Briarcliffe Acres: Groundwater and Lake Level Monitoring Program
Report on Year 1
Submitted by:

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RATIONALE FOR STUDY

As the Town of Briarcliffe Acres Comprehensive Plan states, the goals of stormwater and lake management are to protect, maintain, and enhance the quality of our coastal and lake waters for the enjoyment of present and future generations. The town is tasked with implementing "a freshwater and beach water quality monitoring program, including comprehensive testing;" to educate landowners about their cumulative effects on ponds, marshes, and the ocean;" and to develop a stormwater maintenance management plan and prioritize capital improvement project list which includes dredging of the freshwater ponds." The town's freshwater ponds do serve incidentally as stormwater retention ponds.

PROJECT DESCRIPTION

A groundwater and lake level monitoring program was initiated in May 2012 to enable the community of Briarcliffe Acres to locally manage their water resources. The major water resource of concern is a series of networked lakes that are used for stormwater retention and as a source of irrigation water. Groundwater is also being used as a source of irrigation water. Extended drought conditions have led to lowered lake levels.

To learn how to better maintain suitable lake levels, a monitoring program was instituted to document the relationship between groundwater and lake water levels.

The study was designed to help answer the following questions:

- What are the average and instantaneous elevations of the water table at three sites located along a shore-perpendicular transect, i.e., at a site upslope of the lakes, at the lakes, and at a location downslope of the lakes.
- How does irrigation with well water influence lake and groundwater levels?
- How does irrigation from the lakes influence lake and groundwater levels?
- Is the water level in the lakes so low that it is permitting salt-water intrusion?
- How much does rain, or the lack of it, influence ground water levels?

The data provided by this study could be used to:

- Provide an objective basis for limiting irrigation in the town on an as needed basis, especially around the lakes.
- Evaluate the degree to which saltwater intrusions are affecting the salinity of the lakes.

- Provide data that can be used to support a grant application for the dredging of the lakes.
- Provide public access to groundwater and lake information, resulting in better-informed property owners.
- Provide access to groundwater scientists at CCU who can advise on lake and groundwater management strategies.
- Possibly assist with troubleshooting of septic tank problems caused by a high water table.

PROJECT PARTNERS

The Briarcliffe Acres Groundwater and Lake Level Monitoring Program is jointly funded by the town of Briarcliffe Acres and by Horry County's stormwater department. The scientific work and data delivery is being conducted by the Burroughs & Chapin Center for Marine and Wetlands Studies under the supervision of Drs. S. Libes and R. Peterson. Field work is performed by undergraduate science majors.

PROJECT DESIGN

The program design provides for continuous observation of groundwater and lake levels using Onset Hobo™ water level loggers. The water level measurements are collected every 15 minutes and are corrected for temperature and barometric pressure. Rain data for this monitoring program is being obtained from a meteorology station (Vaisala WXT520) located at the seaward end of the Apache Campground Fishing Pier which is approximately 2.8 miles southwest of the project site. The data are collected with an impact sensor which is calibrated by the OEM annually. Specific conductivity is measured in North Lake every 15 minutes with an Onset Hobo saltwater conductivity™ logger. Data are downloaded monthly by a Coastal Carolina University undergraduate who processes the data and submits it for upload to the project website.

PROJECT WEBSITE

All data are available online at: http://bccmws.coastal.edu/bagw/index.html. Water levels are presented relative to a user selectable set of vertical datums:

- ✓ Mean Sea Level (MSL)
- ✓ Mean Tide Level (MTL)
- ✓ Mean Low Water (MLW)
- ✓ North American Vertical Datum of 1988 (NAVD88)

and as depth below the land surface. The website also includes a description of the project goals and information on how to interpret the monitoring data.

PROJECT PRESENTATIONS

The following presentations have been delivered on the status of this project:

Thepaut, B., S. Libes, and R. Peterson (2013) Briarcliffe Acres Groundwater Monitoring Program Report, Briarcliffe Acres Town Council, January 22, 2013, Briarcliffe Acres, South Carolina (oral) http://bccmws.coastal.edu/wwa/files/BA%20FW%20presentation%20012113%20revised%2042113.pdf

Thepaut, B., S. Libes, R. Peterson, N. Edelman, and T. Garigen (2013) Community-based Groundwater and Lake Level Management in Briarcliffe Acres, SC, SC Environmental Conference, held in Myrtle Beach, SC, March 10-12, 2013. (poster) http://bccmws.coastal.edu/wwa/files/Briarcliffe_Acres_Poster_SCEC_13_%20Thepaut_Libes_Peterson%20030513.pdf

Thepaut, B., S. Libes, R. Peterson, N. Edelman, and T. Garigen (2013) Community-based Groundwater and Lake Level Management in Briarcliffe Acres, SC, Coastal Carolina University Undergraduate Research Competition, April 18, 2013, 2nd place award in the poster presentation division (poster)

RESULTS

The following is a brief description of observations made from 5/24/12 to 5/31/13, covering the first 12 months of the monitoring program.

Rain Climatology

Rain is important in resupplying water to the lakes and the groundwater aquifer. The monthly rain climatology during the period of record is provided in Figure 1. The top panel shows the total monthly accumulation in inches and the bottom panel, the number of rain events that generated more than 0.1 inches of accumulation with a day. The record is notable for the large amounts of rain that fell in July and August 2012 and in April 2013.

