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TECHNICAL MEMORANDUM

To:	Cedar Lake Improvement Lake Board	**Date:**	March 29, 2016
From:	Brian Boyer, K&A Mark Kieser, K&A	**cc:**	Doug Pullman, Aquest
RE:	**Findings for 2015 Cedar Lake Groundwater/Surface Water Level Monitoring**		

This memorandum presents 2015 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 ongoing data collection efforts in 2015 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 drier summers. 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 2015 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 2015 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 also evaluated to assess rainfall for 2015 and compared with past rainfall records.

2015 Precipitation and Water Level Data

The 2015 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 and 5 (Figures 2, 4, 5, and 6, respectively) are in areas where groundwater is moving away from the lake, as reflected in the 2015 piezometer water levels that were below the lake water level. Sites 2, 6 and 7 (Figures 3, 7, 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. 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 data 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 1998-2015 (minus 2006 when there were no local functioning rain gauges) reflect a 17-year summer average (June-September) of 12.14 inches of rainfall. The observed 2015 rainfall data are just below-average for rainfall, measuring 10.94 inches during these summer months. The previous 2014 summer exhibited above-average summer precipitation amounting to 14.14 inches. Rainfall in 2012 and 2013 was below-average, while 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 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 also plotted on Figure 13 for sake of comparison.

The 2015 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 until mid-July (representing lake outflow conditions). The 2015 Cedar Lake water levels were

plotted with April-November recorded rainfall (refer to 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), the Figure 14 2015 Cedar Lake water levels held relatively steady and within inches of the northern lake outflow structures. 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.

2015 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 2015 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 53.6 and 223.2 million gallons (Mgal), respectively, into Cedar Lake from March 14 to July 16, 2015 (refer to Figure 19). During the same time period, 46.3 Mgal flowed out of the Cedar Lake watershed via the King's Corner road culvert during this same period. Measured outflow volume leaving Cedar Lake totaled 118 Mgal during this time period.

As noted on Figure 17, the magnitude of the recorded lake outflow (based on water levels) is potentially not representative of typical conditions due to ongoing observed beaver dam activity at the outflow area again this past year. The total estimated volume of 118 Mgal is, however, a more reasonable approximation this year since most discernible lake outflows ceased in mid-July.

Figure 20 is intended to summarize observed flows associated with the Kings Corner culvert location. The plotted flows from April 11 to November 22, 2015 reflect a total volume of 46.3 Mgal over 226 days. This is very similar to the data observed in 2014. It

is important to keep in mind that these flows reflect "lost inflow" volume to Cedar Lake. It is for this reason that we recommend moving forward with planned property improvements on the newly acquired Lake Board property to mitigate these losses. The maximum observed high water elevation at the Kings Corner culvert in 2014 was 610.57. While the 2015 data reveal a very similar high water elevation during the spring of 2015 at 610.88. Since 2009, this location has had an average high water elevation of 611.13 and a maximum observed elevation of 612.86. Based upon the recent survey performed by Northeast Land Surveys of Oscoda, these elevations are quite manageable within the Lake Board parcel (consistent with previous berming concepts discussed).

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 flow from the west to the east beneath the railroad tracks at six culvert locations. We expect that this will continue to allow more surface water to pass to the lake via Sherman and Jones Creeks. However, this will also likely result in increased surface water losses 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 2015 lake level monitoring continue to demonstrate how Cedar Lake first and foremost responds quite directly to prevailing summer month rainfall amounts. Lake levels for 2015, 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 2015 lake levels were adequate for targeted summer conditions. However, the beaver dam at this location still needs removal action. The 2014 railroad culvert cleanouts appear to have provided late season groundwater recharge benefits into the northwest cedar swamp, as we did observe discernible creek flows once again in September despite being a relatively dry month. 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 2015 data also continue to illustrate the large volume of water loss through the King's Corner culvert. This supports the need for pursuing a water control berm at this location with the benefit being extended summer surface flows from Sherman Creek into the lake as well as increased groundwater recharge to the north of King's Corner Road which will also benefit groundwater discharge to the lake.

Based on 2015 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 2016 calendar year. Such data will be vital to maintaining a comprehensive and unbroken historic water level

record. Such 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, and 3) physical improvements associated with the 2014 culvert flow repair efforts conducted by the railroad in the northwest cedar swamp area. Costs for ongoing 2016 water level monitoring will be provided separately to the Lake Board with other WMP related costs. The costs for 2016 monitoring should, however, be very similar to the 2015 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.

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

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

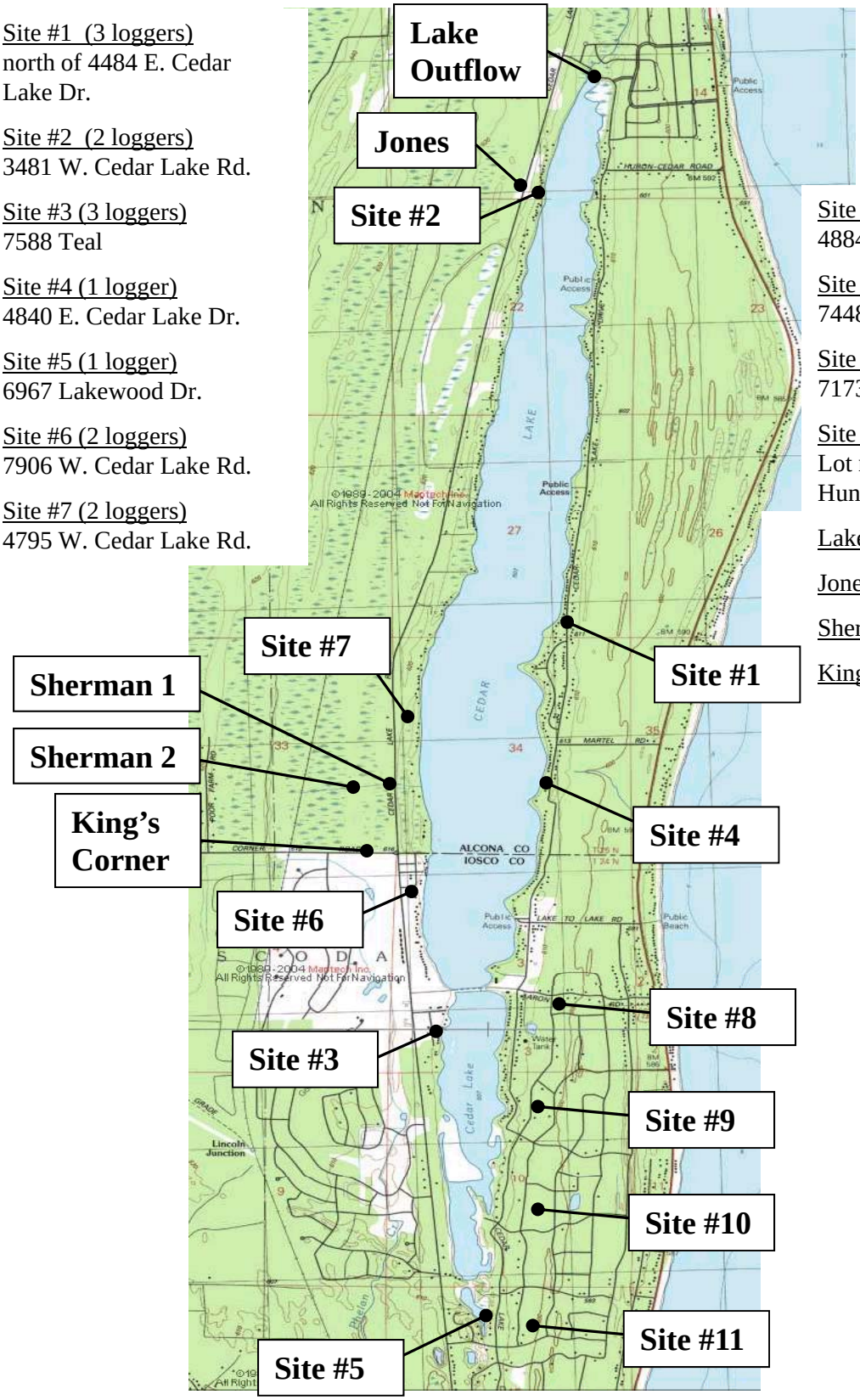
Site #3 (3 loggers)
7588 Teal

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.



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. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 1)

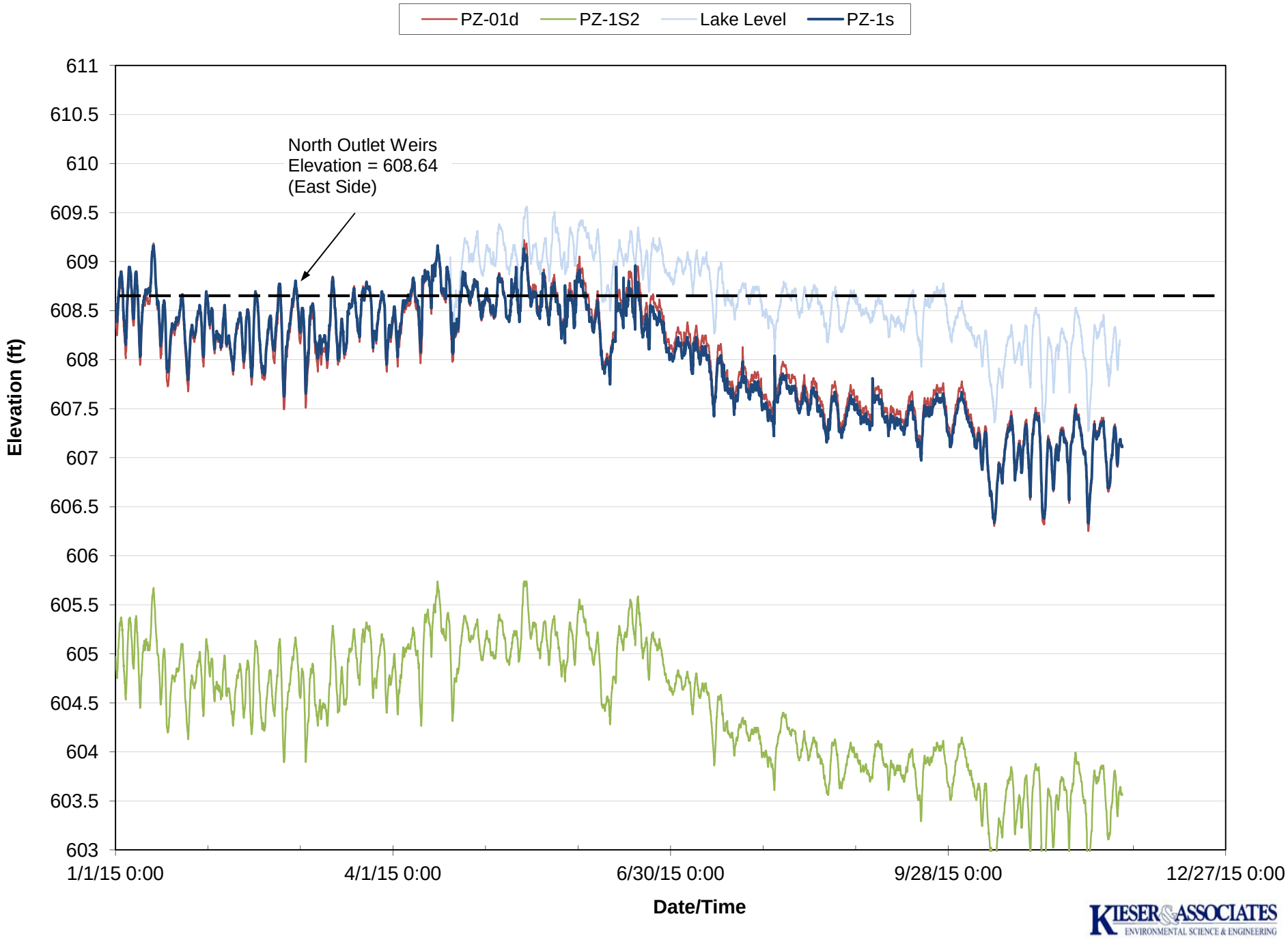

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Figure 3. 2014 Cedar Lake Groundwater /Surface Water Elevations (Site 2)

