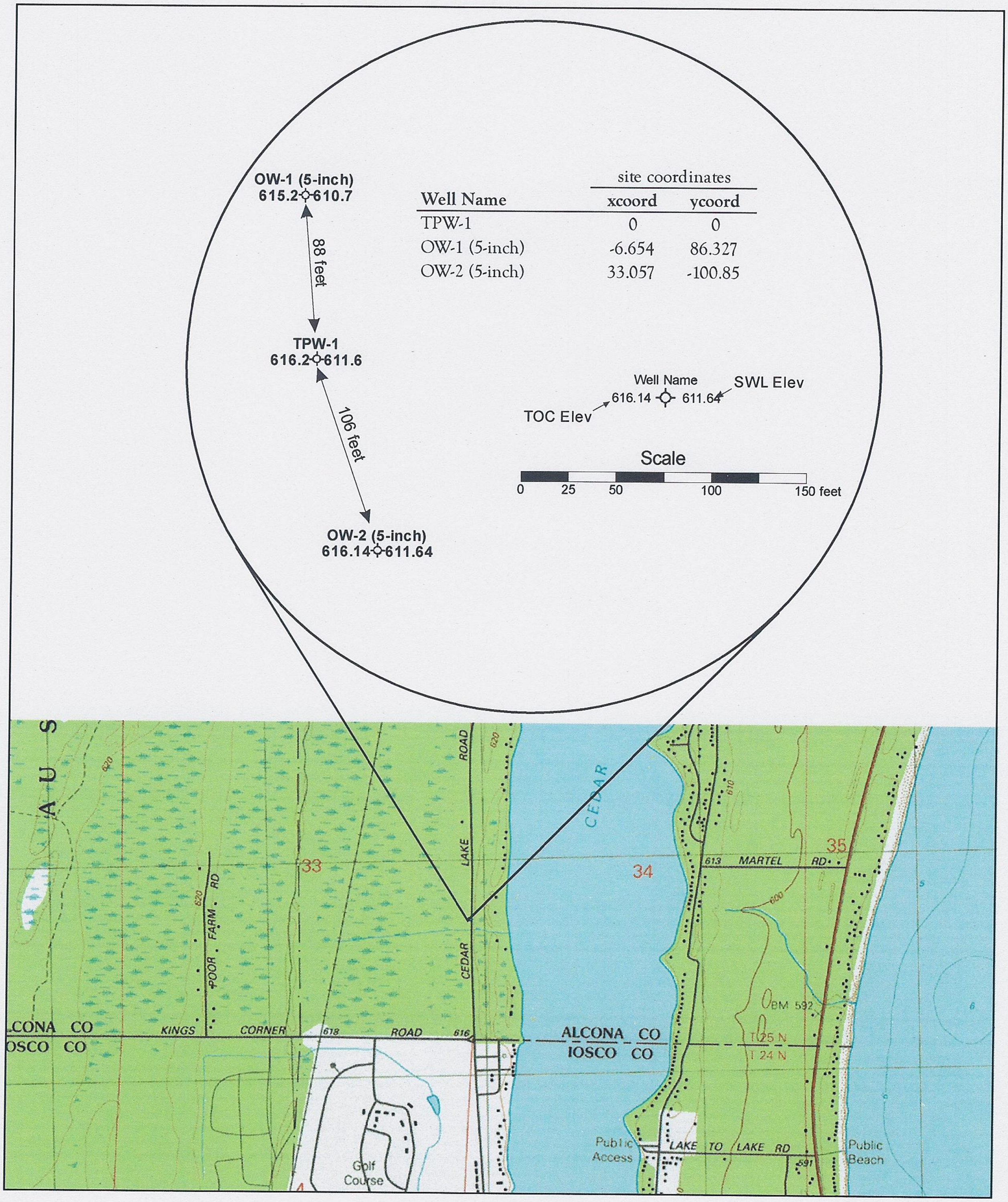

Figure 3. **Local Map of the Test Well Site at Cedar Lake**

Given the arrangement of wells at the site, the local groundwater flow direction based on static water level elevations is difficult to determine. However, based on local drainage in this immediate area, it is likely that the local groundwater flow direction is east-southeast toward Cedar Lake.

The geology in this area consists of sandy soils from the surface to a depth of about 32 feet, which rests on a clayey layer between about 32 and 55 feet. Beneath the intervening clay layer lies a "lower" sandy interval between about 55 and 70 feet. Clayey soils extend at least seven feet below the lower aquifer from 70 to at least 77 feet below grade. The upper sandy interval is saturated and unconfined, and the "lower" aquifer appears to be under semi-confined conditions. The 12-inch test pumping well and both observation wells were installed within the "lower" 15 feet of sandy formation. Static water levels within the lower aquifer are about 3.5 feet below grade in this area.

A localized graphical illustration of the drift package at the wellsite is shown below:

