EnvironmentalSafetyHealthGeotechnical

O'Reilly, Talbot & Okun
[A S S O C I A T E S]
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J2463-03-01
September 14, 2016

BETA Group, Inc.
315 Norwood Park South
Norwood, Massachusetts 02062
Attn: Alan Hanscom

Re: Chicopee Levee Slope Stability
Uniroyal Filling Project
Chicopee, Massachusetts

Dear Mr. Hanscom:

This letter presents results for the slope stability analysis for the Uniroyal Filling project located in Chicopee, Massachusetts. Our work involved the review of previous plans and reports prepared by the U.S. Army Corps of Engineers (USACE) and Baystate Environmental Consultants (BEC), stability analyses of the proposed conditions, and preparation of this report. No subsurface information or testing was performed as part of this project. The analyses presented in this report are limited to the assumed conditions as described below. Should any of the conditions change, we recommend that additional analyses be performed to evaluate the proposed changes.

This letter is subject to the attached Limitations.

SITE INFORMATION & PROPOSED WORK

The Site is located within the former Uniroyal Complex off Grove Street in Chicopee, Massachusetts. Specifically, the area addressed in this letter is located within the lower level, western portion of the Site, adjacent to the Chicopee River levee. At the time of this letter, we understand that a portion of the buildings within the proposed work area have been demolished and that the remaining buildings will be demolished prior to the start of filling. Existing condition plans prepared by Heritage Survey, Inc. and dated 2009 are attached as Sheets 1 through Sheet 5.

The proposed work will consist of filling behind the levee with excess construction soils as part of an overall redevelopment of the Site. The fill will be placed in the low lying areas created between the levee and the sloping terrain in the eastern portion of the Site. We understand that backfill soils will consist of excess construction soils from local construction sites. The soils may contain oil and hazardous constituents at concentrations below reportable conditions in the Massachusetts Contingency Plan (MCP). A Beneficial Use Determination (BUD) will be obtained from the MassDEP to allow the subject fill soils to be reused at the Site. Since fill will be placed against the existing levee, a permit from the USACE will also be obtained.

We understand that the area to be filled is approximately located between levee stations 30+00 and 50+00. This area does not extend to the floodwall located further upstream, which terminates at approximate station 25+50. According to project plans, the fill soils will be placed to the approximate top of the levee (approximate elevation 100); therefore, maximum fill heights will be on the order of 15 feet. A final grading plan has not been prepared at the time of this letter; however, we have assumed that the fill soils on the land side (east) of the levee, extend along a relatively flat surface until grades are matched to the east.

INFORMATION SOURCES

The slope stability analysis was based on information provided in the following documents:

- Plan titled "Topographic Plan of Land in Chicopee, Massachusetts, Surveyed for The City of Chicopee" by Heritage Surveys, Inc., dated December 12, 2009;
- Plan set titled "Connecticut River Flood Control Project, Chicopee Falls, Mass" prepared by Green Engineering Affiliates, Inc. for the U.S. Army Engineer Division, New England, dated April 1963;
- Design memorandum titled "Chicopee Falls Local Protection Project, Design Memorandum No. 5" by the U.S. Army Engineering Division, New England, dated March 1963;
- "FEMA Accreditation Report, Chicopee Falls Flood Control System" by Baystate Environmental Consultants, Inc., dated November 2010; and
- "Design and Construction of Levees Engineering Manual"- EM 1110-2-1913, U.S. Army Corps of Engineers, dated April 2000.

The information obtained from these sources that were used in our evaluation included the following:

- Details on levee construction;
- Design flood elevations and river levels;
- Existing ground surface topography;
- Subsurface information; and
- Soil properties.

SLOPE STABILITY ANALYSIS

Slope stability was evaluated using the SLOPE/W computer program using the Spencer method. The SLOPE/W program performs a limit equilibrium analysis using various analytical methods to determine the factor of safety and the critical failure surface. The Spencer method, which assumes that the resultant interslice forces have constant slope through the sliding mass, was chosen per USACE guidance.

The slope stability for typical design conditions of the work area was evaluated using a limit equilibrium analyses. The Spencer Method determines the critical failure surface and the minimum factor of safety. Levee slope stability was analyzed for critical design condition as described in the USACE *Design and Construction of Levees*, EM 1110-2-1913, namely under normal, 100 year flood conditions, and rapid drawdown. For these analyses, only failure into the river side was considered, since the placement of fill on the landward side increases the resistance to failures in that direction. The results of the recent analyses are attached.

Model Information

Our analysis was performed on a section modeled at Station 41+00, which is described in BEC's report as being typical of station 39+25 to station 50+00. In addition, a "worst case" section was analyzed at Station 13+30. This section is typical of Stations 9+50 to 16+82 and Stations 25+25 to 39+25. Levee geometry was based upon typical cross sections provided in the "Connecticut River Flood Control Project, Chicopee Falls, Mass" plan set and stability analysis provided in BEC's report. Soil properties were based upon information provided in BEC's report. A table of soil values used in the analysis is provided below.

Table 1
Soil Properties

Soil Layer	Total Unit Weight (lb/ft3)	Effective Strength		Total Strength	
		Cohesion	Friction	Cohesion	Friction
Compacted Impervious Fill	118	0	35	0	35
Compacted Gravel Fill	120	0	32	0	32
Silty Sand	110	0	30	0	27
Till	130	0	35	0	35
Riprap	140	0	42	0	42
Crushed Fill	120	0	30	0	30

Notes:

1. Assumed soil properties based upon values provided in 2010 BEC report.

The sections were analyzed for the three separate conditions as described in the USACE manual: rapid drawdown (performed using the USACE 3-stage method), long-term (steady seepage during 100 year flood conditions), and normal water conditions. Analyses of each of these potential failure mechanisms for existing conditions were previously evaluated by BEC, and were documented in their November 2010 FEMA Accreditation Report (a copy of the pertinent portion of that report, Appendix A-4.4 is attached). An additional condition was analyzed for total embankment failure during rapid drawdown. In general, this analysis forced the failure plane to be seated within the underlying silty sand (or weakest layer).

As provided in the USACE design manual, the recommended minimum factor of safety for rapid drawdown is between 1.0 to 1.2, and the recommended minimum factor of safety for long term (steady seepage) is 1.4. A specific factor of safety for normal water conditions is not provided in the USACE design manual; therefore, a value of 1.4 was used.

Results

Based upon our analysis, the computed factors of safety for the proposed conditions met or exceeded the required minimums specified above. The results are compared to previous values and required minimums are shown in Table 2. In general, the computed values for each condition were similar to the computed values by BEC and the proposed landside filling has only minimal impact on levee stability. Therefore, it appears that the proposed fill will likely have little effect on the stability of the levee.

Table 2
Factors of Safety Against Sliding

Condition	Analyzed Factor of Safety			USACE Minimum Factor of Safety
	Proposed Conditions		Existing Condition	
	Station 41+00	Station 13+30	BEC Factor of Safety	
Normal Water Conditions	1.5	1.5	1.6	None Provided [1.]
Long Term (Steady Seepage)	1.6	1.5	1.7	1.4
Rapid Drawdown	1.4	1.2	1.3 - 1.5	1.0 - 1.2
Total Embankment (Failure within silty sand)	2.4	1.7	Not Analyzed	None Provided [1.]

Notes:

1. No minimum factor of safety provided, assumed to be 1.4

This analyses are limited to the assumed conditions as described above. Should any of the conditions change, we recommend that analyses be performed to evaluate the proposed changes.

ADDITIONAL RECOMMENDATIONS

To limit the buildup of hydrostatic pressures against the landside of the levee, we recommend that a drainage layer be placed between the landside slope and proposed construction fill. The drainage layer should consist of a minimum of one foot of crushed stone wrapped in a non-woven geotextile fabric and be tied into the existing toe drain. A typical drainage detail is attached as Figure 1. The crushed stone should meet the grain size requirements presented in Table 3.

Table 3
Grain Size Distribution

Size	Crushed Stone
	Percent Finer by Weight
4 inch	100
1 inch	100
¾ inch	90-100
½ inch	10-50
⅜ inch	0-20
No. 4	0-5

We appreciate the opportunity to be considered for this project. If you have any questions, please do not hesitate to contact us.

Sincerely yours,
O'Reilly, Talbot & Okun Associates, Inc.

Stephen McLaughlin
Project Engineer

Michael J. Talbot, P.E.
Principal

Ashley L. Sullivan, P.E.
Project Reviewer

Attachments: Limitations, Topographic Plans (Sheet 1 through 5), Drainage Detail, OTO 2016 Slope Stability Analysis – Proposed Fill Condition, BEC Appendix A-4.4 – 2010 Embankment and Foundation Seepage Stability

LIMITATIONS

LIMITATIONS

1. The observations presented in this report were made under the conditions described herein. The conclusions presented in this report were based solely upon the services described in the report and not on scientific tasks or procedures beyond the scope of the project or the time and budgetary constraints imposed by the client. The work described in this report was carried out in accordance with the Statement of Terms and Conditions attached to our proposal.

