ARP IV: Structural Steel Disposal Analysis

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DATE: November 9, 2011

Introduction

The Accelerated Retrieval Project facility (ARP IV) was a fabric-covered sprung structure (approximately 270 feet by 234 feet) that was designed to provide containment for the retrieval of the transuranically contaminated waste (i.e., targeted waste) within Pit 5 of the Subsurface Disposal Area (SDA). Upon the completion of the targeted waste retrieval, a cap will be installed to permanently cover the non-targeted waste, which was re-buried and backfilled at the same general area within Pit 5 of the SDA. During waste exhumation, targeted wastes were removed from the disposal pit. Non-targeted waste was placed into the disposal pit in either 4 feet by 4 feet soil sacks or bulk disposed. The waste material re-buried was covered by 4 feet of compacted, low plasticity soil and backfilled to the original ground surface (prior to retrieval). Upon completion of the waste retrieval project a permanent cap will be installed. The permanent cap has conceptually been designed as an Evaportranspiration (ET) Barrier with an approximate thickness of 15 to 20 feet.

It is currently proposed that the sprung structure - after being demolished - be cut into segments with manageable lengths (50-60 ft) and laid flat over the backfilled excavation at Pit 5. The steel segments will then be covered by a minimum of 2 feet of clean soil before being enclosed by the permanent ET Barrier. A concern was raised by CWI about the potential impact – whether it is positive or negative - of the structural steel segments on the operation and performance of the ET Barrier. This technical memorandum (TM) presents a study conducted by CH2M HILL in attempt to evaluate this impact.

Scope of Work

The study presented in this technical memorandum (TM) only focuses on the potential impact of disposing of the structural steel segments on the operation and performance of the permanent ET Barrier. Design recommendations for the permanent ET Barrier to meet the subsidence requirements are not discussed in this TM

Limitations

This TM has been prepared for the exclusive use of CWI in accordance with generally accepted geotechnical engineering practice. No other warranty, express or implied, is made. Conclusions and recommendations provided in this TM are based on input information

provided by CWI and previous studies conducted by other consultants for the Department of Energy (DOE).

CH2M HILL is not responsible for any claims, damages, or liability associated with the mis-interpretation or re-use of the analysis results by others without the express written authorization of CH2M HILL.

Analysis Approach

The impact of the structural steel segments can be evaluated by conducting a subsidence analysis for the landfill at Pit 5 with and without considering the disposed steel segments under the permanent ET Barrier. In general, landfill subsidence can be assumed as the compression of the waste mass (including both primary and secondary compression) plus the settlement resulted from the collapse of voids and/or cavities in the fill layer and around the waste containers due to corrosion, oxidation, or biochemical decay.

In this study, the landfill subsidence analysis was conducted using a finite element (FE) model developed through the use of the computer program Plaxis (version 9). The assumptions and input parameters for the FE analysis are discussed in the following sections.

Description of the FE Model

Figure 1 shows the plane strain FE model and material properties developed for the subsidence analysis. As shown in this figure, the non-targeted waste is covered by a 4 feet of clayey soil, which is overlain by the 15-foot thick ET Barrier (Mattson et al. 2004). The ET Barrier was assumed to consist of a 6 feet of cohesionless soil layer (i.e., sand and gravel) underlying a 9 feet of cohesive soil layer (i.e., clay and top soil). The 2 feet of clean soil cover placed over the structural steel segments is included in the lower cohesionless soil layer of the ET Barrier. Based on the Excavation Plan for the Accelerated Retrieval Project (WMF-1615) - Pit 5 Retrieval Area (ARP IV), the thickness of the non-targeted waste varies significantly with maximum thickness of 17 feet. In this analysis, the non-targeted waste was assumed to be uniformly distributed with average thickness of 10 feet. The structural steel segments were modeled using a layer of geogrid (i.e., tension-only member) with the tensile stiffness (EA) equivalent to that of a Tensar BX-1100 geogrid (approximately 400 lb/ft).

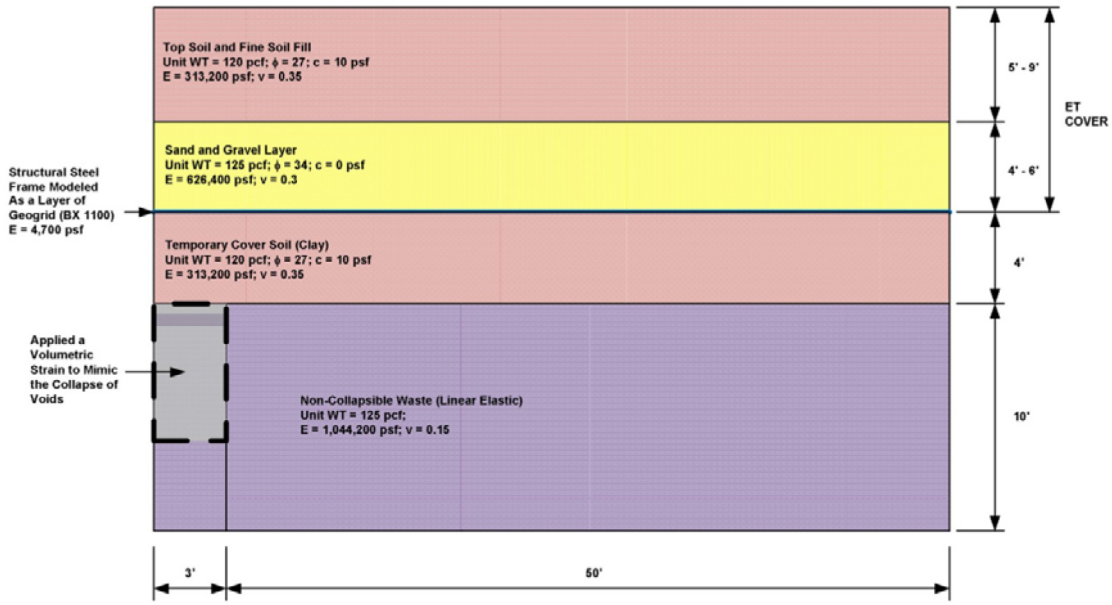


Figure 1. FE model used in the subsidence analysis of the non-targeted waste at Pit 5.

The subsidence of the non-targeted waste at Pit 5 was induced by applying a compressive volumetric strain in a 3-foot wide column within the non-targeted waste layer. The applied volumetric strain was determined from a trial and error analysis in which the calculated settlement at the top of the 4-foot waste soil cover layer had to be similar to the average subsidence of 1.4 feet measured at the SDA facility (Keck and Seitz 2002). The volumetric strain determined from this trial and error process was used for the full model in which the ET Barrier and the structural steel layer were considered. Figure 2 shows the results of the trial and error analysis which indicate that the compression in the non-targeted waste column must be at least 2 feet in order to create a surface subsidence that is comparable to the measured subsidence at the SDA facility.

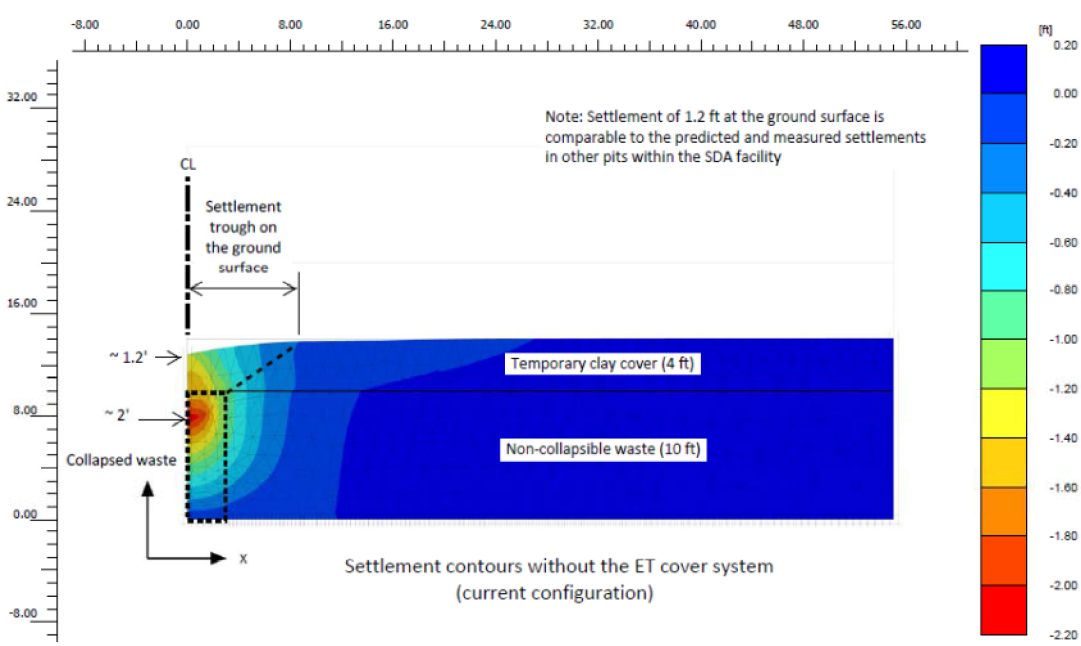


Figure 2. Required compressibility in the 3-foot wide waste column to create a surface subsidence that is comparable to the measured subsidence at the SDA facility.

