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engineers · scientists · planners

Alfred Benesch & Company
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P 312-565-0450
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August 8, 2012

Mr. Todd Hileman
Village Manager
Village of Glenview
1225 Waukegan Rd.
Glenview IL 60025

Mr. Richard A. Nahrstadt
Village Manager
Village of Northbrook
1225 Cedar Lane
Northbrook, IL 60062

Subject: Union Pacific Railroad
UPRR Restoration at Shermer Road

Dear Messrs. Hileman and Nahrstadt:

Alfred Benesch & Company (Benesch) is providing this letter in response to a memo received from Mr. Joe Kenney on July 27, 2012. In the memo, the Village requested the additional information from UP & Benesch to be included with the weekly report correspondence. The requests were made in two parts. Each question is provided below with the response provided in **Bold** below:

PART 1 REQUESTS

1. Define the acceptable limits of track movement and thresholds of movement that trigger track adjustment operations.
   Response: The thresholds of movement that trigger track adjustments are specified in the track safety standards published by the Federal Railroad Administration. If and when there are deviations in the track structure that place, or will in short order place some portion of the track outside of the requirements of the Track Safety Standards for Class 4 track (freight train operation not to exceed 60 MPH), the track will be resurfaced.

2. Provide the "Situation Plan" and data from all survey points including the top of rail measurements.
   Response: The updated situation plan (including contours for revised north side slope) will be provided under separate cover. Please see the attachment for track profiles and selected supporting data.

3. Estimate the amount of error in the survey measurements.
   Response: We set two control points along the street that accesses the UPS facility. Those points are outside the limits of any work for this project. We have marked stations along the rails, and attempt to shoot the same horizontal location each time we survey. However, there is no means to mark the top of rail and ensure that we shoot the exact same point each time. We have found (through dumps of the data) that we are typically within 6-inches to 24-inches (horizontally) each time of our original shots. The data is collected by means of a total station instrument, which calculates the elevations based on the measured distance from the shot and angle from horizontal. We estimate a typical vertical variance due to survey methodology of 0.03' to 0.04', which is borne out by the data which is attached.

4. Provide calculations package regarding buried utilities. Include boring logs and other soil analyses.
   Response: Please see attached report for the utility calculations), boring logs and other soil analyses.

5. Provide calculations package regarding slope stability. Include a cross section cut view through the temporary structure indicating fill materials used, compaction procedures, and lift heights.
   Response: Please see attached report for slope stability calculations. The material used for the temporary embankment was crushed concrete base aggregate, and the sieve analysis for the material is included with the attached package. Union Pacific reported that the embankment was placed in 3-inch layers, and compacted with the dozers that were used to place the material.

6. Provide overall photographs of the site and temporary structure for record file.
   Response: Site photos will be forwarded under separate cover.

PART 2 REQUESTS

In addition, the Village also requests the following information from UP & Benesch regarding the collapsed steel bridge structure:

1. Provide original bridge design drawings including general notes detailing required materials properties.

2. Provide recent bridge inspection reports including descriptions and photographs of any fatigue, corrosion, or distortion-induced cracks.

3. Provide any available load rating or fatigue life calculations performed for the structure.

4. Provide location of the entire bridge superstructure and methods used to control custody of and preserve evidence.

5. Provide engineering report describing the cause of the bridge collapse including supporting photographic evidence.

Response to Items 1 through 5, Part 2 Requests: Benesch is not currently involved in any activities regarding the original bridge. Please refer all questions regarding the original bridge to Adrian Guerrero, Director, Public Affairs, 312-777-2037; e-mail inquiries to aguerre@up.com.

ADDITIONAL INFORMATION

Union Pacific has arranged for two six-inch pumps and one three-inch pump to be on site to drain any storm runoff from the north side to the south side outfall. This arrangement will continue until a final determination is made regarding the type and timing of construction of the replacement bridge, at which time the situation will be reevaluated.

Please let us know if you have any questions or if we can be of further assistance.

LICENSED PROFESSIONAL ENGINEER
RICHARD D.
CONRATH
062-044784
Richard D Conrath
STATE OF ILLINOIS
EXPIRATION DATE 11-30-2013
DATE: 8-08-2012

Richard D Conrath

Richard D. Conrath, P.E.
Vice President

RDC:r

Union Pacific Railroad
Shermer Road Track Monitor

Track 1 - West Rail - Sta 2+00			Sta 4+00			Sta 5+50			Sta 6+50		
Date	Elevation		Date	Elevation		Date	Elevation		Date	Elevation	
7/6/12	---		7/6/12	---		7/6/12	---		7/6/12	---	
7/8/12	---		7/8/12	---		7/8/12	---		7/8/12	---	
7/9/12	663.33		7/9/12	663.24		7/9/12	663.63		7/9/12	---	
7/10/12	663.29		7/10/12	663.22		7/10/12	663.61		7/10/12	663.62	
7/11/12	663.31		7/11/12	663.24		7/11/12	663.60		7/11/12	663.64	
7/12/12	663.36	Track Reprofiled	7/12/12	663.49	Track Reprofiled	7/12/12	663.68	Track Reprofiled	7/12/12	---	Track Reprofiled
7/13/12	663.35		7/13/12	663.46		7/13/12	663.70		7/13/12	663.64	
7/14/12	663.41		7/14/12	663.51		7/14/12	663.72		7/14/12	663.67	
7/15/12	663.39		7/15/12	663.48		7/15/12	663.68		7/15/12	663.64	
7/16/12	---		7/16/12	663.49		7/16/12	663.72		7/16/12	663.68	
7/17/12	663.42		7/17/12	---		7/17/12	663.73		7/17/12	663.66	
7/18/12	663.39		7/18/12	663.52		7/18/12	663.70		7/18/12	663.65	
7/19/12	663.40		7/19/12	663.53		7/19/12	---		7/19/12	---	
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7/21/12	663.42		7/21/12	663.55		7/21/12	663.75		7/21/12	663.70	
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7/25/12	663.37		7/25/12	663.48		7/25/12	663.70		7/25/12	663.66	
7/26/12	663.41		7/26/12	663.48		7/26/12	663.68		7/26/12	663.64	
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7/28/12	663.41		7/28/12	663.50		7/28/12	663.73		7/28/12	663.69	
7/31/12	663.40		7/31/12	663.49		7/31/12	663.74		7/31/12	663.68	

Union Pacific Railroad
Shermer Road Track Monitor

Track 1 - East Rail - Sta 2+00			Sta 4+00			Sta 5+50			Sta 6+50		
Date	Elevation		Date	Elevation		Date	Elevation		Date	Elevation	
7/6/12	---		7/6/12	---		7/6/12	---		7/6/12	---	
7/8/12	---		7/8/12	---		7/8/12	---		7/8/12	---	
7/9/12	663.30		7/9/12	663.24		7/9/12	663.59		7/9/12	---	
7/10/12	663.27		7/10/12	663.22		7/10/12	663.58		7/10/12	663.64	
7/11/12	663.29		7/11/12	663.23		7/11/12	663.59		7/11/12	663.63	
7/12/12	663.39	Track Reprofiled	7/12/12	663.51	Track Reprofiled	7/12/12	663.71	Track Reprofiled	7/12/12	---	Track Reprofiled
7/13/12	663.39		7/13/12	663.49		7/13/12	---		7/13/12	663.65	
7/14/12	663.42		7/14/12	663.54		7/14/12	663.73		7/14/12	663.68	
7/15/12	663.41		7/15/12	663.50		7/15/12	663.70		7/15/12	663.65	
7/16/12	---		7/16/12	663.53		7/16/12	663.73		7/16/12	663.69	
7/17/12	663.44		7/17/12	---		7/17/12	663.72		7/17/12	663.65	
7/18/12	663.42		7/18/12	663.52		7/18/12	663.72		7/18/12	663.67	
7/19/12	663.42		7/19/12	---		7/19/12	---		7/19/12	---	
7/20/12	663.41		7/20/12	663.53		7/20/12	663.73		7/20/12	663.68	
7/21/12	663.44		7/21/12	663.55		7/21/12	663.77		7/21/12	663.71	
7/22/12	663.44		7/22/12	663.55		7/22/12	663.75		7/22/12	---	
7/23/12	663.42		7/23/12	663.51		7/23/12	663.72		7/23/12	663.66	
7/24/12	663.39		7/24/12	663.51		7/24/12	663.70		7/24/12	663.65	
7/25/12	663.41		7/25/12	663.52		7/25/12	663.71		7/25/12	663.66	
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7/31/12	663.44		7/31/12	663.53		7/31/12	663.71		7/31/12	663.69	

Union Pacific Railroad
Shermer Road Track Monitor

Track 2 - West Rail - Sta 2+00			Sta 4+00			Sta 5+50			Sta 6+50		
Date	Elevation		Date	Elevation		Date	Elevation		Date	Elevation	
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7/8/12	663.38		7/8/12	663.39		7/8/12	663.61		7/8/12	663.57	
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7/10/12	663.43		7/10/12	663.36		7/10/12	663.55		7/10/12	663.58	
7/11/12	663.42		7/11/12	663.35		7/11/12	663.57		7/11/12	663.57	
7/12/12	663.42		7/12/12	663.35		7/12/12	663.60		7/12/12	663.58	
7/13/12	663.43		7/13/12	663.35		7/13/12	663.58		7/13/12	663.59	
7/14/12	663.48	Track Reprofiled	7/14/12	663.38	Track Reprofiled	7/14/12	663.61	Track Reprofiled	7/14/12	663.63	Track Reprofiled
7/15/12	663.45		7/15/12	663.36		7/15/12	663.59		7/15/12	663.60	
7/16/12	663.49		7/16/12	663.38		7/16/12	663.61		7/16/12	663.63	
7/17/12	663.49		7/17/12	663.43		7/17/12	663.61		7/17/12	663.62	
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7/19/12	663.47		7/19/12	---		7/19/12	---		7/19/12	---	
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7/21/12	663.50		7/21/12	663.41		7/21/12	663.65		7/21/12	663.66	
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7/28/12	663.48		7/28/12	663.39		7/28/12	663.62		7/28/12	663.64	
7/31/12	663.50		7/31/12	663.41		7/31/12	663.63		7/31/12	663.65	

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Track 2 - East Rail - Sta 2+00		Sta 4+00			Sta 5+50			Sta 6+50		
Date	Elevation	Date	Elevation		Date	Elevation		Date	Elevation	
7/6/12	---	7/6/12	---		7/6/12	---		7/6/12	---	
7/8/12	663.43	7/8/12	663.36		7/8/12	663.59		7/8/12	663.59	
7/9/12	663.38	7/9/12	---		7/9/12	663.60		7/9/12	663.57	
7/10/12	663.36	7/10/12	663.37		7/10/12	663.59		7/10/12	663.55	
7/11/12	663.35	7/11/12	663.36		7/11/12	663.59		7/11/12	663.55	
7/12/12	663.36	7/12/12	663.38		7/12/12	663.61		7/12/12	663.58	
7/13/12	663.37	7/13/12	663.38		7/13/12	663.61		7/13/12	663.58	
7/14/12	663.42	7/14/12	663.41		7/14/12	663.63		7/14/12	663.60	
7/15/12	663.40	7/15/12	663.38		7/15/12	663.62		7/15/12	663.57	
7/16/12	663.44	7/16/12	663.42		7/16/12	663.63		7/16/12	663.61	
7/17/12	663.44	7/17/12	663.46		7/17/12	663.64		7/17/12	663.60	
7/18/12	663.41	7/18/12	663.40		7/18/12	663.62		7/18/12	663.60	
7/19/12	---	7/19/12	---		7/19/12	---		7/19/12	---	
7/20/12	663.41	7/20/12	663.40		7/20/12	663.65		7/20/12	663.61	
7/21/12	663.44	7/21/12	663.43		7/21/12	663.67		7/21/12	663.63	
7/22/12	663.43	7/22/12	663.43		7/22/12	663.66		7/22/12	663.64	
7/23/12	663.41	7/23/12	663.39		7/23/12	663.61		7/23/12	663.59	
7/24/12	663.40	7/24/12	663.38		7/24/12	663.61		7/24/12	663.60	
7/25/12	663.41	7/25/12	663.38		7/25/12	663.62		7/25/12	663.57	
7/26/12	663.44	7/26/12	663.54	Bad Shot	7/26/12	663.74	Bad Shot	7/26/12	663.69	Bad Shot
7/27/12	663.45	7/27/12	663.44		7/27/12	663.68		7/27/12	---	
7/28/12	663.44	7/28/12	663.41		7/28/12	663.65		7/28/12	663.62	
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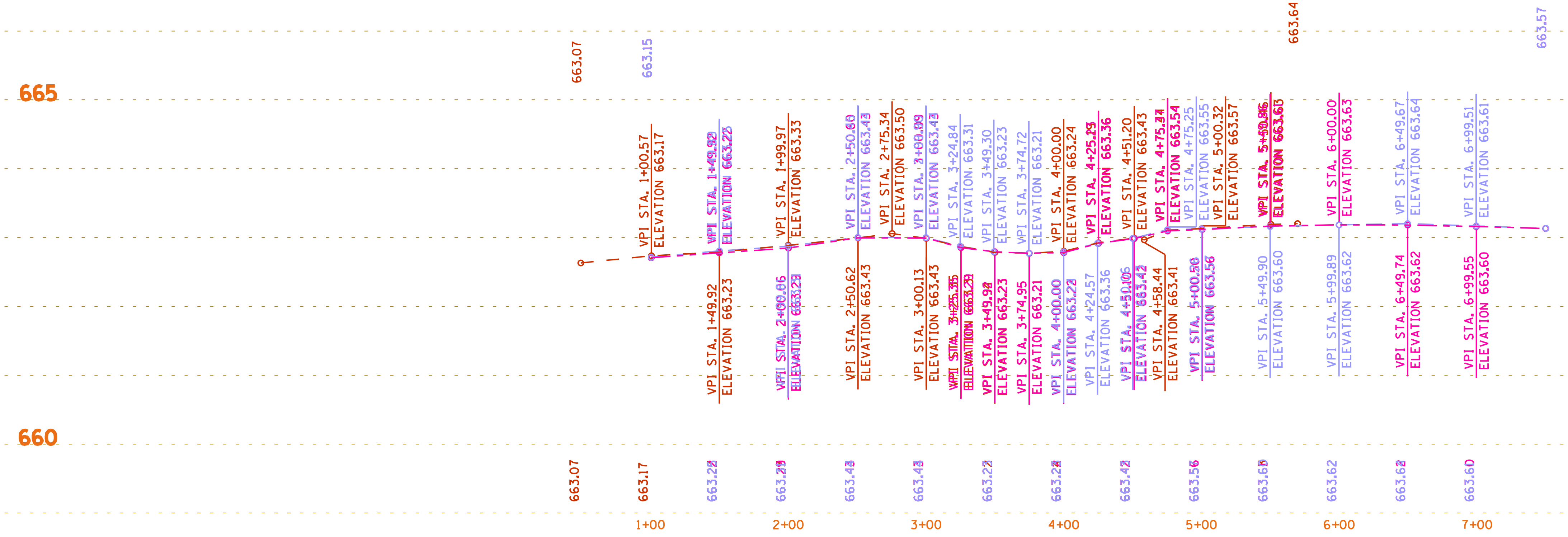

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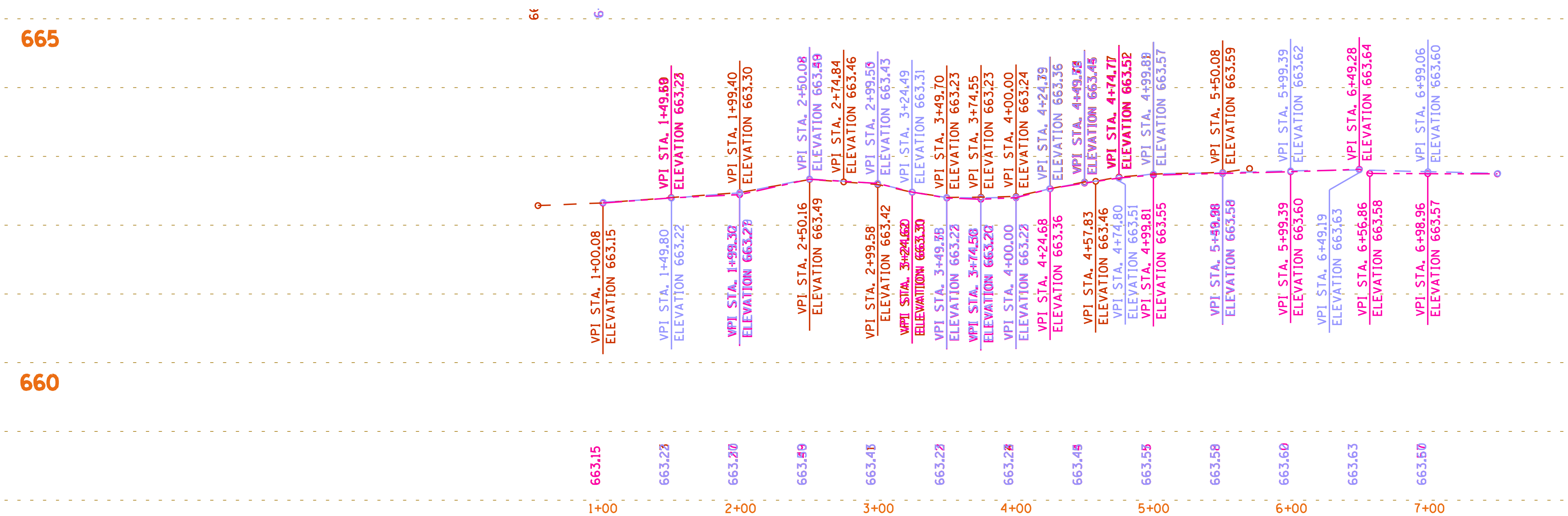