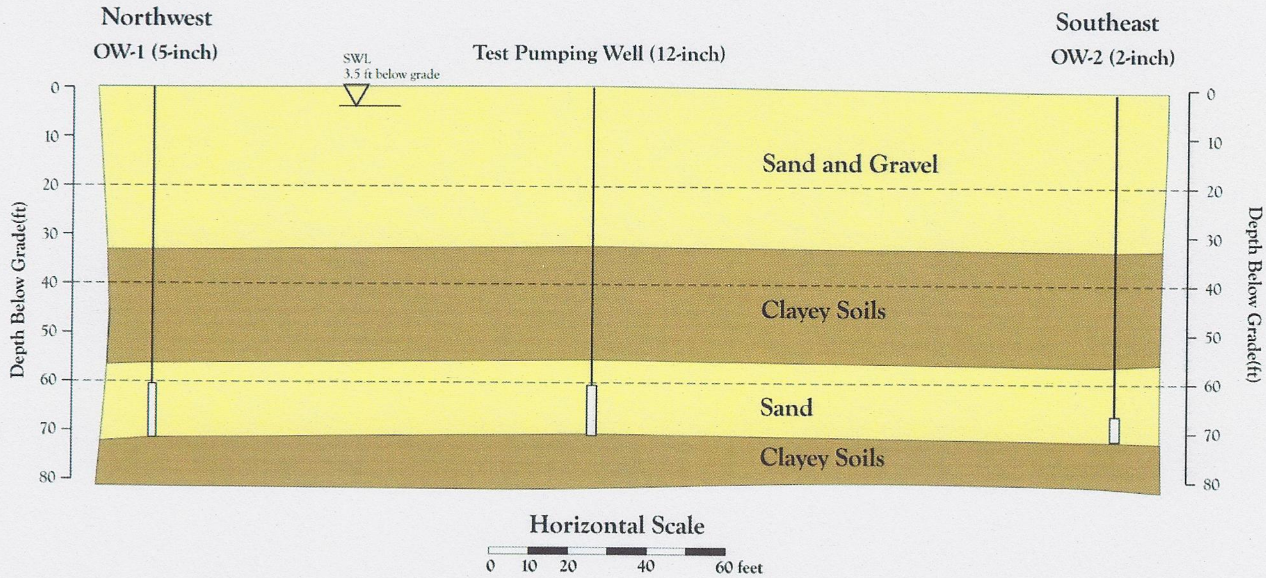

Figure 4. Local Geologic Cross-Section Viewing Northeast

Aquifer Testing

The layout of the aquifer test is shown in Figure 3, above. The aquifer test was performed using the 12-inch PVC well as the pumping well, with a test pumping rate set at 155 gpm (20.7 ft^3/min). The well was pumped for a duration of 24 hours. Drawdowns were monitored in the pumping well and both observation wells using pressure transducers and a data-logging instrument.

Examination of the shape of the semi-log plot in Figure 5 suggests that the aquifer is slightly leaky-confined, or may indicate the presence of a weak recharge-type boundary in the area. In the case of a recharge boundary, either the Lake or the wetland areas or both could provide the conditions for recharge-type boundaries. The plot shows reasonably reversible drawdown and recovery behavior.

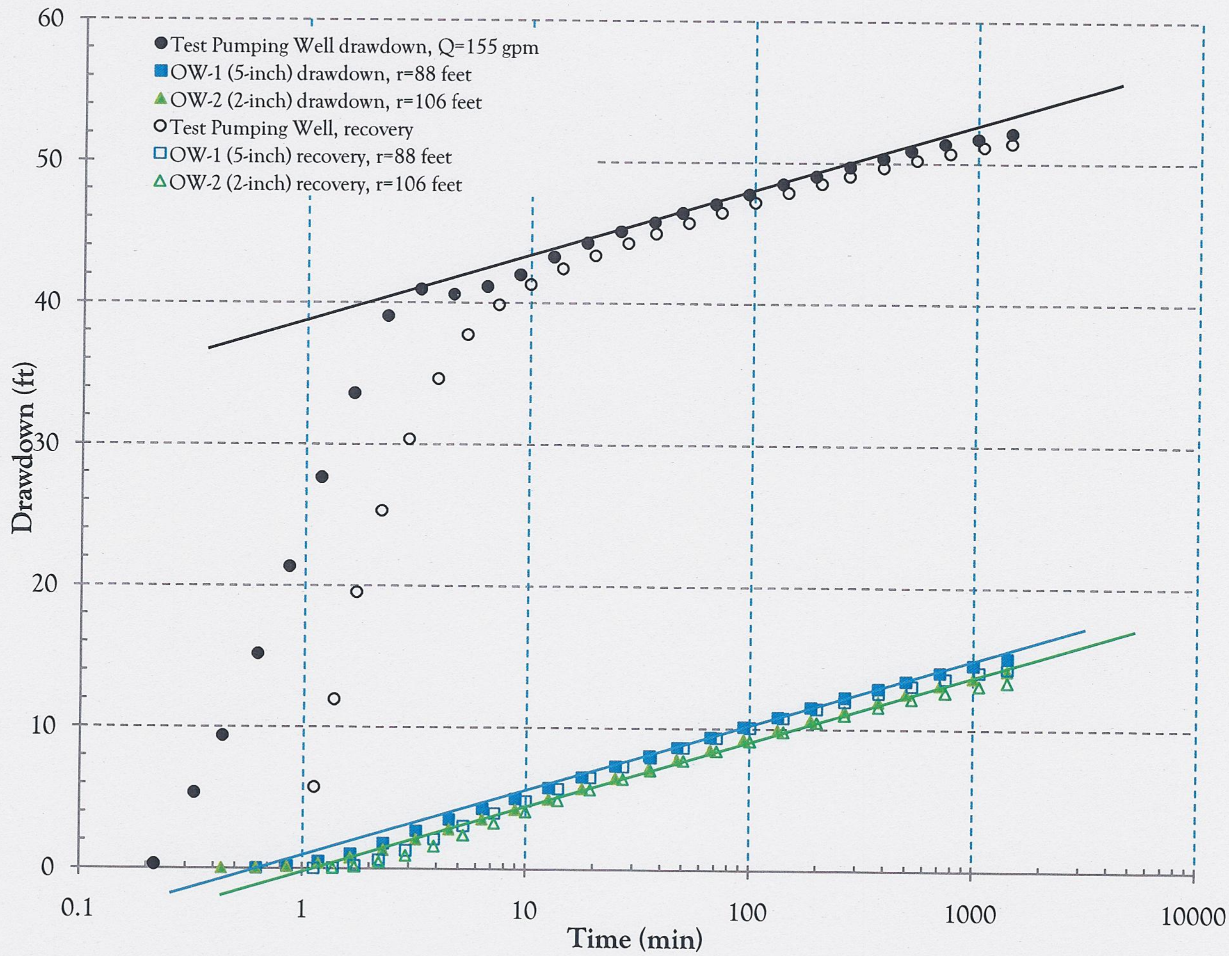

Figure 5 **Semi-Log Plot of Cedar Lake Aquifer Test on the 12-inch Test Pumping Well Showing the Pumping Well and Both Observation Wells, October 2010, Q=155 gpm**

