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Hydraulic Laboratory Technical Memorandum PAP-1102

Canal Lining Drawdown Tests for the Brock Reservoir Inlet Canal

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

May 2014

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Introduction and Study Objectives

Brock Reservoir and the Brock Reservoir Inlet Canal are recently constructed components of the All American Canal which conveys water from Imperial Dam on the Colorado River to Imperial Valley in southern California. The Brock Reservoir Inlet Canal is approximately 6.5 miles long. The Brock Inlet Canal and the Coachella Canal are fed from the All American Canal at the same location in the southeast corner of California. Water passing through the canal is delivered to the Brock Reservoir re-regulation storage facility.

The Brock Inlet Canal is a concrete-lined canal with a depth of 16.5 feet, a bottom width of 18.5 feet and 2:1 (H:V) sloping side walls. The canal is constructed in an area featuring coarse-grained sandy soils that provide relatively high hydraulic conductivity. In the operation of a concrete lined canal pore pressure that can build up behind the lining as a result of leakage through the lining poses a potential threat for damaging the lining if the water level in the canal is lowered too rapidly.

If the elevation of the top of the saturated zone – referred to as the phreatic surface – behind the lining exceeds the water surface elevation in the canal, the lining will be subject to a differential force tending to push the lining away from the bank. When this situation is present it is important to keep the differential between the phreatic surface and the canal water surface elevations within a limit such that the resultant net force differential will be insufficient to cause damage to the lining.

The site stratigraphy has been characterized as “a thick sequence of alluvium or aeolian sand” (Lung, 2005). This geologic material would have comparatively high hydraulic conductivity which would enable water that leaks through the canal lining to move down gradient more quickly than would be the case with more finely textured soils. This drawdown test was commissioned by the Operations Group of Reclamation’s Yuma Area Office (YAO) to determine whether existing drawdown constraints could be modified to enhance operating flexibility. Reclamation’s Technical Service Center (TSC) provided assistance in the setup and performance of the drawdown test.

Drawdown Test Setup

Equipment for the Brock Inlet Canal drawdown test was installed during the week of August 19, 2013 during a period when the canal was out of service while additional expansion joints were being installed in the concrete lining. YAO opted to install pore pressure monitoring sites at locations spaced approximately one mile apart along each side of the canal. Sites were selected such that sites along a given side of the canal are approximately half way between stations on the opposite side of the canal. A total of 13 pore pressure monitoring stations were installed with seven sites on the right bank of the canal and six on the left bank. Figure 1 is a location map showing the approximate location of the pore pressure monitoring stations.

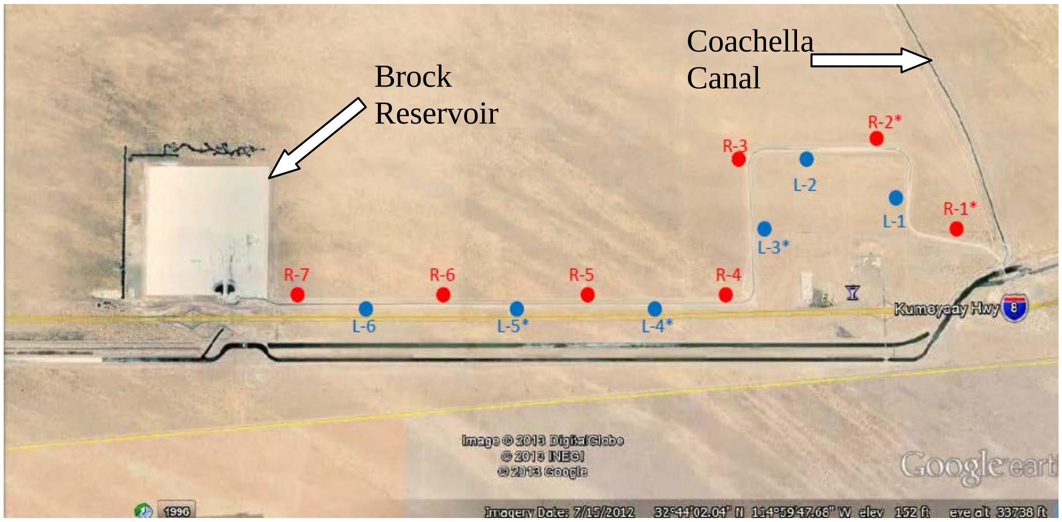


Figure 1. Brock Inlet Canal Pore Pressure Monitoring Site Map

For the purpose of referencing the sites within this report, pore pressure monitoring stations along each side of the canal have been given identifying numbers (as seen on in Figure 1) beginning at the upper end of the canal. Each site has also been given an R or L prefix, signifying that the site is either on the right or left side of the canal. Hence sites R-1 thru R-7 are on the right side of the canal and sites L-1 thru l-6 are on the left side of the canal. Site identifiers shown in Figure 1 with an asterisk added (R-1*, R-2*, L-3*, L-4* and L-5*) are sites where electronic level sensing and data-logging equipment was also installed.

Stainless steel safety ladders are spaced approximately 750 feet apart along each side of the canal. Ladder locations are staggered from side to side of the canal. Pore pressure monitoring station locations were selected so that each site was adjacent to a safety ladder.

The pore pressure monitoring taps were installed approximately three feet up the canal wall slope from the canal invert. To install the taps a 5/8" diameter hole was first drilled through the concrete lining. A stainless steel "packer" fitting with a medium density polyethylene (MDPE) sleeve seal was installed in the bored hole. Figure 2 shows a packer fitting and the MDPE sleeve.

Figure 2. Packer Fitting and MDPE Sleeve Seal

As may be seen in Figure 2 the packer fittings have a tapered stem with coarse threads on one end. The other end of a packer has a 3/8” male pipe thread on the outside as well as a 1/8” female pipe thread on the inside of the fitting. Just beyond the male pipe threads the packers are configured with a hexagon shoulder. To install each packer the MDPE sleeves was fitted over the tapered stem. The packer and sleeve were then driven into a hole bored through the concrete lining until the top of the sleeve was approximately even with the surface of the concrete. Next the packer was tightened securely by rotating it clockwise using a box-end wrench fitted over the hexagon section.

Once a packer had been installed in the lining a 90^o elbow was threaded onto the 3/8” male thread leaving the elbow pointing toward the top of the lining. A hose barb fitting for ½” ID tubing was threaded into the upper port of the elbow. Clear vinyl ½” ID tubing was attached to the hose barb and run from the pore pressure tap to the top of the canal lining. Sections of 1/2” schedule 40 galvanized pipe were attached to the canal lining adjacent to the packer and extending to the top of the lining to provide a rigid anchoring mechanism for the clear vinyl tubing.   The tubing was secured to the galvanized pipe using nylon tie strips. Figure 3 shows YAO personnel installing equipment at a pore pressure monitoring site.

Figure 3. Pore Pressure Monitoring Station Installation

For similar drawdown tests performed at the Charles Hansen Feeder Canal in northern Colorado in 2011 and 2012 TSC engineers had encountered pore pressure taps where no differential head readings could be obtained due to the fact that water level in the pore pressure sight tubes was never observed to be above the canal water surface elevation (Wahl 2012). With the deep sandy soils underlying the Brock Inlet Canal, the TSC opted to add the ability to electronically measure and log pressures in the pore pressure sight tube and in the canal at a location near the elevation of the pore pressure tap at selected sites.

This equipment would provide knowledge of pore pressures in circumstances where water level in the sight tube remained below the canal water surface. Bubbler sensing systems equipped with two position solenoid valves capable of measuring pressure at two locations using a single pressure transducer were installed at five of the thirteen pore pressure monitoring stations. Figure 4 is a close up view showing how the bubbler ports are installed near the bottom of the canal wall. Figure 5 shows a broader view of the same site.

At each of the bubbler-equipped monitoring stations, a bubbler sensor w/solenoid valve & programmable controller is installed in an electrical enclosure mounted on a post at the top of the canal lining. Two 1/4” ID vinyl tubes that link the canal and pore pressure taps with the solenoid valve are installed inside ½” PVC electrical conduit. The PVC conduit is secured to the canal lining and extends down from the electrical enclosure to a location approximately one foot up the sloped was from the pore pressure tap.

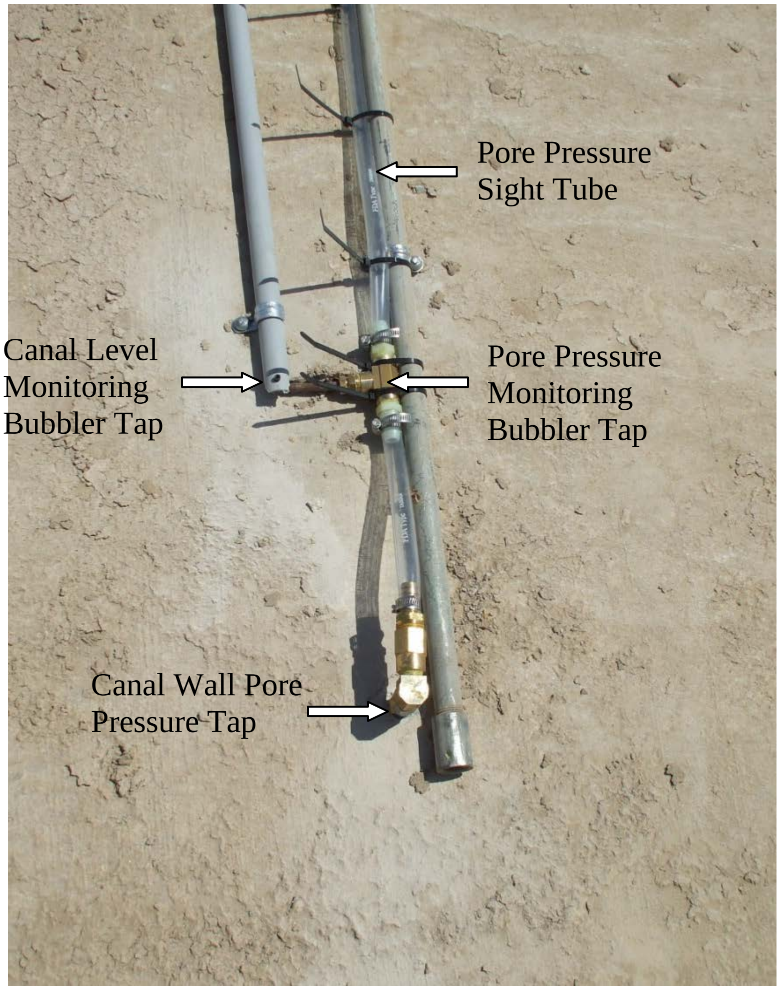


Figure 4. Bubbler-Equipped Pore Pressure Monitoring Site

For the bubbler line monitoring the canal level a tap fitting is installed at the lower end of the conduit. The bubbler line monitoring pore pressure is installed with a 90^o elbow at the lower end of the conduit. At the same elevation as the canal level tap a tee fitting is installed in the pore pressure sight tube. A short section of bubbler tube oriented horizontally links this tee fitting with the elbow in the pore pressure bubbler line.

The pressure transducers used in the bubbler sensing devices measure gage pressure and return an analog signal (0-5 volts) to the control unit. Within the programmable control unit the 0-5 volt signal is translated via a 12-bit analog to digital converter to a value from 0 to 4095. The relationship between the digital values obtained and the actual pressures being measured is a linear correlation. Thus to convert a digital signal value to a pressure value (in ft. H_20 for this application) the applicable calculation is: (sensor slope) x (signal value) + (offset value) = pressure.

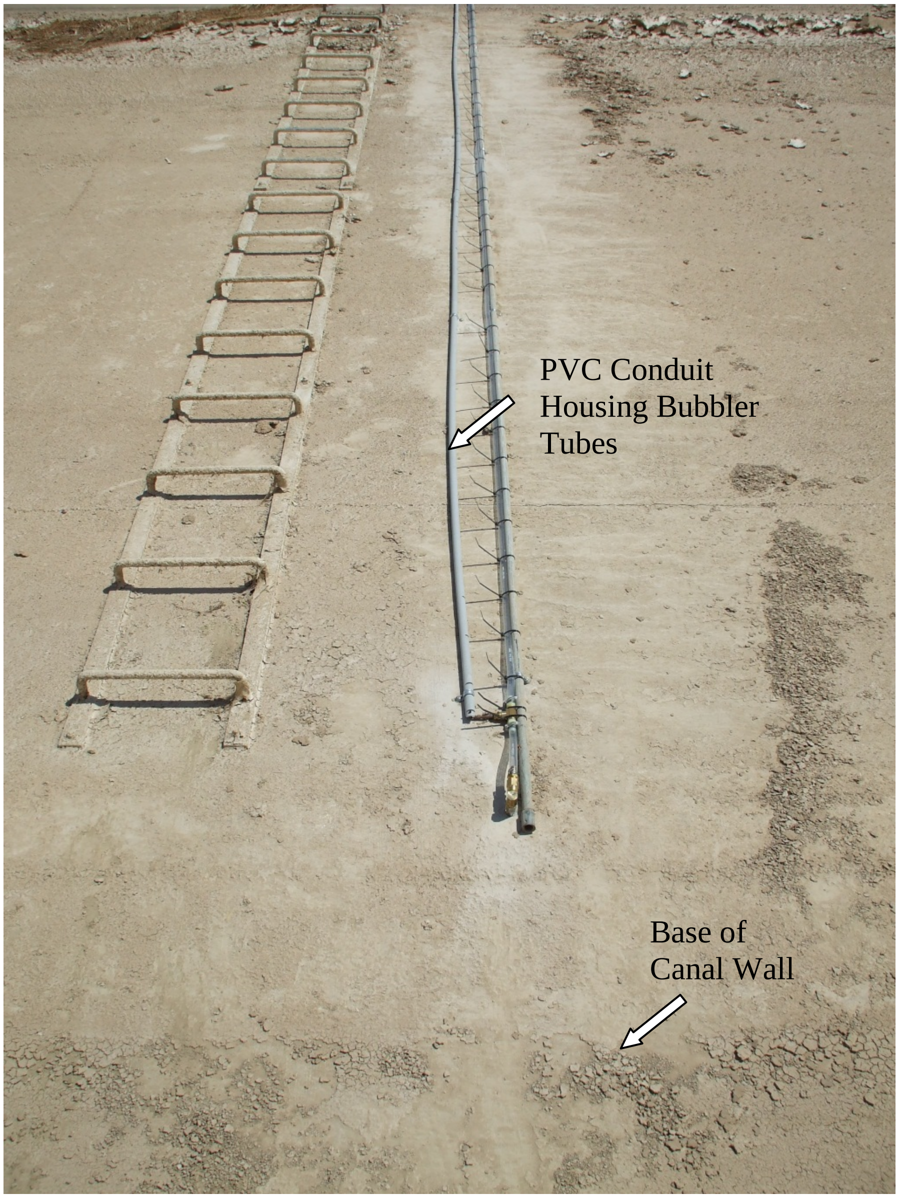


Figure 5. Bubbler-Equipped Pore Pressure Monitoring Station

A sensor slope value of 0.00355 obtained from a laboratory calibration of a 5 psi bubbler unit identical to the units used for this drawdown test was programmed into the control units at all bubbler-equipped sites. With placement of the canal water level bubbler taps and the pore pressure sight tube bubbler tap at the same level at each of the sites, use of the same offset value for both canal level pressure and pore pressure level provided a measurement of pressure differential. For simplicity of equipment setup an offset value of zero was used for both bubbler ports at each site. Data logged during the test enabled determination of the appropriate offset value to present atmospheric pressure readings as a value of zero in the plotted data presented in this report.

During the week of August 19 pore pressure taps and sight tubes were installed at each of the 13 pore pressure monitoring stations. Bubbler tubes were installed at each of the bubbler-equipped sites. Steel pipe poles for mounting electronic equipment were installed and solar panels were mounted to the pipe poles at the bubbler-equipped sites. Installation of the bubbler sensors and programmable control units was completed when TSC personnel returned to participate in performing the drawdown test in late October.

Drawdown Test Procedure

On the morning of October 31, 2013 Tom Gill from TSC met with YAO personnel including Jesse Alvarado, Russ Phelps, Hong Nguyen-DeCorse, Doug Hipp, Aaron Marshall, Jacob Davis and Mike Igoe at the YAO office. The YAO staff discussed the procedure they planned to use to perform the drawdown test. The previously existing drawdown criteria were:

> Water surface drawdown shall not exceed the following limits:
>
> - 6 inches in any 1-hour period (may be taken at any rate)
> - 12 inches in any 2-hour period
> - 12 inches in any 24-hour period

The YAO operations group reported that when the canal was brought back into service after the pore pressure taps and sight tubes were installed, YAO personnel had poured dyed water into some of the pore pressure sight tubes to see what levels of pore pressure could be detected. Apparently as many as three one-pint bottles of dyed water had been poured into a sight tube. Within a short time interval (seconds to a few minutes) the dyed water drained from the sight tubes so that it was no longer visible.

These observations – along with familiarity with the soils in the area of the canal – were suggested by the YAO operations staff as evidence that minimal issues with pore pressures behind the canal lining were anticipated for the drawdown testing. They noted that drawdowns in one foot increments and one drawdown increment of three feet had been performed without incident while dewatering the canal for the expansion joint installation project that was ongoing as the drawdown test pore pressure taps were installed.

The YAO operations staff indicated that they planned to start the drawdown test with a one foot drawdown to be followed by a three foot drawdown. If observed pore pressures were sufficiently below the water surface elevation in the canal, YAO indicated a desire for subsequent larger drops in canal level to be included in the drawdown test procedure.

Installation of Electronic Monitoring Equipment

On October 31 following the meeting at YAO, Tom Gill, Jesse Alvarado and Jacob Davis traveled from the YAO office to the Brock Inlet Canal. The first task undertaken was installation of the bubbler sensors and programmable controllers at the five bubbler-equipped pore pressure monitoring stations, beginning at the R-1 location. Table 1 shows data logged at the R-1 site while the setup was being completed.

Table 1. Logged data during equipment setup at the R-1 site

Date Stamp (MMDDYY)	Time Stamp (HHMM)	Canal Tap Pressure (ft. H_2O)	Sight Tube Pressure (ft. H_2O)
103113	1105	1.458577	1.456506
103113	1110	1.458813	1.45763
103113	1115	1.455441	1.455263
103113	1120	9.956744	1.457334
103113	1125	9.961418	1.461831
103113	1130	9.954377	1.462245
103113	1135	1.461831	9.894916
103113	1140	9.976684	1.462067

Before connections to the bubbler air pump and solenoid valve were wired at the R-1 site the sensor was operated for three pressure-reading/data-logging cycles (Time Stamps 1105 – 1115 in Table 1). The pressure being read under this condition was atmospheric pressure at both taps. With the zero offset value programmed into the controller, the computed values returned for atmospheric pressure were approximately 1.46 ft. H_2O for each bubbler port. After bubbler tube connections were complete (Time Stamps 1120 – 1130) pressure values in in the range of 9.96 ft. H_2O were recorded for the canal tap while the recorded pore pressure tap readings remained near 1.46 ft. H_2O – essentially atmospheric pressure.

To check performance of the electronic sensing equipment the bubbler line connections to the solenoid valve were reversed for one measurement cycle (Time Stamp 1135). The readings obtained for this cycle with the bubbler lines reversed are very close to the same but in reverse order to the readings obtained prior to reversing the lines. This outcome provided verification that both ports of the bubbler sensing equipment were functioning properly.

Having verified the function of the sensing equipment, the bubbler lines were switched back and the site was left in operating mode to measure and log pressures at five minute intervals throughout the test. Similar equipment installations were subsequently completed at the R-2, L-3, L-4 and L-5 sites.

Brock Inlet Canal Drawdown Test

The testing schedule spanned the PDT to PST time change in California. To eliminate confusion this might introduce in data records, all reported time is in Arizona (MST) time – which Arizona maintains throughout the year.

Installation of electronic equipment at the bubbler-equipped sites was finished at approximately 4:30 PM on 10/31/13. YAO immediately contacted Imperial Irrigation District (IID) operators to initiate a one foot drawdown of the canal level. At the time the drawdown test was initiated the canal had been continuously filled for approximately six weeks.

[It should be noted that during the bubbler installation at site L-4 the clock in programmable controller unit was not functioning properly. This unit was repaired and reinstalled by 6:00 PM on 10/31/13 and was in service from that time through the remainder of the data collection.]

Logged data documenting the initial one foot drawdown was downloaded from the bubbler-equipped sites the following morning (11/01/13). Data download from all bubbler-equipped sites was completed by approximately 9:30 AM. It was noted that for data logged up to that time, all pore pressure readings at all bubbler-equipped sites were showing atmospheric pressure readings for each logging cycle.

IID operators were contacted to request a three foot drop in canal level. This drawdown began at approximately 9:40 AM. The canal level had largely stabilized by noon. With the canal level nearly stable, dyed water was poured into the pore pressure sight tubes at each of the non-bubbler-equipped pore pressure monitoring sites as well as at the R-1 and R-2 bubbler equipped sites.

It was calculated that one pint of liquid volume should fill approximately 12 feet of the ½” ID vinyl sight tube (representing a vertical depth of approximately 5.3 feet). One pint of water was poured into each sight tube. At each of the non-bubbler equipped sites and at the bubbler-equipped R-1 site, the dyed water drained rapidly from the sight tubes and could not be seen. At the bubbler-equipped R-2 site the dyed water in the sight tube was observed to drain at a slower pace.

Logged data documenting the three foot drawdown step was retrieved from the bubbler-equipped sites on the morning of 11/02/2013. A preliminary examination of this data showed pore pressures for bubbler-equipped sites had remained at atmospheric pressure level for all sites until dyed water was poured into the L-1 and L-2 sight tubes at about noon on 11/01/2013. For the L-1 site, the sight tube apparently drained completely within the 5 minute logging interval as there was no recorded deviation in pore pressure from the atmospheric level. For the L-2 site a spike in measured sight tube pressure was measured beginning at 12:35 PM. This data spike that coincided with the pouring of dyed water into the sight tube (initially in excess of 5.5 ft. H_2O pressure) dissipated back to an atmospheric pressure level over a period of approximately 4 hours. This data spike may be seen in Figure 6.

