

Groundwater Level Monitoring In Shallow Wells in the Herring River Basin Cape Cod National Seashore

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Purpose

Eight shallow groundwater monitoring wells are located at various wetland areas in the Herring River basin. In general, these “wetland wells” were intended to facilitate monitoring of groundwater levels before, during, and after restoration of tidal flow to the Herring River basin, testing the hypothesis that mean groundwater elevations will increase. The groundwater level data might also be used in some currently undefined manner to assess hydrologic or other changes that might occur with restoration of tidal flow to the basin.

Locations of the monitoring wells are shown on the map in Figure 1. The wells were installed in Spring 2005. The wells are 1½” PVC and have 1-2 feet of 0.010” slotted well screen. Well construction characteristics are provided in Table 1.

Table 1. Summary of monitoring well characteristics.

Site ID	Casing Stick up from Ground Surface (ft)	Total Depth (ft)	Depth below ground surface (ft)	UTM Zone 19	
				Northing	Easting
Black Pond	1.02	5.0	3.98	4646020	414855
Bound Brook	1.09	3.3	2.21	4645240	412684
High Toss	1	5.05	4.05	4644080	412408
Merrick Island	1.07	5.0	3.93	4644801	412513
Mill Creek	1.29	5.02	3.73	4642946	412423
Nieski	0.52	5.15	4.63	4643069	412650
Pole Dike	1.5	5.0	3.5	4644530	413451
Ryder	1.6	4.5	2.9	4646253	411697

The soil type, elevation, and degree of saturation vary greatly among the sites. Although all the wells were installed at sites that were originally (pre-1909) occupied by tidal salt marsh, they are very different today. Those at higher elevations (e.g., above High Toss Rd) are in highly decomposed, effectively drained, usually dry, and often highly permeable acid-sulfate soils. Others (e.g. Bound Brook marsh) are in low-lying, and thus still saturated, highly organic peat.

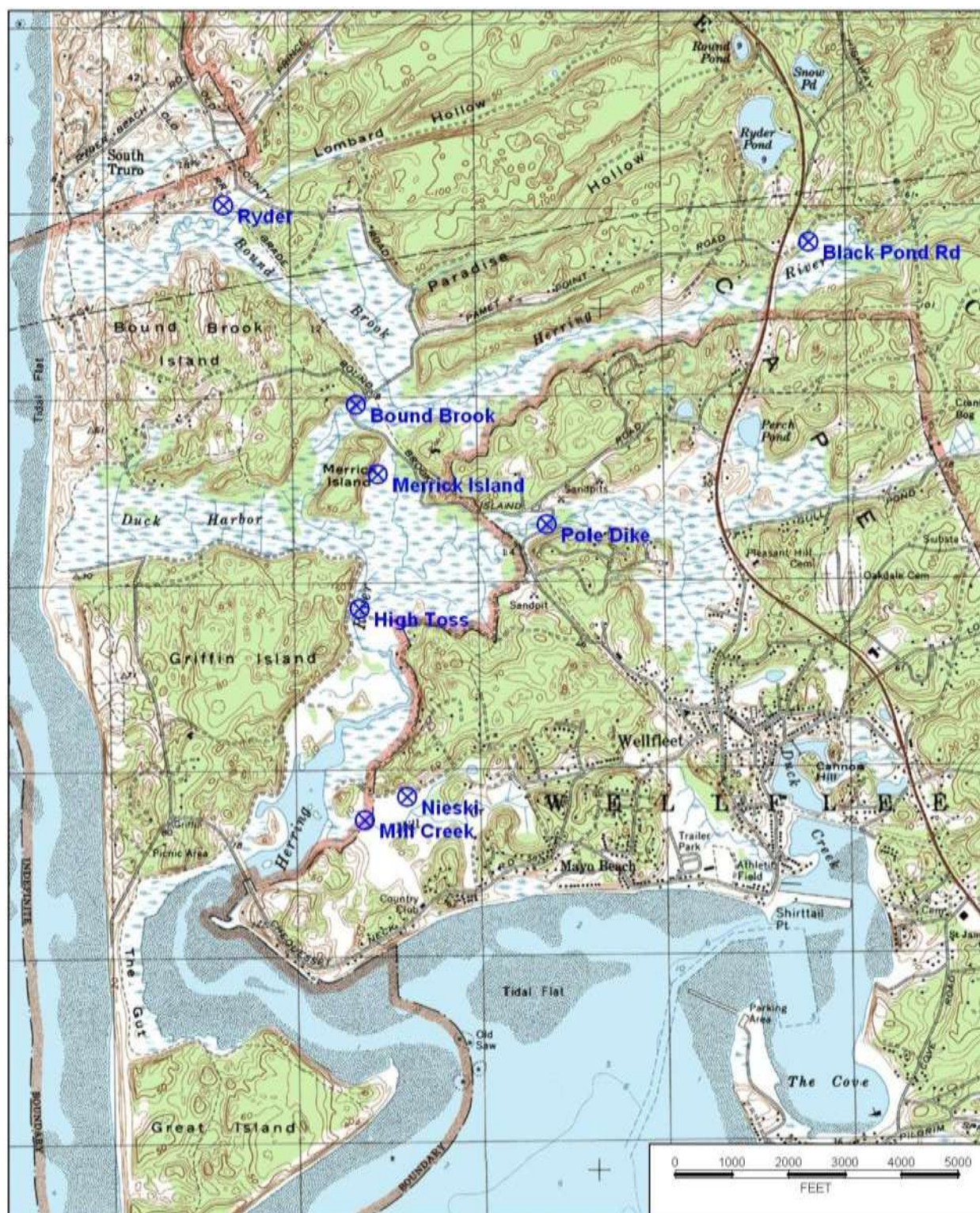


Figure 1. Locations of Herring River “wetland” monitoring wells.

PVC well screens are driven into the wetland peat deep enough to reach the water table throughout the year, but not deep enough to penetrate underlying non-wetland sediments; i.e. the objective is to monitor water level in the vegetated wetland proper, and not in the underlying sandy aquifer where the hydraulic head may be significantly different.

In the past, water levels were measured weekly or monthly. Volunteers made the measurements during the first year. Kelly (Chapman) Medeiros began making monthly measurements sometime in May 2006. In the Fall 2010, HOBO water level dataloggers were installed in these wells to provide a period of continuous water level monitoring. Objectives of monitoring with dataloggers are;

1. Look for correlation between water levels and tidal fluctuation.
2. Document water level changes in response to rainfall-recharge events.
3. Document the magnitude of water level change at each site.