The plot in Figure 6 below shows that the drawdown data from both wells yield similar transmissivity and storage values. In this case, the straight line analysis (after Cooper and Jacob, 1946[1]) was be applied to the early time data before the effects of leakance and (or) boundaries take

[1] Cooper, H.H., and C.E. Jacob, 1946, A generalized Graphic Method for Evaluating Formation Constants and Summarizing Well-Field History, Transactions of American Geophysical Union, Vol 27, No.4

over. This analysis yields a relatively low transmissivity value of 0.76 ft^2/min, which is plausible given the textural characteristics and saturated thickness of the formation. The calculated storage coefficient (S) from this method is about 0.0002 which is also reasonable for this system. Water levels in the immediate vicinity of the pumping well were very close to the bottom of the confining layer at or near 500 minutes, which may have caused a localized conversion from confined to unconfined conditions. This can explain the late time behavior at the observation wells at or near the same times. Aquifer boundaries could also explain this behavior, as can a weak leaky condition across the confining layer.

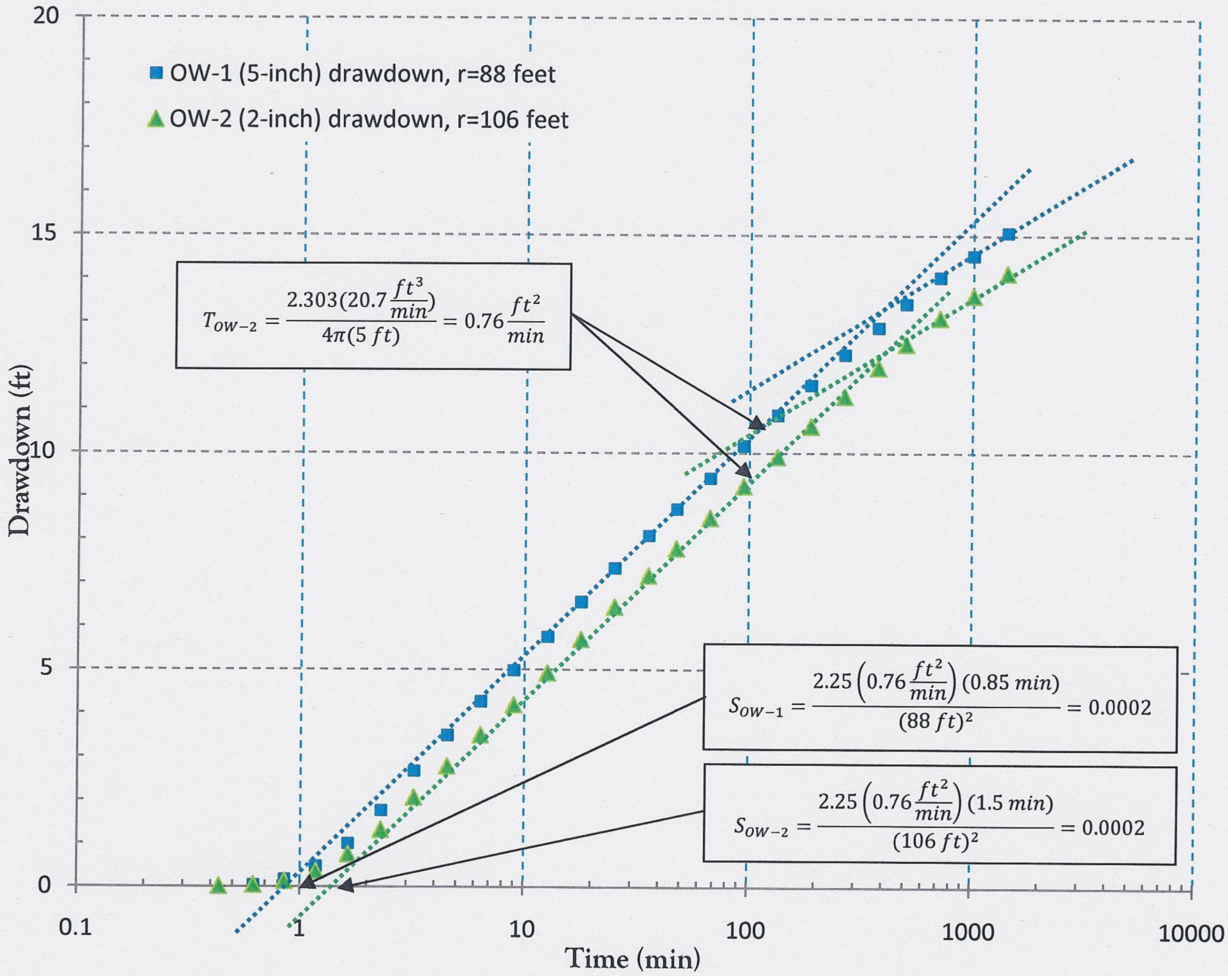

Figure 6 Semi-Log Plot of Cedar Lake Aquifer Test on the 12-inch Test Pumping Well Showing the Observation Wells, October 2010, Q=155 gpm

The type curve solution utilized the leaky-confined model after Hantush and Jacob[2]. This analysis assumes that water is instantaneously transmitted across the confining layer from a source aquifer

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[2] Hantush, M.S., C.E. Jacob, 1955, Non-steady Radial Flow in an Infinite Leaky Aquifer, Am. Geophys. Union Trans. vol 36, pp 95-100

to the pumped interval, which may or may not be a realistic assumption given that the intervening clayey layer is relatively sand free and dense. However, the presence of an upper saturated aquifer tends to satisfy the model assumption, and the effects of leakance are seen only after long pumping times. Partial penetration effects were not incorporated.