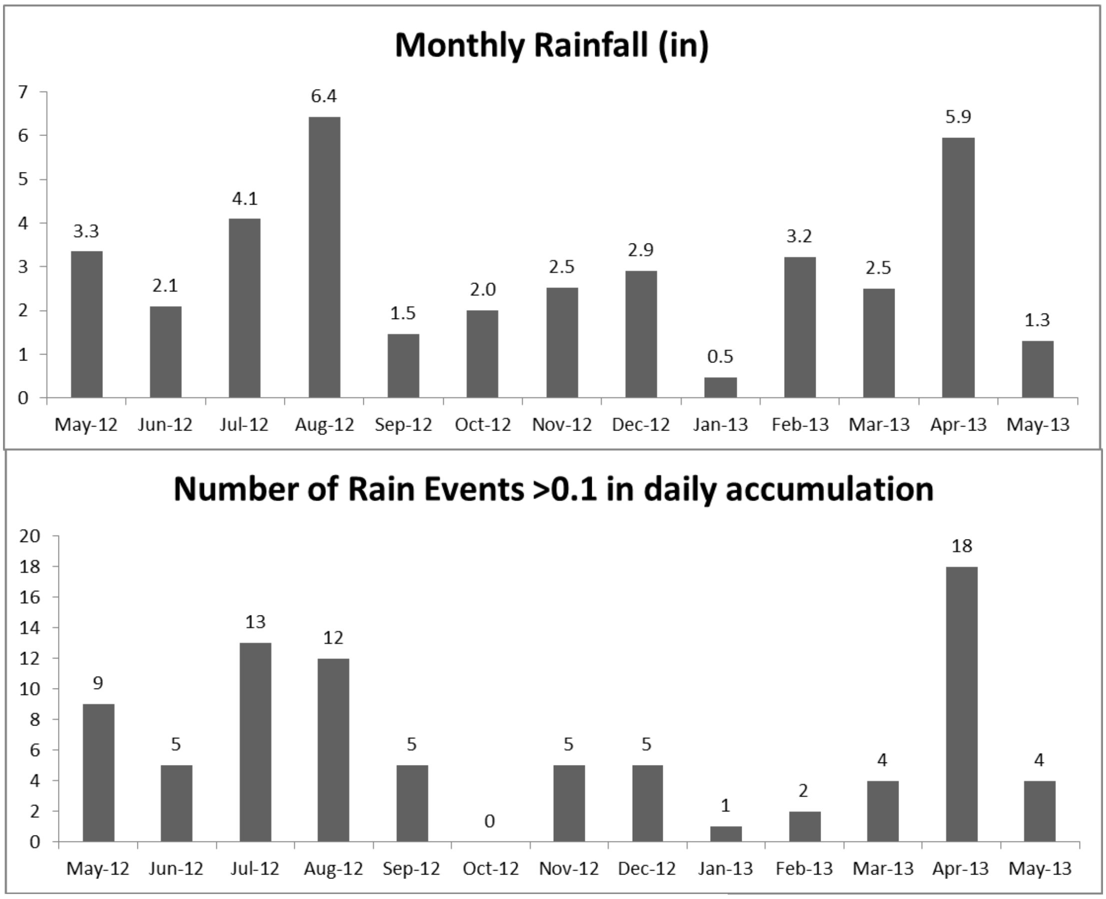

Figure 1. Rainfall at Apache Pier during period of record.

According to the US Drought monitor (http://droughtmonitor.unl.edu/archive.html), Horry County was in a moderate drought until June 5, 2012 followed by an abnormally dry period that lasted until August 21, 2012. Normal conditions continued until October 16, 2012 when the lack of rainfall resulted in the return of abnormally dry conditions that persisted until March 19, 2013. In other words, 47% of the monitoring period has been characterized by normal conditions and 63% by abnormally dry conditions. No drought has been present.

The long term climatology of north eastern Horry County, in the region where Briarcliffe Acres is located, is shown in **Figure 2.** This data were obtained from the US Drought Monitor at: http://droughtmonitor.unl.edu/archive.html . Data are archived back to 5/20/99. As shown in **Figure 3**, north eastern Horry County has been abnormally dry for 24% of this period of record. Drought conditions have been present for an additional 20% of the period. The most severe droughts occurred in 2002 and 2007-2008. A lesser drought was present in 2011-2012.

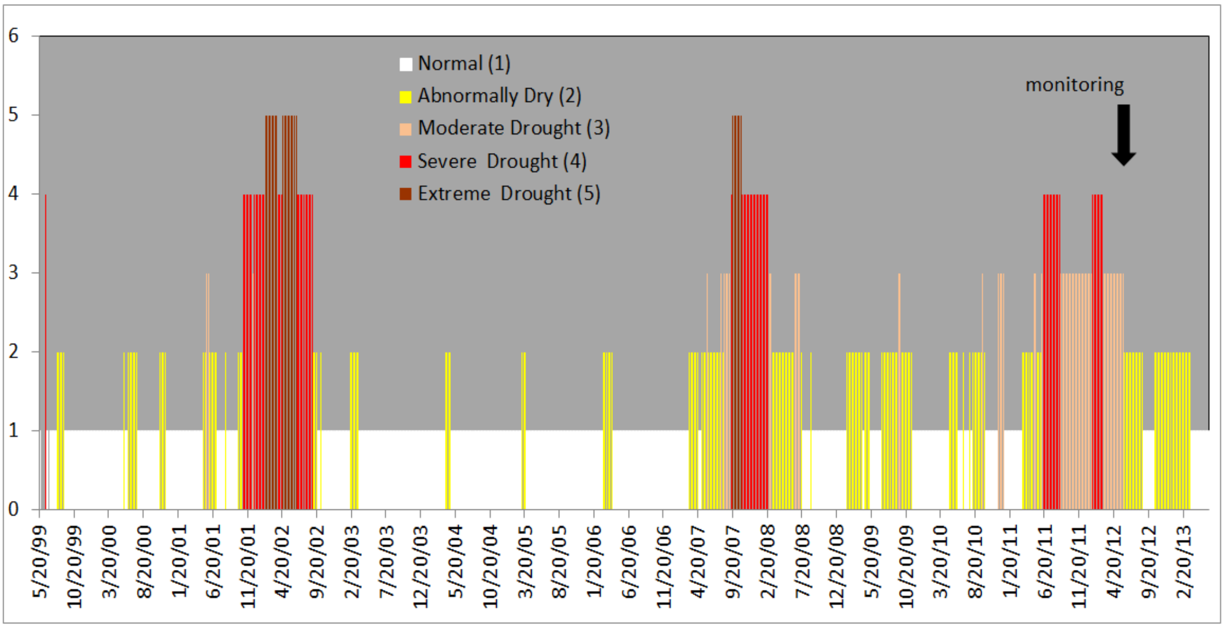

Figure 2. Drought status of north eastern Horry County from 5/20/99 to 6/11/13.

