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ENVIRONMENTAL SCIENCE & ENGINEERING

TECHNICAL MEMORANDUM

To:	Cedar Lake Improvement Lake Board	**Date:**	March 30, 2018
From:	Mark Kieser, K&A Josh Kieser, K&A	**cc:**	Doug Pullman, Aquest
RE:	**Findings for 2017 Cedar Lake Groundwater/Surface Water Level Monitoring**		

This memorandum presents 2017 results compiled by Kieser & Associates, LLC (K&A) related to the ongoing water level monitoring program at Cedar Lake, Alcona and Iosco Counties, Michigan. K&A staff were authorized to continue management and oversight of ongoing data collection efforts in 2017 on behalf of the Lake Board. The purpose of the long-term monitoring program is to best understand critical needs and relevant influences on water levels in Cedar Lake.

Desirable summer month water levels in Cedar Lake are a function of both rainfall and management strategies that will support water level maintenance in dry summer months. These management strategies, as defined in the approved Cedar Lake Watershed Management Plan (WMP), relate to ongoing efforts to bolster water retention in the northwest cedar swamp from winter and spring months, extending into summer months. Water control management efforts include railroad culvert clean-outs in 2014 and the construction of a wetland enhancement berm in 2017 to retain water levels in the cedar swamp and reduce out-of-watershed losses through King's Corner Culvert. Other potential future management strategies, as per the WMP, include improving Sherman and Jones Creek water retention using instream grade structure controls, and utilizing deep groundwater withdrawal augmentation wells. This technical memorandum discusses these potential managements strategies in relation to current and historic lake level data. Water level data being collected for Cedar Lake are vital to assessing, understanding, and cost-effectively pursuing appropriate water level control options in a phased manner.

Program Background

A volunteer water level monitoring program was initially developed at select groundwater and surface water monitoring sites around Cedar Lake in 2004. Since then, water level monitoring efforts have expanded to include additional critical areas using automated water level logger equipment in lieu of intermittent volunteer measurements. The 2017 water level monitoring program included 25 level loggers located around the lake (Figure 1). Consistent with previous years, a combination of surface water stations along with shallow and deep groundwater stations were monitored to document surface/groundwater interactions and their influence on Cedar Lake water levels. Sherman Creek, Jones Creek, and the King's Corner road culvert were likewise included in the 2017 monitoring program to assist with calculating estimates of creek flows in and out of Cedar Lake, as well as culvert flows out of the northwest cedar swamp away from the lake. The Jones Creek monitoring station was removed on September 1, 2017 in anticipation of the culvert replacement as part of the Alcona County Road Commission project along West Cedar Lake Road. This monitoring station will be re-installed and re-surveyed in spring 2018. Rain gage data collected at Cedar Lake and submitted by Rex Vaughn were evaluated and used to assess rainfall for 2017 and compared with past rainfall records.

2017 Precipitation and Water Level Data

The 2017 water level data from the nearshore groundwater monitoring sites 1-7, along with Cedar Lake water levels, are graphically illustrated in Figures 2-8. Sites 1, 3, 4, 5 and 6 (Figures 2, 4, 5, 6 and 7, respectively) are in areas where groundwater is moving away from the lake, as reflected in the 2017 piezometer water levels that were below the lake water level. Sites 2 and 7 (Figures 3 and 8, respectively) are located in areas where groundwater is entering the lake, with piezometer groundwater levels near or above those measured in the lake. Site 2, located nearest the wetland complex northwest of the lake, signifies why this area is an important groundwater source to the lake and further emphasizes the importance of wetland protection in this critical area. (Note: during the 2016 monitoring season, the level logger equipped within PZ-2s ceased to operate correctly. The manufacturer was able to recover the previous year's data from this 7-year old level logger, which was replaced with a new logger, installed September 22, 2017). Sites 8-11 (Figures 9-12, respectively) document conditions beyond the lake toward the southeast within an area of Lakewood Shores that is well-drained. Water level data for these four sites continue to confirm shallow groundwater loss towards Lake Huron with increasing distance from the lake.

Historic summer precipitation totals for the Cedar Lake area are presented in Figure 13. These data represent precipitation data available from a rain gauge installed at Cedar Lake and monitored by volunteers. Available rainfall data from 1998-2017 (minus 2006 when there were no local functioning rain gauges) reflect a 19-year summer average (June-September) of 12.10 inches of rainfall. The observed 2017 data are just below-average for rainfall, totaling 11.39 inches during these summer months. Notably, April 2017 experienced above-average rainfall of 6.27 inches. The previous summer of 2016 exhibited average summer precipitation amounting to 12.18 inches. Rainfall in 2015 was below average, while 2014 was above-average. Summer precipitation in the years 2012-2013 was recorded below-average, while in 2008-2011, summer precipitation was above-average.