Results and Discussions

Figures 3 and 4 show the results obtained from the full model in which the subsidence at Pit 5 was calculated with and without considering the structural steel layer. Attachment A includes the detailed analysis documentation. As can be seen in these figures, the subsidence at the surface of the ET Barrier was unchanged in both cases, which indicates that the impact of the structural steel layer, if any, can be negligible. In our opinion, this finding is understandable due to the following reasons:

1) The weight of the structural steel segments is insignificant compared to the weight of the ET Barrier. Based on the input from CWI, the average weight of the structural steel is only about 9.7 psf, which is much less than the weight of the ET Barrier (approximately 1,800 psf for a 15-foot thick ET Barrier). The weight of the structural steel layer was not considered in the model as it was modeled as a layer of geogrid (i.e., weightless element).

2) The tensile stiffness of approximately 400 lb/ft assumed for the structural steel layer was too small to cause a considerable reduction in the differential settlement within the ET Barrier. In reality, the tensile stiffness of the structural steel layer should be even less than the assumed tensile stiffness as the steel segments are not connected. Moreover, the large openings within each steel segment could allow the soil in the fill and the ET Barrier to move through as the waste under the steel layer collapses.

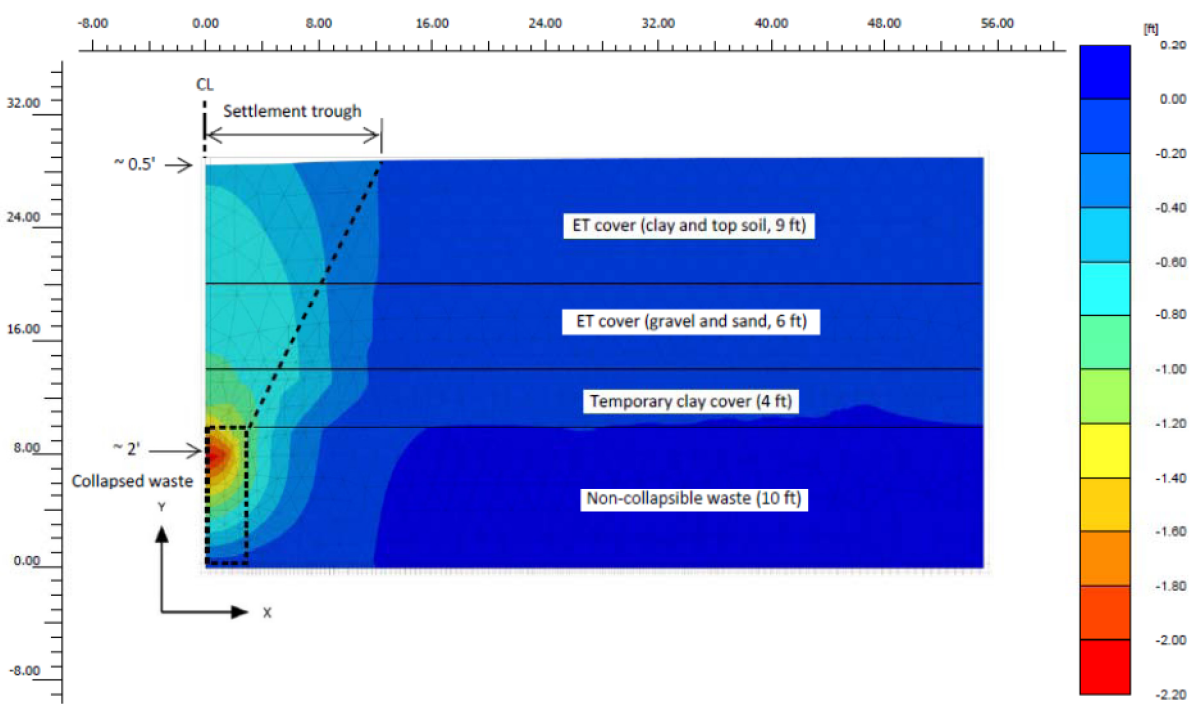


Figure 3. Settlement contours without considering the structural steel layer.

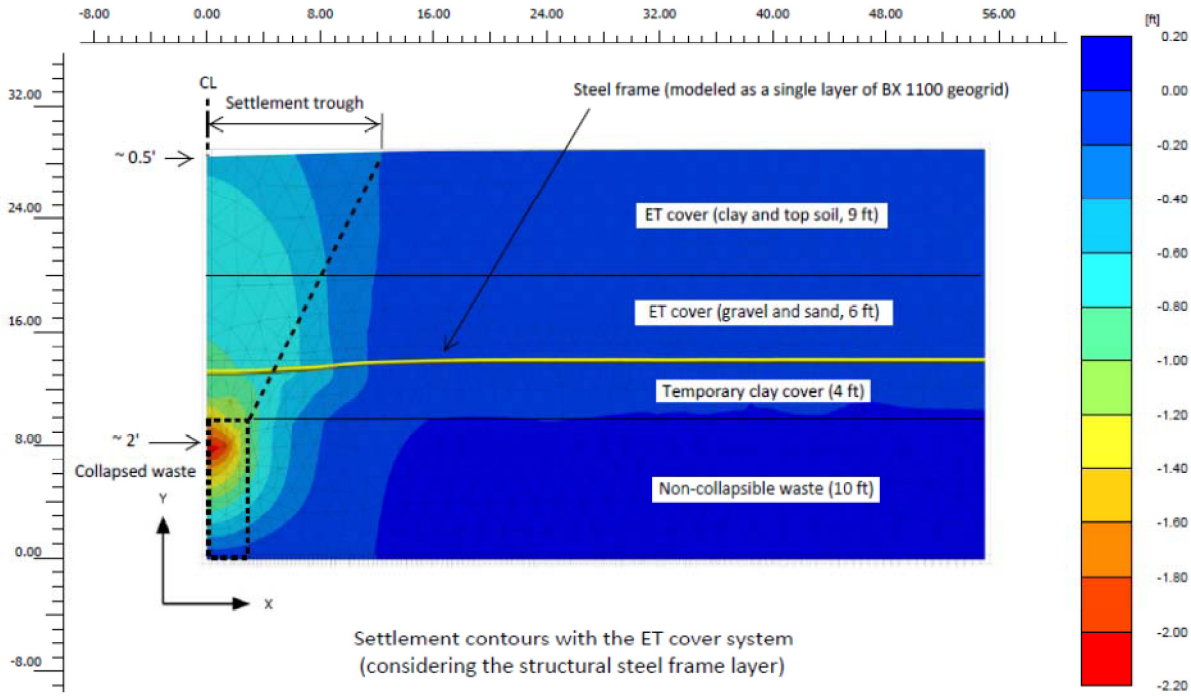


Figure 4. Settlement contours with the structural steel layer modeled as a geogrid layer.

Closure

The following conclusions and recommendations were provided based on the results obtained from the FE analyses.

- The steel segments from the ARP IV sprung structure, which are currently planned to be placed on top of the non-targeted waste at Pit 5, are not likely to cause any significant impact (either negative or positive) on the future performance of the ET Barrier due to subsidence in the buried waste induced by the structural steel disposal. The differential settlement in the ET Barrier is still anticipated to occur in the future due to the consolidation of non-target wastes placed back into the pit. However, the differential settlement in the ET Barrier is not caused or affected by the disposed structural steel layer, assuming the clean soil cover planned for structural steel is properly placed and compacted.

- To minimize the differential settlement in the ET Barrier that is caused by the collapse of voids in the clean soil cover placed over the structural steel, the soil in this layer should be compacted to 95% relative density with relation to the standard Proctor (ASTM D698).

References

Keck, K. N. and Seitz, R. R. (2002). "*Potential for Subsidence at Low-Level Radio Active Waste Disposal Area*." Report Prepared for the Department of Energy. INEEL/-EXT-02-01154.

Mattson, E., Ankeny, M., Dwyer, S., Hampton, N., Matthern, G., Pace, B., Parsons, A., Plummer, M., Reese, S, Waugh, J. (2004). "*Preliminary Design of an Engineered Surface*

Barrier at the Subsurface Disposal Area." Report Prepared for the Department of Energy, ICP-EXT-04-20016.

Plaxis (2009). *User's Manual*.

