DOING FIELD WORK IN YOUR OFFICE: AN AUTOMATED APPROACH TO WATER LEVEL MEASUREMENTS

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ABSTRACT

The New York State Energy Research and Development Authority (NYSERDA) manages a shut-down low-level radioactive waste disposal facility in Western New York. Recently, NYSERDA developed an innovative application of the Vibrating Wire Piezometer (VWP) technology to allow the remote, automated measurement of water elevations within the radioactive waste disposal trenches. The use of this technology has significantly reduced the potential for worker slips and falls on wet or snow-covered trench cap surfaces and has also reduced the level of effort needed to conduct routine water level measurements. In addition, the system has improved the flexibility and reliability of the water elevation measurement process. NYSERDA believes that this type of remote, automated monitoring system has great potential for use in stewardship programs at sites that may require long-term monitoring.

PROJECT SETTING

NYSERDA maintains and monitors the State-Licensed Disposal Area (SDA), a shut-down commercial radioactive waste disposal site at the Western New York Nuclear Service Center. The Center is located 35 miles south of Buffalo, New York, near the hamlet of West Valley, and adjacent to the West Valley Demonstration Project, a federally and state-funded cleanup project.

Between 1963 and 1975, approximately 2.5 million cubic feet of radioactive waste was disposed of in 14 unlined trenches, which were constructed in low permeability clay. Over the years, water accumulated in these trenches by percolating through the compacted clay cap or through shallow groundwater pathways. The water, which comes into contact with waste in the trenches, becomes contaminated with radionuclides and hazardous chemical constituents. In 1975, after water filled two of the disposal trenches and seeped through the trench caps, the facility was shut down.

Because of the potential for water to accumulate in the trenches, routine and accurate water level measurements are of great importance to NYSERDA and the involved regulatory agencies. Water level measurements are conducted monthly, with the data reported to the regulators within five business days. In addition, a statistical assessment is performed annually on each trench to evaluate any upward or downward trends in water levels.

The trenches range from 450 to 650 feet in length and are approximately 20-feet deep. Trench cross-sections are trapezoidal in shape, with a top width of 35 feet and a bottom-floor width of 20 feet. The trenches were sloped approximately two percent along their entire length during construction to allow water to drain into a low point where a trench sump was located. A vertical pipe extends from each sump to above the trench cap, providing a way to routinely monitor trench water levels.

Various water infiltration control measures were conducted in the 1960s through the 1980s. These efforts were of limited success and water continued to enter and accumulate in the trenches. As a result, NYSERDA took more aggressive steps to control water infiltration. These efforts included the construction of a subsurface groundwater barrier wall along the upgradient side of the facility and the
installation of water-impermeable geomembrane covers over the tops of the compacted clay caps. After completion of the last infiltration control project in 1996, water accumulation in all of the trenches appeared to be eliminated.

While the covers were successful at eliminating water infiltration, they were slippery when wet, and this condition was further exacerbated when the covers were coated with a thin layer of snow. The slip-and-fall hazard was significant and had to be resolved. Figure 1 shows an aerial view of the disposal trench geomembrane covers, a NYSERDA staff member conducting a manual measurement of trench water levels and winter-time trench surface conditions.
To reduce the potential for slips and falls and minimize the level of effort needed to perform the water level monitoring while improving flexibility and reliability of the water level measurement process, NYSERDA began evaluating options for a remotely operated and automated measurement technology. The measurement technology had to be precise and accurate to meet regulatory requirements. Further, the instrumentation had to operate in trenches containing radioactive and hazardous constituents as well as during the hot and cold weather extremes experienced at the West Valley site.

**VIBRATING WIRE PIEZOMETERS**

The VWP technology was selected for monitoring water levels in the trench sumps at the SDA. The VWP instrumentation is durable and reliable and offers a high degree of accuracy, precision and resolution. The VWPs are designed to minimize drift from initial calibration, which is extremely important to NYSERDA as this design helps reduce the concerns of radioactive waste generation and radiological health and safety issues associated with the removal of failed instruments from the trenches.

VWPs are designed to be driven into fine grain materials such as sand, silt or clay; embedded into earth fills and concrete; or inserted into boreholes or pipes. One of the benefits of this technology over other pressure transducer-type systems is the long life of the VWP, which makes it well suited for installation in locations that are not easily accessible. VWP manufacturers have conducted and documented studies that demonstrate VWPs retaining an accuracy of +/- 0.5% for over 25 years (1). VWPs are also relatively easy to install and use and, because of their size, occupy minimal space within the trench sump, which allows NYSERDA to install other instruments in the sump as needed.

The frequency of measurements can be varied as required using the automated measurement control unit without impacting manpower or costs. Automation provides improved precision relating to manual measurements. However, the most important factor is that the automation eliminates or reduces the need to walk on the geomembrane cover during poor weather conditions, which effectively minimizes the potential for slips and falls.

**Data Acquisition**

The major components of the piezometer are: a sensing element (i.e., a wire attached to a diaphragm), housing and a filter. One end of the piezometer-wire is attached to the center of the diaphragm and the other end attached to the transducer housing. The wire is electronically “plucked” by two magnets. This produces the vibrating wire period, which is the “raw data” for the water level measurement. The vibrating wire period is directly proportional to the pressure exerted on the diaphragm.

**Data Conversion and Water Elevation Calculation**

The vibrating wire period value is then sent to the automated measurement control unit where the value is converted to frequency. The frequency value is then compared to the natural frequency of the wire (i.e., with no pressure exerted on the diaphragm).

