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COLORADO REGISTERED PROFESSIONAL ENGINEER
THOMAS A. CHAPEL
33848
4/9/15

Technical Memorandum

To:	Ms. Linda Kaiser	**From:**	Thomas A. Chapel, CPG, PE
Company:	Stoller Newport News Nuclear (SN3)	**Date:**	April 9, 2015
Re:	Instrumentation and Monitoring, Rocky Flats OLF	**Tt Project #:**	114-181750

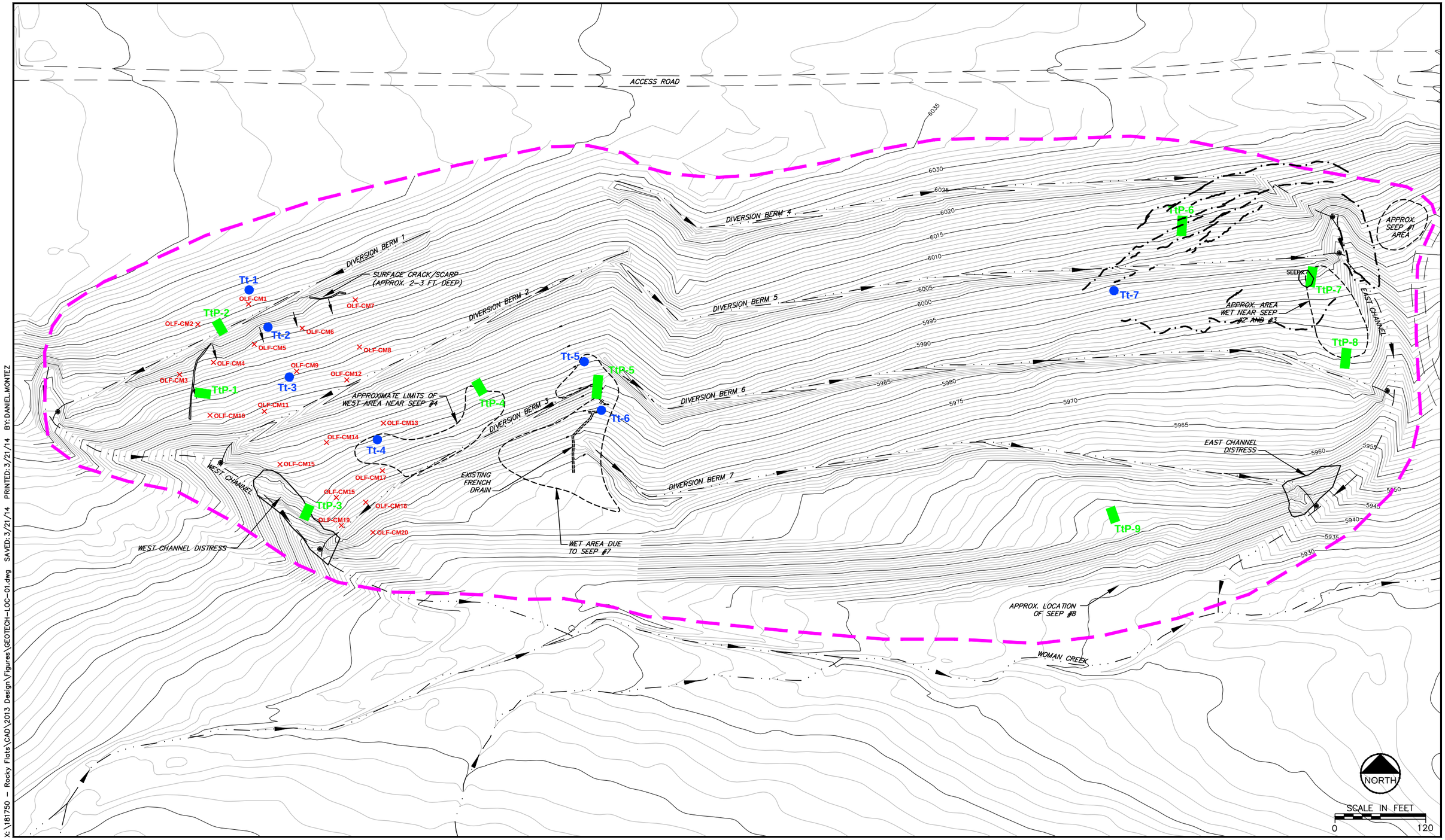
Introduction

This technical memorandum provides a summary and evaluation of data collected from instrumentation at the Rocky Flats Original Landfill (OLF) during calendar year 2014. Previously collected data have been updated with information collected during 2014. Data from piezometers located on the outside of the inclinometer casings were not available, reviewed, or correlated with the inclinometer data for this period because the piezometers are no longer functional and data were not collected during 2014. The last functional readings of the piezometers were recorded on March 4, 2013.

Background information regarding the results of the geotechnical investigation conducted in 2008 (Tetra Tech 2008) during which the inclinometers were installed has been provided in our previous technical memoranda and is not repeated here (Tetra Tech, 2010, Tetra Tech, 2011, and Tetra Tech, 2012). Information regarding the piezometers is also available in these previous reports.

Background

Minor localized surface cracking, differential settlement, slumping and subsidence has been previously documented at the site, and similar minor distress continued during 2014. Figure 1, Plan View of OLF Site, shows the locations of the localized cracking, slumping and settling, seeps, test pits for the 2008 geotechnical investigation and the inclinometers. A summary of performance of the instruments prior to this reporting is provided in the following sections. Following a major precipitation event on the Front Range during September 2013 visible slope movement occurred in the northeast quadrant of the OLF. Significant movement of several of the inclinometers was measured following that event. Movement in that area continued during 2014. During 2014 the eastern portion of the OLF was re-graded to reduce weight and flatten slopes in key areas where distress has been observed.



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Project No. 181750

March 2014

LEGEND:

- DITCH/CHANNEL/CREEK
- SLUMP OR SUBSIDENCE LINE AND DIRECTION
- ROAD
- SETTLEMENT MONUMENT (EXISTING)
- APPROXIMATE LIMITS OF GEOTECHNICAL INVESTIGATION
- TEST PIT LOCATION
- TEST BORING AND INCLINOMETER LOCATION
- CRACKS OBSERVED FOLLOWING SEPTEMBER 2013 HENRY PRECIPITATION EVENT

Figure 1
Plan View of OLF Site

Instrumentation and Monitoring

Inclinometer readings began on April 13, 2008. Deflections of the inclinometers were manually read approximately monthly throughout each year, starting on April 13, 2008. Inclinometer readings are obtained by inserting a 32 inch long probe into the inclinometer tube, and taking electronic readings of the vertical and horizontal orientation of the instrument at one foot intervals along the length of the tube. Wheels on the top and bottom of the probe align the measurement instrument in precise grooves along the length of the tube. Inclinometer readings are taken in two perpendicular directions created by the orientation of the grooves, relative to the A-axis and the B-axis of the inclinometer tube. The direction of the slope movement is indicated by the relative movement of each inclinometer tube along both the A and B-axes. In general, the A-axis is oriented parallel to the gradient of the slope and the B-axis is oriented perpendicular to the A-axis. A lack of movement along both axes indicates a stable slope. Due to the length and diameter of the probe, large inclinometer tube deflections and deformations can prevent the probe from being inserted over the full length of the tube. Large enough deflections can cause the tube to break, also preventing insertion of the probe beyond the point of the break.

Little movement was observed for any of the inclinometers from April 2008 to April, 2009. Following a period of heavy precipitation in April 2009 deflections became apparent. The largest deflections were noted in inclinometers Tt-2, Tt-3 and Tt-4, on the western edge of the OLF. This was the area with the most pronounced differential settling, slumping and surface cracking observed in 2007.

Inclinometer Tt-2 was installed to a depth of 34 feet. Sometime after the August 19, 2009 reading, slope movement resulted in inclinometer tube deformation or breakage and the inclinometer could not be read below a depth of 25 feet. Therefore, subsequent readings have been taken to a depth of 25 feet.

Inclinometer Tt-3 was installed to a depth of 38 feet. Slope movement at this location also resulted in inclinometer tube deformation or breakage, and the inclinometer could not be read below a depth of 33 feet. Therefore, subsequent readings have been taken to a depth of 33 feet.

After April 19, 2010, the inclinometer probe could not be lowered beyond the 13-foot level in Tt-4. On 9/26/13, the instrument could not be lowered more than 9 feet. The bottom of the instrument had dirt on it when pulled up, so we surmise the tube is broken. We've been monitoring to the 9 foot depth since October, 2013. For October and November, 2013 readings, no deflection was noted between zero and nine feet.

The deformed or broken casing likely indicates movement of the slope at or near the location of the break/obstruction. For the inclinometer in Tt-2, the depth at which the casing deformed or broke corresponds with the depth in the boring where soft clay was found. For the inclinometer in Tt-3, the casing is deformed or broken at a depth of 33 feet, which corresponds to a location in the subsurface where the geologic materials changed from sandy gravelly clay to claystone bedrock. The 2008 geotechnical investigation concluded that the slope failures were occurring in this weak clay layer that is below the landfill deposits, on top of or in the upper portions of the bedrock. It is our opinion that monitoring of the inclinometers at the OLF should continue, in order to monitor the relative movement over time to the depths that can be measured.

Tetra Tech noted previously that in general, there is a correlation between water in the subsurface and the movement that is occurring at the OLF. Some of the change in the subsurface water condition is likely related to recharge of the upper hydrostratigraphic unit that occurs well upgradient of the OLF, and some of the change is due to an influx of water into the subsurface in the vicinity of the OLF. The relative influence of these two sources on the movement that is occurring is not known. Measures that are undertaken to decrease infiltration of surface water in the immediate vicinity of the OLF will not affect the up-gradient infiltration and therefore will not impact movement that results from up-gradient infiltration. However, the general decrease in movement recorded by the inclinometers during 2011 and 2012 may be related to a gradual stabilization as a result of improvements made to the drainage features on the OLF that were constructed by SN3 in 2009. Since 2012 was also an exceptionally dry year, it is possible that reduced movement was related to lower groundwater levels as a result of the decreased precipitation.

The precipitation in the area was measured by SN3 using on-site devices during the period of record for the inclinometers and piezometers. SN3 has noted that some inaccuracy of the precipitation measurements is likely during events when significant snowfall accumulates on the devices. When significant snow accumulates some of the snow may blow or fall off the device instead of accumulating in the device. A new meteorological station was constructed during 2014, and will be used for collecting and reporting precipitation data beginning in 2015.

A graph showing monthly precipitation values for 2014 is included in Attachment B. In general, the graphs show that during the period of record for these piezometers and inclinometers, precipitation at the site was higher between May and September and lower between October and April.