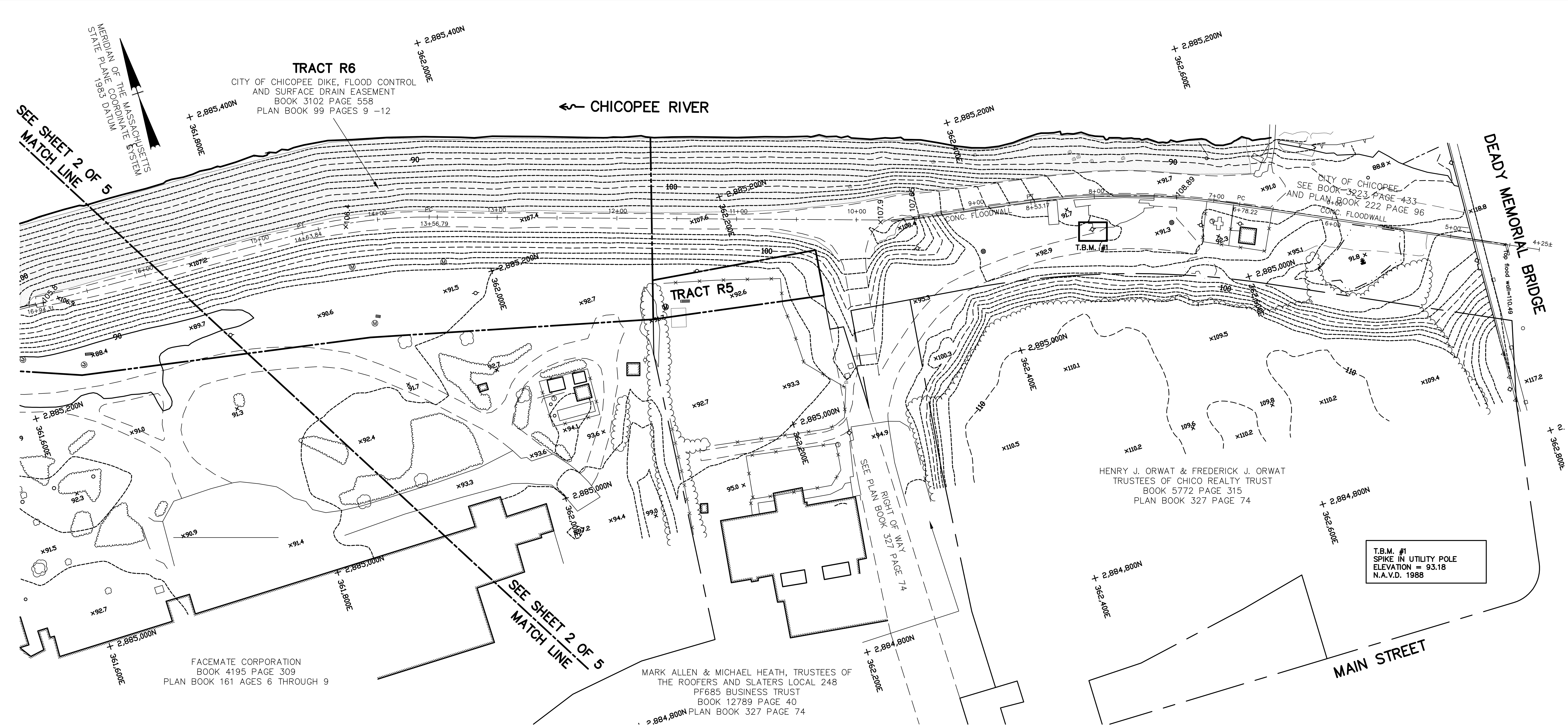
2. The analysis and recommendations submitted in this report are based in part upon the data obtained from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until construction. If variations then appear evident, it may be necessary to reevaluate the recommendations of this report.

3. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more erratic. For specific information, refer to the boring logs.

4. In the event that any changes in the nature, design or location of the proposed structures are planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing by O'Reilly, Talbot & Okun Associates Inc. It is recommended that we be retained to provide a general review of final plans and specifications.

5. Our report was prepared for the exclusive benefit of our client. Reliance upon the report and its conclusions is not made to third parties or future property owners.

SITE PLANS



LINE & SYMBOL LEGEND

- TRAFFIC SIGNAL
- RAILROAD CONTROL BOX
- RAILROAD SWITCH
- SHRUB
- ROCK
- MARSH SYMBOL
- HYDRANT
- GATE/VALVE
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SURVEYOR'S NOTES:

1. TOPOGRAPHIC DATA SHOWN HEREON IS BASED UPON AERIAL PHOTOGRAPHY TAKEN DURING APRIL, 2008. PHOTOGRAPHY AND MAPPING WERE PERFORMED BY COL-EAST, INC. OF NORTH ADAMS, MA AND SUPPLEMENTED WITH GROUND SURVEYS PERFORMED BY HERITAGE SURVEYS, INC. FROM MAY, 2008 THROUGH SEPTEMBER, 2009.

2. FOR REFERENCE TO BOUNDARY LINE AND EASEMENTS SEE A PLAN PREPARED BY HERITAGE SURVEYS, INC. TITLED "PLAN OF FLOOD CONTROL AND LEVEE EASEMENT IN CHICOPEE, MASSACHUSETTS SURVEYED FOR THE CITY OF CHICOPEE", DATED JUNE 15, 2009, SHEETS 1 THROUGH 4.

3. UNDERGROUND UTILITY LOCATIONS SHOWN HEREON ARE BASED UPON SURFACE FEATURES AS LOCATED BY SURVEY AND AVAILABLE RECORD DATA, AND ARE APPROXIMATE. ACTUAL LOCATIONS SHOULD BE VERIFIED WITH THE APPROPRIATE UTILITY COMPANY AND/OR MUNICIPAL DEPARTMENT PRIOR TO FINAL DESIGN AND/OR CONSTRUCTION.

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NORTH AMERICAN VERTICAL DATUM 1988

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CHICOPEE FLOOD CONTROL WORKS
CHICOPEE FALLS SYSTEM SHEET 1 OF 5

TOPOGRAPHIC PLAN OF LAND IN
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SURVEYED FOR
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SCALE: 1" = 40'

0' 20' 40' 60' 80' 120'

DATE: DECEMBER 12, 2009

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COMMONWEALTH OF MASSACHUSETTS BRUCE A. COOMBS No. 27814

JOB # 6289-080505 | DWG # 6289FALLS TOPO | MAP # 6289-091212

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CHICOPEE FALLS SYSTEM SHEET 2 OF 5

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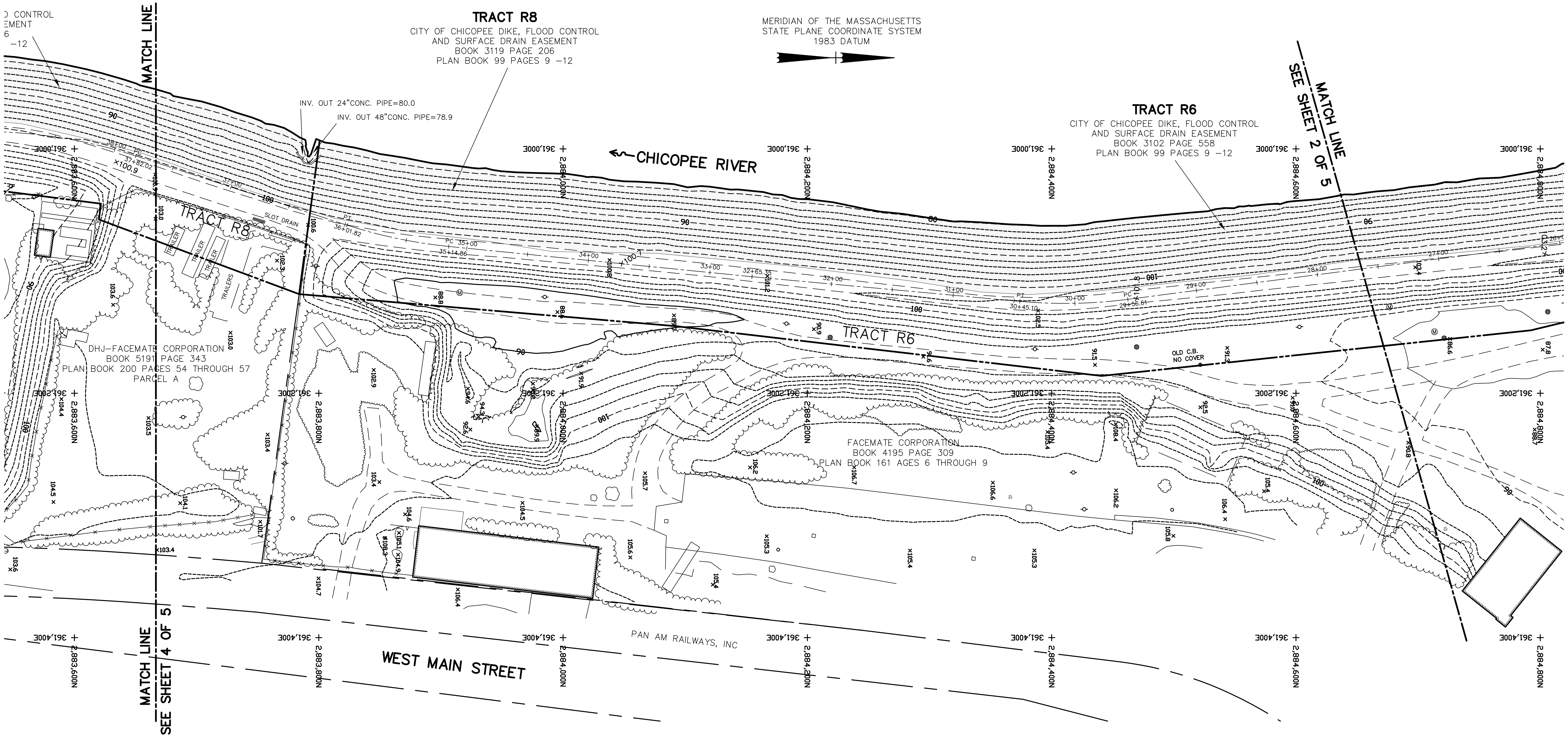

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CHICOPEE FALLS SYSTEM SHEET 3 OF 5

