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TECHNICAL MEMORANDUM

To:	Cedar Lake Improvement Lake Board	**Date:**	May 22, 2017
From:	Brian Boyer, K&A Mark Kieser, K&A	**cc:**	Doug Pullman, Aquest
RE:	**Findings for 2016 Cedar Lake Groundwater/Surface Water Level Monitoring**		

This memorandum presents 2016 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 2016 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 other management strategies that will support water level maintenance in dry summer months. The latter efforts, as defined in the approved Cedar Lake Watershed Management Plan (WMP) relate to bolstering water retention in the northwest cedar swamp from winter and spring months extending into summer months. This will be accomplished by improving water controls at the King's Corner Culvert to reduce out-of-watershed losses, improving Sherman and Jones Creek water retention using instream grade structure controls, and utilizing deep groundwater withdrawal augmentation wells as per the WMP. Water level data being collected for Cedar Lake are vital to assessing, understanding and cost-effectively pursuing these 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, these water level monitoring efforts have expanded to include additional critical areas using automated water level logger equipment in lieu of intermittent volunteer measurements. The 2016 water level monitoring program included 23 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 2016 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. Rain gage data collected and submitted by Rex Vaughn were evaluated and used to assess rainfall for 2016 and compared with past rainfall records. During a period of gage malfunction in June and July, other nearby precipitation data were gathered from the Harrisville, MI CO-OP Station (#203628) in Alcona County.

2016 Precipitation and Water Level Data

The 2016 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 2016 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-2d ceased to operate correctly. Fortunately, the manufacturer was able to extract the data, however, this 7-year old level logger will be replaced in 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 to 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 information available from the Harrisville, MI CO-OP Station (#203628), the Oscoda, MI Wurtsmith Airport Station (#14808), and a rain gauge installed at Cedar Lake and monitored by volunteers. Available rainfall data from 1998-2016 (minus 2006 when there were no local functioning rain gauges) reflect an 18-year summer average (June-September) of 12.14 inches of rainfall. The observed 2016 data are average for rainfall, measuring 12.18 inches during these summer months. The previous 2015 summer exhibited just below-average summer precipitation amounting to 10.94 inches. Rainfall in 2014 was above average, while 2012 and 2013 were below-average. The years 2008-2011 each had summer precipitation recorded above-average.

More 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/month during the critical summer months (June-September), an average summer month rainfall of 2.75 inches would be necessary. In other words, if natural rainfall patterns result in less than 2.75 inches in a given summer month, a lake level drop of approximately 3 inches or more can be expected. Likewise, 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.

The 2016 level logger data near the Cedar Lake outflow structures demonstrate that the lake had water levels greater than the established legal lake level of 608.64 feet for most of the year (representing lake outflow conditions). The most notable drops below the legal lake level occurred in August and October. The 2016 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 early season to mid-summer 2016 Cedar Lake water levels remained above the legal lake level, though steadily declining from March to August, then remaining relatively steady through November. Lake levels remained within a few inches of the northern lake outflow structures throughout the later portion of 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.

2016 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 significant 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 diverts 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.

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 2016 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.

The Jones Creek and Sherman Creek monitoring data reveal inflows of 648 and 922 million gallons (Mgal), respectively, into Cedar Lake from March 21 to July 22, 2016 (refer to Figure 19). These flows are significantly greater than flows in 2015 during a similar time period. Measured outflow volume leaving Cedar Lake also exceeded 2015 outflows, totaling 2,621 Mgal during this time period, with discernible lake outflows continuing through the monitoring season. During the same time period, March to July, 185 Mgal flowed out of the Cedar Lake watershed via the King's Corner road culvert.

Figure 20 summarizes observed flows associated with the Kings Corner culvert location. The total plotted flows from March 21 to November 18, 2016 reflect a total volume of 216 Mgal over 243 days. This outflow is significantly more than the data observed in 2015 (46.3 Mgal) during a similar period. It is important to keep in mind that these flows reflect "lost inflow" volume to Cedar Lake. For this reason, we continue to recommend moving forward with planned property improvements on the newly acquired Lake Board property to further mitigate losses. The maximum observed high water elevation at the Kings Corner culvert in 2016 was 610.3. The proposed berm project spillway is set to overflow at elevation 611.0 feet.

Of important note to surface water inflows to the lake, a total of six railroad culverts passing beneath the Lake State Railway within the northwest wetland complex area were given specific maintenance attention by railroad representatives in August/September of 2014. These efforts have since restored wetland surface water flow from the west to the east beneath the railroad tracks at six culvert locations. The 2016 data confirm our expectation that these actions have allowed more surface water to consequently pass to the lake via Sherman and Jones Creeks. Surface water will continue to be lost, however, through the King's Corner culvert until a water level control berm can be implemented on the Lake Board parcel.

Conclusions and Recommendations

Data from 2016 lake level monitoring continue to demonstrate how Cedar Lake first and foremost responds quite directly to prevailing summer month rainfall amounts. Lake levels for 2016 appear to have been within the WMP desired levels; this largely being a function of rainfall similar to the observed historic average for June through September. Lake outflow data and lake levels still suggest that 2016 lake levels were adequate for targeted summer conditions, especially considering a partial removal of a beaver dam at the lake outflow location. The 2014 railroad culvert cleanouts appear to have provided 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. The 2016 data also demonstrate a significant increase in the volume of water lost through the King's Corner culvert. As a result, lost outflow at Kings Corner could be even further reduced with a water control berm.

Based on 2016 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 2017 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 recently Lake Board-acquired properties surrounding this creek, 2) King's Corner impacts and potential water level control berm design and maintenance needs, 3) potential future benefits with grade control structures in Jones Creek, and 4) the future need for installing an augmentation well. These latter two items will only become relevant after the first two items are implemented.

Lastly, we recommend that the Jones Creek monitoring station be removed temporarily during an upcoming Alcona County Road Commission project along West Cedar Lake Road. Once the road work is complete, this monitoring equipment should be re-installed and surveyed to minimize data loss. We further recommend that the Road Commission match existing culvert invert elevations on both ends of the new culvert to the existing invert elevations as much as possible to ensure maintained fish passage through this man-made structure.

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

Site #1 (3 loggers)
north of 4484 E. Cedar Lake Dr.

Site #2 (2 loggers)
3481 W. Cedar Lake Rd.

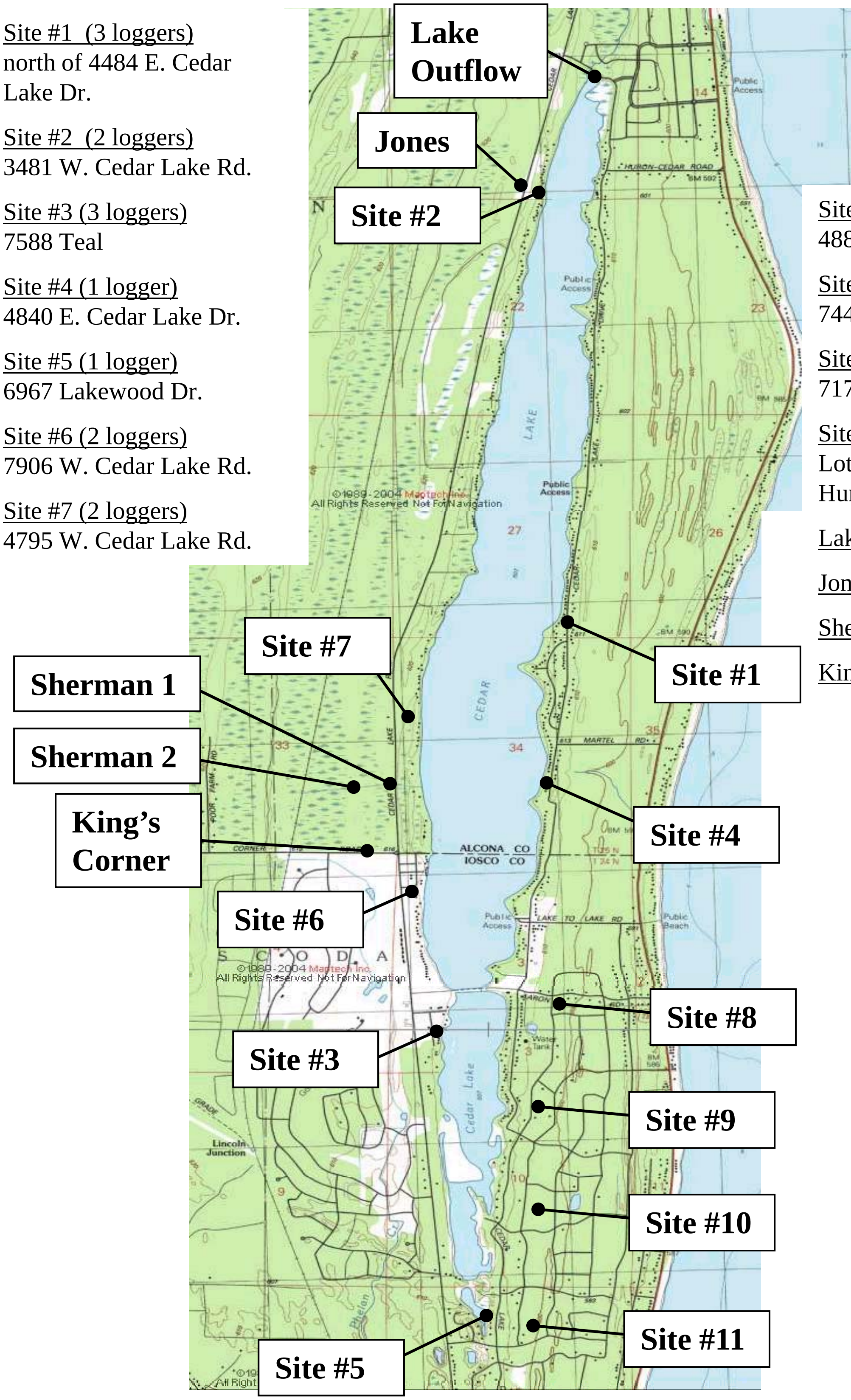
Site #3 (3 loggers)
7588 Teal

Site #4 (1 logger)
4840 E. Cedar Lake Dr.