The Location of each borehole instrumented with inclinometers is shown on Figure 1. The specifics of each borehole/inclinometer are discussed below when significant changes occurred during the reporting interval. A lack of comment on a particular time interval indicates that the performance of the instrumentation during the intervening period was not interpreted as being significant, or was reported during a previous interval. Graphs showing the movement of each axis of the inclinometers are shown in Attachment A.

Tt-1 (82108I). Tt-1 was intentionally placed outside of the historical slide area. Cumulative movement of Tt-1 between April, 2008 and the end of 2014 was measured to be less than 0.1 inches in both the A- axis and B-axis directions during 2014.

Tt-2 (82208I). The inclinometer readings for Tt-2 showed additional movement in the A-axis direction of approximately 2 inches between April, 2013 and November 28, 2014 (the last reading recorded during 2014). Movement of 0.6 inches was recorded on the B-axis during the same time interval.

Tt-3 (82308I). Cumulative movement of Tt-3 between April, 2008 and the end of 2014 was measured to be approximately 0.2 inches in the A- axis. Movement in the B-axis direction was negligible during 2014.

Tt-4 (82408I). The inclinometer readings for Tt-4 show minor movement continuing on both axes: a cumulative movement of 1.7 inches on the A-axis and approximately 0.25 inches on the B-axis between 2008 and 2014.

Tt-5 (82508I). The inclinometer readings for Tt-5 show a cumulative movement of 2.6 inches on the A-axis and approximately 2.1 inches on the B-axis between 2008 and 2014. More than 1 inch of movement was recorded in May 2014, which prompted a review of the data by Tetra Tech and a site visit to observe the area by SN3. This movement followed a period of high precipitation which occurred at the site in May. The movement was addressed in a letter to SN3 dated September 23, 2014. A copy of the letter is included in Attachment A. The inclinometer data indicate that movement originates at a depth of about 31 feet.

Tt-6 (82608I). The inclinometer readings for Tt-6 show a cumulative movement of 1.6 inches on the A-axis and approximately 0.2 inches on the B-axis between 2008 and 2014. The inclinometer data indicate that movement originates at a depth of about 21 feet.

Tt-7 (82708I). Visible slope movement occurred in the vicinity of Tt-7 following the September 2013 precipitation event. When measurements were attempted on September 26, 2013, the instrument could not be lowered more than 9 feet. That depth is coincident with the depth at which previous deflections had been measured. The bottom of the instrument had dirt on it when pulled up, suggesting that the tube was broken as a result of that movement. Readings taken during 2013 show that approximately 1.8 inches of movement had occurred in alignment with the A axis, and about 2.1 inches of total movement had occurred in alignment with the B axis through August 2013.

The inclinometer readings for Tt-7 show minor movement continuing on both axes during 2014: movement of 0.1 inches on the A-axis and B-axis was recorded through 2014.

2014 Review

Tetra Tech was asked by SN3 to conduct a review and evaluation of documents, design concepts, and mitigation procedures related to the OLF at the Rocky Flats site. The purpose of the review was to evaluate previous design decisions and provide our opinions as to whether the previous design concept decisions remain valid.

The review did not identify factors, conditions, or changes in conditions at the site that suggest a different approach should be considered. There have been no land use changes downstream or downslope that would result in increased risk to human health and safety if a slope failure were to occur. Since inspections are required and on-going, the additional effort required to look for evidence of cracking and slope movement seems small in comparison with the cost of implementing engineering controls that would be required to further reduce or eliminate the localized slope instability. This review did not identify omissions or changes that would suggest a different approach to managing the localized instability should be implemented. A copy of the 2014 is included in Attachment C.

Recommendations

The recommendations made in the original report (Tetra Tech, 2008), our 2010 Technical Memorandum, and the 2014 review and technical memorandum remain valid. The instrumentation indicates that instability is caused by one or more weak layers in the shallow subsurface, and movement is exacerbated by precipitation events and elevated water levels. Slope stability modeling indicates the large scale, overall slope is stable. However, localized failures have occurred on the OLF under elevated water level conditions. A reduction in the water level alone is not considered adequate to ensure the long term stability of the slope, however it is possible that the reduced movements recorded by inclinometers during 2011 and 2012 are related to drainage improvements constructed at the OLF during the same time frame. Drainage features designed during 2013 and 2014 (Tetra Tech, 2013) may reduce movements in the eastern portion of the OLF. Continued monitoring and regular maintenance of distress are recommended.

Limitations

The above opinions and recommendations are based on a reasonable degree of certainty. This report has been prepared based upon a review of climate, weather and design documents, field investigation and testing, geotechnical engineering analyses, site visits, and our experience. The conclusions represent our best judgment based on the information available. Should additional information become available we should be allowed to review that information and modify our conclusions accordingly.

References

Tetra Tech, Inc. 2008. Rocky Flats Original Landfill Geotechnical Investigation Report. Jefferson County, Colorado. June.

Tetra Tech, Inc. 2010. Technical Memorandum, Instrumentation and Monitoring, Rocky Flats OLF, April.

Tetra Tech, Inc. 2011. Technical Memorandum, Instrumentation and Monitoring, Rocky Flats OLF, April.

Tetra Tech, Inc. 2012. Technical Memorandum, Instrumentation and Monitoring, Rocky Flats OLF, April.

Tetra Tech, Inc. 2013. OLF East Perimeter Channel and Berm Modifications, Rocky Flats Site, CO. November 22.

Tetra Tech, Inc. 2012. Technical Memorandum, Instrumentation and Monitoring, Rocky Flats OLF, April.

Tetra Tech, Inc. 2014. OLF East Perimeter Channel and Berm Modifications, Rocky Flats Site, CO. September 22.

Attachment A
Inclinometer Data

September 23, 2014

Ms. Linda Kaiser
S.M. Stoller
Rocky Flats
DOE-OLM/Stoller
11025 Dover Street, Suite 1000
Westminster, Colorado 80021

Subject: Inclinometer Data, May 2014
Original Landfill (OLF)
Rocky Flats

Dear Ms. Kaiser:

As you requested Tetra Tech reviewed printouts of movement recorded by seven inclinometers that were installed at the OLF in 2008. Inclinometer 80508I indicated movement greater than 1 inch, and therefore you asked me to review the data and provide this letter regarding that movement.

Inclinometer 80508I is located in the central part of the OLF, west of diversion berm 6 and north of diversion berm 3. There is a "seep" located in the vicinity of inclinometer 80508I, but I am not aware of previous slope distress in this area.

Although inclinometer 80508I moved more than an inch, very little movement was recorded by inclinometer 80608I, which is located approximately 75 feet downslope of 80508I. This suggests that movement is localized. I understand that you visited the site on September 18 and did not observe any surface expression of the distress in the vicinity of 80508I.

I suggest continued observations and inclinometer readings to monitor the distress. If any surface disturbance is noted, cracks should be mapped and filled in to reduce the risk of surface water infiltration.

Please contact the undersigned with if you have questions or if we can provide additional information.

Sincerely,
Tetra Tech, Inc.