Attachments

Attachment A – ARP IV Structural Steel Analysis Documentation

ATTACHMENT A

ARP IV Structural Steel Analysis Documentation

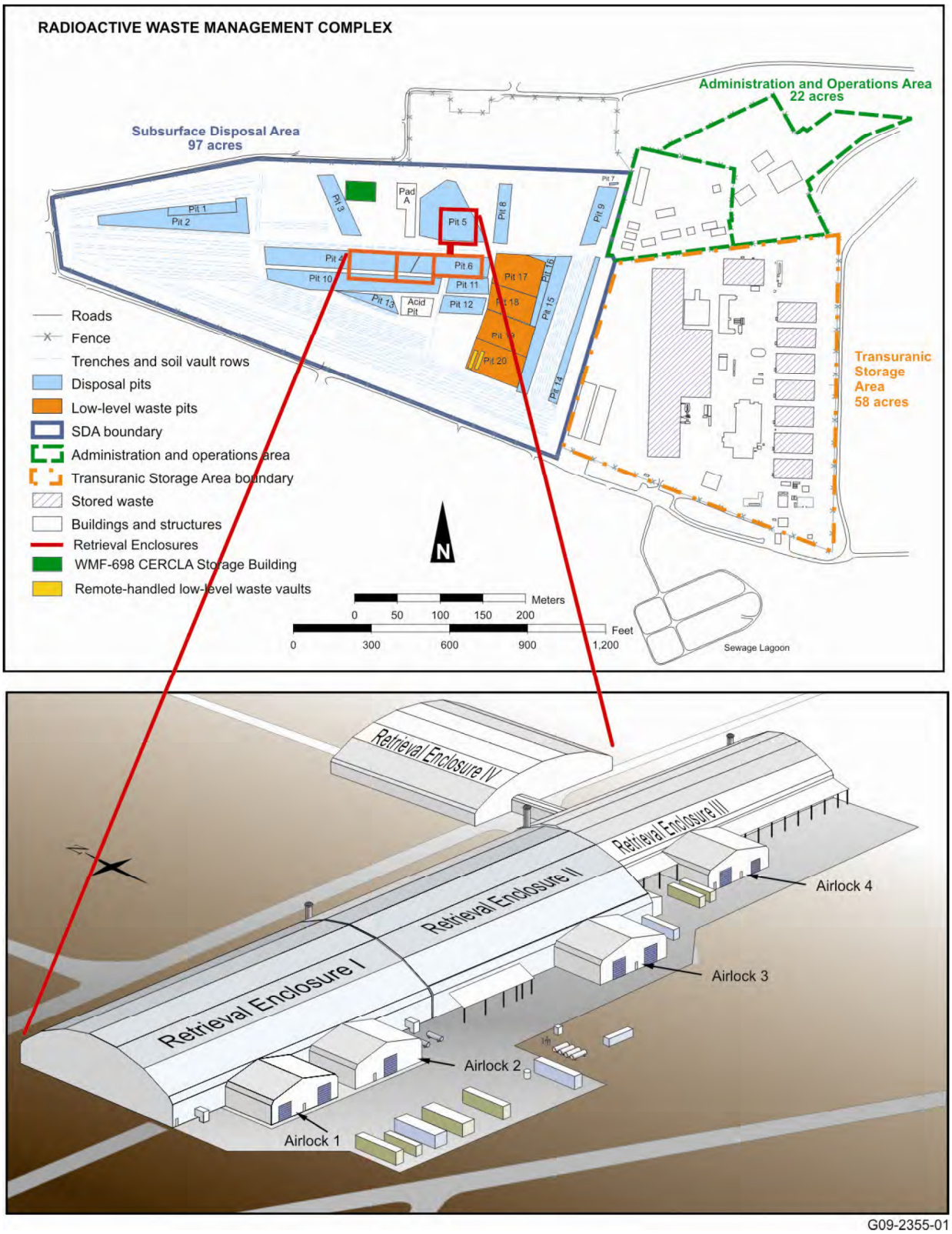
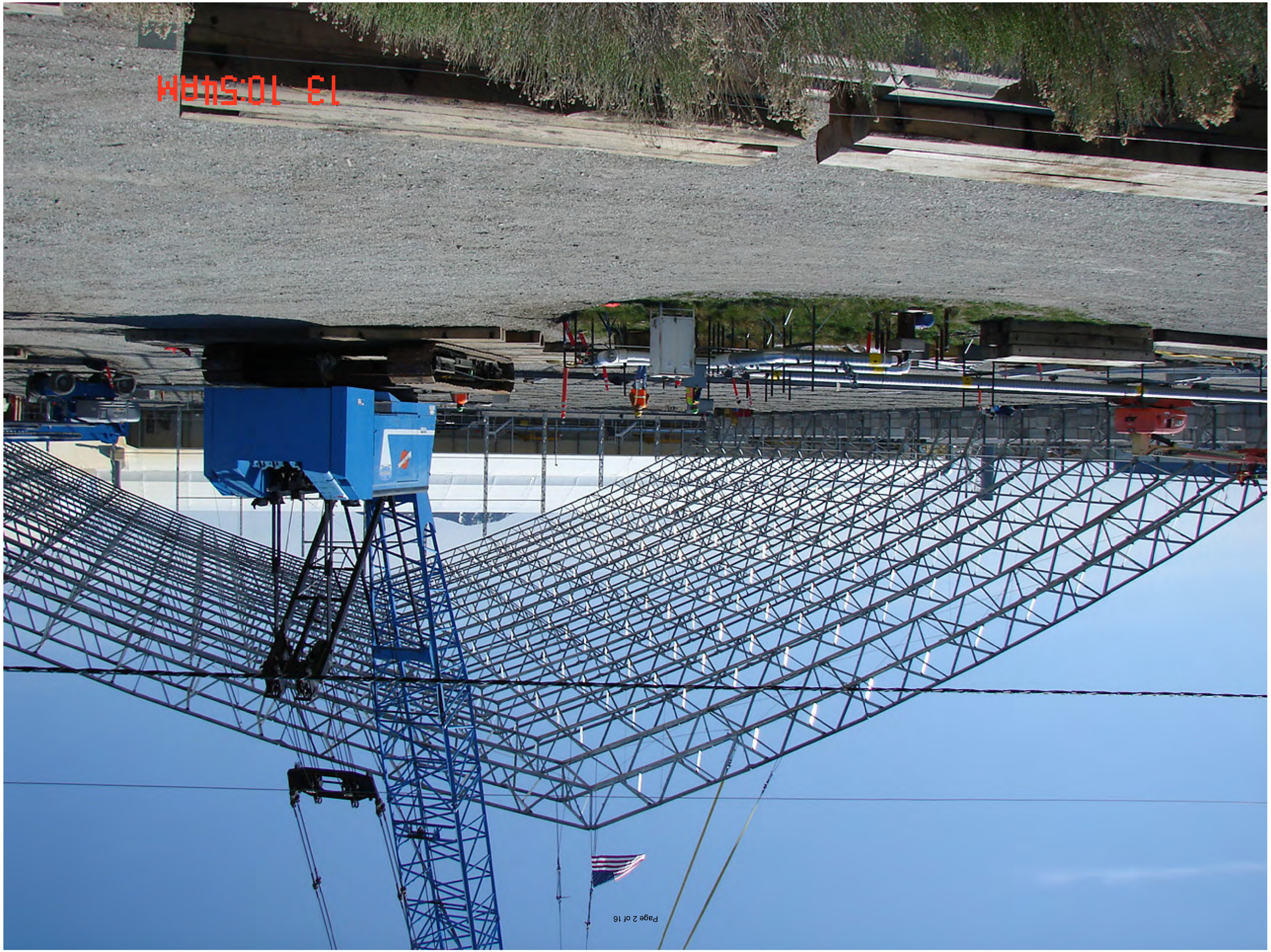


Figure 2. Map of the Subsurface Disposal Area showing ARP IV location within Pit 5.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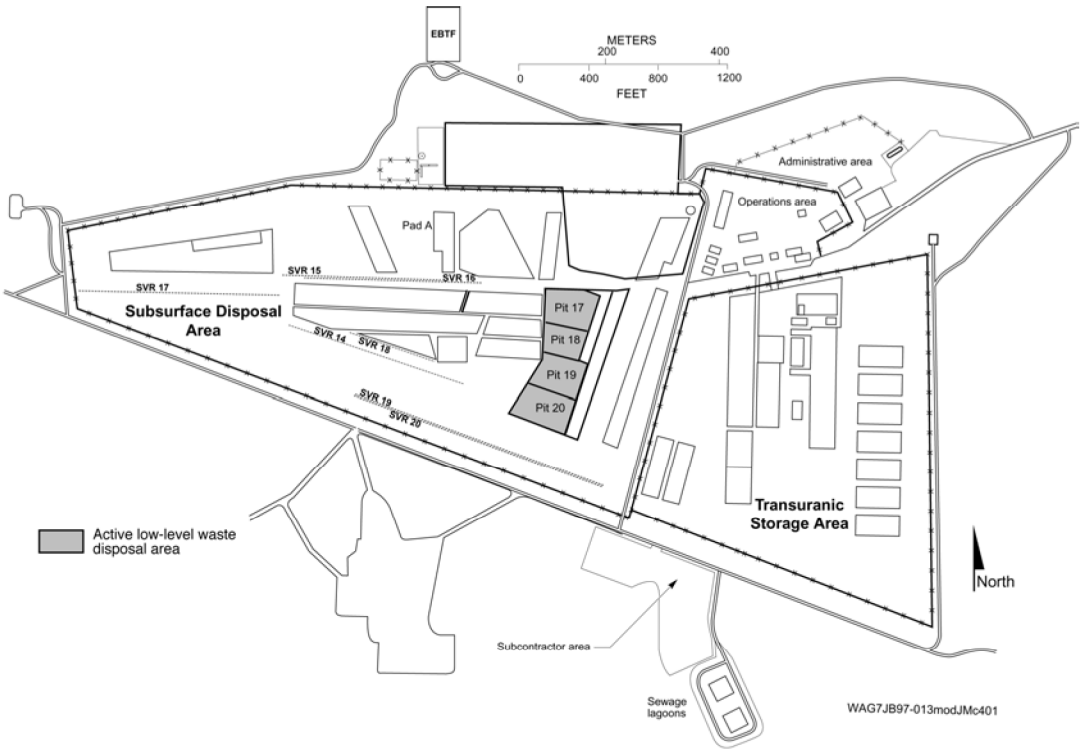


Figure 2. Facilities at the RWMC, including the active LLW disposal pits and soil vault rows.

Figure 3. Photo of currently operating LLW disposal pits within the SDA.