Monthly measurements are inadequate because of the large variability of water levels at these wells. Depending on when the measurements are made relative to significant precipitation events, water levels can vary by a foot or more.

Field measurements

Water levels in the monitoring wells are measured periodically with an electronic water level meter (Heron Dipper-T). Water level measurements are repeated to assure that the measurement is correct and has been recorded correctly.

In 2010-11, measurements were made mostly just when data were downloaded from the HOBO dataloggers. In 2012, we plan to make at least one water level measurement near the middle of each monitoring period. That will provide a reference water level measurement that is not affected by removal or deployment of the datalogger at the well.

The PVC well casing is set in peat and could shift vertically over time. To check for this, steel rebar has been driven through the peat layer and firmly into basal sand beside each PVC casing, at all wells except Nieski. The distance from top of PVC to top of rebar is checked at each monthly sampling to determine whether the PVC has shifted vertically.

Some of the wells are located in standing water. At these locations, we also measure and record the distance from the top of the well to the water surface on the outside of the well.

Datalogger standard operating procedures

The HOBO dataloggers are about 1 inch diameter and 6 inches long. The memory capacity is about 21,700 samples, recording both pressure and temperature. Dataloggers for this project are programmed to record at 10 minute intervals (144 measurements/day). Available storage capacity is about 150 days.



Water level measurements are made at the start and end of each monitoring period. Starting in 2012, additional measurements will be made to provide data for calibration and verification of the pressure measurements recorded by the HOBO datalogger. There is no defined length for the monitoring periods. Data are downloaded when convenient. Generally monitoring periods are between 2-5 months in length. After 5 months, the datalogger memory will be filled and the instrument will stop recording new data.

Dataloggers are deployed in the monitoring wells by attaching them to a length of wire or rope to suspend them approximately 2-3 feet below water level to assure that they will remain submerged during the dry season. The same rope/wire attachment is used each time to assure that the datalogger is always suspended at the same distance from the top of the well.

The datalogger must be removed from the well to download data. Data is downloaded using a HOBO waterproof shuttle, or by using a HOBO base station connected directly to a laptop computer. The file naming convention is to use the name of the site and the starting and ending date of the monitoring period, e.g., "BoundBrook_102210_122210". The datalogger will continue logging, but will have a new start time/date stamp for the next data retrieval.

Testing aquifer connectivity

When we looked at the initial set of data from the dataloggers (Oct-Dec 2010), it appeared that water levels in a couple of the wells did not respond in the expected manner. Subsequently all of the wells were tested to determine whether the water level in the wells was in good connection with the aquifer and responding to fluctuations of the water level in the aquifer.

The water level in each well was measured. Approximately a liter of water was poured in the well to fill it to the top of the pipe. The water level was measured about 5 minutes later. If the water in the wells quickly returned to the original water level, it was assumed that the screened area was open and water was able to freely flow in or out of the well.

The well screen in monitoring wells at Merrick Island and Pole Dike Creek was apparently plugged because the water level did not return to its original level. The PVC pipe remained full with little to no discernable water level change. These wells were determined to be non-functioning and regular monitoring has been discontinued. The other 6 wells function properly.

Barometric pressure correction

The dataloggers measure total pressure. As the water level rises, the depth of submergence increases and the pressure increases. The measured total pressure is the sum of the pressure from the water pressure and atmospheric pressure. We must subtract the barometric pressure to get the pressure due to the weight of the overlying water. The HOBOWare software does this with an internal program after reading the date, time, and pressure for both a water level logger and a barometric pressure logger.

Barometric pressure was monitored with a HOBO datalogger on the shelf at the NPS North Atlantic Coastal Laboratory. Barometric pressure is recorded at 10-minute intervals, the same as water level data. The barometric pressure data for each monitoring period are appended to a TXT

file to create a master file of barometric pressure. The master file can then be used as a continuous record, allowing barometric compensation for each data file from each well regardless of the start and stop times for data files. (Otherwise we could only do barometric compensation for the common time period of both the barometric pressure and water level data files. This created problems if the reference water level measurement occurred outside the overlap of the two data files.)

Reference level

Pressure measurements are converted to depth to water by anchoring the pressure reading to a water level measurement for some particular date and time. For example, we might measure the water level at 1.0 foot below ground surface at a time when the pressure transducer reads 1.0 psi. All subsequent pressure readings are converted to depth to water based on this anchor point or reference level. If the pressure increases, the water level is rising. If the pressure decreases, the water level is dropping. The reference level measurement can occur anytime within the period that the datalogger is recording pressure measurements.

Reference water levels are entered from the “*barometric compensation assistant*” software included in the HOBOWare package as described in the user’s manual;

To enter a reference water level, check the Use a Reference Water Level box, enter the water level, and indicate whether it is in feet or meters.

- Enter the water level as a *positive number* if it is measured upward from a reference point below the water's surface, such as the water's height above sea level.
- Enter the water level as a *negative number* if it is measured downward from a reference point above the water's surface, such as a well cap.

Then, from the drop-down, select the logged time and value that is closest to the time when you measured the water level.

- When selecting a logged value and time to link to the reference level, make sure the logger readings have stabilized. When a logger is first deployed in water, it takes some time for its temperature to reach equilibrium. You will get the best accuracy if you link your reference reading to a stabilized logger reading.
- When using a reference water level, the resulting series data will contain water level values relative to this reference level. If you do not use a reference water level, the resulting series data will contain values for absolute sensor depth.

These steps are illustrated in the screen shot of the barometric compensation assistant software shown on Figure 2.