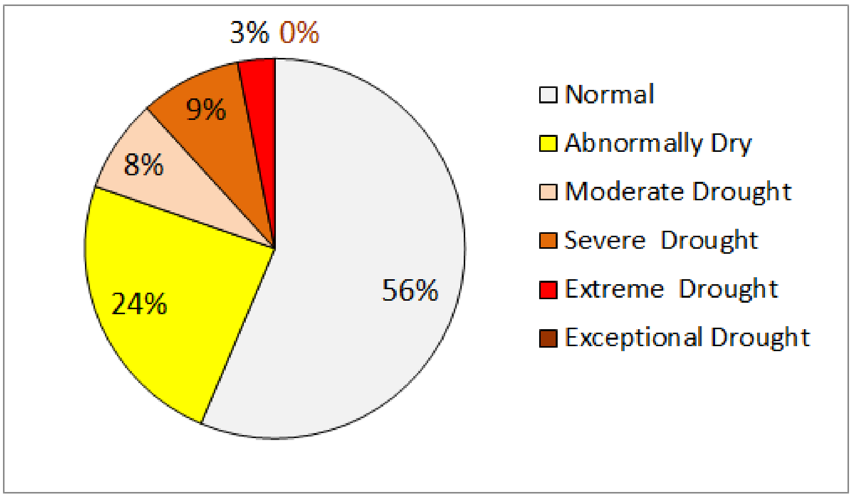

Figure 3. Persistence of drought in north eastern Horry County from 5/20/1999 to /11/2013.

Water levels

Average water levels at the three well sites and two lakes for each month are shown in **Figure 4.** Graphs on the left show water levels relative to mean sea level and on the left as depth below the land surface. In the case of the latter, the lake levels are referenced to a benchmark on the road adjacent to North Lake. The maximum and minimum daily average value for each month is represented by the vertical line running through the monthly average value.

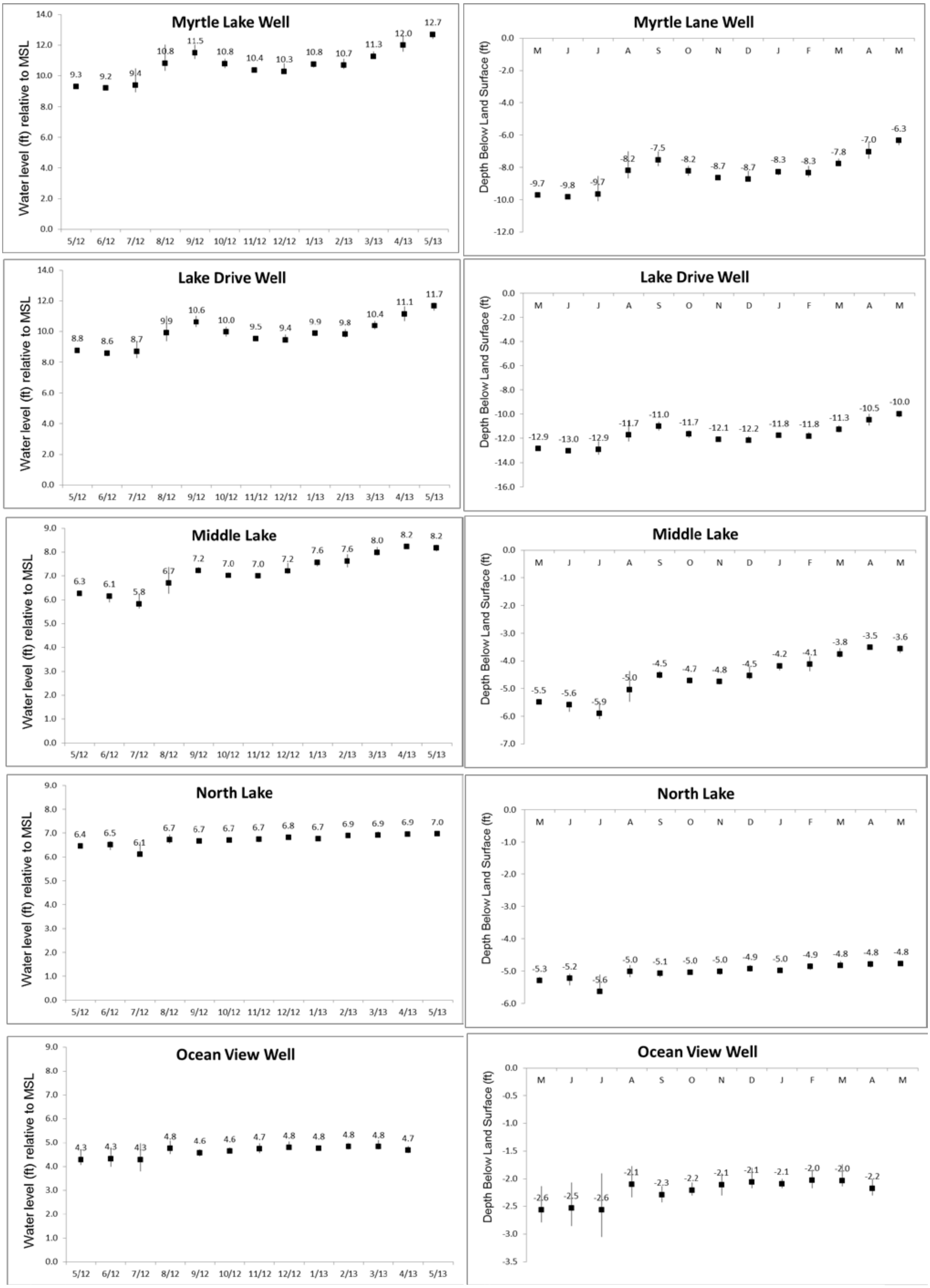

Figure 4. Monthly mean water elevations in feet. Graphs on the left are referenced to mean sea level. Graphs on the right are referenced to the land surface.

Table 1 contains a summary of when the maximum and minimum water levels and conductivities were observed. Water levels reached maximum values in Spring 2013 and remain high. The monthly average in May 2013 was the highest of the period of record for all the lakes and wells except for the Ocean View site, which was within 0.1 ft. of its maximal monthly average. The latter was observed in Aug 2012, Sept 2013 and March 2013. A secondary peak in water levels occurred in Aug 2012 at the other wells and Middle Lake. In contrast, the water level in North Lake has been relatively constant, with an overall increase in the monthly mean value of 0.6 ft. through the period of record.