Thomas A. Chapel, CPG, PE
Principal Engineer

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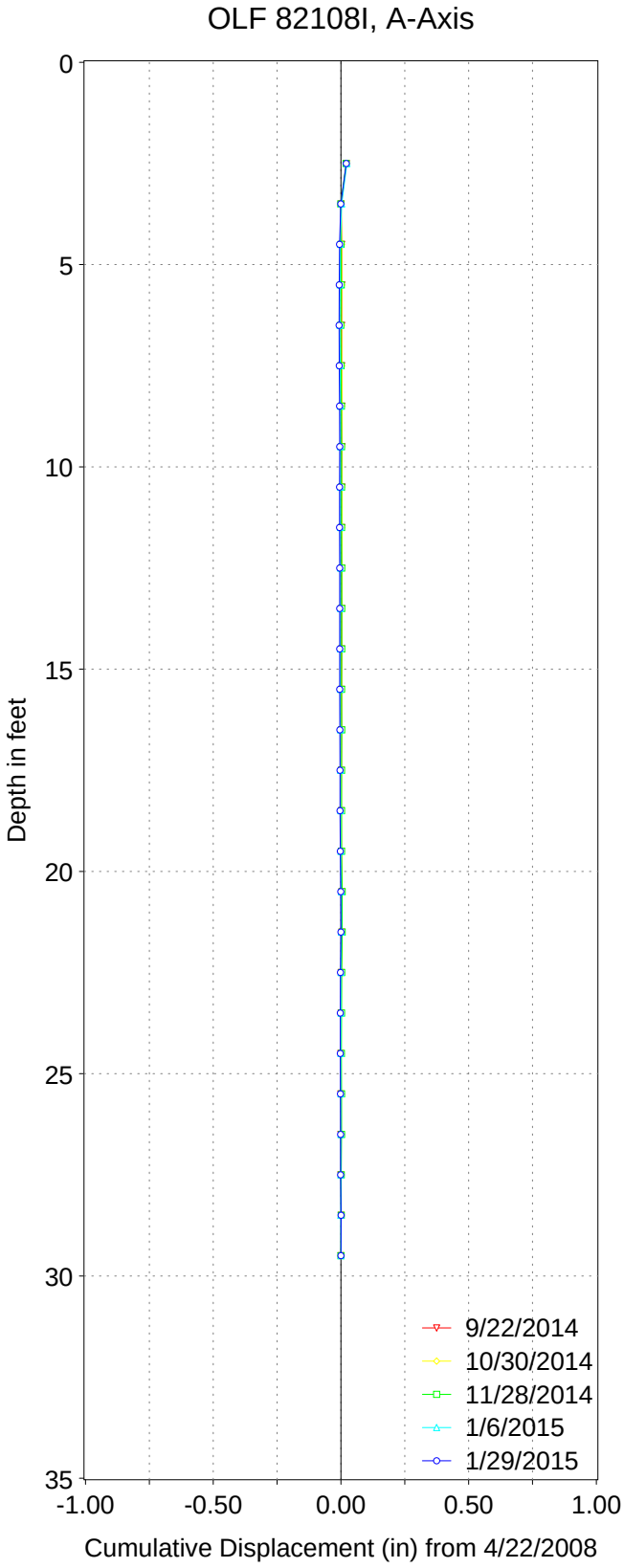
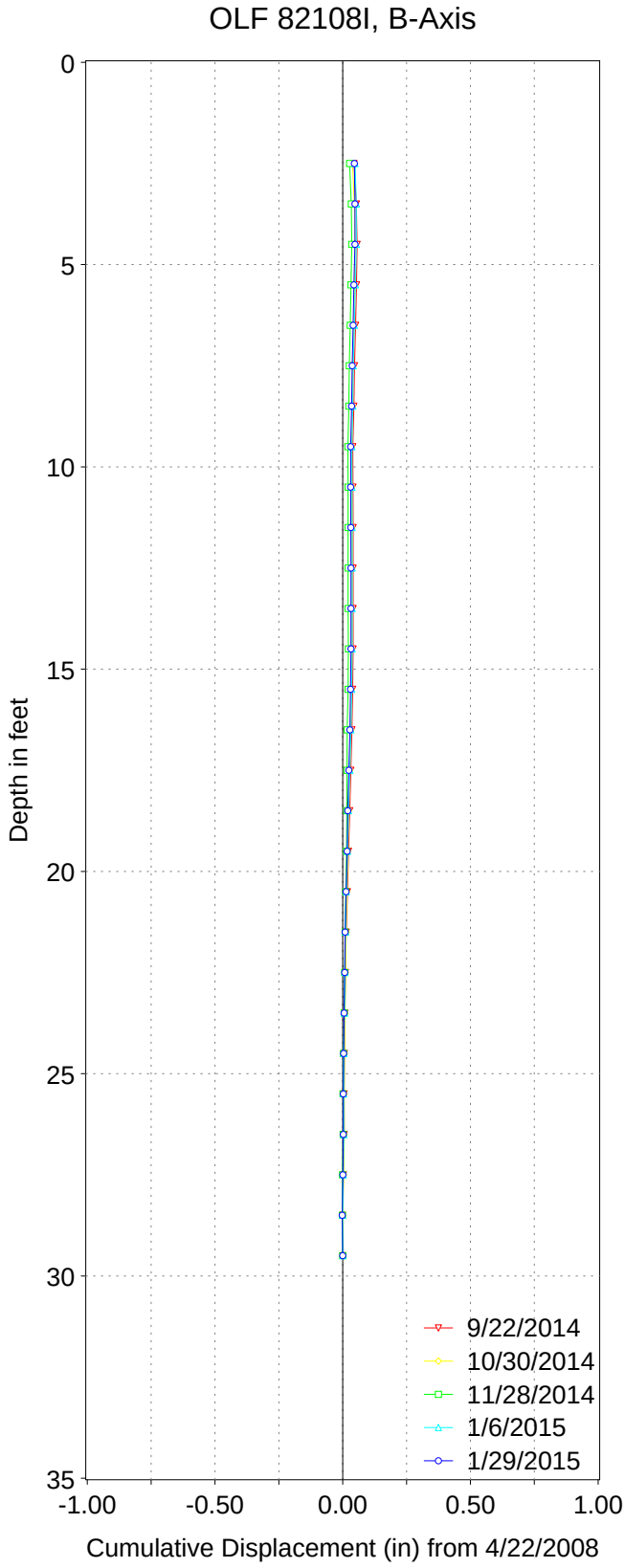
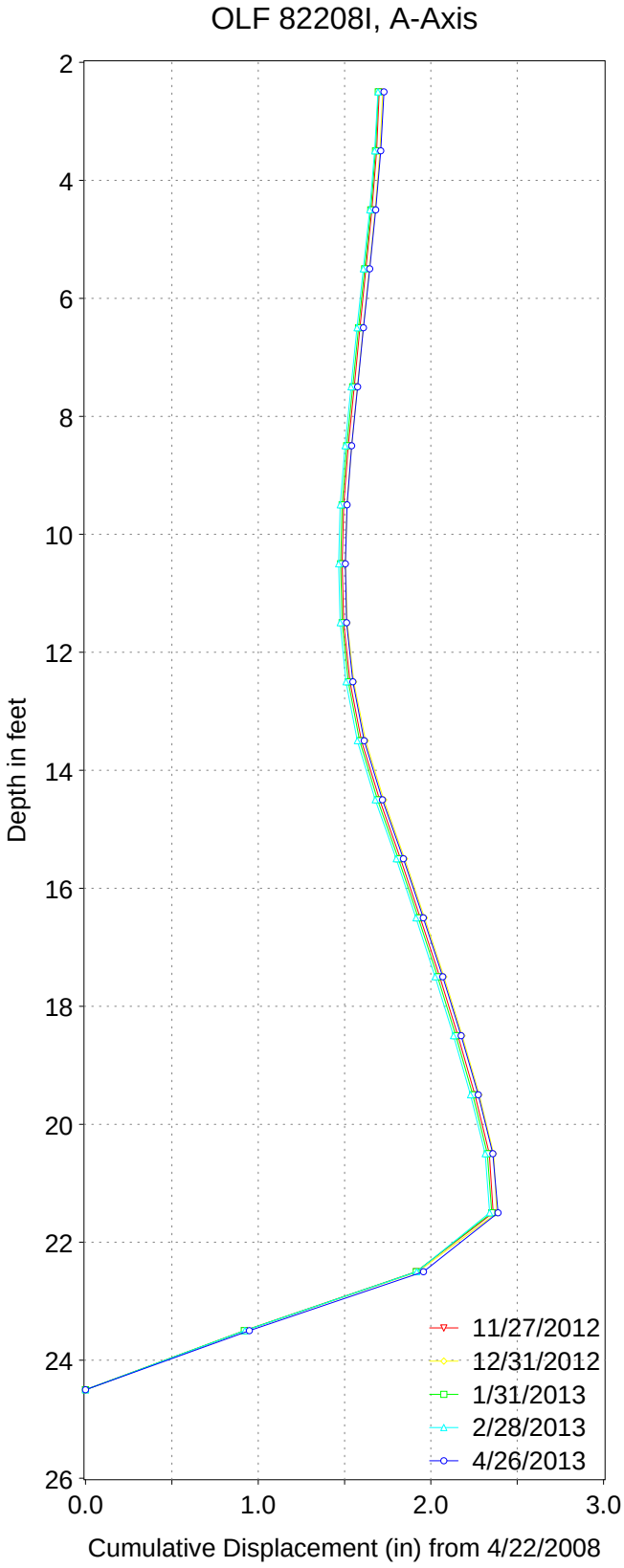