Site #5 (1 logger)
6967 Lakewood Dr.

Site #6 (2 loggers)
7906 W. Cedar Lake Rd.

Site #7 (2 loggers)
4795 W. Cedar Lake Rd.



NORTH

Site #8 (1 logger)
4884 Arron Dr.

Site #9 (1 logger)
7448 Lakewood Dr.

Site #10 (1 logger)
7173 Huntington Dr.

Site #11 (1 logger)
Lot north of 6933 Huntington Dr.

Lake Outflow (1 logger)

Jones Creek (1 logger)

Sherman Creek (2 loggers)

King's Corner (1 logger)

Sites 1-3 were original Phase I monitoring locations.

Sites 4-7 were added as part of Phase II monitoring efforts.

Sites 8-11 were added as part of Augmentation Feasibility Study efforts.

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Map of groundwater and surface water elevation monitoring sites located around the perimeter of Cedar Lake.

FIGURE 1

Figure 2. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 1)

Figure 3. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 2)

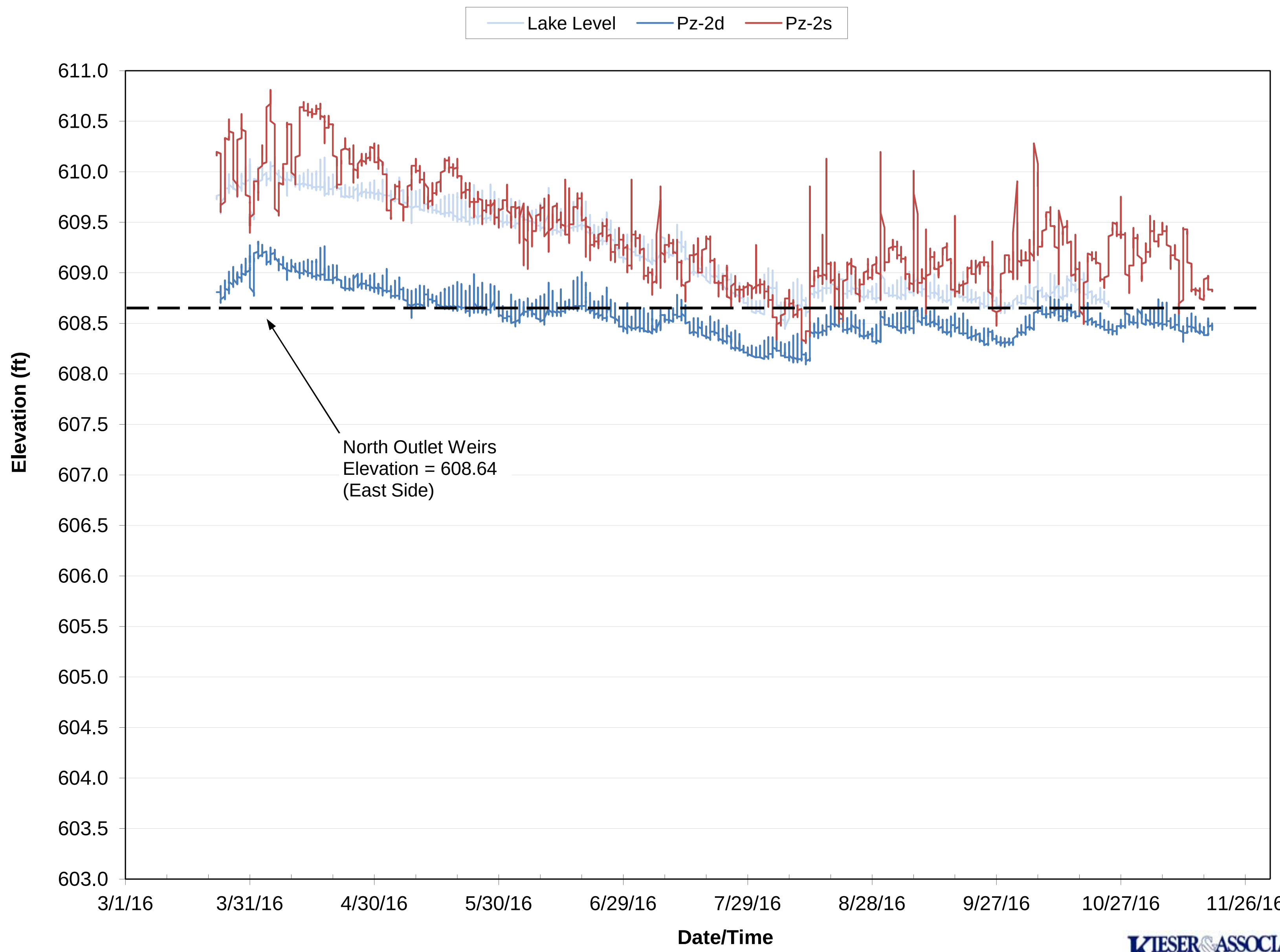

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Figure 4. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 3)

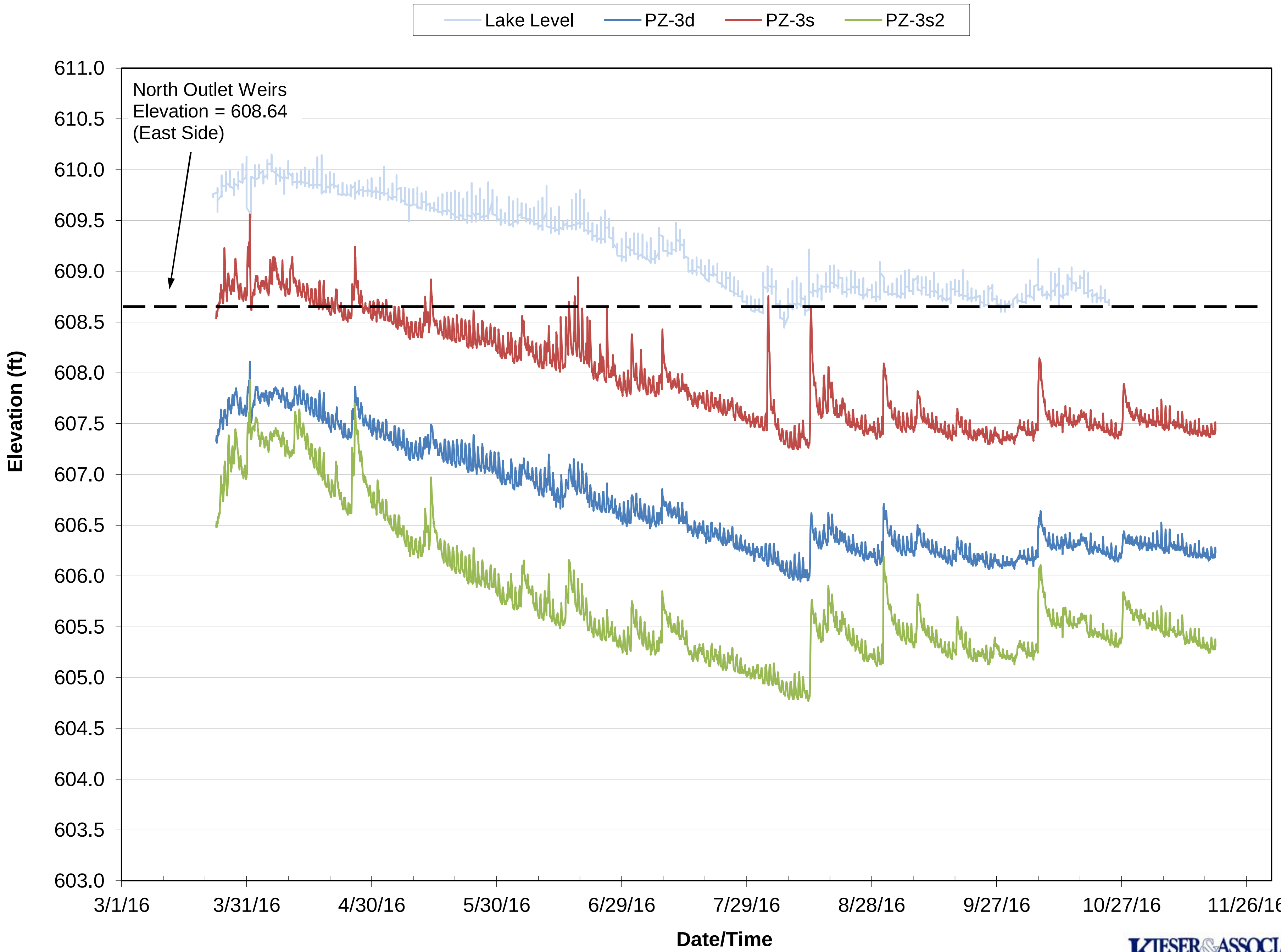

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Figure 5. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 4)