Table. 1. Summary of water level and conductivity extremes from daily mean values.

Elevation summary for 5/24/12 to 6/1/13						Conductivity (µS/cm)
	Myrtle Ln. Well	Lake Dr. Well	Middle Lake	North Lake	Ocean View Well	
Dates						
Min	7/7/12 to 7/9/12	7/9/2012	7/27/2012	7/27/12 to 7/28/12	7/8/2012	4/25/2013
Max	5/7/13 to 5/11/13	5/6/13 to 5/11/13	4/29/2013	4/29/2013	3/24/2013	5/2/2013
Feet above Mean Sea Level						
Min	12.9	11.9	8.3	7.1	5.1	284
Max	9.0	8.3	5.6	5.8	3.8	578
Range	3.9	3.6	2.7	1.2	1.3	294
Feet below Land Surface						
Min	-6.2	-9.8	-3.4	-4.7	-1.7	
Max	-10.1	-13.3	-6.1	-5.9	-3.1	

Table 1 also contains the range in daily mean elevation observed during the period of record. The upland wells have varied by about 4 ft. and the Ocean View well by 1.3 feet. Middle Lake has varied by 2.7 feet and North Lake by 1.2 feet.

Figure 5 is a boxplot that shows how the daily mean elevations of the water level have varied on a daily basis relative to the elevation of the water surface at Middle Lake. This boxplot shows that the water levels at the upland wells were always above the lake levels. The surface of North Lake has usually, but not always, been below the surface of Middle Lake. The water level in the Ocean View well has always been below that of the lakes as shown in **Figure 6**.

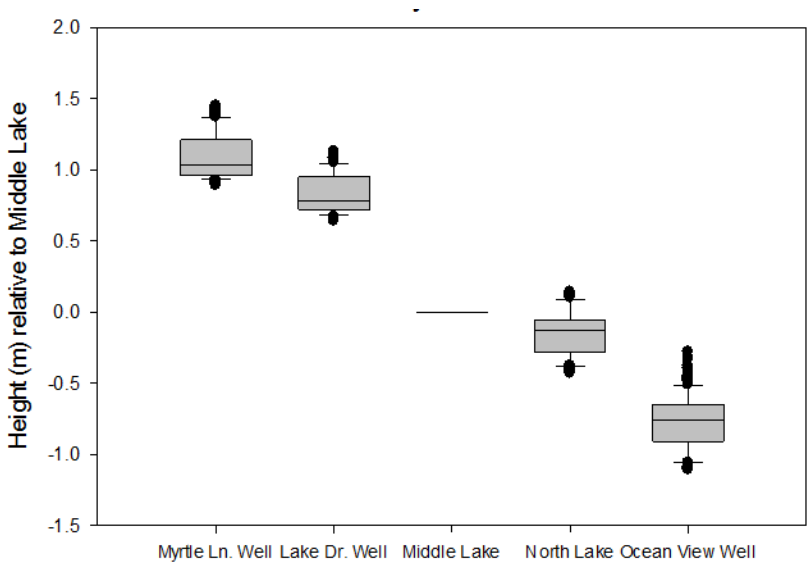

Figure 5. Boxplot of daily mean height (in meters) relative to Middle Lake.

Figure 6 shows the water elevation graph that can be accessed at the project website. This graph depicts the daily mean values for the period of record. To obtain the 15 minutes measurements, users must select the daily or weekly option for displaying the data. The monthly option uses hourly averages. Figure 6 shows that the water levels are highest at Myrtle Lane, decreasing in the following order: Lake Drive well, Middle Lake, North Lake and the Ocean View well.

Note that the y scale at the website resizes when series are deactivated. This can be done by clicking on the series name located at the bottom of the chart. At the daily and weekly scales, the rain data from Apache Pier are also co-plotted.