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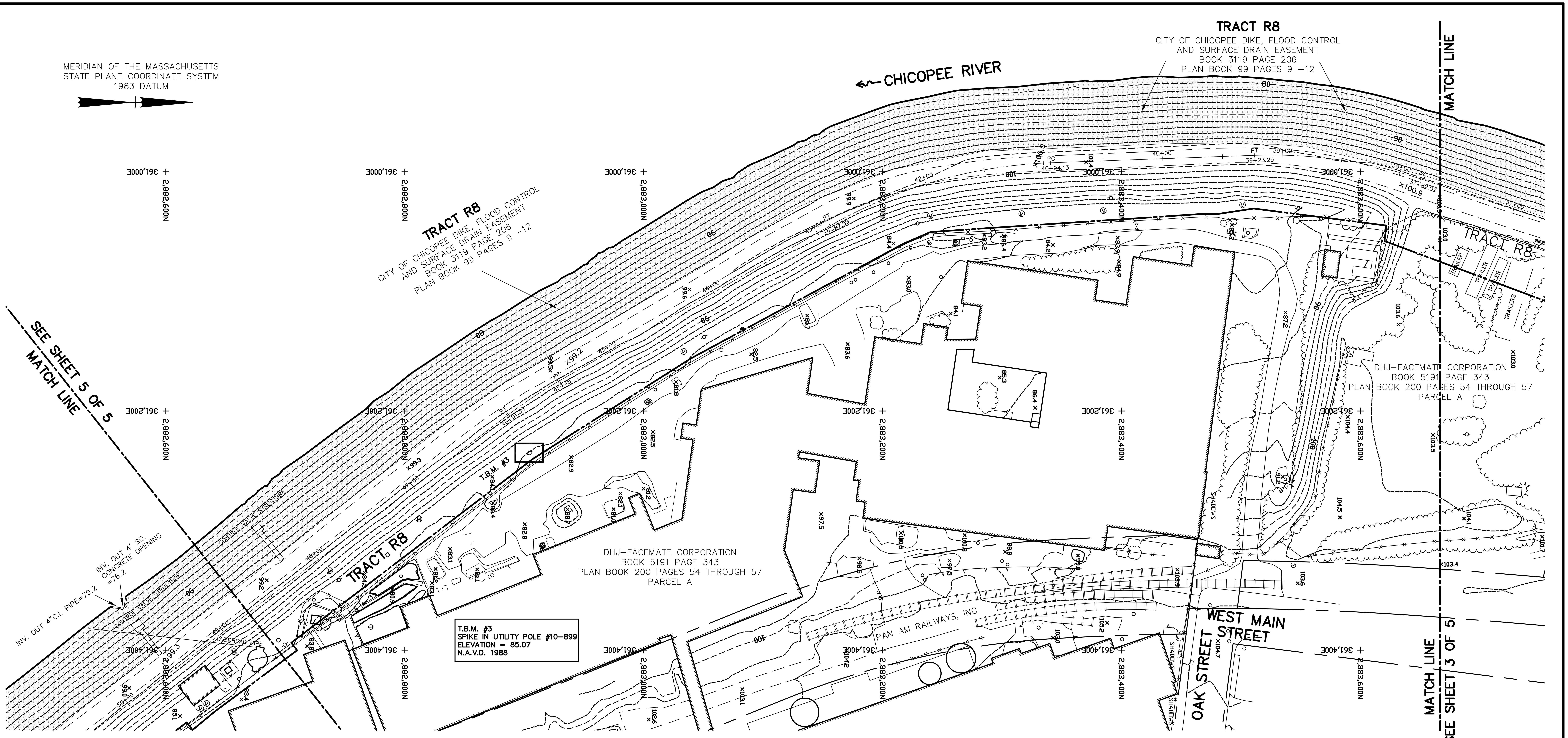

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SURVEYOR'S NOTES:

1. TOPOGRAPHIC DATA SHOWN HEREON IS BASED UPON AERIAL PHOTOGRAPHY TAKEN DURING APRIL, 2008. PHOTOGRAPHY AND MAPPING WERE PERFORMED BY COL-EAST, INC. OF NORTH ADAMS, MA AND SUPPLEMENTED WITH GROUND SURVEYS PERFORMED BY HERITAGE SURVEYS, INC. FROM MAY, 2008 THROUGH SEPTEMBER, 2009.

2. FOR REFERENCE TO BOUNDARY LINE AND EASEMENTS SEE A PLAN PREPARED BY HERITAGE SURVEYS, INC. TITLED "PLAN OF FLOOD CONTROL AND LEVEE EASEMENT IN CHICOPEE, MASSACHUSETTS SURVEYED FOR THE CITY OF CHICOPEE", DATED JUNE 15, 2009, SHEETS 1 THROUGH 4.

3. UNDERGROUND UTILITY LOCATIONS SHOWN HEREON ARE BASED UPON SURFACE FEATURES AS LOCATED BY SURVEY AND AVAILABLE RECORD DATA, AND ARE APPROXIMATE. ACTUAL LOCATIONS SHOULD BE VERIFIED WITH THE APPROPRIATE UTILITY COMPANY AND/OR MUNICIPAL DEPARTMENT PRIOR TO FINAL DESIGN AND/OR CONSTRUCTION.

4. LOCATION OF FLOODWALL AND LEVEE BASELINES SHOWN ARE APPROXIMATE AND ARE BASED UPON PLANS PREPARED BY THE U.S. ARMY CORPS OF ENGINEERS FOR CHICOPEE RIVER FLOOD CONTROL DATED APRIL, 1963. NO MONUMENTATION OF BASELINES WAS FOUND AND IS HISTORICAL ONLY.

5. TOP CONCRETE FLOODWALL AND CENTERLINE LEVEE GRADES IN BOLD TYPE ARE FIELD LOCATED BY SURVEY AND ARE NOT THE RESULT OF AERIAL MAPPING. REFER TO LEGEND FOR AERIAL SPOT HEIGHT INDICATORS.

NORTH AMERICAN VERTICAL DATUM 1988

NOTE: FOR THIS FLOOD CONTROL SYSTEM, ELEVATIONS IN NGVD29 CAN BE OBTAINED BY ADDING 0.70 FEET TO THE ELEVATIONS SHOWN ON THIS PLAN.

CHICOPEE FLOOD CONTROL WORKS
CHICOPEE FALLS SYSTEM SHEET 5 OF 5

TOPOGRAPHIC PLAN OF LAND IN
CHICOPEE, MASSACHUSETTS
SURVEYED FOR
THE CITY OF CHICOPEE

SCALE: 1" = 40'

0' 20' 40' 60' 80' 120'

DATE: DECEMBER 12, 2009

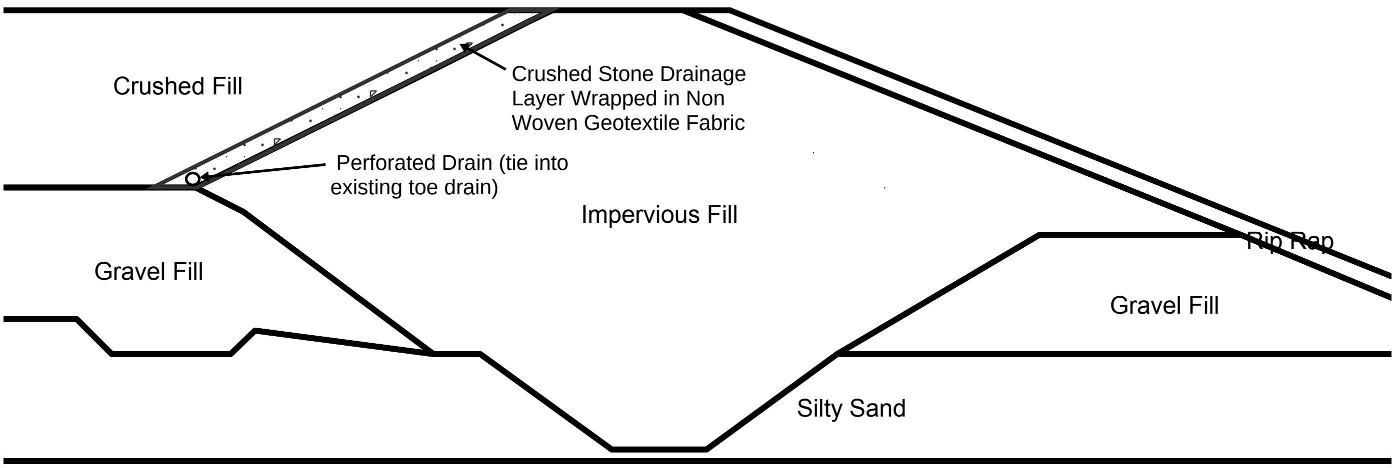
HERITAGE SURVEYS, INC.
REGISTERED PROFESSIONAL LAND SURVEYORS
COLLEGE HIGHWAY & CLARK STREET
POST OFFICE BOX 1
SOUTHAMPTON, MASSACHUSETTS
(413) 527-3600