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— · — ·	07/10/12
— — —	07/11/12

RICHARD D. CONRATH
062-044784
Richard D Conrath

EXPIRATION DATE 11-30-2013
DATE: 07-12-2012

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UNION PACIFIC

DRAWN BY: RDC
CHECKED BY:
DATE: 07-12-2012
SHEET NUMBER
of

UNION PACIFIC RAILROAD
LOCATION & DESCRIPTION:
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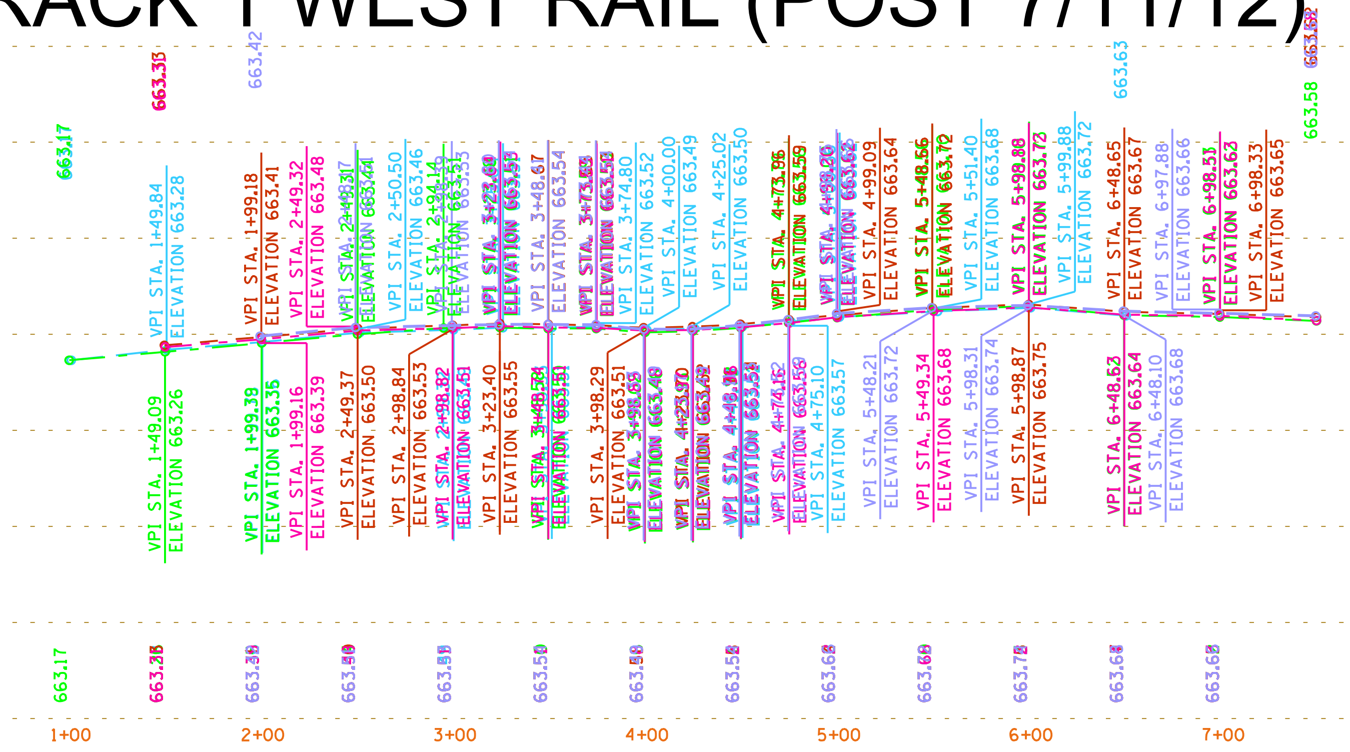

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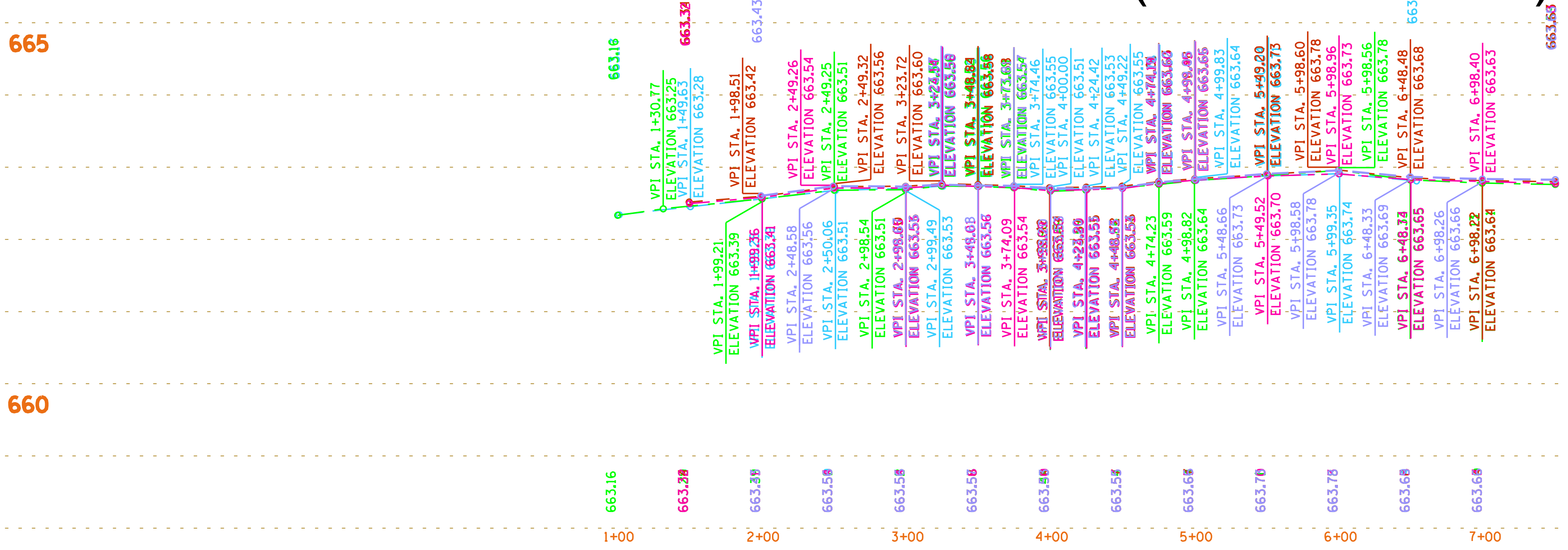

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— — —	07/14/12
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— — —	07/16/12

LICENSED PROFESSIONAL ENGINEER
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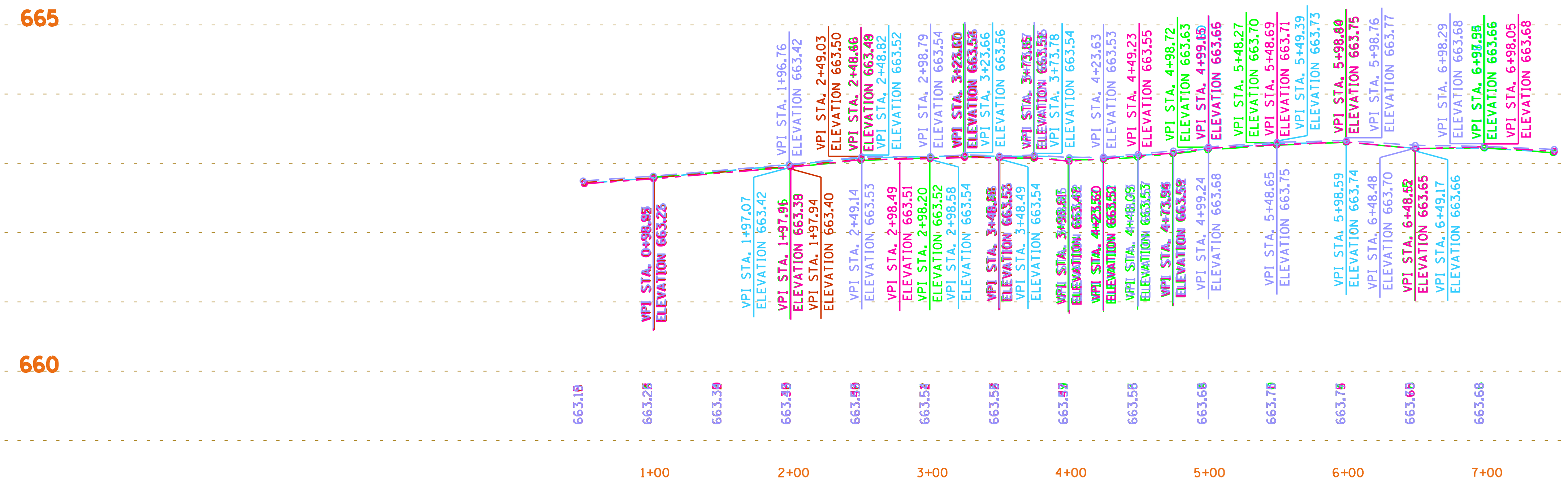

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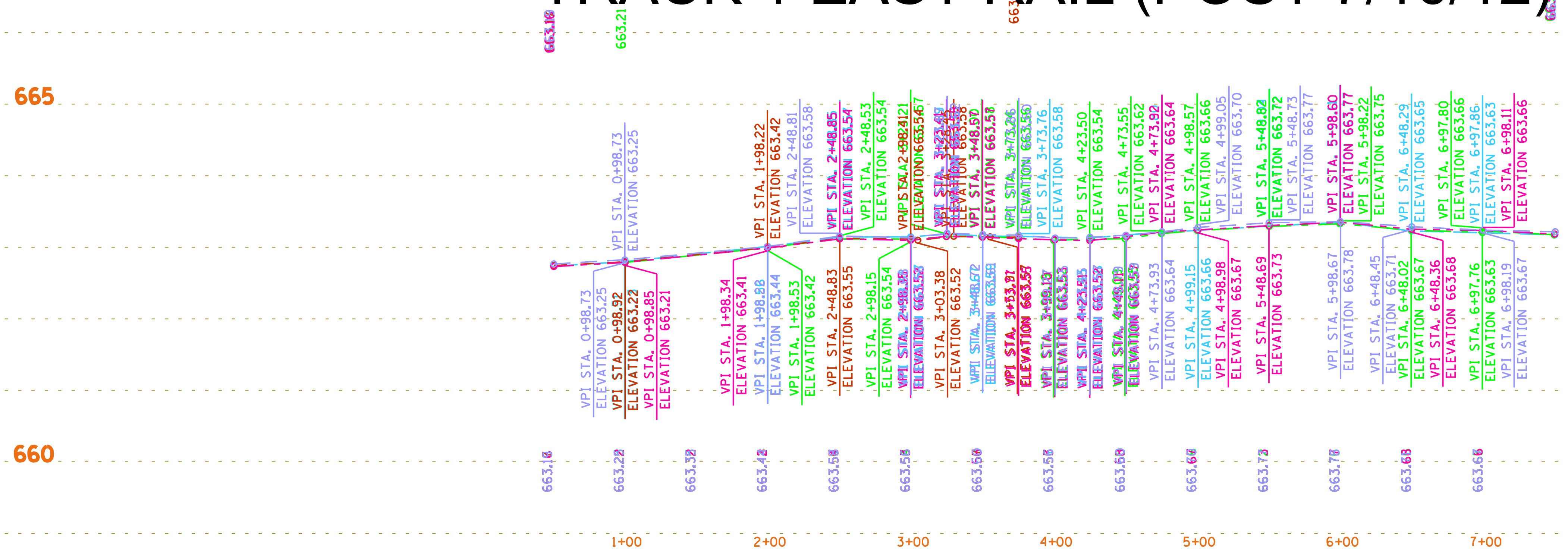

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— — —	07/17/12
— · —	07/18/12
— — —	07/19/12
— · · —	07/20/12
— — —	07/21/12

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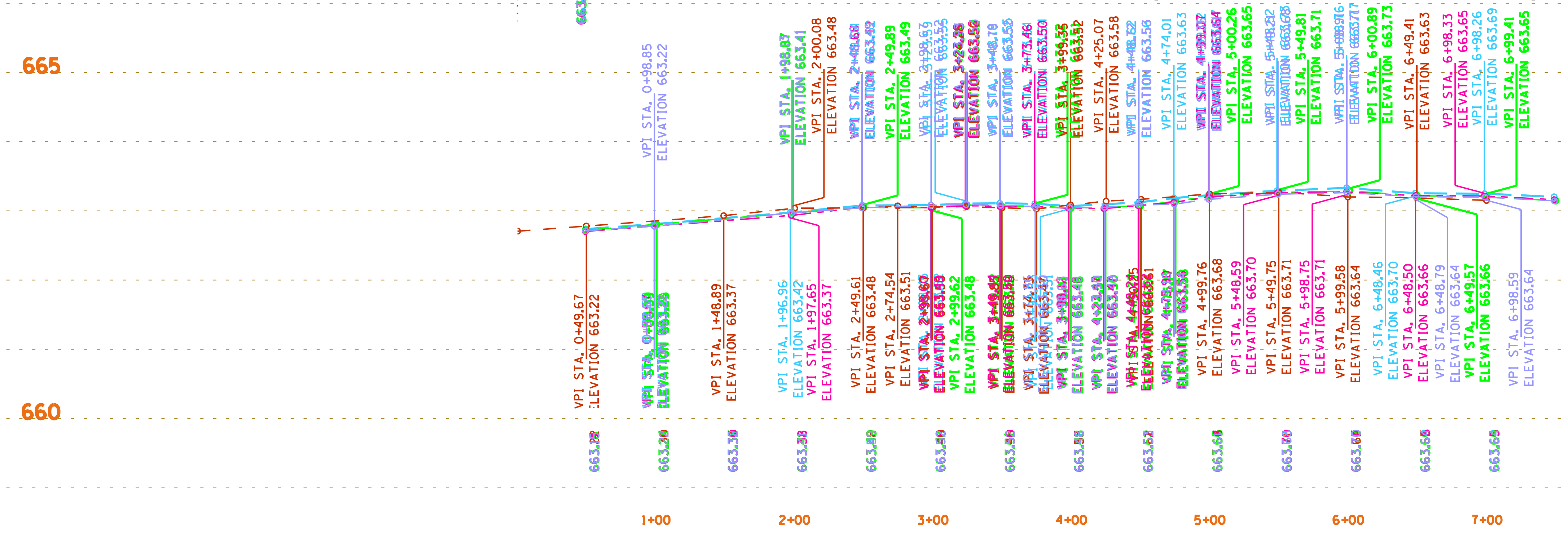

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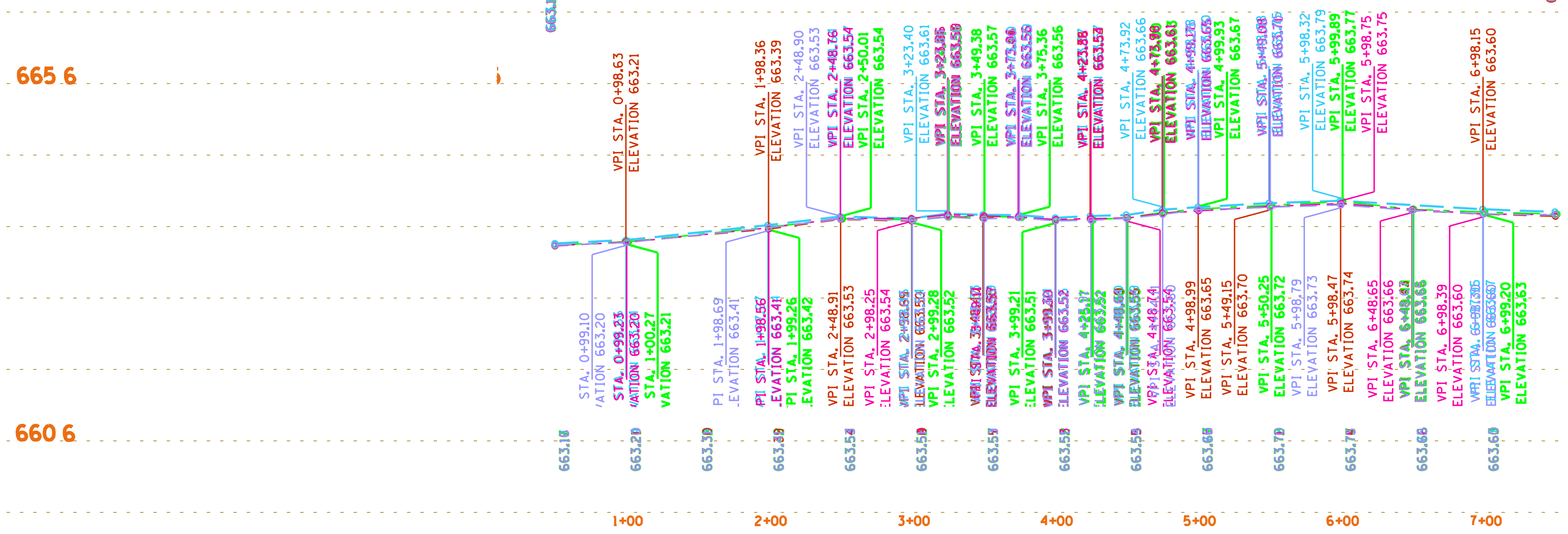