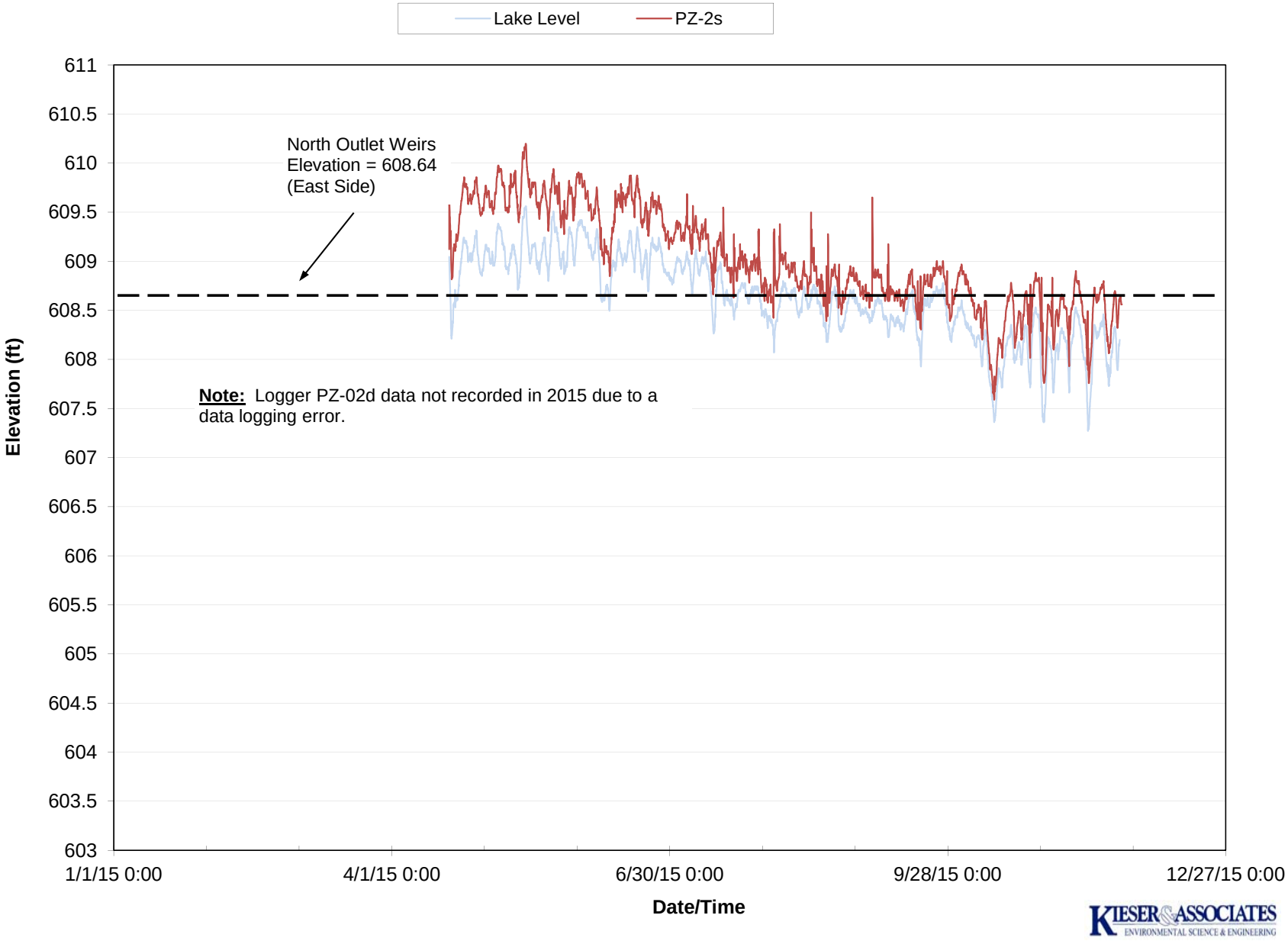

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Figure 4. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 3)

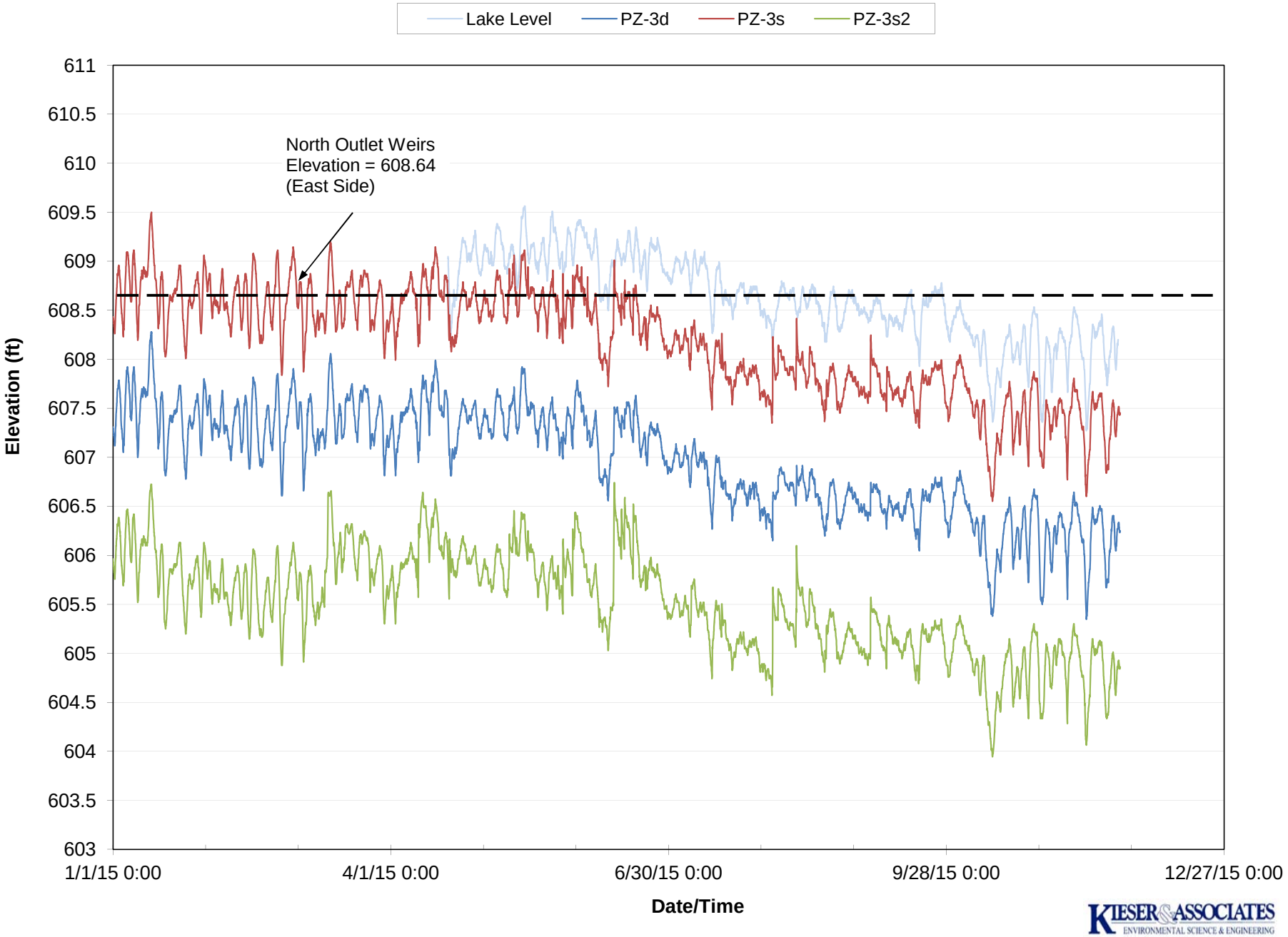

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Figure 5. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 4)