Importantly, with respect to rainfall, the Cedar Lake Augmentation Feasibility Study completed by K&A in 2011 revealed that, in order to avoid water level decreases greater than 3-inches per month during the critical summer months (June-September), an average summer month rainfall of 2.75 inches would be necessary. In other words, in a given summer month, if natural rainfall patterns result in less than 2.75 inches, a lake level drop of approximately 3 inches or more can be expected. Therefore, a June-September average of 11 inches of rainfall (i.e., 2.75 inches multiplied by 4 months) can be used to assess each summer season as a whole with regards to desired lake level conditions. This target threshold is plotted on Figure 13 for sake of comparison. As described in the next section, several management implementations since 2014 to improve the connectivity and retention of water in the northwest cedar swamp may be positively affecting the aforementioned target threshold by lessening the effect of low precipitation during dry summer months on lake level drops.

The 2017 level logger data near the Cedar Lake outflow structures demonstrate that the lake had water levels near or slightly above the established legal lake level of 608.64 feet for most of the year (representing lake outflow conditions). The most notable drop below the legal lake level occurred from mid-September to mid-October. A beaver dam which had become reestablished near the lake outflow location had some effect on lake levels above and below the dam, potentially inhibiting lake outflow volumes for much of 2017, until it was mechanically removed in early October. The 2017 Cedar Lake water levels were plotted with April-November recorded rainfall (Figure 14) to observe lake level response to local precipitation. As previously noted, and illustrated in Figure 14, the local precipitation has a direct impact on Cedar Lake water levels with observed responses corresponding to local rain events.

Consistent with the target rainfall threshold data plotted on Figure 13 (i.e., 11 inches per summer season), Figure 14 shows that 2017 Cedar Lake water levels steadily declined from March to May, after heavy spring rains. While rainfall events in May, June, and July, caused slightly-elevated lake levels for several days, lake levels remained mostly steady near the legal lake level from May to September. Lake levels dropped below the legal lake level for several days in mid-September but returned to above legal lake levels after rainfall events in mid-October. Lake levels remained less than 11 inches above and less than 2 inches below the northern lake outflow structures elevation throughout the monitoring period. Due to the relatively small size of the Cedar Lake watershed contributing area, summer rainfall is an important factor in maintaining Cedar Lake levels. Those years with below-average rainfall result in significant drops in Cedar Lake water levels as water losses exceed water gains to the lake.

2017 Estimated Surface Flows

Water level loggers located at the lake outflow area (north end), Sherman Creek, Jones Creek, and King's Corner culverts (west side of the lake) were used to monitor incoming and outgoing surface flows of the lake. Both Jones Creek and Sherman Creek are important sources of incoming surface water flows to the lake from the wetland complex northwest of Cedar Lake. On the other hand, the King's Corner road culvert historically diverted water from the immediate watershed to the south, toward Phelan Creek and Van Etten Lake, resulting in water loss from the Cedar Lake watershed that would otherwise help support desired Cedar Lake water levels. A major water detention effort to reduce water loss via King's Corner culvert was undertaken in fall 2017 with the construction of a wetland enhancement berm on the newly acquired Lake Board property, parallel to King's Corner Road. Construction began on August 28 and was completed by October 20, 2018.

The two Cedar Lake outflow structures at the north end of the lake discharge to Lake Huron once water levels exceed the legal lake level. Figures 15-18 illustrate estimated surface inflows and outflows associated with Cedar Lake for spring and summer 2017 at these four monitoring locations. All flow monitoring data are derived from long-term water level stage-discharge relationships specific to each location. Flow data from all four of these critical locations were combined and plotted together as illustrated on Figure 19.

During a 120-day early-spring to mid-summer period from March 24 to July 21, 2017, the Jones Creek and Sherman Creek monitoring data reveal inflows of 109 and 1,106 million gallons (Mgal), respectively, into Cedar Lake (refer to Figure 19). These flows were greater in Sherman Creek, lesser in Jones Creek, and slightly less overall than 2016 flows during a similar early-spring to mid-summer time period. Measured 2017 outflow volume leaving Cedar Lake totaled 64 Mgal during this same time period, significantly less than 2016 outflow volume, with discernible lake outflows occurring mostly in spring, and then only sporadically through the monitoring season. During the same time period, March to July 2017, 86 Mgal flowed out of the Cedar Lake watershed via the King's Corner road culvert, measuring approximately 100 Mgal less than in 2016.

Figure 20 summarizes observed flows associated with the Kings Corner culvert location for the entire monitoring season. The total plotted flows from March 24 to November 3, 2017 reflect a total volume of 87 Mgal over 225 days. This outflow is substantially less than the data observed in 2016 (216 Mgal) during a similar period. It is important to keep in mind that these flows reflect "lost inflow" volume to Cedar Lake. The maximum observed high water elevation at the Kings Corner culvert in 2017 was 611.22. Since 2009, this location has had an average high-water elevation of 611.13 and a maximum observed elevation of 612.86.