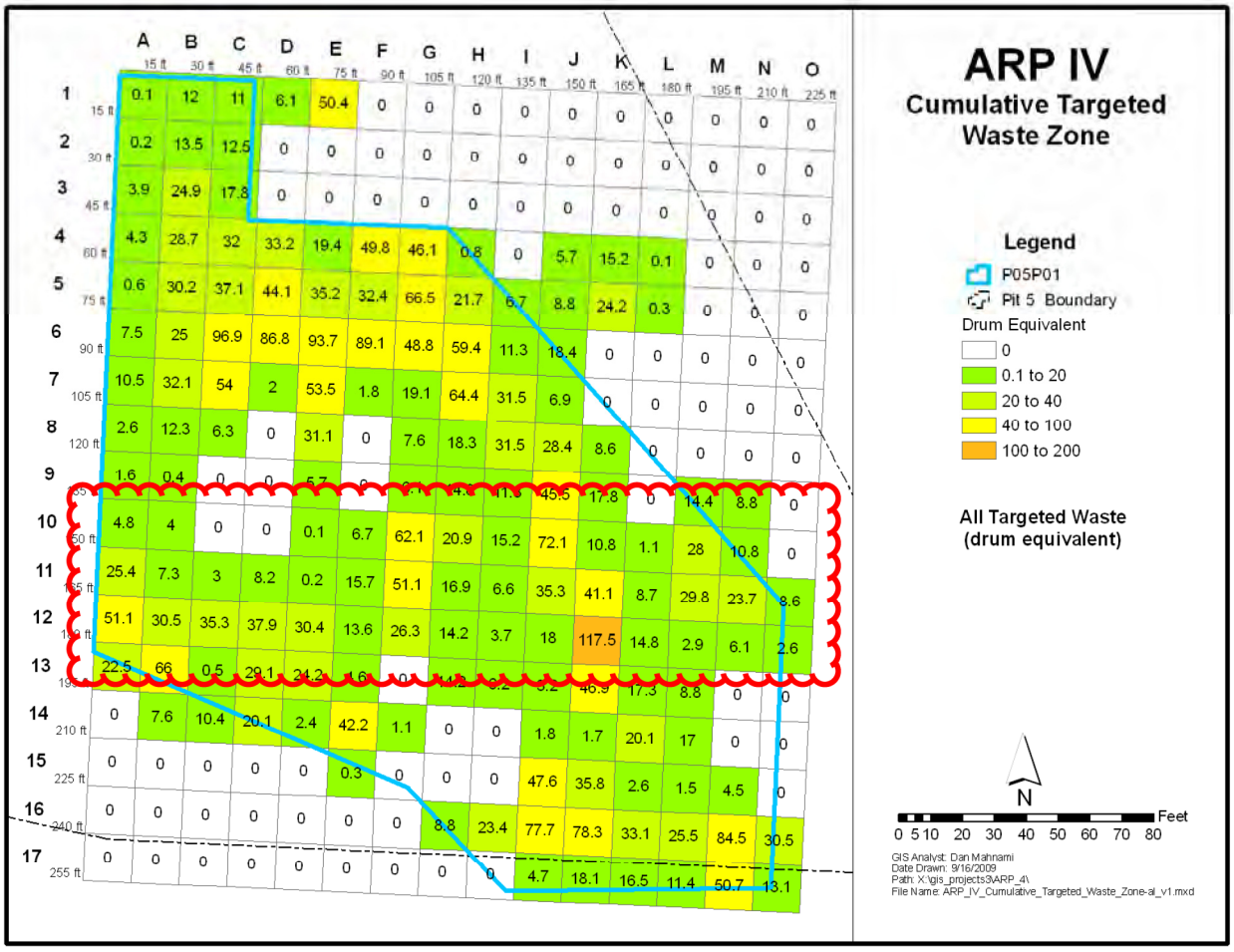


Figure 4. Cumulative Targeted Waste Zone (drum equivalent).

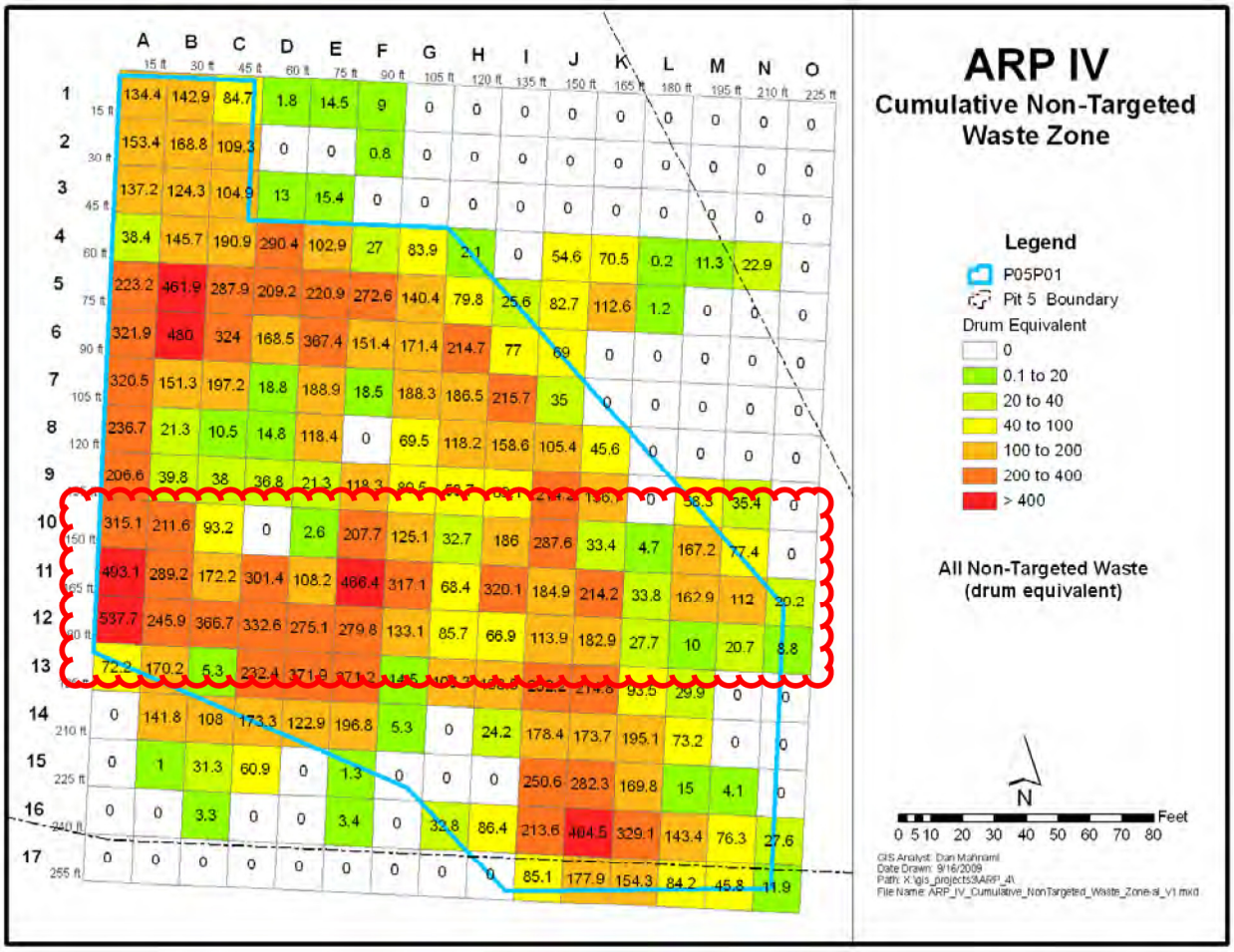


Figure 5. Cumulative Non-Targeted Waste Zone (drum equivalent).

Estimate of the Thickness of the Non-Targeted Waste and Overburden Layer at Pit 5

Project: ICDF
Structure: APR IV
Engineer: H. Pham
Date: 7/12/2011
Checker:

Parameter	Average Thickness of Waste within Rows 10 -12 Before Retrieval (From Figures 18 and 19)														
	Col. A	Col. B	Col. C	Col. D	Col. E	Col. F	Col. G	Col. H	Col. I	Col. J	Col. K	Col. L	Col. M	Col. N	Col. O
Depth to Top of Waste Before Retrieval (ft)	5.0	6.0	4.0	3.0	2.5	3.0	4.0	4.5	4.0	4.5	3.5	4.0	4.0	3.5	3.0
Depth to Bottom of Pit (ft)	20.0	21.0	20.0	14.0	20.0	22.0	20.0	22.0	34.0	42.0	26.0	22.0	28.0	30.0	28.0
Average Thickness of Waste Before Retrieval (ft)	15.0	15.0	16.0	11.0	17.5	19.0	16.0	17.5	30.0	37.5	22.5	18.0	24.0	26.5	25.0
Bottom of Pit Elevation (ft)	-20.0	-21.0	-20.0	-14.0	-20.0	-22.0	-20.0	-22.0	-34.0	-42.0	-26.0	-22.0	-28.0	-30.0	-28.0

Note: Assume top of landfill is at Elev. 0 ft.