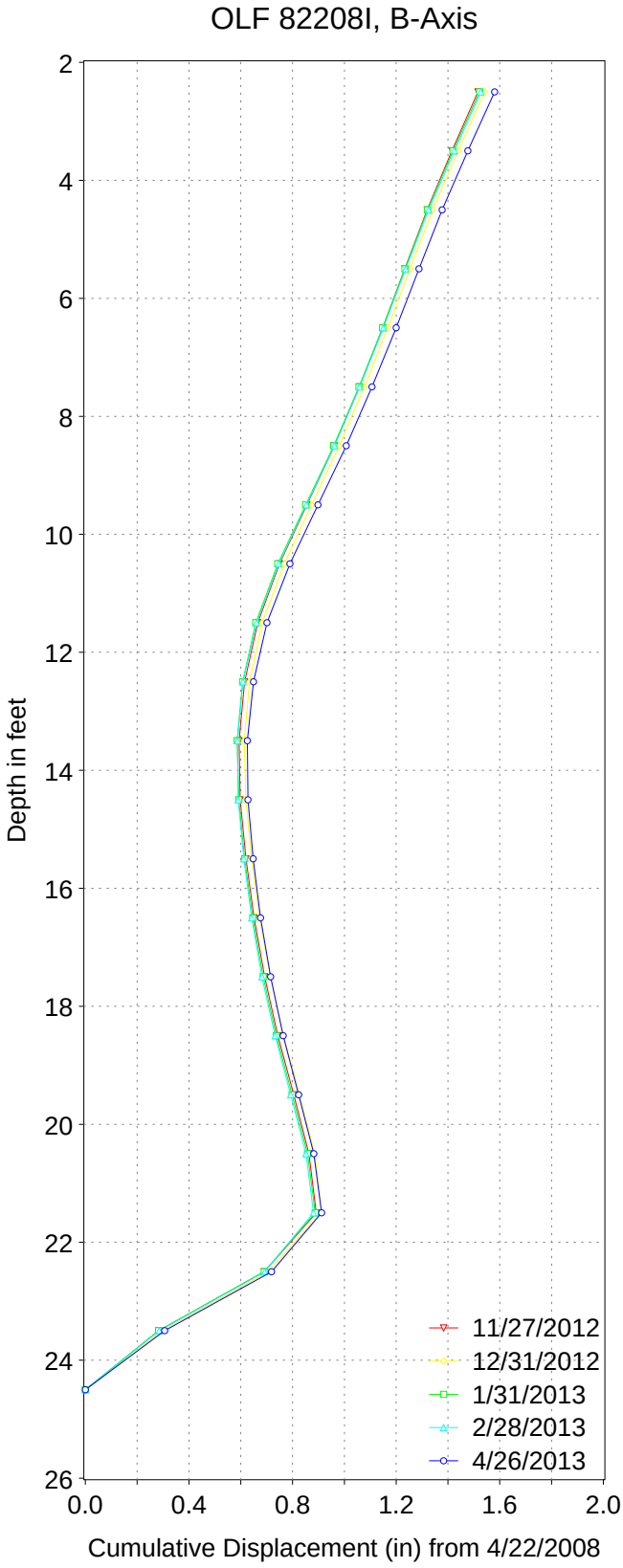


Rocky Flats OLF

Borehole Tt-1

Bad Data: 8/30/10, 9/9/10, 9/30/10, 1/26/11, 6/30/11

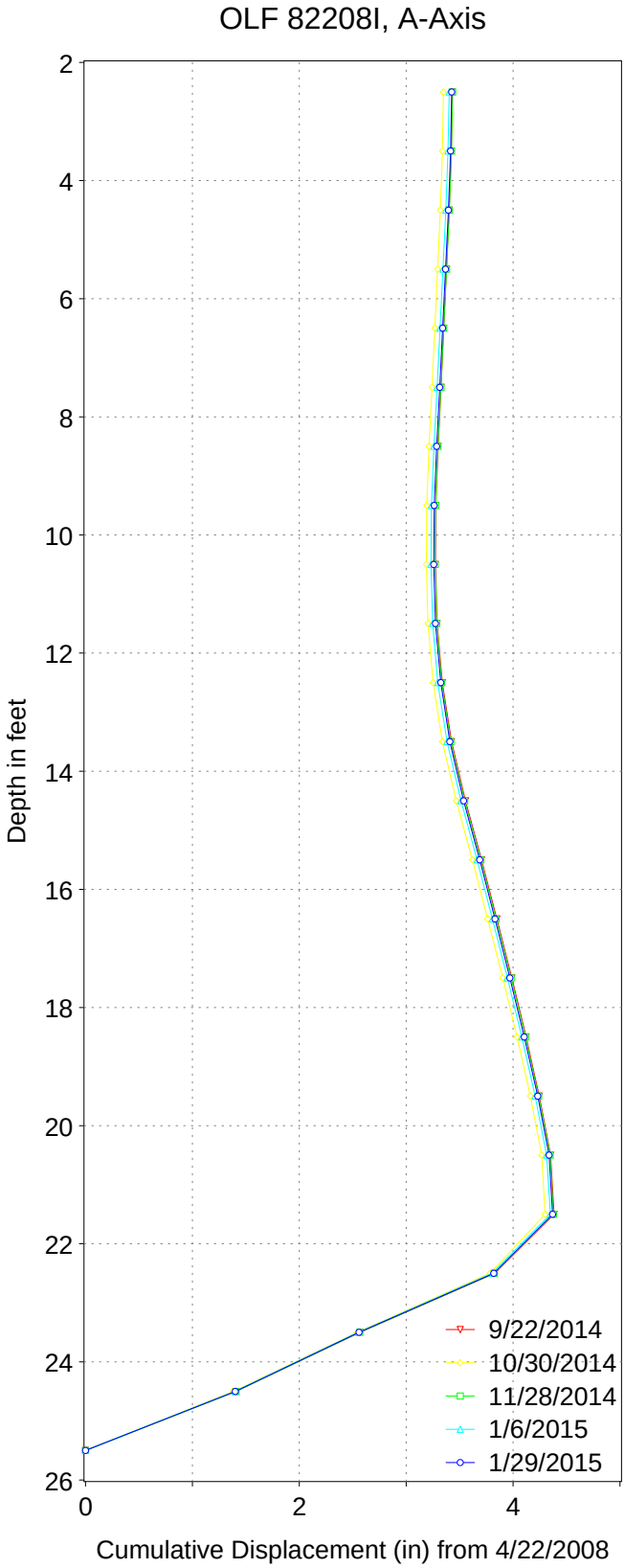


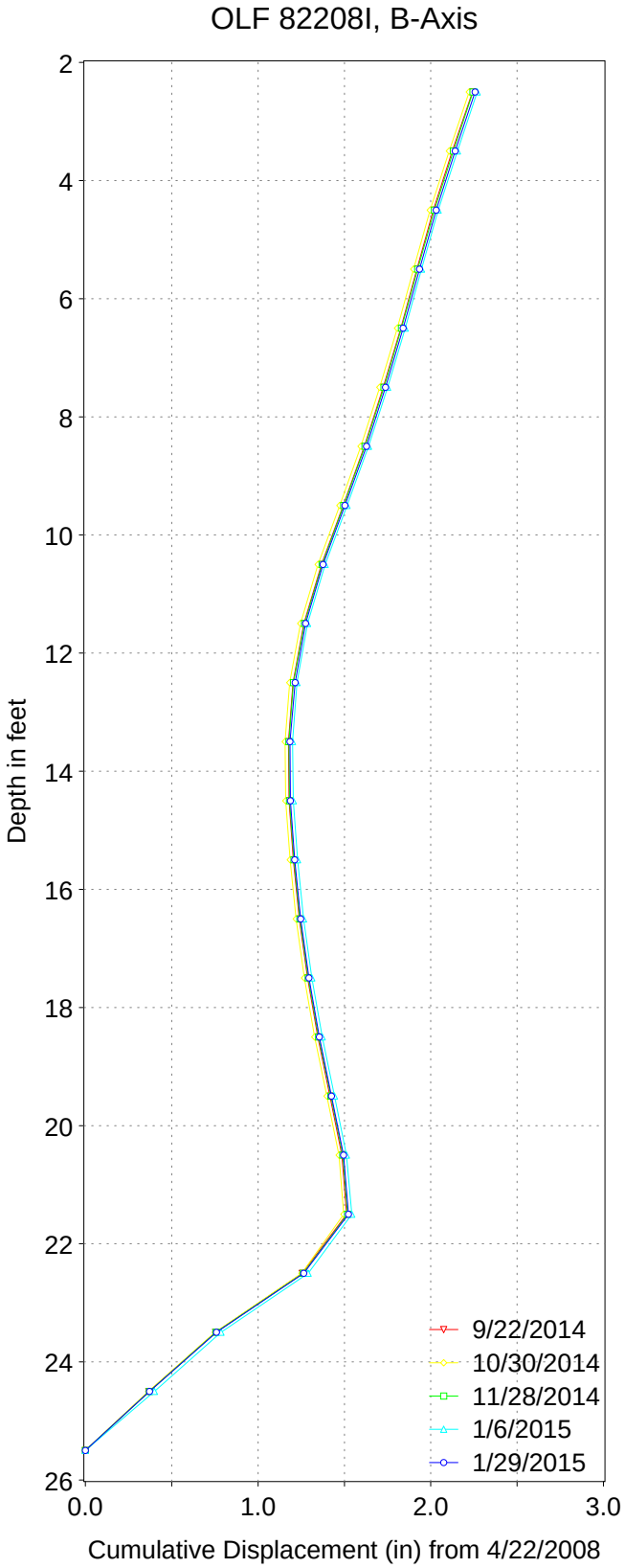


Rocky Flats OLF

Borehole Tt-2

Initial depth 34ft; this plot shows readings to 24ft
Bad Data: 9/30/10, 10/28/10, 11/18/10, 1/26/11