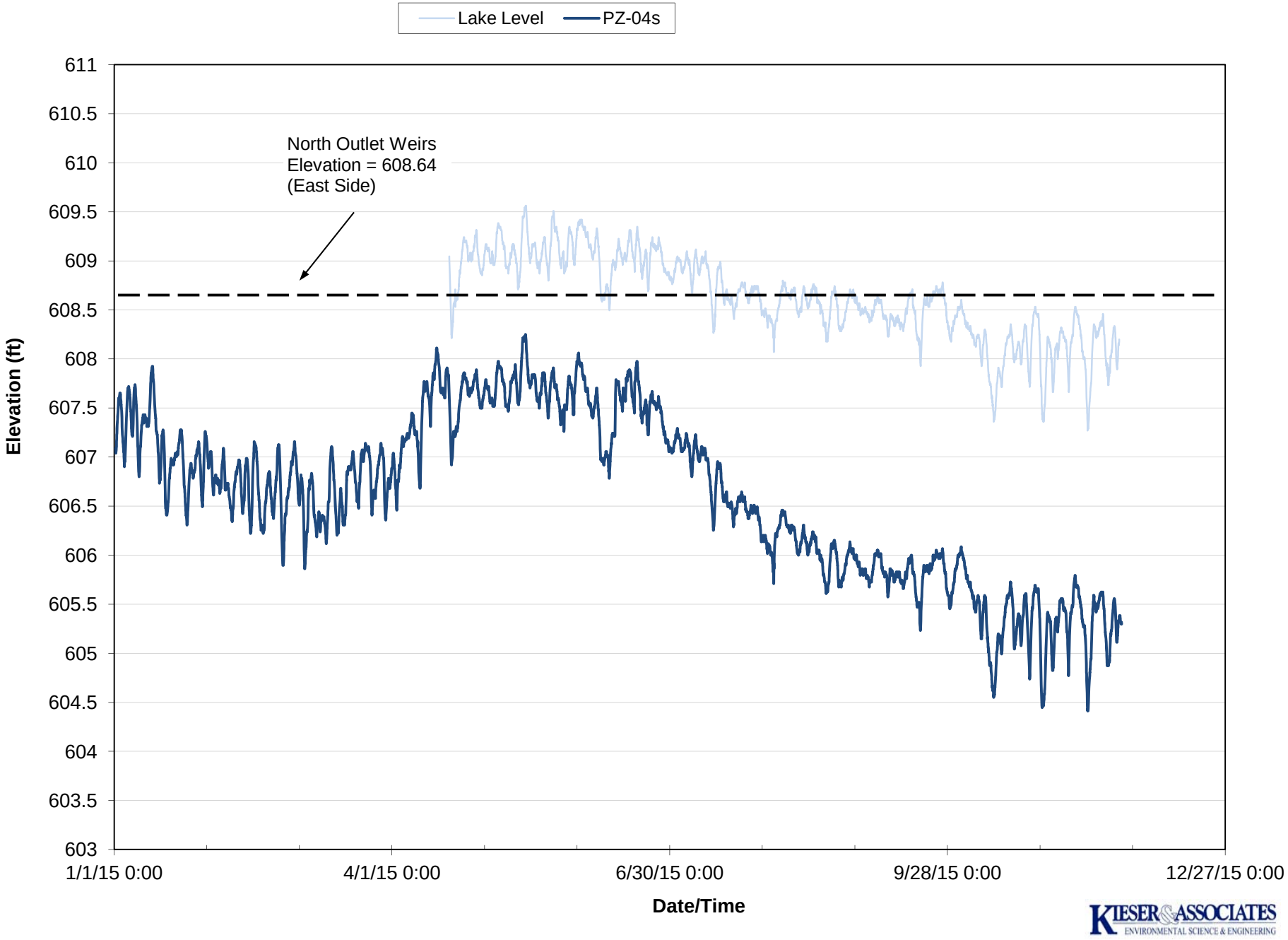

Figure 6. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 5)

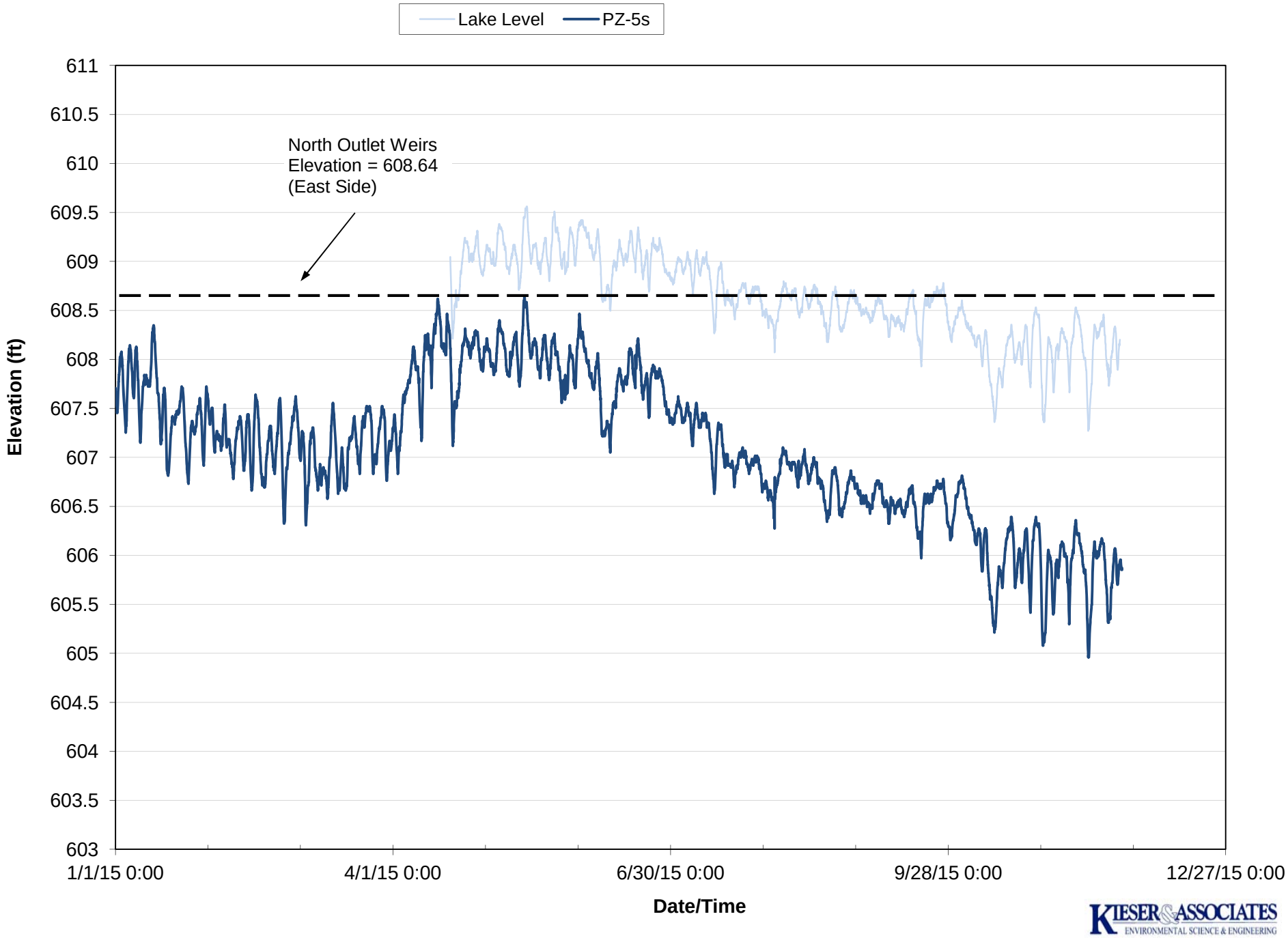

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Figure 7. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 6)

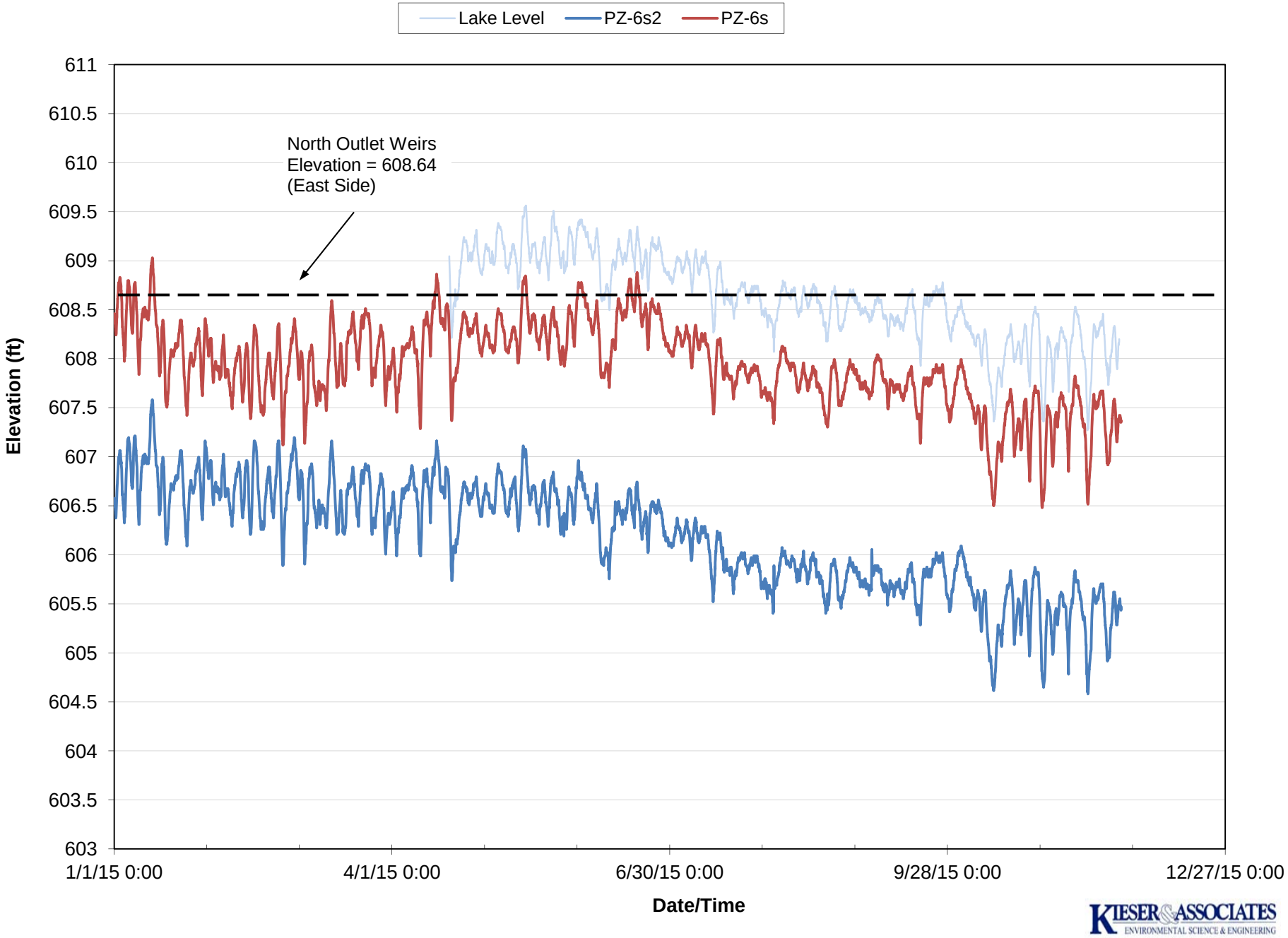

Figure 8. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 7)