COMMONWEALTH OF MASSACHUSETTS
BRUCE A. COOMBS
No. 27814

Bruce A. Coombs

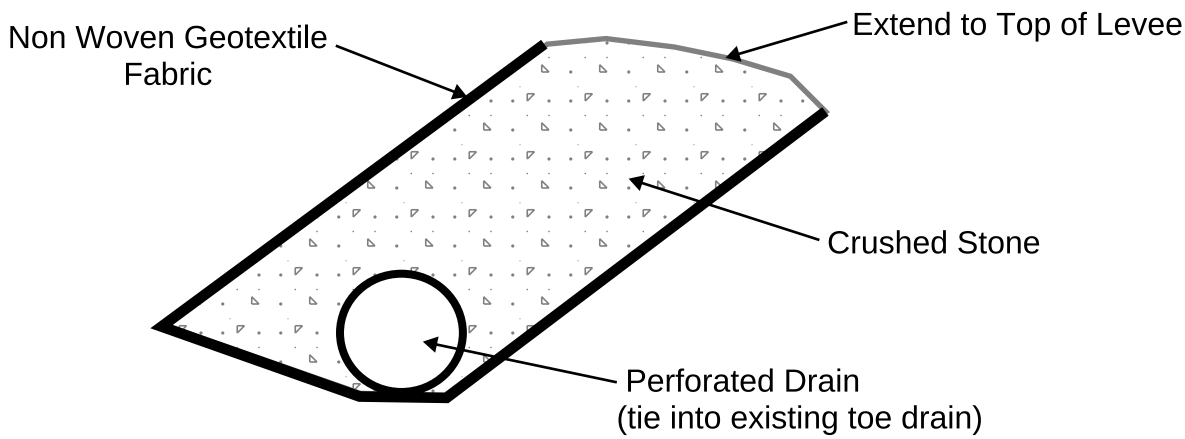
JOB #	6289-080505	DWG #	6289FALLS TOPO	MAP #	6289-091212

DRAINAGE DETAIL



Typical Cross Section - Drainage Layer

N.T.S



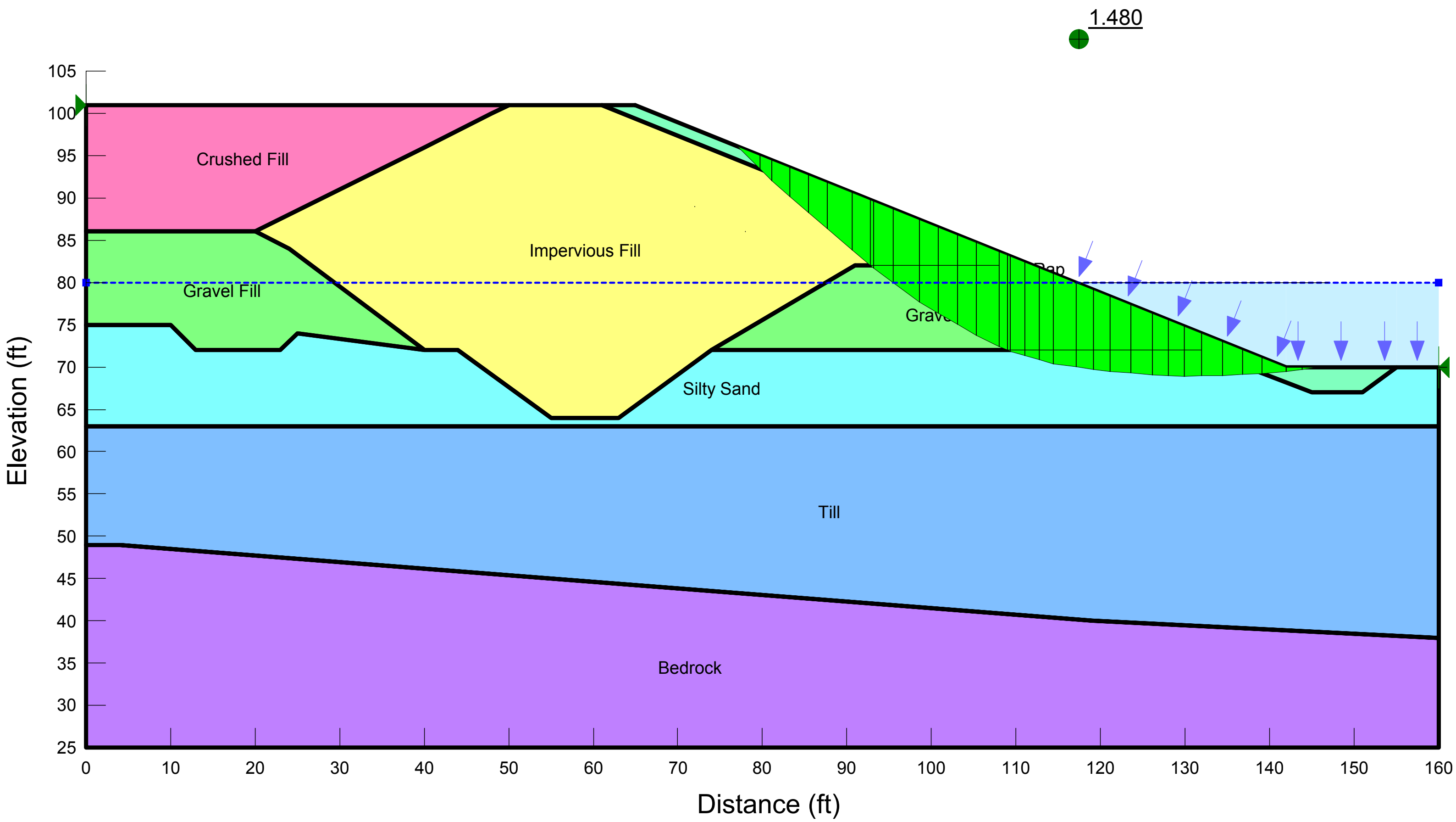
Typical Drainage Layer Detail

N.T.S

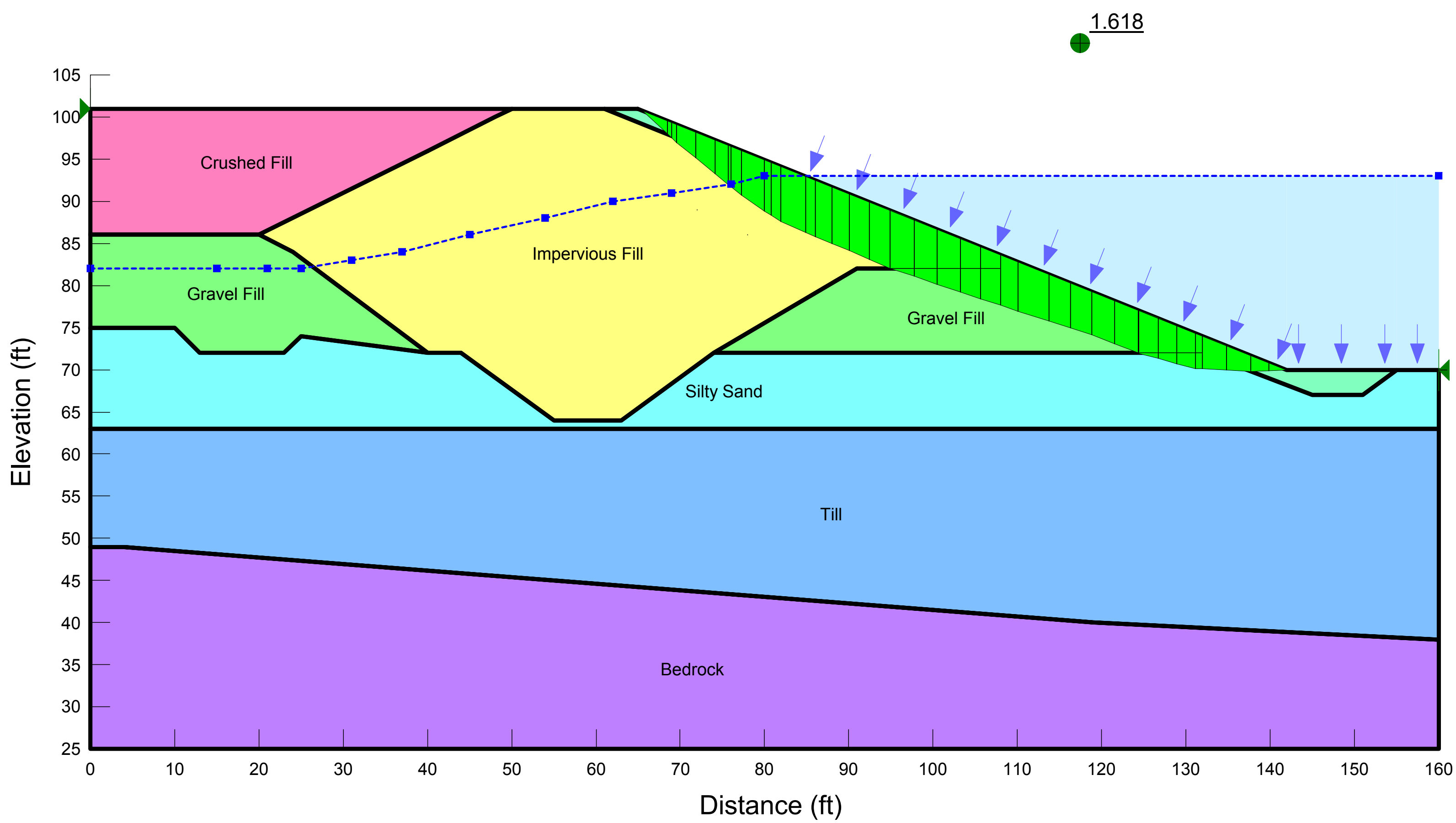
FILE

DESIGNED BY: SMM DRAWN BY: SMM CHECKED BY: MJT DATE: SEPTEMBER 2016	UNIROYAL FILLING PROJECT CHICOPEE LEVEE CHICOPEE, MASSACHUSETTS	NOT TO SCALE	PROJECT No. J2463-03-01
O'REILLY, TALBOT & OKUN ASSOCIATES ENGINEERING 293 BRIDGE STREET SUITE 500 SPRINGFIELD, MA 01103 PHONE:(413) 788-6222 EMAIL: OFFICE@OTO-ENV.COM	DRAINAGE LAYER DETAILS		FIGURE No. 1