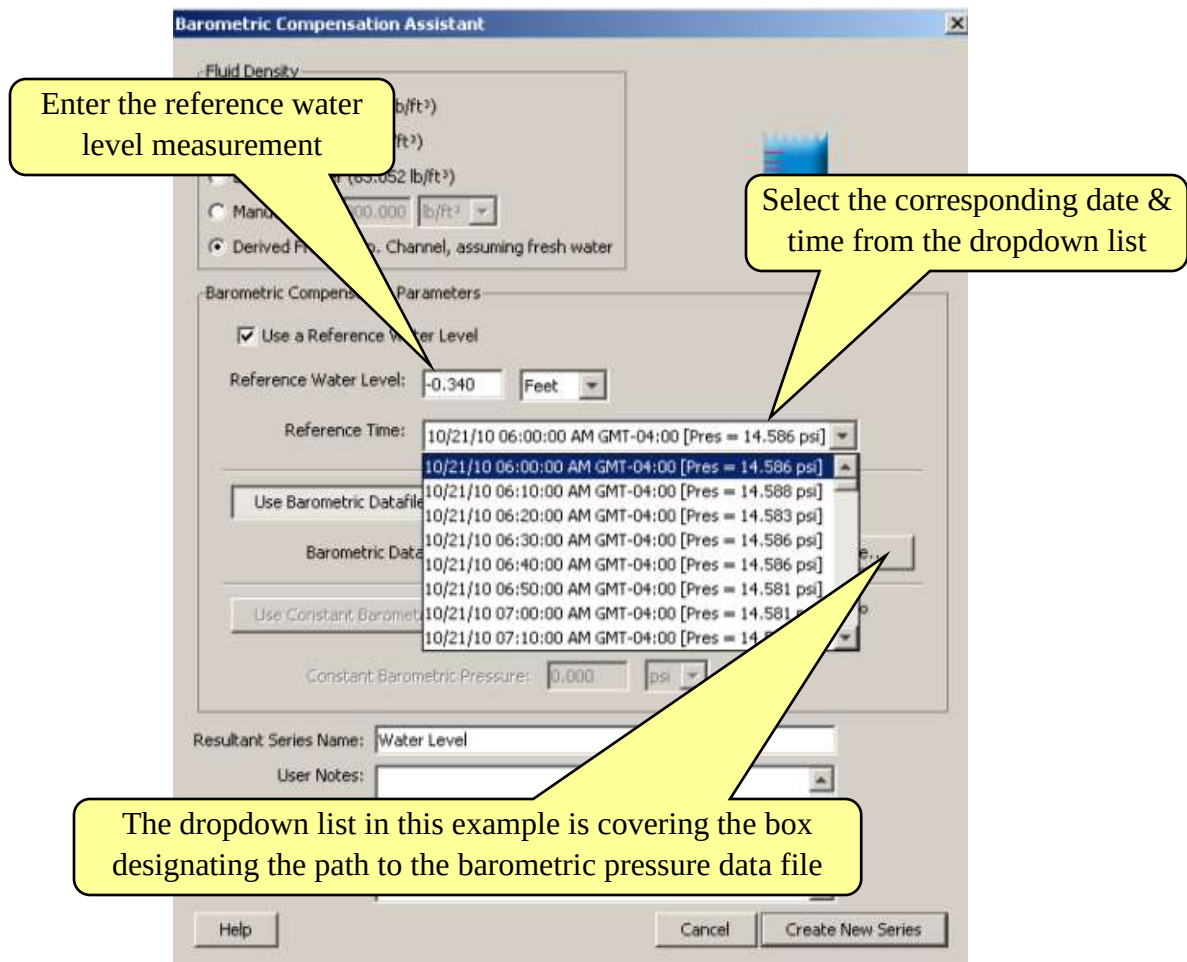


Figure 2. Screen shot of the barometric compensation assistant and reference level data entry.

During the monitoring in 2011, we learned that it is better to have a reference water level measurement from sometime in the middle of the monitoring period. There is a period of equilibration needed after a datalogger is removed for downloading and then redeployed.

Drift correction

All pressure sensors drift over time. Drift is a gradual change of the signal response to an identical stress over time. For example, assume that the water level remains constant at 1.0 feet, and that the datalogger records the water once a day for 10 days, and that the recorded water level after 10 days is 1.1 feet. The drift is 0.1 feet. We compensate for the drift by prorating the differential between the recorded water level and the measured water over the monitoring period. In this case, we would adjust the water level by 0.01 feet per day to have a total correction of 0.1 feet after 10 days.

If the reference level is at the beginning of the time series, then the maximum drift correction occurs at the end of the data file. The time ratio should start at 0 and increase to 1. The time ratio is calculated as:

$$ratio = \frac{current\ time - start\ time}{end\ time - start\ time}$$

where *current time* is the only variable. Start time and end time are constant values.

If the reference level is at the end of the time series, then the maximum drift correction occurs at the beginning of the data file. The time ratio should start at 1 and decrease to 0. The time ratio is calculated as:

$$ratio = \frac{end\ time - current\ time}{end\ time - start\ time}$$

where *current time* is the only variable. Start time and end time are constant values.

In both cases, the drift correction is the time ratio (a number between 0 and 1) times the total observed drift (the difference between the measured and recorded water level).

An example of drift correction is provided in Figures 3 and 4.