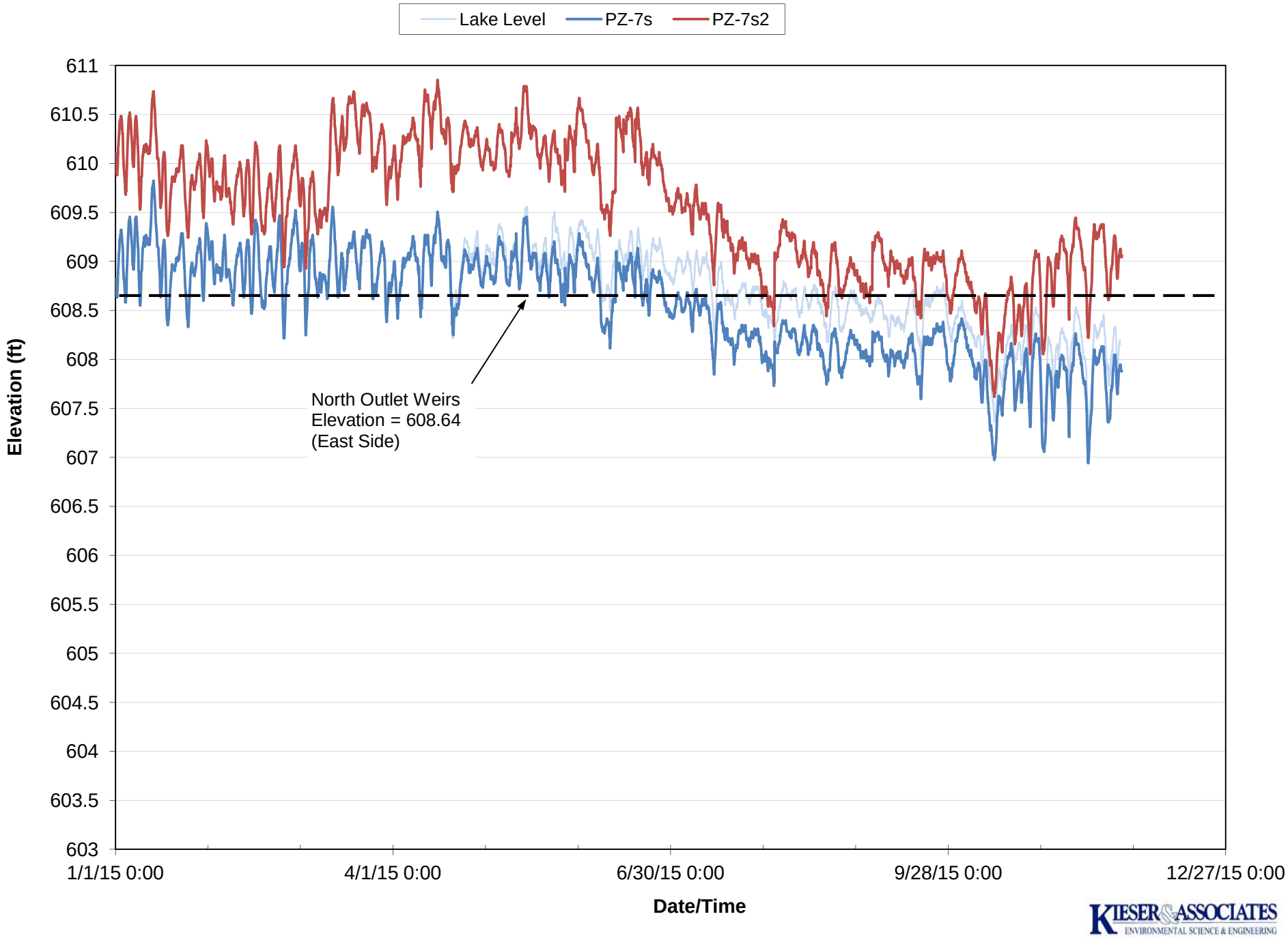

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Figure 9. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 8)

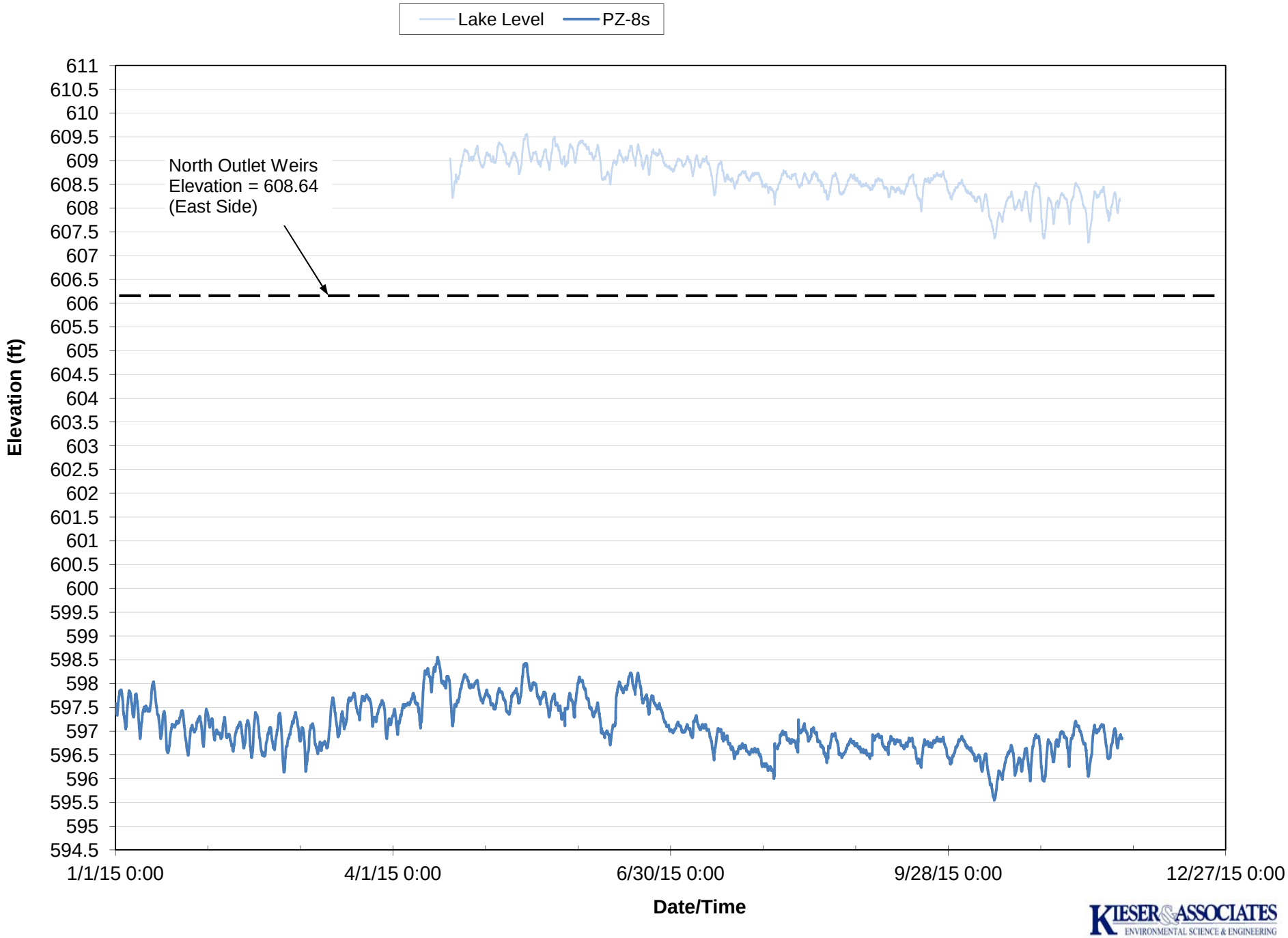

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Figure 10. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 9)

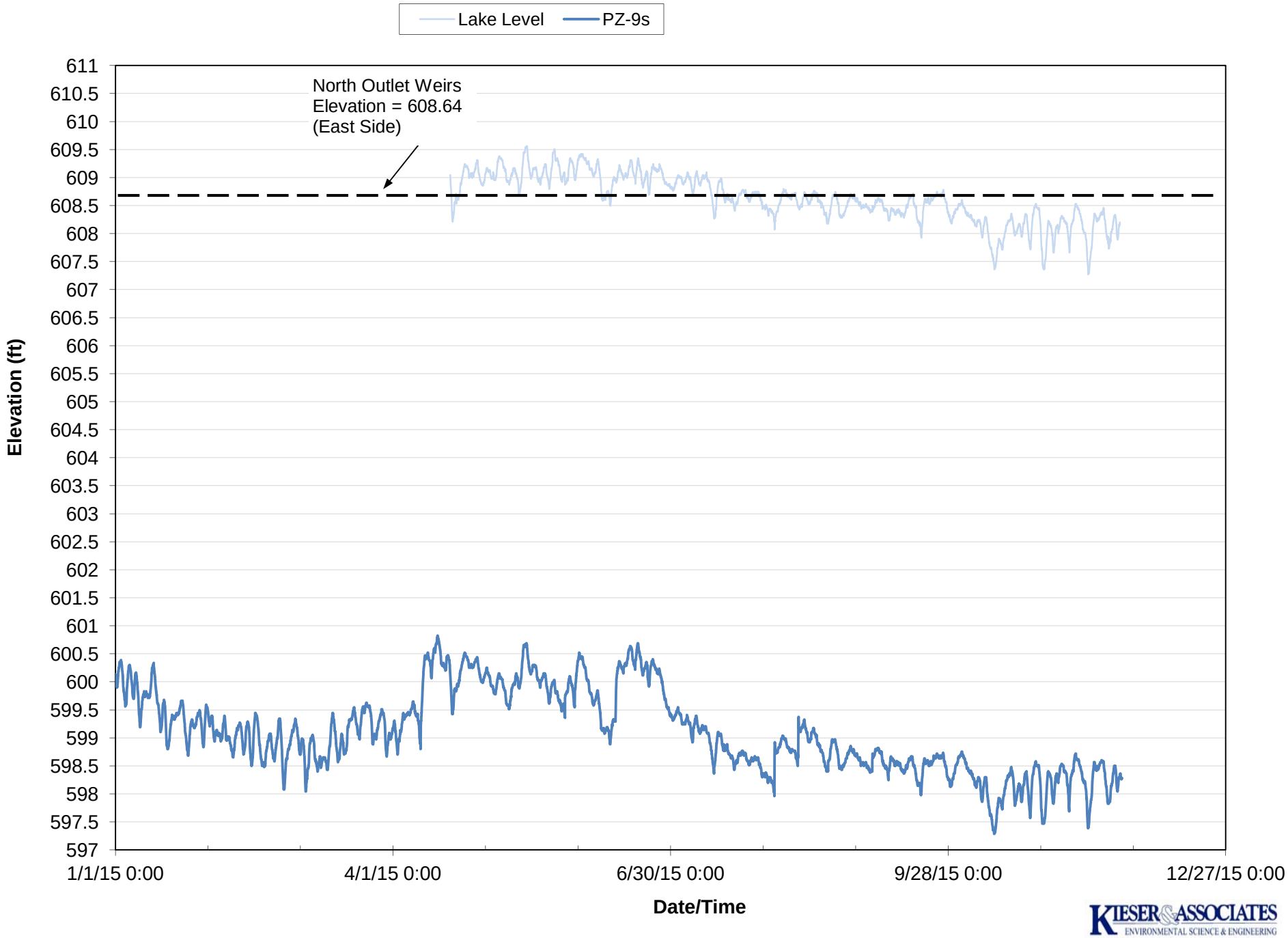

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Figure 11. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 10)