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— — —	07/22/12
— · —	07/23/12
— — —	07/24/12
— · · —	07/25/12
— — —	07/26/12

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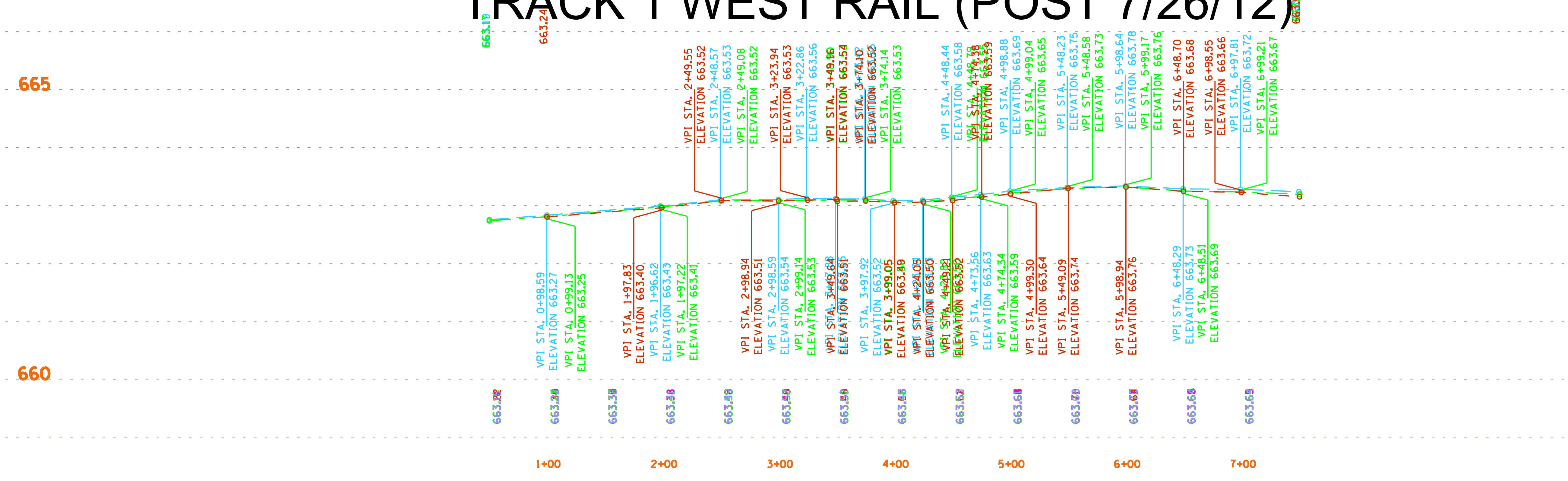
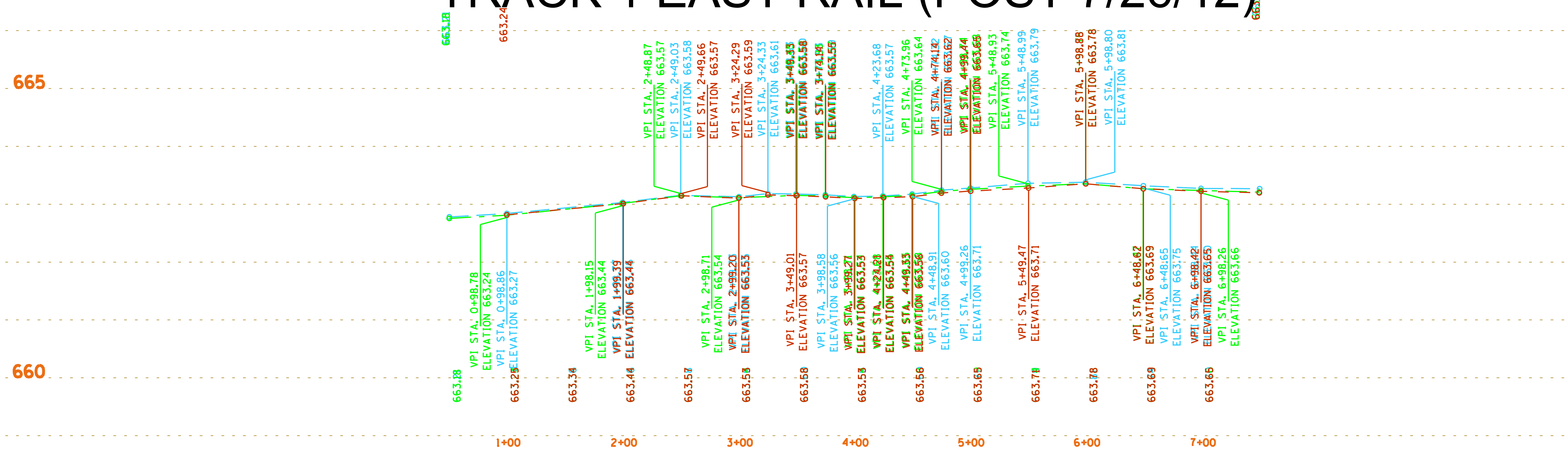


TRACK 1 EAST RAIL (POST 7/26/12)



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— — —	07/27/12
— · —	07/28/12
– – –	07/31/12

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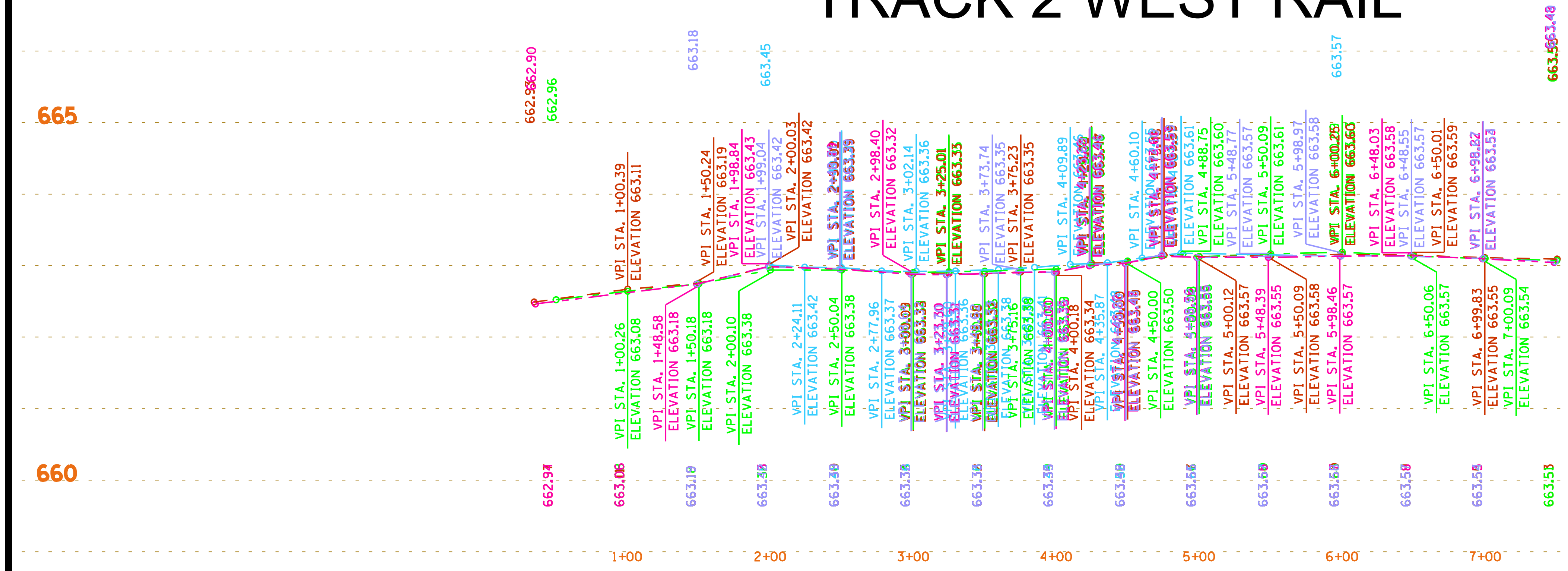
TRACK 2 WEST RAIL



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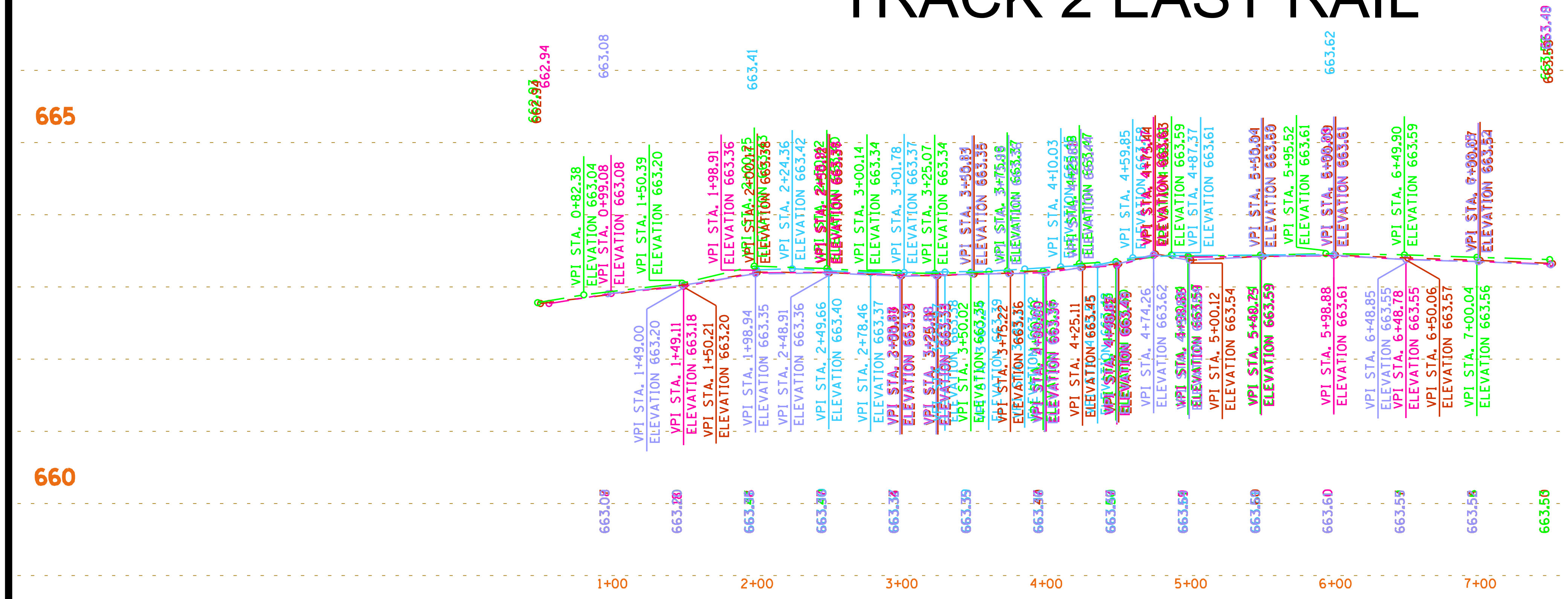

LEGEND

- — — — 07/06/12
- —·—·— 07/08/12
- — — — 07/09/12
- —··—··— 07/10/12
- — — — 07/11/12

RICHARD D. CONRATH
062-044784

EXPIRATION DATE 11-30-2013
DATE: 07-12-2012

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UNION PACIFIC

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SHEET NUMBER
of

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LOCATION & DESCRIPTION:
TRACK 2 PROFILE
SHEET TITLE:

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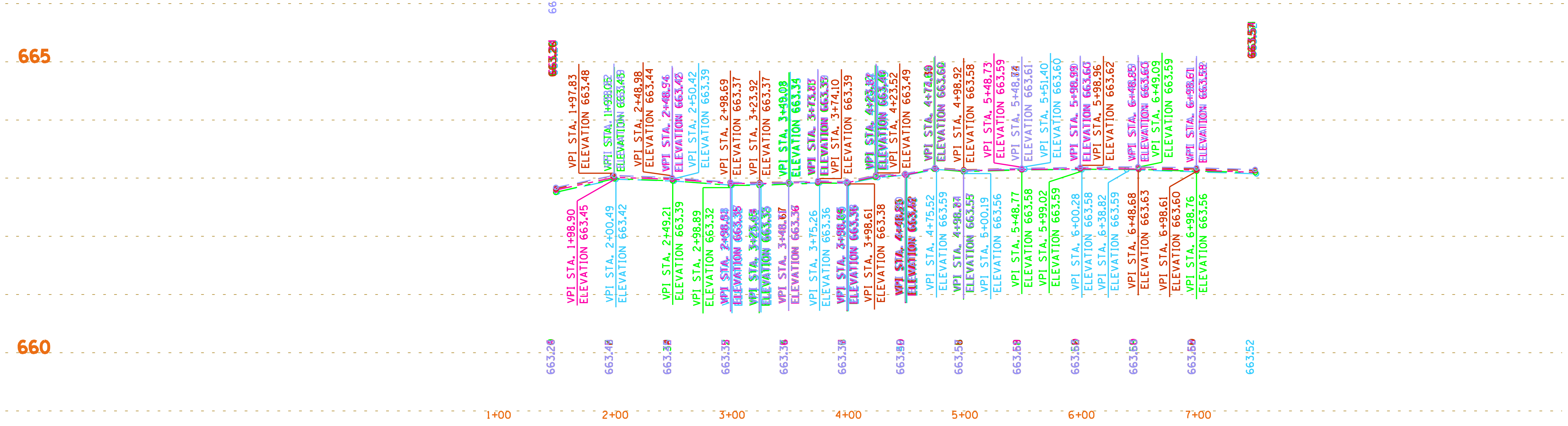

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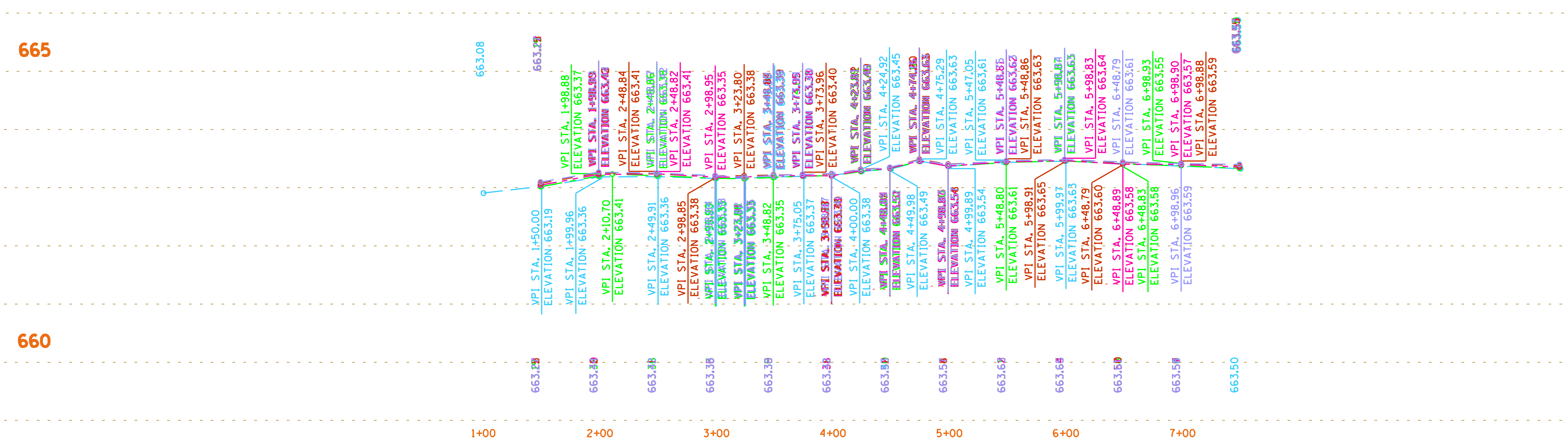