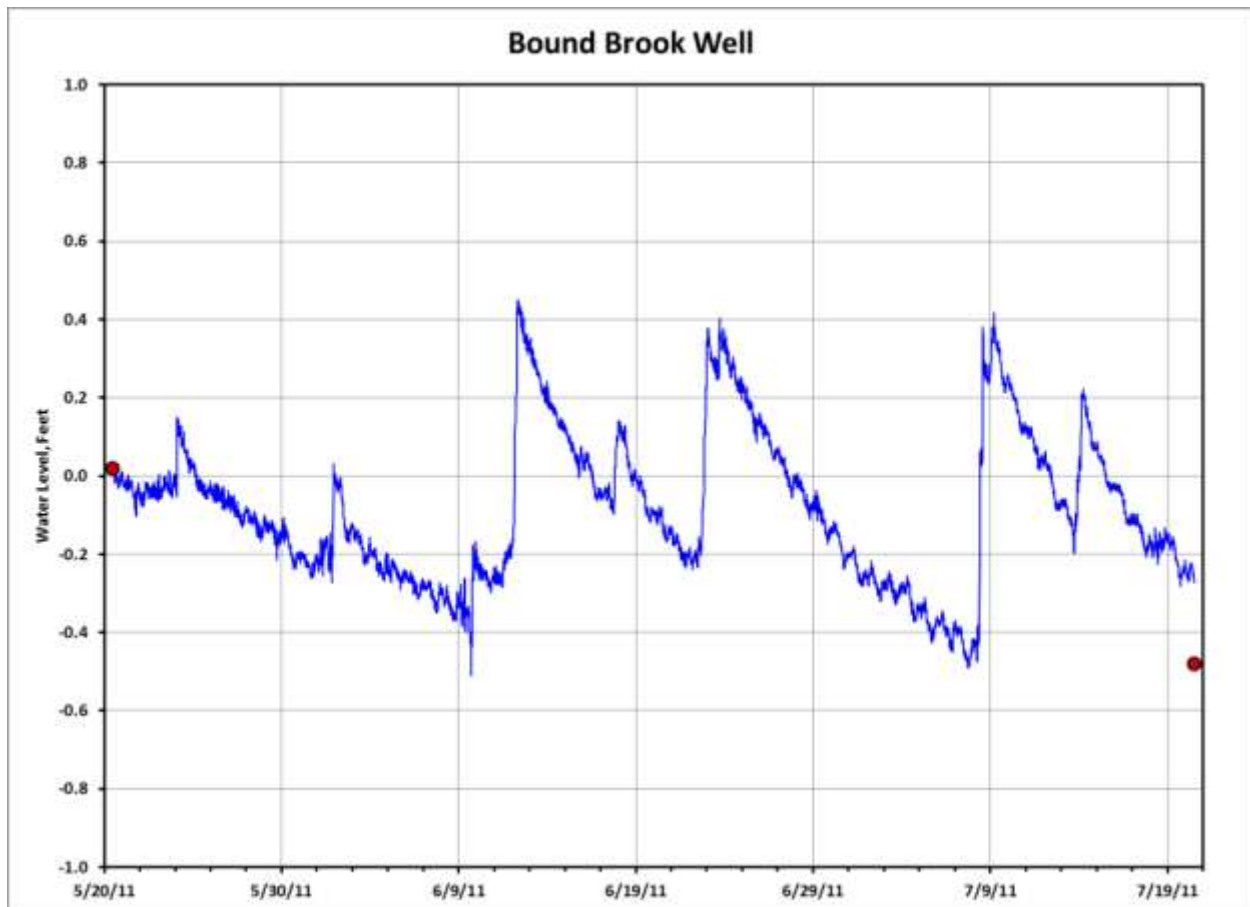


Figure 3. Graph of water level at the Bound Brook monitoring well after correcting for barometric pressure changes. The beginning water level measurement on May 20 was used as the reference level for this dataset and anchors the data at the start of the file to that measurement.

The calculated water level measurement is off by nearly 0.2 feet by the end of the dataset. This is an extreme case and likely represents both measurement error and instrument drift.

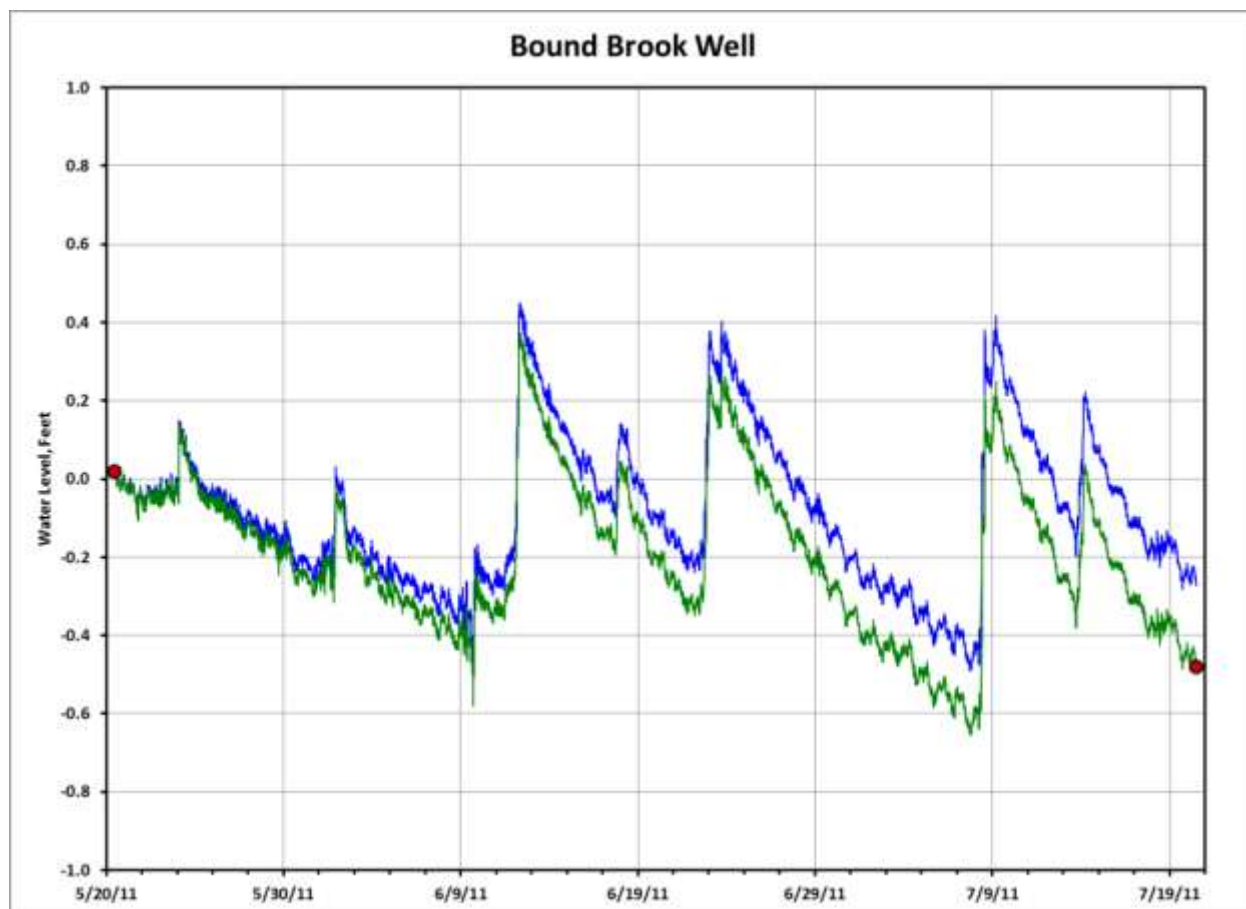


Figure 4. Graph of the dataset after correcting for drift. The initial reference level measurement acts as a hinge or pivot point. The measurement error and drift are prorated over the monitoring period, forcing the final recorded data to match the water level measurement on July 20.

Data compilation and archiving

After processing data corrections for barometric compensation and anchoring the data to a reference level, the data are exported to an Excel worksheet. Additional corrections are applied to the Excel worksheet for sensor drift. Each worksheet includes all of the processed data from one download of the datalogger. The resulting worksheet might include data for 1-5 months. The dataloggers have a capacity of 21,700 pressure and temperature samples. At the current sampling rate of 10 minute intervals (144 samples/day) the dataloggers have a capacity of 150 days.

Additional worksheets are added to the “master” Excel file for each well for each sampling period. Currently, we have 6 worksheets in the Excel file for each monitoring well.