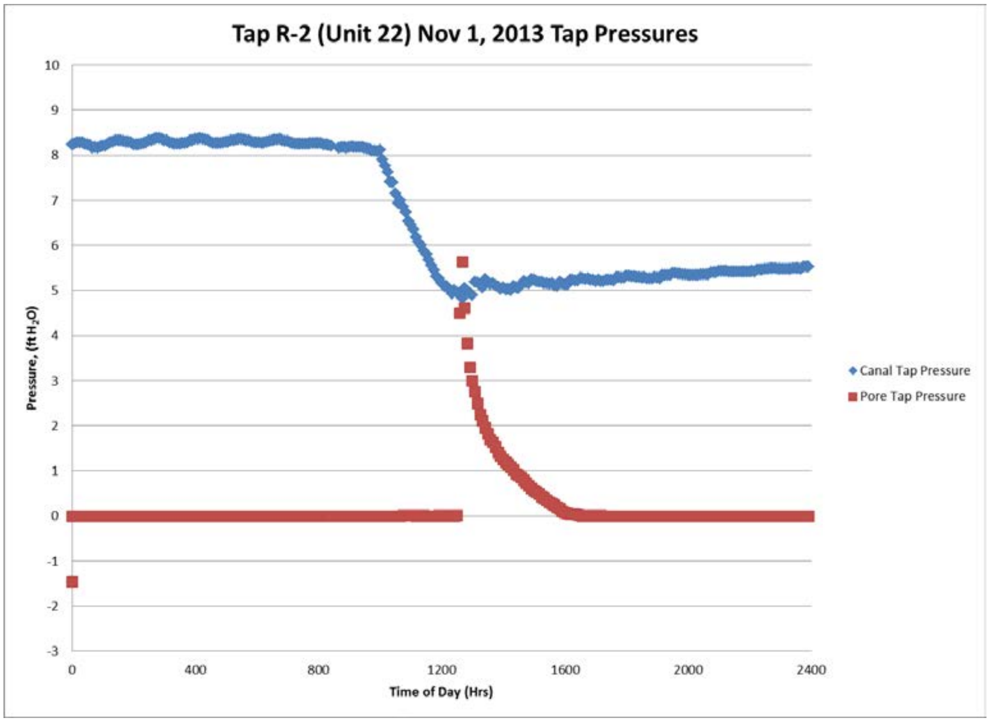


Figure 6. Plot of Nov. 1 data at the R-2 Tap

Drawdown testing activities were resumed on 11/04/2013. IID operators were contacted to request a four foot drop in canal level at approximately 8:30 AM. Beginning at approximately 11:30 AM visual assessment of pore pressure at each of the 13 monitoring stations was made – again by pouring approximately one pint of dyed water into each site tube including all of the bubbler equipped sites.

At this point in the test the canal water level had dropped sufficiently that the entire submerged segment of the sight tubes was visible. At ten of the thirteen pore pressure monitoring sites the dyed water was completely drained from the sight tubes within a matter of minutes. Dyed water levels at the L-2 site and at the bubbler-equipped R-2 and L-5 sites dropped more gradually. Figure 7 is a photo showing the red dye in the sight tube at the L-5 site during this visual assessment.

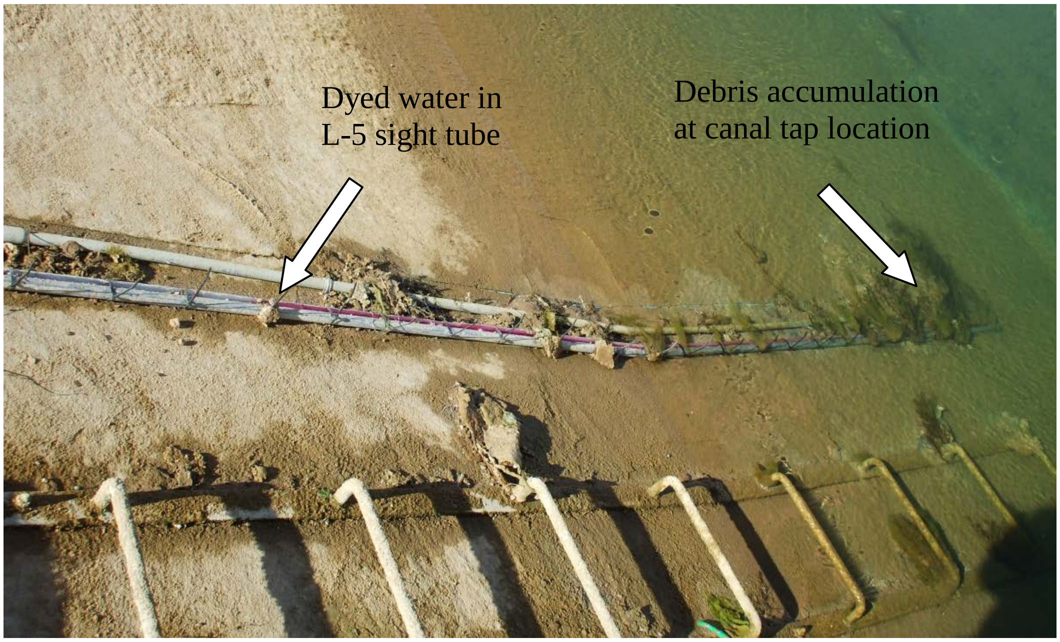


Figure 7. Red dyed water in the L-5 sight tube

Another item visible in Figure 7 is the debris accumulation at the location of the canal bubbler tap. The nature by which a bubbler sensor operates tends to provide a self-cleaning capability. In the event a tap becomes clogged, the bubbler will – within its operational range – continue to build pressure until the clog becomes dislodged. This would potentially result in an occasional excessively high apparent pressure measurement. Figure 8 shows the logged data at the L-5 station for 11/04/2013.

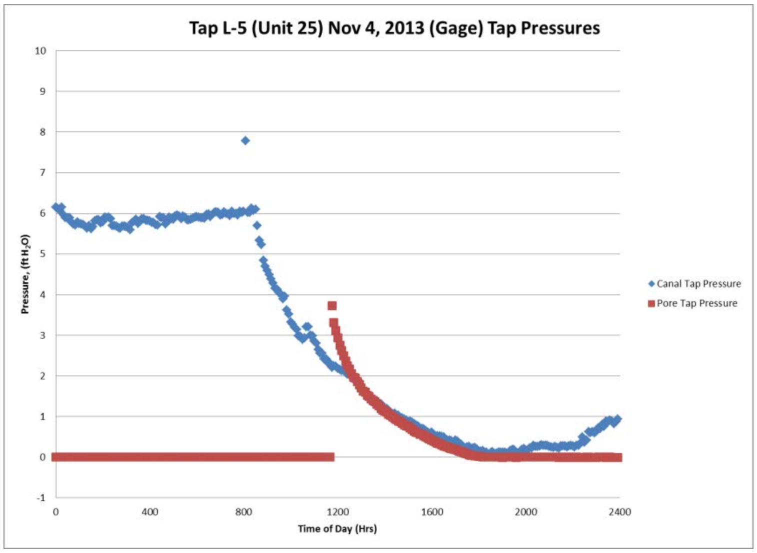


Figure 8. 24 hour plot of measured pressures at the L-5 site

From Figure 8 it is clear that prior to pouring dyed water into the sight tube at the L-5 site the measured pore pressure is at atmospheric pressure (zero gage pressure) at the site tube bubbler tap. This implies that any phreatic surface in the soil behind the canal lining is lower than the elevation of the tap. An outlier data point is seen for the canal tap pressure in Figure 8 at approximately 8:00 AM. This high value may be the result of debris having temporarily clogged the canal tap port.

It is apparent from Figure 8 that the spike in measured sight tube pressure seen beginning at approximately noon is a function of pouring the dyed water into the sight tube as opposed to something related to the changing water level in the canal. The information presented in Figures 7 & 8 serves to provide verification that the electronic pore pressure monitoring equipment was functioning properly. During periods of time when the dyed water was visible above the sight tube bubbler tap, readings exceeding atmospheric pressure were measured and recorded.

Following the visual assessment using dyed water, IID operators were contacted to request an additional four foot drop in canal level at approximately 12:30 PM. This drop would lower the canal to the minimum level to which the canal could be drained by gravity-driven flow given the water level in Brock Reservoir at that time. Data documenting the drawdowns performed on 11/04/2013 was collected on the morning of 11/05/2013.

After the data had been obtained from all bubbler-equipped sites, IID operators began refilling the canal at approximately noon. Following the canal refilling, logged data from the L-4 and L-5 sites was collected the evening of 11/06/2013 and from the L-3, R-1 and R-2 sites on the morning of 11/07/2013.

Drawdown Test Results

Data was retrieved from the bubbler-equipped monitoring sites in a comma-delimited text file format that could be readily imported into the Excel spreadsheet software. The unprocessed comma delimited data files retrieved from the field unit logs are included [in digital format in a CD packaged with this Report – the data record for each site in 8 point font will take 34 pages to display]. Twenty-four hour plots at each station are included in Appendix A.

As discussed in the Drawdown Test Setup section of this report the measured pressure representing atmospheric pressure at each station was determined from data recorded during the test. At each site the measured value for atmospheric pressure was approximately the 1.46 ft. H_2O observed during the setup at the R-1 site.

The retrieved data has been post-processed by applying the offset value to adjust atmospheric pressure measurements to zero. Both the canal level and the pore pressure bubbler taps were installed at essentially the same elevation at a given station so that the same offset value could be applied to both the canal pressure and pore pressure measurements. Figures 9, 10, 11, 12 and 13 are plots showing gage pressures measured at sites R-1, R-1, L-3, L-4 and L-5 respectively from 10/31/2013 thru 11/05/2103. It should be noted that the water level pressure values shown represent pressure from the water column above the tap location and do not represent the total depth of water in the canal.

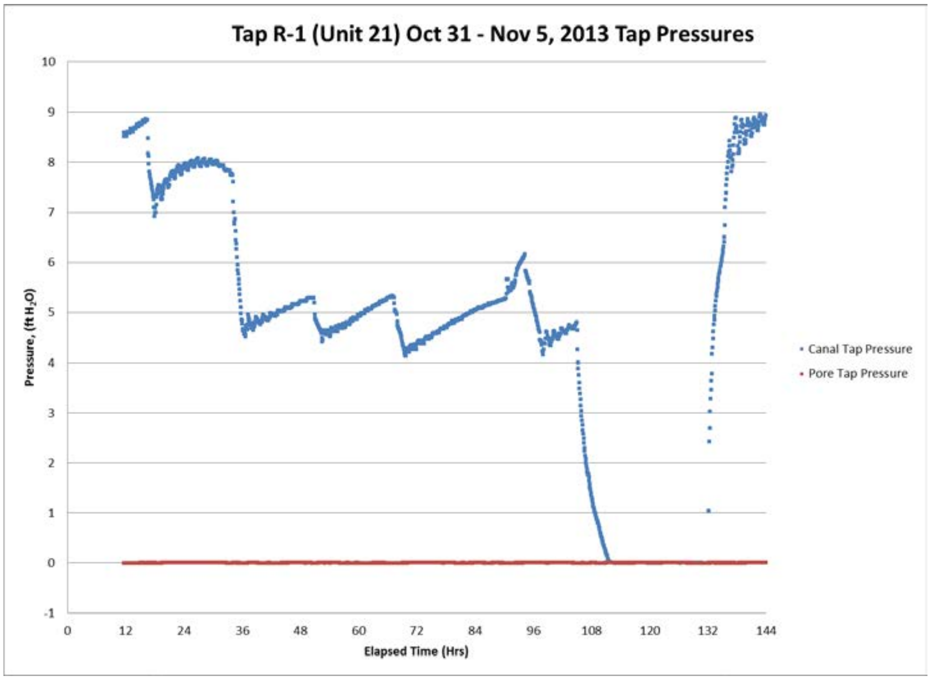


Figure 9. Tap R-1 Measured Pressures

As discussed in the *Brock Inlet Canal Drawdown Test* section of this report a pint of liquid would be expected to fill a length of the ½" ID sight approximately 12 feet long representing a vertical water column of approximately 5.3 feet. In Figure 13, the remaining red dyed water visible in the tube accounts for less than half of the volume that was poured into the tube.

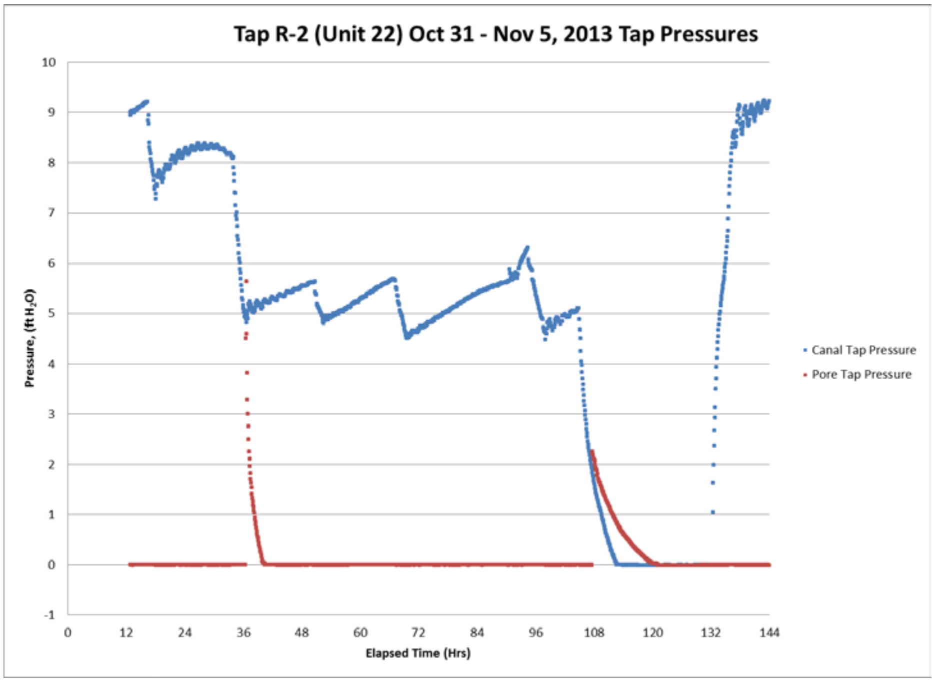


Figure 10. Tap R-2 Measured Pressures

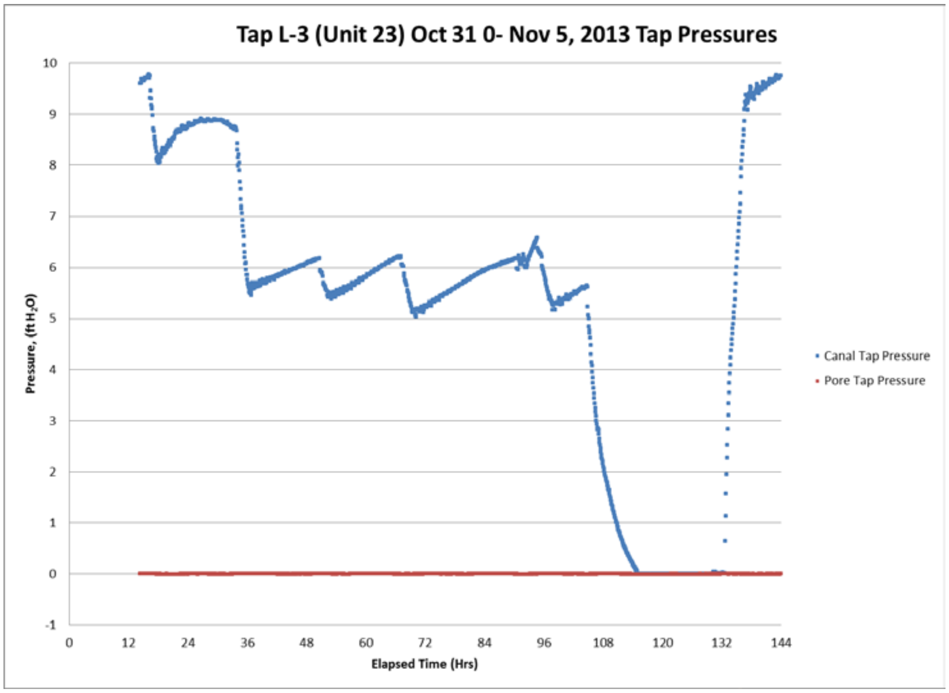


Figure 11. Tap L-3 Measured Pressures

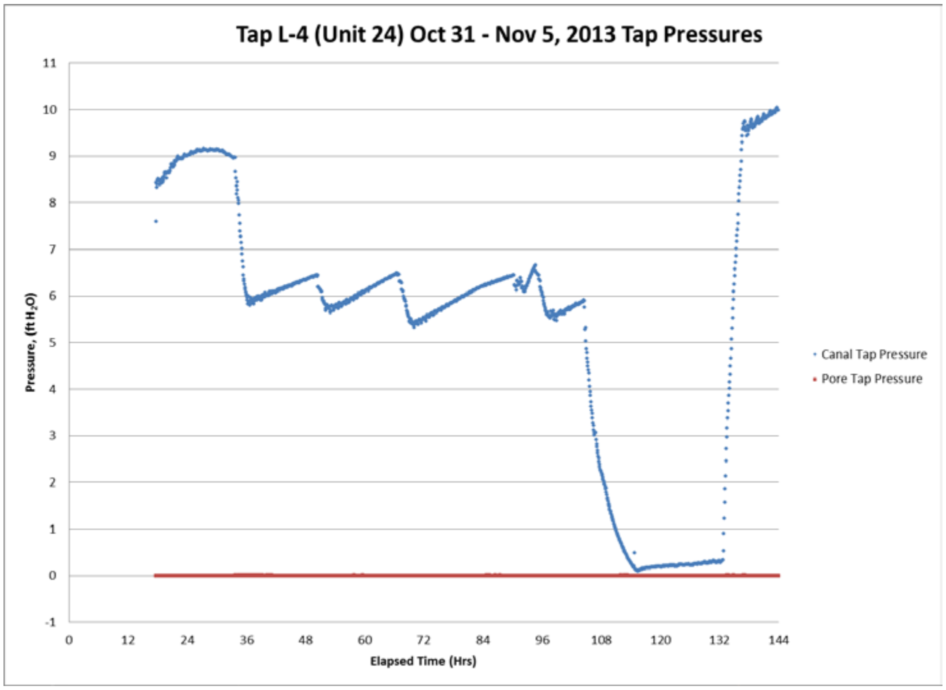


Figure 12. Tap L-4 Measured Pressures

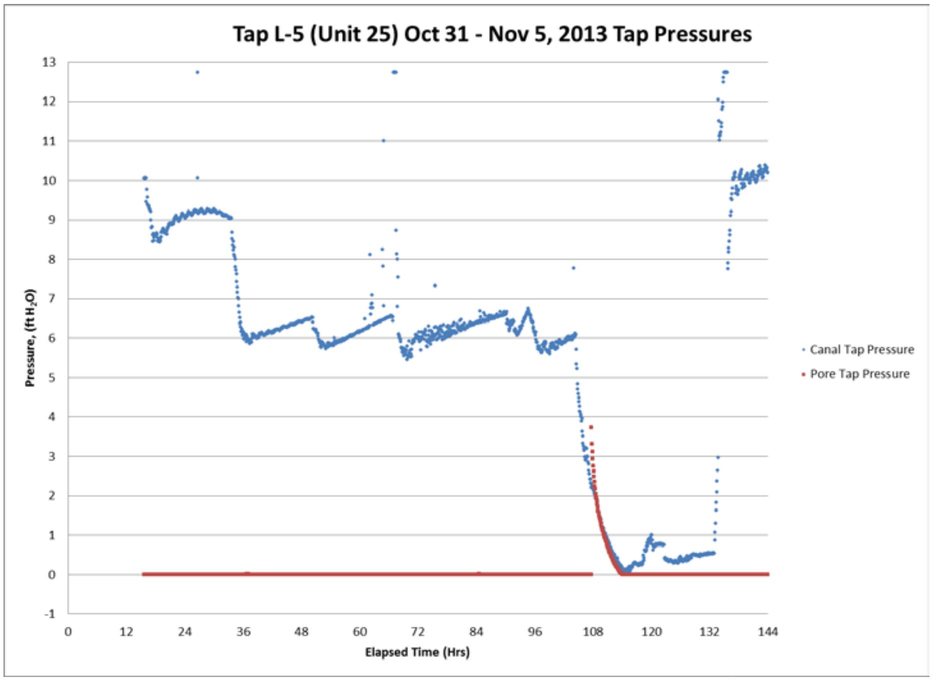


Figure13. Tap L-5 Measured Pressures

Discussion of Test Results

From the plotted data presented in Figures 9 through 13 it is apparent that measured pore pressures at the five bubbler-equipped sites would have remained at atmospheric pressure level throughout the drawdown test if dyed water had not been poured into pore pressure sight tubes. Visual observations made at the non-bubbler equipped sites during the two times dyed water was poured into the sight tubes would lead to a similar assessment of pore pressure levels at those sites.

Figures 9, 10 & 11 presenting data from the R-1, R-2 and L-3 sites respectively, show that during the minimum canal level period when the canal bubbler taps at these locations were above the water level, the canal tap pressure readings were the same as the pore tap pressure.   Figures 12 & 13 presenting data from the L-4 and L-5 sites show that during the minimum canal level the canal tap pressures are higher than the pore tap pressures (presumed to be atmospheric pressure). This is consistent with the observed position of the canal tap levels at the respective sites which remained slightly submerged during the minimum water level period.

Spikes seen in pore tap pressures at sites L-2 and R-5 serve to verify that the electronic pressure sensing equipment monitoring the pore pressures at those sites was functioning properly. At times when a water column existed above the bubbler tap in a sight tube, the electronic sensing equipment measured and logged pressures greater than atmospheric pressure.

In Figure 13 a significant number of apparent “outlier” values were recorded for canal level pressures which are all higher than adjacent data points. During testing it was observed that a mat of aquatic debris had accumulated around the bubbler canal tap location at the L-5 site. Debris can cause erroneous measurements because air pressure in the bubbler tube must continue to increase until an air bubble is eventually forced out.

A bubbler tap that becomes intermittently clogged would result in some water level pressure readings greater than the actual water level. Since the same transducer monitors both taps, the absence of similar outliers in the pore pressure record seen in Figure 13, suggests that the outliers that appear in the water level data are not due to instability of the pressure transducer, but rather are likely the result of intermittent clogging of the water level pressure tap.