This analysis using the leaky-confined model and ignoring partial penetration is as follows;

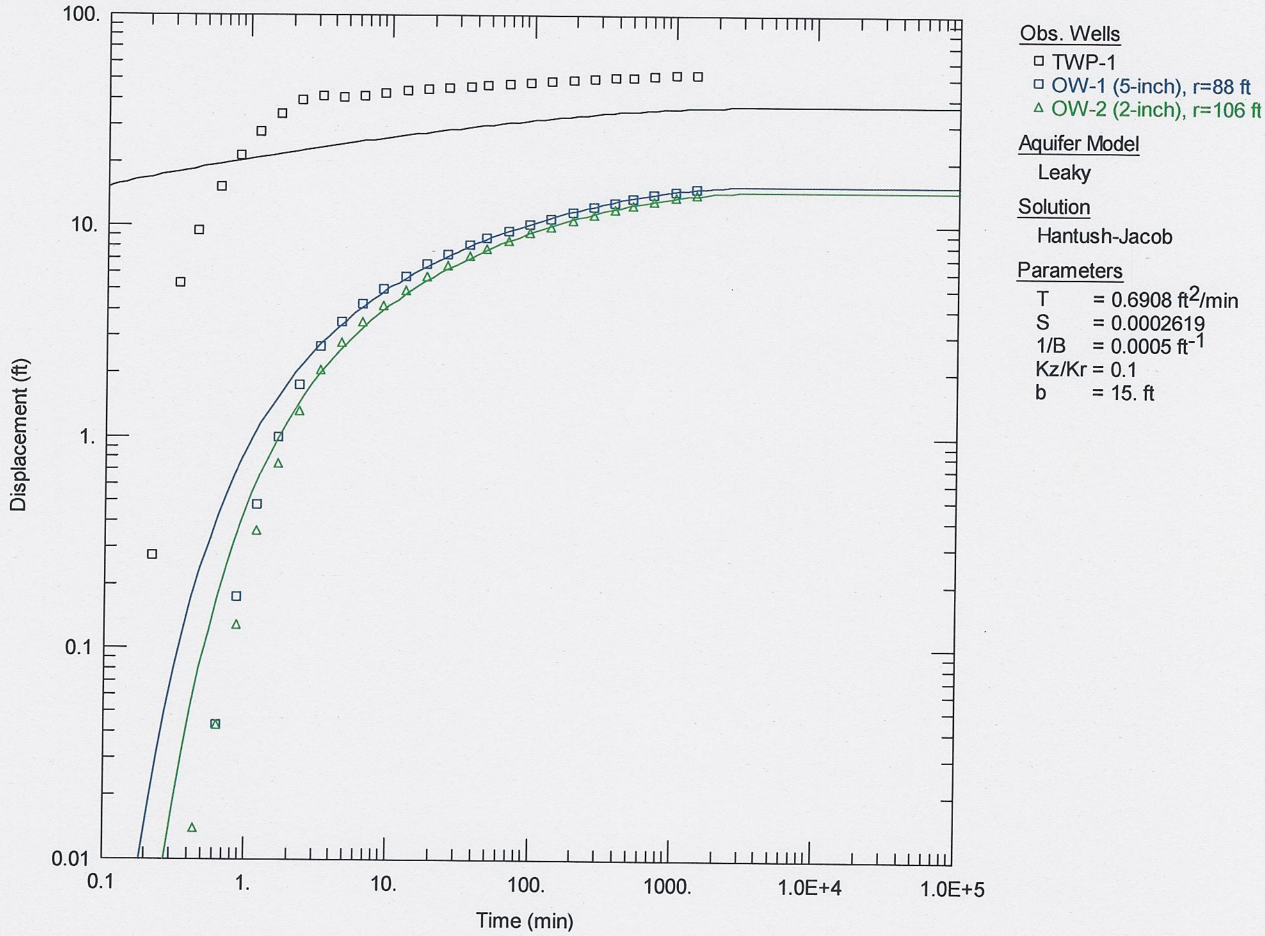


Figure 7 **Leaky-Confined Solution of Cedar Lake Aquifer Test (after Hantush and Jacob, 1955) Q=155 gpm**

The results derived from this solution are reasonably similar to those derived from the straight line analysis, but in this case a small leakance value improves the late time change in drawdown. The resulting horizontal hydraulic conductivity averaged over the entire aquifer thickness (b=15 feet) would be, therefore, about 66 ft/day.

Using this predictor set, the theoretical drawdown after 24 hours at the pumping well is about 36 feet, while the actual drawdown was about 52 feet, representing an apparent well efficiency (or correction factor) of about 69%[3] (which is plausible). The plot of drawdown at the test pumping well is as shown and extrapolated to 100 days. This plot reveals an extrapolated 100 day drawdown of about 57 feet without accounting for leakance.