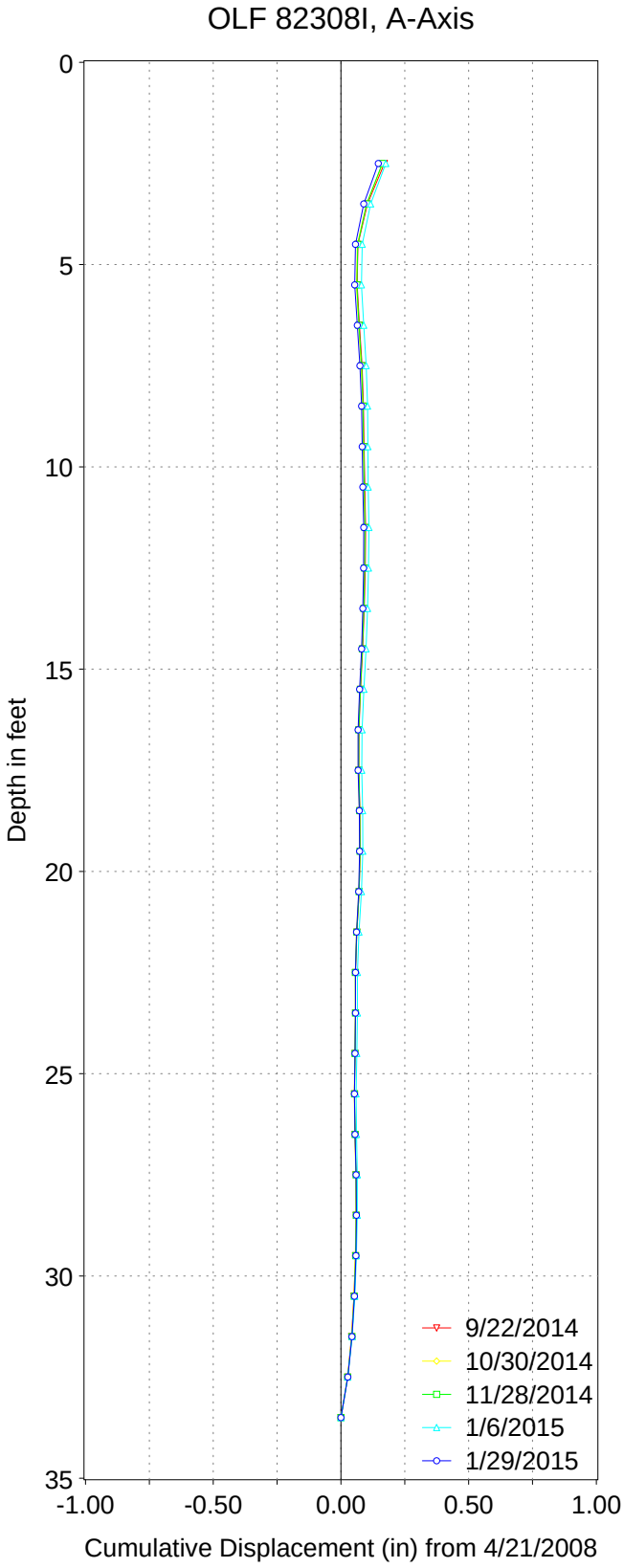


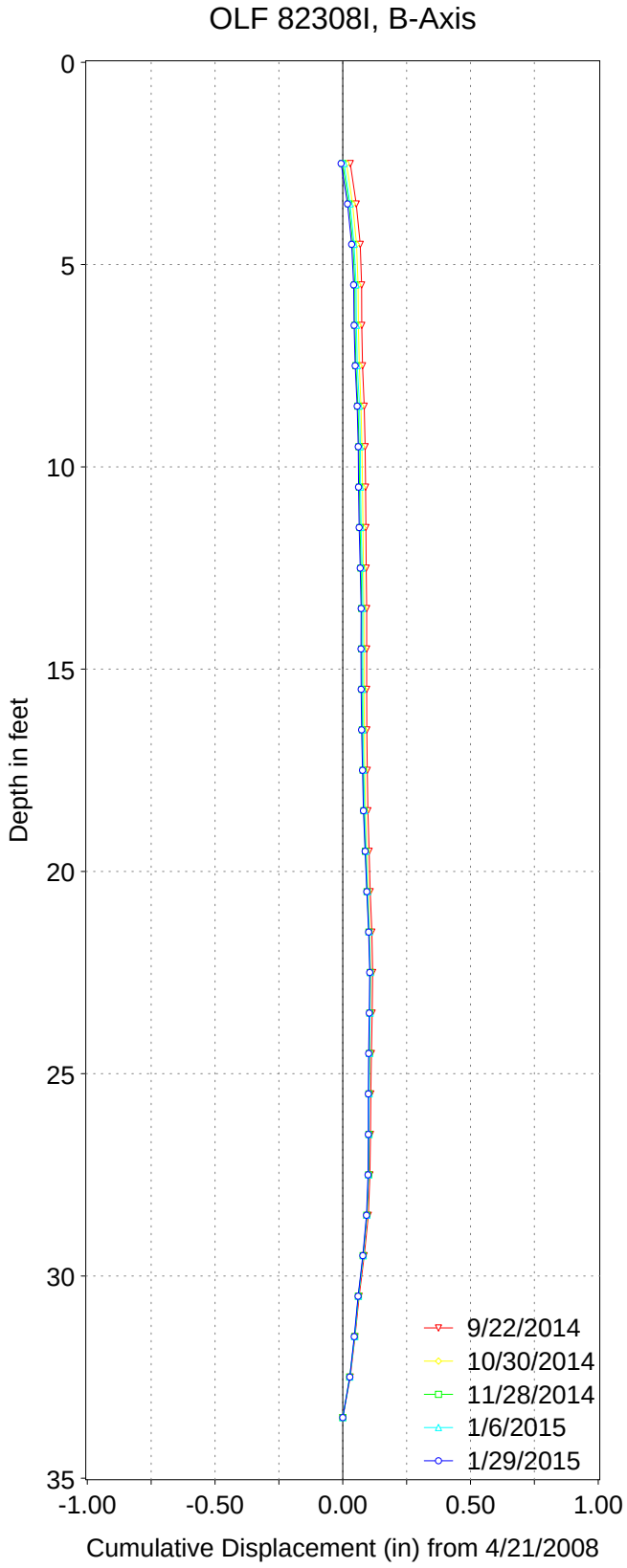


Rocky Flats OLF

Borehole Tt-2

initial depth 34ft; this plot shows readings to 25ft

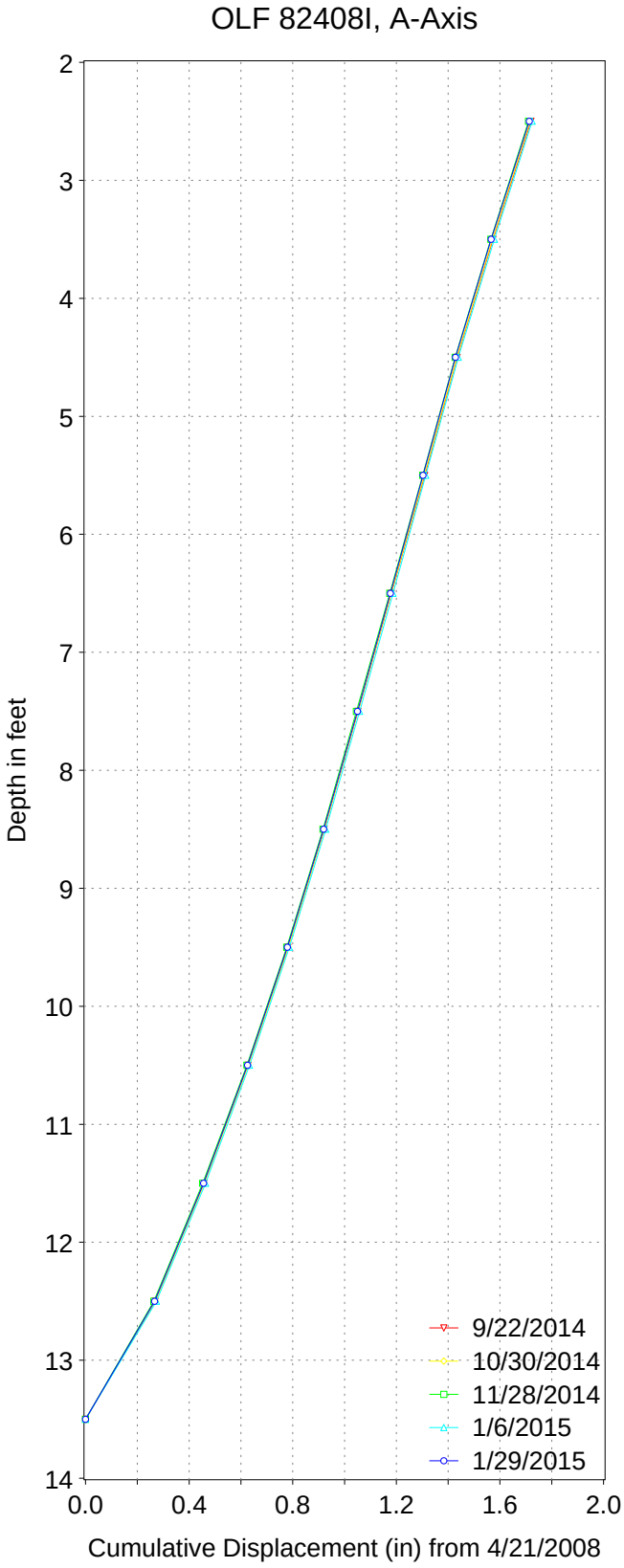


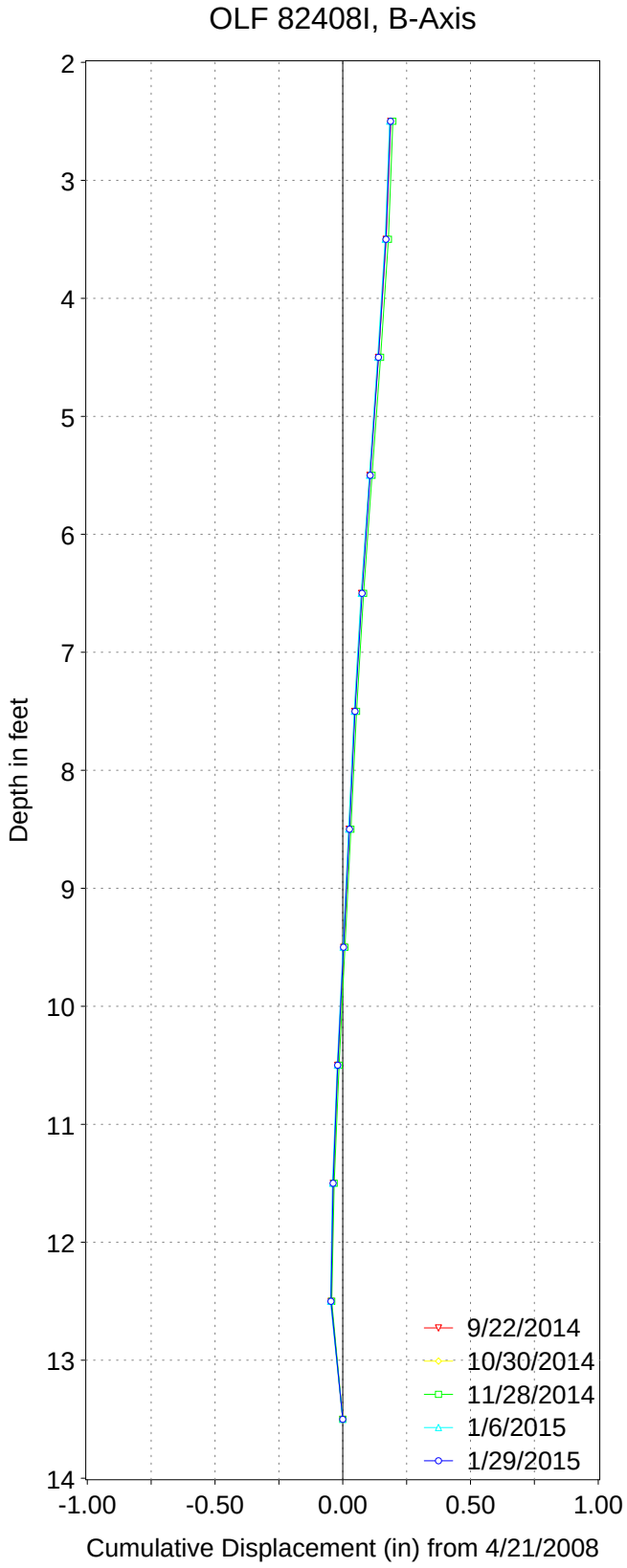


Rocky Flats OLF

Borehole Tt-3

Initial depth 38ft; could not read past 33ft after 5/14/09
Bad Data: 8/30/10, 9/9/10, 9/30/10, 8/22/12





Rocky Flats OLF

Borehole Tt-4

Initial depth 29ft; this plot shows readings to 13ft
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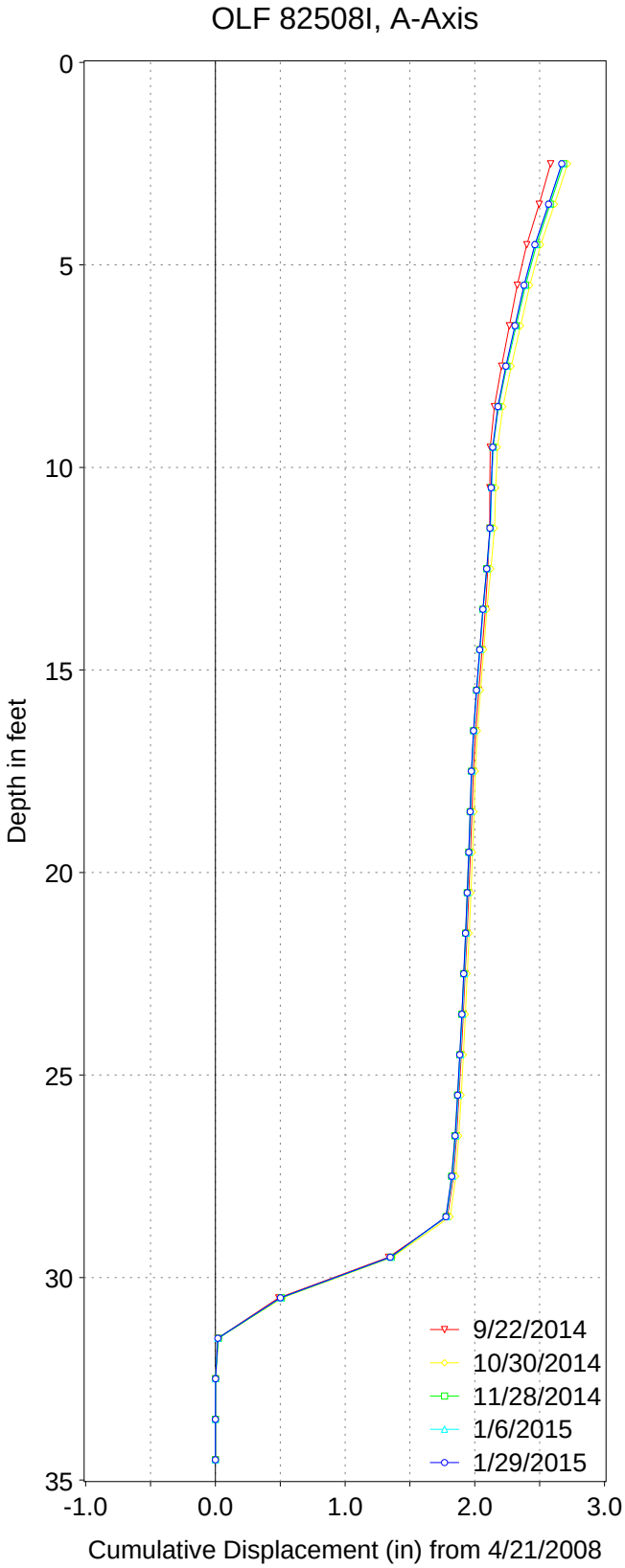