There was no evidence that groundwater levels behind the canal lining were at or above the pore pressure tap elevation at any of the thirteen pore pressure monitoring stations at any time during the drawdown test. This was not entirely unexpected given the deep sandy soils underlying the canal – which was also the material used to construct the earthen canal banks – and the fact that recently constructed canal lining is in good condition.

Soil characterization information and soil test boring data are included in Appendix B of this report. Soils underlying the canal and materials used in construction of the canal banks are classified poorly graded sands (SP) and poorly graded sands with silt (SP-SM). Test boring to fifty feet performed prior to construction of the canal shows that essentially the same material is present over the entire bore column.

The cause for the extended drain times required after dyed water was poured into the sight tubes at the R-2, L-2 and L-5 sites is uncertain. Local factors may offer the most likely possibilities. As the pore taps were being installed in the canal lining a greater amount of residue from the concrete drilling process may have accumulated at the base of some of the tap bores, which would retard travel of the dyed water from the sight tube into the soil underlying the canal lining.

Another potential factor would be windblown materials that had accumulated in the sight tubes since installation of the tubes in August. Some of the sight tubes were cut longer than needed and a curl formed in the one foot or so of excess tube at the top of the canal lining. As the dyed water was being poured into the sight tubes during the drawdown test it was observed that a noticeable amount of material had collected in the lower side of these curls. Attempts were made to clean the debris from these tubes, but if this operation was not fully successful, then it is possible that as this debris was washed down with the dyed water into the fittings and pore pressure tap, a clog capable of slowing the draining rate of the dyed water from the sight tubes could have formed.

Post-Test Data

After the drawdown test had been concluded the electronic level sensing and logging equipment remained in operation thru 12/14/2013. The logging interval was extended from the five minute interval used during the drawdown test to fifteen minutes. Post test data was downloaded on 12/14/2013 at which time the level sensing, data logging and solar charging equipment was removed.

Data available on the circular log buffers at the time of the download included just over three a three week period with the earliest readings date stamped on 11/23/13. Figures 14 thru 18 are plots of the post test data.

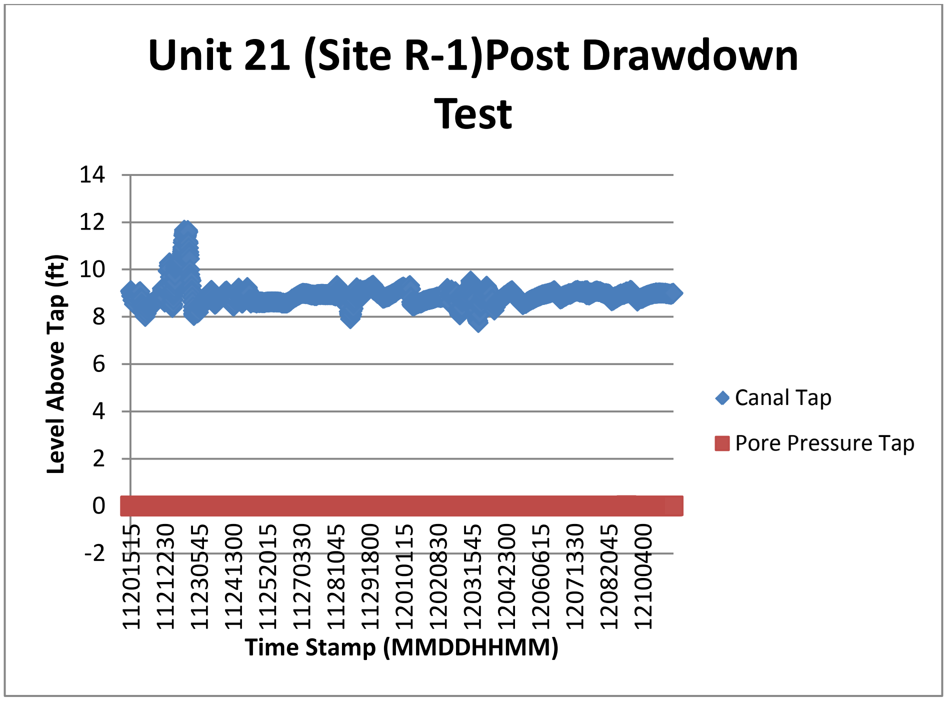


Figure 14. Site R-1 Post Test Data

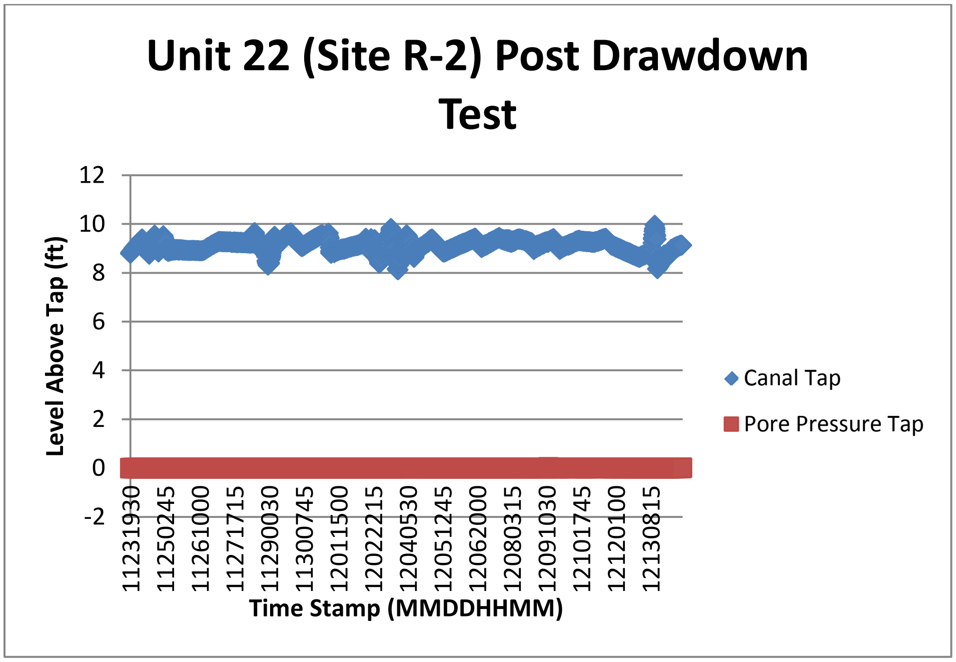


Figure 15. Site R-2 Post Test Data

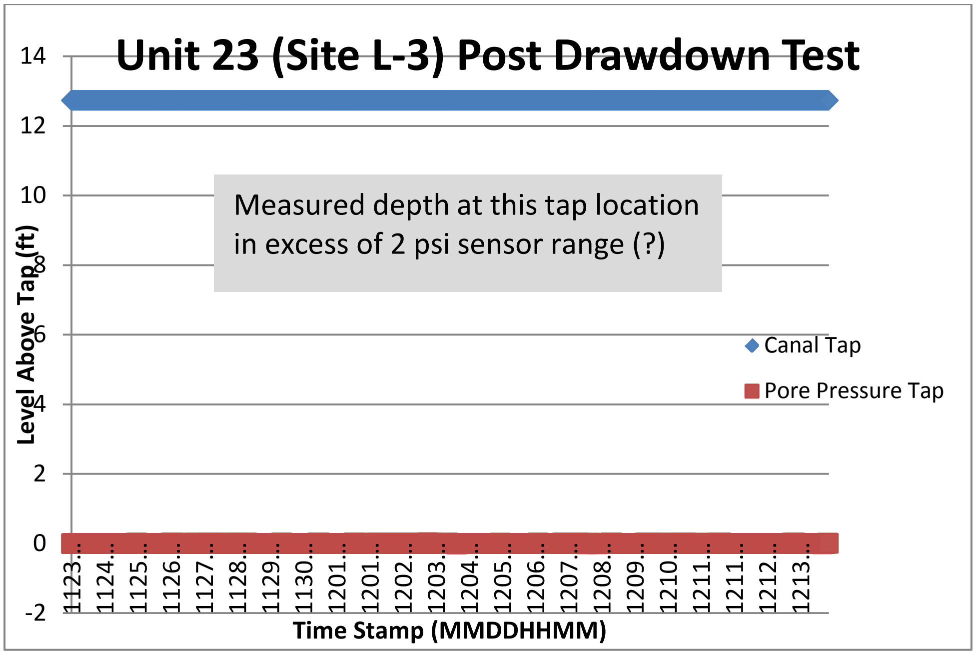


Figure 16. Site L-3 Post Test Data

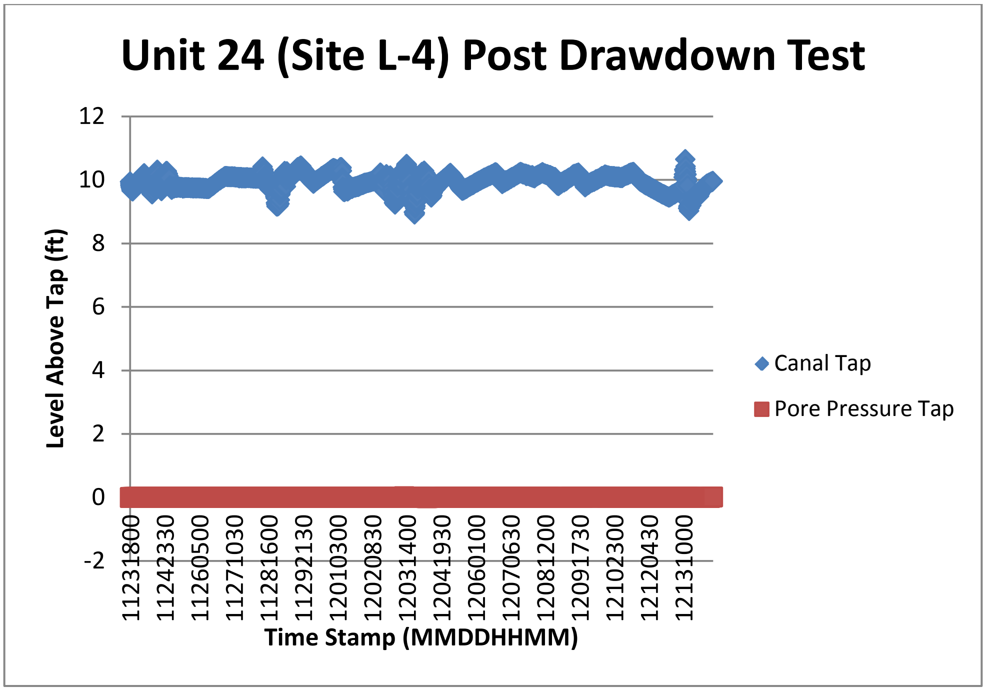


Figure 17. Site L-4 Post Test Data

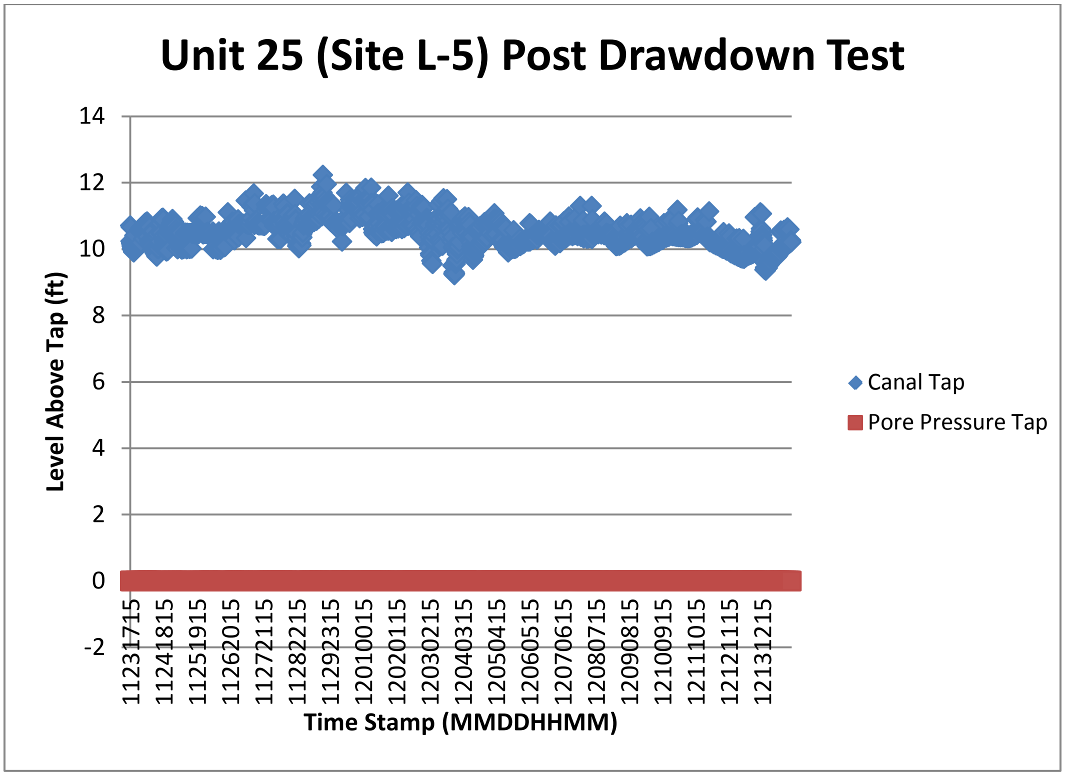


Figure 18. Site L-5 Post Test Data

In the post-test data sets from each bubbler equipped site, the pressures measured at pore pressure site tube bubbler tap are all atmospheric pressure. The flat-line canal tap pressure readings seen in Figure 15 for the L-3 site are at a value of approximately 12.5 ft. H_2O. This pressure would exceed the operating range of the bubbler sensing system pressure transducers which are rated for 0-2 psi gage pressure. The flat line canal pressure plot is the result of a saturation-level output from the sensor.

A comparison of drawdown test plots and post test plots for the respective sites – Figures 9 & 14 for the R-1 site; Figures 10 &15 for the R-2 site; Figures 11 & 16 for the L-3 site; Figures 12 & 17 for the L-4 site; and Figures 13 & 18 for the L-5 site – show that for each of the sites other than the L-3 site, the range of canal pressures in the post test data set are similar to pressures recorded as the canal was refilled at the end of the drawdown test. For the L-3 site the post-test data set is showing a pressure almost 3 ft. H_20 greater than the refill canal pressure seen in Figure 11. A clogged bubbler orifice might explain the recorded canal tap pressures at this site.

Summary

The double bubbler level sensing equipment was installed at selected tap sites to enable pore pressures at or below the canal surface elevation to be monitored in comparison with the canal level in the event pore pressures were below the canal level and could not be detected in the sight tubes. The electronically obtained data from these sites shows that groundwater levels behind the canal lining were not detected at or above the elevation of the sight tube taps at any of the bubbler-equipped sites during either the drawdown test or in post-test data record. By the end of the post-test data the canal had been continuously full for almost 6 weeks following the completion of the drawdown test.

The bubbler-sensed pressures were confirmed by observations, as dyed water was poured into sight tubes during the drawdown tests. While consistent measured and observed results were obtained during the drawdown test at all pore pressure monitoring stations, a degree of uncertainty must recognized given the modest number of total sites (13) and the spacing between sites (approximately one mile).

The collected data showed that during this testing period a phreatic surface was not present beneath the canal lining at the pressure tap locations. Thus, the driving force needed to cause differential loading and failure of the canal lining during a rapid drawdown event was not present. However, there is still the potential for a phreatic surface to exist in the future due to several factors:

- potential differences in weather and climate conditions,
- weathering or cracking of the canal lining as it ages,
- variations in embankment conditions that were not detected at the limited sampling locations included in this test, or
- a phreatic surface behind the canal lining at an elevation below the pressure taps.

Because no phreatic surface was present, the collected data does not provide any estimate of the rate of pore pressure drop during a canal drawdown event if a saturated zone does exist behind the canal lining in the future. The observed rate of water level drop in the sight tubes that exhibited slow drainage are not necessarily an indicator of the drawdown rate, since pouring water into the tubes did not actually saturate the soil; the rate of water level drop in these tubes is most likely a function of local conditions in the immediate vicinity of each tap.

The observations made during this drawdown test and associated uncertainties were considered during the development of modified drawdown criteria for this canal. The new criteria were based on an assessment of potential risk, considering both probabilities and consequences of failure. Appendix C includes a copy of the newly recommended drawdown criteria developed by the Technical Service Center's Water Conveyance Group. These criteria are specific to this canal and should not be applied to any other situation.

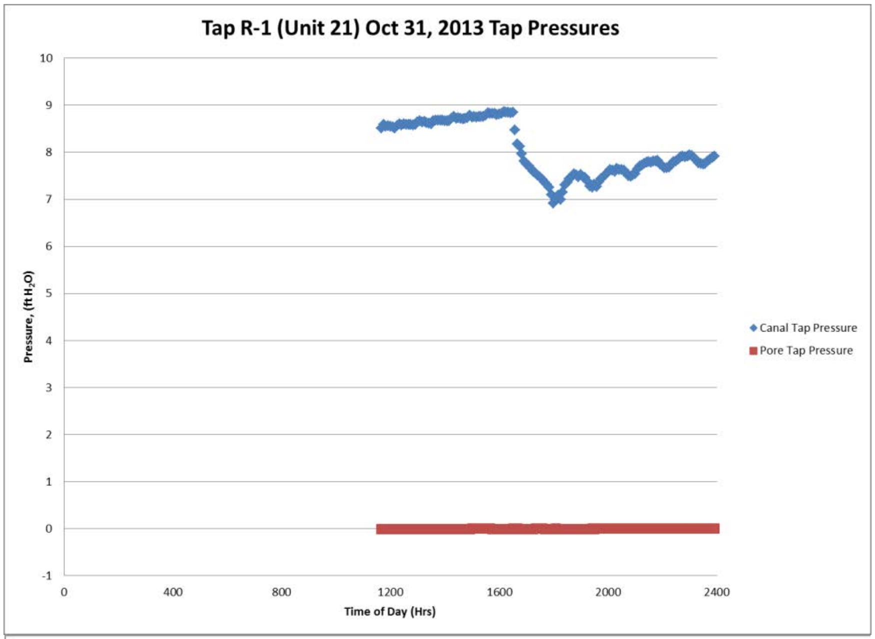
References

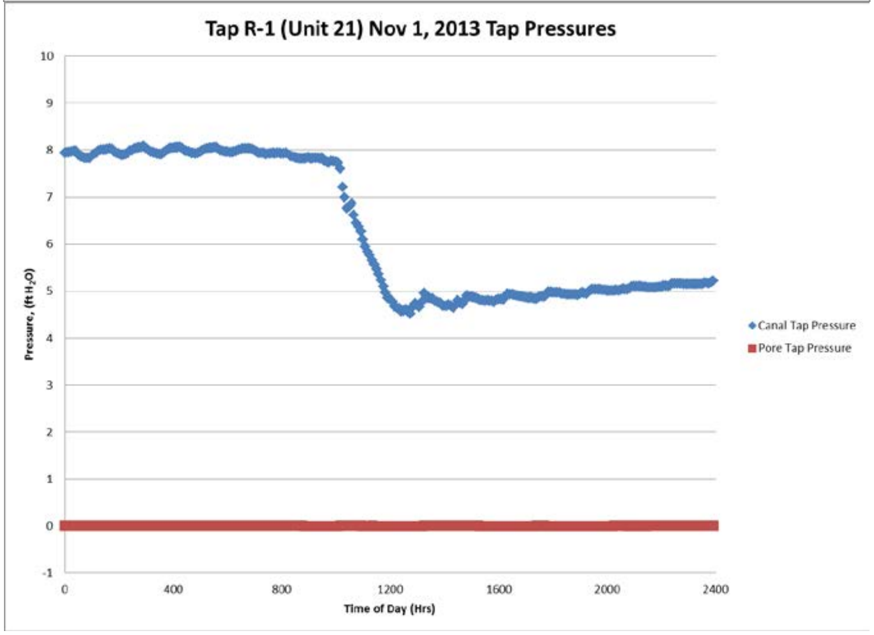
Lung, R. All American Canal Drop 2 Reservoir Investigation. U.S. Department of Interior, Bureau of Reclamation, Lower Colorado Region, Boulder City NE. July 2005.

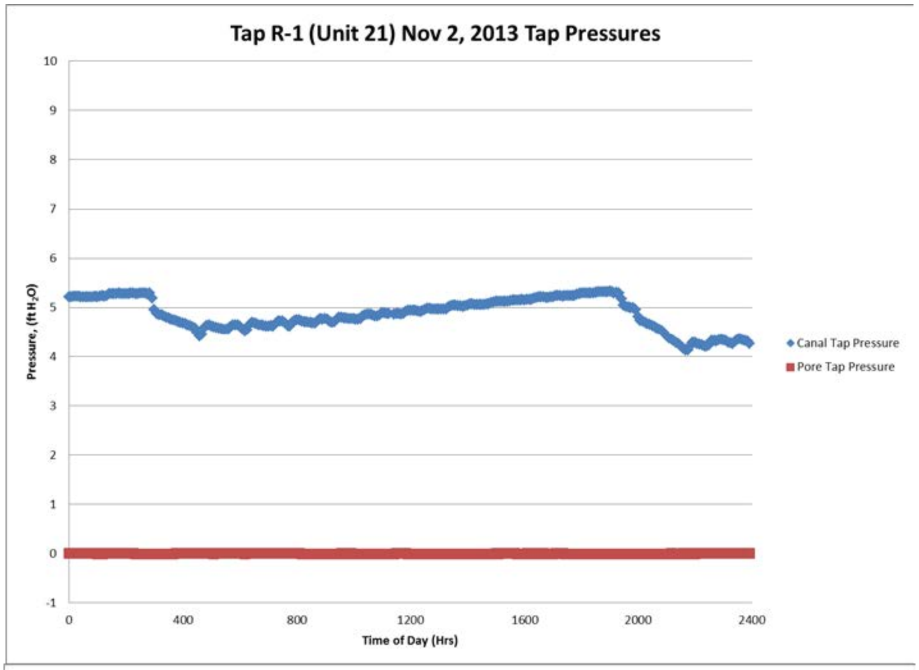
Wahl, T.L. and Duke, W.C. Canal Lining Drawdown Tests and Development of New Drawdown Criteria for the Charles Hansen Feeder Canal Colorado Big Thompson Project. Hydraulic Laboratory Technical Memorandum PAP-1071. U.S. Department of the Interior. Bureau of Reclamation. Technical Service Center. Hydraulic Investigations and Laboratory Services Group. Denver CO. December 2012.