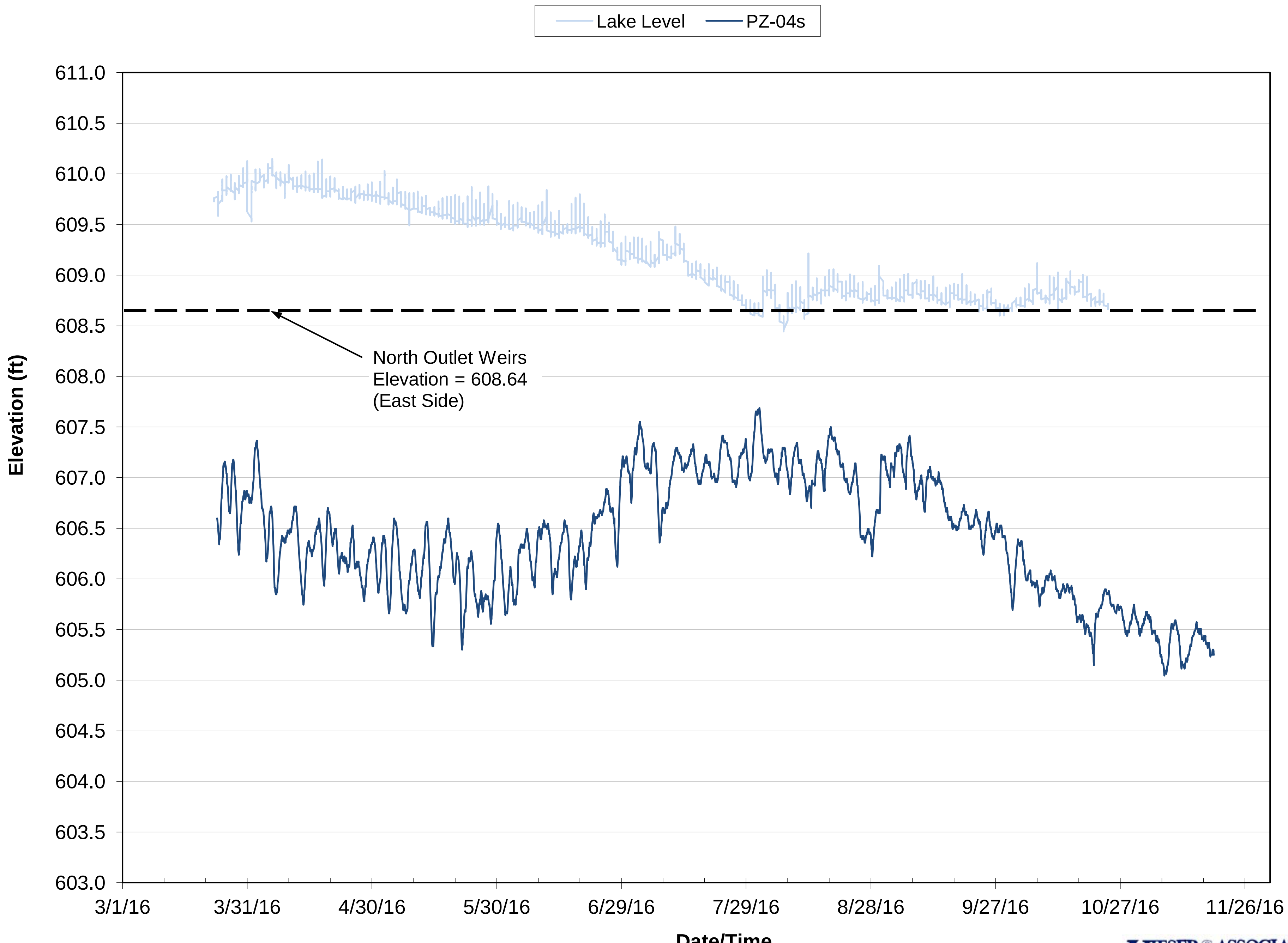

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Figure 6. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 5)

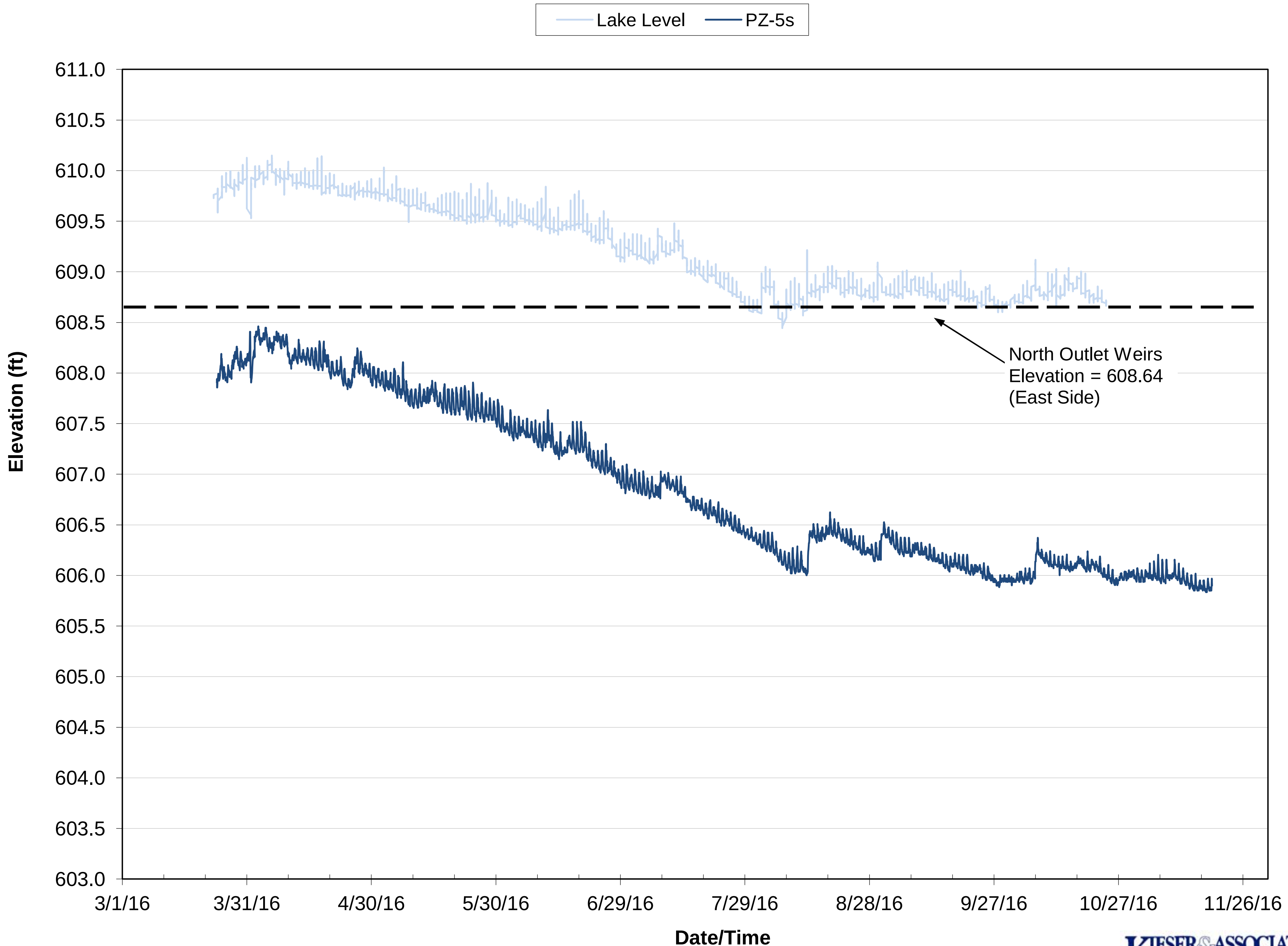

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Figure 7. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 6)

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Figure 8. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 7)