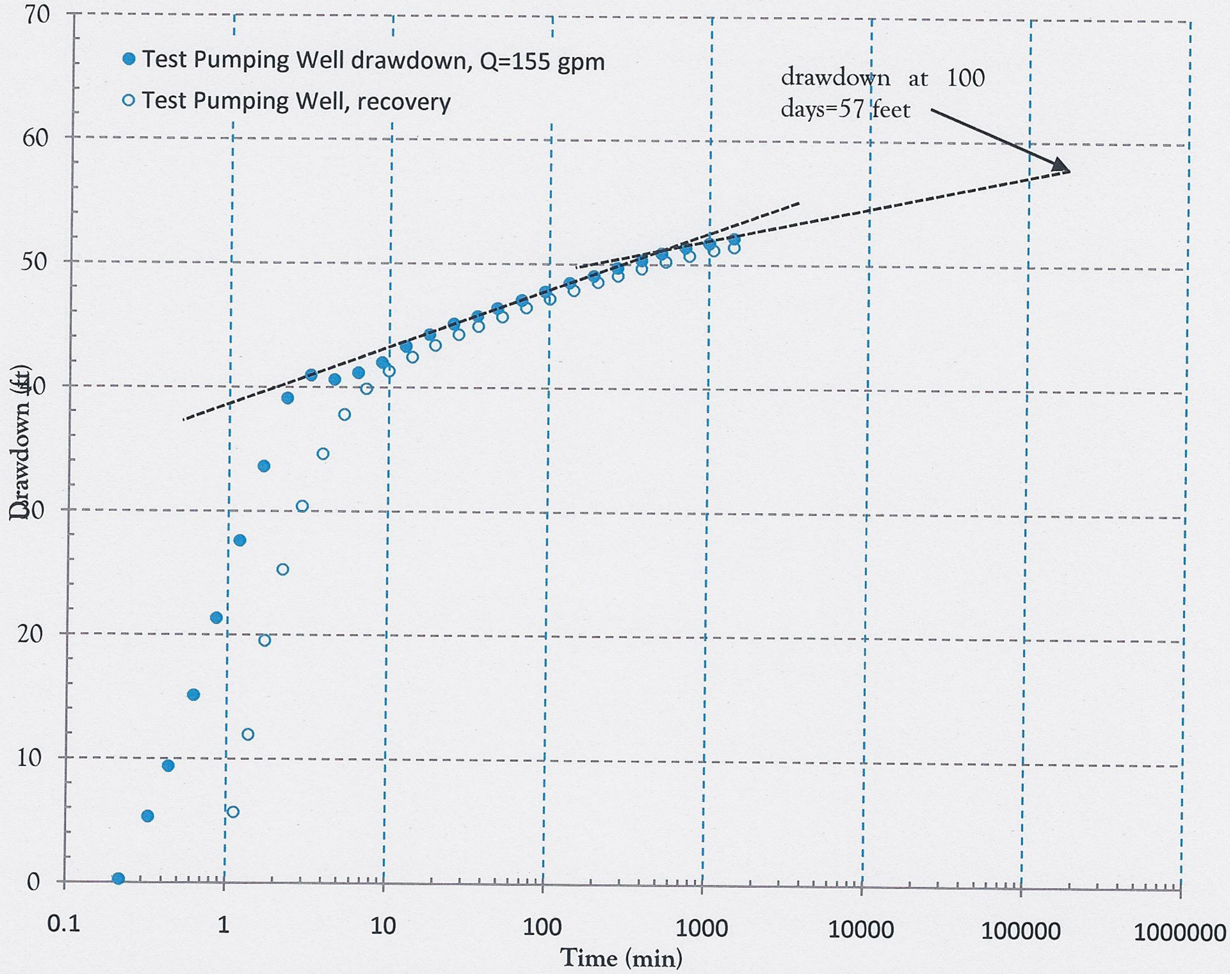


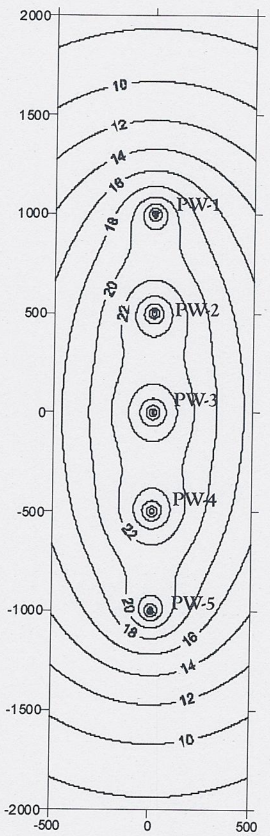
Figure 9 **Test Pumping Well Drawdowns at Cedar Lake (Q=155 gpm) from October, 2010 Aquifer Test**

Using the model predictor set, the pumping water level after 100 days at 155 gpm would be about 37 feet. After adding back the entrance losses, the actual pumping water level will be about 54 feet which is reasonably similar to the extrapolated plot in Figure 9 (the extrapolated curve, however, does not account for leakance). While this pumping rate would be acceptable for a single well, the goal will be to provide 500 gpm from a system of wells which would be run continuously over the summer months. The 100 day pumping period will provide a reasonable approximation to the actual demands that will be placed on this local aquifer.