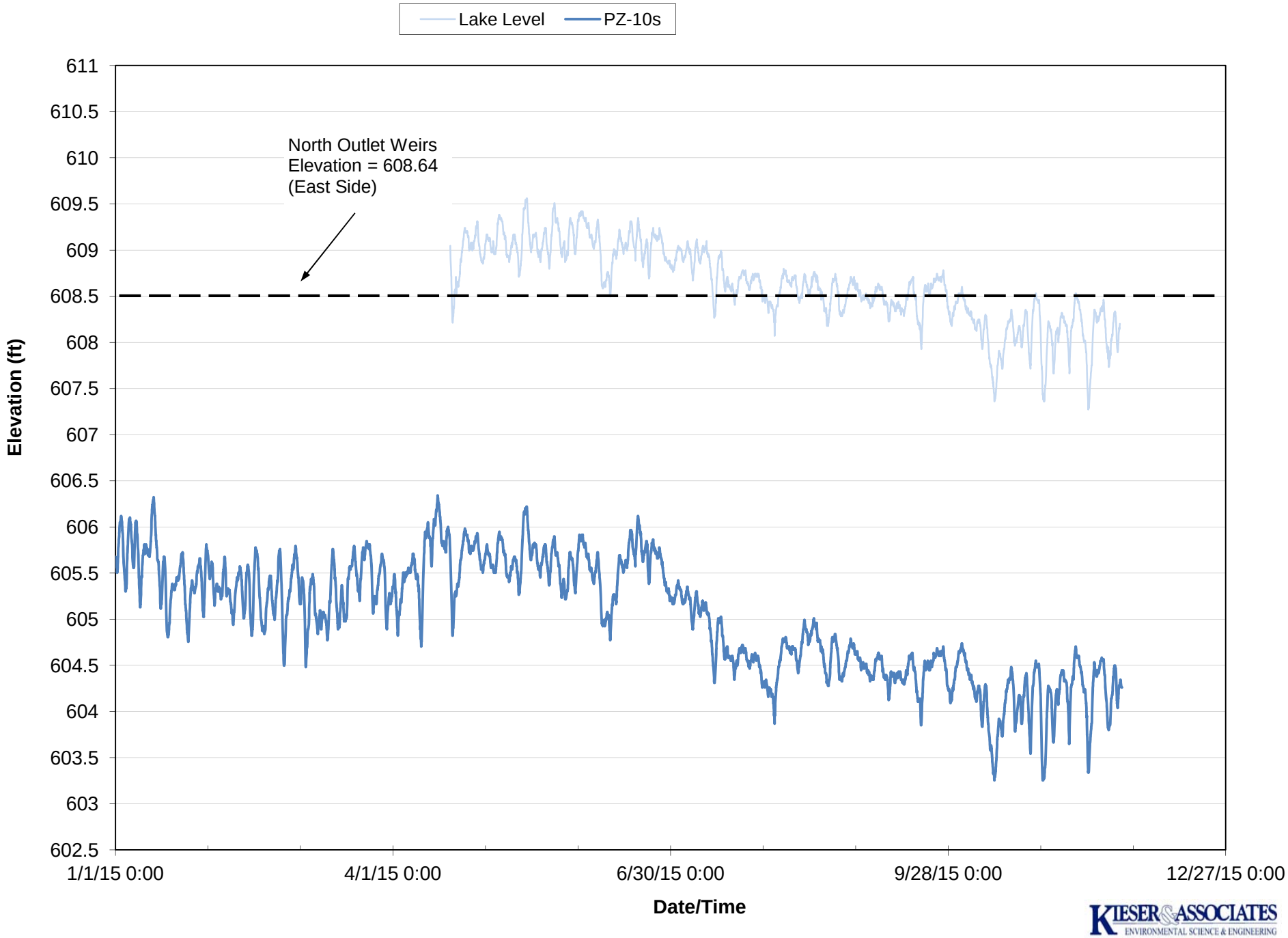

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Figure 12. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 11)

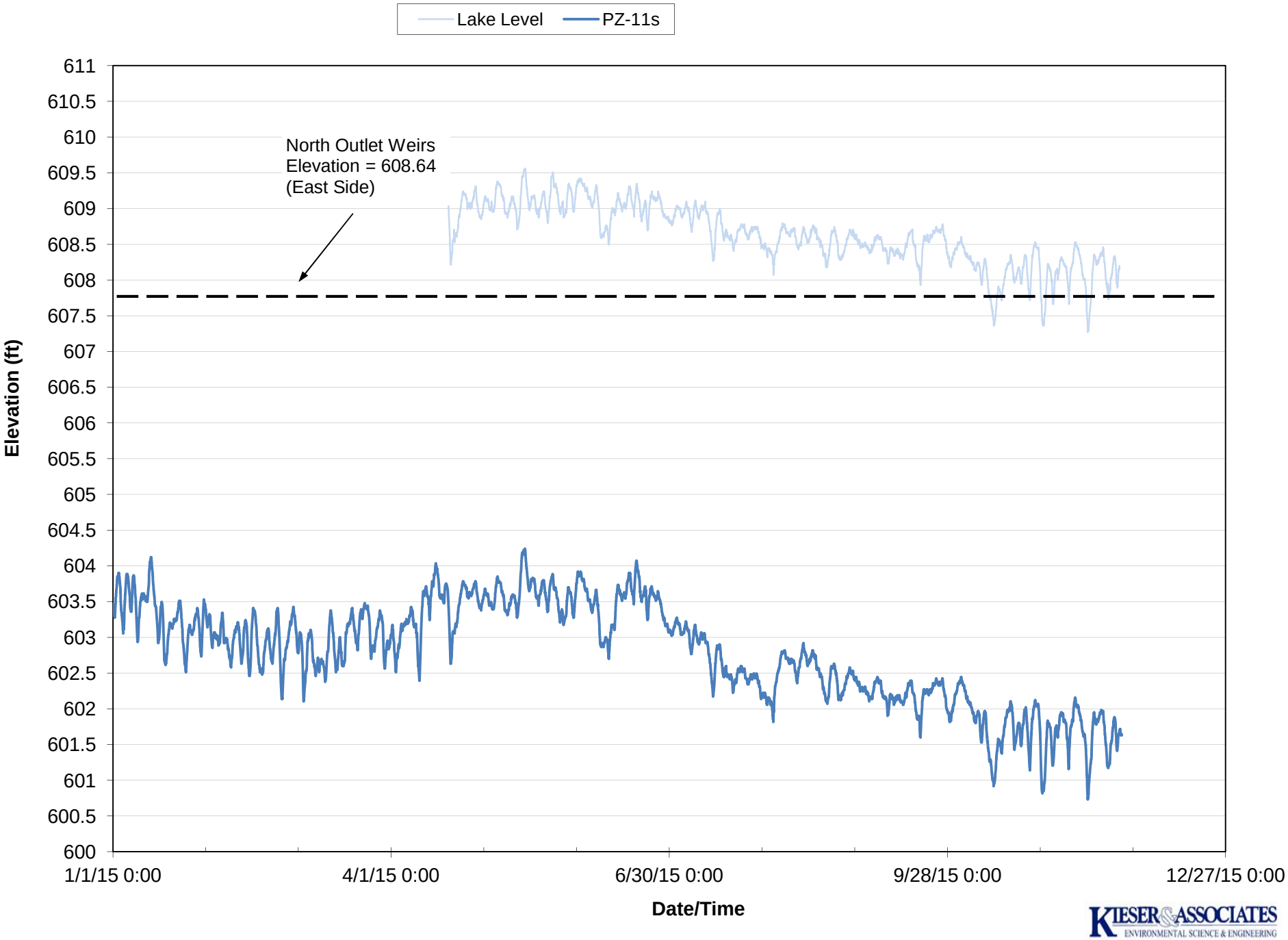

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Figure 12. 2015 Cedar Lake Groundwater /Surface Water Elevations (Site 11)

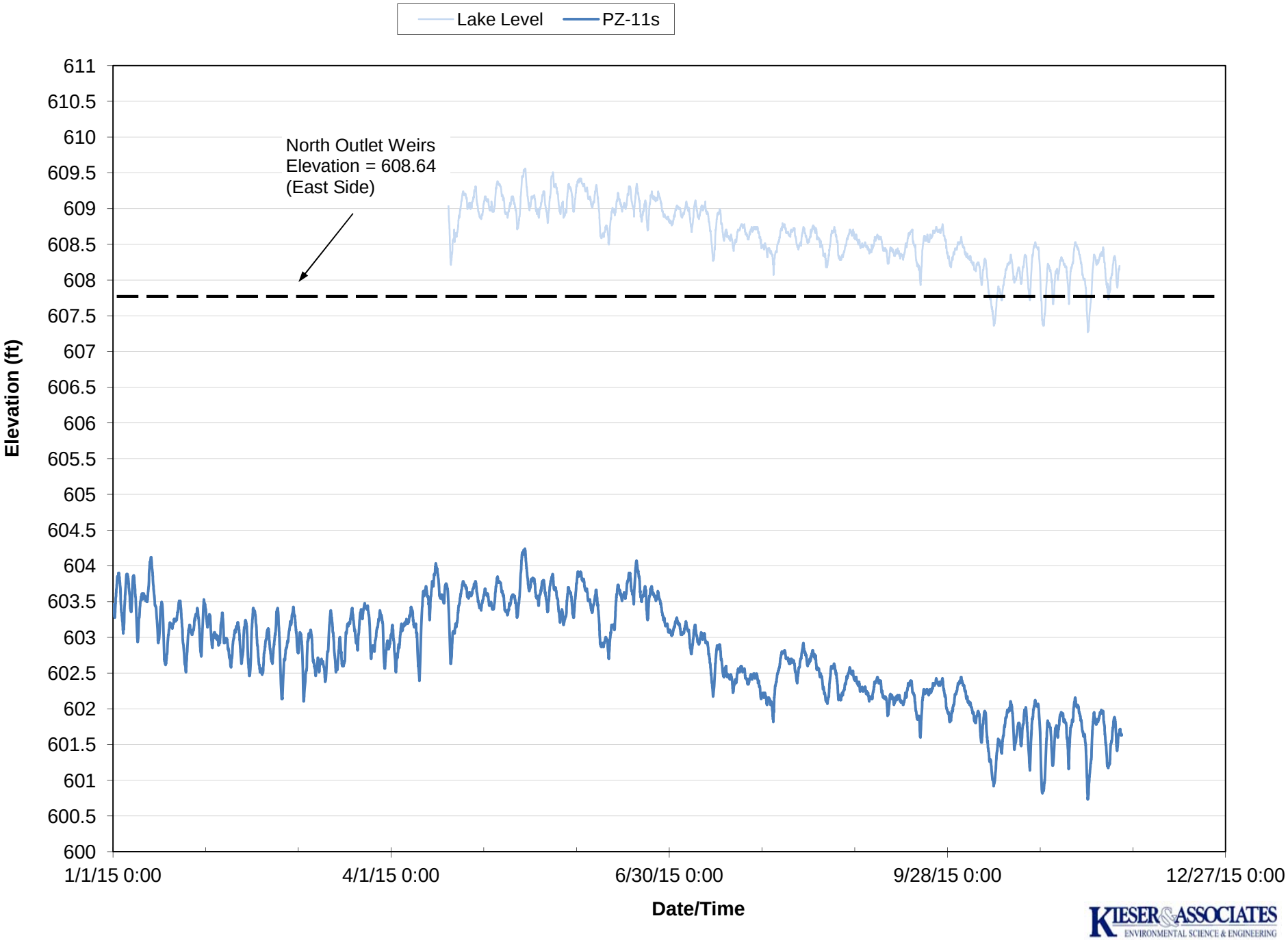

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Figure 13. Summer (Jun - Sept) Precipitation Totals for Cedar Lake
(Precipitation Source: Harrisville, MI, CO-OP Station #203628,
Alcona County Cedar Lake Rain Gauge,
Oscoda, MI Oscoda Wurtsmith Airport Station #14808, Iosco County)