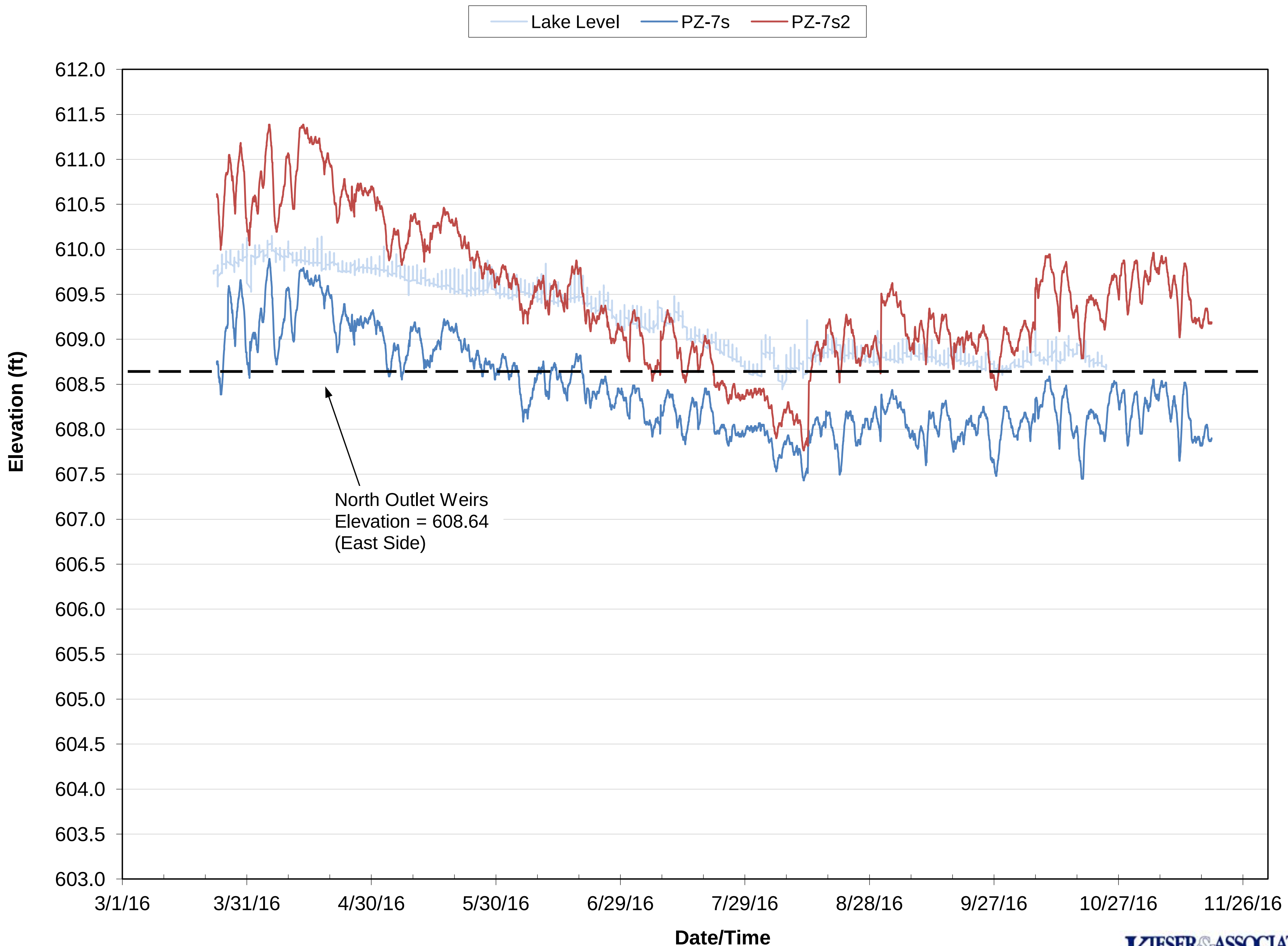

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Figure 9. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 8)

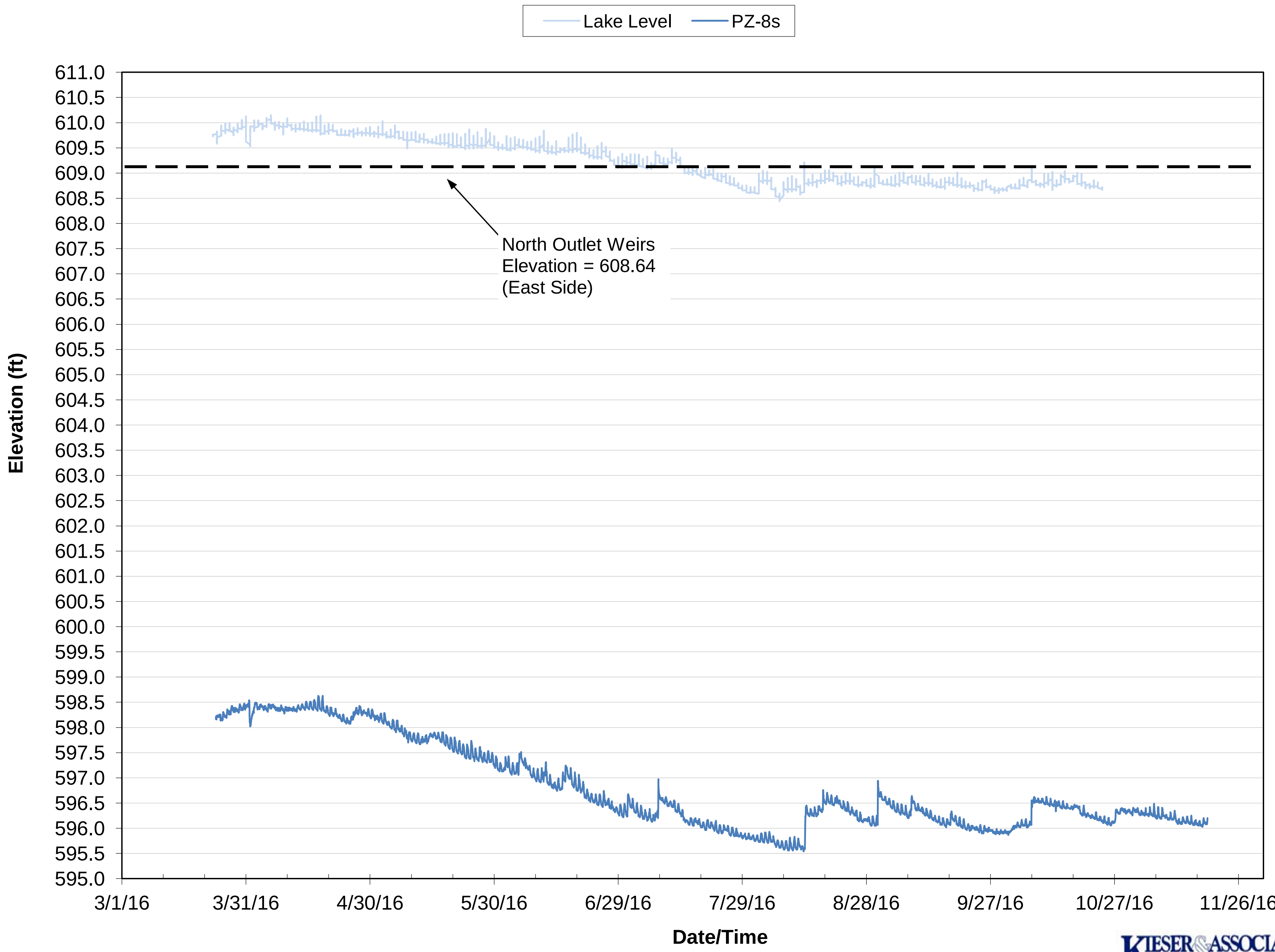
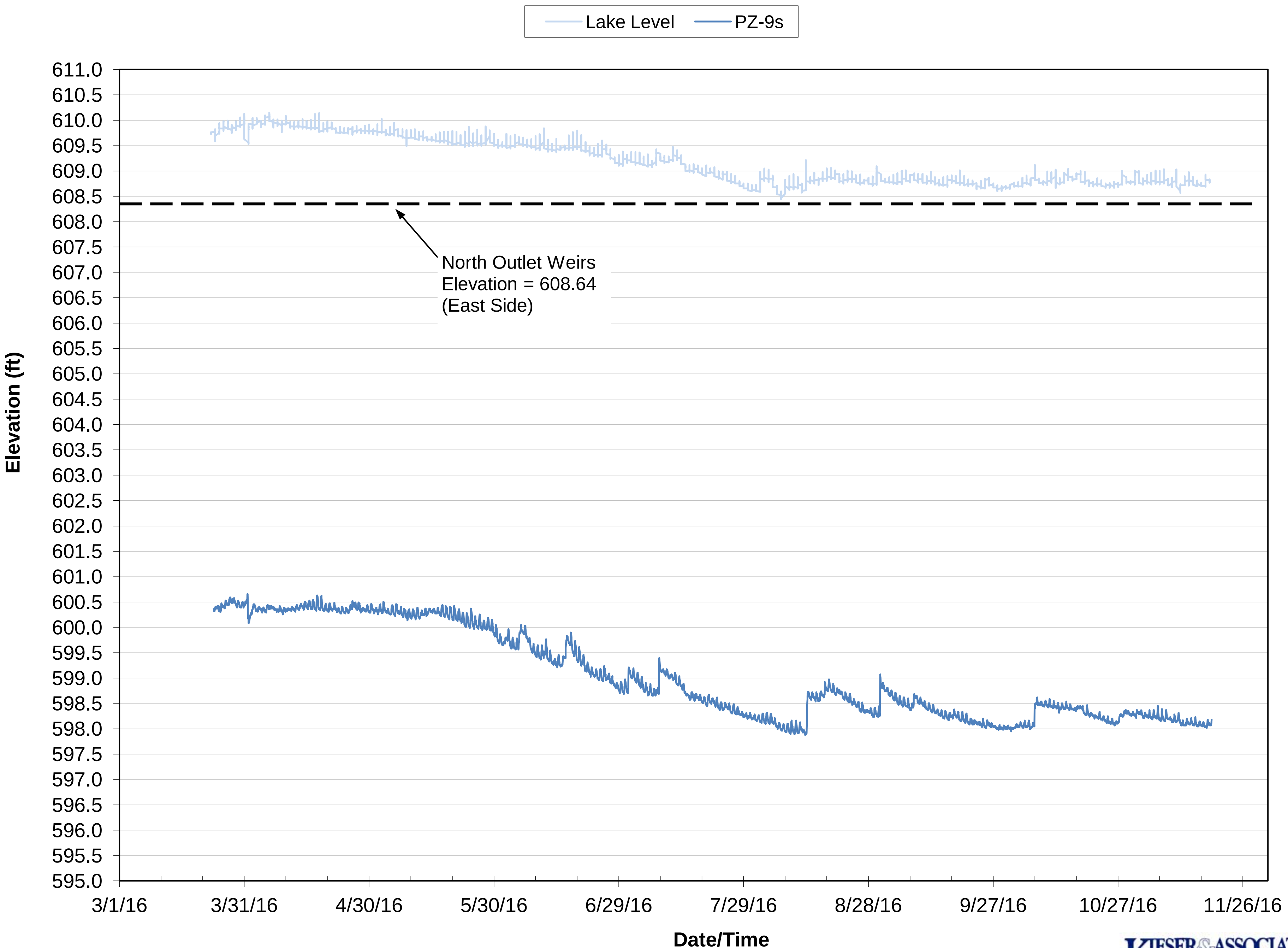