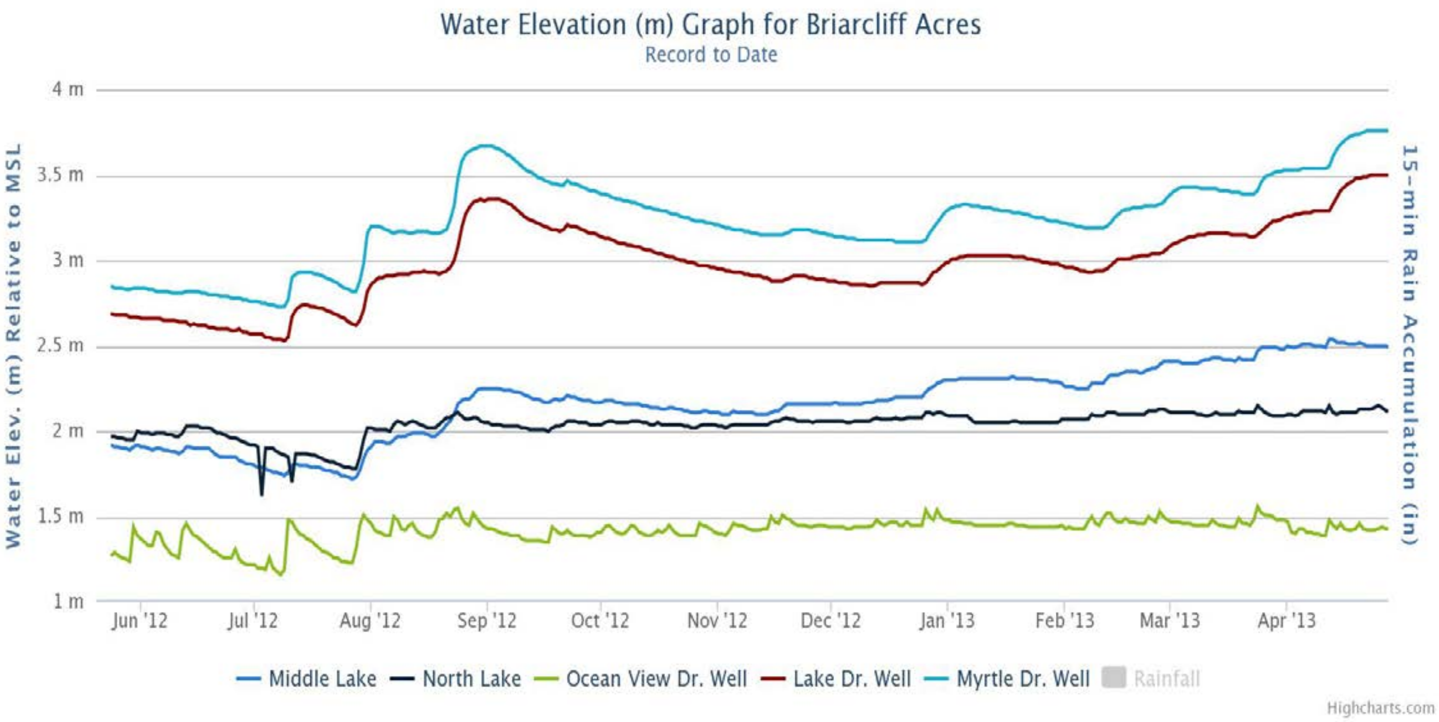

Figure 6. Water levels (in meters) at all sites during the period of record relative to mean sea level.

Figure 7 shows that during periods of relatively low water level, i.e. June 2012, the water level in the Ocean View well exhibits a diurnal oscillation with amplitude of 4" (0.1 m). Minimum levels are observed late in the day around 6 PM. This daily variation is thought to be due evapotranspiration by plants. The water levels at the Ocean View well are much closer to the land surface (within 2 ft.) than the other wells – 6 to 10 feet at Myrtle Lane and 10 to 13 feet at Lake Dr. The shallowest water table is expected to be more influenced by water uptake via plant roots than the deeper ones. This effect should be greatest when water table is lowest, i.e. during drought conditions. The Ocean View well's water level also exhibits a diurnal oscillation, albeit of a lower amplitude, when water levels are higher. This was surprising given this site's close proximity to the ocean. It was expected to have a semidaily oscillation from the tides, but this has not been observed.

Figure 7. Diurnal oscillation in water level at Ocean View well (meters below the land surface). Conductivity in North Lake is shown in the top panel as a proxy for rain.

Figure 7 also shows the conductivity in North Lake. The abrupt decline on June 12 is due to rainfall. This causes a concurrent abrupt increase in the water level at the Ocean View well. The shallowest hourly average value during this period was 1.5 ft. (0.45 m) below the land surface.

Conductivity in North Lake

Specific conductivity is measured every 15 minutes in the bottom waters of North Lake. **Figure 8** shows the time trend for the period of record. Average daily conductivities ranged from 284 to 578 µS/cm. In other words, total dissolved solid concentrations have ranged by a factor of 2. As illustrated in **Figure 7** and below in **Figure 9,** rainfall results in rapid declines in specific conductivity due to dilution of dissolved solids.

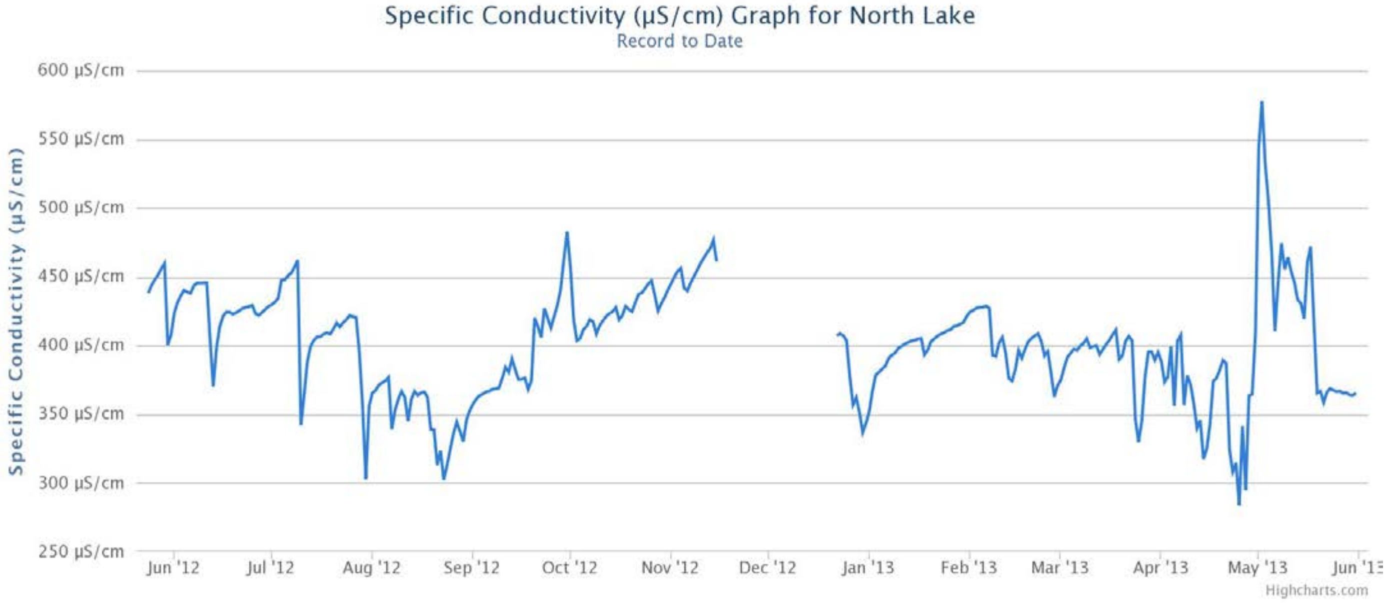

Figure 8. Conductivity in North Lake for the period of record. The data gap from 11/15/12 to 12/23/12 was due to a sensor malfunction.

A notable abrupt increase in conductivity occurred from Apr 29 to May 2, 2013. On April 29th, specific conductivity had declined to 340 µS/cm following a 1.77" rainfall earlier that day. This was followed by a period of increasing conductivity with a maximum level of 593 µS/cm observed on May 2. Levels then declined back to 400 µS/cm by May 6, 2013. This suggests that some ionic material that contributed to the overall conductivity of the water was flushed into North Lake with the rain on Apr 29th.