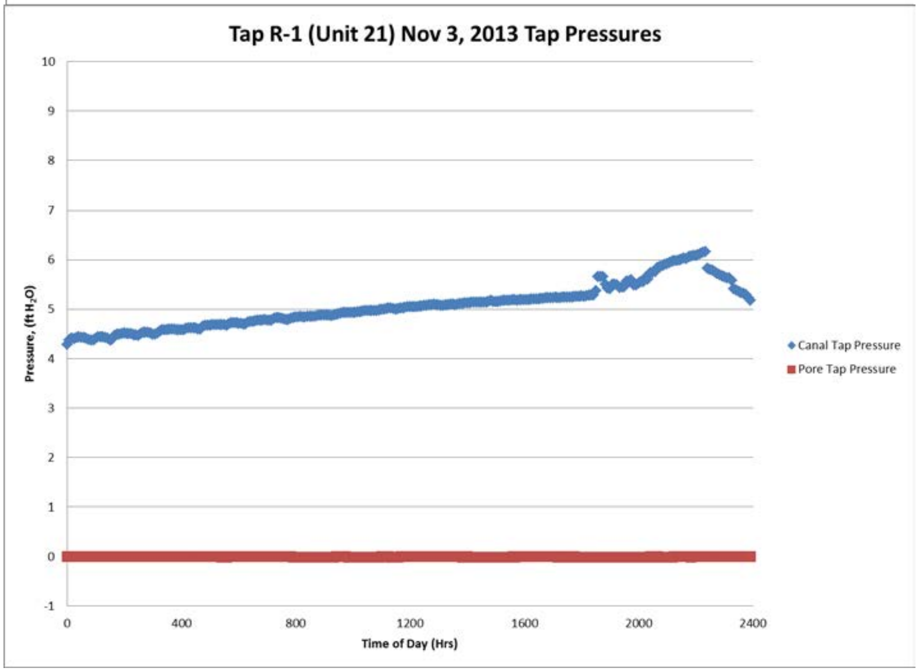
Appendix A

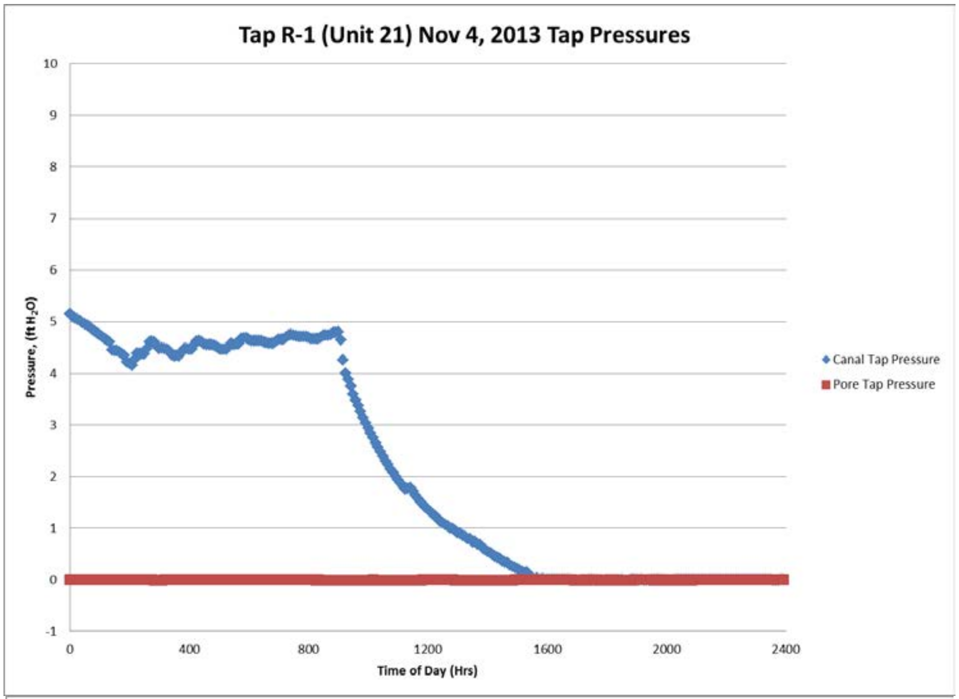
Plotted Data in 24 Hour Segments
Site R-1 (Unit 21)

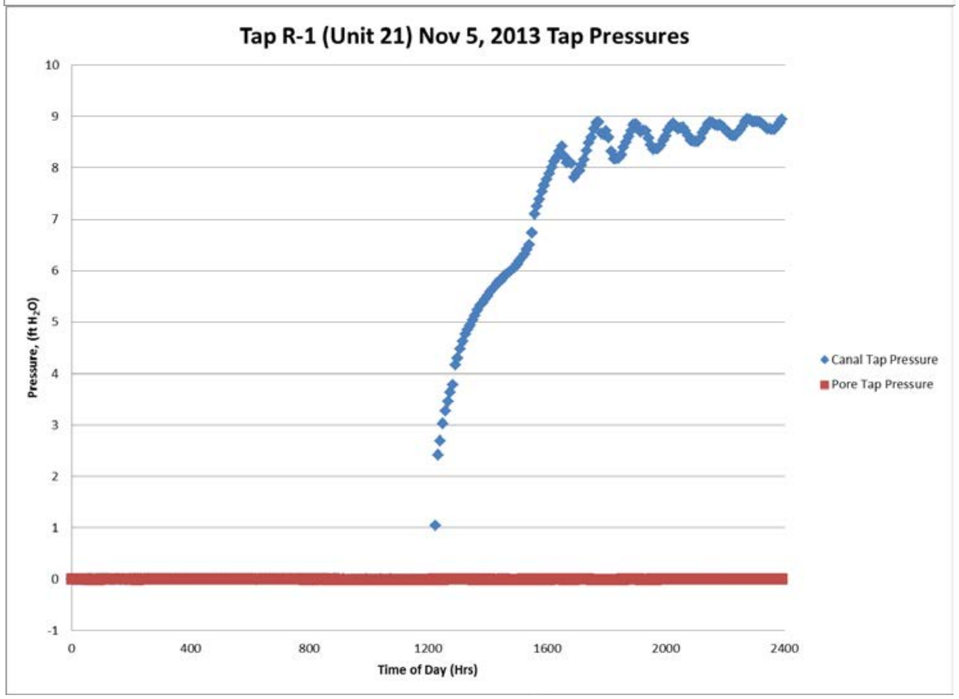




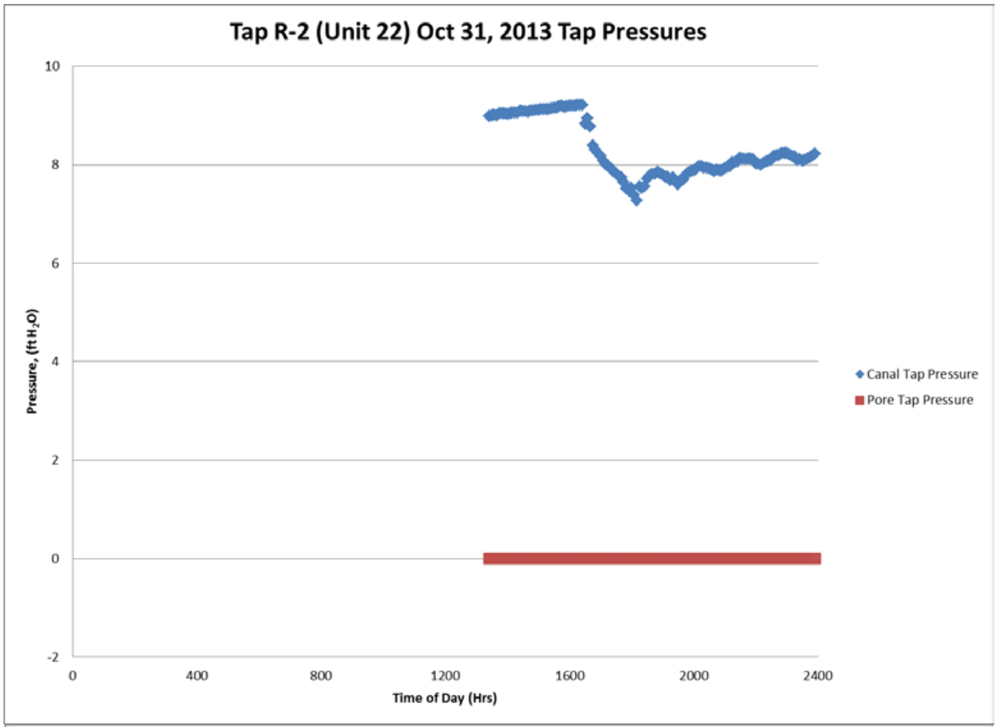

Tap R-1 (Unit 21) Nov 2, 2013 Tap Pressures
10
9
8
7
6
5
4
3
2
1
0
-1
Pressure, (ft H2O)
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

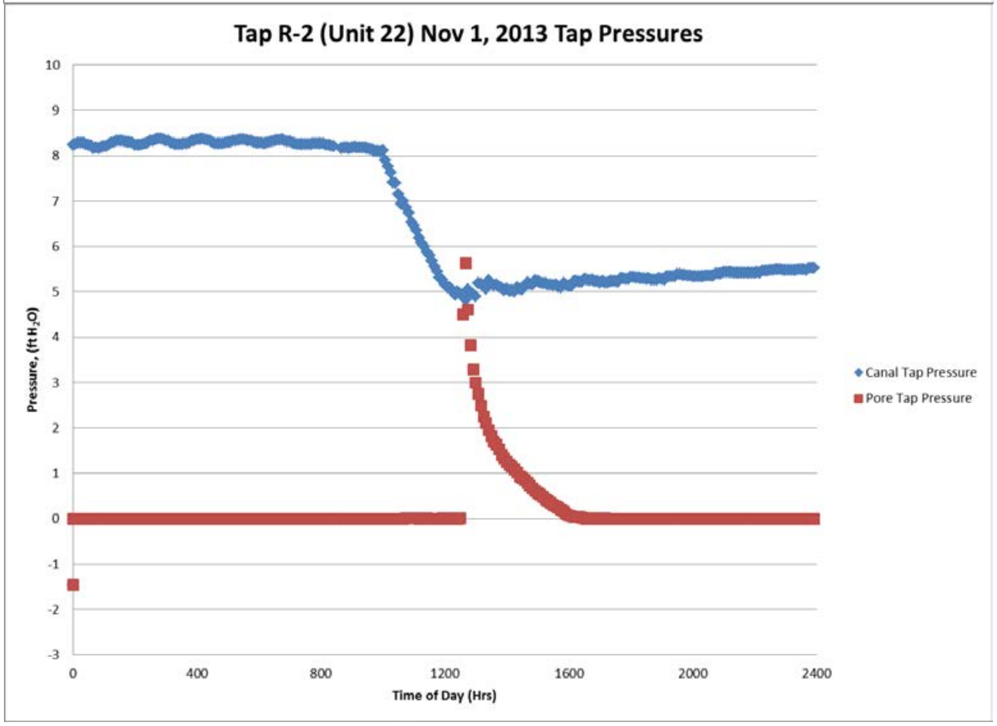

Tap R-1 (Unit 21) Nov 3, 2013 Tap Pressures
10
9
8
7
6
5
4
3
2
1
0
-1
Pressure, (ft H2O)
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

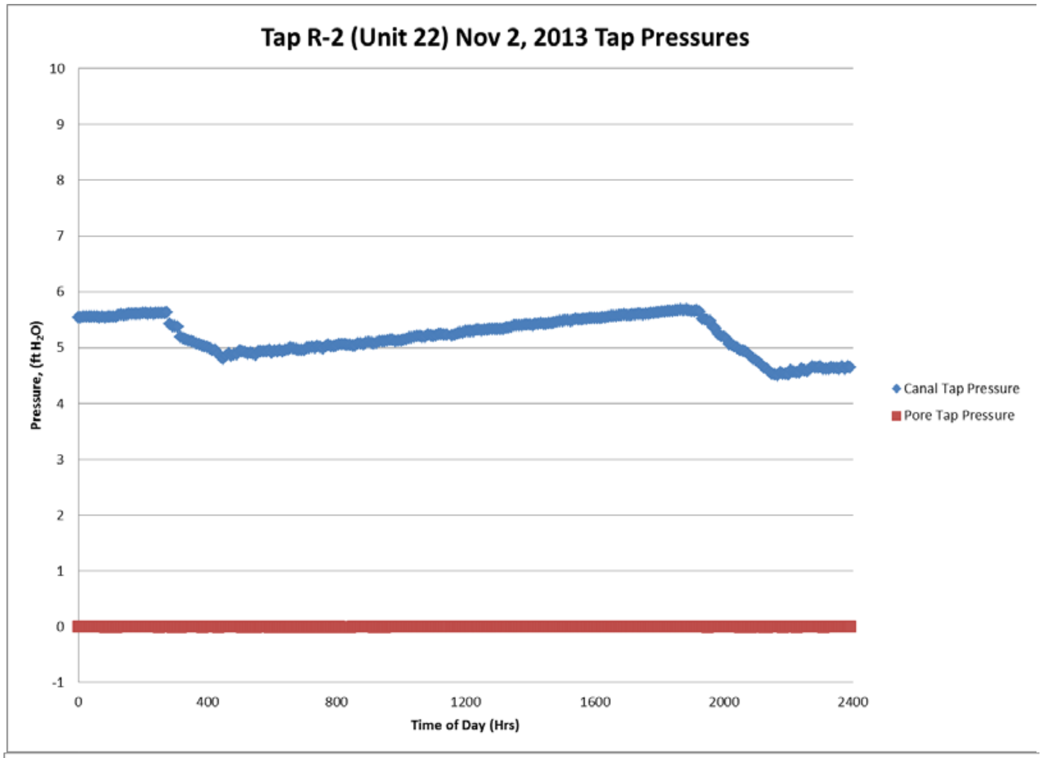

Tap R-1 (Unit 21) Nov 4, 2013 Tap Pressures
Pressure, (ft H_2O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

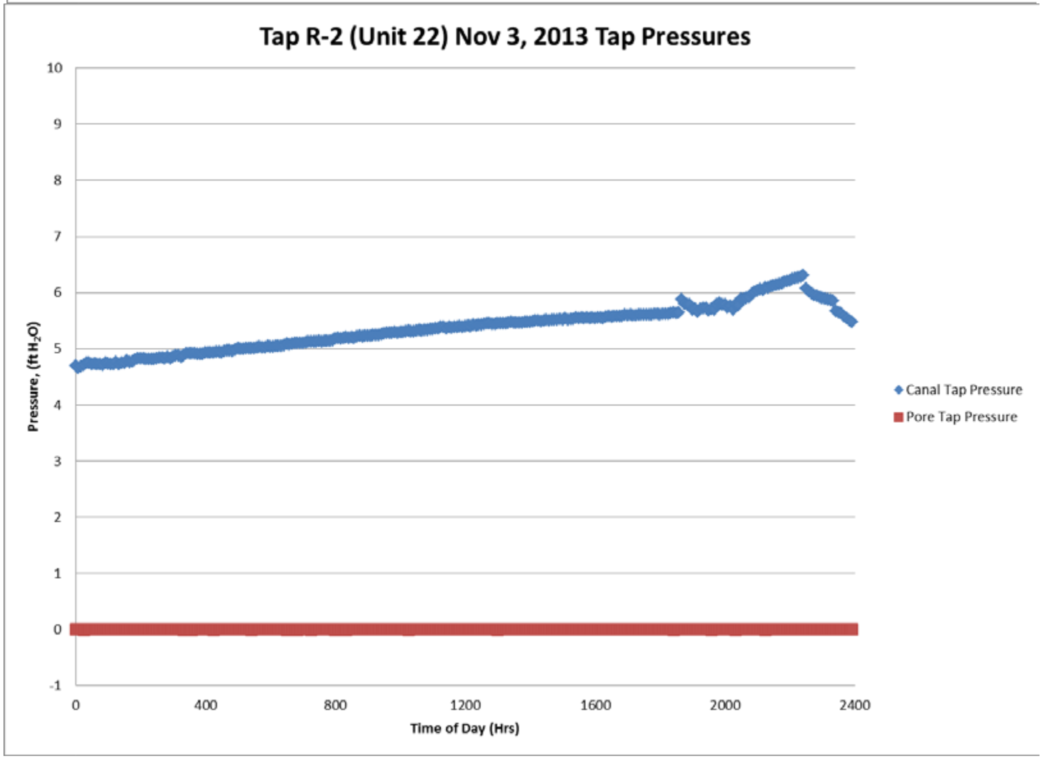

Tap R-1 (Unit 21) Nov 5, 2013 Tap Pressures
Pressure, (ft H_2O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

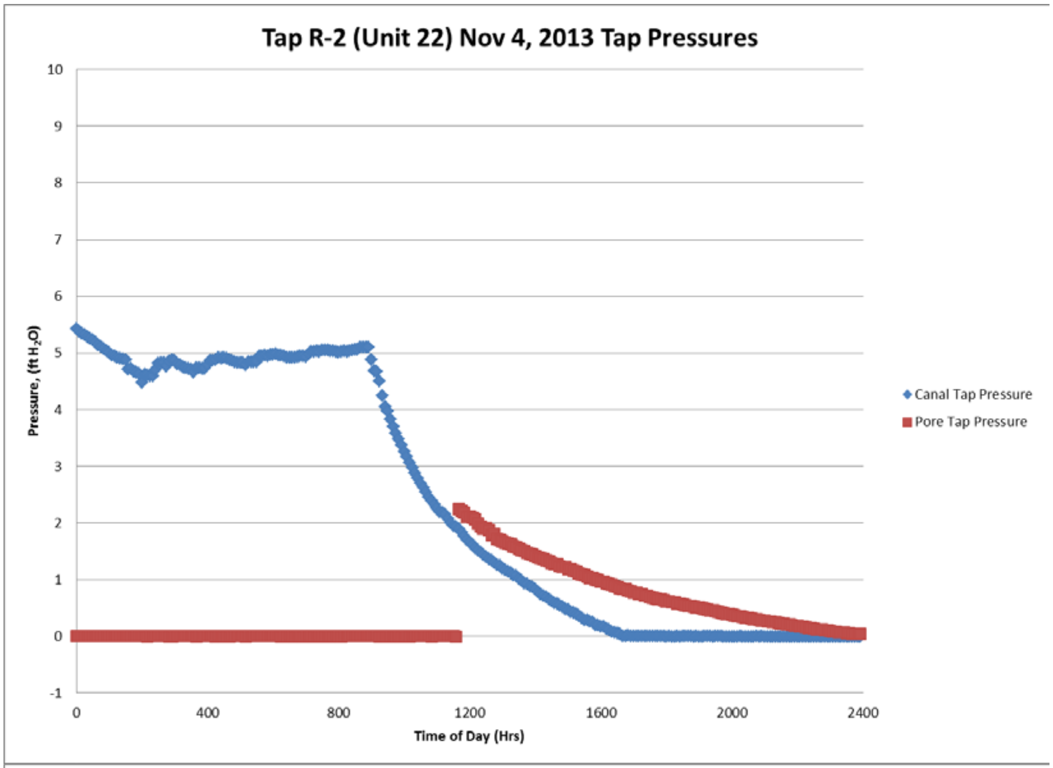
Site R-2 (Unit 22)

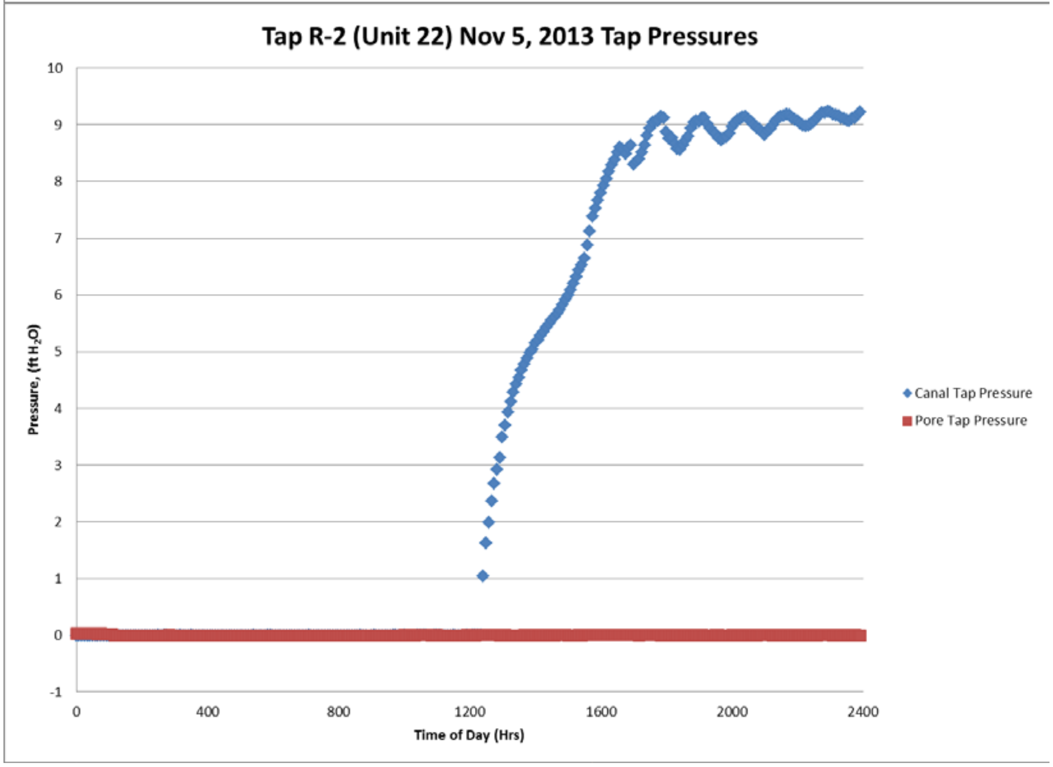




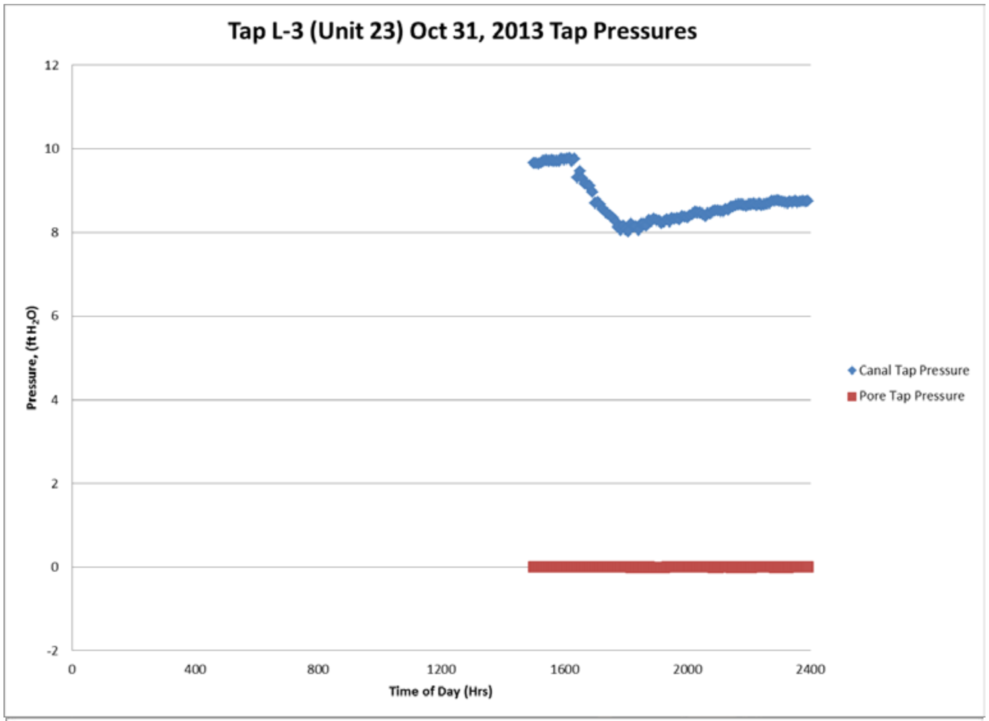

Tap R-2 (Unit 22) Nov 2, 2013 Tap Pressures
Pressure, (ft H$_2$O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