Figure 10. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 9)



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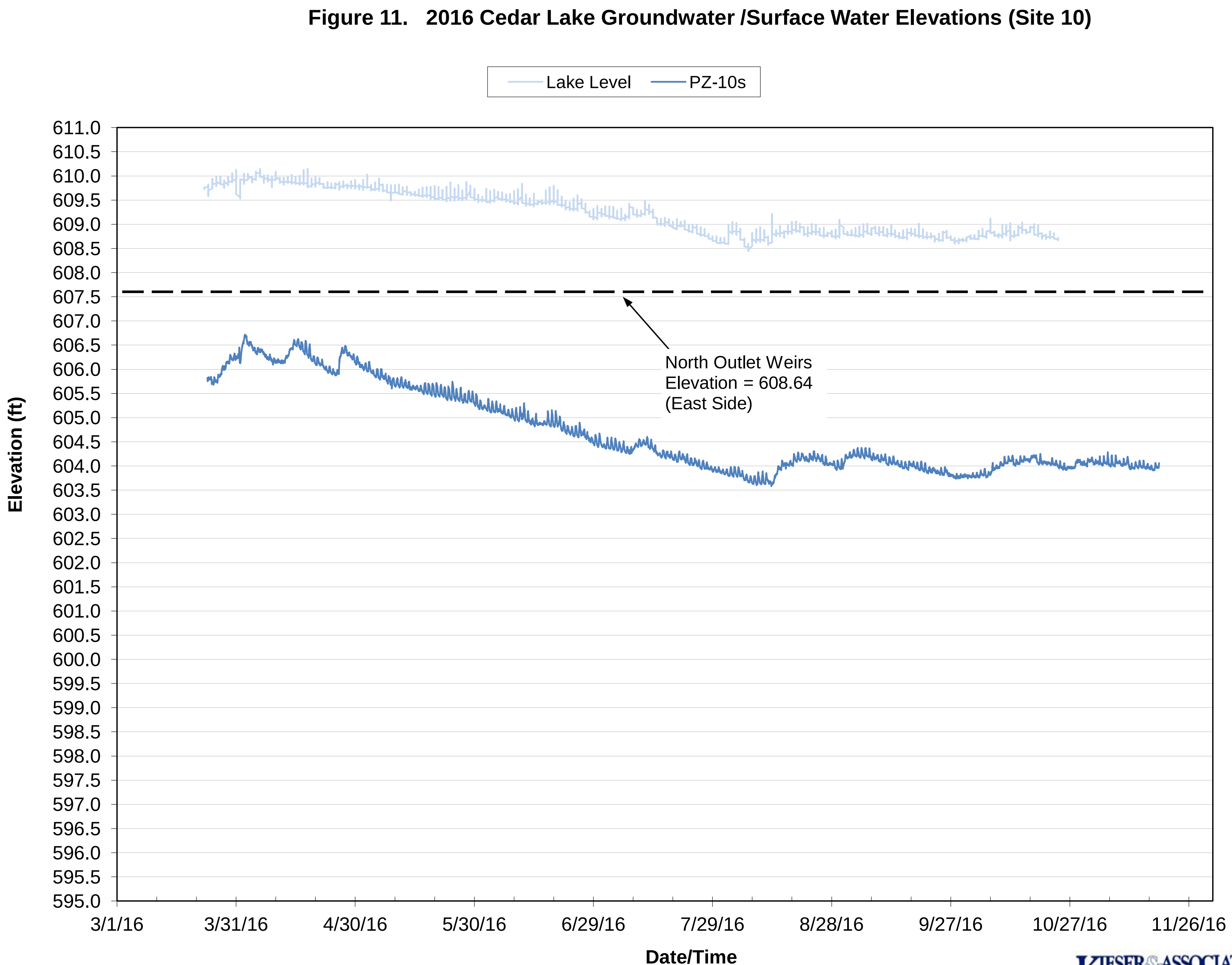

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Figure 12. 2016 Cedar Lake Groundwater /Surface Water Elevations (Site 11)

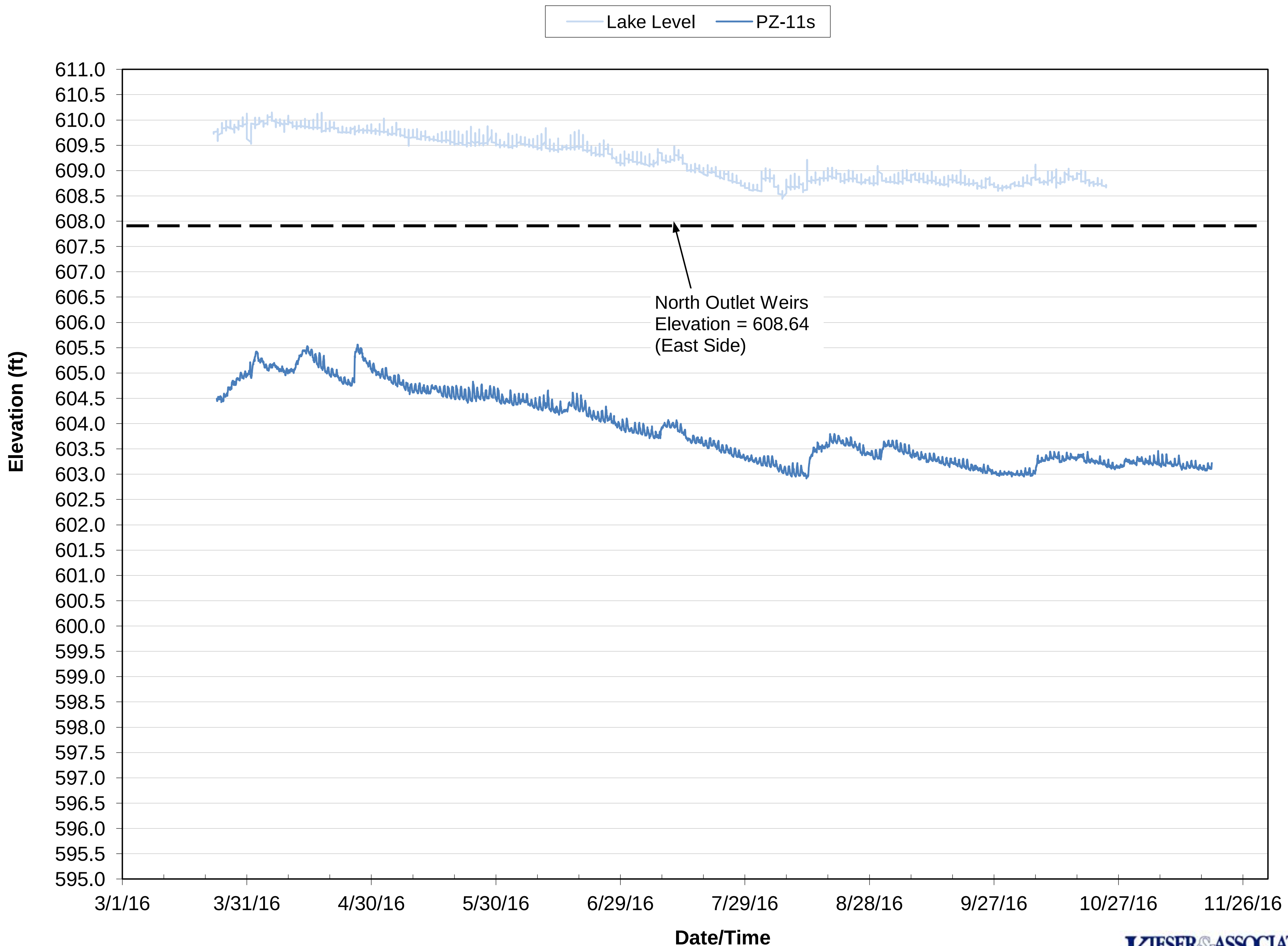

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Figure 13. Summer (Jun - Sept) Precipitation Totals for Cedar Lake
(Precipitation Source: Harrisville, MI, CO-OP Station #203628,
Alcona County Cedar Lake Rain Gauge,
Oscoda, MI Oscoda Wurtsmith Airport Station #14808, Iosco County)