LEGEND

— — —	07/12/12
—·—·—	07/13/12
– – – –	07/14/12
—··—··	07/15/12
— — —	07/16/12

RICHARD D. CONRATH
062-044784

Richard D Conrath

EXPIRATION DATE 11-30-2013
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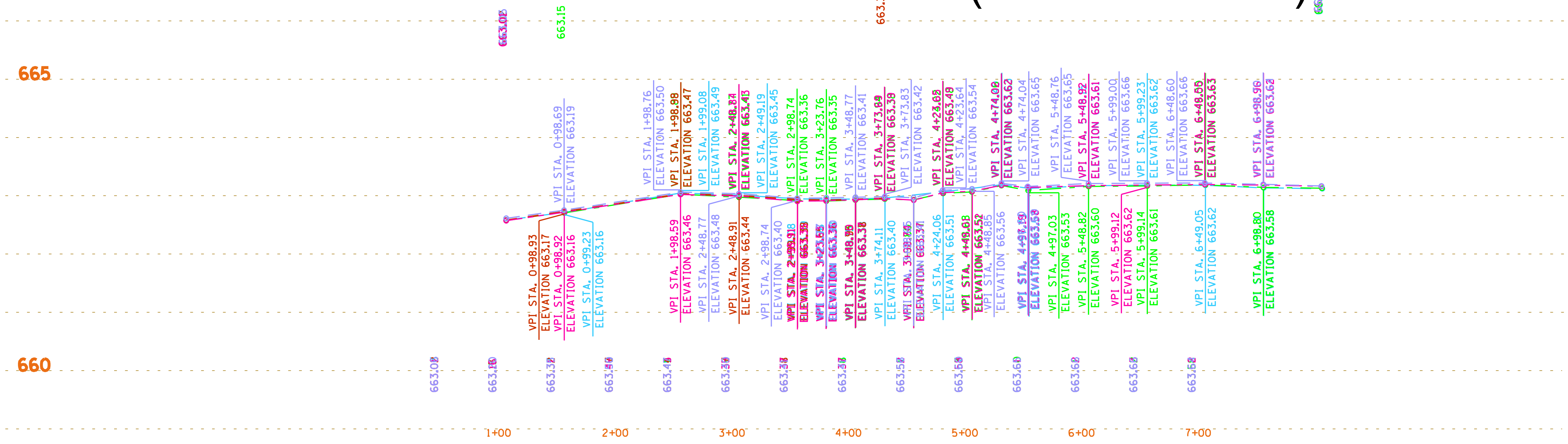

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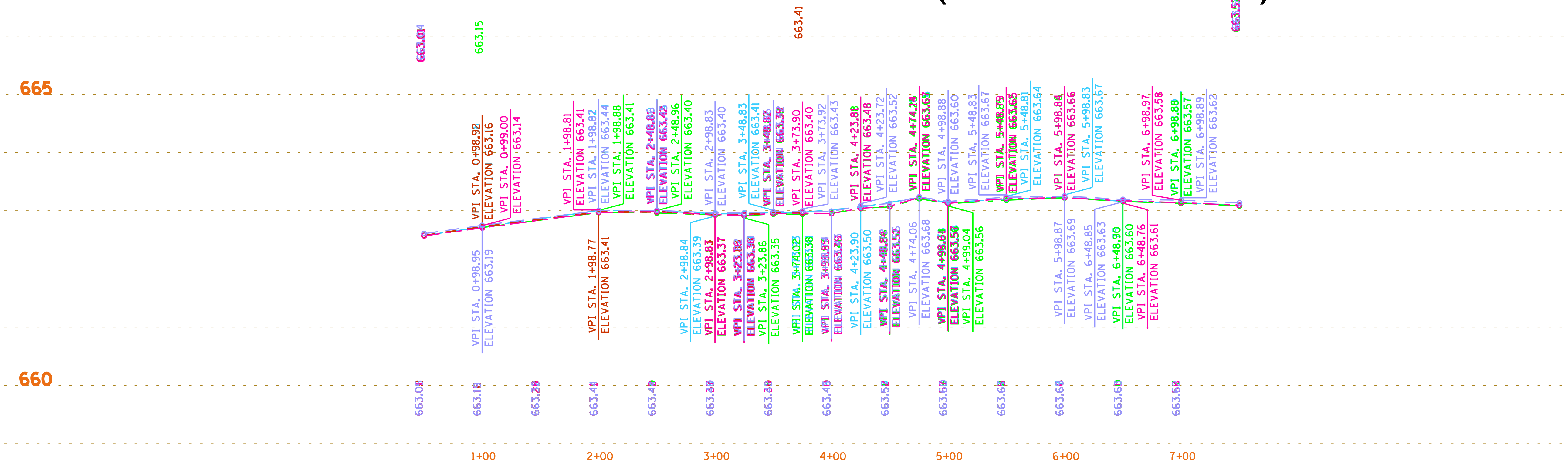

LEGEND

— — —	07/17/12
—·—·—	07/18/12
– – – –	07/19/12
—··—··—	07/20/12
— — —	07/21/12

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062-044784

EXPIRATION DATE 11-30-2013
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LOCATION & DESCRIPTION:
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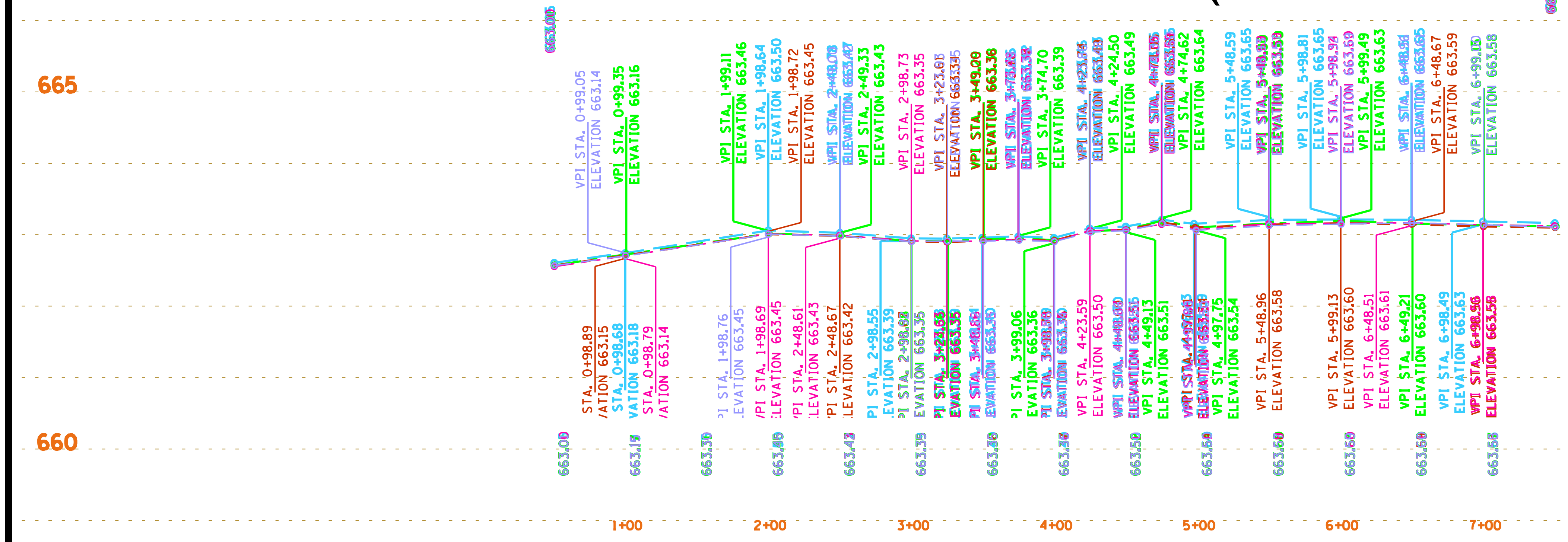
SHEET TITLE:

$$colortable$$
$$pentable$$
filename.dgn
$$model$$
$$date$$

TRACK 2 WEST RAIL (POST 7/21/12)



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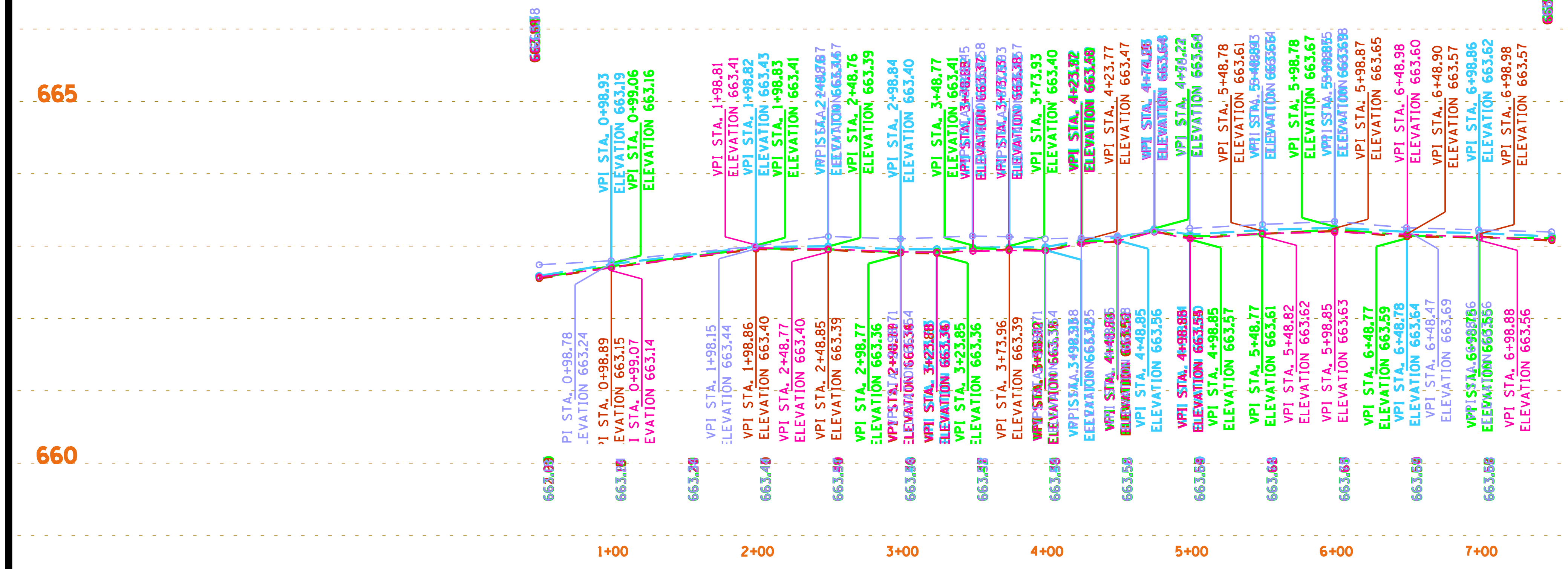

LEGEND

— — —	07/22/12
— · — · —	07/23/12
— — —	07/24/12
— · · — · · —	07/25/12
— — —	07/26/12

RICHARD D. CONRATH
062-044784

EXPIRATION DATE 11-30-2013
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UNION PACIFIC RAILROAD
LOCATION & DESCRIPTION:
TRACK 2 PROFILE
SHEET TITLE:

$$colortable$$
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filename.dgn
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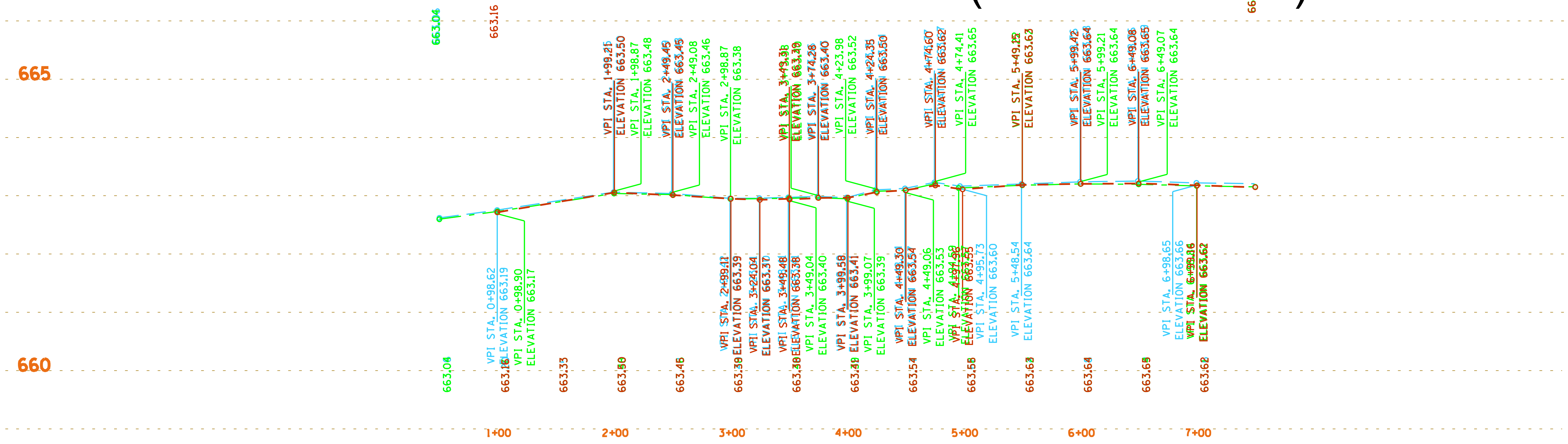
filename.dgn

TRACK 2 WEST RAIL (POST 7/26/12)



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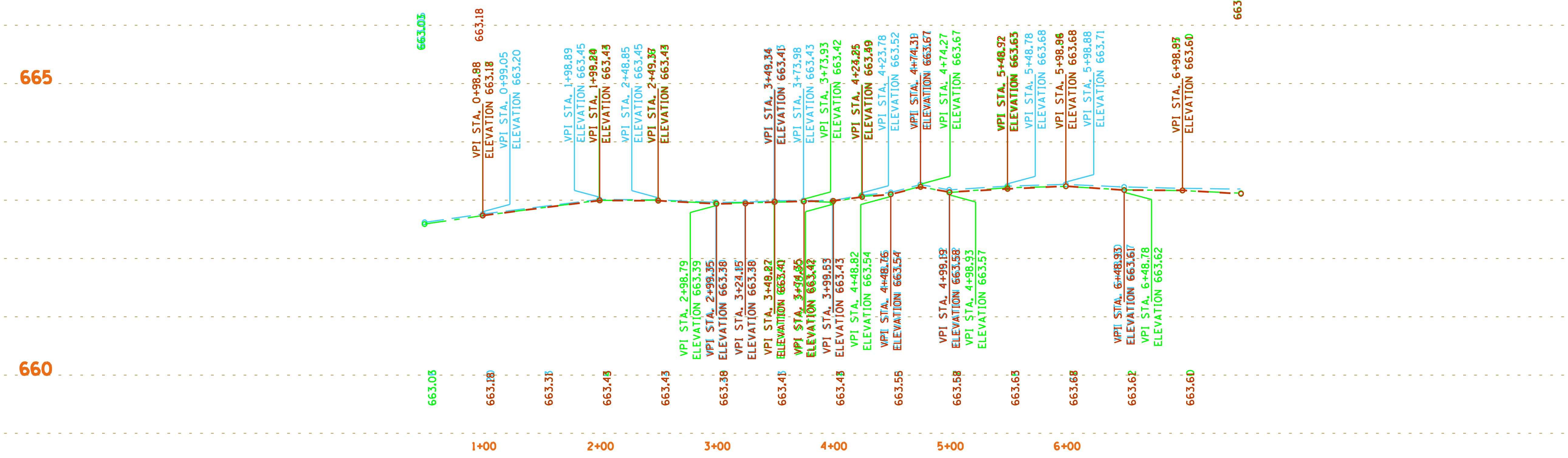

LEGEND

— — —	07/27/12
— · — · —	07/28/12
– – – –	07/31/12

LICENSED PROFESSIONAL ENGINEER
RICHARD D. CONRATH
062-044784
STATE OF ILLINOIS
Richard D Conrath

EXPIRATION DATE 11-30-2013
DATE: 07-12-2012

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UNION PACIFIC

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CHECKED BY:	LOCATION & DESCRIPTION: TRACK 2 PROFILE
DATE: 07-12-2012	
SHEET NUMBER of	SHEET TITLE:

$$colortable$$
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2.0 LABORATORY ANALYSES 2

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APPENDIX D. SIEVE ANALYSES

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1.0 SUBSURFACE EXPLORATION

On July 13, 2012, two exploratory borings were taken to depths of 30 feet below the existing grade to establish the general subsurface conditions of the area under consideration. The borings were made in accordance with ASTM D 1452, Standard Practice for Soil Investigation and Sampling by Auger Borings. A machine-driven, hollow-stem auger having an inside diameter of 3-1/4inches was used to advance the holes for split-barrel sampling.

Penetration tests were performed with a Automatic Free-Fall SPT Hammer (hammer efficiency approximately 88%) in accordance with ASTM D 1586, Standard Method for Penetration Test and Split-Barrel Sampling of Soils. Representative samples of soil were obtained for identification purposes. The resistance of the soil to penetration of the sampler, measured in blows per foot (N), is an indication of the relative density of cohesionless soil and of the consistency of cohesive soil.