Parameter	Average Thickness of Targeted Waste within Rows 10 -12 Before Retrieval (From Figures 4)														
	Col. A	Col. B	Col. C	Col. D	Col. E	Col. F	Col. G	Col. H	Col. I	Col. J	Col. K	Col. L	Col. M	Col. N	Col. O
Total Number of Equivalent Drums	81.3	103.8	38.8	75.2	30.7	36.0	139.5	52.0	25.5	125.4	169.4	24.6	60.7	40.6	11.2
Equivalent Thickness of Waste After Retrieval (ft)	1.0	1.3	0.5	1.0	0.4	0.5	1.8	0.7	0.3	1.6	2.1	0.3	0.8	0.5	0.1

Parameter	Average Thickness of Non-Targeted Waste within Rows 10 - 12 (From Figure 5)														
	Col. A	Col. B	Col. C	Col. D	Col. E	Col. F	Col. G	Col. H	Col. I	Col. J	Col. K	Col. L	Col. M	Col. N	Col. O
Total Number of Equivalent Drums	1345.9	746.7	632.1	634.0	385.9	953.9	575.3	186.8	573.0	586.4	430.5	66.2	340.1	210.1	38.0
Equivalent Thickness of Waste After Retrieval (ft)	17.0	9.5	8.0	8.0	4.9	12.1	7.3	2.4	7.3	7.4	5.5	0.8	4.3	2.7	0.5

	Total Thickness of Waste within Rows 10 - 12 Before Retrieval														
Total Thickness of Waste Before Retrieval	18.1	10.8	8.5	9.0	5.3	12.5	9.1	3.0	7.6	9.0	7.6	1.2	5.1	3.2	0.6

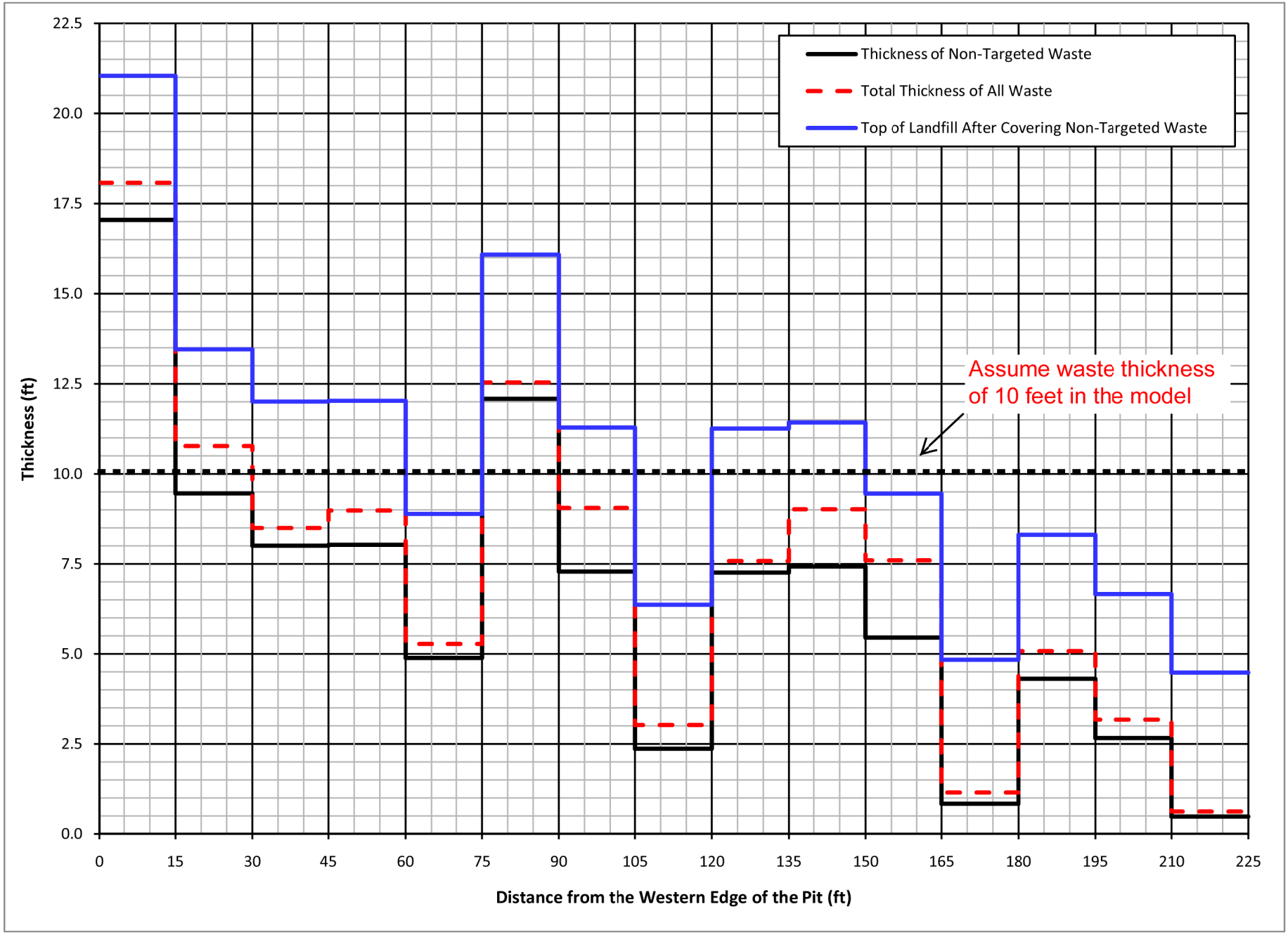

Thickness of Non-Targeted Waste
Total Thickness of All Waste
Top of Landfill After Covering Non-Targeted Waste
Assume waste thickness of 10 feet in the model
Thickness (ft)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
Distance from the Western Edge of the Pit (ft)

Table 3. Summary statistics for Subsurface Disposal Area subsidence features observed from 1983 to 1997.

Measurement	Minimum	Maximum	Sample standard deviation	Arithmetic mean
Length (ft)	1.5	192	33.75	24.41
Width (ft)	0.75	66	8.94	8.78
Maximum depth of subsidence (ft)	NA	8	1.55	1.99
Average depth of subsidence (ft)	NA	NA	1.13	1.37
Time to occurrence after disposal unit closure (days)	163	12675	2733	6261

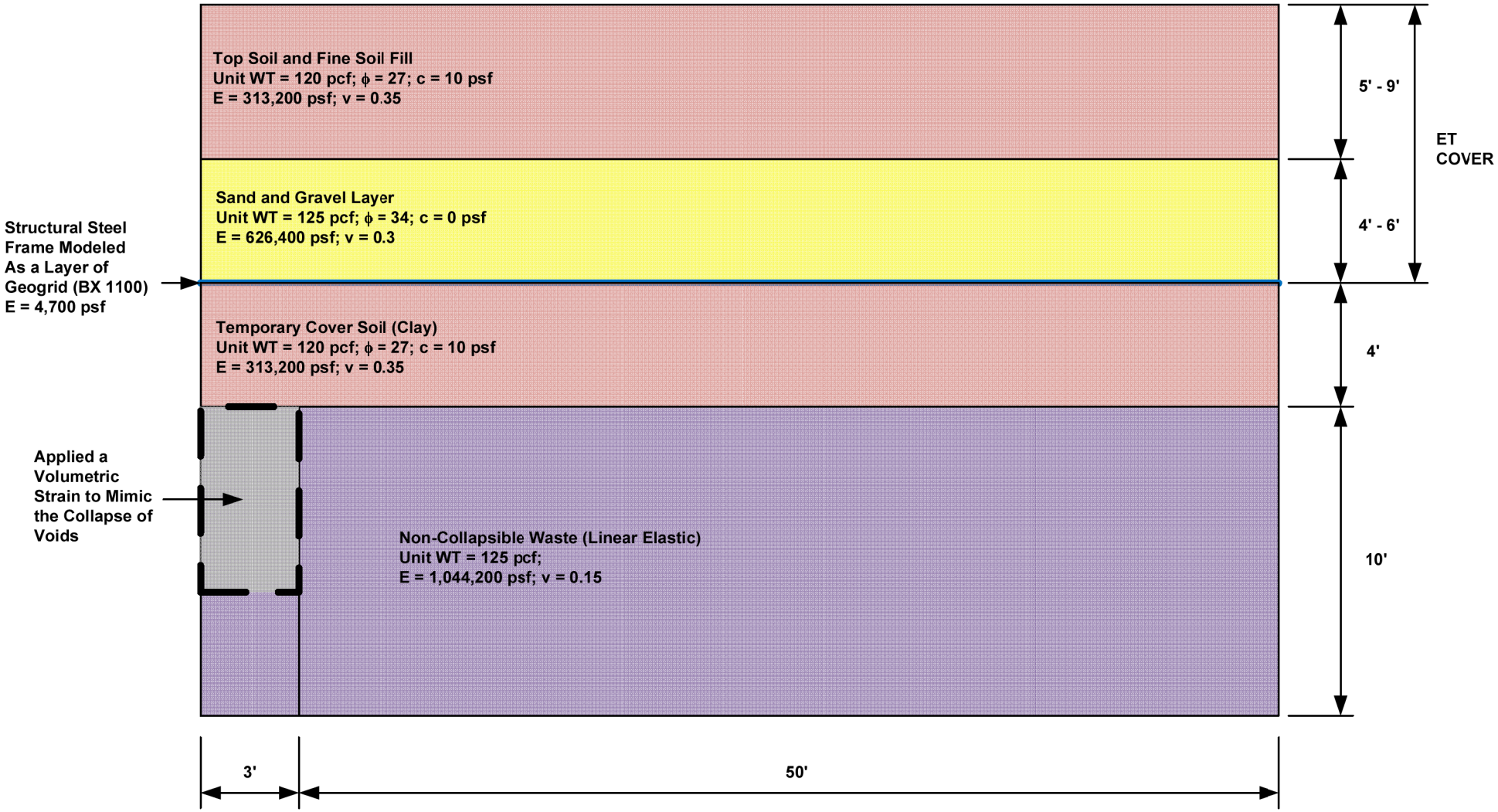
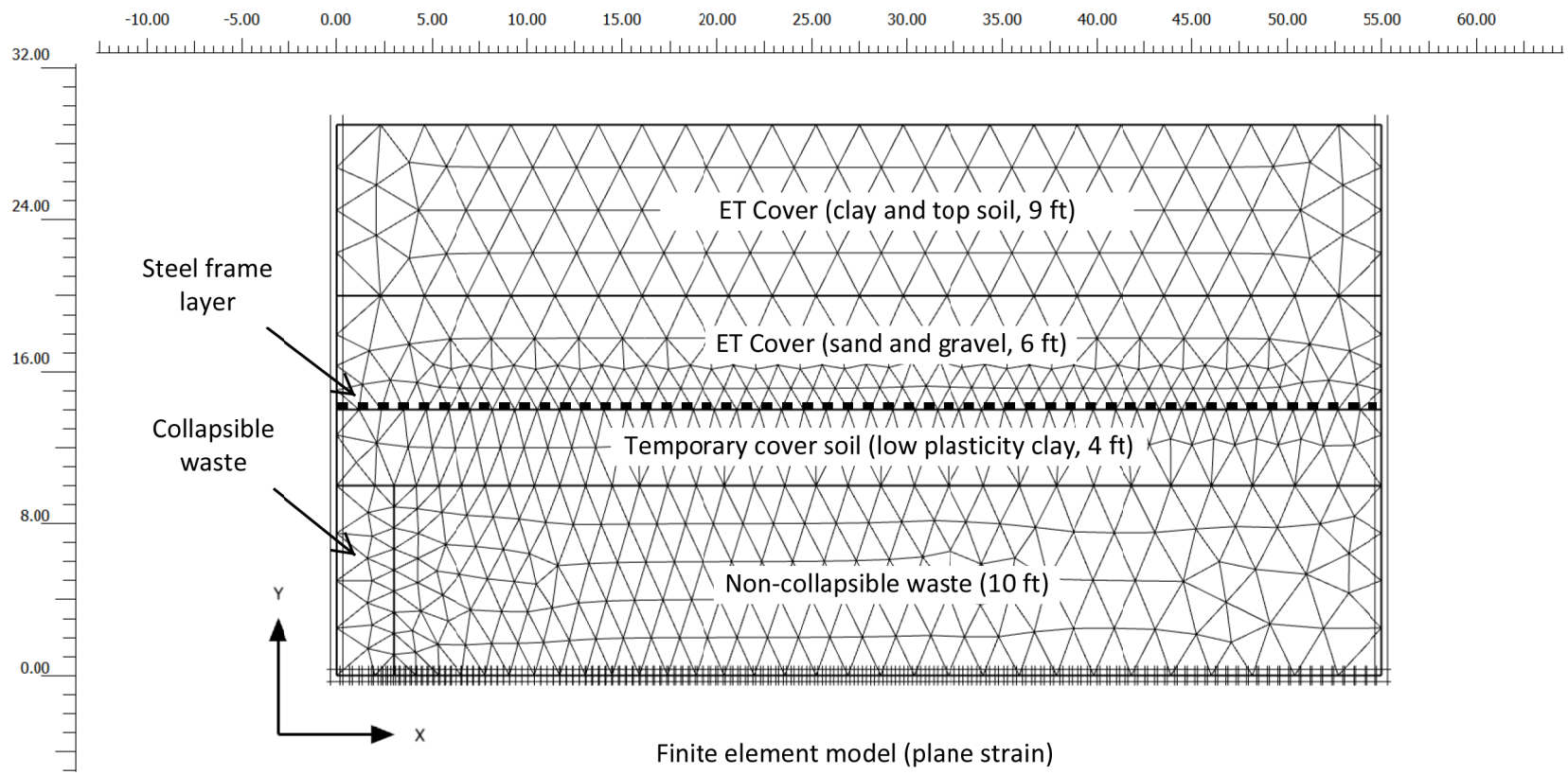