Copies of Excel files for each well are maintained on PCS by Larry Martin at NPS Water Resources Division and Kelly Medeiros at Cape Cod National Seashore. And additional copy is

maintained on the – Drive at the Cape Cod National Seashore LAN. In the future, data will be uploaded to the NPS Aquarius database when it becomes available servicewide.

Changes for 2012

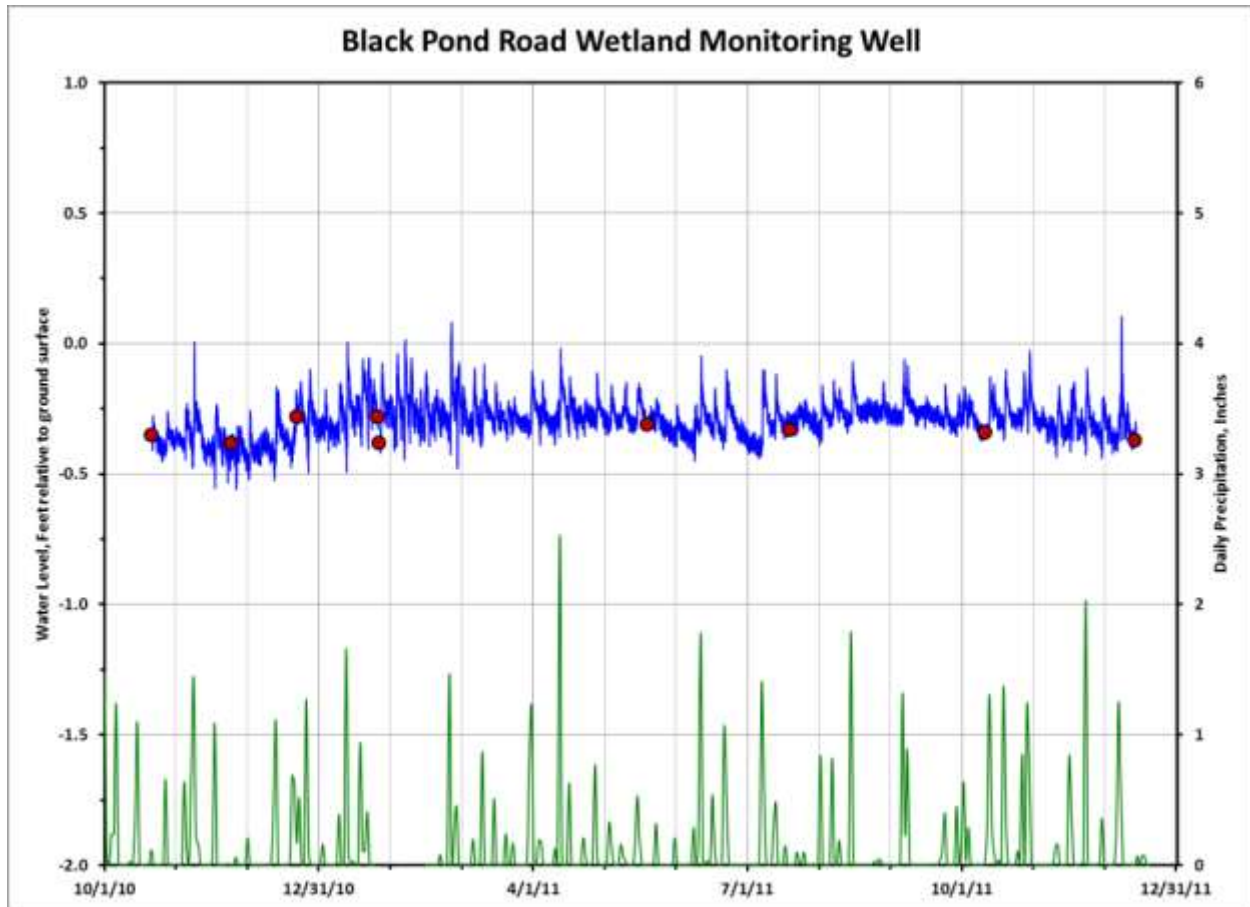
Only a few minor changes are planned for the monitoring program in 2012.

1. Redeploy the HOBO at Nieski deeper in the well. It appears the water level drops below the pressure transducer in the summer.
2. Measure the water level in each well at least once in the middle of each monitoring period. We want a reference water level somewhere in the middle of the data set.
3. Be gentle when measuring the water level at the beginning and end of each period. Make the measurement at the end of the monitoring period while the datalogger is still in the well. At the start of the monitoring period, install the pressure transducer, wait 10-15 minutes, and then make the water level measurement. (Or maybe redeploy all of the dataloggers and then go back and make the water level measurements.) The idea is to allow plenty of time for the water level to equilibrate before making the water level measurement.
4. We need to check the data and measurements at the Bound Brook well. The site is always dry at ground surface, but the data show that the water level in the well is above ground surface much of the year.

Data plots

Data plots for each of the monitoring wells are shown on the following pages. All of the data plots use the same range for the x and y axis to facilitate comparison of the data from different wells. Zero on the y-axis coincides with ground surface. Water levels greater than zero indicate the depth of surface water above ground surface. Negative numbers are the depth to water below ground surface.