[3] Apparent Well Efficiency=(theoretical dd)/(actual dd)=(36ft)/(52ft)=0.69

In order to simulate the interfering drawdowns resulting from several simultaneously pumping wells, we used the type curve matching software AQTESOLV to provide a regularly gridded drawdown distribution. The software utilizes the principal of superposition by cumulating the individual drawdowns from each well to produce a composite overall drawdown distribution. By trial and error, the production well array spacing and pumping rates were adjusted to ultimately consist of five wells, each well spaced at least 500 feet apart along a line oriented north-south, and each well pumping at a rate of 100 gpm. Wells are assumed to have an apparent well efficiency of 69%, and the maximum allowable drawdown was not allowed to fall below five feet above the top of the screened interval. The predictor set and results of this analysis are as follows:

- transmissivity (T) 0.69 ft^2/min, hydraulic conductivity (K) 66 ft/day
- aquifer storage coefficient (S) 0.00026
- aquifer thickness (b) 15 feet
- leakance (1/B) 0.0005 ft^{-1}
- pumping duration (t) of 100 days
- assumed production well "efficiency" of 69%
- each well (if constructed and developed similarly) will have about 51 feet of available drawdown measured from grade (assuming the top of the screen is set at 60 feet, the SWL is 4 feet, and allow 5 feet above the screened interval).



Well No.	Model DD	Corrected DD
PW-1	29.9	43.3
PW-2	32.3	46.8
PW-3	32.5	47.1
PW-4	32.3	46.8
PW-5	29.9	43.3

Figure 14 **Drawdown Distribution after 100 days with (5) Production Wells, each Pumping 100 gpm. Aquifer Properties: T=0.69 ft^2/min, S=0.0002, b=15 feet, 1/B=0.0005 ft^{-1} (from AQTESOLV output)**

Based upon this analysis, a system of five wells can be placed along a linear array as shown, and each equipped with a pump rated at 100 gpm. If the wells are operated during the summer months, and it is assumed that the duration of operation will be about 100 days. The maximum capacity of about 500 gpm can be achieved when all five wells are operating simultaneously over this time period. At this combined rate and duration, the drawdowns at each well will not exceed five feet above the tops of the well screens.

If you have any questions regarding the above discussion or other matters, please do not hesitate to call me.

Sincerely,

Williams & Works, Inc.

Daniel J. Whalen, P.E.

Attachments: Well Construction Logs
Aquifer Test Data

STATE OF MICHIGAN
DANIEL J. WHALEN
ENGINEER
NO. 36925
LICENSED PROFESSIONAL ENGINEER

ATTACHMENT A – WELL CONSTRUCTION LOGS

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Wellogic

Import ID:

Tax No: | **Permit No:**

County: Alcona | **Township:** Greenbush

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
25N 09E	33	Active		

Well ID: 01000003335

Elevation:

Latitude: 44.5167400000

Longitude: -83.3411100000

Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
1/2 MILE NORTH OF COUNTY LINE RD., & 75 FT. WEST OF CEDAR LAKE RD.

Well Owner: CEDAR LAKE IMPROVEMENT BOARD

Well Address:
CEDAR LAKE RD.
OSCODA, MI 48750

Owner Address:
1822 W. MILHAM, STE 1C
PORTAGE, MI 49024

Drilling Method: Rotary
Well Depth: 70.00 ft. **Well Use:** Irrigation
Well Type: New **Date Completed:** 10/26/2010

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: Centralizer

Diameter: 12.00 in. to 60.00 ft. depth SDR: 21.00

Borehole: 17.50 in. to 78.00 ft. depth

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 3.60 ft. Below Grade (Not Flowing)
Unrestricted Flow Rate: **Yield Test Method:** Air
Well Yield Test:
Pumping Level 70.00 ft. after 8.00 hrs. at 200 GPM

Formation Description	Thickness	Depth to Bottom
Brown Sand & Gravel	32.00	32.00
Gray Clay	23.00	55.00
Gray Sand	15.00	70.00
Gray Clay	8.00	78.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 12.00 in. **Blank:**
Screen Material Type: Stainless steel-wire wrapped

Slot	Length	Set Between
40.00	10.00 ft.	60.00 ft. and 70.00 ft.

Fittings: Coupling

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	18.00	None	0.00 ft. to 50.00 ft.

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	250 ft.	East

Drilling Machine Operator Name: C. KAGE
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 2055
Business Name: Raymer Company, Inc.
Business Address: 1357 Comstock Street, Marne, MI, 49435

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks: FURTHER TEST PUMPING INFORMATION TO BE AVAILABLE FROM AQUIFER ANALYSIS REPORT. KIESER & ASSOCIATES, LLC. CONSULTANTS.

Other Remarks:

ATTENTION WELL OWNER: FILE WITH DEED

Contractor 11/8/2010 10:07 AM

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Wellogic

Import ID:

Tax No: **Permit No:**

County: Alcona **Township:** Greenbush

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
25N 09E	33	Active		

Well ID: 01000003336

Elevation:

Latitude: 44.5169400000 OW1

Longitude: -83.3411300000

Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
1/2 MILE NORTH OF COUNTY LINE RD. & 75 FT. WEST OF CEDAR LAKE RD.

Well Owner: CEDAR LAKE IMPROVEMENT BOARD

Well Address:
CEDAR LAKE RD.
OSCODA , MI 48750

Owner Address:
1822 W. MILHAM, STE 1C
PORTAGE, MI 49024

Drilling Method: Rotary
Well Depth: 70.00 ft. **Well Use:** Test well
Well Type: New **Date Completed:** 10/18/2010

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: Centralizer

Diameter: 5.00 in. to 60.00 ft. depth SDR: 21.00

Borehole: 8.75 in. to 77.00 ft. depth

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 3.50 ft. Below Grade (Not Flowing)
Unrestricted Flow Rate: **Yield Test Method:** Test pump
Well Yield Test:
Pumping Level 36.25 ft. after 2.00 hrs. at 94 GPM

Formation Description	Thickness	Depth to Bottom
Brown Sand & Gravel	32.00	32.00
Gray Clay	23.00	55.00
Gray Sand	15.00	70.00
Gray Clay	7.00	77.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 4.50 in. **Blank:**
Screen Material Type: PVC-slotted

Slot	Length	Set Between
12.00	10.00 ft.	60.00 ft. and 70.00 ft.