The wetland enhancement berm spillway, completed in fall 2017, was constructed to overflow at an elevation of 611.0 feet so as not to permanently alter historic water levels. Comparing late-fall volume loss from King's Corner culvert demonstrates how the wetland enhancement berm constructed on the Lake Board property will mitigate losses during and after construction. Rainfall totals in September and October of 2016 and 2017 were comparable at 6.91 and 6.70 inches, respectively, while outflow losses at Kings Corner culvert during these months were substantially different at 3.06 Mgal in 2016 and 0.05 Mgal in 2017, respectively. The effectiveness of the new wetland enhancement berm on the Lake Board parcel should be closely monitored to definitively demonstrate additional long-term improvements to water retention in the wetlands via reductions to water volume lost through King's Corner culvert.

In addition to the wetland berm constructed in 2017, another recent improvement regarding surface water inflows from the northwest cedar swamp to the lake included the clearing of six railroad culverts passing beneath the Lake State Railway within the northwest wetland complex area. These were given specific maintenance attention by railroad representatives in August/September of 2014. These efforts restored flow from the west to the east beneath the railroad tracks at six culvert locations.

Notably, the 2011 Cedar Lake Augmentation Feasibility Study suggested that the volume required to offset a 1-month lake level drop of 3-inches in Cedar Lake equates to approximately 91 Mgal per month (of inflow and direct rainfall), totaling 364 Mgal over the four-month summer season. The study assesses potential water control implementation options and their feasibility related to multiple indicators including cost, total available volume, and other restrictions. The 2017 level logger data suggest that, in the summer months June-September since 2014, volumes contributed to Cedar Lake via Sherman and Jones Creek have increased significantly, from 41.6 Mgal in 2014, to 581.9 MGAL in 2017, a comparative increase of 540.3 Mgal into Cedar Lake. Comparing these findings to the aforementioned 364 MGAL 4-month season total calculated in 2011 to offset lake level drops in dry years, shows that these improvements to wetland connectivity and water retention may offset any immediate need to pursue other, potentially costlier management options. Figure 21 demonstrates this analysis by comparing summer season (June-September) monthly rainfall totals with summer season monthly combined total volumes contributed to Cedar Lake via Sherman and Jones Creeks, from 2014-2017.

Conclusions and Recommendations

Data from 2017 lake level monitoring continue to demonstrate how Cedar Lake first and foremost responds quite directly to prevailing summer month rainfall amounts. Lake levels for 2017 appear to have been within the WMP desired levels; this largely being a function of rainfall only slightly below the observed historic average for June through September, but also water flow and detention improvements in the northwest cedar swamp. Lake outflow data and lake levels still suggest that 2017 lake levels were adequate for targeted summer conditions.

The 2017 data also demonstrate an overall decrease from 2016 in the volume of water lost through the King's Corner culvert, in spite of comparable precipitation. The wetland berm was under construction from September to mid-October 2017 and therefore does not account for the decrease in losses from King's Corner prior to September. However, a preliminary comparison of precipitation and outflow losses in September and October of 2016 and 2017 demonstrates the potential future improvements in wetland water retention as a result of the berm.

The 2014 railroad culvert cleanouts also appear to have provided significant additional surface flows, as well as late season groundwater recharge benefits into the northwest cedar swamp. These surface flows may be indicative of the improved surface connections with the cedar swamp located on the west side of the railroad tracks. Figure 21 demonstrates the increase in surface water volume entering Cedar Lake through Sherman and Jones Creeks during summer months since 2014. Importantly, identifying and implementing future regular maintenance needs to the railroad culverts will ensure long-term connectivity via these culverts.

Combined with additional water retention impacts from the new berm project, these watershed improvements may prove to mitigate any immediate need to pursue deep groundwater withdrawal augmentation wells as outlined in the WMP and feasibility study. Moreover, proposed instream grade structures for Sherman Creek may ultimately provide the naturalized solution to mitigate long-term concerns of future lake level drops during dry summers. This too would also benefit the ecology of the lake by protecting important springtime fish-spawning habitat.

Based on 2017 observations and the noted importance of scientifically valid water level data for making informed watershed (water level) management decisions, we recommend the Cedar Lake monitoring program be continued during the 2018 calendar year. Such data will be vital to maintaining a comprehensive and unbroken historic water level record. These data will be used to further evaluate: 1) Sherman Creek instream grade control structure needs within the Lake Board-acquired properties surrounding this creek, 2) quantified improvements on wetland water level retention resulting from the newly constructed wetland berm, including identifying future maintenance needs, and 3) ongoing improvements and future maintenance needs associated with the 2014 culvert flow repair efforts conducted by the railroad in the northwest cedar swamp area.

As such, we also recommend that the mid-lake piezometer, installed mid-2017 to assess impacts of the now-removed beaver dam on lake level, be removed and installed on the north side of the berm overflow to provide a thorough understanding of water level impacts from the berm. The Jones Creek monitoring station, which was temporarily removed for the 2017 Alcona County Road Commission project along West Cedar Lake Road, will be replaced and resurveyed as part of the 2017-2018 budget.

If you have any questions regarding the information provided within this technical memorandum, please do not hesitate to contact our office at (269) 344-7117.