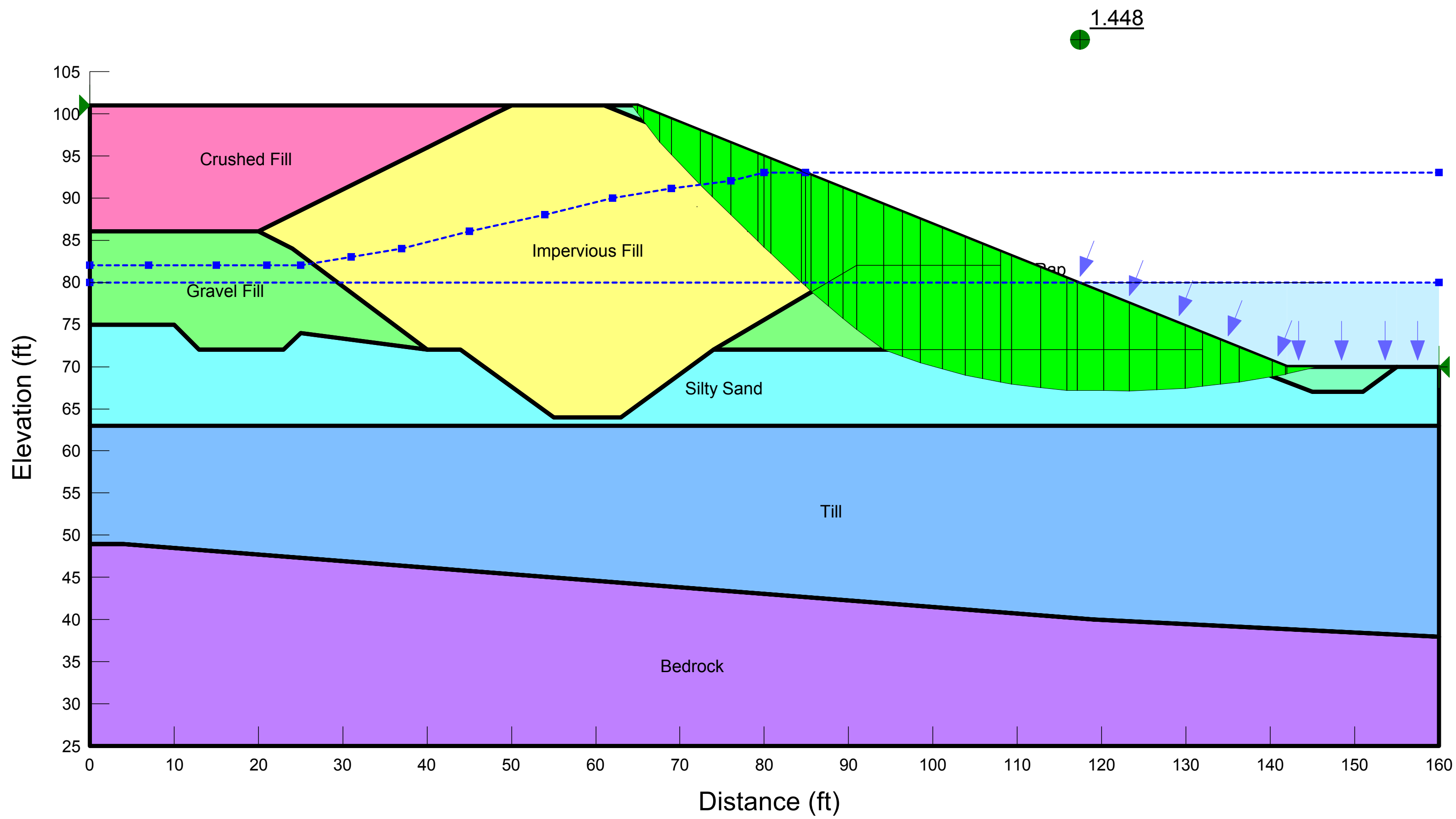
2016 SLOPE STABILITY ANALYSIS - PROPOSED FILL CONDITION



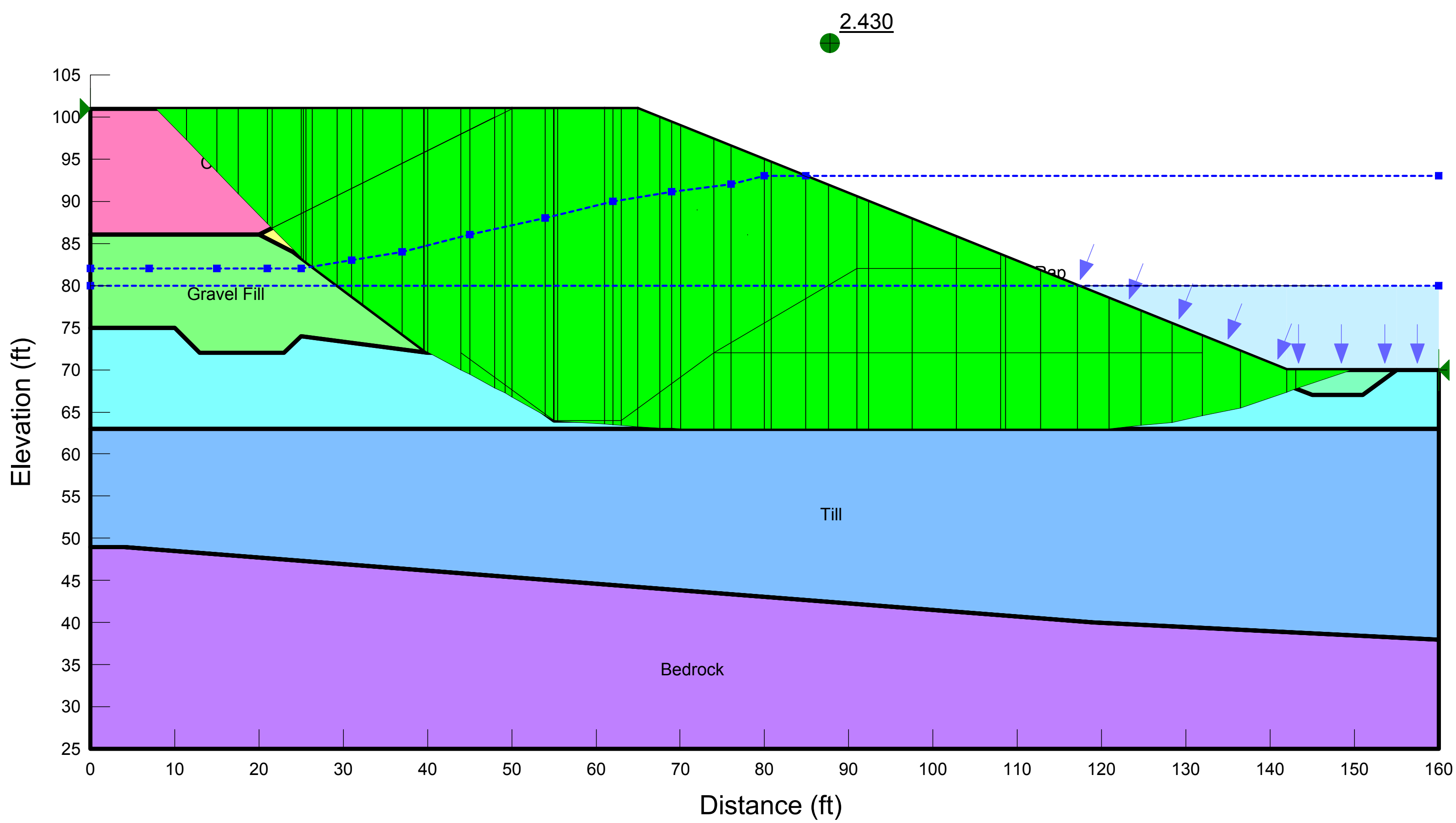
Station 41+00 - Normal Water Conditions



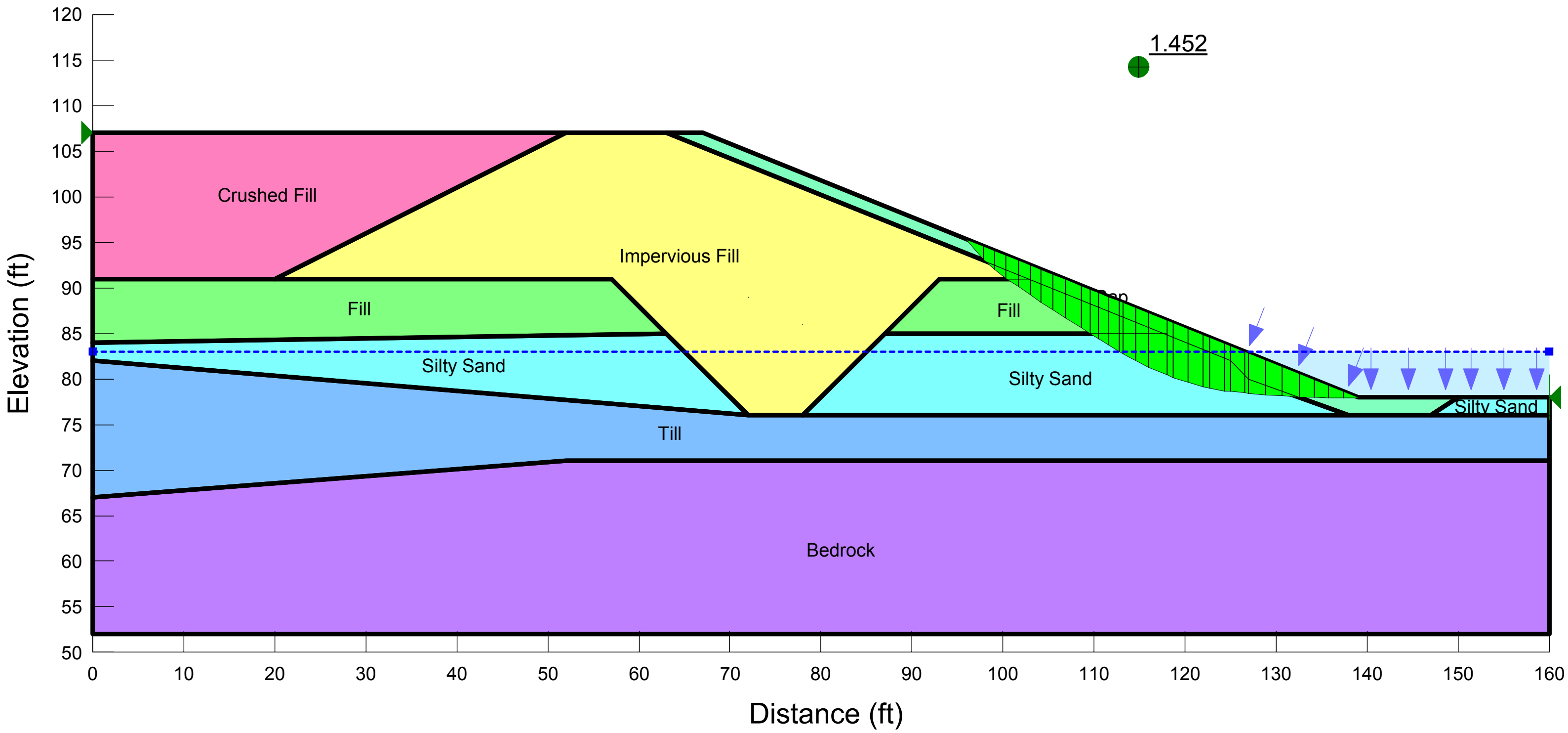