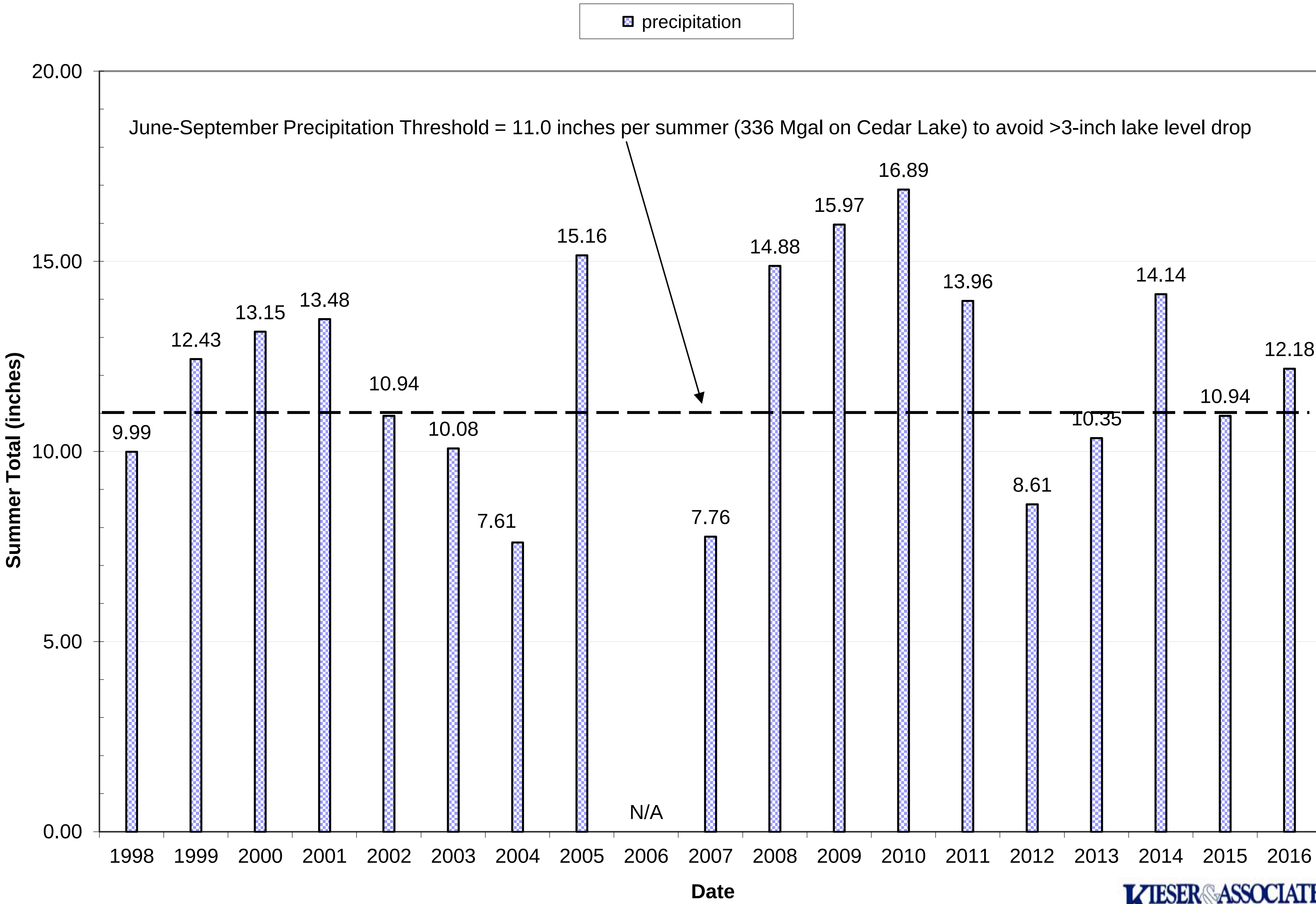

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Figure 14. 2016 Cedar Lake Water Elevelation and Measured Rainfall

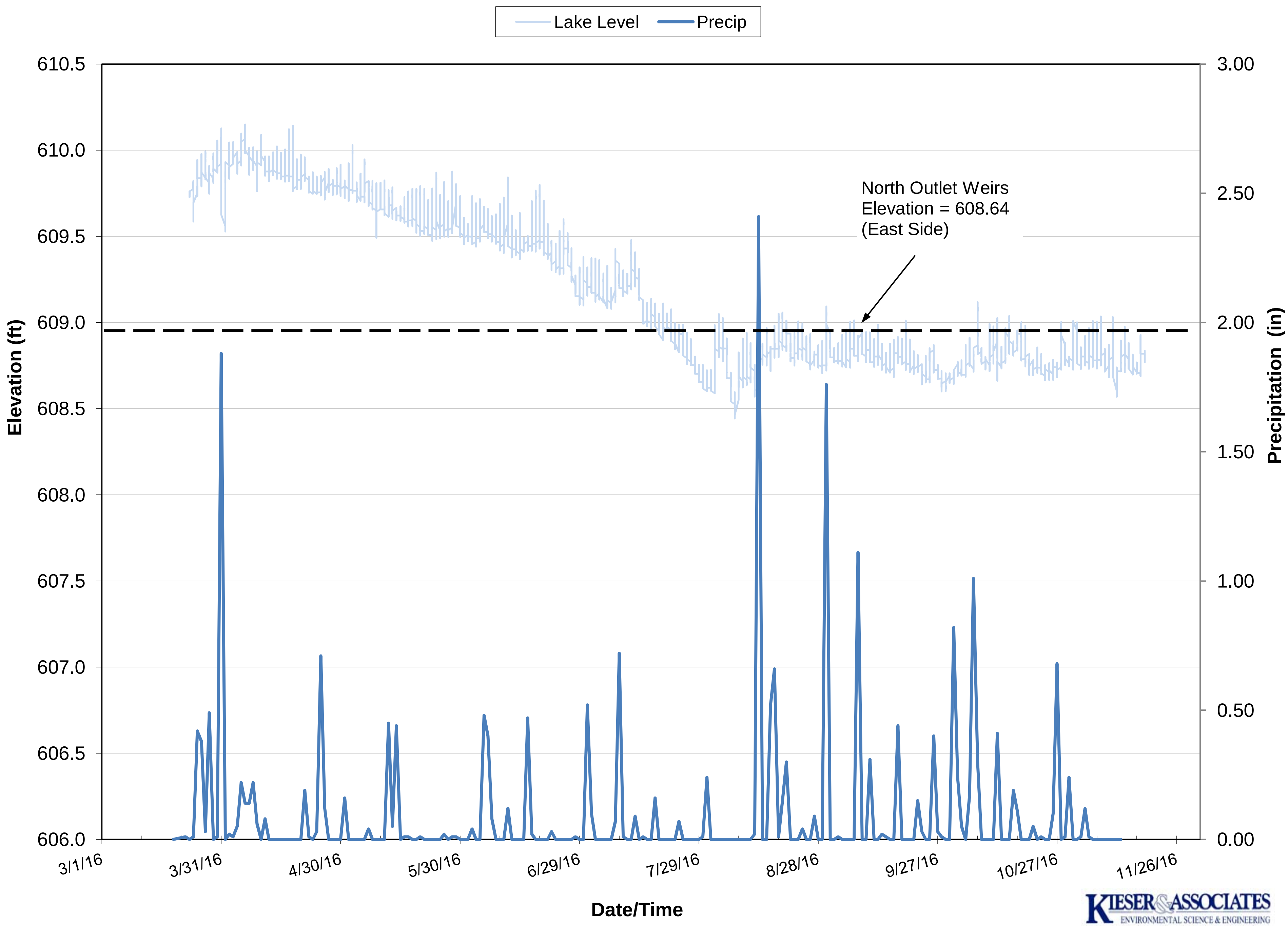

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Figure 15. 2016 Estimated Jones Creek Flows