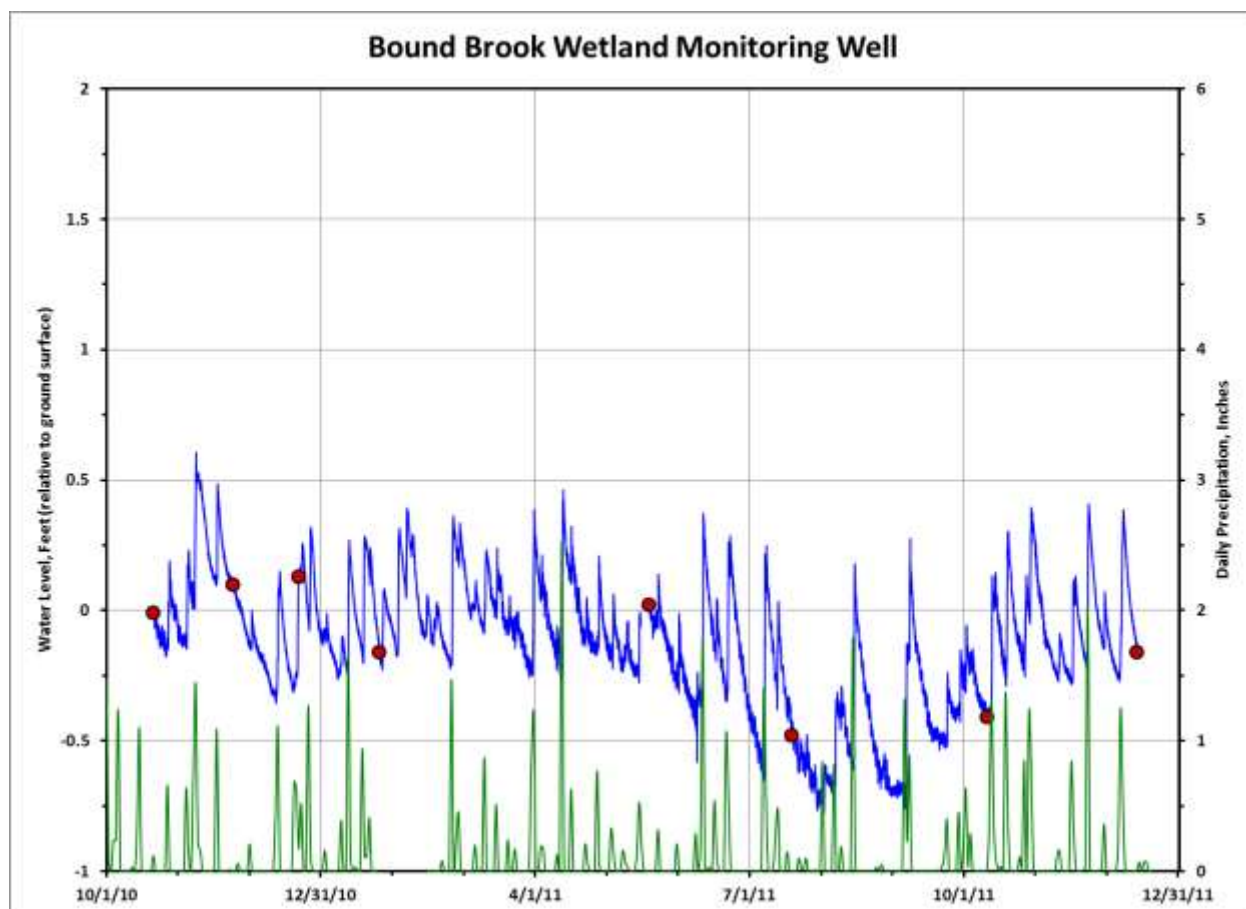
On each chart, red dots are water level measurements, the green line is daily precipitation, and the blue line is the water level in the well recorded at 10-minute intervals after correcting for barometric pressure and sensor drift.



Water levels in the Black Pond Road monitoring well are almost always below ground surface. Water levels fluctuate with a small range, generally between 0-½ feet below ground surface.

The site is very wet and spongy. It is only 10 feet from a ditch that in the wet season and most of the dry season is always filled with standing water. The well is at the base of the slope, at the edge of the wetland area, in the upper reaches of the Herring River basin, east of Hwy 6.

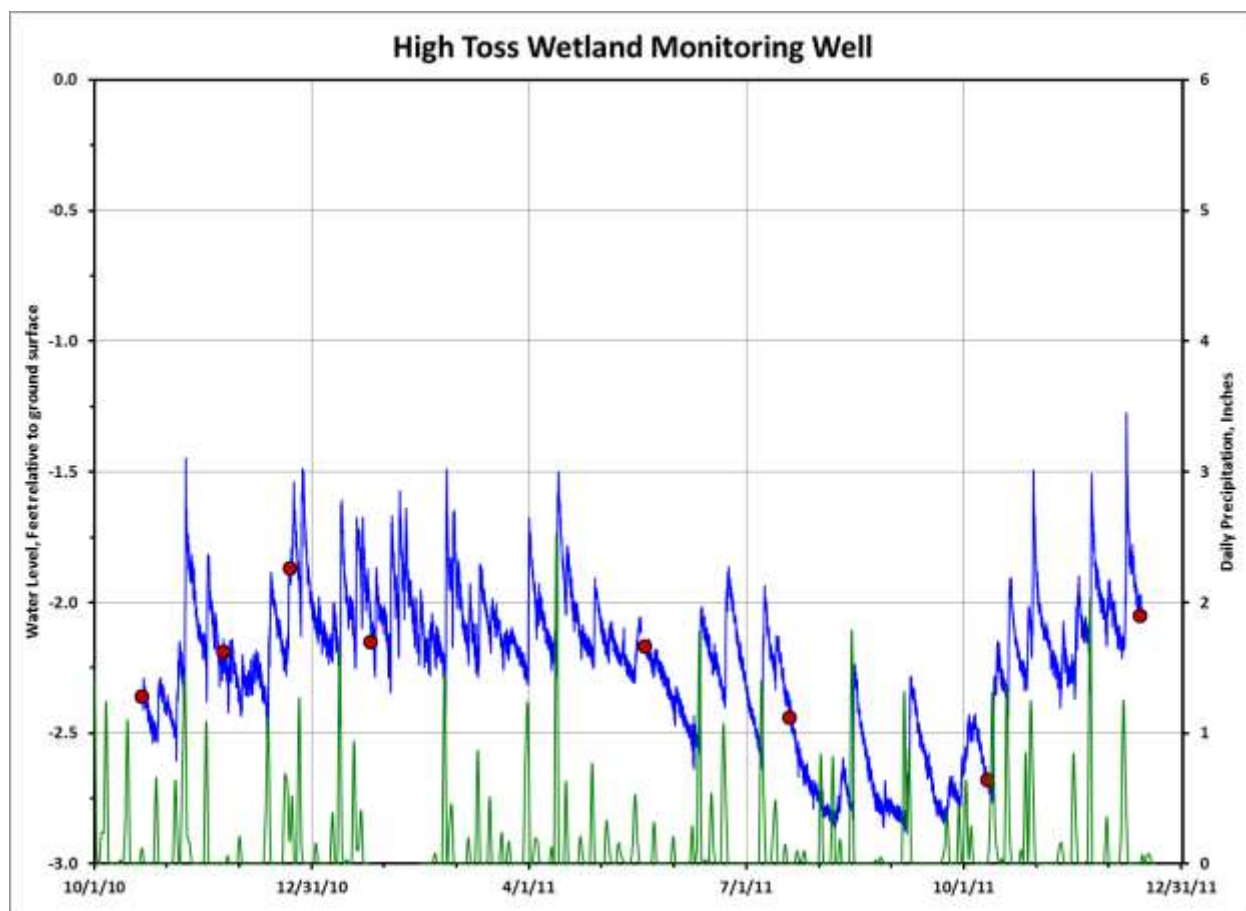




The Bound Brook site is dry most of the time. There is never standing water at ground surface, which is curious because the water level in the well is above ground much of the time. The water level shows an immediate and dramatic response to rainfall-recharge events. Water level generally ranges from about 0.5 foot above ground surface to 0.5 foot below ground surface, but dropping to about 0.75 feet below ground surface during dry periods.