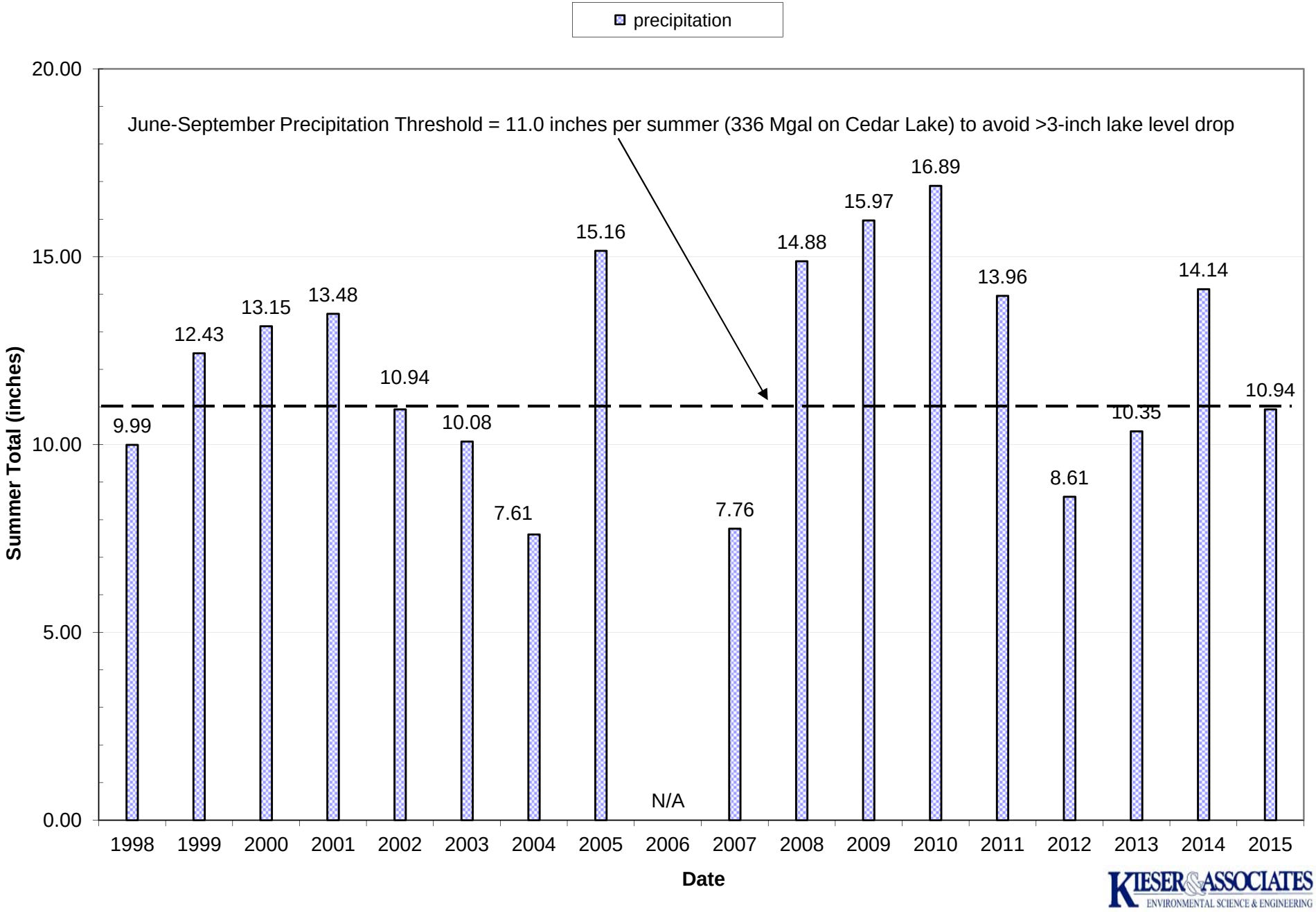

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Figure 14. 2015 Cedar Lake Water Elevelation and Measured Rainfall

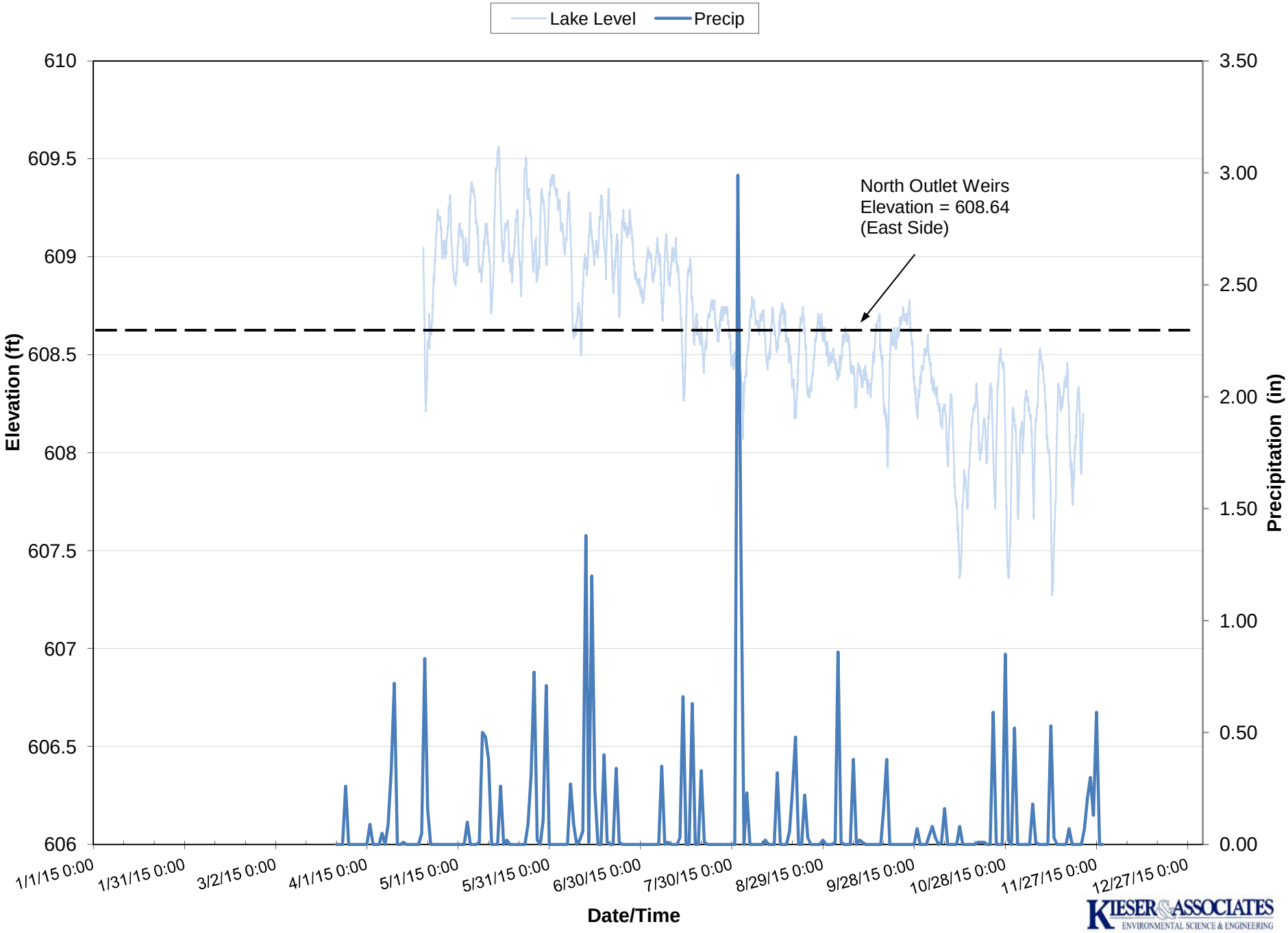

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Figure 15. 2015 Estimated Jones Creek Flows