Pressure is calculated by the standard algorithm (2):

\[ P = K(f_2^2 - f_1^2) + A \]  

(Eq. 1)
where: $P$ = calculated pressure
$f_2$ = frequency with no pressure exerted on diaphragm
$f$ = measured frequency at pressure $P$
$A, K$ = calibration constants specific to each VWP

The pressure value is then converted to a depth of water column and the water elevation is calculated by adding this value to the surveyed reference elevation of the instrument. This calculated value would be the actual water level if the levels did not need barometric correction; but because the VWP responds to barometric pressure changes as well as water (head) fluctuations, the change in barometric pressure must be removed from the calculated water level. A barometer is installed in the automated measurement control unit, which records the barometric pressure on the same interval as the trenches. The barometric correction value is then subtracted from the VWP reading, thus leaving the change in water level.

The calculations listed above are recorded by the automated measurement control unit that logs the data and stores it for eventual transfer to the office computer.

**INSTALLATION**

The VWPs and the automated measurement control unit for recording and calculating data were installed in June 1998. The installation was completed in several steps, including the removal of the previous instrumentation and the installation of instrumentation to provide backup to the VWPs.

The actual VWP installation included lowering the piezometers to an acceptable depth, running the cables from the sump to a central automated measurement control unit and connecting the control unit with a NYSERDA office computer.

Each VWP installed at the SDA is attached to a junction box and cable hanger, which is banded to the sump casing. Each junction box contains a terminal arrester to protect the cable and the automated measurement control unit from over-voltage due to a lightning strike. This arrester does not actually protect the piezometer from being struck, but minimizes the damage back to the automated measurement control unit. The cable is then routed from the sump to the automated measurement control unit, which is located in the SDA field trailer.

Several methods of cable retention were considered for utility, durability, ease of installation and safety. Cable runs were covered with the same geomembrane material covering the trenches. The use of geomembrane-cover material mitigates safety concerns by offering a low profile that minimizes tripping hazards for NYSERDA staff.

**TROUBLESHOOTING**

After the VWPs and the automated measurement control unit system were installed, several troubleshooting activities were required to obtain consistent, defensible data.

**Cable Replacement**

In response to the increased resistance attributed to the type and length of the cable (i.e., some trenches have cable runs of greater than 1,200 feet), NYSERDA replaced the original plenum cable with a land-
burial rated cable. This cable provides additional shielding of the wire to help protect the signal from stray noise.

Fig. 2. Plot of barometric pressure external to the trench (blue) and the VWP instrument response within Trench 10N (green). The offset between the two plots represents the “lag” time required for the air pressure within the trench to equilibrate with external barometric pressure changes.
Frequency Improvements

The VWP system has various options for excitation of the wire for vibrating wire period determination. NYSERDA assessed two methods of wire excitation and concluded that one of these methods, the single-band chirp of the pluck-and-listen method, is more accurate and precise for water level measurements at the SDA.

Barometric Pressure Correction

The VWPs installed by NYSERDA do not have a direct vent for automatic barometric pressure correction. So, as stated earlier, barometric pressure correction has to be included in the final calculation of the water levels.

The standard approach to calculating the barometric pressure correction factor is to subtract the current barometric value from the date of installation barometric value. Barometric pressure is measured using a barometer external to the sumps. The barometric pressure correction presented some difficulties in that the standard correction approach did not adequately account for observed differences in atmospheric and

Figure 3: Plot of barometric pressure external to the trench (blue), and VWP instrument response within Trench 10S (green). No barometric pressure “lag” time is observed in this trench. The corrected water elevation plot for this trench is shown in red.
trench barometric pressures. The construction of each sump contributes significantly to the rate of equilibration of the internal trench pressure with atmospheric pressure and it may take 6 to 24 hours for the internal trench air pressure to equilibrate with the external atmospheric pressure conditions. Therefore, NYSERDA needed to identify the “lag” (equilibration) time and had to correct each affected trench appropriately. Figure 2 shows this “lag” between internal trench pressure and atmospheric pressure for one of the trenches. Once the barometric contribution had been adequately addressed and the lag time issue resolved, the data plots became very stable and NYSERDA was able to view the actual water level changes. Figure 3, is the plot of Trench 10S, which unlike Trench 10N, does not have barometric equilibration lag issues.

MAINTENANCE

Maintenance activities completed since the time of installation include replacing the failed piezometers in Trenches 2 and 3, and updating the software with new releases. The piezometers located in Trenches 2 and 3 failed shortly after installation. It is not clear why these units failed, but it is suspected that the failure was related to a lightning strike. There have been four upgrades to the software since the time of installation. These upgrades have aided in the usability of the system, the graphic support/capability and the archival functions.

CONCLUSIONS

Over the short term, NYSERDA sees tremendous benefits to using the VWPs and the automated measurement control unit. In particular, immediate improvements are seen in terms of worker health and safety, data quality, traceability and accuracy. The long life and low maintenance of the VWP instrumentation make it ideal for use in a contaminated environment. Looking to the future, there is much potential for the use of automated remote technologies in long-term monitoring and maintenance or stewardship programs at the SDA as well as many other contaminated sites.

REFERENCES

2. GEONOR AS, “Instructions for Use/- Calibration Data - Pore Pressure Gauge Model M-600/M-610,” GEONOR AS, P. O. Box 99 - Roa, 0701 Oslo, Norway (1997)