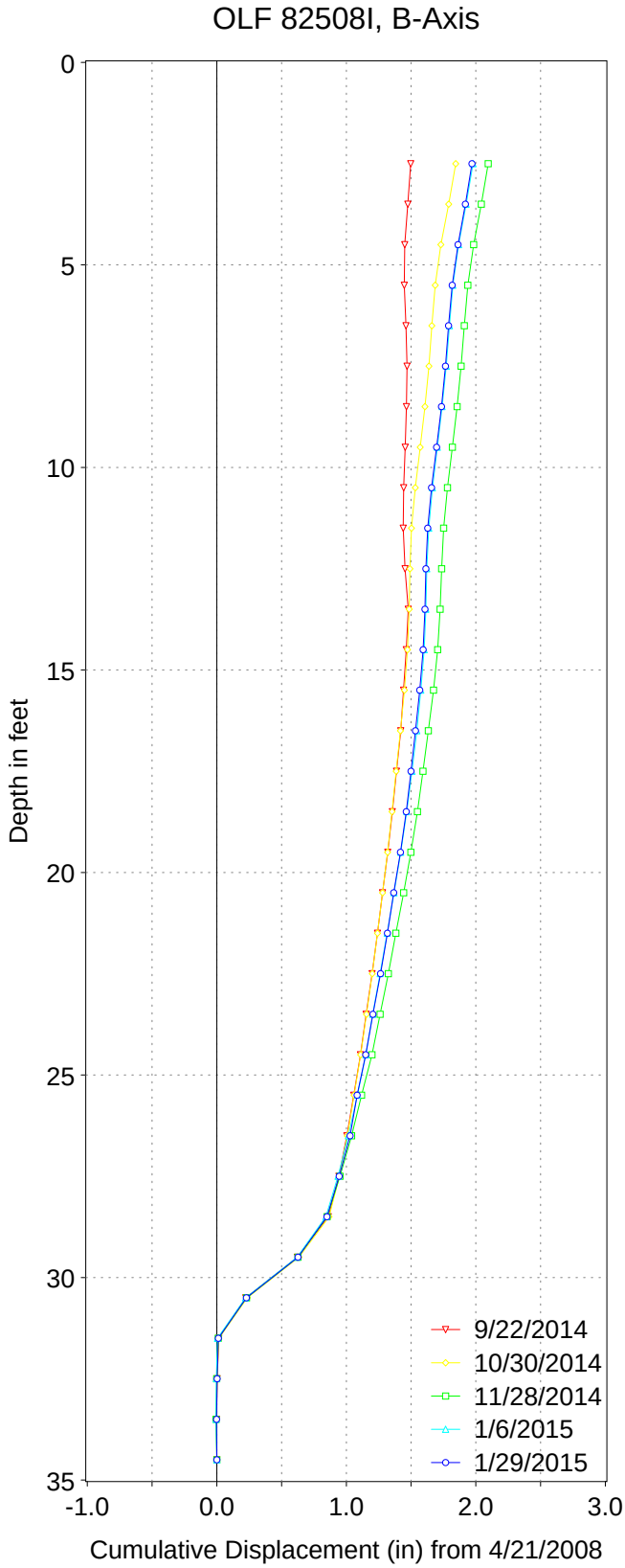

Rocky Flats OLF

Borehole Tt-5

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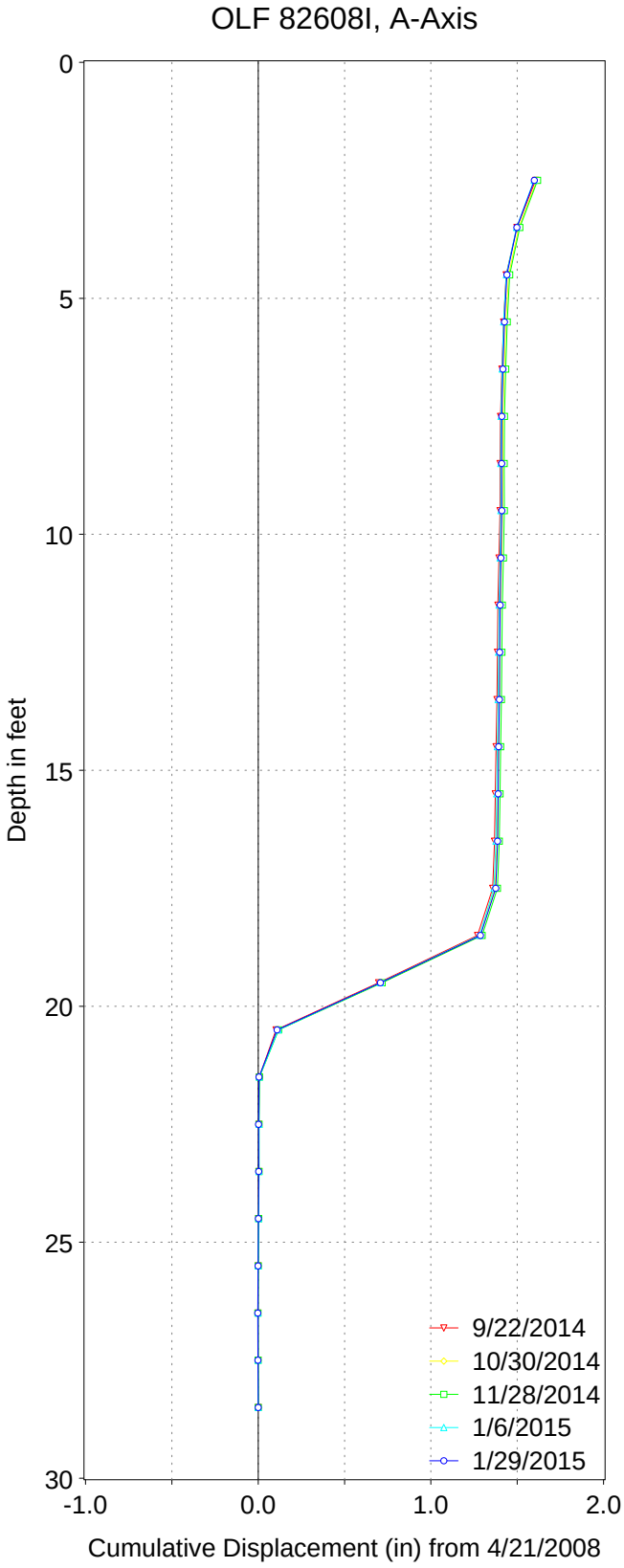