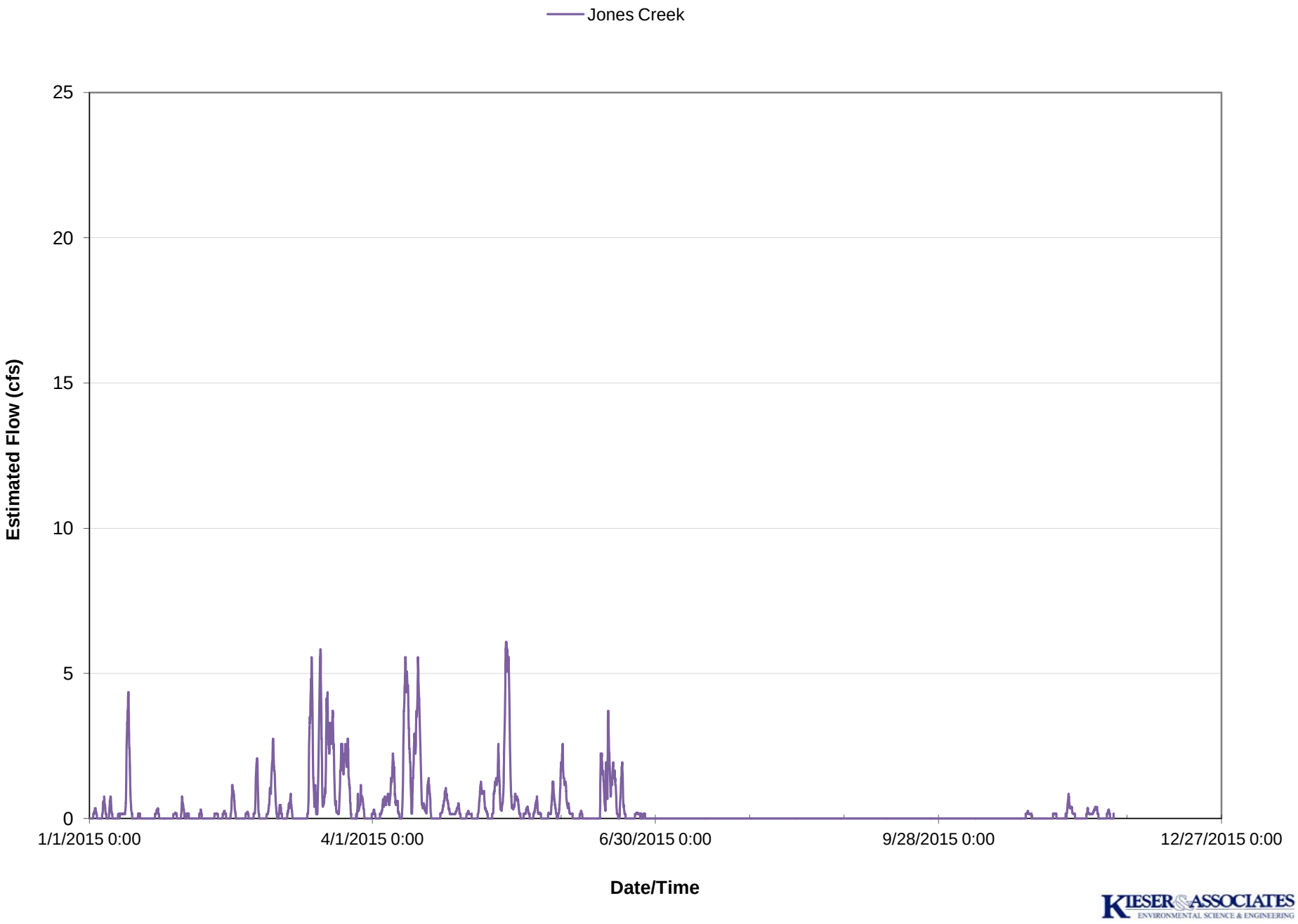

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Figure 16. 2015 Estimated Sherman Creek Flows

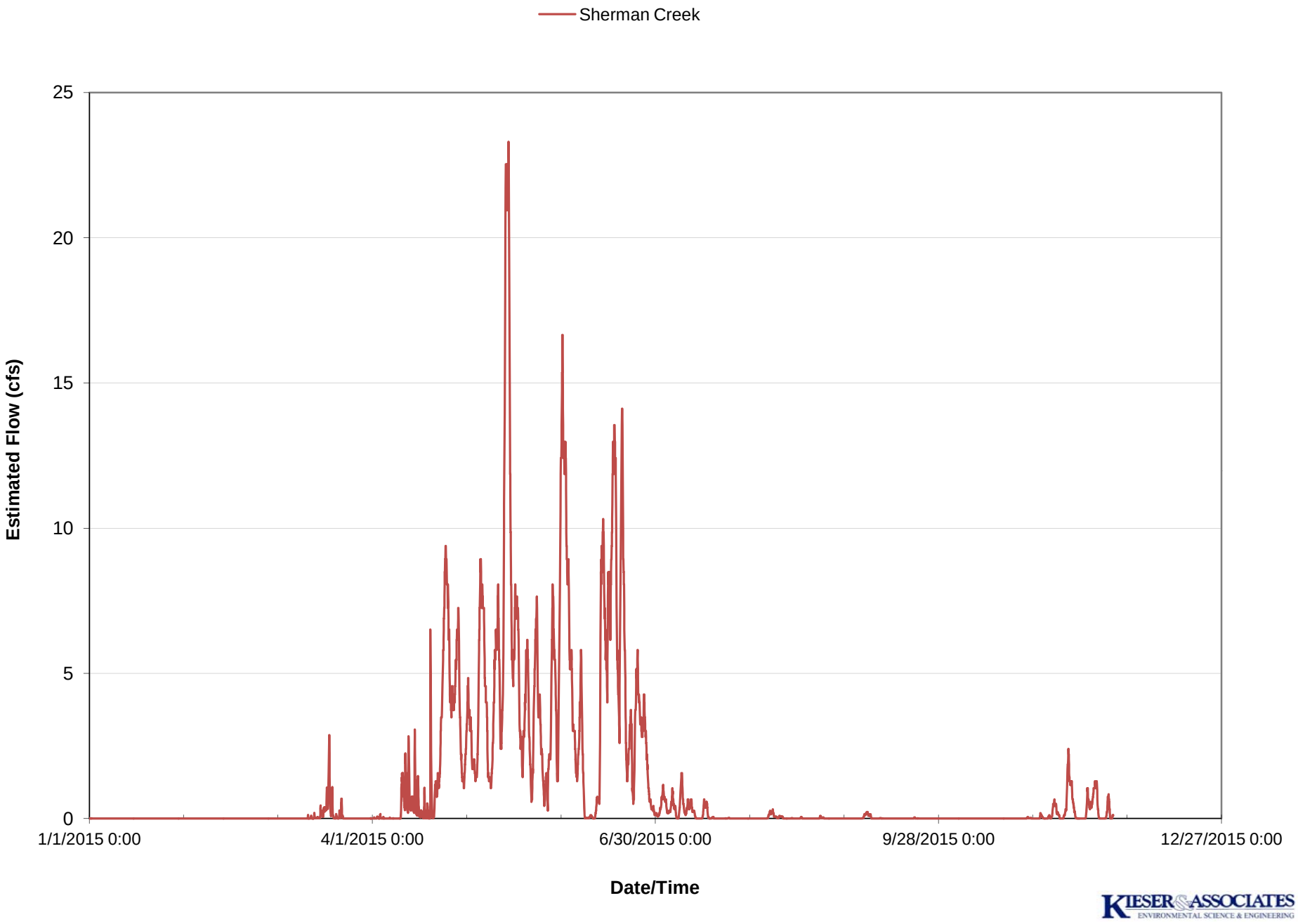

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Figure 17. 2015 Estimated Cedar Lake Outflows

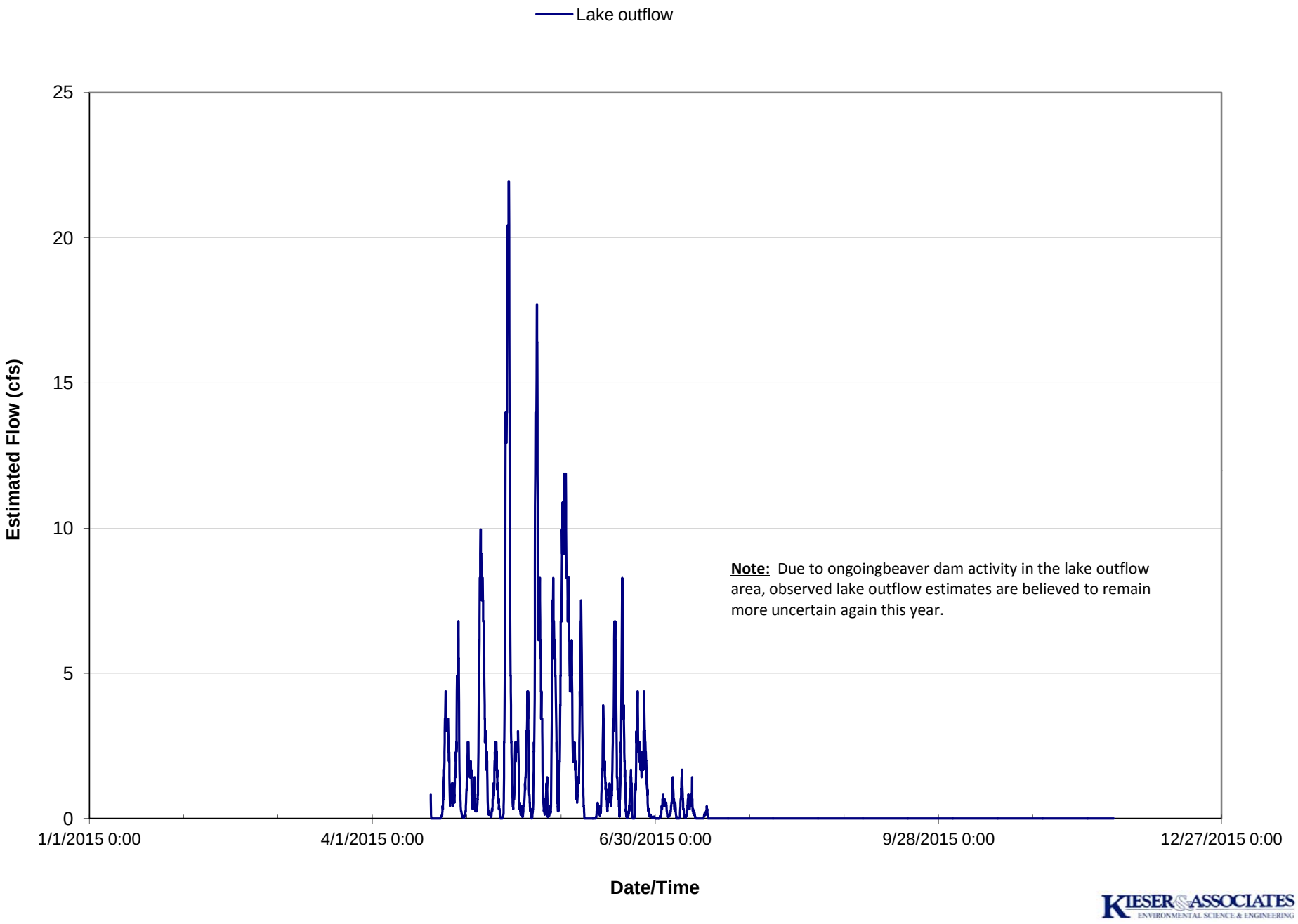

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Figure 18. 2015 Estimated Kings Corner Flows