FIGURE 1
FINITE ELEMENT MODEL TO PREDICT THE SUBSIDENCE AT PIT 5 AS RESULT OF VOID COLLAPSE

ICDF PROJECT
APR IV – PIT 5

CH2MHILL

Output Version 2010.1.0.6380



Finite element model (plane strain)

PLAXIS	Project description: Modeling of Void Collapse in Pit 5		Date: 7/20/2011
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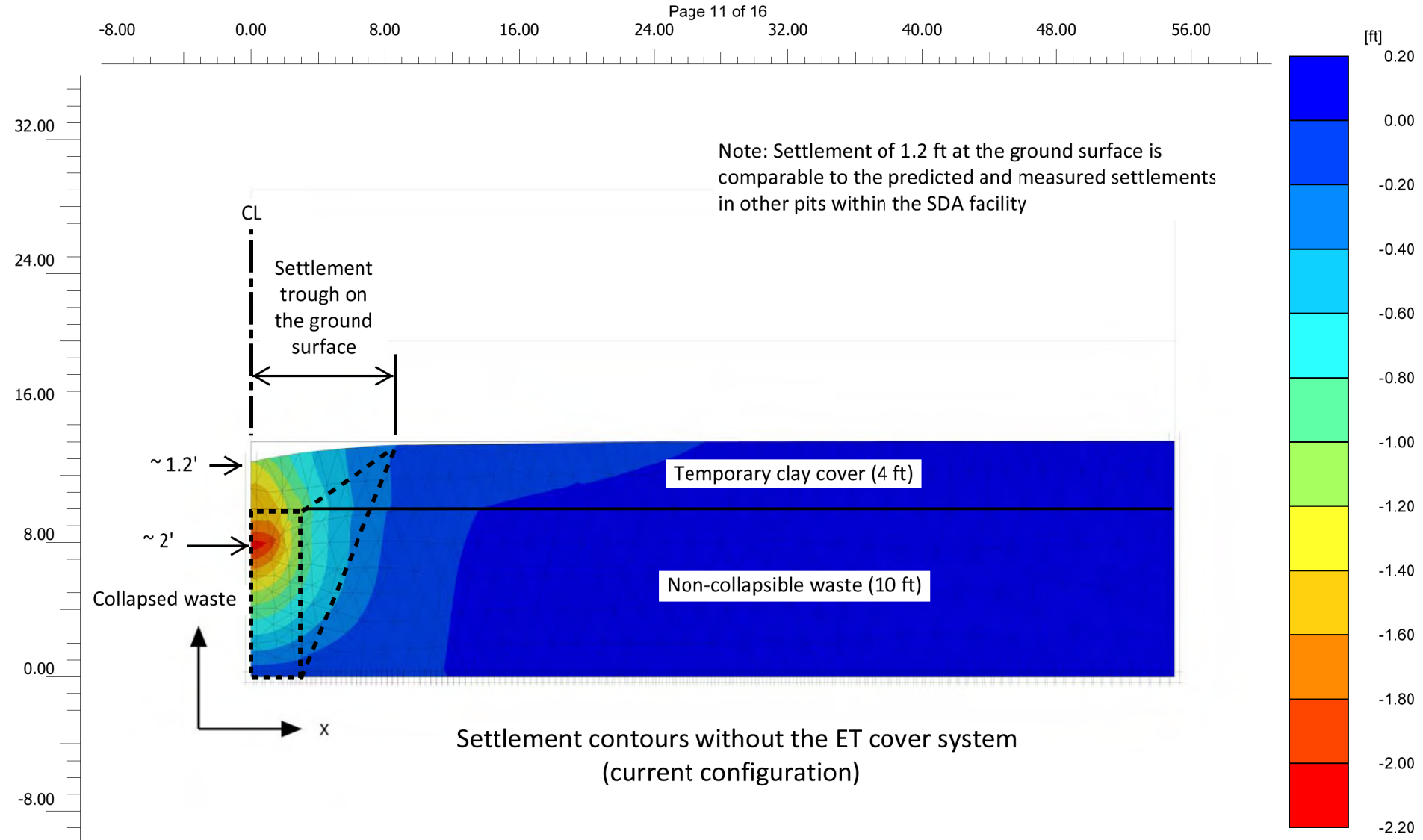


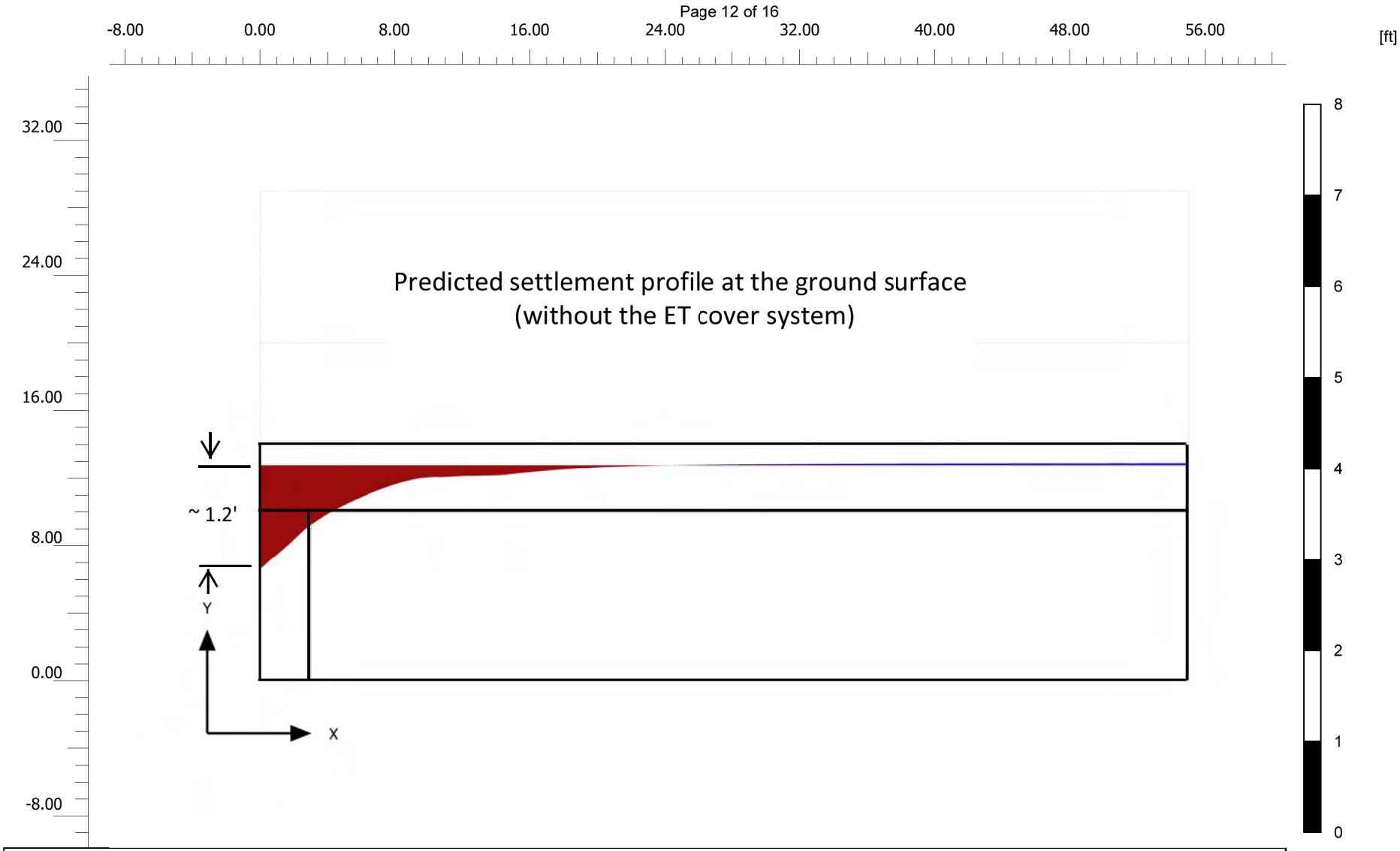
Settlement contours without the ET cover system (current configuration)