The site is at the edge of an upland area, on the east side of a fire road.

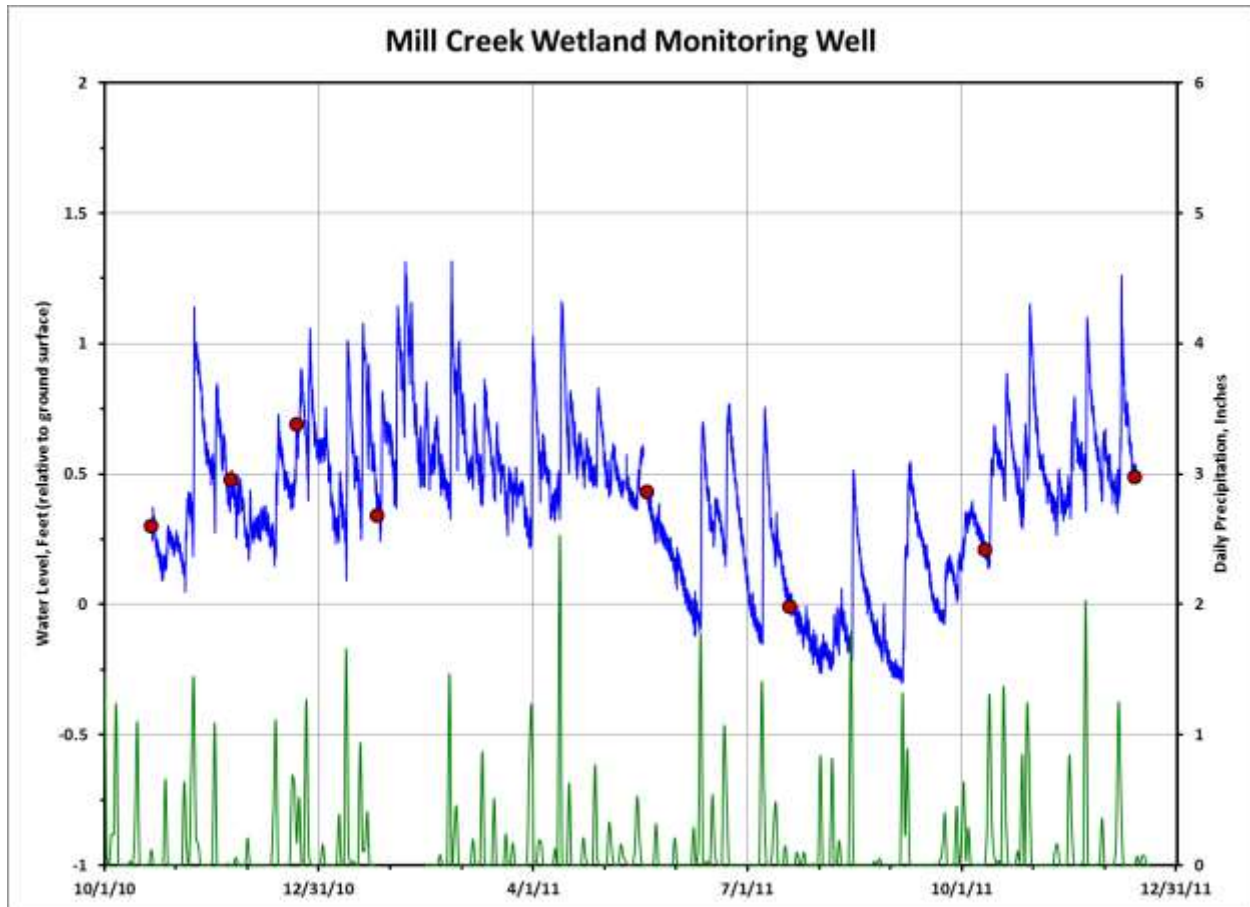




Water level at the High Toss well is almost always more than $1\frac{1}{2}$ feet below ground surface. Water level responds quickly to rainfall-recharge. Following recharge events, the water level quickly recedes to its base level of about 0.4 feet below ground surface in the winter months. In the summer months, the water level drops to about $2\frac{3}{4}$ feet below ground surface.

This well is located on the downstream (south) side of High Toss Road and about 100 feet east of the culvert where the road crosses the Herring River. The well is in an upland area of pine trees and is always dry.