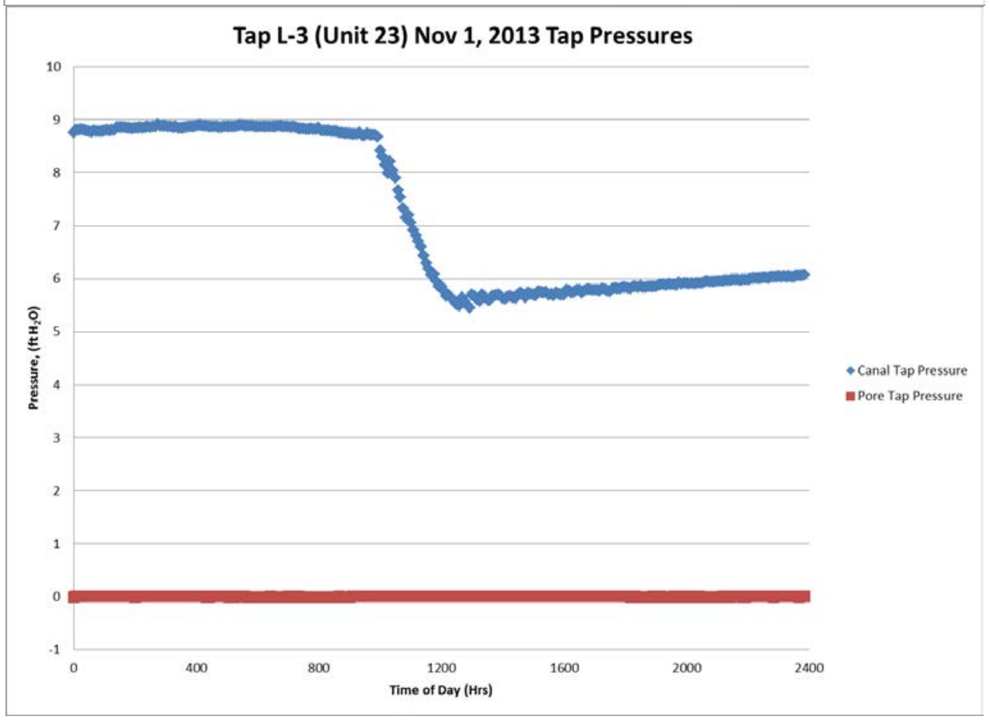

Tap R-2 (Unit 22) Nov 3, 2013 Tap Pressures
Pressure, (ft H$_2$O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

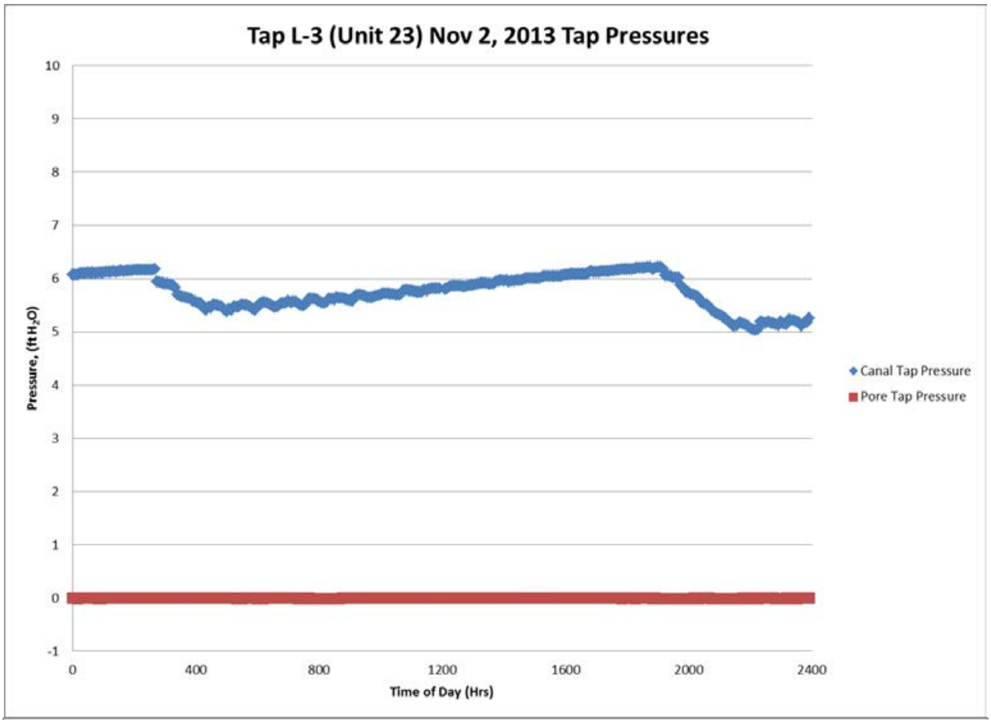

Tap R-2 (Unit 22) Nov 4, 2013 Tap Pressures
Pressure, (ft H$_2$O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

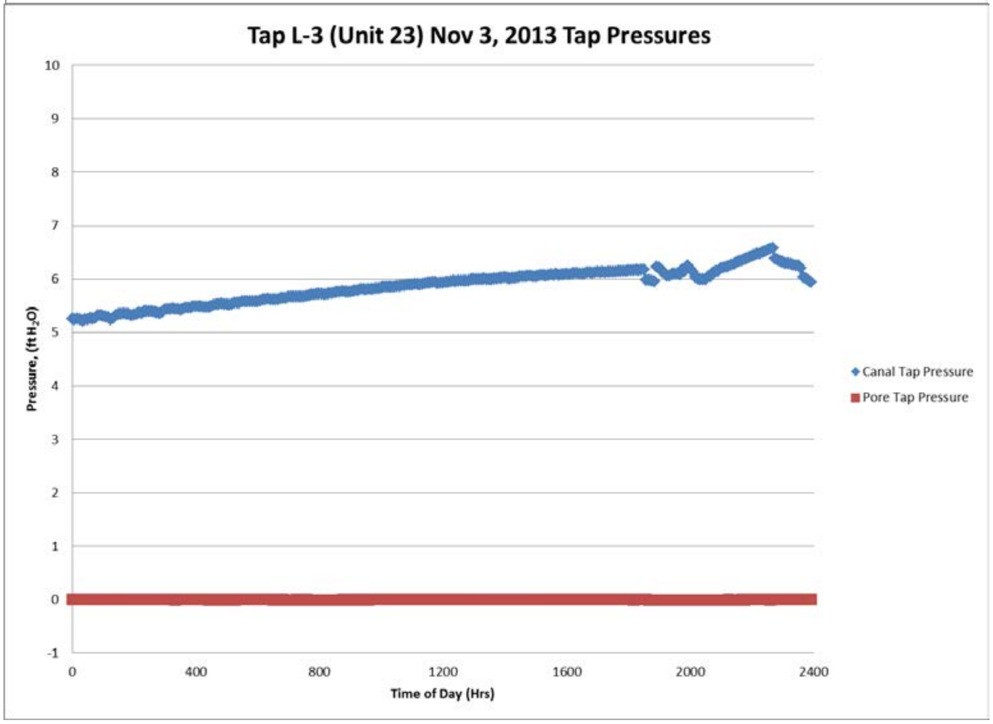

Tap R-2 (Unit 22) Nov 5, 2013 Tap Pressures
Pressure, (ft H$_2$O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

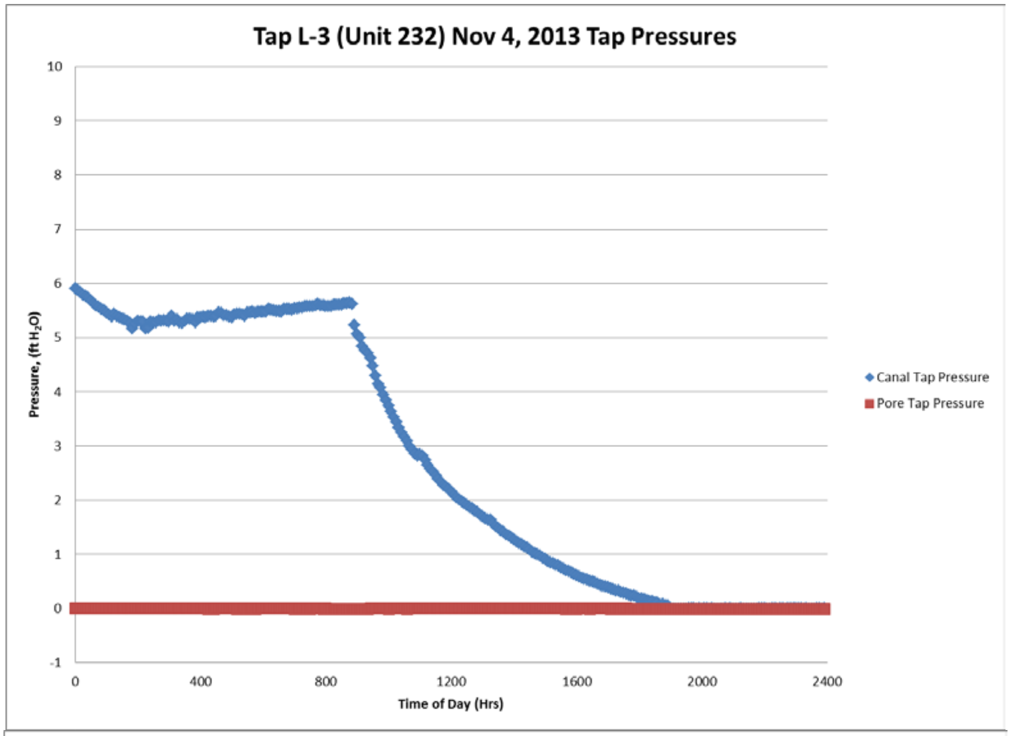
Site L-3 (Unit 23)

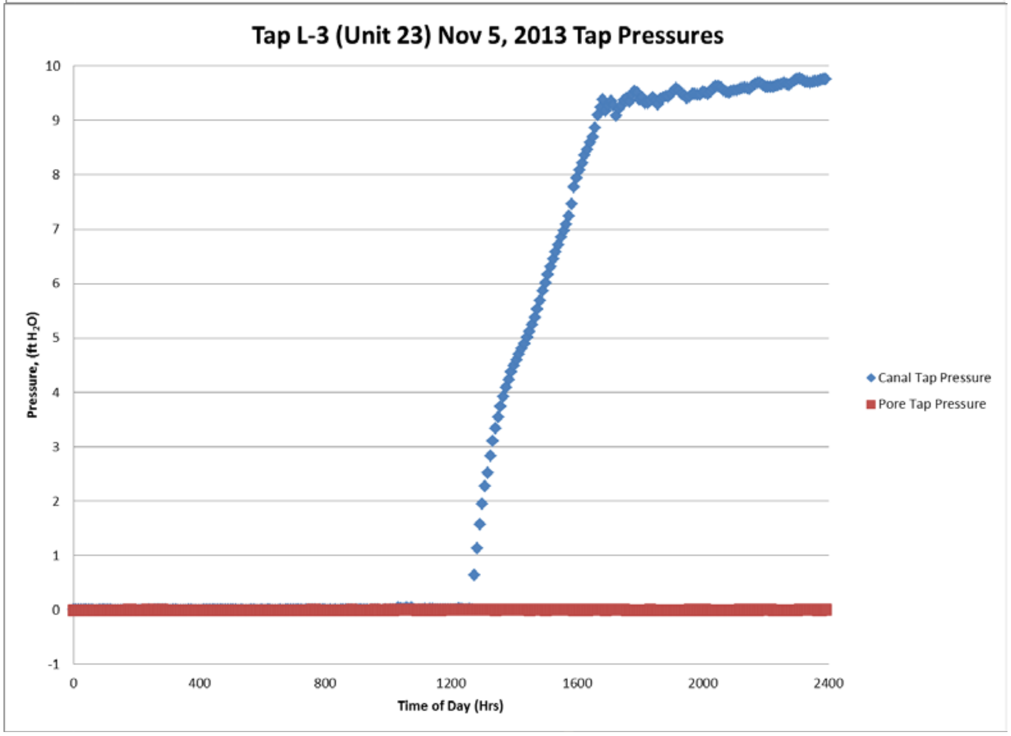




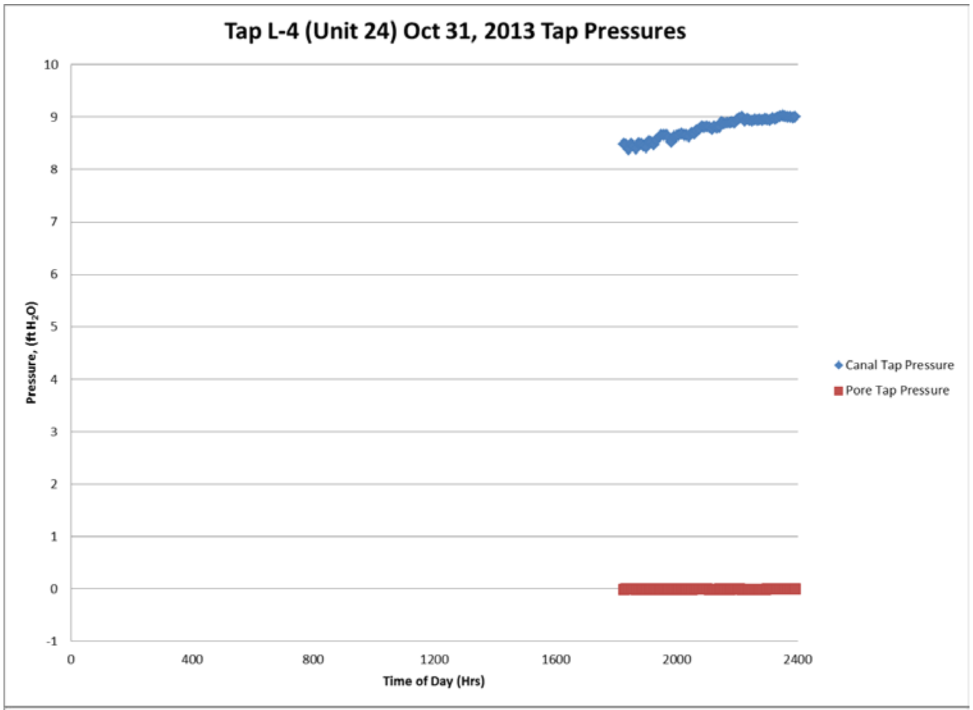

Tap L-3 (Unit 23) Nov 2, 2013 Tap Pressures
10
9
8
7
6
5
4
3
2
1
0
-1
Pressure, (ft H2O)
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
Canal Tap Pressure
Pore Tap Pressure

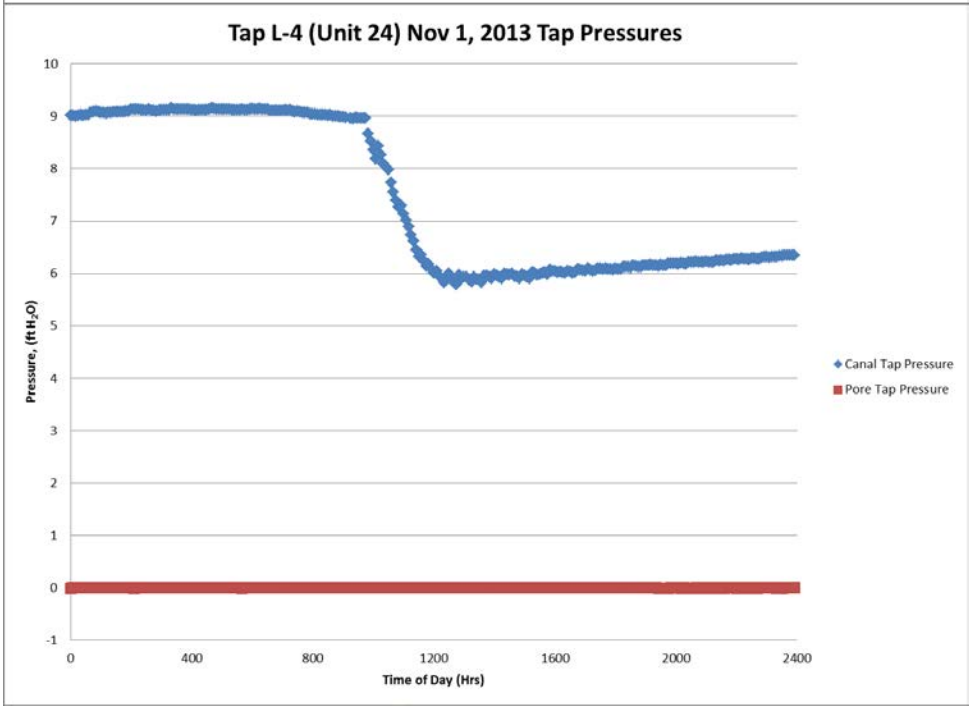

Tap L-3 (Unit 23) Nov 3, 2013 Tap Pressures
10
9
8
7
6
5
4
3
2
1
0
-1
Pressure, (ft H2O)
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
Canal Tap Pressure
Pore Tap Pressure

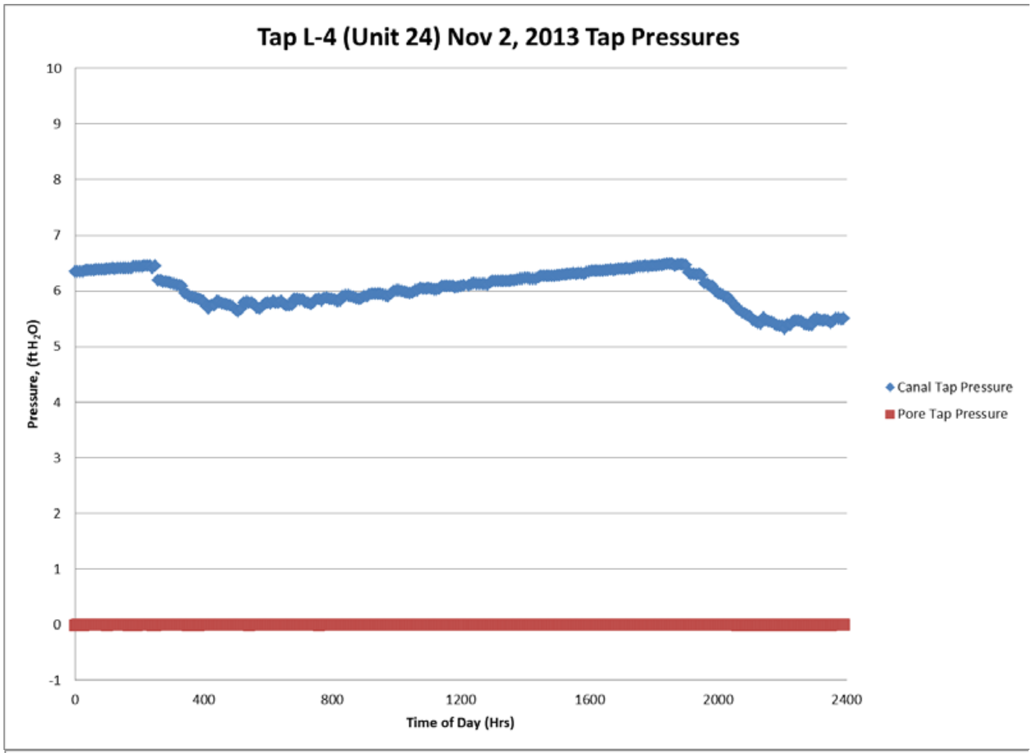

Tap L-3 (Unit 232) Nov 4, 2013 Tap Pressures
Pressure, (ft H₂O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
Canal Tap Pressure
Pore Tap Pressure