The vicinity map and the boring location plan are presented in Appendix A. The boring logs (see Appendix B) present the data obtained in the subsurface exploration. The logs include the surface elevations, the approximate depths and elevations of major changes in the character of the subsurface materials, visual descriptions of the materials in accordance with the criteria presented in Appendix C, groundwater data, and the penetration resistance recorded in blows per 0.5-ft increments of depth. Three disturbed samples of the on-site, compacted crushed concrete were obtained for laboratory testing.

The locations of the borings were determined by Benesch's surveyors and the locations are shown on the boring logs.. Elevations (approximate) at the boring locations were also determined by Benesch's surveyors with reference to NAVD88. Water level readings were made in the auger borings at times and under conditions stated on the boring logs.

2.0 LABORATORY ANALYSES

The split-barrel soil samples obtained during the subsurface exploration were examined in the laboratory by a member of Benesch's professional engineering staff to supplement the field identification. Standard tests were performed on selected samples to determine the engineering properties of the foundation materials.

The moisture contents selected soil samples were determined in the laboratory. These test results are presented in the boring logs opposite the respective sample locations. The moisture contents were determined in accordance with either ASTM D 4643, Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method, or ASTM D 2216, Standard Test Method for Determination of Water (Moisture) Content of Soil and Rock by Mass.

The unconfined compressive strengths of the split-barrel samples were estimated in the laboratory with a calibrated hand penetrometer. These strengths are presented on the boring logs and are estimates only.

The plasticity characteristics of six air-dried samples of glacial till were determined in accordance with ASTM Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (D 4318). These limits of consistency (Atterberg limits) are used in the Unified Soil Classification System as a basis for laboratory differentiation between materials of appreciable plasticity (clays) and slightly plastic or nonplastic materials (silts). The test results are presented in Table 1.

TABLE 1
ATTERBERG LIMITS

Boring No.	Depth, ft	Liquid Limit, %	Plastic Limit, %	Plasticity Index	Group Symbol
B-1	6.0-7.5	26	15	11	CL
B-1	11.0-12.5	33	16	17	CL
B-1	21.0-22.5	34	17	17	CL
B-2	3.5-5.0	31	16	15	CL
B-2	13.5-15.0	37	16	21	CL
B-2	26.0-27.5	34	16	18	CL

A sieve analysis was performed on one sample of the existing fill in accordance with ASTM D 1140, Standard Test Method for Amount of Material in Soils Finer Than the No. 200 (75-μm) Sieve. The test results are presented in Table 2.

TABLE 2
Sieve Analyses Data

Boring No.	Depth, ft	Percent Finer Than No. 200 Sieve by Weight
B-1	1.5-3.0	47

Washed sieve analyses were performed on three samples of the on-site, imported crushed concrete. The results of these tests, performed in accordance with ASTM C136, Standard Methods for Sieve Analysis of Fine and Coarse Aggregates, are presented in Appendix D.

3.0 ANALYSES

Benesch was informed that the crushed concrete was placed and compacted in approximately 3-inch-thick lifts using a Cat D-7 bulldozer and a Cat 693 track loader.

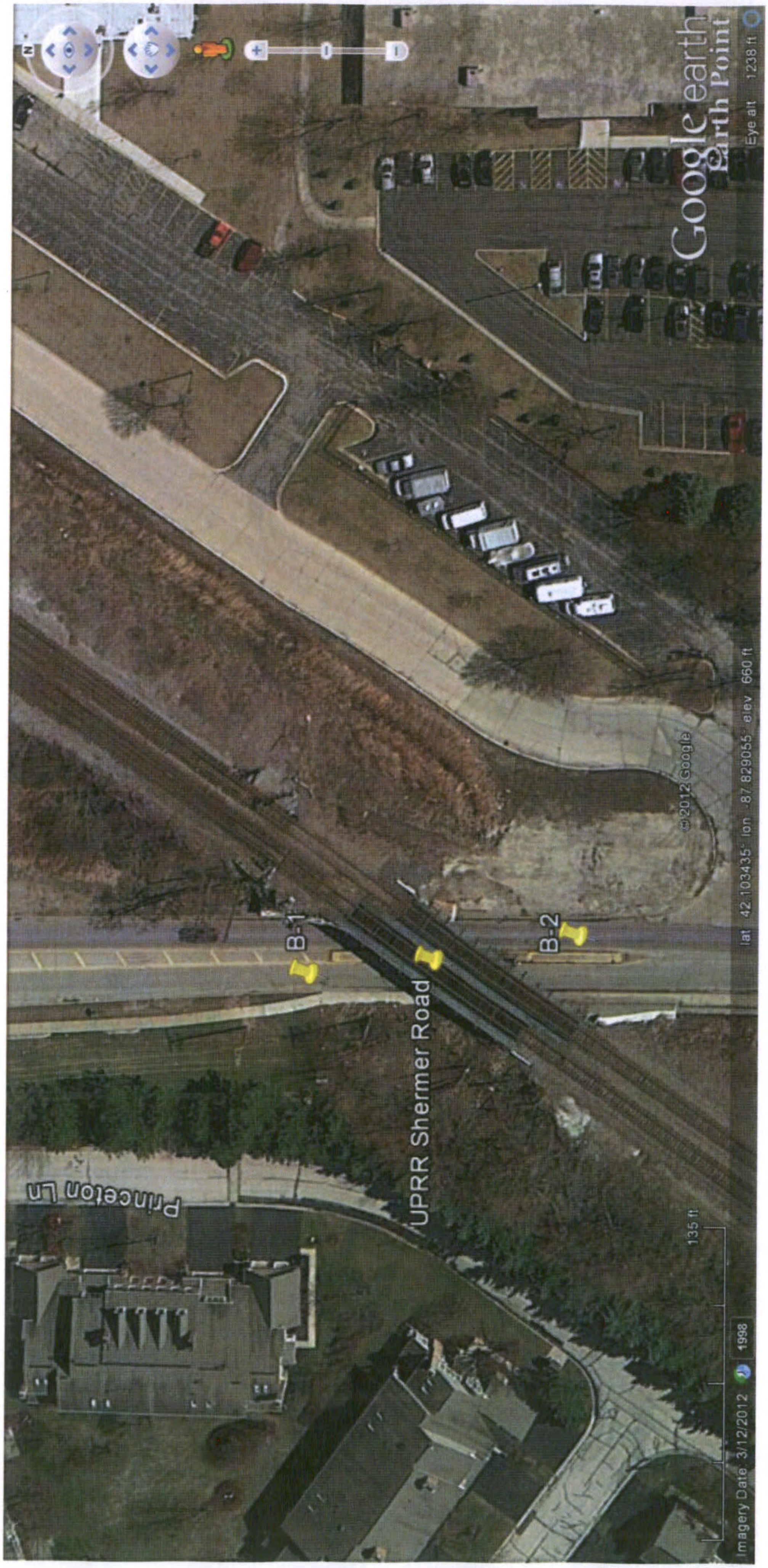
1. Vertical Pressures Induced on Existing Utility Lines. Calculations were performed to estimate the pressures on the buried utilities before and after the crushed concrete was placed. Because the exact depths of the utilities were not known, several depths were assumed. The calculated vertical pressures from the overlying soils at 3, 5, 10, and 15 feet below the street level prior to placement of the crushed concrete are 345, 575, 1175, and 1775 psf, respectively. The calculated additional vertical pressures at these same depths from the weight of the crushed concrete are 1955, 1950, 1920, and 1850 psf, respectively. The calculated additional vertical pressures at these same depths from railroad live load are 640, 585, 480, and 410 psf, respectively. Appendix E presents the vertical pressure calculations. Determinations should be made if the existing utilities can withstand the increased pressures.

2. Settlement. Calculations were performed to estimate the amount of consolidation settlement of the soils beneath the existing utilities due to the weight of the crushed concrete. The greatest settlement would be for the shallow utilities. Based on book values for soil properties, the estimated settlement beneath the weight of the crushed concrete for a utility located 5 feet below the street level is 0.5 inches, which would occur at the intersection of the centerline of the tracks and the centerline of the underlying, buried street. The estimated settlement of a utility at the toe of the embankment is negligible (less than 1/4 inches). Calculations to estimate any additional settlement of the utilities under the weight of a loaded train were not performed as the duration of any stand time is minimal. Settlement from a passing train is not expected to occur because of the cohesive nature of the soils beneath the utilities. Appendix E presents the settlement calculations.

3. Slope Stability. Analyses were performed for the crushed concrete embankment using circular failures generated using the Simplified Bishop method of slices. The results of slope stability analyses provided safety factors against failure of at least 1.3 for both the short-term (undrained) and long-term (drained) conditions assuming a 1.5(H):1.0(V) side slope and loaded coal cars on both tracks. A factor of safety of 1.3 is considered adequate to assume the slope will remain stable over the short and long terms. Appendix F presents the slope stability calculations.

APPENDIX A. VICINITY MAP AND BORING LOCATION PLAN


N
Willow Rd
Well Log 220; Permit #136266
UPRR Shermer Road
Shermer Rd
Cornell Ct
Radcliff Ct
Harvard Ct
Yale Ct
Dartmouth Ct
Rutgers Ct
560 ft
© 2012 Google
Google earth
Earth Point
Imagery Date: 3/12/2012
1998
lat 42.104246° lon -87.828956° elev 650 ft
Eye alt 3077 ft


B-1
B-2
UPRR Shermer Road
Princeton Ln
©2012 Google
Google earth
Earth Point
lat 42.103435° lon -87.829055° elev 660 ft
Eye alt 1238 ft
135 ft
Imagery Date 3/12/2012
1998

APPENDIX B. BORING LOGS

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www.benesch.com

PROJECT: UPRR Shermer Road
LOCATION: N 1980748.937, E 1121013.241
Chicago, IL
JOB NO.: 00010228.00
RIG / METHOD: B-57 / Hollow-Stem
CREW: Geo Services, Inc. (Danielle/Jim/Moe)

BORING LOG

BORING No.: B-1
SHEET 1 of 2
DATE: 7-13-2012

WATER LEVELS ∇ 26.0 IAD ▼ 21.0 on 7/13/12 at end of day

ELEV	DEPTH (feet)	LOG	LITHOLOGY DESCRIPTION	SAMPLE	SPT	qu (tsf)	MOISTURE (%)	DEPTH (feet)
646.7 646.0	0.0 0.7	■	ASPHALT; 8" thick					0.0
646.0 645.3	0.7 1.4	▨	CONCRETE; 8" thick					
645.2 643.7	1.5 3.0	▨	CL - SANDY LEAN CLAY; 10-20% fine gravel; 25-35% fine to coarse sand; medium plasticity; yellowish brown; moist; very stiff; with chunks of dark grayish brown lean clay. (Fill)	◣	6 11 11 (22)		7.83	2.5
643.2 641.7	3.5 5.0	▨	CL - LEAN CLAY; 5-10% fine gravel; medium plasticity; brown mottled with yellowish brown slightly mottled with dark yellowish brown; wet; stiff; with a trace of organics. (Fill)	◣	2 4 4 (8)	3.0* 4.5*		5.0
640.7 639.2	6.0 7.5	▨	CL - LEAN CLAY; 0-5% fine gravel; 0-5% fine to medium sand; medium plasticity; dark grayish brown; wet; stiff. (Glacial Till)	◣	1 3 4 (7)	3.0* 3.75*	13.6	7.5
638.2 636.7	8.5 10.0	▨	CL - LEAN CLAY; 0-5% fine to medium sand; medium plasticity; dark grayish brown; wet; stiff. (Glacial Till)	◣	2 3 4 (7)	2.0* 2.5*		10.0
635.7 634.2	11.0 12.5	▨	CL - LEAN CLAY; 0-5% fine to medium sand; medium plasticity; very dark grayish brown; wet; stiff to very stiff. (Glacial Till)	◣	2 4 6 (10)	2.75* 1.75*	19.2	12.5
633.2 631.7	13.5 15.0	▨	CL - LEAN CLAY; 0-5% fine sand; medium plasticity; very dark grayish brown; wet; stiff. (Glacial Till)	◣	2 3 5 (8)	2.0* 2.0*		15.0
630.7 629.2	16.0 17.5	▨	CL - LEAN CLAY; 0-5% fine to medium sand; medium plasticity; very dark grayish brown; wet; stiff. (Glacial Till)	◣	1 3 4 (7)	1.5* 1.5*	20.1	17.5
628.2 626.7	18.5 20.0	▨	CL - LEAN CLAY; 0-5% fine sand; medium plasticity; very dark grayish brown; wet; medium stiff to stiff. (Glacial Till)	◣	1 2 4 (6)	1.25* 1.5*		20.0

* Unconfined compressive strength was estimated using a calibrated hand penetrometer.

Figure B - 1a

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www.benesch.com

PROJECT: UPRR Shermer Road

LOCATION: N 1980748.937, E 1121013.241
Chicago, IL

JOB NO.: 00010228.00
RIG / METHOD: B-57 / Hollow-Stem
CREW: Geo Services, Inc. (Danielle/Jim/Moe)

BORING LOG

BORING No.: B-1

SHEET 2 of 2

DATE: 7-13-2012

WATER LEVELS ▽ 26.0 IAD ▼ 21.0 on 7/13/12 at end of day

ELEV	DEPTH (feet)	LOG	LITHOLOGY DESCRIPTION	SAMPLE	SPT	qu (tsf)	MOISTURE (%)	DEPTH (feet)
								20.0
625.7	21.0 ▼	▨	CL - LEAN CLAY; 0-5% fine to coarse sand; medium plasticity; dark grayish brown; saturated; medium stiff to stiff. (Glacial Till)	◢	1 3 3 (6)	1.25* 1.25*	19	
624.2	22.5							22.5
623.2	23.5	▨	CL - LEAN CLAY; 0-5% fine sand; medium plasticity; dark grayish brown; saturated; very stiff; with a trace of calcium carbonate concretions. (Glacial Till)	◢	4 8 6 (14)	1.75* 2.0*		
621.7	25.0							25.0
620.7	26.0 ▽	▨	CL - LEAN CLAY; medium plasticity; dark grayish brown; saturated; stiff. (Glacial Till)	◢	7 4 4 (8)	2.0*	19.9	
619.2	27.5							27.5
618.2	28.5	▨	CL - LEAN CLAY; medium plasticity; dark grayish brown; saturated; stiff. (Glacial Till)	◢	2 3 4 (7)	1.5* 1.75*	20.7	
616.7	30.0		Boring Terminated at: 30.0ft					30.0
								32.5
								35.0
								37.5
								40.0

* Unconfined compressive strength was estimated using a calibrated hand penetrometer.

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PROJECT: UPRR Shermer Road
LOCATION: N 1980558.695, E 1121035.827
Chicago, IL
JOB NO.: 00010228.00
RIG / METHOD: B-57 / Hollow-Stem
CREW: Geo Services, Inc. (Danielle/Jim/Moe)

BORING LOG

BORING No.: B-2
SHEET 1 of 2
DATE: 7-13-2012

WATER LEVELS ∇ No groundwater was encountered to depth of boring

ELEV	DEPTH (feet)	LOG	LITHOLOGY DESCRIPTION	SAMPLE	SPT	qu (tsf)	MOISTURE (%)	DEPTH (feet)
645.6	0.0	⁂	CONCRETE; 9.5" thick					0.0
644.8	0.8							
644.6	1.0	▨	CL - LEAN CLAY; 5-10% fine sand; medium plasticity; yellowish brown mixed with gray; wet; stiff. (Fill)	◣	3 4 5 (9)	4.5* 2.0*		
643.1	2.5							2.5
642.1	3.5	▨	CL - LEAN CLAY; 0-5% fine to coarse gravel; 0-5% fine sand; medium plasticity; brown; wet; very stiff. (Fill)	◣	3 5 8 (13)	4.5+* 4.5*	16.4	
640.6	5.0							5.0
639.6	6.0	▨	CL - LEAN CLAY; 0-5% fine gravel; 0-5% fine sand; medium plasticity; brown mottled with dark grayish brown; wet; very stiff to hard. (Glacial Till)	◣	4 6 13 (19)	2.5* 4.5+*		
638.1	7.5							7.5
637.1	8.5	▨	CL - LEAN CLAY; 0-5% fine to coarse gravel; 0-5% fine sand; medium plasticity; brown mottled with dark grayish brown; wet; medium stiff to stiff; with a trace of calcium carbonate nodules. (Glacial Till)	◣	3 3 5 (8)	1.0*	17.4	
635.6	10.0							10.0
634.6	11.0	▨	CL - LEAN CLAY; 0-5% fine to medium sand; medium plasticity; dark grayish brown slightly mottled with very dark gray; wet; stiff. (Glacial Till)	◣	2 3 4 (7)	1.75* 1.75*		
633.1	12.5							12.5
632.1	13.5	▨	CL - LEAN CLAY; 0-5% fine gravel; medium plasticity; dark grayish brown; wet; medium stiff to stiff. (Glacial Till)	◣	1 2 3 (5)	1.25* 2.0*	20.6	
630.6	15.0							15.0
629.6	16.0	▨	CL - LEAN CLAY; 0-5% fine gravel; 0-5% fine sand; medium plasticity; very dark grayish brown; wet; medium stiff to stiff. (Glacial Till)	◣	1 2 3 (5)	1.25* 1.5*		
628.1	17.5							17.5
627.1	18.5	▨	CL - LEAN CLAY; 0-5% fine to coarse sand; medium plasticity; dark grayish brown; wet; stiff. (Glacial Till)	◣	1 2 4 (6)	1.5* 2.0*	20.4	
625.6	20.0							20.0

* Unconfined compressive strength was estimated using a calibrated hand penetrometer.