Station 41+00 - 100yr Flood



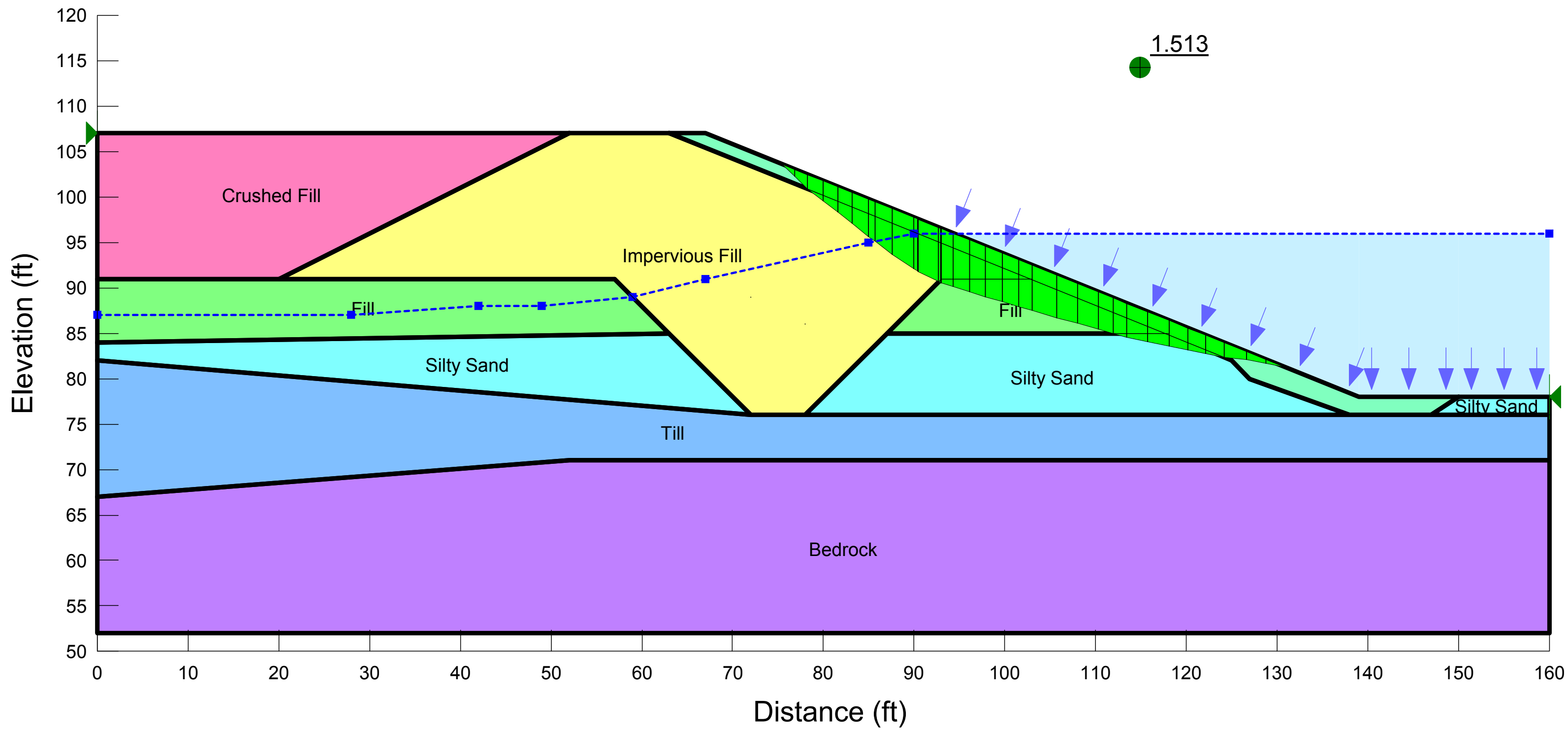
Station 41+00 - 100yr Rapid Drawdown



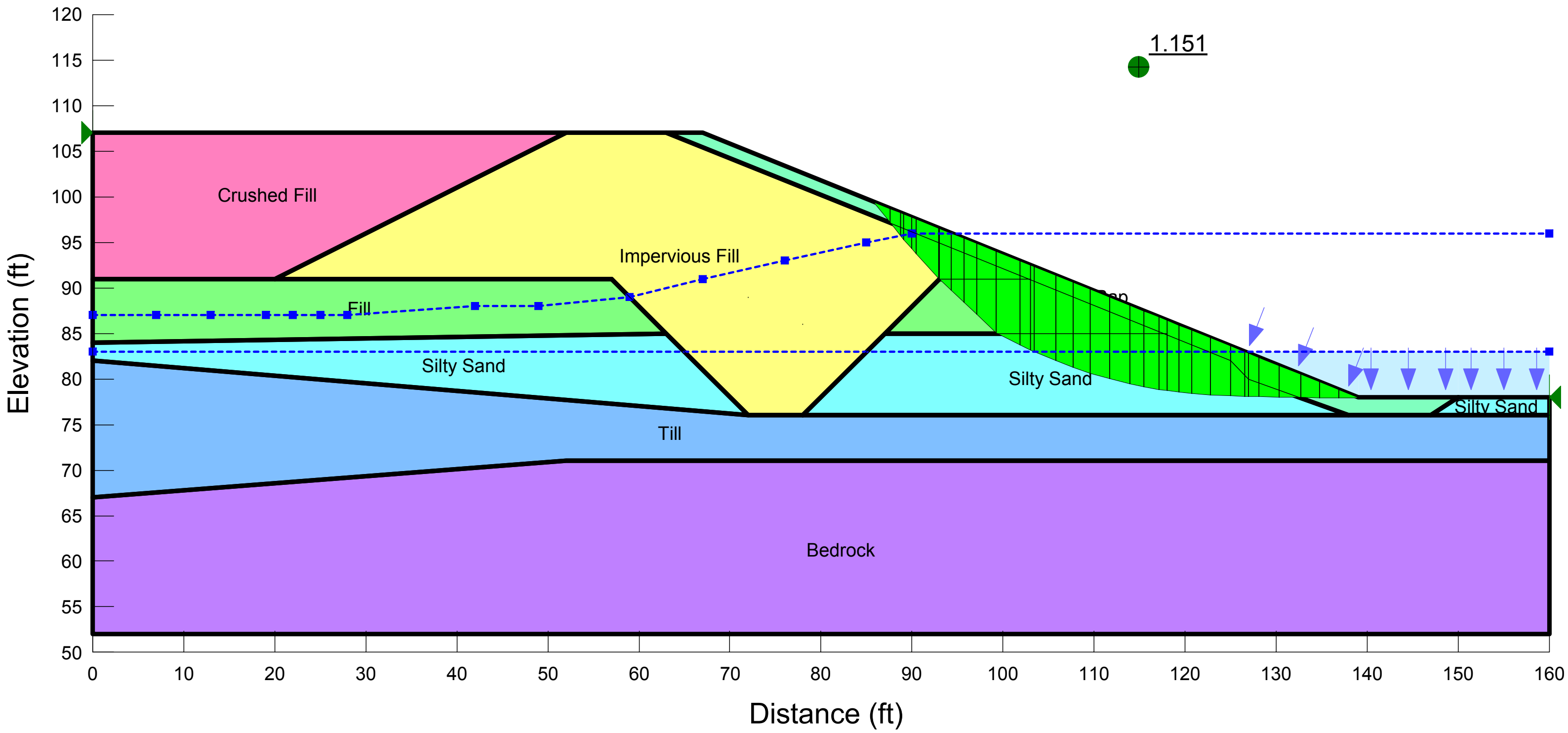
Station 41+00 - 100yr Rapid Drawdown - Embankment Failure