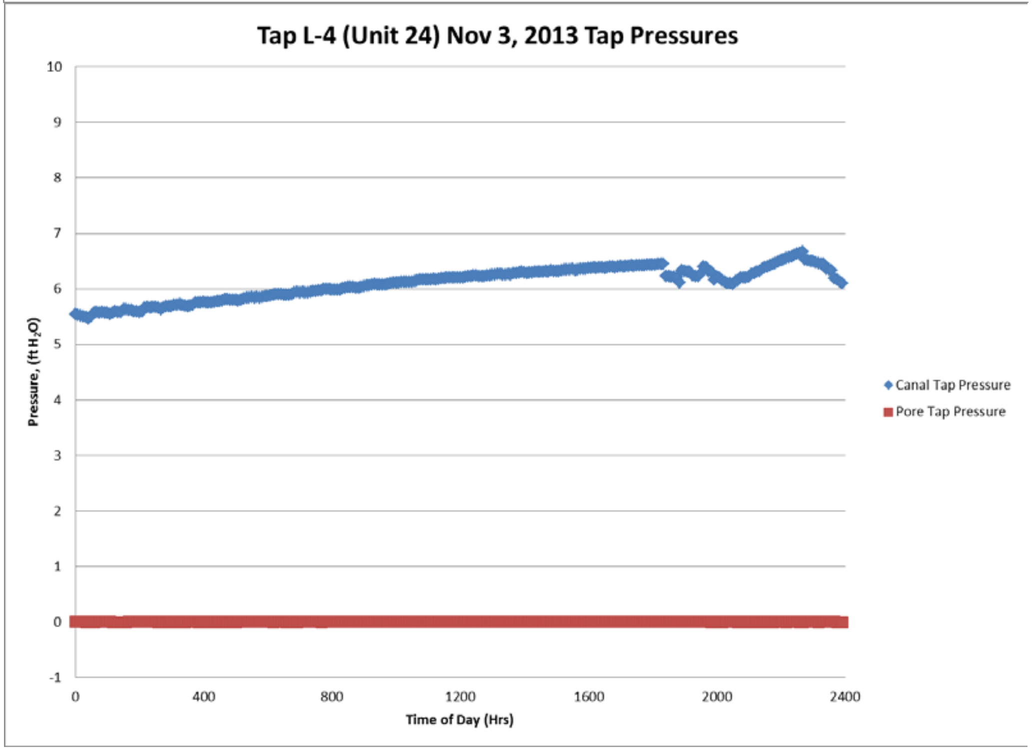

Tap L-3 (Unit 23) Nov 5, 2013 Tap Pressures
Pressure, (ft H₂O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
Canal Tap Pressure
Pore Tap Pressure

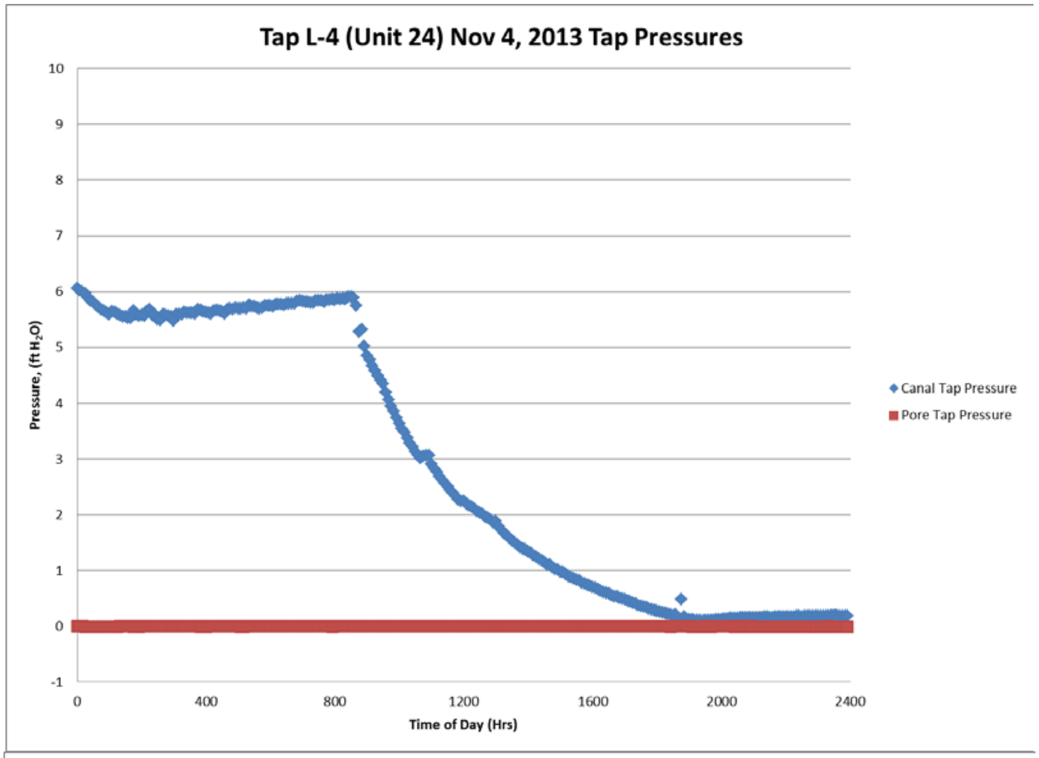
Site L-4 (Unit 24)

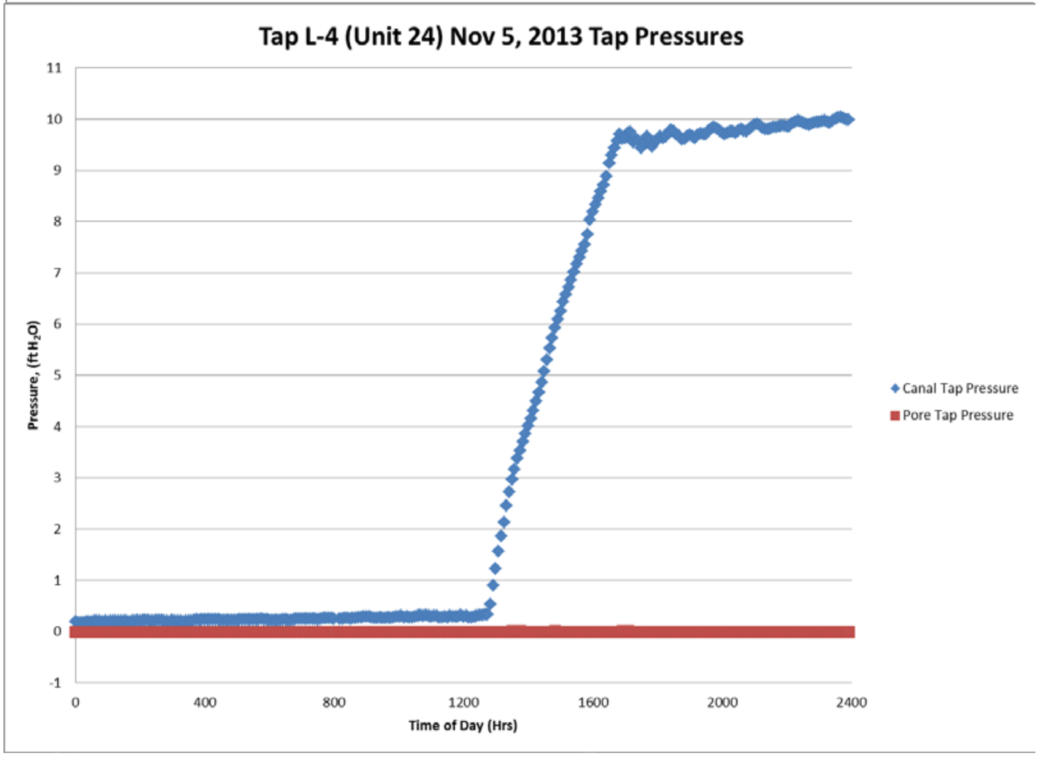




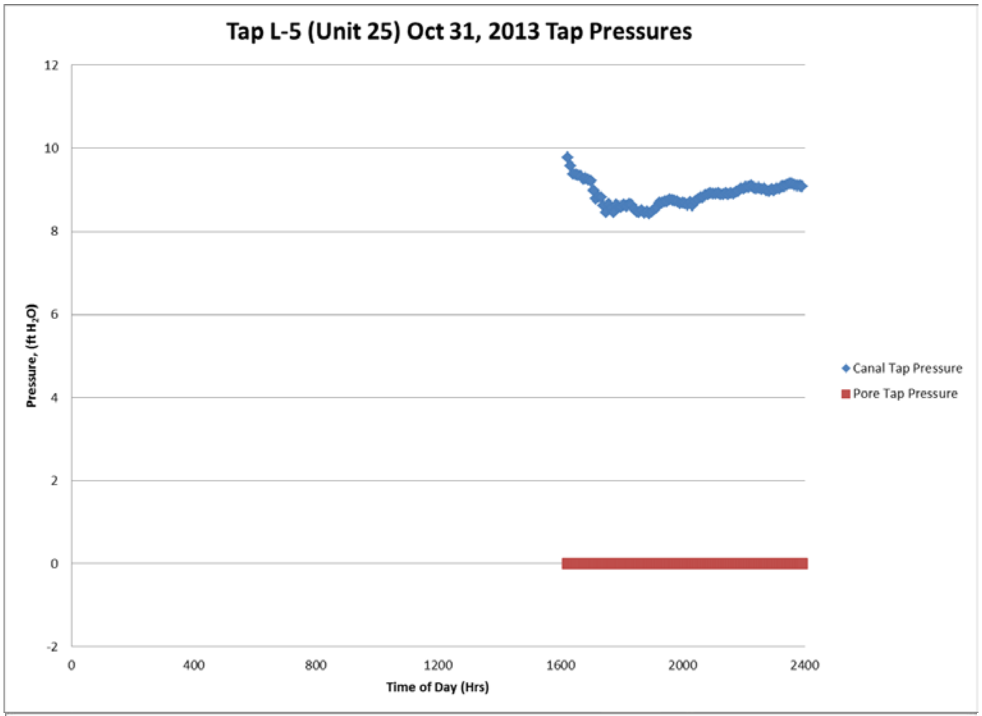

Tap L-4 (Unit 24) Nov 2, 2013 Tap Pressures
Pressure, (ft H_2O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

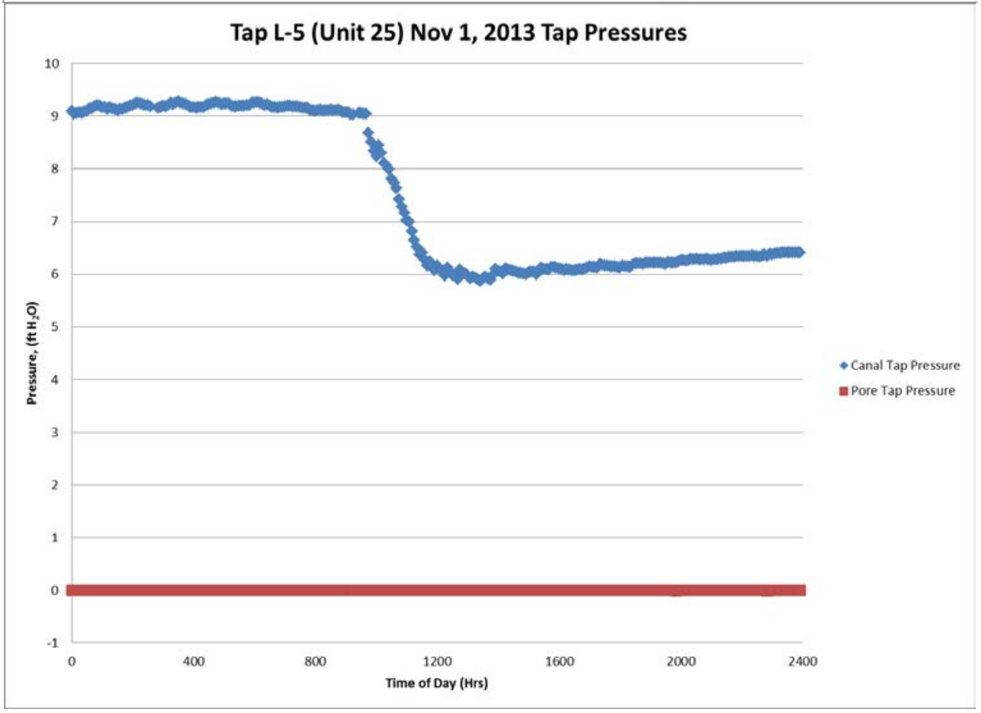

Tap L-4 (Unit 24) Nov 3, 2013 Tap Pressures
Pressure, (ft H_2O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

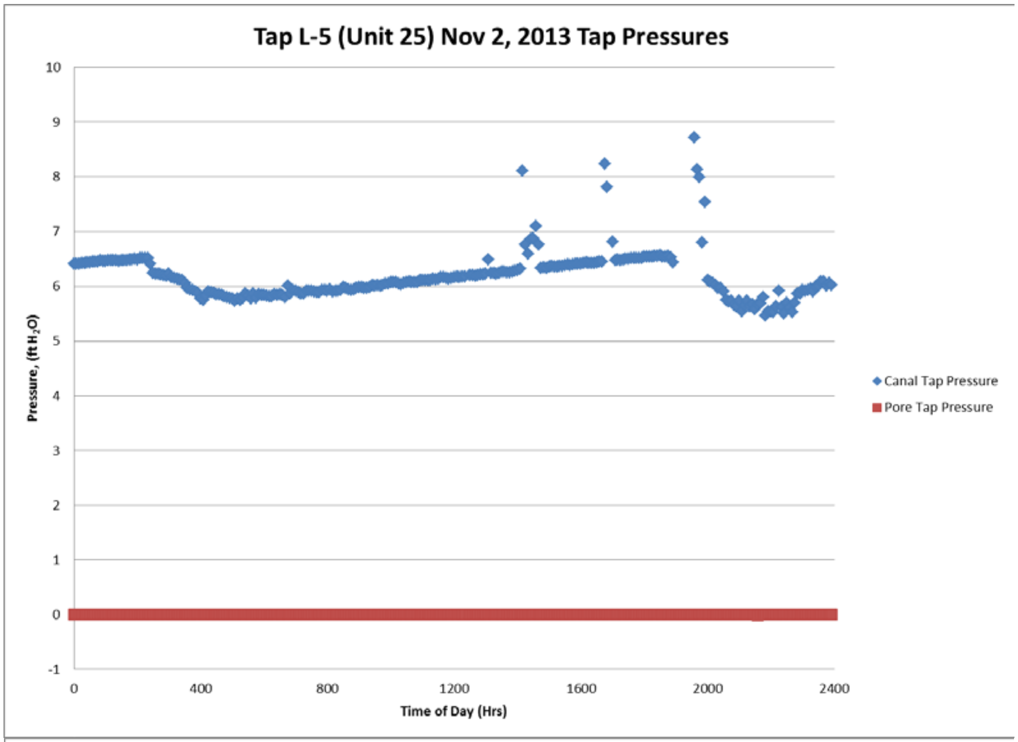

Tap L-4 (Unit 24) Nov 4, 2013 Tap Pressures
Pressure, (ft H2O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
Canal Tap Pressure
Pore Tap Pressure

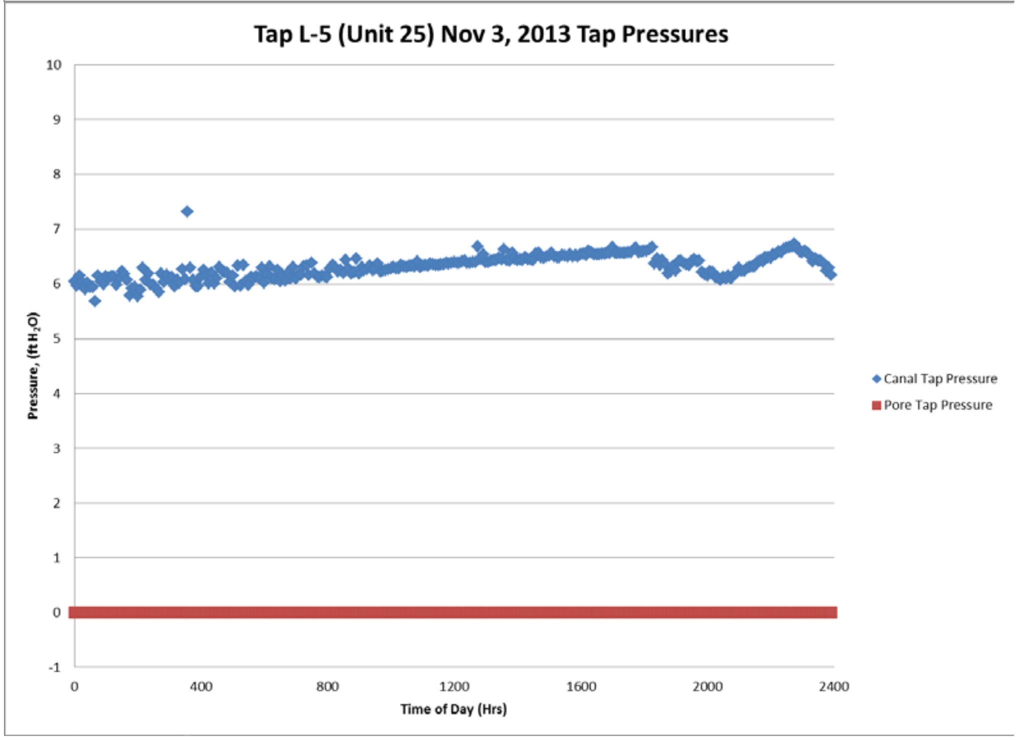

Tap L-4 (Unit 24) Nov 5, 2013 Tap Pressures
Pressure, (ft H2O)
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
Canal Tap Pressure
Pore Tap Pressure

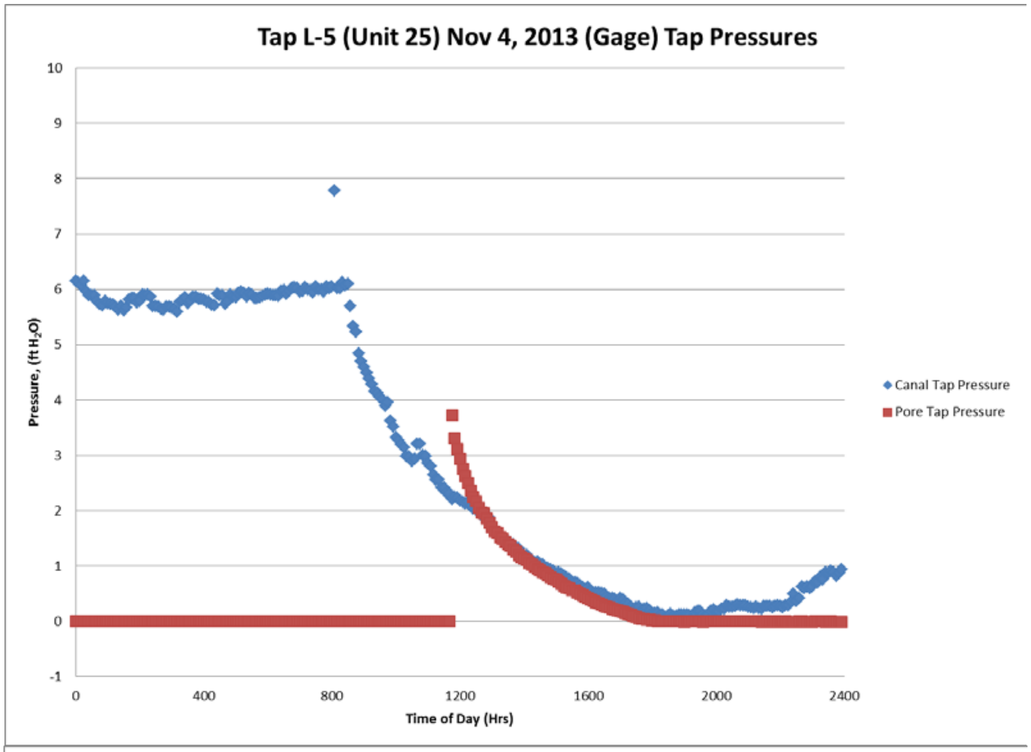
Site L-5 (Unit 25)

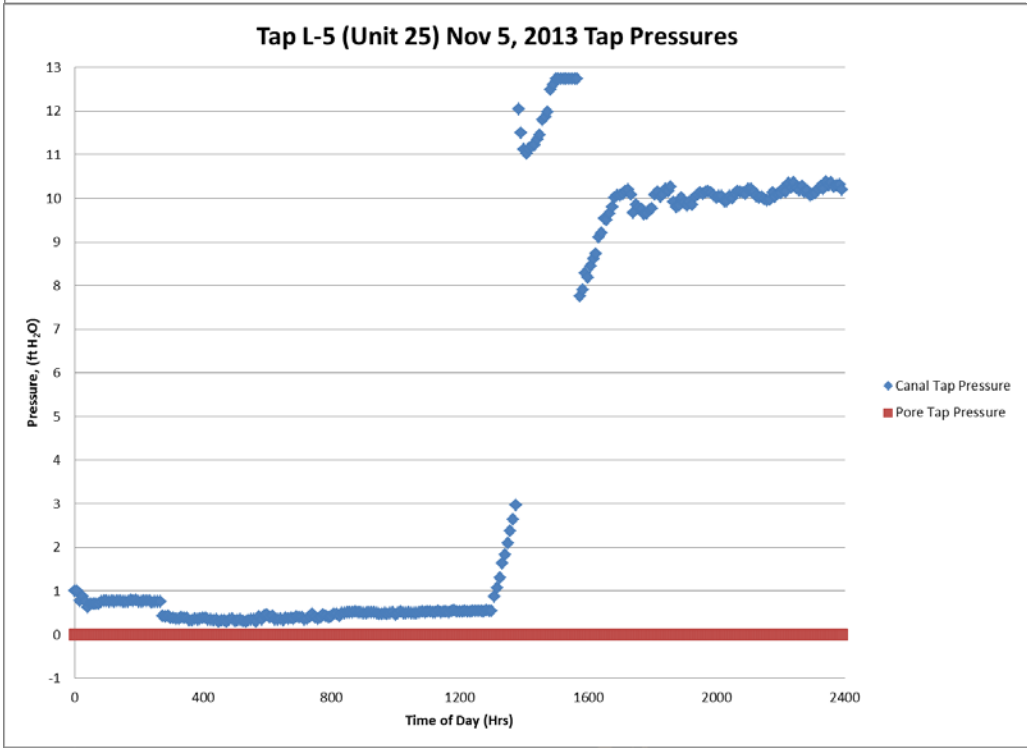





Tap L-5 (Unit 25) Nov 2, 2013 Tap Pressures
Pressure, (ft H_2O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure


Tap L-5 (Unit 25) Nov 3, 2013 Tap Pressures
Pressure, (ft H_2O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure


Tap L-5 (Unit 25) Nov 4, 2013 (Gage) Tap Pressures
Pressure, (ft H_2O)
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure


Tap L-5 (Unit 25) Nov 5, 2013 Tap Pressures
Pressure, (ft H_2O)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0
400
800
1200
1600
2000
2400
Time of Day (Hrs)
◆ Canal Tap Pressure
■ Pore Tap Pressure