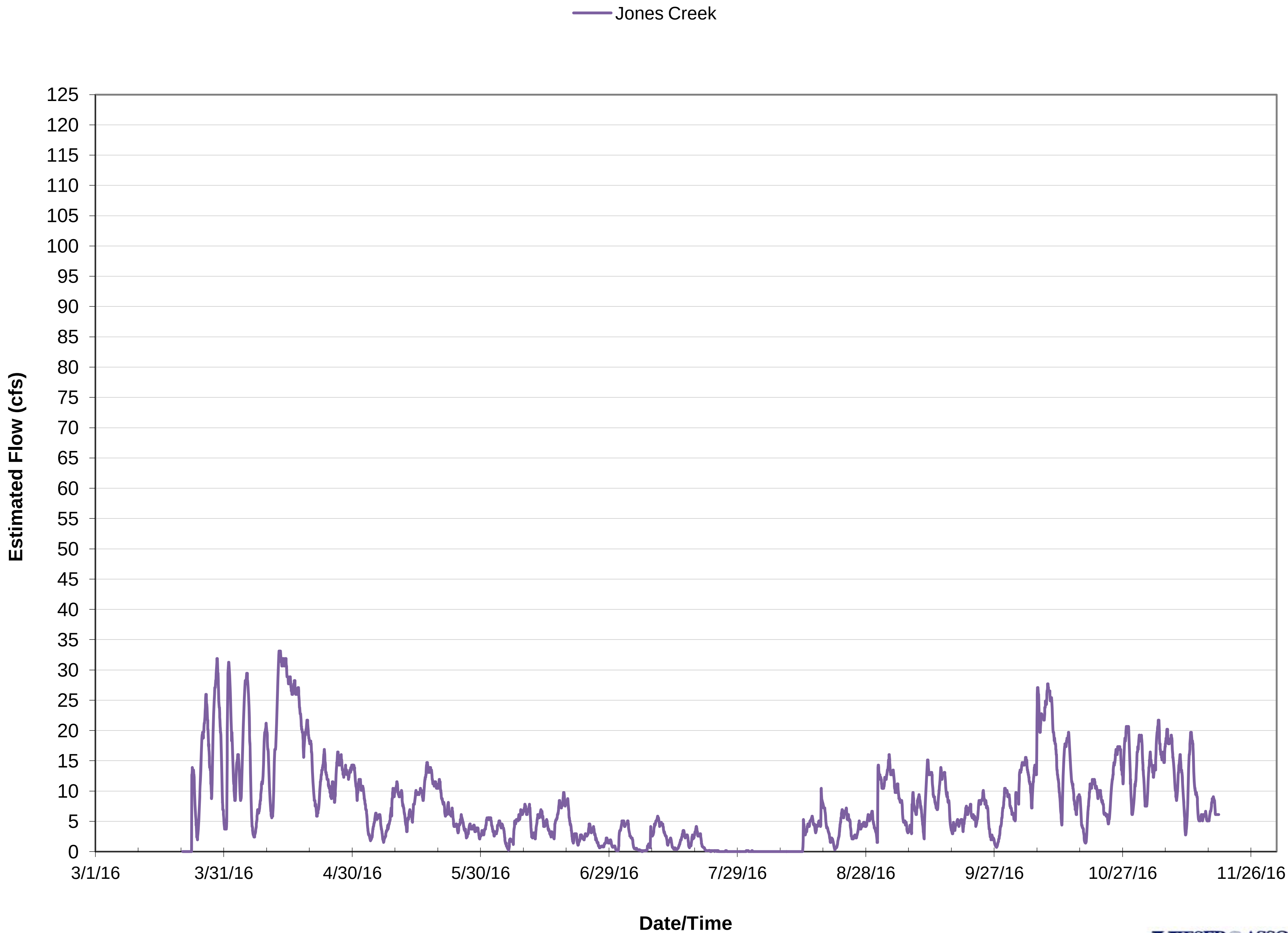

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Figure 16. 2016 Estimated Sherman Creek Flows

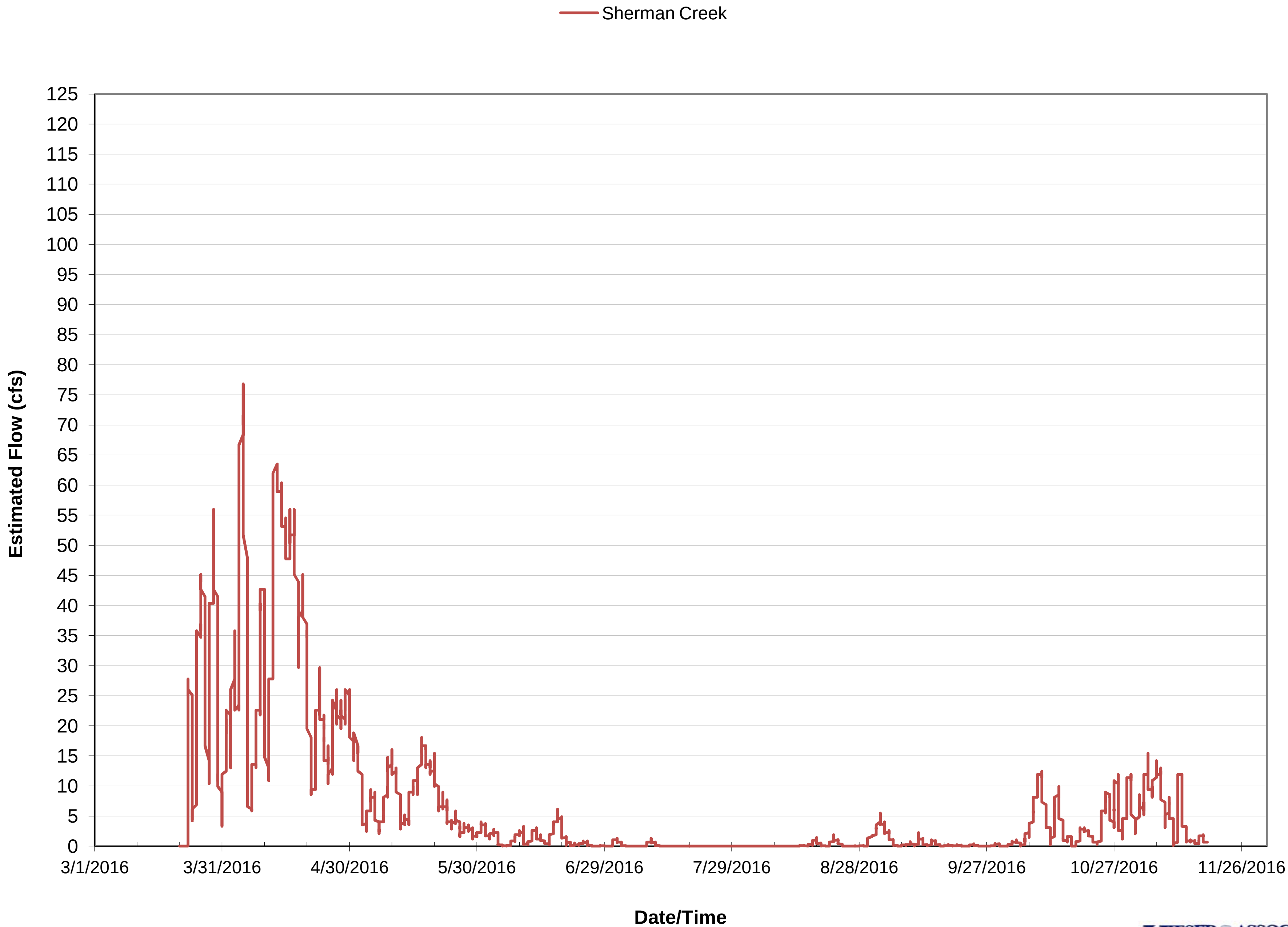

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Figure 17. 2016 Estimated Cedar Lake Outflows

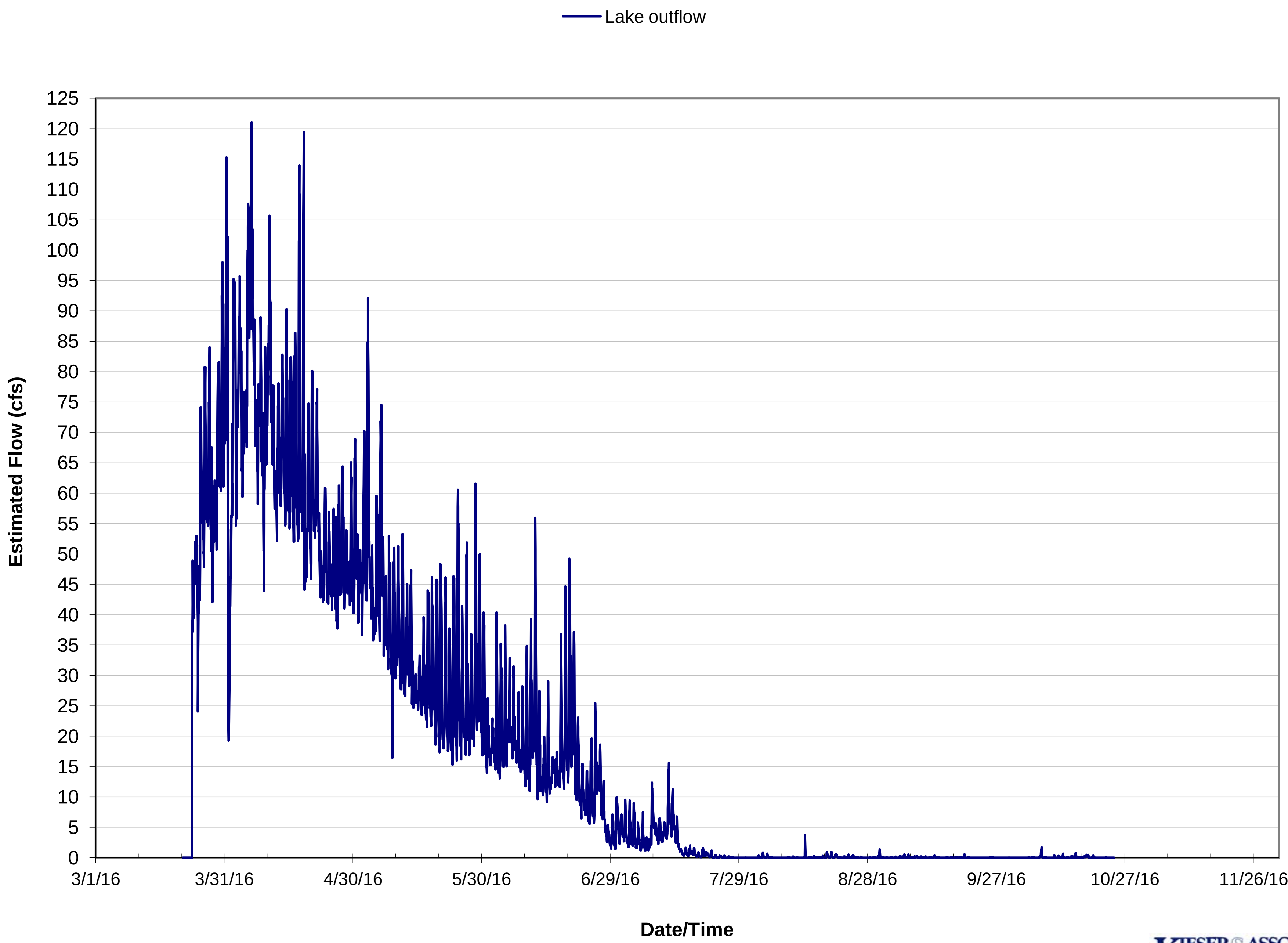

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Figure 18. 2016 Estimated Kings Corner Flows