Total displacements u_y

Maximum value = 0.03463 ft (Element 174 at Node 3248)

Minimum value = -2.106 ft (Element 18 at Node 475)

PLAXIS	*Project description* Modeling of Void Collapse in Pit 5		*Date* 7/20/2011
	Project filename ICDF_Model2_15ft_60P ...	*Step* 184	*User name* CH2M HILL, Inc.

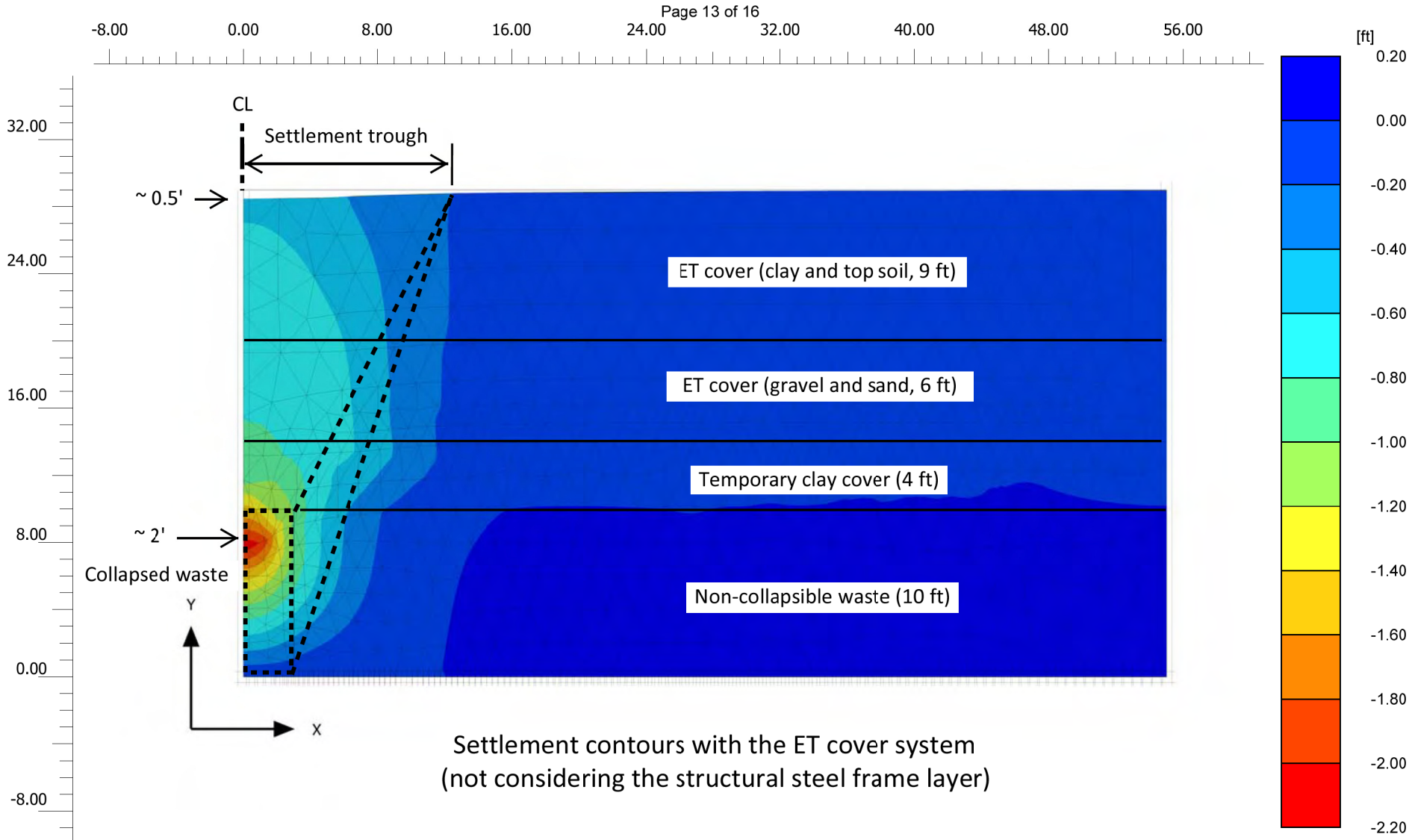


Total displacements u_y (scaled up 5.00 times)

Maximum value = 0.02520 ft

Minimum value = -1.221 ft

PLAXIS	*Project description* Modeling of Void Collapse in Pit 5		*Date* 7/20/2011
	Project filename ICDF_Model2_15ft_60P ...	*Step* 184	*User name* CH2M HILL, Inc.



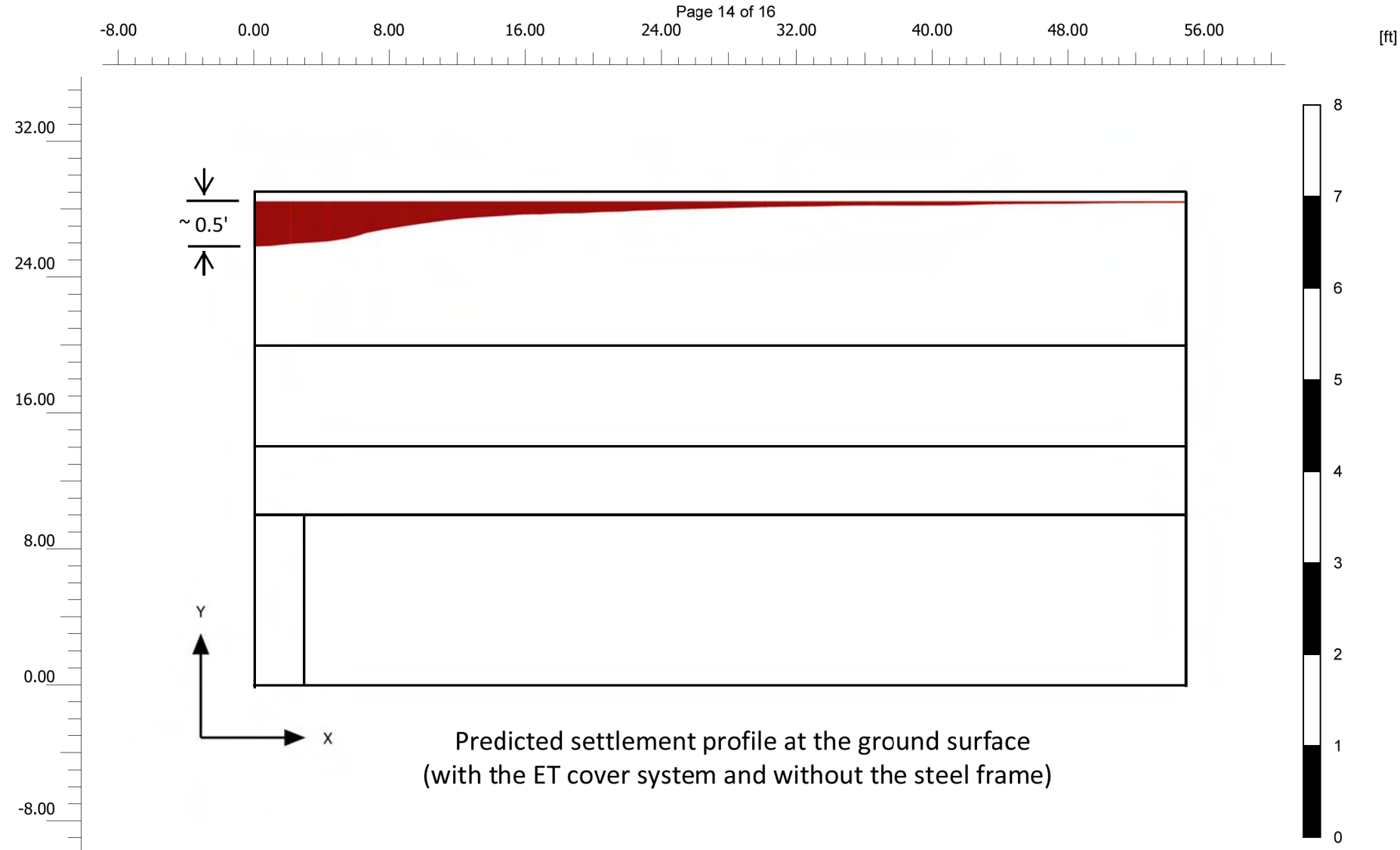
Settlement contours with the ET cover system
(not considering the structural steel frame layer)

Total displacements u_y

Maximum value = 0.02150 ft (Element 275 at Node 2970)

Minimum value = -2.107 ft (Element 18 at Node 475)

PLAXIS	*Project description* Modeling of Void Collapse in Pit 5		*Date* 7/20/2011
	Project filename ICDF_Model2_15ft_60P ...	*Step* 318	*User name* CH2M HILL, Inc.