Another notable feature of the conductivity record are periods containing diurnal oscillations that peak in the morning. The amplitude of these oscillations are on the order of 5 µS/cm. A possible cause is uptake of bicarbonate ion associated with photosynthesis by phytoplankton and emergent aquatic vegetation.

DISCUSSION & CONCLUSIONS

Conductivity & Water Levels

The water levels in the lakes and upland wells are currently near the highest levels for the period of record, reflecting a sustained period of normal to above normal rainfall. The lowest water levels were observed in June 2012.

At the start of the monitoring, the surface water at North Lake was higher than in Middle Lake. This reversed on August 23, 2012 such that during the remaining period of record Middle Lake's water level has been higher than in North Lake. The level of North Lake has been relatively constant compared to the long-term rise in Middle Lake, suggesting control via an overflow structure. The effect of pumping conducted on May 2, 2012 is discussed in a later section.

The water tables in the upland wells (Myrtle Lane and Lake Drive) always lie above the surface levels of the lakes suggesting the groundwater supplies water to the lakes. The water surface of both lakes lie above the Ocean view water table, suggesting water can drain from lakes downslope towards to this well and into the swash and ocean.

Rain influences conductivity in North Lake as shown in **Figure 9** which illustrates the dilution that resulted following rain events on Aug 19, 21, 23 and 24 in 2012. The decline due to dilution of the dissolved solids is relatively rapid during low water levels. These are accompanied by rapid rises in the lake levels and in the Ocean View water table. Rises in the upland wells occur more slowly, but within 24 hours following rainfall. This is still a relatively short response time and reflects rapid infiltration through sandy soils.

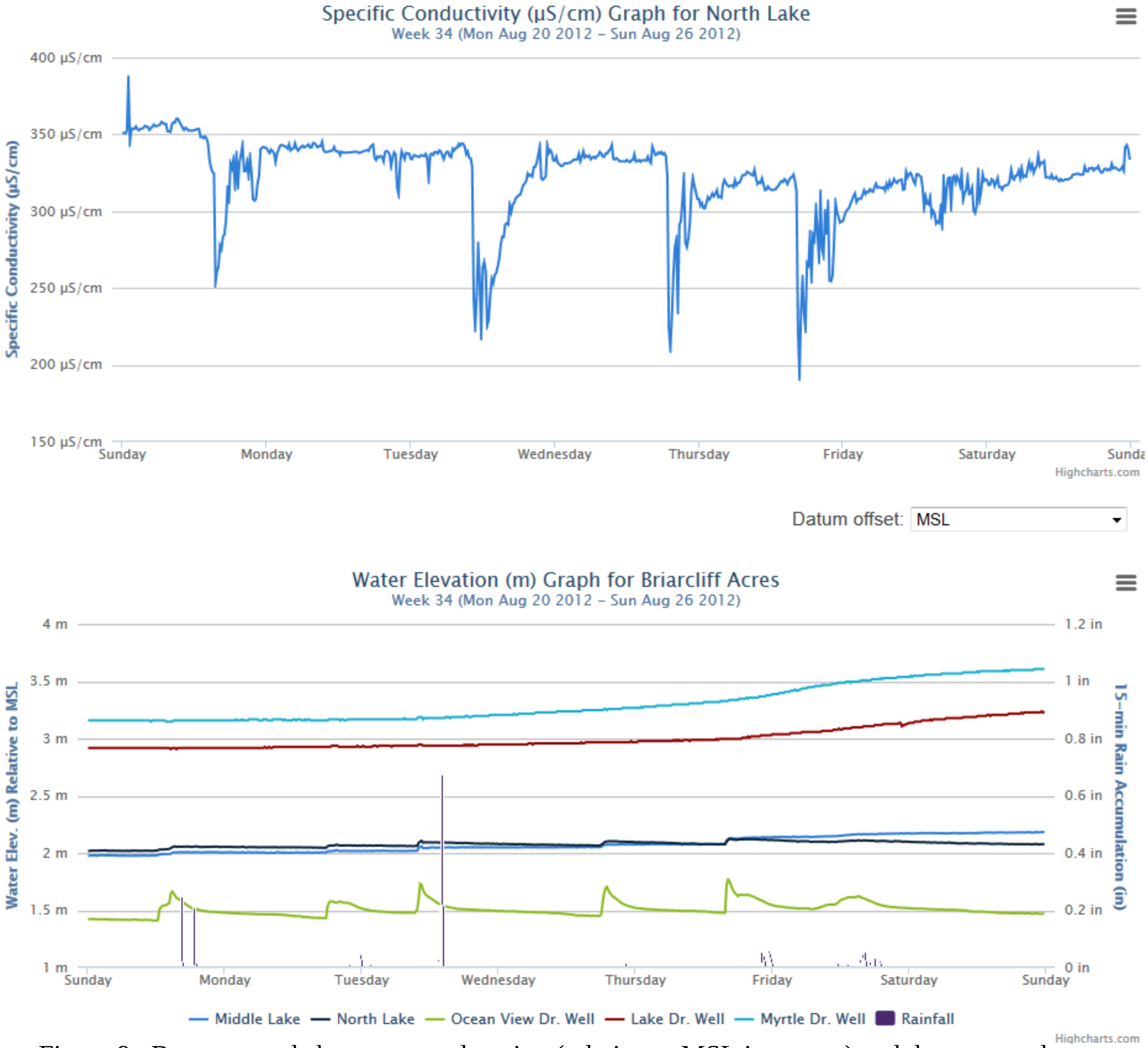

Figure 9. Bottom panel shows water elevation (relative to MSL in meters) and the top panel, conductivity, illustrating the effects of a series of rain events. More detail on rain timing and lake levels is provided in **Figures 10 and 11.** The times of the rainfall are referenced to UTC and thus are offset from the water level data by 4 hours. This will be corrected in future revisions of the project website.

A slower rate of rise in the conductivity is seen when water levels are higher as shown in **Figures 10 and 11**. This suggests that when lake levels are low, more runoff is reaching the lake quicker and is observable as more dilution in conductivity. The relatively rapid return of conductivity to pre-dilution levels could be due to mixing with incoming groundwater, which is expected to have higher conductivities that the rain water.

Figure 10. Left hand graphs show impact of rain fall when water elevations are relatively low. Right-hand graphs show impact of rain fall when water elevations are higher.