Fittings: Coupling

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	7.00	None	0.00 ft. to 50.00 ft.

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	250 ft.	East

Drilling Machine Operator Name: C. KAGE
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 2055
Business Name: Raymer Company, Inc.
Business Address: 1357 Comstock Street, Marne, MI, 49435

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks: TEST WELL ALSO USED FOR OBSERVATION PURPOSES FOR AQUIFER ANALYSIS REPORT. KIESER & ASSOCIATES, LLC, CONSULTANTS

Other Remarks:

EQP-2017c (4/2010)

ATTENTION WELL OWNER: FILE WITH DEED

Contractor 11/8/2010 10:33 AM

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No: | **Permit No:**

County: Alcona | **Township:** Greenbush

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
25N 09E	33	Active		

Well ID: 01000003337

Elevation:

Latitude: 44.5164600000 OW2

Longitude: -83.3410300000

Method of Collection: GPS Std Positioning Svc SA Off

Distance and Direction from Road Intersection:
1/2 MILE NORTH OF COUNTY LINE RD. & 75 FT. WEST OF CEDAR LAKE RD.

Well Owner: CEDAR LAKE IMPROVEMENT BOARD

Well Address:
CEDAR LAKE RD.
OSCODA, MI 48750

Owner Address:
1822 W. MILHAM, STE. 1C
PORTAGE, MI 49024

Drilling Method: Rotary
Well Depth: 70.00 ft. **Well Use:** Other
Well Type: New **Date Completed:** 10/19/2010

Casing Type: PVC plastic **Height:** 1.00 ft. above grade
Casing Joint: Solvent welded/glued
Casing Fitting: Centralizer

Diameter: 2.00 in. to 65.00 ft. depth SDR: 21.00

Borehole: 6.25 in. to 77.00 ft. depth

Pump Installed: No
Pressure Tank Installed: No
Pressure Relief Valve Installed: No

Static Water Level: 3.50 ft. Below Grade (Not Flowing)
Unrestricted Flow Rate: **Yield Test Method:** Air
Well Yield Test:
Pumping Level 20.00 ft. after 2.00 hrs. at 20 GPM

Formation Description	Thickness	Depth to Bottom
Brown Sand & Gravel	32.00	32.00
Gray Clay	23.00	55.00
Gray Sand	15.00	70.00
Gray Clay	7.00	77.00

Screen Installed: Yes **Filter Packed:** Yes
Screen Diameter: 2.00 in. **Blank:**
Screen Material Type: PVC-slotted

Slot	Length	Set Between
10.00	5.00 ft.	65.00 ft. and 70.00 ft.

Fittings: Coupling

Well Grouted: Yes **Grouting Method:** Grout pipe outside casing

Grouting Material	Bags	Additives	Depth
Bentonite slurry	6.00	None	0.00 ft. to 60.00 ft.

Geology Remarks:

Wellhead Completion: 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	250 ft.	East

Drilling Machine Operator Name: C. KAGE
Employment: Employee

Contractor Type: Water Well Drilling Contractor **Reg No:** 2055
Business Name: Raymer Company, Inc.
Business Address: 1357 Comstock Street, Marne, MI, 49435

Water Well Contractor's Certification

This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.

Signature of Registered Contractor **Date**

General Remarks: OBSERVATION WELL USED FOR AQUIFER ANALYSIS REPORT. KIESER & ASSOCIATES, LLC, CONSULTANTS.
Other Remarks: Well Use:OBSERVATION

ATTENTION WELL OWNER: FILE WITH DEED

Contractor 11/8/2010 10:53 AM

Attachment B – Aquifer Test Data

Cedar Lake Aquifer Test
12-inch PVC Test Pumping Well, Q=155 gpm
October, 2010

	drawdown		
	Q=155 gpm	r=88 feet	r=106 feet
Time (min)	Test PW-1	OW-1	OW-2
0.22	0.27		
0.33	5.33		
0.43	9.40		0.01
0.62	15.16	0.04	0.04
0.85	21.34	0.17	0.13
1.18	27.62	0.48	0.36
1.64	33.61	1.00	0.75
2.29	39.06	1.76	1.31
3.22	40.94	2.67	2.06
4.52	40.62	3.48	2.78
6.36	41.14	4.26	3.50
8.97	42.01	4.98	4.19
12.64	43.28	5.76	4.93
17.83	44.26	6.56	5.70
25.17	45.09	7.34	6.45
35.53	45.76	8.09	7.17
47.37	46.39	8.69	7.79
66.88	47.03	9.42	8.50
94.46	47.76	10.17	9.23
133.40	48.47	10.86	9.91
188.41	49.03	11.55	10.61
266.12	49.71	12.25	11.29
375.88	50.32	12.88	11.95
501.23	50.88	13.43	12.50
707.99	51.38	14.04	13.11
1000.05	51.74	14.54	13.62
1419.30	52.15	15.08	14.14

		recovery	
		r=88 feet	r=106 feet
Time (min)	Test PW-1	OW-1	OW-2
1.12	5.73	0.01	
1.36	11.93	0.06	0.01
1.71	19.54	0.22	0.13
2.20	25.28	0.62	0.45
2.89	30.38	1.27	0.92
3.87	34.61	2.09	1.58
5.25	37.75	3.03	2.36
7.20	39.86	3.94	3.21
9.96	41.30	4.82	4.03
13.85	42.43	5.70	4.85
19.36	43.38	6.51	5.63
27.13	44.26	7.29	6.39
36.00	44.93	7.94	7.00
50.64	45.71	8.68	7.72
71.31	46.44	9.37	8.43
100.52	47.17	10.08	9.13
141.77	47.86	10.79	9.81
200.04	48.52	11.44	10.47
266.59	49.07	11.96	10.99
376.35	49.66	12.56	11.59
531.40	50.21	13.10	12.14
750.41	50.70	13.60	12.63
1059.77	51.17	14.07	13.09
1419.77	51.43	14.31	13.35