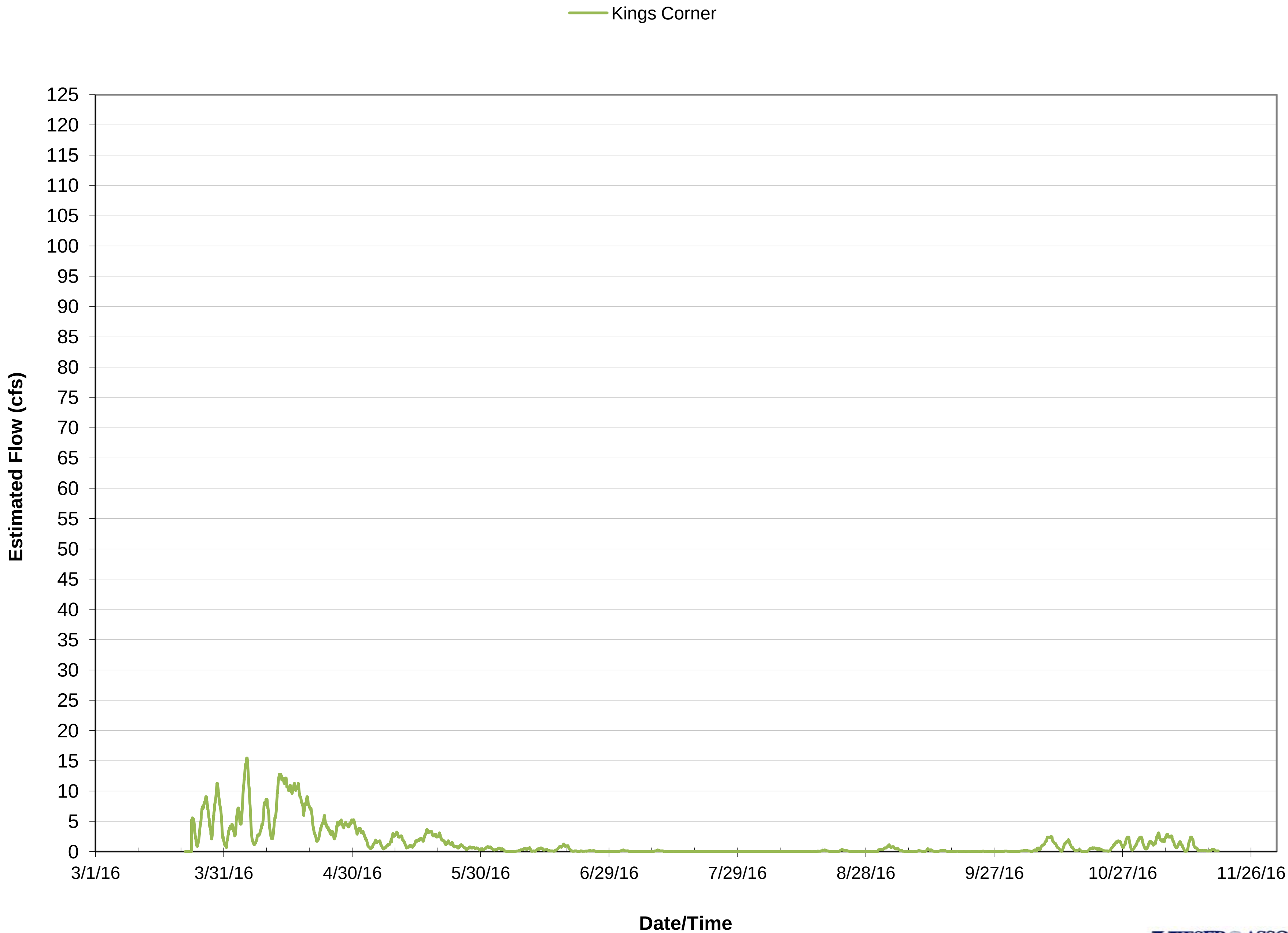

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Figure 19. 2016 Estimated Cedar Lake Inflows/Outflows

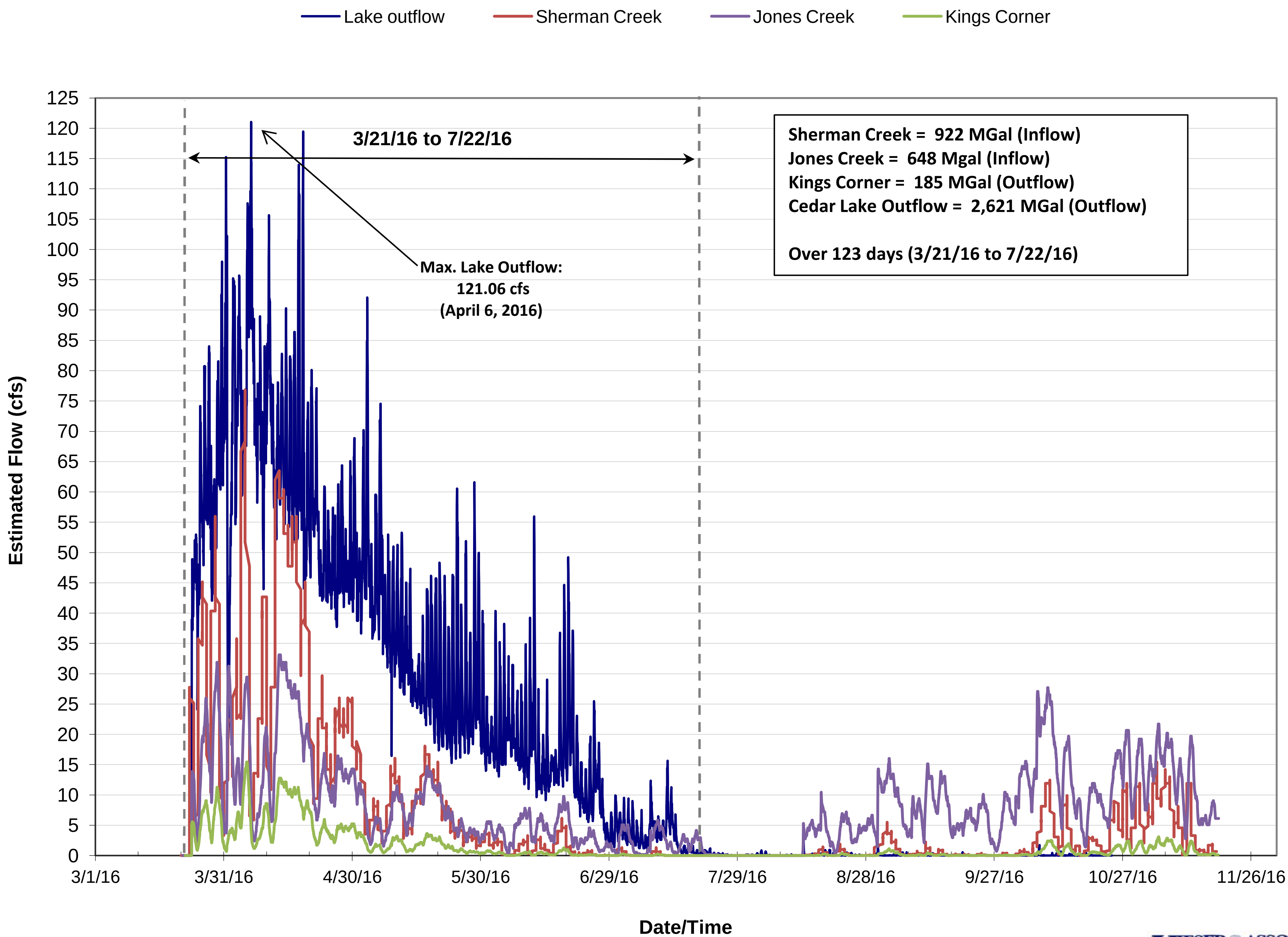

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Figure 20. 2016 Estimated Kings Corner Total Outflow Losses