Predicted settlement profile at the ground surface
(with the ET cover system and without the steel frame)

Total displacements u_y (scaled up 5.00 times)

Maximum value = -0.01783 ft

Minimum value = -0.5319 ft

PLAXIS	*Project description* Modeling of Void Collapse in Pit 5		*Date* 7/20/2011
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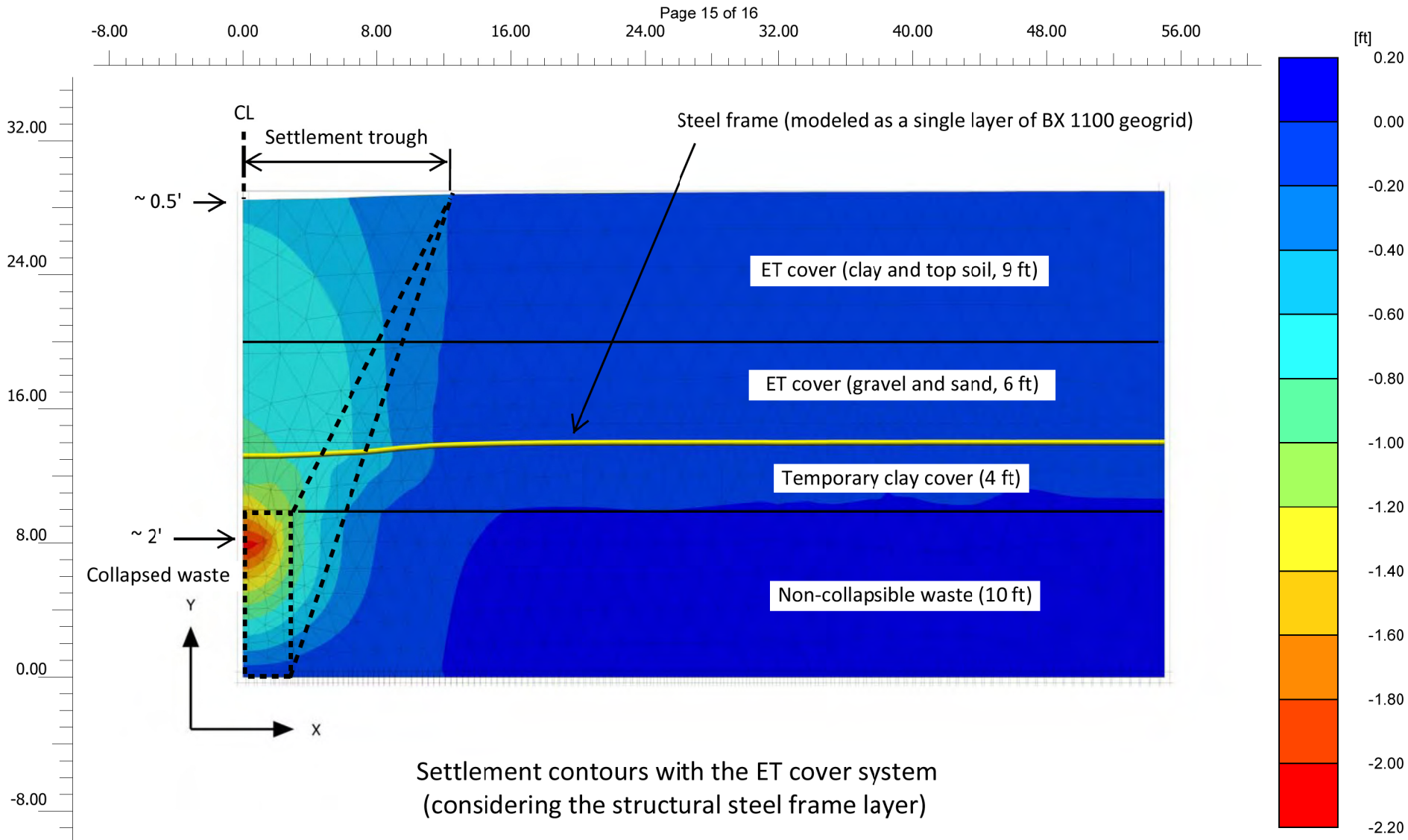

Settlement contours with the ET cover system
(considering the structural steel frame layer)

Total displacements u_y

Maximum value = 0.02141 ft (Element 275 at Node 2970)

Minimum value = -2.104 ft (Element 18 at Node 475)

PLAXIS	*Project description* Modeling of Void Collapse in Pit 5		*Date* 7/20/2011
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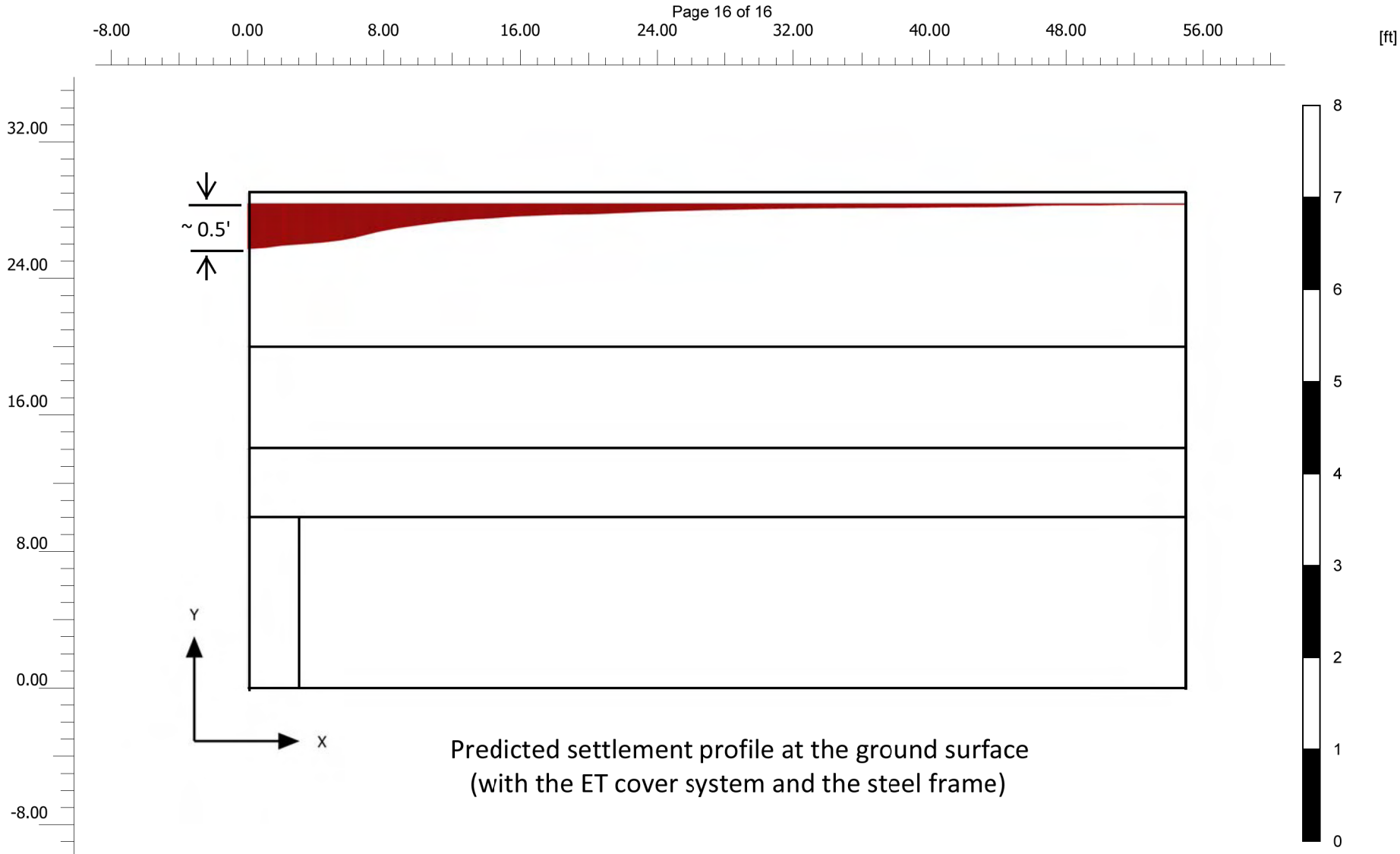

Predicted settlement profile at the ground surface
(with the ET cover system and the steel frame)

Total displacements u_y (scaled up 5.00 times)

Maximum value = -0.01495 ft

Minimum value = -0.5355 ft

PLAXIS	*Project description* Modeling of Void Collapse in Pit 5		*Date* 7/20/2011
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