APPENDIX F

2022 CEDAR LAKE AUGMENTATION WELL

COST BREAKDOWN

Groundwater Augmentation Well Site Construction Costs				
Description	**Quantity**	**Unit**	**Unit Costs**	**Total Costs**
CLIB Site @ Kings Corner				
Design survey & legal property surveys per site		LS	$ 25,000.00	$ -
Easement negotiations & acquisition		Acres	$ 4,500.00	$ -
Drilling and pumping well installation per well plus existing well	5	Ea.	$ 32,400.00	$ 162,000.00
Site access for five well locations (clear/grub/temporary road)	2,500	LFT	$ 25.00	$ 62,500.00
Site access, miscellaneous fill or gravel to enhance well access	2,000	CYD	$ 25.00	$ 50,000.00
Electrical service for site (TBD)	1	LS	$ 10,000.00	$ 10,000.00
site	2,500	LFT	$ 5.00	$ 12,500.00
Outlet to swamp with one structure	1250	LFT	$ 75.00	$ 93,750.00
Stone riprap discharge	25	CYD	$ 100.00	$ 2,500.00
Restoration and site clean-up	2,500	LFT	$ 2.00	$ 5,000.00
			Subtotal =	*$ 398,250.00*
Mobilization & Specifications per site		5%		$ 19,912.50
Contingency per site		10%		$ 39,825.00
			Site Subtotal =	***$ 457,987.50***
Jones Creek Site				
Design survey & legal property surveys per site	1	LS	$ 25,000.00	$ 25,000.00
Topographic survey of larger drainage area	1	LS	$ 12,000.00	$ 12,000.00
Easement negotiations & acquisition	1.5	Acres	$ 4,500.00	$ 6,750.00
Property acquisition	1	LS	$ 100,000.00	$ 100,000.00
Drilling and pumping well installation per well	5	Ea.	$ 27,000.00	$ 135,000.00
Site access for five well locations (clear/grub/temporary road)	2,500	LFT	$ 25.00	$ 62,500.00
Site access, miscellaneous fill or gravel to enhance well access	2,000	CYD	$ 25.00	$ 50,000.00
Electrical service for site (TBD)	1	LS	$ 10,000.00	$ 10,000.00
Electrical connections between wells on each site	2,500	LFT	$ 5.00	$ 12,500.00
Outlet to swamp with one structure	1250	LFT	$ 75.00	$ 93,750.00
Stone riprap discharge	25	CYD	$ 100.00	$ 2,500.00
Restoration and site clean up	2,500	LFT	$ 2.00	$ 5,000.00
			Subtotal =	*$ 515,000.00*
Mobilization & specifications per site		5%		$ 25,750.00
Contingency per site		10%		$ 51,500.00
			Site Subtotal =	***$ 592,250.00***
1,000 gpm Proposed Pumping Installation Costs				
2 Well Sites (CLIB and Jones Creek)				$ 1,050,238
Design Engineering/Permitting Fees (18%)		18%	18%	$ 189,043
Stakeholder Coordination (Lump sum)		LS	LS	$ 10,000
			Probable Installation Costs =	**$ 1,249,280**
			Annual O&M Costs =	**$ 114,000**
1,500 gpm Proposed Pumping Installation Costs				
3 Well Sites (CLIB, Jones Creek, plus one other)				$ 1,642,488
Design Engineering/Permitting (18%)		18%		$ 295,648
Stakeholder Coordination (Lump sum)		LS		$ 10,000
			Probable Installation Costs =	**$ 1,948,135**
			Annual O&M Costs =	**$ 164,000**

Notes:

- In addition to the previous option, these costs include considerations for easement negotiations and acquisition for well sites and direct conveyance to nearby swamps. Pipes discharge to Sherman and Jones swamps. The wetlands act as conveyance to Cedar Lake.
- Capital costs include property acquisition for the Jones Creek site, and easement negotiations for property around the well sites themselves.
- Annual O&M costs associated with pump operation will vary according to local precipitation amounts and Cedar Lake volume needs
- O&M costs include an estimated $.09/kWhr for 7.5 hp electrical pumping costs from 11 (or 16) wells over 120 days and other maintenance costs as per below

Electrical and Operational Costs for Year Similar to 2020 Summer Pumping Conditions					
Pump H.P.	**230 V 3o kW**	**Hours**	**Days**	**kWH**	
7.5	4.487	24	120	96,919.20	
			Cost/kWh	$ 0.09	
			Cost per 100 gpm well/season	$ 8,722.73	
Well Site	**gpm**	**120-day Electrical Operation Cost/Site**	**Cumulative 120-day Augmentation Electrical Costs**	**Annual Misc. Parts & Maintenance**	**Annual Operational Costs**
1 (CLIB)	600	$ 52,336	$ 52,336	$ 9,000	$ 61,336
2 (Jones)	500	$ 43,614	$ 95,950	$ 9,000	$ 114,000
3 (other)	500	$ 43,614	$ 139,564	$ 6,000	$ 164,000

Note:
4.487 is the kW used per hour for a 7.5 hp motor that is 230 volts 3 phase service.