BORING LOG UPRR SHERMER ROAD BORING LOGS.GPJ HWS.GDT 8/7/12

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PROJECT: UPRR Shermer Road
LOCATION: N 1980558.695, E 1121035.827
Chicago, IL
JOB NO.: 00010228.00
RIG / METHOD: B-57 / Hollow-Stem
CREW: Geo Services, Inc. (Danielle/Jim/Moe)

BORING LOG

BORING No.: B-2
SHEET 2 of 2
DATE: 7-13-2012

WATER LEVELS ⊻ No groundwater was encountered to depth of boring

ELEV	DEPTH (feet)	LOG	LITHOLOGY DESCRIPTION	SAMPLE	SPT	qu (tsf)	MOISTURE (%)	DEPTH (feet)
								20.0
624.6	21.0	▨	CL - LEAN CLAY; 0-5% fine to coarse sand; medium plasticity; dark grayish brown; wet; stiff. (Glacial Till)	◣	1 3 3 (6)	1.25* 1.75*		
623.1	22.5							22.5
622.1	23.5	▨	CL - LEAN CLAY; 0-5% fine to coarse sand; medium plasticity; very dark grayish brown; wet; stiff. (Glacial Till)	◣	2 2 4 (6)	2.0* 2.0*	20.2	
620.6	25.0							25.0
619.6	26.0	▨	CL - LEAN CLAY; 0-5% fine gravel; 0-5% fine to coarse sand; medium plasticity; very dark grayish brown; wet; stiff. (Glacial Till)	◣	3 3 5 (8)	1.75* 2.0*		
618.1	27.5							27.5
617.1	28.5	▨	CL - LEAN CLAY; 0-5% fine gravel; medium plasticity; dark grayish brown; wet; stiff to very stiff. (Glacial Till)	◣	3 4 6 (10)	2.75* 2.5*	19.1	
615.6	30.0		Boring Terminated at: 30.0ft					30.0
								32.5
								35.0
								37.5
								40.0

* Unconfined compressive strength was estimated using a calibrated hand penetrometer.

Figure B - 2b

APPENDIX C. CRITERIA USED FOR SOIL CLASSIFICATION

USCS SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS MORE THAN 50% OF MATERIALS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LESS THAN 5% FINES)	●	GW	WELL-GRADED GRAVEL
			○	GP	POORLY-GRADED GRAVEL
		GRAVELS WITH FINES (MORE THAN 12% FINES)	○	GM	SILTY GRAVEL (LOW PLASTIC FINES)
			▨	GC	CLAYEY GRAVEL (MEDIUM TO HIGH PLASTIC FINES)
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LESS THAN 5% FINES)	⁘	SW	WELL-GRADED SAND
			░	SP	POORLY-GRADED SAND
		SANDS WITH FINES (MORE THAN 12% FINES)	░	SM	SILTY SAND (LOW PLASTIC FINES)
			▨	SC	CLAYEY SAND (MEDIUM TO HIGH PLASTIC FINES)
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	▥	ML	SILT (0-15% SAND) SILT WITH SAND (15-30% SAND) SANDY SILT (30-50% SAND)
			▨	CL	LEAN CLAY (0-15% SAND) LEAN CLAY WITH SAND (15-30% SAND) SANDY LEAN CLAY (30-50% SAND)
			▤	OL	ORGANIC SILTS AND LEAN CLAYS
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50	▥	MH	ELASTIC SILT (0-15% SAND) ELASTIC SILT WITH SAND (15-30% SAND) SANDY ELASTIC SILT (30-50% SAND)
			▨	CH	FAT CLAY (0-15% SAND) FAT CLAY WITH SAND (15-30% SAND) SANDY FAT CLAY (30-50% SAND)
			▦	OH	ORGANIC ELASTIC SILTS AND FAT CLAYS
HIGHLY ORGANIC SOILS			⁂	PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

GENERAL NOTES

CRITERIA FOR DESCRIBING CLAY SOILS

MOISTURE CONDITION

Description	Criteria
Dry	Absence of moisture, dusty, dry to touch.
Moist	Damp, slightly wet, moisture content below plastic limit.
Wet	Moisture content above the plastic limit.
Saturated	Very wet. Usually soil is below the water table.

CONSISTENCY

Description	Penetration Resistance, N_{60} (blows/ft)[1]
Very Soft	Less than 3
Soft	3 to 4
Medium Stiff	5 to 8
Stiff	9 to 16
Very Stiff	16 to 32
Hard	Greater than 32

CRITERIA FOR DESCRIBING GRANULAR SOILS

MOISTURE CONDITION

Description	Criteria
Dry	Absence of moisture, dry to the touch.
Moist	Damp but no visible free water.
Wet	Visible free water.
Saturated	Usually soil is below water table.

DENSITY

Description	Penetration Resistance, N_{60} (blows/ft)[1]
Very Loose	Less than 5
Loose	5 to 10
Medium Dense	11 to 30
Dense	31 to 50
Very Dense	Greater than 50

CRITERIA FOR DESCRIBING ROCK

STRENGTH/HARDNESS

Description	Criteria
Very Soft	Permits denting by moderate pressure of the fingers.
Soft	Resists denting by the fingers, but can be abraded and pierced to a shallow depth by a pencil point.
Moderately Soft	Resists a pencil point, but can be scratched and cut with a knife blade.
Moderately Hard	Resistant to abrasion or cutting by a knife blade, but can be easily dented or broken by light blows of a hammer.
Hard	Can be deformed or broken by repeated moderate hammer blows.
Very Hard	Can be broken only by heavy, and in some rocks, repeated hammer blows.

[1] Blow counts shown on the boring logs are those recorded directly in the field and have not been corrected for hammer efficiency. The boring log blow counts must be corrected to an equivalent hammer efficiency of 60% in order to use the criteria in this table.

ROCK QUALITY DESIGNATION (RQD)

This is a general method by which the quality of the rock at a site is obtained based on the relative amount of fracturing and alteration.

The Rock Quality Designation (RQD) is based on a modified core recovery procedure that, in turn, is based indirectly on the number of fractures (except those due directly to drilling operations) and the amount of softening or alteration in the rock mass as observed in the rock cores from a drill hole. Instead of counting the fractures, an indirect measure is obtained by summing the total length of core recovered by counting only those pieces of hard and sound core which are 4 inches or greater in length. The ratio of this modified core recovery length to the total core run length is known as the RQD.

An example is given below from a core run of 60 inches. For this particular case, the total core recovery is 50 inches yielding a core recovery of 83 percent. On the modified basis, only 38 inches are counted the RQD is 63 percent.

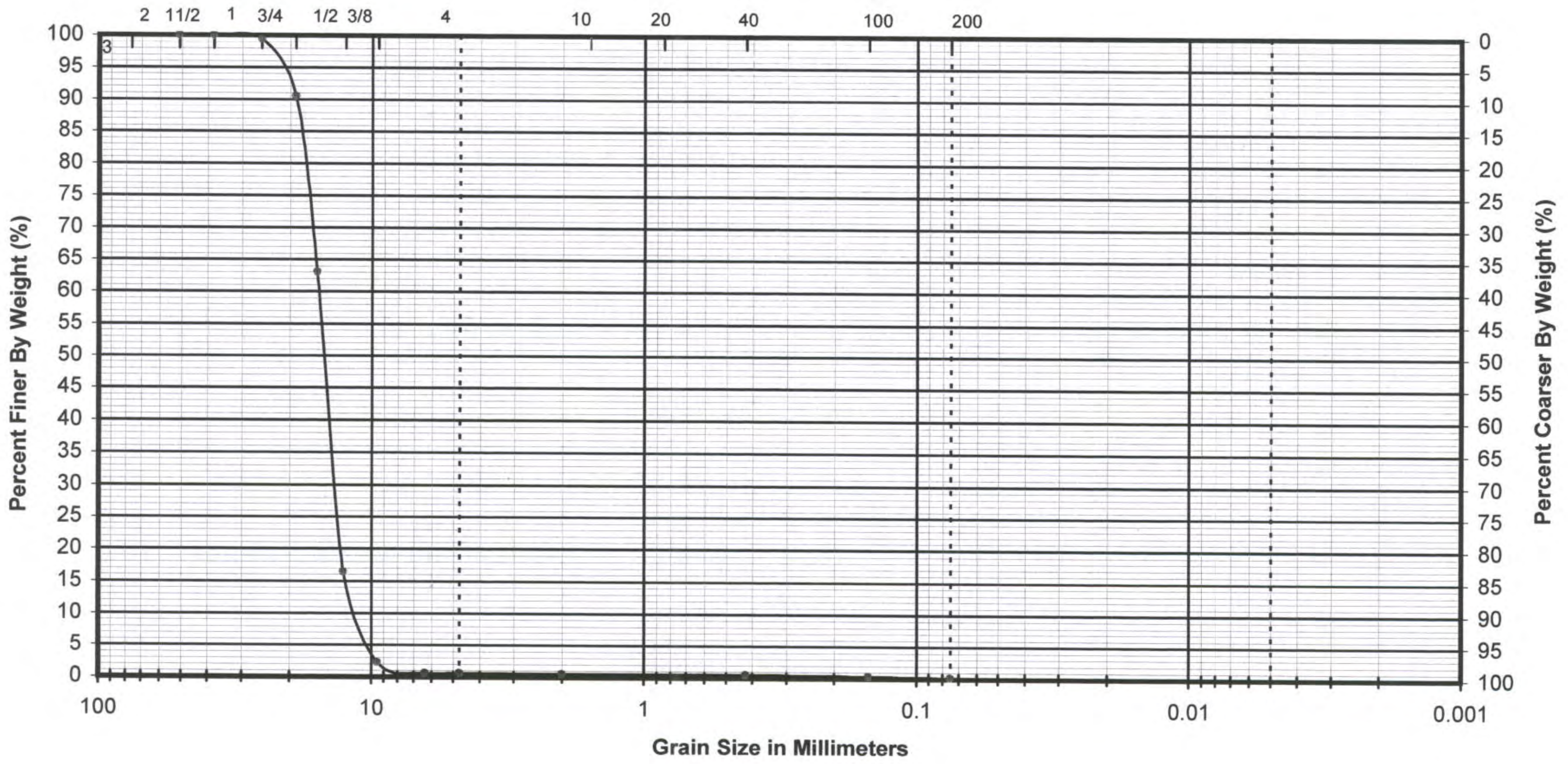
CORE RECOVERY, in	MODIFIED CORE RECOVERY, in
10	10
2	-
2	-
3	-
4	4
5	5
3	-
4	4
6	6
4	4
2	-
5	5
-----	-----
50	38

% Core Recovery = 50/60 = 83%; RQD = 38/60 = 63%

A general description of the rock quality can be made for the RQD value as follows:

RQD	DESCRIPTION OF ROCK QUALITY
0 – 25	Very Poor
25 – 50	Poor
50 – 75	Fair
75 – 90	Good
90 – 100	Excellent

APPENDIX D. SIEVE ANALYSES



<table>
<tr><td rowspan="2">GRAVEL</td><td colspan="3">SAND</td><td rowspan="2">SILT</td><td rowspan="2">CLAY</td></tr>
<tr><td>COARSE</td><td>MEDIUM</td><td>FINE</td></tr>
</table>

Sample Location	**North Side Northeast End**
Sample Date	**7/10/12**
Test Date	**7/11/12**
Test By	**JE**
Report Date	**7/11/12**
Reviewed By	**DOB**
Job No	

CLASSIFICATION-ASTM D 2487

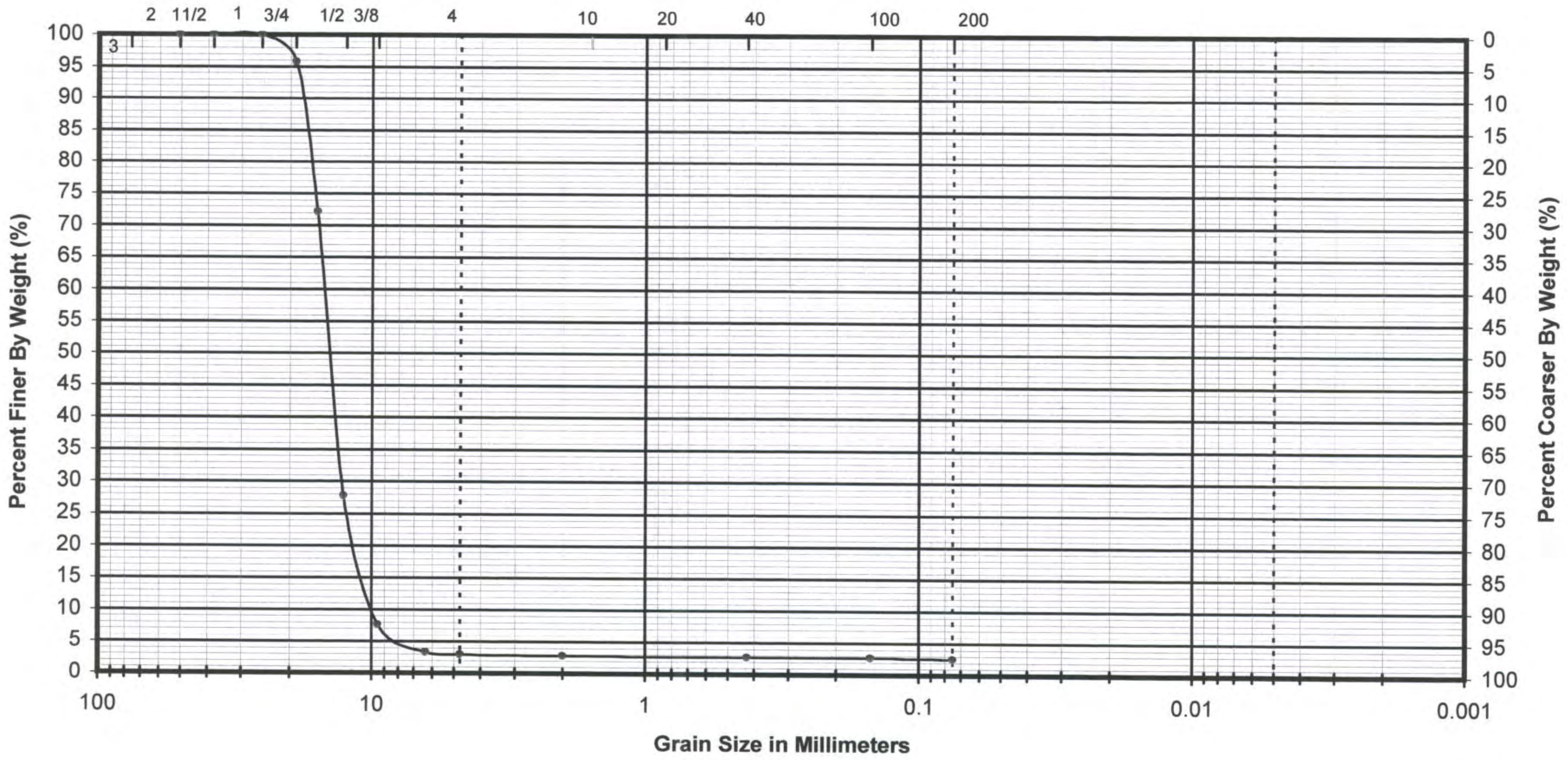
POORLY GRADED GRAVEL (GP)