Appendix B

Soil Characteristics Information
Pre-Construction Soils Investigation Data

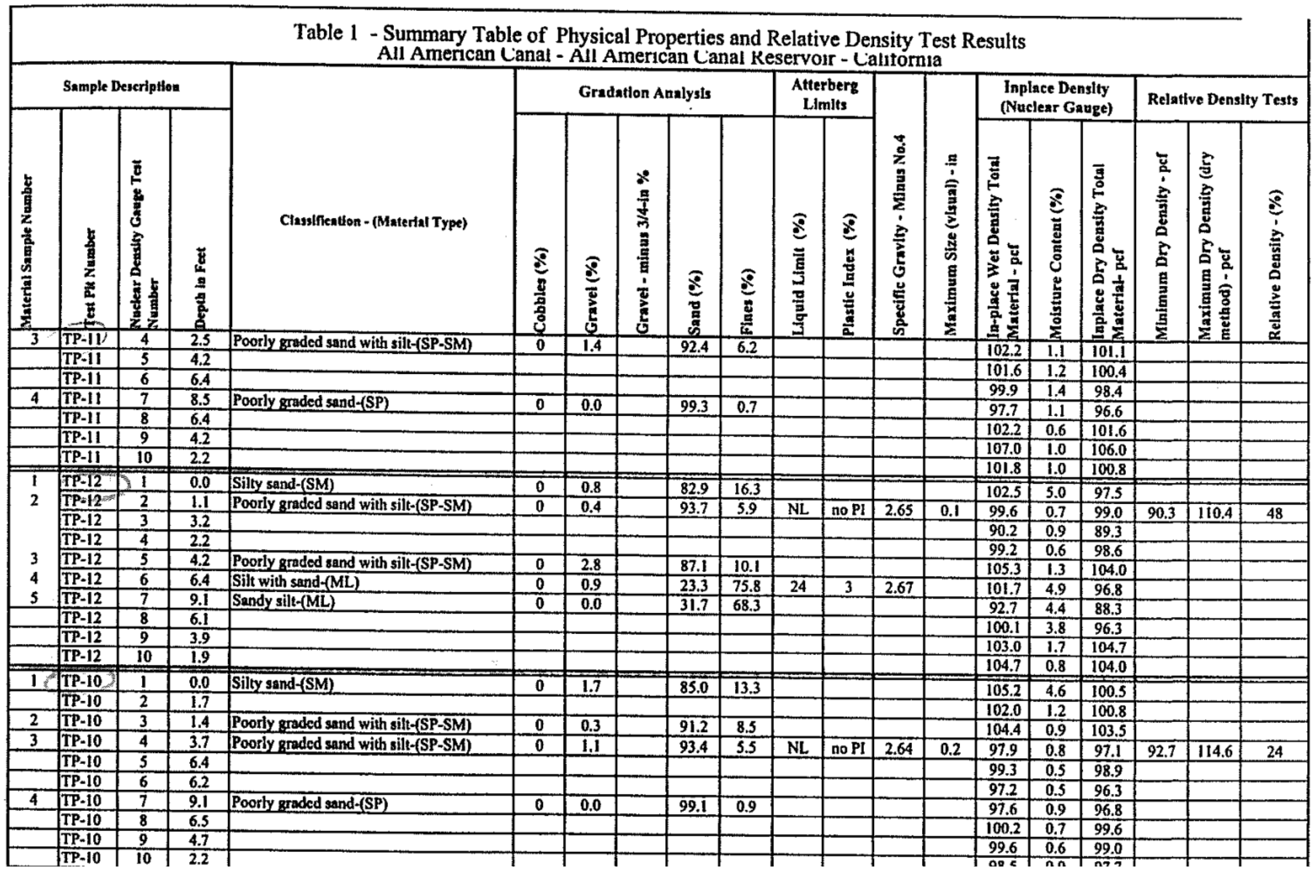
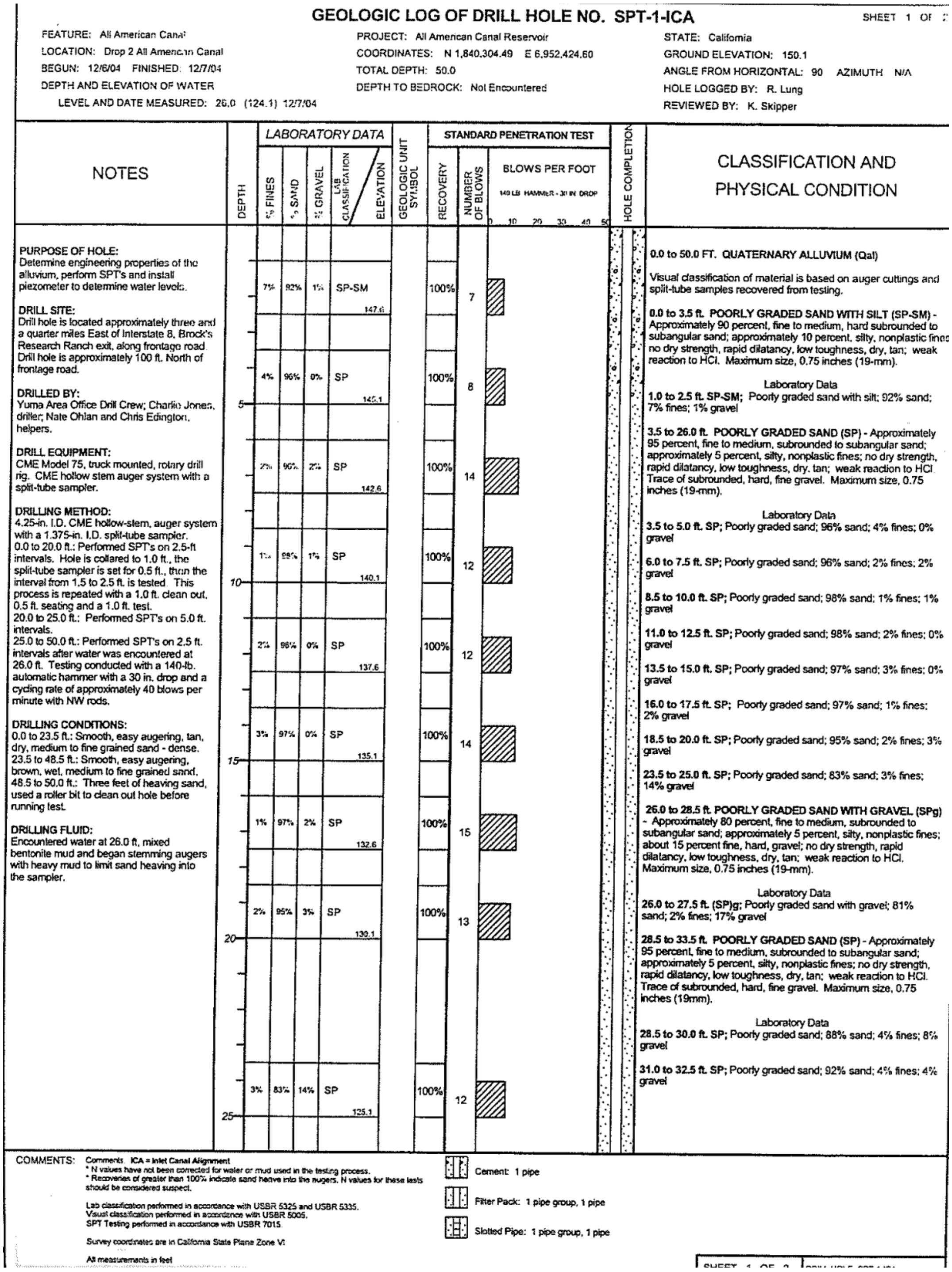


Table 1 - Summary Table of Physical Properties and Relative Density Test Results
All American Canal - All American Canal Reservoir - California

Sample Description				Classification - (Material Type)	Gradation Analysis					Atterberg Limits		Specific Gravity - Minus No.4	Maximum Size (visual) - in	Inplace Density (Nuclear Gauge)			Relative Density Tests		
Material Sample Number	Test Pit Number	Nuclear Density Gauge Test Number	Depth in Feet		Cobbles (%)	Gravel (%)	Gravel - minus 3/4-in %	Sand (%)	Fines (%)	Liquid Limit (%)	Plastic Index (%)			In-place Wet Density Total Material - pcf	Moisture Content (%)	Inplace Dry Density Total Material- pcf	Minimum Dry Density - pcf	Maximum Dry Density (dry method) - pcf	Relative Density - (%)
3	TP-11	4	2.5	Poorly graded sand with silt-(SP-SM)	0	1.4		92.4	6.2					102.2	1.1	101.1			
	TP-11	5	4.2											101.6	1.2	100.4			
	TP-11	6	6.4											99.9	1.4	98.4			
4	TP-11	7	8.5	Poorly graded sand-(SP)	0	0.0		99.3	0.7					97.7	1.1	96.6			
	TP-11	8	6.4											102.2	0.6	101.6			
	TP-11	9	4.2											107.0	1.0	106.0			
	TP-11	10	2.2											101.8	1.0	100.8			
1	TP-12	1	0.0	Silty sand-(SM)	0	0.8		82.9	16.3					102.5	5.0	97.5			
2	TP-12	2	1.1	Poorly graded sand with silt-(SP-SM)	0	0.4		93.7	5.9	NL	no PI	2.65	0.1	99.6	0.7	99.0	90.3	110.4	48
	TP-12	3	3.2											90.2	0.9	89.3			
	TP-12	4	2.2											99.2	0.6	98.6			
3	TP-12	5	4.2	Poorly graded sand with silt-(SP-SM)	0	2.8		87.1	10.1					105.3	1.3	104.0			
4	TP-12	6	6.4	Silt with sand-(ML)	0	0.9		23.3	75.8	24	3	2.67		101.7	4.9	96.8			
5	TP-12	7	9.1	Sandy silt-(ML)	0	0.0		31.7	68.3					92.7	4.4	88.3			
	TP-12	8	6.1											100.1	3.8	96.3			
	TP-12	9	3.9											103.0	1.7	104.7			
	TP-12	10	1.9											104.7	0.8	104.0			
1	TP-10	1	0.0	Silty sand-(SM)	0	1.7		85.0	13.3					105.2	4.6	100.5			
	TP-10	2	1.7											102.0	1.2	100.8			
2	TP-10	3	1.4	Poorly graded sand with silt-(SP-SM)	0	0.3		91.2	8.5					104.4	0.9	103.5			
3	TP-10	4	3.7	Poorly graded sand with silt-(SP-SM)	0	1.1		93.4	5.5	NL	no PI	2.64	0.2	97.9	0.8	97.1	92.7	114.6	24
	TP-10	5	6.4											99.3	0.5	98.9			
	TP-10	6	6.2											97.2	0.5	96.3			
4	TP-10	7	9.1	Poorly graded sand-(SP)	0	0.0		99.1	0.9					97.6	0.9	96.8			
	TP-10	8	6.5											100.2	0.7	99.6			
	TP-10	9	4.7											99.6	0.6	99.0			
	TP-10	10	2.2																



GEOLOGIC LOG OF DRILL HOLE NO. SPT-1-ICA

SHEET 1 OF

FEATURE: All American Canal
LOCATION: Drop 2 All American Canal
BEGUN: 12/6/04 FINISHED: 12/7/04
DEPTH AND ELEVATION OF WATER
LEVEL AND DATE MEASURED: 26.0 (124.1) 12/7/04

PROJECT: All American Canal Reservoir
COORDINATES: N 1,840,304.49 E 6,952,424.60
TOTAL DEPTH: 50.0
DEPTH TO BEDROCK: Not Encountered

STATE: California
GROUND ELEVATION: 150.1
ANGLE FROM HORIZONTAL: 90 AZIMUTH N/A
HOLE LOGGED BY: R. Lung
REVIEWED BY: K. Skipper

NOTES

PURPOSE OF HOLE:
Determine engineering properties of the alluvium, perform SPT's and install piezometer to determine water levels.

DRILL SITE:
Drill hole is located approximately three and a quarter miles East of Interstate 8, Brock's Research Ranch exit, along frontage road. Drill hole is approximately 100 ft. North of frontage road.

DRILLED BY:
Yuma Area Office Drill Crew; Charlie Jones, driller; Nate Ohlan and Chris Edington, helpers.

DRILL EQUIPMENT:
CME Model 75, truck mounted, rotary drill rig. CME hollow stem auger system with a split-tube sampler.

DRILLING METHOD:
4.25-in. I.D. CME hollow-stem, auger system with a 1.375-in. I.D. split-tube sampler.
0.0 to 20.0 ft.: Performed SPT's on 2.5-ft intervals. Hole is collared to 1.0 ft., the split-tube sampler is set for 0.5 ft., then the interval from 1.5 to 2.5 ft. is tested. This process is repeated with a 1.0 ft. clean out, 0.5 ft. seating and a 1.0 ft. test.
20.0 to 25.0 ft.: Performed SPT's on 5.0 ft. intervals.
25.0 to 50.0 ft.: Performed SPT's on 2.5 ft. intervals after water was encountered at 26.0 ft. Testing conducted with a 140-lb. automatic hammer with a 30 in. drop and a cycling rate of approximately 40 blows per minute with NW rods.

DRILLING CONDITIONS:
0.0 to 23.5 ft.: Smooth, easy augering, tan, dry, medium to fine grained sand - dense.
23.5 to 48.5 ft.: Smooth, easy augering, brown, wet, medium to fine grained sand.
48.5 to 50.0 ft.: Three feet of heaving sand, used a roller bit to clean out hole before running test.

DRILLING FLUID:
Encountered water at 26.0 ft, mixed bentonite mud and began stemming augers with heavy mud to limit sand heaving into the sampler.

LABORATORY DATA					STANDARD PENETRATION TEST	
% FINES	% SAND	% GRAVEL	LAB CLASSIFICATION	ELEVATION	RECOVERY	NUMBER OF BLOWS
7%	92%	1%	SP-SM	147.6	100%	7
4%	96%	0%	SP	145.1	100%	8
2%	96%	2%	SP	142.6	100%	14
1%	98%	1%	SP	140.1	100%	12
2%	98%	0%	SP	137.6	100%	12
3%	97%	0%	SP	135.1	100%	14
1%	97%	2%	SP	132.6	100%	15
2%	95%	3%	SP	130.1	100%	13
3%	83%	14%	SP	125.1	100%	12

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 50.0 FT. QUATERNARY ALLUVIUM (Qal)

Visual classification of material is based on auger cuttings and split-tube samples recovered from testing.

0.0 to 3.5 ft. POORLY GRADED SAND WITH SILT (SP-SM) - Approximately 90 percent, fine to medium, hard subrounded to subangular sand; approximately 10 percent, silty, nonplastic fines no dry strength, rapid dilatancy, low toughness, dry, tan; weak reaction to HCl. Maximum size, 0.75 inches (19-mm).

Laboratory Data

1.0 to 2.5 ft. SP-SM; Poorly graded sand with silt; 92% sand; 7% fines; 1% gravel

3.5 to 26.0 ft. POORLY GRADED SAND (SP) - Approximately 95 percent, fine to medium, subrounded to subangular sand; approximately 5 percent, silty, nonplastic fines; no dry strength, rapid dilatancy, low toughness, dry, tan; weak reaction to HCl. Trace of subrounded, hard, fine gravel. Maximum size, 0.75 inches (19-mm).

Laboratory Data

3.5 to 5.0 ft. SP; Poorly graded sand; 96% sand; 4% fines; 0% gravel

6.0 to 7.5 ft. SP; Poorly graded sand; 96% sand; 2% fines; 2% gravel

8.5 to 10.0 ft. SP; Poorly graded sand; 98% sand; 1% fines; 1% gravel

11.0 to 12.5 ft. SP; Poorly graded sand; 98% sand; 2% fines; 0% gravel

13.5 to 15.0 ft. SP; Poorly graded sand; 97% sand; 3% fines; 0% gravel

16.0 to 17.5 ft. SP; Poorly graded sand; 97% sand; 1% fines; 2% gravel

18.5 to 20.0 ft. SP; Poorly graded sand; 95% sand; 2% fines; 3% gravel

23.5 to 25.0 ft. SP; Poorly graded sand; 83% sand; 3% fines; 14% gravel

26.0 to 28.5 ft. POORLY GRADED SAND WITH GRAVEL (SPg) - Approximately 80 percent, fine to medium, subrounded to subangular sand; approximately 5 percent, silty, nonplastic fines; about 15 percent fine, hard, gravel; no dry strength, rapid dilatancy, low toughness, dry, tan; weak reaction to HCl. Maximum size, 0.75 inches (19-mm).

Laboratory Data

26.0 to 27.5 ft. (SP)g; Poorly graded sand with gravel; 81% sand; 2% fines; 17% gravel

28.5 to 33.5 ft. POORLY GRADED SAND (SP) - Approximately 95 percent, fine to medium, subrounded to subangular sand; approximately 5 percent, silty, nonplastic fines; no dry strength, rapid dilatancy, low toughness, dry, tan; weak reaction to HCl. Trace of subrounded, hard, fine gravel. Maximum size, 0.75 inches (19mm).

Laboratory Data

28.5 to 30.0 ft. SP; Poorly graded sand; 88% sand; 4% fines; 8% gravel

31.0 to 32.5 ft. SP; Poorly graded sand; 92% sand; 4% fines; 4% gravel

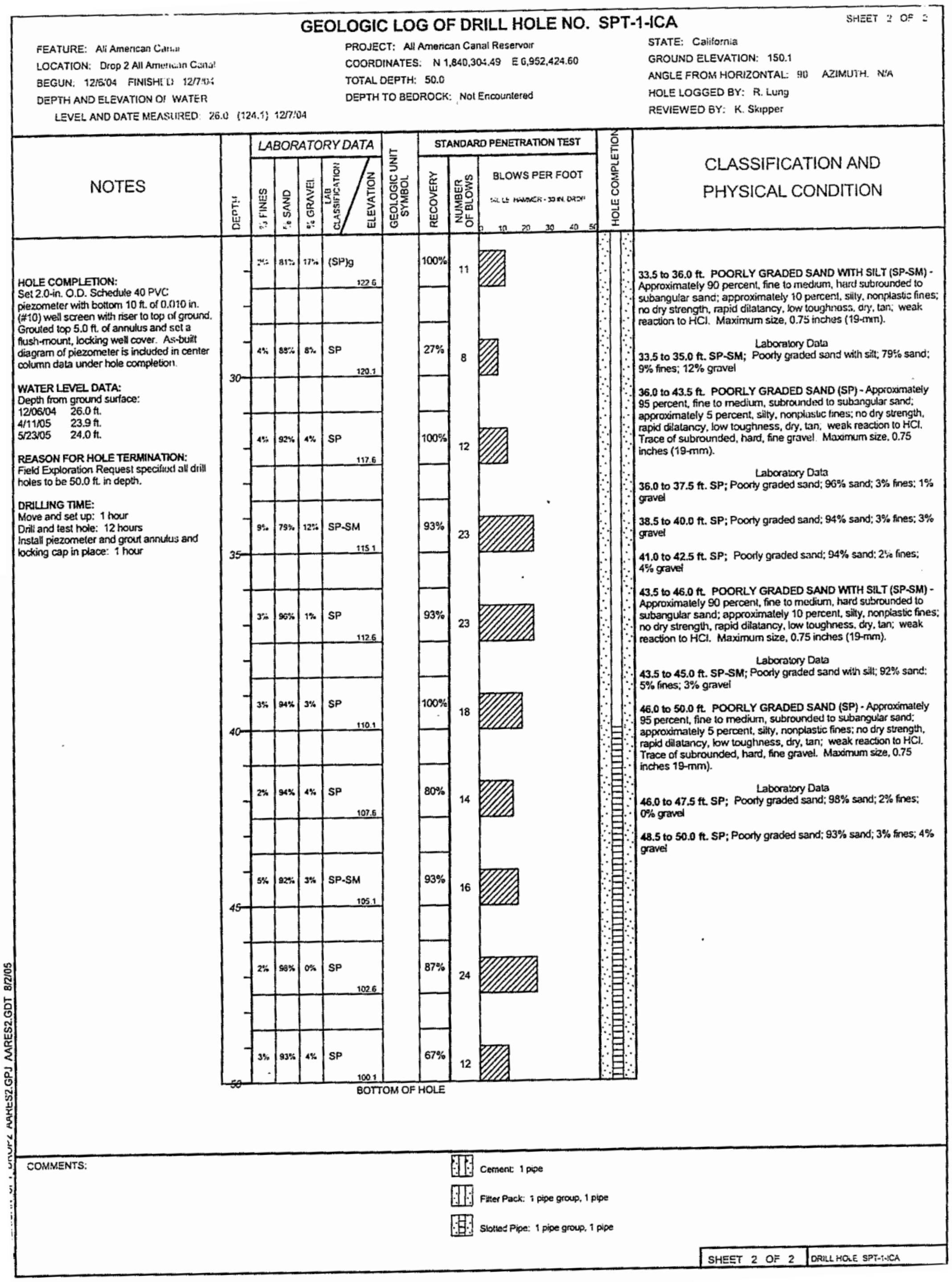
COMMENTS: Comments: **ICA = Inlet Canal Alignment**
* N values have not been corrected for water or mud used in the testing process.
* Recoveries of greater than 100% indicate sand heave into the augers. N values for these tests should be considered suspect.

Lab classification performed in accordance with USBR 5325 and USBR 5335.
Visual classification performed in accordance with USBR 5005.
SPT Testing performed in accordance with USBR 7015.

Survey coordinates are in California State Plane Zone VI

All measurements in feet

Cement: 1 pipe
Filter Pack: 1 pipe group, 1 pipe
Slotted Pipe: 1 pipe group, 1 pipe



SHEET 2 OF 2

GEOLOGIC LOG OF DRILL HOLE NO. SPT-1-ICA

FEATURE: All American Canal
LOCATION: Drop 2 All American Canal
BEGUN: 12/6/04 FINISHED 12/7/04
DEPTH AND ELEVATION OF WATER
LEVEL AND DATE MEASURED: 26.0 (124.1) 12/7/04

PROJECT: All American Canal Reservoir
COORDINATES: N 1,840,304.49 E 6,952,424.60
TOTAL DEPTH: 50.0
DEPTH TO BEDROCK: Not Encountered

STATE: California
GROUND ELEVATION: 150.1
ANGLE FROM HORIZONTAL: 90 AZIMUTH: N/A
HOLE LOGGED BY: R. Lung
REVIEWED BY: K. Skipper

NOTES

HOLE COMPLETION:
Set 2.0-in. O.D. Schedule 40 PVC piezometer with bottom 10 ft. of 0.010 in. (#10) well screen with riser to top of ground. Grouted top 5.0 ft. of annulus and set a flush-mount, locking well cover. As-built diagram of piezometer is included in center column data under hole completion.