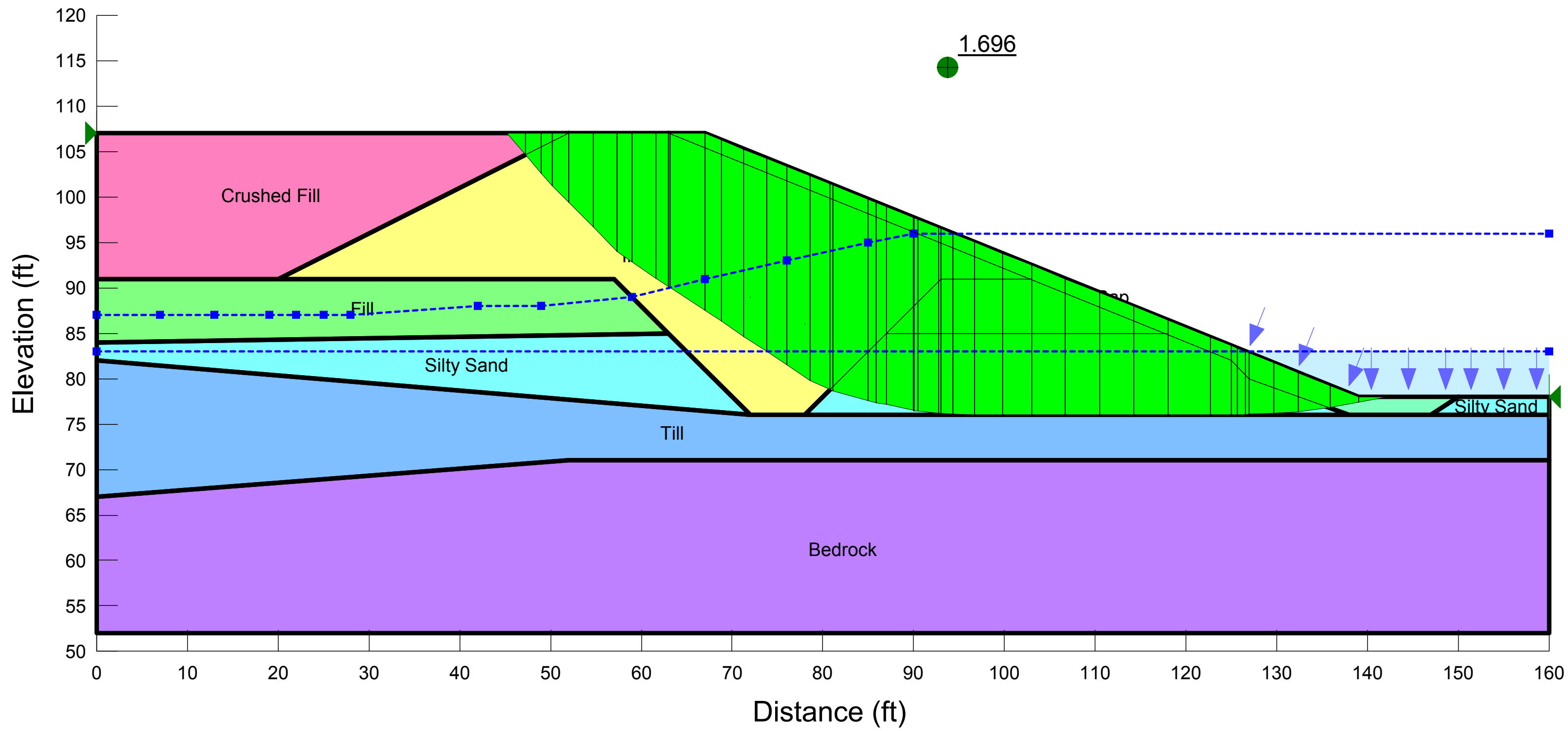
Station 13+30 - Normal Water Conditions



Station 13+30 - 100yr Flood



Station 13+30 - 100yr Rapid Drawdown



Station 13+30 - 100yr Rapid Drawdown - Embankment Failure

2010 BEC REPORT - APPENDIX A-4.4
EMBANKMENT AND FOUNDATION
SEEPAGE & STABILITY

<u>APPENDIX A-4.4</u>

EMBANKMENT
AND
FOUNDATION
SEEPAGE & STABILITY

EMBANKMENT AND FOUNDATION SEEPAGE AND STABILITY ANALYSIS
CHICOPEE FALLS FLOOD CONTROL SYSTEM

CHICOPEE FLOOD CONTROL WORKS
CITY OF CHICOPEE
HAMPDEN COUNTY, MASSACHUSETTS

November, 2010
GZA GeoEnvironmental, Inc.

1 SEEPAGE

Seepage was evaluated for the Chicopee Falls Levee using SEEP/W 2007 a two-dimensional finite element seepage modeling software created by GEO-SLOPE International, Ltd, and analyzed in general accordance with USACE Technical Letter ETL 110-2-569 *Design Guidance for Levee Underseepage*. Seepage was evaluated for Normal and 100 Year Flood per FEMA regulations 44 CRF 65.2 and 65.10, assuming steady-state seepage conditions. Flow and exit gradients were estimated in the vicinity of the drain from SEEP/W results and compared to the limiting gradient criteria of 0.5. The seepage analyses were also performed with an assumed non-functional toe drain in order to determine if the required criteria would be met even with a compromised or non-functioning drain.

2 STABILITY

Slope Stability simulations were performed using guidance from USACE *Design and Construction of Levees*, EM 1110-2-1913 under normal and 100 year flood (steady-state seepage and sudden drawdown), for the landside and riverside slopes. Models were evaluated using SLOPE/W, a two-dimensional finite element slope stability modeling software created by GEO-SLOPE International, Ltd. utilizing the Spencer method and incorporating the parent SEEP/W model's seepage forces and phreatic surfaces. Staged Rapid Drawdown was modeled using the USACE 3-stage method.

3 TYPICAL SECTIONS

Station 13+30 (typical of Station 9+50 to 16+82 and 25+25 to 39+25) was selected as a representative cross-section to analyze the Chicopee Falls Levee system, as Station 13+30 had the loosest fill and loss of washwater was noted during boring (indicative of high permeability). Station 13+30 appears to represent the "worst case" along the Chicopee Falls Levee. An additional cross section was analyzed at Station 41+00 (typical of Station 39+25 to Station 50+00) that did not incorporate the gravelly sand layer. Two final cross sections were analyzed for seepage only at Station 9+00 (typical of Station 0+00 to 9+50) and 20+00 (typical of Station 16+82 to 25+50), as representative "worst-case" wall sections, where the difference between flood elevation and landside grade and/or difference between bottom of footing and top of bedrock were greatest.

4 SEEPAGE ANALYSES AND RESULTS

Hydraulic conductivities were estimated from grain-size distribution correlations and from published literature. Material properties and a typical cross-section can be found at the end of Appendix A-4.4. Boundary conditions were applied along the landside ground and wall surface. The toe drain was modeled as a point element with zero pressure head, surrounded by a flux section to estimate drain flow. An additional load case was modeled without the toe drain to check whether seepage would present an issue if the toe-drain was not functioning as designed. Elevations for normal and flood pools can be found in the Calculation Summary Sheets and the Freeboard Evaluation Plans at the end of Appendix A-4.4.

The computed exit gradients for the Chicopee Falls Levee system were found to be less than the limiting gradient criteria of 0.5, per ETL 110-2-569 *Design Guidance for Levee Underseepage.* The evaluated sections of the Chicopee Falls Levee had acceptable gradients for the 100-year flood with and without a functioning toe drain. Estimates of gradients and unit flow rates through the toe drain can be found in the Calculation Summary Sheet at the end of Appendix A-4.4.

5 STABILITY ANALYSES AND RESULTS

Minimum factors of safety against normal and flood conditions were conservatively assumed to be 1.4 using USACE guidance from EM 1110-2-1913. A specific factor of safety for sudden drawdown is not given in EM 1110-2-1913, but rather a range from 1.0 to 1.2 based upon the period of sustained flood level is recommended. GZA used a value of 1.0 for factor of safety against sudden drawdown in our analyses, which we consider appropriate based upon our assumption of steady-state seepage and instantaneous flood elevations. Material unit weights, strength and internal friction angle values were estimated using SPT N-value correlations and values from published engineering literature.

All computed factors of safety against sliding were greater than the minimums specified above.

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Engineers and Scientists

JOB	15.0702100.50 - Chicopee River Levee		
SHEET NO.	1	**OF**	2
CALCULATED BY	RDH/JGD	**DATE**	5/13/2010
CHECKED BY	JGD	**DATE**	5/13/2010
SCALE	N/A		

Objective: To assess seepage and stability of the **Chicopee Falls Section** of the Chicopee Flood Control Works

Method:

1) Develop typical cross section of levee at **Station 13+30, typical from Station 9+50 to 16+82 and 25+25 to 39+25** (See attached figure).
2) Determine material parameters from test borings and typical values of similar materials.
3) Calculate location of phreatic surface within levee for normal and flood conditions, using SEEP/W. Calculate factor of safety against piping failure (where applicable).
4) Using pore water data from SEEP/W, calculate factors of safety against slope failure for the following load cases defined by requirements of EM 1110-2-1913, Section 6-7302. Steady-state factors of safety calculated for both riverside and landside slopes using Spencer method. Rapid drawdown factor of safety calculated using USACE 3-stage method.

Case #1 - Steady-state seepage at normal pool
Case #2 - Steady-state seepage at 100yr Flood
Case #3 - Rapid Drawdown from 100 yr Flood (Riverside only)

5) Where applicable, the above load cases were also checked for non-functioning drains and/or cutoffs

Subsurface Information:

- Test borings CF-1 through CF-11 and Exploration Location Plan by GZA (2009)
- "Chicopee River Flood Control - Chicopee Falls, Chicopee River, Massachusetts" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated April 1963
- "Chicopee Falls Local Protection Project - Design Memorandum No. 5 - Embankments and Foundations" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated March 1963

Assumptions:

- Soil strata interpreted from available test boring data and design drawings, actual configuration may vary.