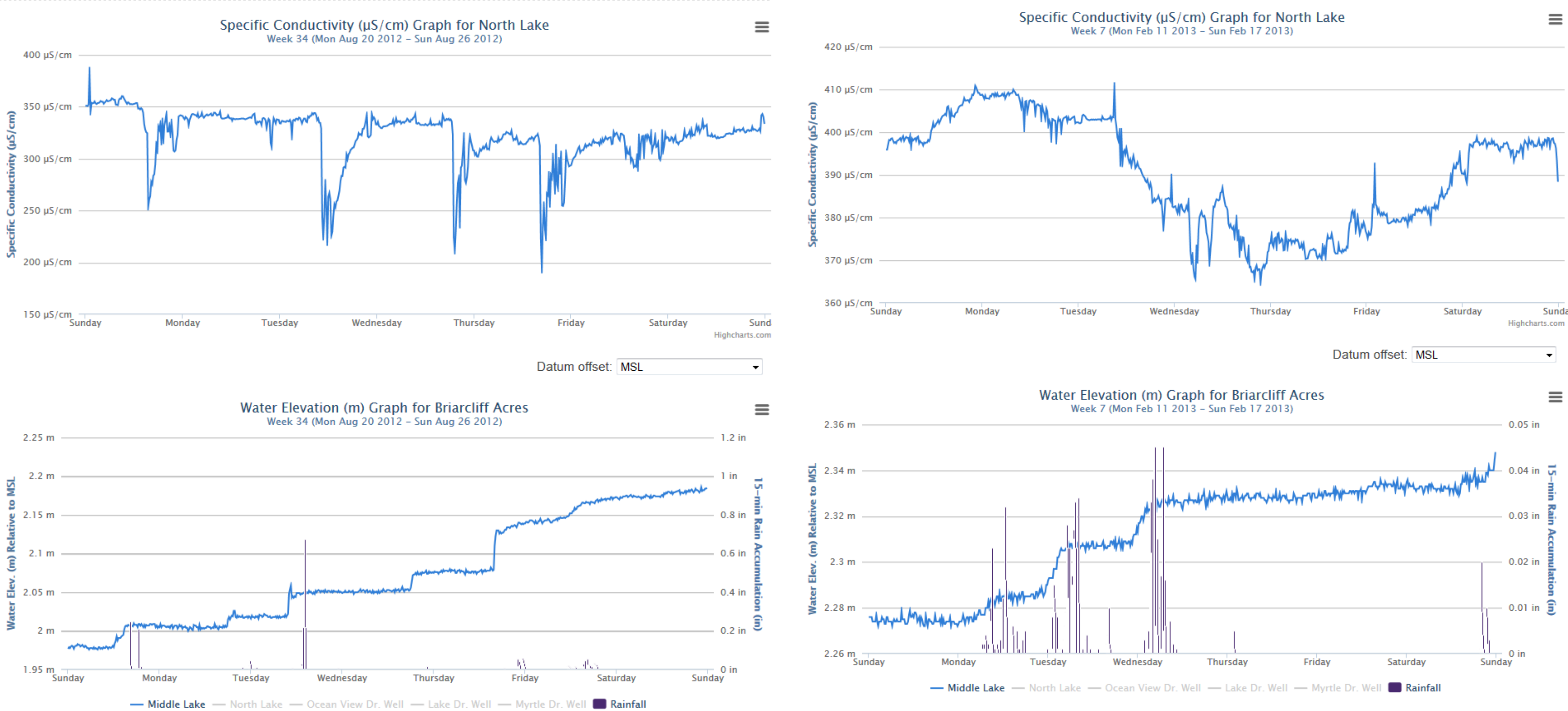

Figure 11. Same as previous figure, showing only North Lake

When water levels are high, the slower rates of decline in conductivity following rainfall are matched by slower rates of water elevation rise. This suggests a slower delivery of rain water, i.e. some upstream retention and/or the buffering effect of larger volumes of water.

The limited range of conductivities observed provide no evidence for saline intrusions which is not surprising given the normal to above normal rainfall that had fallen through the period of record.

Water levels at North Lake

Water levels in North Lake were very high in August 2012 due to abundant rainfall in the preceding two months (**Figure 12**). To reduce overflow, water was pumped from North Lake to Middle Lake on May 2, 2012. The effect of this on the levels of the lakes is shown in **Figure 13**.

Figure 12. Rain accumulation since 5/24/13

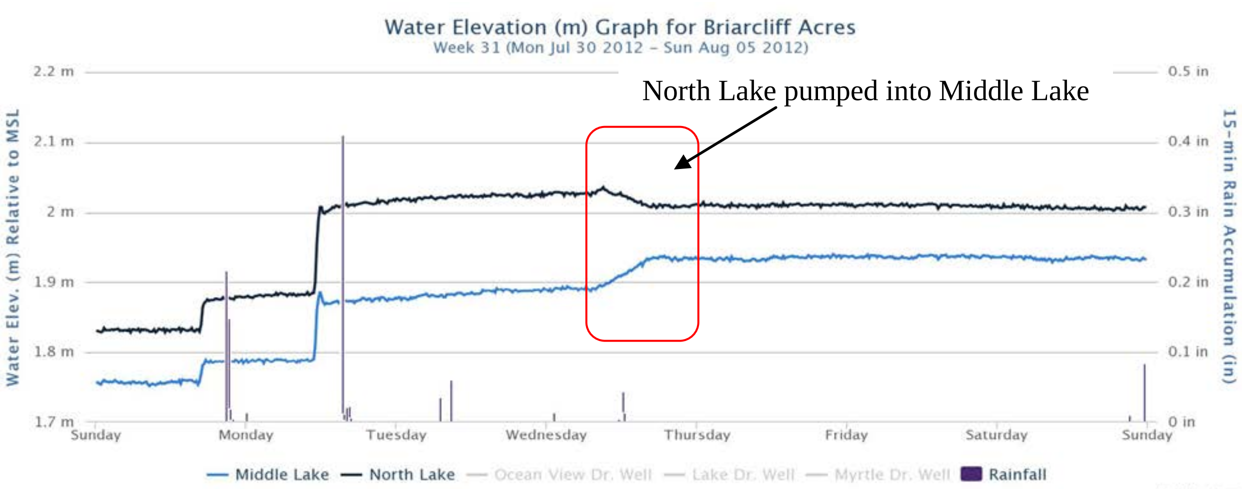

Figure 13. Water levels in Middle and North Lakes when North Lake water was pumped into Middle Lake.