WATER LEVEL DATA:
Depth from ground surface:
12/06/04 26.0 ft.
4/11/05 23.9 ft.
5/23/05 24.0 ft.

REASON FOR HOLE TERMINATION:
Field Exploration Request specified all drill holes to be 50.0 ft. in depth.

DRILLING TIME:
Move and set up: 1 hour
Drill and test hole: 12 hours
Install piezometer and grout annulus and locking cap in place: 1 hour

LABORATORY DATA					STANDARD PENETRATION TEST	
% FINES	% SAND	% GRAVEL	LAB CLASSIFICATION	ELEVATION	RECOVERY	NUMBER OF BLOWS
2%	81%	17%	(SP)g	122.6	100%	11
4%	88%	8%	SP	120.1	27%	8
4%	92%	4%	SP	117.6	100%	12
9%	79%	12%	SP-SM	115.1	93%	23
3%	96%	1%	SP	112.6	93%	23
3%	94%	3%	SP	110.1	100%	18
2%	94%	4%	SP	107.6	80%	14
5%	92%	3%	SP-SM	105.1	93%	16
2%	98%	0%	SP	102.6	87%	24
3%	93%	4%	SP	100.1	67%	12

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

33.5 to 36.0 ft. POORLY GRADED SAND WITH SILT (SP-SM) - Approximately 90 percent, fine to medium, hard subrounded to subangular sand; approximately 10 percent, silty, nonplastic fines; no dry strength, rapid dilatancy, low toughness, dry, tan; weak reaction to HCl. Maximum size, 0.75 inches (19-mm).

Laboratory Data
33.5 to 35.0 ft. SP-SM; Poorly graded sand with silt; 79% sand; 9% fines; 12% gravel

36.0 to 43.5 ft. POORLY GRADED SAND (SP) - Approximately 95 percent, fine to medium, subrounded to subangular sand; approximately 5 percent, silty, nonplastic fines; no dry strength, rapid dilatancy, low toughness, dry, tan; weak reaction to HCl. Trace of subrounded, hard, fine gravel. Maximum size, 0.75 inches (19-mm).

Laboratory Data
36.0 to 37.5 ft. SP; Poorly graded sand; 96% sand; 3% fines; 1% gravel

38.5 to 40.0 ft. SP; Poorly graded sand; 94% sand; 3% fines; 3% gravel

41.0 to 42.5 ft. SP; Poorly graded sand; 94% sand; 2% fines; 4% gravel

43.5 to 46.0 ft. POORLY GRADED SAND WITH SILT (SP-SM) - Approximately 90 percent, fine to medium, hard subrounded to subangular sand; approximately 10 percent, silty, nonplastic fines; no dry strength, rapid dilatancy, low toughness, dry, tan; weak reaction to HCl. Maximum size, 0.75 inches (19-mm).

Laboratory Data
43.5 to 45.0 ft. SP-SM; Poorly graded sand with silt; 92% sand; 5% fines; 3% gravel

46.0 to 50.0 ft. POORLY GRADED SAND (SP) - Approximately 95 percent, fine to medium, subrounded to subangular sand; approximately 5 percent, silty, nonplastic fines; no dry strength, rapid dilatancy, low toughness, dry, tan; weak reaction to HCl. Trace of subrounded, hard, fine gravel. Maximum size, 0.75 inches 19-mm).

Laboratory Data
46.0 to 47.5 ft. SP; Poorly graded sand; 98% sand; 2% fines; 0% gravel

48.5 to 50.0 ft. SP; Poorly graded sand; 93% sand; 3% fines; 4% gravel

COMMENTS:

Cement: 1 pipe
Filter Pack: 1 pipe group, 1 pipe
Slotted Pipe: 1 pipe group, 1 pipe

SHEET 2 OF 2 | DRILL HOLE SPT-1-ICA

DROP2 AARES2.GPJ AARES2.GDT 8/2/05

7-1336-A (1-86)
Bureau of Reclamation

LOG OF TEST PIT OR AUGER HOLE

SHEET 2 OF 3
HOLE NO TP-10-AACE

FEATURE: All American Canal Reservoir Drop 2
LOCATION: All American Canal Drop 2
COORDINATES: N 1,840,251.453 E 6,940,640.046
APPROXIMATE DIMENSIONS: approx. 38 x 33 ft. x 9.1 ft. deep
TOTAL DEPTH: 9.1 ft. DEPTH TO WATER: N/A
PROJECT: All American Canal
GROUND ELEVATION: 143.1
METHOD OF EXPLORATION: Cat 240 el Trackhoe
HOLE LOGGED BY: George Eatman
DATE EXCAVATED: 12/9/2004

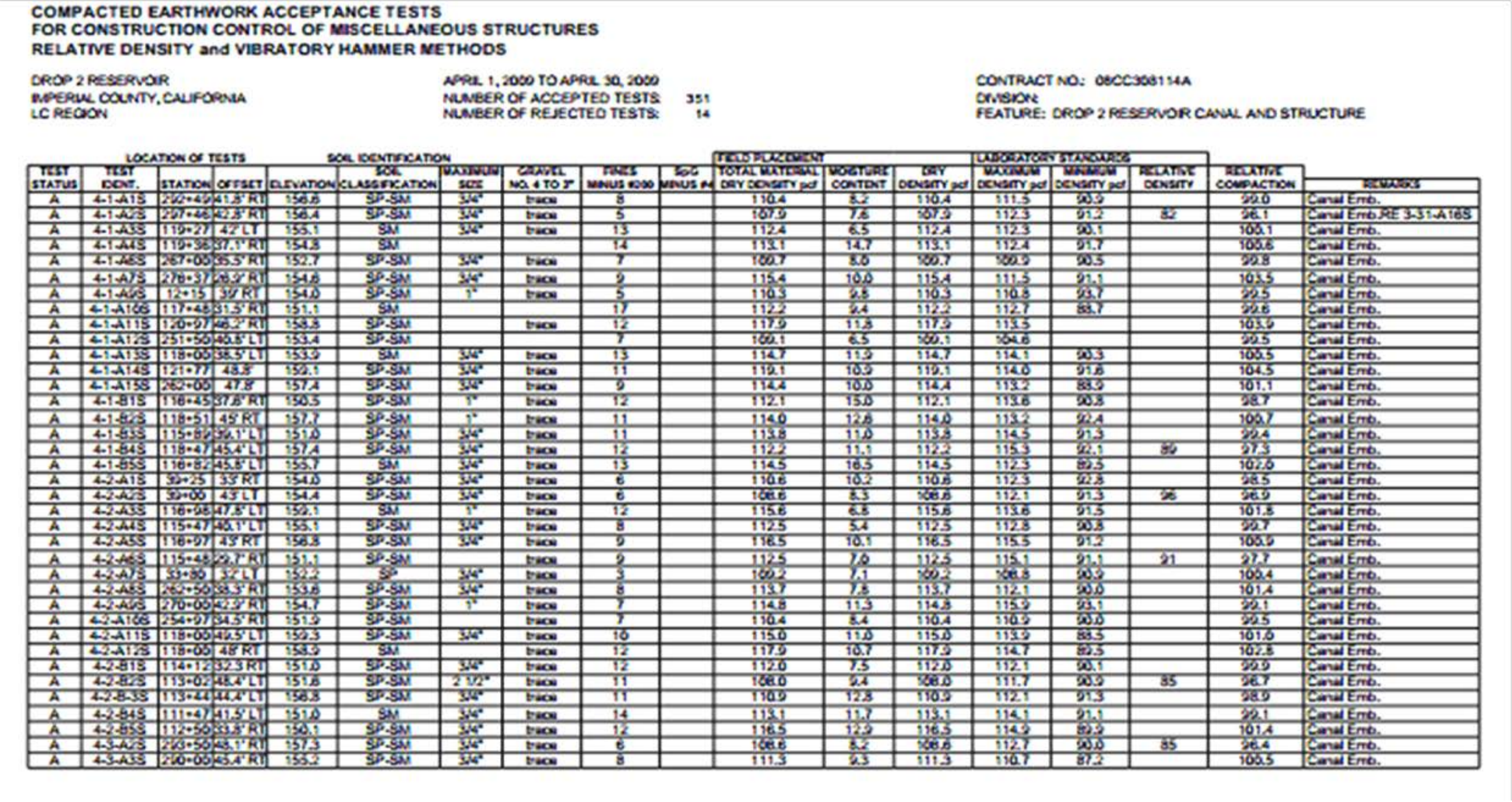
CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
SP (visual) SP (lab classif.) One 4.5-lb sack sample	9.1 ft POORLY GRADED SAND AND TRACE OF GRAVEL: About 100% predominantly fine sand; maximum size fine sand; moderate reaction with HCl. IN-PLACE CONDITION: Very soft, loose, dry, gray. Pit bottom. LAB TEST DATA: Sample 4 had 0.0% gravel, 99.1% sand, 0.9% fines. Cu = 1.54, Cc = 0.94. Laboratory Classification is POORLY GRADED SAND One 4.6-lb sack sample obtained from depth 9.1 ft where Nuclear Density Test 7 Conducted

Nuclear gauge Density Tests

Depth	Wet Density	Dry Density	Moisture%
0.000	105.2	100.5	4.6
1.730	102.0	100.8	1.2
1.416	104.4	103.5	0.9
3.742	97.9	97.1	0.8
6.443	99.3	98.9	0.5
6.175	97.2	96.3	0.5
9.115	97.6	96.8	0.9
6.471	100.2	99.6	0.7
4.733	99.6	99.0	0.6
2.172	98.5	97.7	0.9

REMARKS:

AACR_TEST_PIT_LOG AACRES-TP DROP 2.GPJ AACRES-TP DROP 2.GDT 4/12/05



COMPACTED EARTHWORK ACCEPTANCE TESTS
FOR CONSTRUCTION CONTROL OF MISCELLANEOUS STRUCTURES
RELATIVE DENSITY and VIBRATORY HAMMER METHODS

DROP 2 RESERVOIR
IMPERIAL COUNTY, CALIFORNIA
LC REGION

APRIL 1, 2009 TO APRIL 30, 2009
NUMBER OF ACCEPTED TESTS: 351
NUMBER OF REJECTED TESTS: 14

CONTRACT NO.: 08CC308114A
DIVISION:
FEATURE: DROP 2 RESERVOIR CANAL AND STRUCTURE

	LOCATION OF TESTS				SOIL IDENTIFICATION					FIELD PLACEMENT			LABORATORY STANDARDS				
TEST STATUS	TEST IDENT.	STATION	OFFSET	ELEVATION	SOIL CLASSIFICATION	MAXIMUM SIZE	GRAVEL NO. 4 TO 3"	FINES MINUS #200	SpG MINUS #4	TOTAL MATERIAL DRY DENSITY pcf	MOISTURE CONTENT	DRY DENSITY pcf	MAXIMUM DENSITY pcf	MINIMUM DENSITY pcf	RELATIVE DENSITY	RELATIVE COMPACTION	REMARKS
A	4-1-A1S	292+49	41.8' RT	156.6	SP-SM	3/4"	trace	8		110.4	8.2	110.4	111.5	90.9		99.0	Canal Emb.
A	4-1-A2S	297+46	42.8' RT	156.4	SP-SM	3/4"	trace	5		107.9	7.6	107.9	112.3	91.2	82	96.1	Canal Emb.RE 3-31-A16S
A	4-1-A3S	119+27	42' LT	155.1	SM	3/4"	trace	13		112.4	6.5	112.4	112.3	90.1		100.1	Canal Emb.
A	4-1-A4S	119+38	37.1' RT	154.8	SM			14		113.1	14.7	113.1	112.4	91.7		100.6	Canal Emb.
A	4-1-A6S	267+00	35.5' RT	152.7	SP-SM	3/4"	trace	7		109.7	8.6	109.7	109.9	90.5		99.8	Canal Emb.
A	4-1-A7S	278+37	26.9' RT	154.6	SP-SM	3/4"	trace	9		115.4	10.0	115.4	111.5	91.1		103.5	Canal Emb.
A	4-1-A9S	12+15	39' RT	154.0	SP-SM	1"	trace	5		110.3	9.8	110.3	110.8	93.7		99.5	Canal Emb.
A	4-1-A10S	117+48	31.5' RT	151.1	SM			17		112.2	9.4	112.2	112.7	88.7		99.6	Canal Emb.
A	4-1-A11S	120+97	46.2' RT	158.8	SP-SM		trace	12		117.9	11.8	117.9	113.5			103.9	Canal Emb.
A	4-1-A12S	251+50	40.8' LT	153.4	SP-SM			7		109.1	6.5	109.1	104.6			99.5	Canal Emb.
A	4-1-A13S	118+00	38.5' LT	153.9	SM	3/4"	trace	13		114.7	11.9	114.7	114.1	90.3		100.5	Canal Emb.
A	4-1-A14S	121+77	48.8'	159.1	SP-SM	3/4"	trace	11		119.1	10.9	119.1	114.0	91.6		104.5	Canal Emb.
A	4-1-A15S	262+00	47.8'	157.4	SP-SM	3/4"	trace	9		114.4	10.0	114.4	113.2	88.9		101.1	Canal Emb.
A	4-1-B1S	118+45	37.6' RT	150.5	SP-SM	1"	trace	12		112.1	15.0	112.1	113.6	90.8		98.7	Canal Emb.
A	4-1-B2S	118+51	45' RT	157.7	SP-SM	1"	trace	11		114.0	12.6	114.0	113.2	92.4		100.7	Canal Emb.
A	4-1-B3S	115+89	39.1' LT	151.0	SP-SM	3/4"	trace	11		113.8	11.0	113.8	114.5	91.3		99.4	Canal Emb.
A	4-1-B4S	118+47	45.4' LT	157.4	SP-SM	3/4"	trace	12		112.2	11.1	112.2	115.3	92.1	89	97.3	Canal Emb.
A	4-1-B5S	116+82	45.8' LT	155.7	SM	3/4"	trace	13		114.5	16.5	114.5	112.3	89.5		102.0	Canal Emb.
A	4-2-A1S	39+25	33' RT	154.0	SP-SM	3/4"	trace	6		110.6	10.2	110.6	112.3	92.8		98.5	Canal Emb.
A	4-2-A2S	39+00	43' LT	154.4	SP-SM	3/4"	trace	6		108.6	8.3	108.6	112.1	91.3	96	96.9	Canal Emb.
A	4-2-A3S	116+98	47.8' LT	159.1	SM	1"	trace	12		115.6	6.8	115.6	113.6	91.5		101.8	Canal Emb.
A	4-2-A4S	115+47	40.1' LT	155.1	SP-SM	3/4"	trace	8		112.5	5.4	112.5	112.8	90.8		99.7	Canal Emb.
A	4-2-A5S	116+97	43' RT	158.8	SP-SM	3/4"	trace	9		116.5	10.1	116.5	115.5	91.2		100.9	Canal Emb.
A	4-2-A6S	115+48	29.7' RT	151.1	SP-SM		trace	9		112.5	7.0	112.5	115.1	91.1	91	97.7	Canal Emb.
A	4-2-A7S	33+80	32' LT	152.2	SP	3/4"	trace	3		109.2	7.1	109.2	108.8	90.9		100.4	Canal Emb.
A	4-2-A8S	262+50	38.3' RT	153.6	SP-SM	3/4"	trace	8		113.7	7.8	113.7	112.1	90.0		101.4	Canal Emb.
A	4-2-A9S	270+00	42.9' RT	154.7	SP-SM	1"	trace	7		114.8	11.3	114.8	115.9	93.1		99.1	Canal Emb.
A	4-2-A10S	254+97	34.5' RT	151.9	SP-SM		trace	7		110.4	8.4	110.4	110.9	90.0		99.5	Canal Emb.
A	4-2-A11S	118+00	49.5' LT	159.3	SP-SM	3/4"	trace	10		115.0	11.0	115.0	113.9	88.5		101.0	Canal Emb.
A	4-2-A12S	118+00	48' RT	158.9	SM		trace	12		117.9	10.7	117.9	114.7	89.5		102.8	Canal Emb.
A	4-2-B1S	114+12	32.3 RT	151.0	SP-SM	3/4"	trace	12		112.0	7.5	112.0	112.1	90.1		99.9	Canal Emb.
A	4-2-B2S	113+02	48.4' LT	151.6	SP-SM	2 1/2"	trace	11		108.0	9.4	108.0	111.7	90.9	85	96.7	Canal Emb.
A	4-2-B-3S	113+44	44.4' LT	158.8	SP-SM	3/4"	trace	11		110.9	12.8	110.9	112.1	91.3		98.9	Canal Emb.
A	4-2-B4S	111+47	41.5' LT	151.0	SM	3/4"	trace	14		113.1	11.7	113.1	114.1	91.1		99.1	Canal Emb.
A	4-2-B5S	112+50	33.8' RT	150.1	SP-SM	3/4"	trace	12		116.5	12.9	116.5	114.9	89.9		101.4	Canal Emb.
A	4-3-A2S	293+50	48.1' RT	157.3	SP-SM	3/4"	trace	6		108.6	8.2	108.6	112.7	90.0	85	96.4	Canal Emb.
A	4-3-A3S	290+00	45.4' RT	155.2	SP-SM	3/4"	trace	8		111.3	9.3	111.3	110.7	87.2		100.5	Canal Emb.

Representative Canal Embankment Compaction Report

Appendix C

Drawdown Criteria Recommendation Memorandum

United States Department of the Interior

BUREAU OF RECLAMATION
P.O. Box 25007
Denver, CO 80225-0007

RECEIVED
MAY 22 '14

DATE	INITIAL	CODE
		68460

IN REPLY REFER TO:

86-68140
PRJ-8.10

MAY 22 2014

MEMORANDUM

To: Area Manager, Yuma, AZ
Attn: YAO-2000 (Condit)

From: Tim Brown Tim P. Brown, P.E.
Manager, Water Conveyance Group – TSC (86-68140)

Subject: Drop 2 Inlet Canal (AKA: Brock Reservoir Inlet Canal) – Canal Drawdown Rate Modification

The Yuma Area Office (YAO) has requested the Technical Service Center (TSC) to relax drawdown criteria for the Brock Reservoir Inlet Canal that are part of the canal's Standing Operating Procedures. The current drawdown limits are no more than 6 inches in any hour with a maximum drawdown of 1 foot per day. Under these limits, approximately 2 weeks are needed to completely unwater the canal (drawing down 1 ft/day from normal depth of 14.23 ft). Faster drawdown would provide a financial benefit by reducing outage periods for maintenance operations that require unwatering of the canal. The TSC was informed that the Brock Reservoir Inlet Canal is typically unwatered two or three times per year.

Drawdown rates are limited for canals in order to limit differential loading on the canal lining that is produced if the phreatic surface in the embankment exceeds the canal water surface. The pressure created by a differential as small as a few inches can displace or crack concrete lining panels. This pressure differential can also transport embankment material creating voids in the embankment foundation material behind the canal lining. In order to justify relaxing drawdown criteria for a canal, the natural rate of drawdown for the phreatic surface in the embankment must be determined through field testing.

Thirteen piezometers were installed in the canal embankments in late August 2013 and a drawdown test was performed from October 31, 2013, through November 5, 2013. See Hydraulic Laboratory Technical Memorandum PAP-1102 for a description of the test, procedures, and data collected. The testing was unable to establish the natural rate of drawdown because a phreatic surface was not detected above the piezometer taps, which were located about 1 mile apart on each side of the canal and about 18 inches above the canal invert. The testing showed that there was no established phreatic surface behind the lining at any of the piezometer taps. It is possible that a phreatic surface existed at a lower elevation than the taps, or at intermediate locations between taps. Because no phreatic surface was detected, the testing was unable to determine what the natural rate of drawdown would be if a phreatic surface were to exist in the future.

As with all canals, there is a baseline risk associated with day-to-day operations. Risk is comprised of two components; probability of failure and consequences of failure.

Faster drawdown rates increase the probability of a failure by increasing the probability of increased pore pressures in the embankment. Factors that make canal failure more likely over time include:

- The canal lining is fairly new and seepage through the lining is likely as low as it will ever be. As the canal ages, the lining will deteriorate and crack, allowing more water transfer into the embankment.
- Lining cracking combined with repeated rapid drawdown cycles could allow embankment materials to be washed into the canal eventually leading to voids behind the lining.

Factors considered when assessing consequences of failure:

- The downstream end of this canal is constructed in fill with the water surface located well above the natural ground surface.
- Interstate 8 is located adjacent to, and very near the canal. A breach in the south embankment could release water directly onto Interstate 8.

Uncertainty should also be considered when assessing risk tolerance. The testing included piezometers at approximately 1-mile intervals. It is possible that some locations with positive pore pressures exist between piezometer sites, but were not detected during the testing.

Recommendation:

Based on consideration of the test data, practical limitations on what the testing revealed, limited number of test locations, and the potential for conditions to change in the future, we recommend the Standing Operating Procedures for the Inlet Canal be changed for unwatering the Inlet Canal as follows:

1. Maximum allowable drawdown will be 7.5 feet per day with an hourly maximum drawdown of 6 inches.

2. The unwatered canal shall be inspected prior to refilling. Inspectors should watch for damaged lining and for embankment materials migrating into the canal. If embankment materials are found, the lining should be sounded with a hammer or similar tool to listen for voids behind the lining.

At the time of the first implementation of these new criteria, TSC engineers should be on-site with Area Office staff for the first inspection. If lining panels or embankment show any drawdown distress, a return to the original drawdown procedures should be implemented and the unwatering procedures should be re-evaluated. Caution is recommended if the canal must be unwatered during or after periods of heavy rain.

The above drawdown rate recommendations do not apply to emergency events. If emergency conditions necessitate canal operations that exceed Standing Operating Procedure drawdown rates, normal inspection procedures and repairs must be completed prior to returning a feature to service.

cc: 86-68100 (LaFond), 86-68140 (Duke, Edwards), 86-68460 (Einhellig, Gill, Wahl)
YAO-2110 (Igoe, Alvarado)