Cu	1
Cc	1
% Gravel	99.4
% Sand	0.4
% Silt/Clay	0.2

PARTICLE-SIZE ANALYSIS ASTM C 136

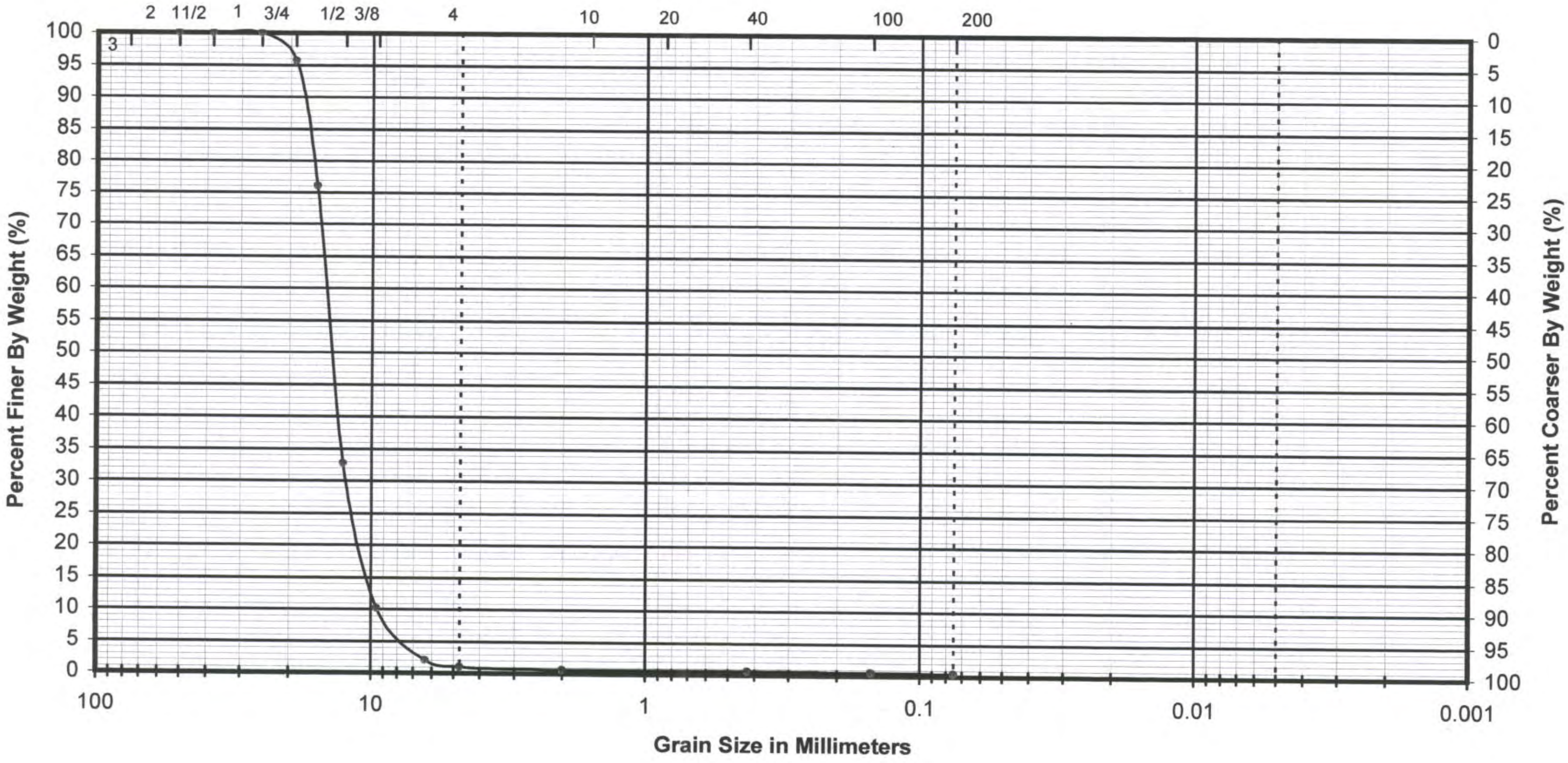
Union Pacific North Line
Shermar Road Bridge
Northbrook/Glenview, Illinois

GEO SERVICES, INC
1235 E. Davis St., Arlington Heights, IL 60005
Arlington Heights, IL 60005
Phone 847-253-3845 • Fax 847-253-0482



GRAVEL	SAND			SILT	CLAY
	COARSE	MEDIUM	FINE		

Sample Location	North Side Midsection	CLASSIFICATION-ASTM D 2487	PARTICLE-SIZE ANALYSIS ASTM C 136
Sample Date	7/10/12	POORLY GRADED GRAVEL (GP)	Union Pacific North Line Shermar Road Bridge Northbrook/Glenview, Illinois
Test Date	7/11/12	Cu 1 Cc 0.5	
Test By	JE	% Gravel 96.7	GEO SERVICES, INC
Report Date	7/11/12	% Sand 0.8	1235 E. Davis St., Arlington Heights, IL 60005
Reviewed By	DOB	% Silt/Clay 2.5	Arlington Heights, IL 60005
Job No			Phone 847-253-3845 • Fax 847-253-0482



<table>
<tr><td rowspan="2">GRAVEL</td><td colspan="3">SAND</td><td rowspan="2">SILT</td><td rowspan="2">CLAY</td></tr>
<tr><td>COARSE</td><td>MEDIUM</td><td>FINE</td></tr>
</table>

Sample Location	North Side Southwest End
Sample Date	7/10/12
Test Date	7/11/12
Test By	JE
Report Date	7/11/12
Reviewed By	DOB
Job No	

CLASSIFICATION-ASTM D 2487

POORLY GRADED GRAVEL (GP)

Cu	2
Cc	1
% Gravel	98.0
% Sand	1.5
% Silt/Clay	0.5

PARTICLE-SIZE ANALYSIS ASTM C 136

Union Pacific North Line
Shermar Road Bridge
Northbrook/Glenview, Illinois

GEO SERVICES, INC
1235 E. Davis St., Arlington Heights, IL 60005
Arlington Heights, IL 60005
Phone 847-253-3845 • Fax 847-253-0482

APPENDIX E. VERTICAL PRESSURE AND SETTLEMENT CALCULATIONS

I. Pressures on Utilities Before and After Filling in Overpass

A. Storm sewer @ 3' below street level.

$p_o = 3'(115 pcf) = \boxed{345 psf = p_o}$ (sand γ)

1. Load from crushed concrete:

a. Rectangular Area

2A = 60 ⇒ A = 30'

2B = 37' ⇒ B = 18.5'

z = 3'

load = 17'(115 pcf) = 1955 psf

Δp = 0.99800 (1955) = 1951.1 psf

b. 2.7:1.0 triangular (treat as infinitely long)

A = 46' $y' = -\frac{37}{2} = -18.5'$

load = 1955 psf

Δp = 0.00071(1955) = 1.4 psf

c. 2.0:1.0 triangular

A = 34' y' = -18.5'

Δp = 0.00067(1955) = 1.3 psf

2. Two trains @ 2300 lb/ft each

2B = 9.0' B = 4.5 y = 0 z = 17+3 = 20'

Δp = 2300(0.27723) = 637.6 psf

p_f = 345 + 1951.1 + 1.4 + 1.3 + 637.6(2) = 3574

p_f = 2298.8 with $\boxed{\text{no trains. Say 2300 psf}}$

$\boxed{\text{Each train adds} \approx 640 \text{ psf}}$

B. Utility @ 5' deep.

$p_o = 5'(115) = \boxed{575 psf = p_o}$

1. Crushed concrete

a. Rectangle = 1937.8 psf

b. Triangles = 5.7 + 6.1 = 11.8 psf

2. Each train = 582.9 psf

z = 5' + 17' = 22'

$P_f = 575 + 1937.8 + 5.7 + 6.1 = 2524.6 = \boxed{2525\text{ psf no trains.}}$

$\boxed{\text{Each train} \approx 585\text{ psf}}$

C. Utility @ 10' deep

$P_0 = 5'(115) + 5'(120) = \boxed{1175\text{ psf} = P_0}$

1. Crushed concrete
   a. Rectangle = 1843.7 psf
   b. Triangles = 37.9 + 35.0 = 72.9 psf
2. Each train z = 17 + 10 = 27'
   479.3 psf

$P_f = 1175 + 1843.7 + 72.9 = 3091.6\text{ psf} = \boxed{3095\text{ psf no trains.}}$

$\boxed{\text{Each train} \approx 480\text{ psf}}$

D. Utility @ 15' deep

$P_0 = 5(115) + 10(120) = \boxed{1775\text{ psf} = P_0}$

1. Crushed concrete
   a. Rectangle = 1673.2 psf
   b. Triangles = 82.8 + 90.7 = 173.5 psf
2. Each train z = 17 + 15 = 32'
   406.5 psf

$P_f = 1775\text{ psf} + 1673.2 + 173.5 = 3621.7\text{ psf} = \boxed{3625\text{ psf no trains}}$

$\boxed{\text{Each train} \approx 410\text{ psf}}$

II. Settlement Due to Crushed Concrete @ Center of Embank. The shallowest utility would have the most settlement. Say utility @ 5' below street level. Look at settlement in 5' increments.

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Project: UPRR Sherman Road	
Project No:	By: Doyle P.
Date: 7-15-12 (Sun.)	Page: 3/4

0' ——— Street

5' o← utility

10' Layer ①

Layer ②

15'

Layer ③

20' ▽ 20'

Layer ④

25'

Layer ⑤

30'

Assumptions:

① Let all fill be:

$\gamma_{wet} = 120$ psf

$w = 20\%$

$\gamma_{dry} = \frac{120}{1.20} = 100$ pcf

$e_0 = \frac{2.7(62.4)}{100} - 1 = 0.685$

$p_c = 4000$ psf (from Dixon)

$C_c = 0.2$ (from Dixon)

$C_r = 20\% C_c = 0.2(0.2) = 0.04$

Seems high for a lean clay. Say $C_r = 0.02$.

② No train load because trains will not likely be parked for a long enough duration to cause settlement of the clay soils.

③ Water at 20'

Layer ①

$z = 7.5'$ $\quad p_0 = 5(115) + 2.5(120) = 875$ psf

$\Delta p = \underset{\uparrow}{1902} + \underset{\nwarrow}{18.4} + \underset{\uparrow}{17.1} = 1938$ psf

Rectangle Triangles

$p_f = 875 + 1938 = 2813$ psf $< p_c = 4000$ psf

$s = \boxed{\frac{5(12)(0.02)}{1+0.685}} \log \frac{2813}{875} = 0.36''$

Layer ②

$z = 12.5'$ $\quad p_0 = 875 + 5(120) = 1475$ psf

$\Delta p = 1765.6 + 57.7 + 62.8 = 1886$ $\quad p_f = 3361$

$s = 0.712 \log \frac{3361}{1475} = 0.25''$

Layer ③

$z = 17.5'$ $\quad p_0 = 1475 + 5(120) = 2075$ psf

$\Delta p = 1572.6 + 119.2 + 108.2 = 1800$ psf; $p_f = 3875$ psf

$s = 0.712 \log \frac{3875}{2075} = 0.19''$

Project: UPRR Shermer Road
Project No:
By: Doyle P.
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Layer ④

$$57.6$$

$$z = 22.5' \quad p_o = 2075 + 2.5(120) + 2.5(120-62.4) = 2519 \text{psf}$$

$$\Delta p = 13657 + 153.8 + 172.0 = 1691.5$$

$$p_f = 2519 + 1692 = 4211 \text{ psf}.$$

Still treat this as $< P_c$. since P_c is probably increasing with depth.

$$S = 0.712 \log \frac{4211}{2519} = 0.16''$$

Layer ⑤

$$z = 27.5' \quad p_o = 2519 + 5(57.6) = 2807 \text{psf}$$

$$\Delta p = 1171.1 + 214.0 + 188.5 = 1573.6 \text{ psf}$$

$$p_f = 4381 \text{ psf}$$

$$s = 0.712 \log \frac{4381}{2807} = 0.14''$$

$$\text{Total} = 0.36 + 0.25 + 0.19 + 0.16 + 0.14 = 1.10''$$

Dixon said it's been his experience that actual settlement is less than calculated. I would agree, especially when using the formulas versus correcting the consolidation curves and using the void ratios directly from the corrected curves. Plus as angular as the crushed concrete is, there is probably some arching effect between the abutments and the center pier. Let's say 50% of the calculated settlement of ≈ 0.5" from cohesive natural soils.

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Comp by: JJC
Date: 7/19/2012
Worksheet: 1 of 1
Check by: WSR
Date: 7/19/2012
Job No.: 10228
Project: **Shermer Road Emergency Response**
Element: Northbrook 10" Water Main

Objective

Determine the structural capacity of the existing 10" DIP watermain under Shermer Road

Assumptions

- The design basis is that the pipe is subject to internal pressure and external pressure from underground loading conditions. It is assumed that, since no change was made to the internal (fluid) loadings, only the external pressures will be checked.
- These caluclations are based on the recommendations of the Ductile Iron Pipe Research Assocation, published in their paper titled "Design of Ductile Iron Pipe".
- It is assumed that the pipe is in pristine condition and that the pipe is 10 inch, Pressure Class 350 Per ASTM A746.
- It is assumed that the pipe was bedded with Type 5 laying Condition (See Attached Figure)

Calculations

Bending Stress Check

Design Maximum Bending Stress, f =	48000	psi	*<< Per "Design of Ductile Iron Pipe" (Attached)*
Modulus of Elasticity, E =	24000000	psi	*<< Per "Design of Ductile Iron Pipe" (Attached)*
Pipe Outside Diameter, D =	11.1	in	*<< Per ASTM 746*
Nominal Pipe Wall Thickness, t =	0.26	in	*<< Per ASTM 746*
Service Allowance =	0.08	in	*<< Per "Design of Ductile Iron Pipe" (Attached)*
Casting Tollerance =	0.06	in	*<< Per "Design of Ductile Iron Pipe" (Attached)*
Pipe Wall Net Thickness, tn =	0.12	in	
Pipe Laying Condition Type =	5		
Bending Moment Coefficient, Kb =	0.128		*<< Per Table 1 Attached*
Deflection Coefficient, Kx =	0.085		*<< Per Table 1 Attached*
Modulus of Soil Reaction, E' =	700	psi	*<< Per Table 1 Attached*
Maximum Load Capacity, Pv =	37.79	psi	*<< Controls*

Deflection Check

Design Deflection, ϕx =	0.333	in	*<< 3% of Outside Diameter*
Minimum Thickness, t1 =	0.2	in	*<< Net thickness plus 0.08"*
Maximum Load Capacity, Pv =	49.96	psi	*<< Does Not Control*

Loading on Pipe (From Doyle Petersen Calculations)

Assuming the Pipe was installed 5' Below the Roadway

Pressure from Original 5' of Overburden =	575	psf
Pressure from Added Crushed Concrete Embankment Fill =	1950	psf
Pressure from Railroad Live Load =	585	psf
Sum =	21.60	psi
Pipe Capacity =	OK	

Assuming the Pipe was installed 10' Below the Roadway

Pressure from Original 5' of Overburden =	1175	psf
Pressure from Added Crushed Concrete Embankment Fill =	1920	psf
Pressure from Railroad Live Load =	480	psf
Sum =	24.83	psi
Pipe Capacity =	OK	

Assuming the Pipe was installed 15' Below the Roadway

Pressure from Original 5' of Overburden =	1775	psf
Pressure from Added Crushed Concrete Embankment Fill =	1850	psf
Pressure from Railroad Live Load =	410	psf
Sum =	28.02	psi
Pipe Capacity =	OK	

TABLE 2 Nominal Thicknesses for Standard Pressure Classes of Ductile-Iron Pipe

Size, in.	Outside Diameter, in. (mm)	Pressure Class				
		150	200	250	300	350
		Nominal Thickness, in. (mm)				
3	3.96 (100.6)	. . .	. . .	. . .	. . .	0.25^A (6.4)
4	4.80 (121.9)	. . .	. . .	. . .	. . .	0.25^A (6.4)
6	6.90 (175.3)	. . .	. . .	. . .	. . .	0.25^A (6.4)
8	9.05 (229.9)	. . .	. . .	. . .	. . .	0.25^A (6.4)
10	11.10 (281.9)	. . .	. . .	. . .	. . .	0.26 (6.6)
12	13.20 (335.3)	. . .	. . .	. . .	. . .	0.28 (7.1)
14	15.30 (388.6)	. . .	. . .	0.28 (7.1)	0.30 (7.6)	0.31 (7.9)
16	17.40 (442.0)	. . .	. . .	0.30 (7.6)	0.32 (8.1)	0.34 (8.6)
18	19.50 (495.3)	. . .	. . .	0.31 (7.9)	0.34 (8.6)	0.36 (9.1)
20	21.60 (548.6)	. . .	. . .	0.33 (8.4)	0.36 (9.1)	0.38 (9.7)
24	25.80 (655.3)	. . .	0.33 (8.4)	0.37 (9.4)	0.40 (10.2)	0.43 (10.9)
30	32.00 (812.8)	0.34 (8.6)	0.38 (9.7)	0.42 (10.7)	0.45 (11.4)	0.49 (12.4)
36	38.30 (972.8)	0.38 (9.7)	0.42 (10.7)	0.47 (11.9)	0.51 (12.9)	0.56 (14.2)
42	44.50 (1130.3)	0.41 (10.4)	0.47 (11.9)	0.52 (13.2)	0.57 (14.5)	0.63 (16.0)
48	50.80 (1290.3)	0.46 (11.7)	0.52 (13.2)	0.58 (14.7)	0.64 (16.3)	0.70 (17.8)
54	57.56 (1450.3)	0.51 (12.9)	0.58 (14.7)	0.65 (16.5)	0.72 (18.3)	0.79 (20.1)
60	61.61 (1564.9)	0.54 (13.7)	0.61 (15.5)	0.68 (17.3)	0.76 (19.3)	0.83 (21.1)
64	65.67 (1668.0)	0.56 (14.2)	0.64 (16.3)	0.72 (18.3)	0.80 (20.3)	0.87 (22.1)

[A] Calculated thicknesses for these sizes and pressure ratings are less than those shown above. Presently these are the lowest nominal thicknesses available in these sizes.

6. Coating and Lining

6.1 *Outside Coating*—The outside coating for use under normal conditions shall be an asphaltic coating approximately 1 mil (0.025 mm) thick. The coating shall be applied to the outside of all pipe, unless otherwise specified. The finished coating shall be continuous and smooth, neither brittle when cold, nor sticky when exposed to the sun, and shall be strongly adherent to the pipe.