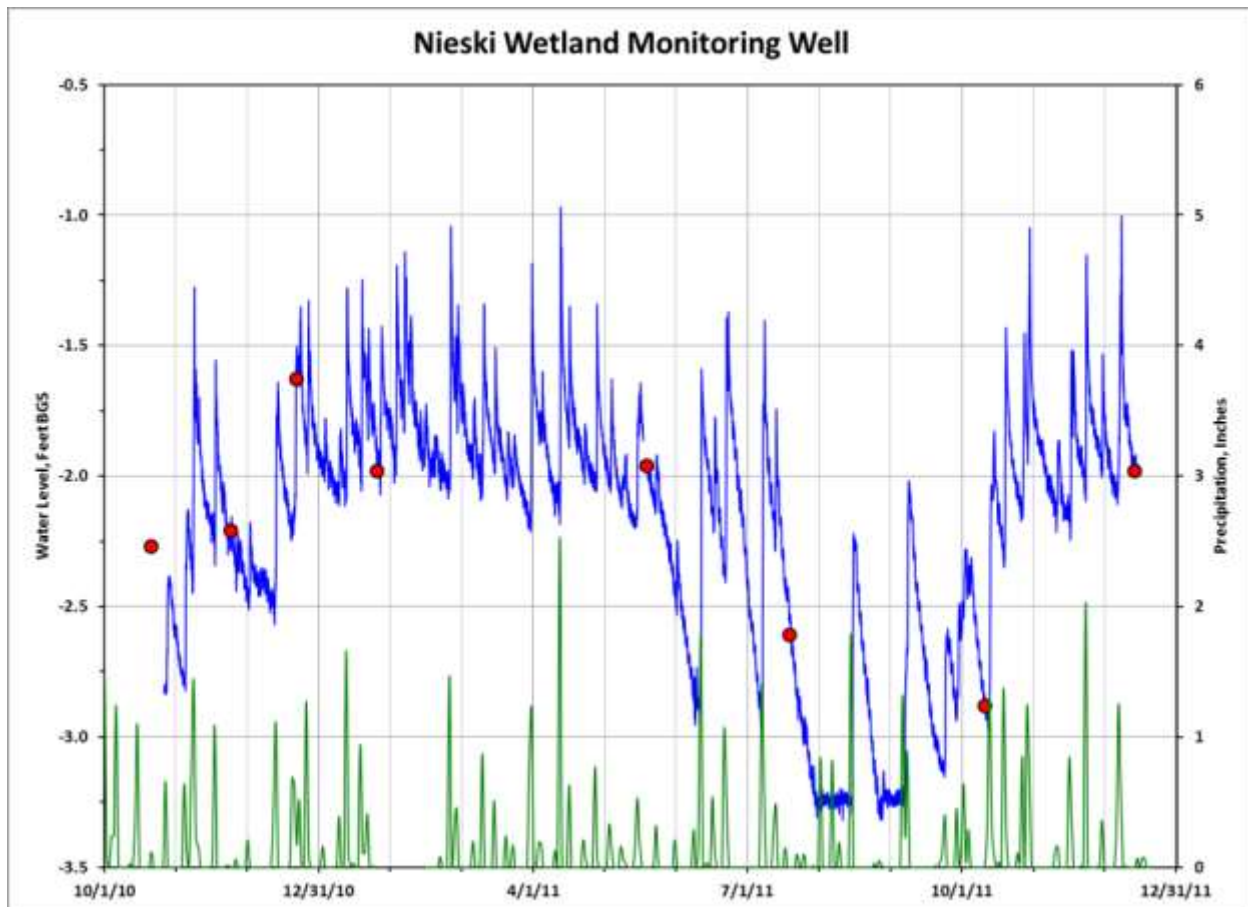




The water level in the Mill Creek wetland monitoring well is above ground surface for most of the year. The site is only dry for short periods between rains in the summer. There is always surface water present at the well; generally a few inches deep.

The well is in the midst of a *Phragmites* patch in Mill Creek.

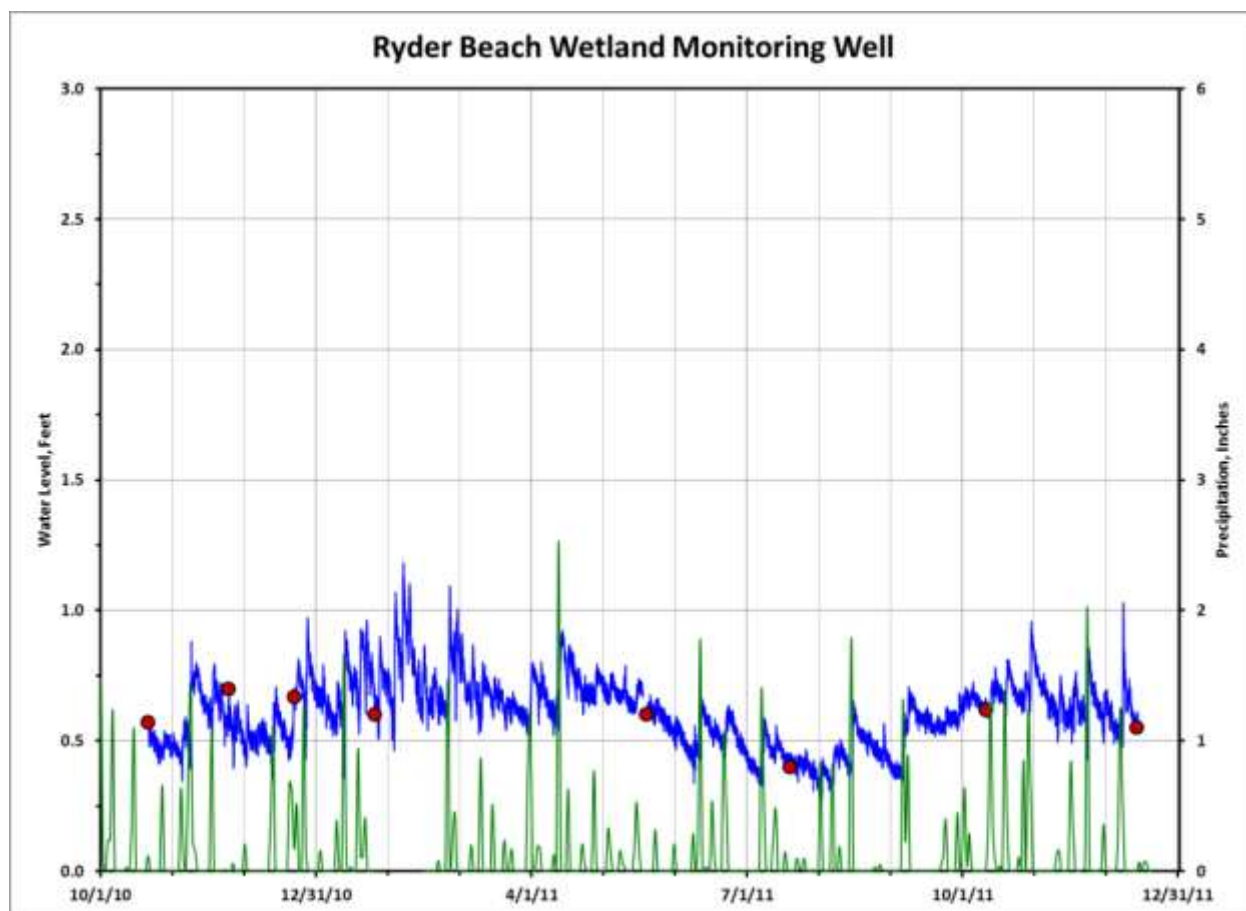




The range of water level fluctuation in the Nieski well is nearly double that seen in any other wetland monitoring well. Water level at this site is always below ground surface, ranging from about 3¼ feet BGS during dry periods in summer to about 1 foot BGS following large precipitation/recharge events in the winter. It appears that the water level may be dropping below the pressure transducer at about -3.25 feet during dry periods of the summer. The transducer should be redeployed deeper in the well.

This well is located in an upland area in the back yard of the Neiski residence. Its location, in an upland area rather than in the floodplain, likely accounts for the greater range of water table fluctuation than is seen at the other wells.





Water level at the Ryder monitoring well is always well above ground surface. There is always standing water at the site, about knee deep. The well is in a lowland area west of the old RR grade.