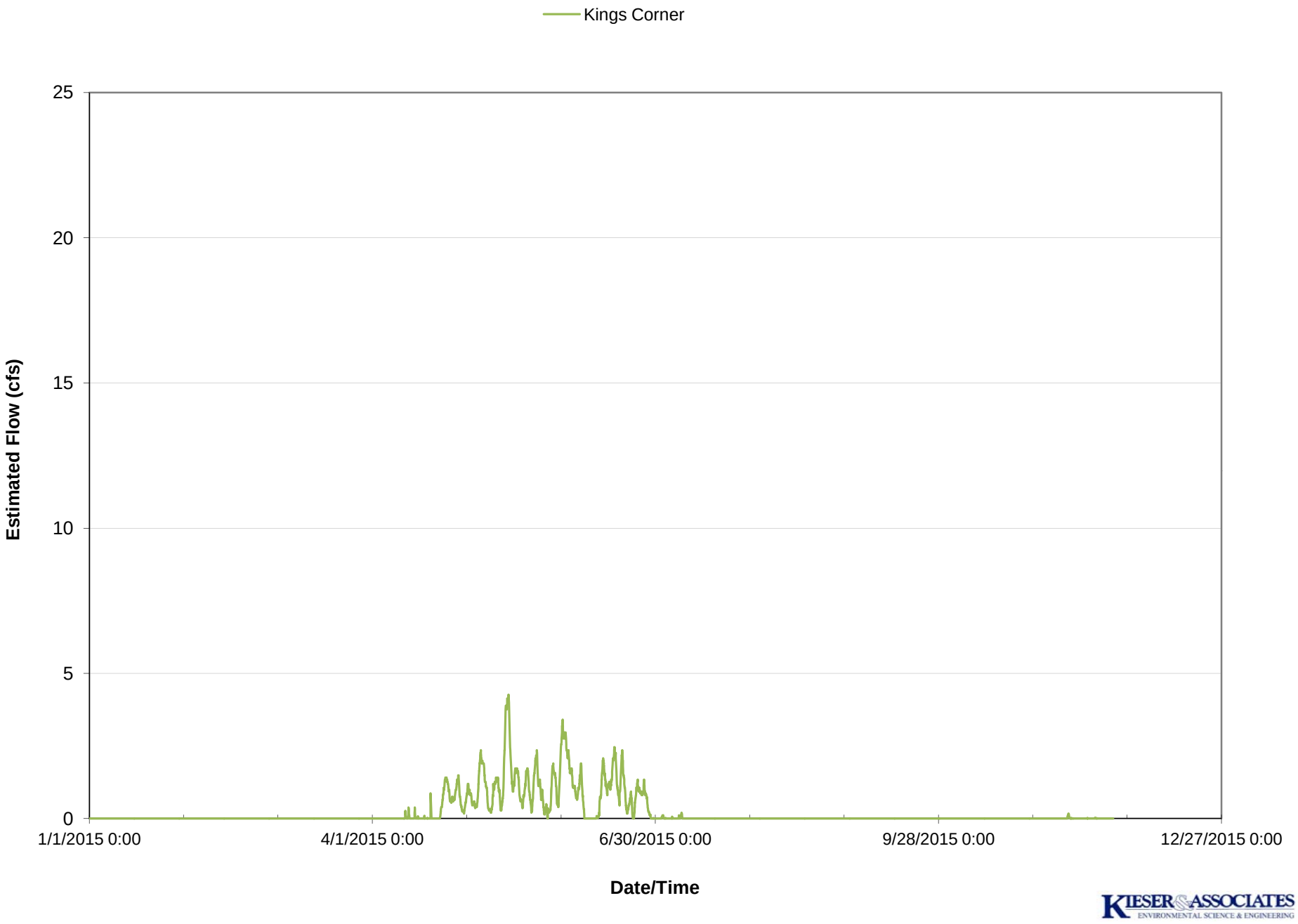

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Figure 19. 2015 Estimated Cedar Lake Inflows/Outflows

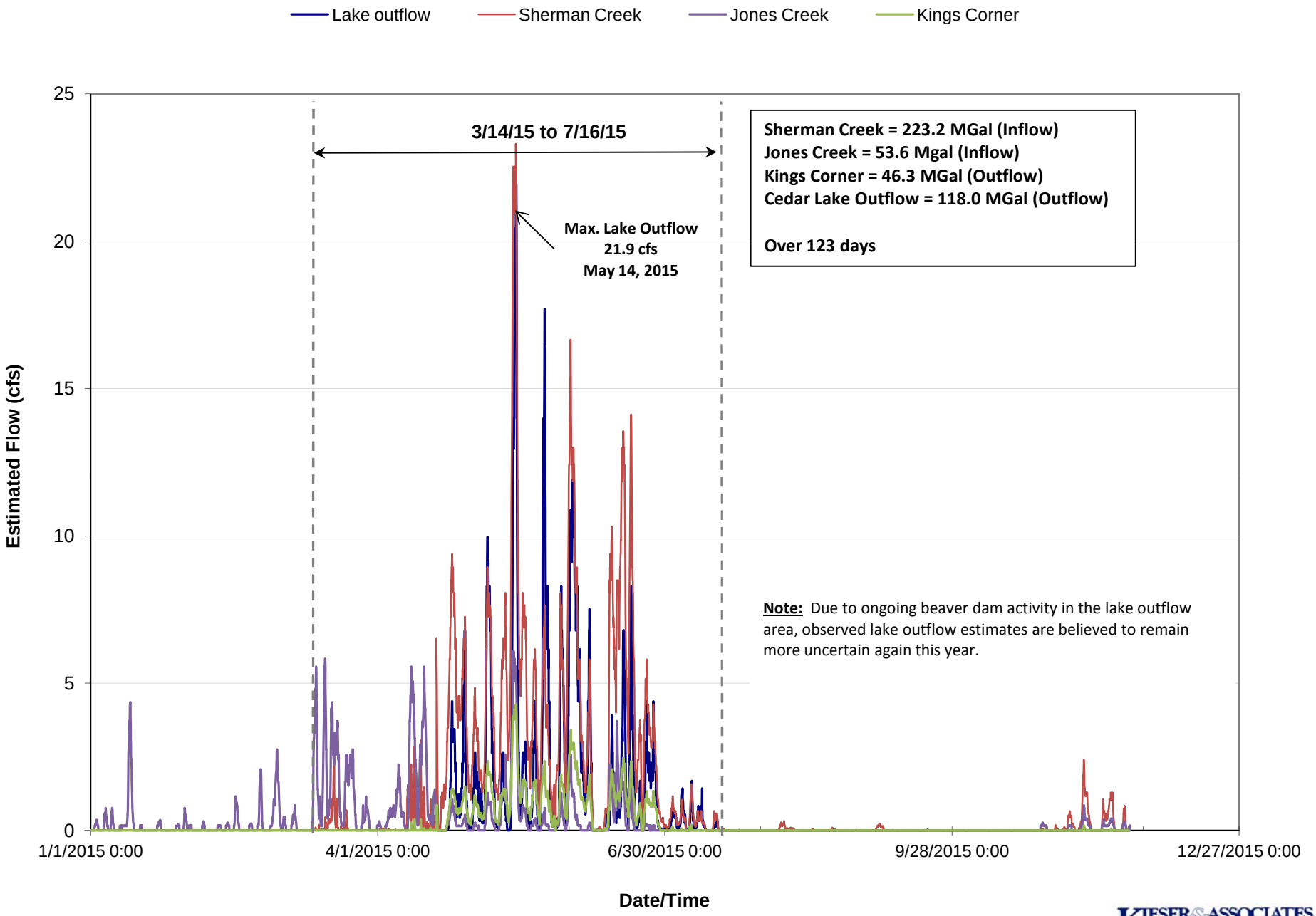

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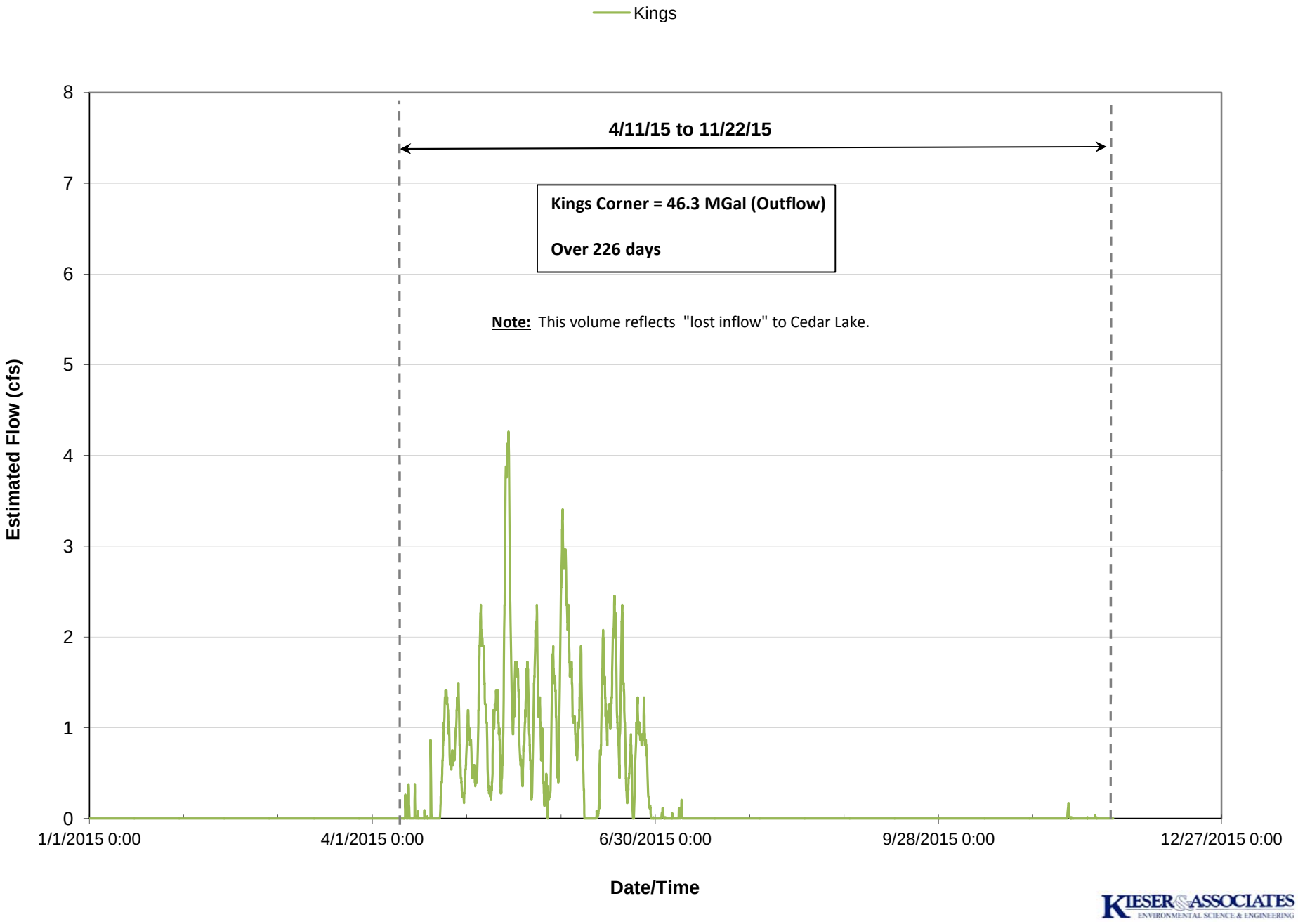
Figure 20. 2015 Estimated Kings Corner Total Outflow Losses



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