Water levels at Ocean View

The water table in the Ocean View well appears to be influenced by evapotranspiration on a daily basis, especially when water levels are relatively low. A similar effect, of much smaller amplitude, was observed in the Myrtle Lane well.

As shown in Table 1, the daily mean depth of the water table at Ocean View ranges from 1.7 to 3.1 feet below the land surface. The shallowest 15-minutes observation has been around 0.35 m (14”) below the land surface. SC law requires a minimum distance from the seasonal high water table of 0.5 ft. (6”). If septic tank field lines are located around 18” to 30” below ground, the water table should not rise any higher than 2 to 3 feet (24” to 36”) below ground.

FUTURE PLANS

Future plans are as follows:

1 - Continue data collection with current deployment design.

2 – Continue to develop the project website.

3 – Continue to enhance data analysis. This will include inspecting the rates of rise and fall in water levels to better resolve interactions between the upland water table and lake levels. We are also looking into measuring the conductivity of water in Middle Lake and the groundwater to see if conductivity can be used as a tracer to determine the percent contribution of the groundwater to the water in the lakes.

4 – The original project plan suggested using an experiment to better quantify the degree to which irrigation is affecting water levels in the lakes. This involved having homeowners stop, or decrease, irrigating with groundwater or lake water for a period of time. The monitoring data would then show how the water levels in the groundwater and lakes respond. Re-initiation of irrigation should further demonstrate how the groundwater and lake levels are linked. This information would help inform the development of an irrigation management plan for Briarcliffe Acres.

NOAA is providing soil moisture forecasts for the summer of 2013 at http://www.cpc.ncep.noaa.gov/soilmst/img/cas_w_mon.lead1.gif . Copies of these forecasts are shown in **Figure 14**. Levels are predicted to be above normal to normal through the end of their forecast period (Sept 2013). According to http://droughtmonitor.unl.edu/forecast.html, below normal rainfall is forecast starting in Nov 2013, persisting through next winter. This suggests that the Summer of 2013 will not be optimal for conducting the proposed experiment.

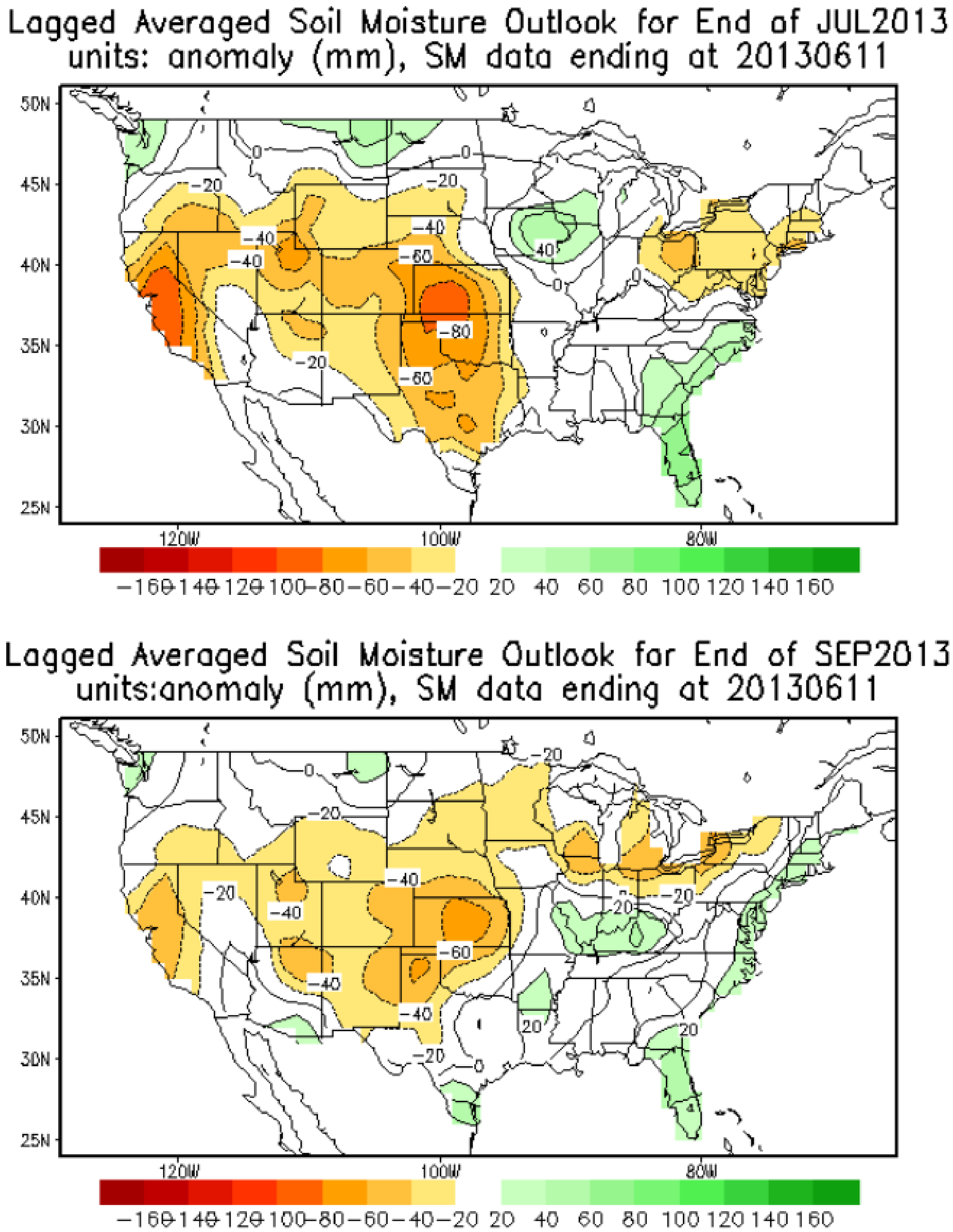

Figure 14. Soil moisture predictions through Sept 2013.