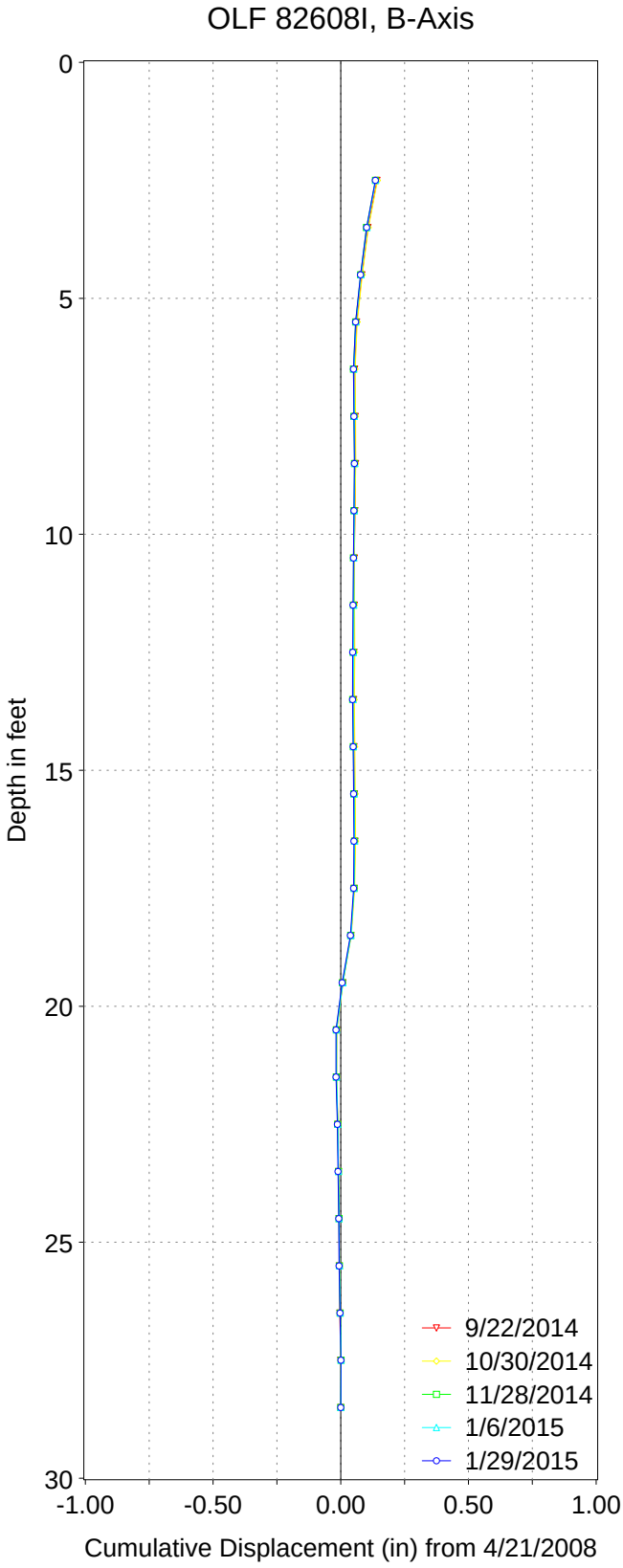

Rocky Flats OLF

Borehole Tt-6

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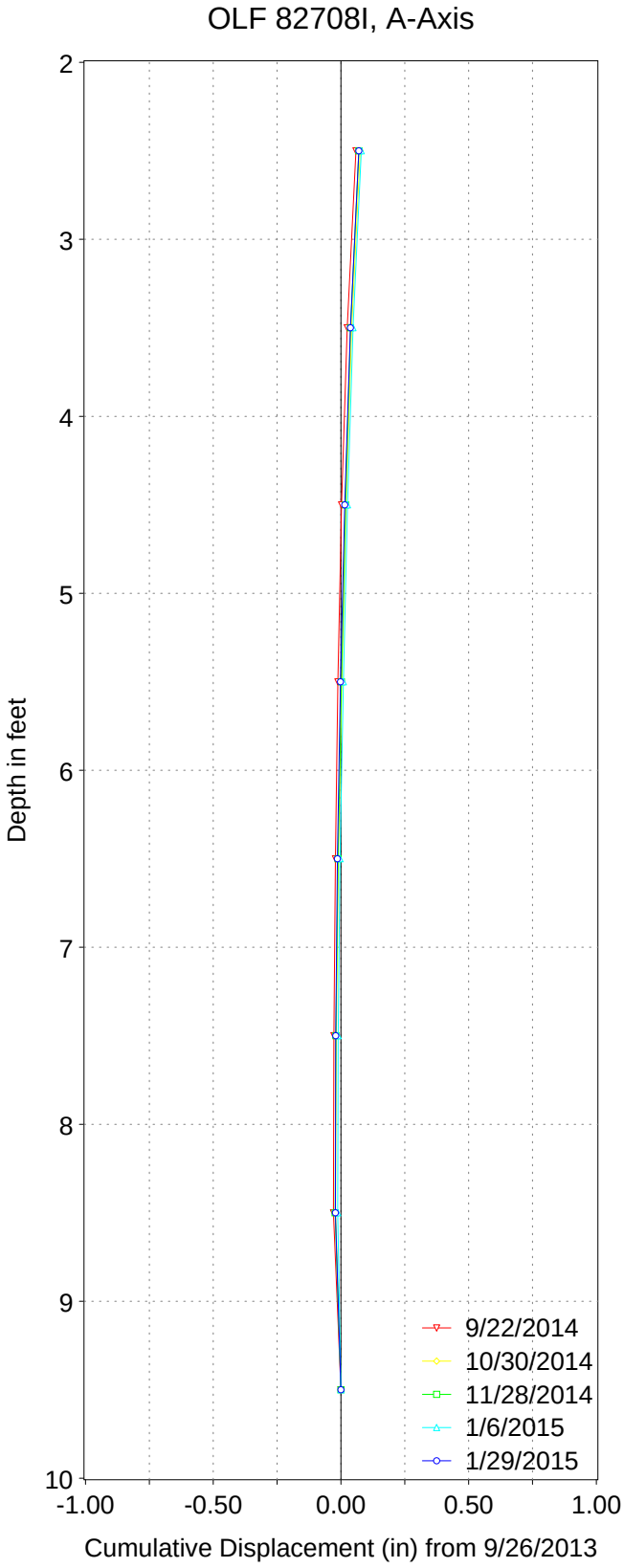
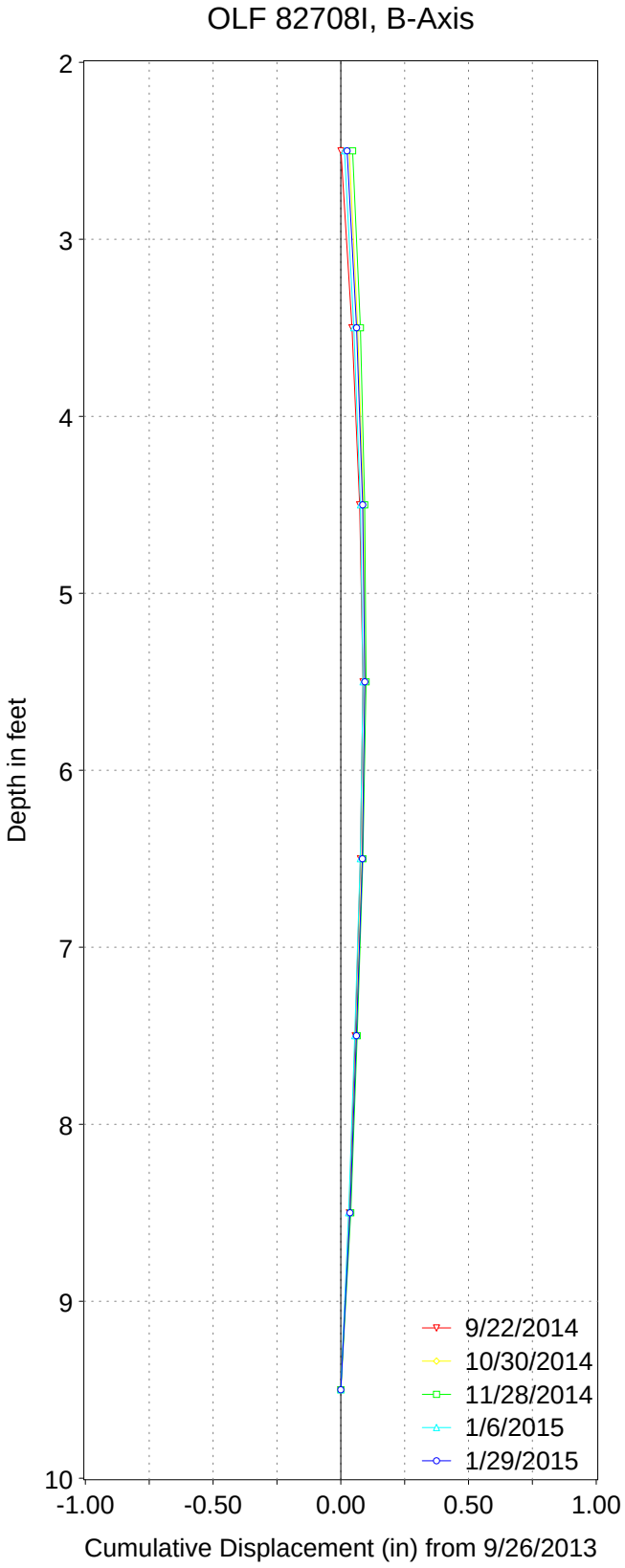




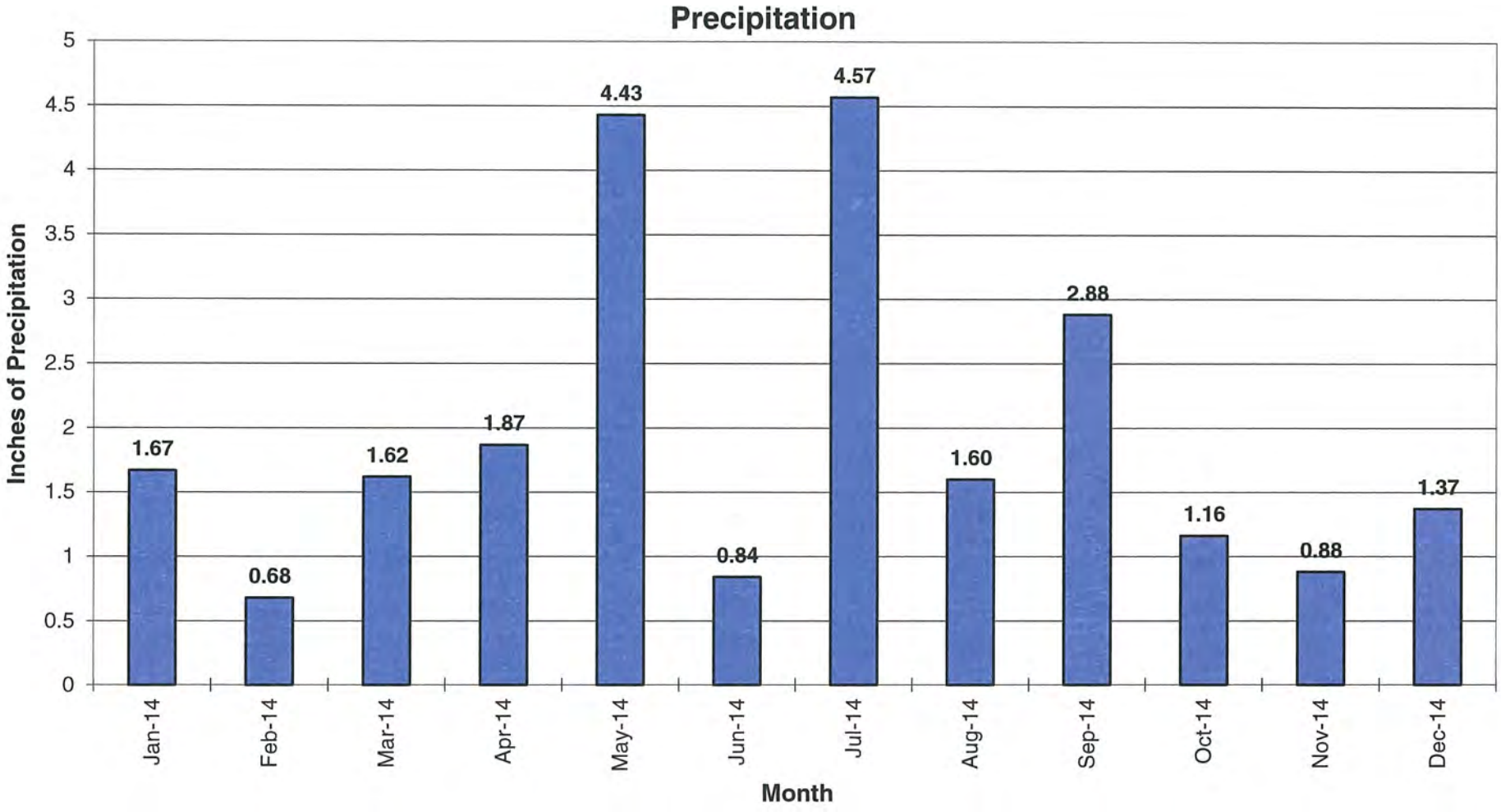
Rocky Flats OLF

Borehole TT-7

Initial depth 28ft; this plot shows readings to 9ft

Bad Readings: 2/27/14

Attachment B
2014 Precipitation Data


Precipitation
Inches of Precipitation
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1.67
0.68
1.62
1.87
4.43
0.84
4.57
1.60
2.88
1.16
0.88
1.37
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14
Month

Attachment C
2014 Review

TETRA TECH

Technical Memorandum

To:	Linda Kaiser	From:	Thomas A. Chapel, CPG, PE
Company:	S.M. Stoller	Date:	September 17, 2014
Project:	Rocky Flats	Project No.:	114-181750
Re:	Original Landfill Review		
CC:	Stephen Pitton		

COLORADO REGISTERED THOMAS A. CHAPEL 33848 PROFESSIONAL ENGINEER 9/17/14

1.0 Introduction and History

Tetra Tech was asked by S.M. Stoller to conduct a review and evaluation of documents, design concepts, and mitigation procedures related to the Original Landfill (OLF) at the Rocky Flats site. The purpose of the review was to evaluate previous design decisions and provide our opinions as to whether the previous design concept decisions remain valid, and to provide an opinion as to whether the current course of action (performing localized and low impact maintenance when evidence of instability is observed) remains the best alternative.

The OLF was an "informal" (not engineered) landfill used for disposal of construction debris and solid sanitary waste from the Rocky Flats site from 1952 to 1968 (Table 1, Item 11). Localized slumping, settling, and seeps were observed in 2007, prompting additional investigation to determine subsurface conditions in and adjacent to the OLF (Table 1, Item 10). Tetra Tech's investigation and analysis concluded that previous design and construction of a buttress fill and other features provided a factor of safety against global slope failure that exceeds recommended guidelines. However, small scale areas of instability were identified that appeared related to high water content in weak soil zones at or near the contact between the claystone bedrock and overlying soil deposits. Tetra Tech concluded that these marginally stable areas would likely continue to undergo movement during and after periods of increased or extended precipitation when water accumulates in weak soil zones within the subgrade.