6.2 *Cement-Mortar Linings*—Unless otherwise specified, the lining shall be cement-mortar in accordance with ANSI/AWWA C 104/A21.4.

6.3 *Special Linings*—For severely aggressive wastes, other types of linings may be available. Such special linings shall be specified in the invitation for bids and on the purchase order.

7. Pipe Design

7.1 This section covers the design of ductile iron pipe for trench loads.

7.2 *Determining the Total Calculated Thickness and Standard Thickness*:

7.2.1 Determine the trench load, P_v. Table 6 gives the trench load, including the earth load, P_e, plus the truck load, P_t, for 2.5 to 32 ft (0.76 to 9.75 m) of cover.

7.2.2 Determine the standard laying condition from the descriptions in Table 3 and select the appropriate table for diameter-thickness ratios from Tables 7-11. Each table lists diameter-thickness ratios calculated for both bending and deflection over a range of trench loads.

pe is a function of soil and ring stiffness. In addition, an upward reaction to the vertical trench load exerted on the pipe develops in the trench embedment below the pipe. This reaction is distributed almost uniformly over the width of bedding of the pipe; the greater the width of bedding, the greater the load-carrying capacity of the pipe. Therefore, certain design criteria dependent on the effective width of bedding and on the available passive resistance of the sidefill soil are essential to calculating ring bending stress and ring deflection of Ductile Iron pipe. These design criteria have been conservatively established from test data for various standard laying conditions discussed later in this article. (See Table 1.) Also, due to its inherent greater ring stiffness, Ductile Iron pipe is less reliant on soil support than other flexible pipe materials.

Bending Stress Design

Design maximum ring bending stress for Ductile Iron pipe is 48,000 psi, which provides safety factors under trench loading of at least 1.5 based on ring yield strength and at least 2.0 based on ultimate ring strength. The following equation is used to calculate the trench load required to develop a bending stress of 48,000 psi at the pipe invert:

$$P_v = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t}-1\right)\left[K_b - \frac{K_x}{\frac{8E}{E'\left(\frac{D}{t}-1\right)^3}+0.732}\right]}$$

where:

P_v = trench load, psi = $P_e + P_t$
P_e = earth load, psi
P_t = truck load, psi
f = design maximum bending stress, 48,000 psi
D = outside diameter, in.
t = net thickness, in.
K_b = bending moment coefficient (Table 1)
K_x = deflection coefficient (Table 1)
E = modulus of elasticity (24 x 10^6 psi)
E′ = modulus of soil reaction, psi (Table 1)

Net Thickness and Service Allowance

A net thickness is computed using both the internal pressure and bending stress equations as described above. The larger of the two net thicknesses is then selected as the net thickness required for internal pressure and bending stress design.

A service allowance (0.08-inch for all pipe sizes) is then added to the larger net thickness. This service allowance provides an additional safety factor for unknowns. The resulting thickness is the minimum thickness t_1.

Deflection Check

Maximum allowable ring deflection for cement-mortar-lined Ductile Iron pipe is 3 percent of the outside diameter. Tests have shown that 3 percent deflection will provide a safety factor of at least 2.0 with regard to failure of the cement-mortar lining. Much larger deflections can be sustained without damage to the pipe wall. The following equation is used to calculate the trench load required to develop a ring deflection of 3 percent of the outside diameter.

$$P_v = \frac{\varnothing x/D}{12K_x}\left[\frac{8E}{\left(\frac{D}{t_1}-1\right)^3} + 0.732E'\right]$$

where:

t_1 = minimum thickness, in. (t + 0.08)
$\varnothing x$= design deflection, in. ($\varnothing x/D = 0.03$)
P_v, K_x, E, E′, and D are the same as in the equation for bending stress.

The t_1 required for deflection is compared to the t_1 resulting from internal pressure and bending stress design. The greater t_1 is used and is called the minimum manufacturing thickness.

Allowance For Casting Tolerance

Once the minimum manufacturing thickness is determined, an allowance for casting tolerance is added to provide the latitude required by the manufacturing process and to prevent the possibility of significant minus deviation from design thickness. Casting allowance is dependent on the pipe size as shown in the table.

Allowances for Casting Tolerance

Size in.	Casting Tolerance in.
3-8	0.05
10-12	0.06
14-42	0.07
48	0.08
54-64	0.09

Standard Laying Conditions

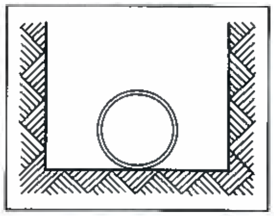
As indicated previously, certain factors dependent on the specified type of laying condition are essential to the design of Ductile Iron pipe for external loads. Two of these factors, the coefficients for bending (K_b) and deflection (K_x), are dependent on the width of bedding at the pipe bottom. The width of bedding is the contact area on the pipe bottom where bedding support is sufficient to develop an equal reaction to the vertical trench load and is commonly referred to as the bedding angle. The other factor is modulus of soil reaction (E′), which is a measure of the passive resistance that can be developed in the sidefill soil. To facilitate design calculations, these factors have been conservatively established from reliable test data for five standard laying conditions (Table 1), thus giving the design engineer a great deal of flexibility in selecting the most economical combinations of wall thickness and bedding and backfill requirements.

Minimum explicit safety factors are set, but actual total field service safety factors far exceed these values. Unparalleled field service history, improvements in manufacturing and quality control, and research results, including load tests and conclusive evidence of high-level corrosion resistance, have led to the establishment of the procedures outlined in this article for the design of Ductile Iron pipe.

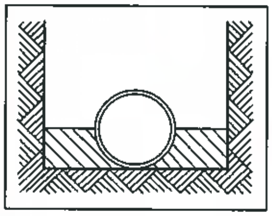
Note: DIPRA has developed a computer program to perform these design calculations. For your free copy of this program, contact DIPRA Headquarters in Birmingham, your local DIPRA Regional Engineer, or download it from our website (http://www.dipra.org).

FIGURE 1

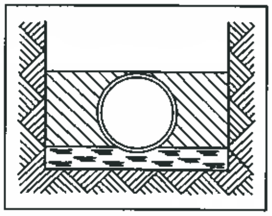
Standard Laying Conditions for Ductile Iron Pipe



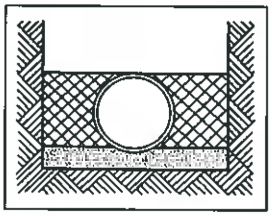
Type 1*
Flat-bottom trench.†
Loose backfill.



Type 2
Flat-bottom trench.†
Backfill lightly consolidated to centerline of pipe.

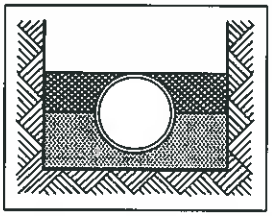


Type 3
Pipe bedded in 4-inch minimum loose soil.‡ Backfill lightly consolidated to top of pipe.



Type 4
Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-inch minimum. Backfill compacted to top of pipe. (Approximately 80% Standard Proctor, AASHTO T-99.)§

(See Table 1 for notes.)



Type 5
Pipe bedded to its centerline in compacted granular material; 4-inch minimum under pipe. Compacted granular or select‡ material to top of pipe. (Approximately 90% Standard Proctor, AASHTO T-99.)§**

TABLE 1

Standard Pipe Laying Conditions

Laying Condition†	Description	E′ psi	Bedding Angle degrees	K_b	K_x
Type 1*	Flat-bottom trench.† Loose backfill.	150	30	0.235	0.108
Type 2	Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.	300	45	0.210	0.105
Type 3	Pipe bedded in 4-in minimum loose soil.‡ Backfill lightly consolidated to top of pipe.	400	60	0.189	0.103
Type 4	Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-in. minimum. Backfill compacted to top of pipe. (Approx. 80 percent Standard Proctor, AASHTO T-99.)§	500	90	0.157	0.096
Type 5	Pipe bedded to its centerline in compacted granular material,** 4-in. minimum under pipe. Compacted granular or select‡ material to top of pipe. (Approx. 90 percent Standard Proctor, AASHTO T-99.)§	700	150	0.128	0.085

Note: Consideration of the pipe-zone embedment condition included in this table may be influenced by factors other than pipe strength. For additional information see ANSI/AWWA C600 "Standard for Installation of Ductile Iron Water Mains and Their Appurtenances."

* For pipe 14 in. and larger, consideration should be given to the use of laying conditions other than Type 1.

**Granular materials are defined per the AASHTO Soil Classification System (ASTM D3282) or the United Soil Classification System (ASTM D2487), with the exception that gravel bedding/backfill adjacent to the pipe is limited to 2" maximum particle size per ANSI/AWWA C600.

† Flat-bottom is defined as "undisturbed earth."

‡ Loose soil or select material is defined as "native soil excavated from the trench, free of rocks, foreign material, and frozen earth."

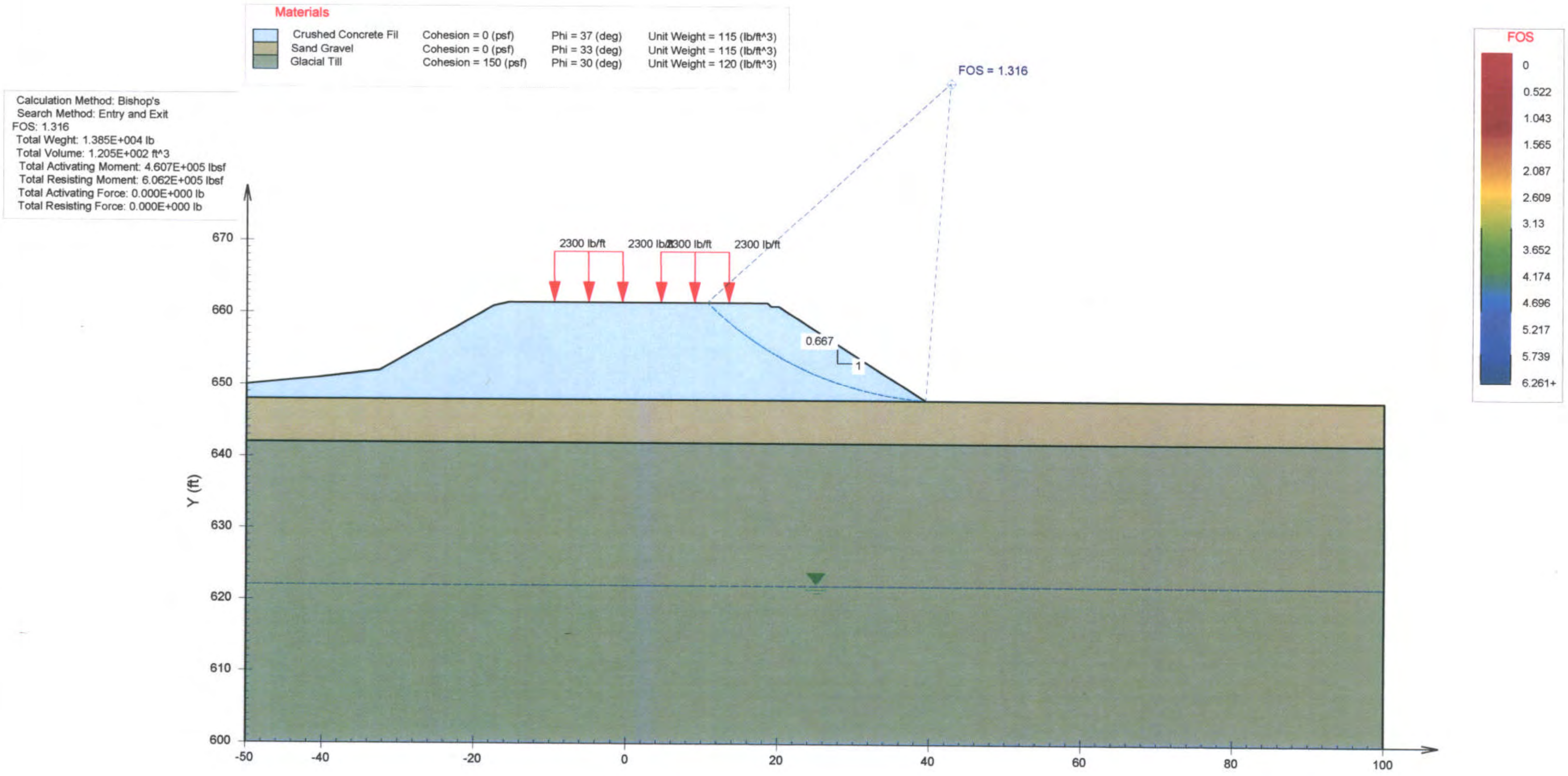
§ AASHTO T-99, "Moisture Density Relations of Soils Using a 5.5 pound Rammer 12-in. Drop."

TABLE 2

Reduction Factors R for Truck Load Calculations

Size in.	Depth of Cover — ft.			
	<4	4-7	7-10	>10
3-12	1.00	1.00	1.00	1.00
14	0.92	1.00	1.00	1.00
16	0.88	0.95	1.00	1.00
18	0.85	0.90	1.00	1.00
20	0.83	0.90	0.95	1.00
24-30	0.81	0.85	0.95	1.00
36-64	0.80	0.85	0.90	1.00

APPENDIX F. SLOPE STABILITY ANALYSIS RESULTS



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TITLE	Long Term Analysis (Drained)

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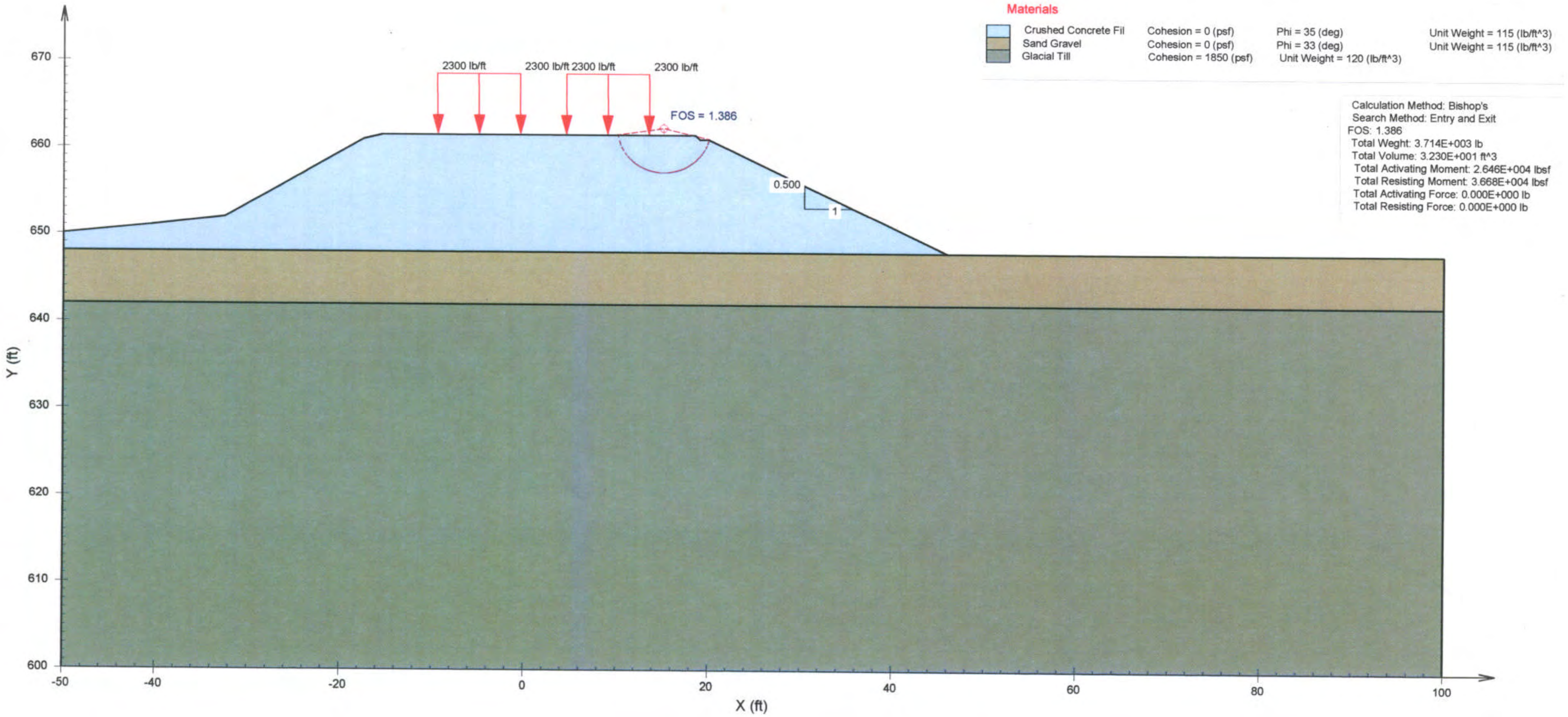
PROJECT No.	10228.00	File No.
Author		
Date	7/12/2012	FIGURE 1



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PROJECT
UPRR Shermer Road

TITLE
Northbrook/Glenview, IL (Undrained Analysis)

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PROJECT No.	10228.00	File No.
Author		FIGURE 2
Date	7/12/2012	