Since 2008, S.M. Stoller and the DOE have continued to monitor the OLF, measuring water levels and movement using instrumentation installed as part of the Tetra Tech investigation, and looking for surface expressions of distress on the slopes. When cracks or scarps have been observed, S.M. Stoller has filled in the cracks and repaired disturbed areas by hand tamping soil into voids. Locations of cracks have been measured and documented using global positioning system (GPS) and land survey techniques.

Following historic precipitation and flooding in September 2011, movement occurred near the eastern boundary of the OLF in the vicinity of the East Perimeter Channel. This movement occurred in areas where cracks had previously been identified by Tetra Tech and S.M. Stoller during "walk-downs," and appeared similar to distress that has occurred on the west side of the OLF. The increased movement prompted a request by DOE to review project documents and prior recommendations to provide an opinion as to whether the previous course of action continues to be a reasonable approach to mitigating distress at the OLF.

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2.0 Documents Reviewed

Table 1 (below) summarizes key documents for the OLF that were compiled by S.M. Stoller and provided to Tetra Tech for review.

Table 1. Rocky Flats OLF Documents for Review

Item No.	Document No.	Date	Title
1	IA-A-002617	March 10, 2005	Final Interim Measure/Interim Remedial Action For The Original Landfill (Including IHSS 115, Original Landfill and IGSS 196, Filter Backwash Pond)
2	IA-A-002949	November 2005	Closeout Report for IHSS Group SW-2 Original Landfill (IHSS 115) and Water Treatment Plant Backwash (IHSS 196)
3	OU05-A-000289	Nov. 10, 1994	Final Phase I RFI/RI Work Plan for Operable Unit 5 Woman Creek Priority Drainage
4	OU05-A-000539	Jan. 22, 1996	Geotechnical Investigation Into the Stability of Slopes in OU5, Rocky Flats Plant
5	OU05-A-000625	Dec. 16, 1994	DRAFT Borrow Source Evaluation for the Closure of the OU5 and OU7 Landfills
6	OU05-A-000728	Dec 2004	Kaiser Hill- Accelerated Action Design for the Original Landfill Rocky Flats Environmental Technology Site **Geotechnical Investigation Phase 3 Stability Analysis Technical Support Memorandum**
7	OU05-A-000729	Dec. 6, 2004	Integrated Flow and VOC Fate and Transport Modeling for the Original Landfill at the Rocky Flats Environmental Technology Site- Technical Report
8	OU05-A-000735	Dec. 21, 2004	"Analysis of Potential Relevant and Appropriate Requirements for Closure of the Original Landfill" and the supporting table, "Relevant and Appropriate Analysis for OLF Cover"
9	PD-A-000102	Feb. 13, 2006	Final Landfill Monitoring and Maintenance Plan Rocky Flats Environmental Technology Site Original Landfill
10	PD-A-000107	June 4, 2008	Tetra Tech: Rocky Flats Original Landfill Geotechnical Investigation Report
11	PD-A-000186	September 2009	Original Landfill Monitoring and Maintenance Plan
12	LTS-111-0056-07-001D	Nov. 23, 2009	AsBuilt West Perimeter Channel Stabilization drawings (6 sheets)
13		June 24, 2014	OLF Inclinometer Data
14	56801_4311-030_EPS SLUMP TOPO	June 5, 2014	Flat Irons Survey, OLF EPC location
15	Post-closure_OLF_MSHEmodeleval	Jan. 23, 2008	Original Landfill Post-Closure (2007) Integrated Surface-Subsurface Hydrologic Flow System Assessment and Model Update, Rocky Flats Site

Of particular relevance were items 4, 6, 10, and 11 on Table 1. Item no. 11, the OLF Monitoring and Maintenance Plan, is a comprehensive document that describes the objectives, procedures, and features related to on-going maintenance and monitoring (M&M) of the OLF. The M&M Plan also provides an excellent summary of work at the site to date and the rationale behind the designs and maintenance procedures. According to the M&M Plan, the key features of the OLF designs are the cover, the buttress fill, and the stormwater management system. The performance of these features is generally controlled by geotechnical conditions that are addressed in three geotechnical engineering investigation reports (Table 1, items 4, 6, and 10). The January, 1996 report focused on slope stability

and concluded that most sliding was prone to occur within the natural claystone formational materials. A December, 2004 report by Kaiser Hill referenced hydrogeologic modeling for the site and included those results in slope stability and deformation analyses. They also referenced a ditch that was used to drain water onto the OLF area slopes. The ditch was reported to have been covered prior to 1983, when an outfall pipe was constructed. After 1986 the outfall pipe was replaced by a buried outfall pipe that drained southeast into the south interceptor ditch (SID). These drainage features were later abandoned, but details of the abandonment are not known. For example:

- was pipe and pipe bedding completely removed, or could lenses and pockets of porous materials remain?
- Was vegetation removed from open trenches, or could organic layers and lenses remain?
- Was trench backfill placed in lifts and compacted? What was the character of the backfill?

Review of documents shown in Table 1did not identify this kind of detailed information. If additional sources exist that might include such information, these details could provide insight as to the causes of some of the seeps and localized areas of instability.

Kaiser Hill reported that re-grading the OLF to a maximum slope of 18 percent and adding a soil buttress at the toe of the slope would raise calculated safety factors to between 1.7 and 1.9 during static analyses, and to between 0.9 and 1.0 for pseudostatic analyses. They further opined that control of surface water is a key to slope stability.

Tetra Tech's 2008 geotechnical investigation supported the conclusions of previous geotechnical investigations, but provided additional guidance as to what types of measures would be effective at improving the stability of the OLF. Analyses and modeling indicated that the design features described in Section 3.0 below were effective in reducing the risk of a large and catastrophic "global" slope failure. The analyses showed that minor increases in the water level in the shallow subsurface are significant enough to result in localized slope failures. Reducing the water level alone, however was not sufficient to increase the calculated safety factors to a typically accepted design value of 1.5. Therefore, engineering controls would be required to reduce the risk of additional, localized slope failures. A range or progression of potential solutions were presented, which would be designed to decrease slope angle, increase soil strength, or decrease water content. These included:

- Regrade the OLF to flatten slopes, either locally or site-wide;
- Improve surface drainage and reduce infiltration;
- Construct a slurry wall up-gradient of the OLF;
- Construct a drain network through and down-gradient of the OLF;
- Grout injection; and
- Dynamic compaction.

As discussed in Tetra Tech's 2008 geotechnical engineering investigation report (Table 1, Item 8), significant reductions in slope inclinations are not considered a feasible alternative at this site due to the presence of the waste and the depth to a low strength layer that contributes significantly to the slope instability.

Surface drainage was addressed by the 2005 construction of the berm and channel system. Adjustments to the channel slopes have been made to reduce ponded water, and regular maintenance of the channels and berms has continued. Snow fences have been added upslope of the OLF to reduce "surge loading" of the OLF during peak cold weather precipitation and snowmelt times.

In our 2008 report (Table 1, Item 8), a slurry wall or drain network was proposed as more robust alternatives to the above mitigation concepts. A slurry wall constructed upstream of the OLF would deflect water flowing at the soil/bedrock interface east and/or west. However, this would tend to de-stabilize slopes subjected to the increased groundwater flow caused by the deflection. Further, surface water infiltration on the OLF would not be reduced. Therefore a slurry wall alternative is considered to be of limited value for this site. A drain system would collect surface water, but would require significant disturbance of the waste, and may not improve performance of the localized areas between the drain elements.

Grout injection and dynamic compaction are costly alternatives that are commonly reserved for situations involving significant risk of damage to downslope structures or public safety rather than localized distress as has been predicted and observed at the OLF.

At a minimum, the maintenance procedures that S.M. Stoller has used at the site since at least 2005 were recommended to continue, and these measures have maintained a low level of localized distress and a correspondingly low level of effort.

Tetra Tech's work also included installation of instrumentation including piezometers and inclinometers to measure water levels and movement and to determine the depth at which movement was prevalent. S.M. Stoller incorporated monitoring of these instruments; results have been included in annual reports for the site.

3.0 Design Concepts

Based on the recommendations in the pre-2005 engineering studies described above, engineering controls and stormwater management structures were designed and constructed in 2005 to control surface water and address large scale slope stability concerns. A two-foot thick soil cover composed of Rocky Flats alluvium was placed over the waste footprint. Seven diversion berms were constructed to drain surface water to the east and west perimeter channels, for discharge to the Woman Creek drainage, and a 20-foot high by approximately 1,000-foot long buttress fill was placed and compacted at the toe of the slope. A rock and geotextile subdrain was constructed as part of the buttress fill. Subsurface gravel drains were added in localized areas on the west side of the OLF to facilitate drainage from seeps and perennially wet areas.

4.0 Maintenance Practices and Conclusions

On-going monitoring and maintenance practices at the OLF have provided a lengthy "track record" of typical slope stability issues and the effectiveness of the solutions implemented. From a global perspective, the slope underlying the OLF has performed as predicted by geotechnical analyses. No evidence of large scale slope movement or distress has been observed. Minor slope movements have continued to be an issue at the site; therefore, on-going maintenance has been required. In general, movement has occurred following periods of wet weather, increased precipitation, or rapid snow melt.

To date, the maintenance has been dictated by frequent observations of the slopes. When cracking, displacement, seepage, or other issues have been observed; the conditions have been documented and addressed. Crack locations have been recorded using a GPS and plotted on images and drawings. Cracks have been filled and tamped to reduce the potential for infiltration of water. In areas where evidence of seepage has been observed at toes of the diversion berms, localized slope stability modeling was used to estimate the potential for failure of the berms. The modeling showed that the slopes are marginally stable, and this information has been used to guide S.M. Stoller in avoiding fill placement in critical areas and reducing the opportunities for water to soak into the subsoils.

The cracking and displacement that occurred following the storm of September, 2011 appears consistent with previous localized movement that has occurred at the site. This review has not identified factors, conditions, or changes in conditions at the site that suggest the current approach is any less valid now than when it was implemented. There have been no land use changes downstream or downslope that would result in increased risk to human health and safety if a slope failure were to occur. Since inspections are required and on-going, the additional effort required to look for evidence of cracking and slope movement seems small in comparison with the cost of implementing engineering controls such as those described above and in the previous geotechnical engineering reports, which would be required to further reduce or eliminate the localized slope instability. This review has not identified omissions or changes that would suggest a different approach to managing the localized instability should be implemented. A minor re-grading operation in the area of the EPC is proposed to flatten slopes, reduce weight, and facilitate drainage from seeps. It is anticipated that this work will reduce the magnitude of localized slope distress, but that on-going maintenance and repairs similar to those implemented to date will continue to be required.