Material Properties:

Strata	Total Unit Weight, γ_t	Effective Strength Cohesion,	Effective Strength Friction	Total Strength Cohesion, c	Total Strength Friction	K Ratio (k_v/k_h)	Saturated Horizontal Permeability, k_{sat}		Notes
Impervious Fill	118	0	35	0	35	1	4.6E-06	1.4E-04	(2),(3)
Existing Fill	120	0	30	0	30	1	3.3E-05	1.0E-03	(4),(5)
Silty Sand	110	0	30	0	27	1	4.6E-06	1.4E-04	(2),(4)
Gravelly Sand	130	0	35	0	35	1	6.6E-05	2.0E-03	(2),(4)
Riprap	140	0	42	0	42	1	8.0E-03	2.4E-01	(1)
Sandstone	-	-	-	-	-	1	1.6E-06	5.0E-05	(1),(6)

(1) - Unit weight and permeability values based on typical values for similar materials
(2) - Permeability values estimated from correlations with grain size distribution
(3) - Drained strength values based on correlations from SPT-N testing, total strength values are estimated
(4) - Drained strength based on values in USACE design
(5) - Permeability values based values used in USACE report
(6) - Strength of sandstone not included in slope stability analysis (assumed impenetrable)

Analysis Results:

SEEPAGE ANALYSIS RESULTS - EXISTING CONDITIONS

Case	River Elevation	Unit Flowrate, Q (1) (through slope into drain)	Exit Gradient, i_e (1)	Limiting Gradient (2)	OK?
1	Normal (El. ±83)	0 $ft^3/s/ft$	N/A	0.5	Y
2	100yr Flood (El. 97.9)	3.3E-05 $ft^3/s/ft$	0.04	0.5	Y
2a	100yr Flood (No Drain)	0 $ft^3/s/ft$	0.14	0.5	Y

- Note: Factor of safety values less than recommended values are shown in italics
(1) - Flow and exit gradient estimated from results of SEEP/W analysis at toe drain or landside face of the levee
(2) - Limiting gradient per requirements of US Army Corps Technical Letter ETL 1110-2-569 "DESIGN GUIDANCE FOR LEVEE UNDERSEEPAGE"

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JOB	15.0702100.50 - Chicopee River Levee		
SHEET NO.	2	OF	2
CALCULATED BY	RDH/JGD	DATE	5/13/2010
CHECKED BY	JGD	DATE	5/13/2010
SCALE	N/A		

SLOPE STABILITY ANALYSIS RESULTS - EXISTING CONDITIONS

Load Case	Loading Condition	Levee Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	Normal Conditions	Riverside	1.4	1.61	
		Landside		1.64	
2	100-year Flood (Steady State)	Riverside	1.4	1.73	
		Landside		1.62	
3	Sudden drawdown from 100yr Flood	Riverside	1.0 - 1.2(1)	1.27	

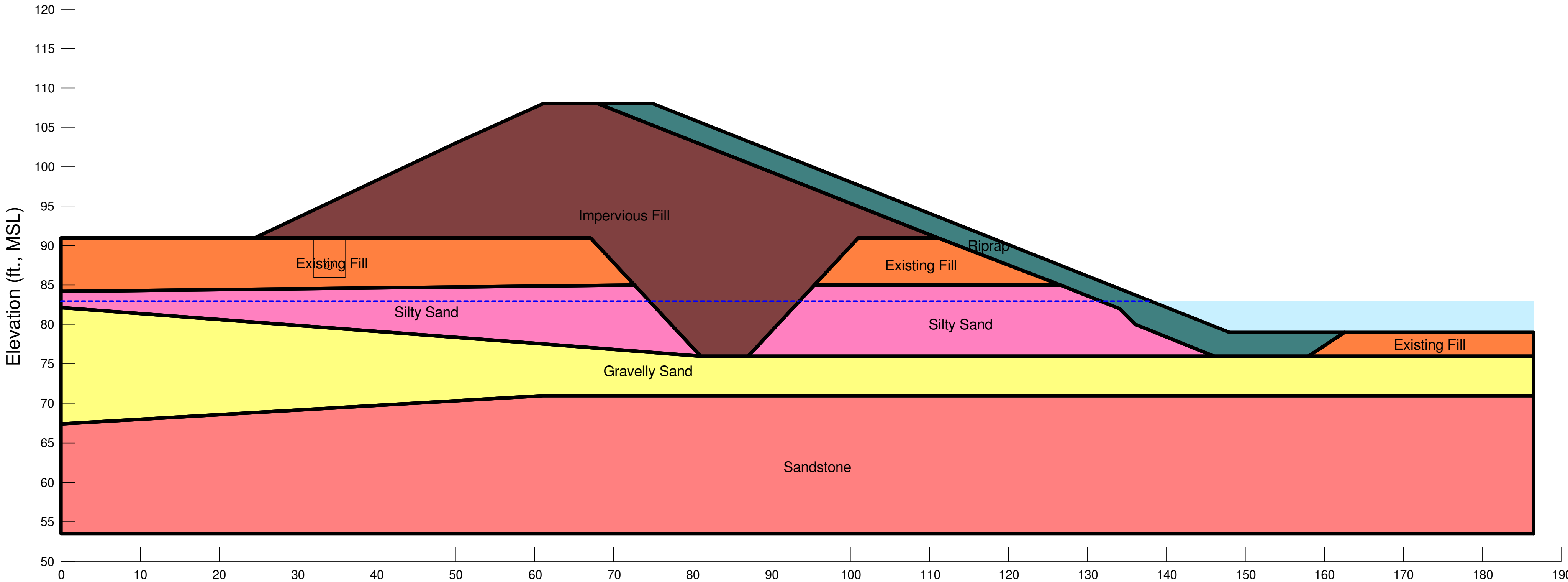
SLOPE STABILITY ANALYSIS RESULTS - EXISTING CONDITIONS - NON-FUNCTIONING DRAINS

Load Case	Loading Condition	Levee Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	Normal Conditions	Riverside	1.4	-	Same as Previous
		Landside		-	Same as Previous
2	100-year Flood (Steady State)	Riverside	1.4	1.70	
		Landside		1.47	
3	Sudden drawdown from 100yr Flood	Riverside	1.0 - 1.2(1)	1.27	

- Note: Factor of safety values less than recommended values are shown in italics
(1) - FS = 1.0 applies to flood levels unlikely to persist for long periods prior to drawdown, FS = 1.2 applies to levels likely to persist for long periods prior to drawdown.

- Refer to Attached SLOPE/W slope stability analysis graphical results

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50

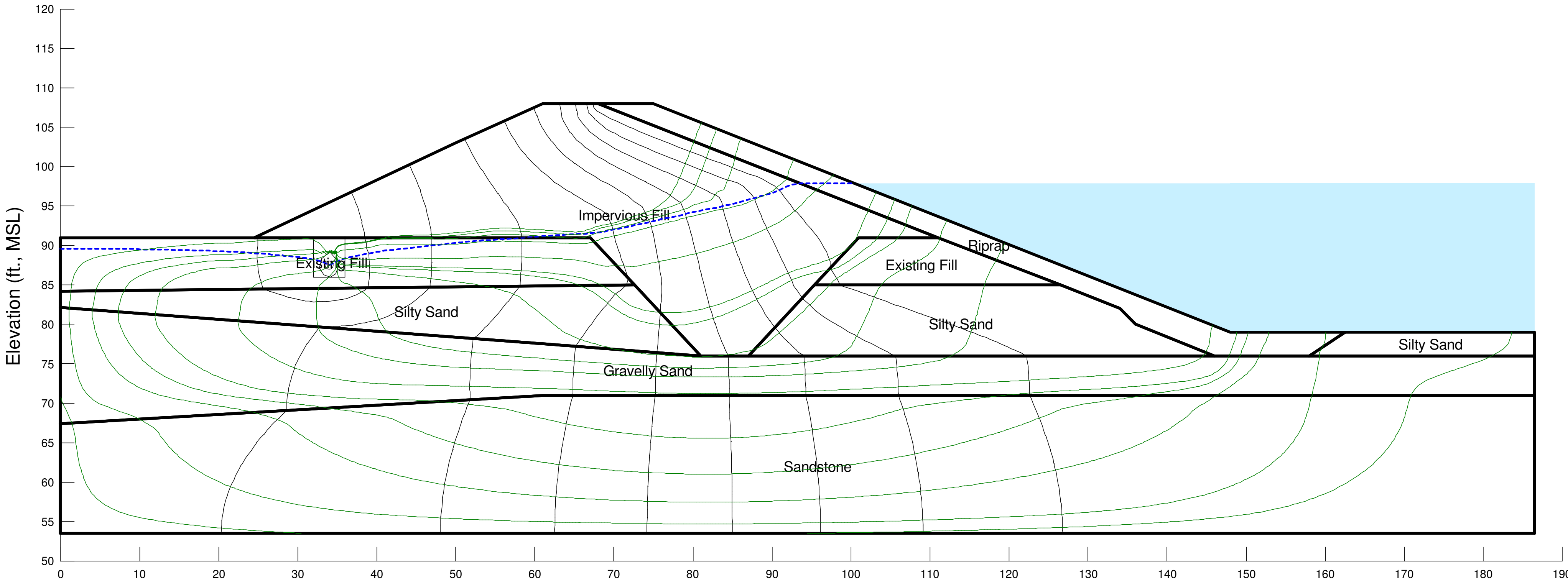


Station 13+30 - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

J:\Branch\NORWOOD\CHICOPEE-LEVEE\Chicopee Falls Explorations\Calcs\Final\Station 0+00 to 39+25\

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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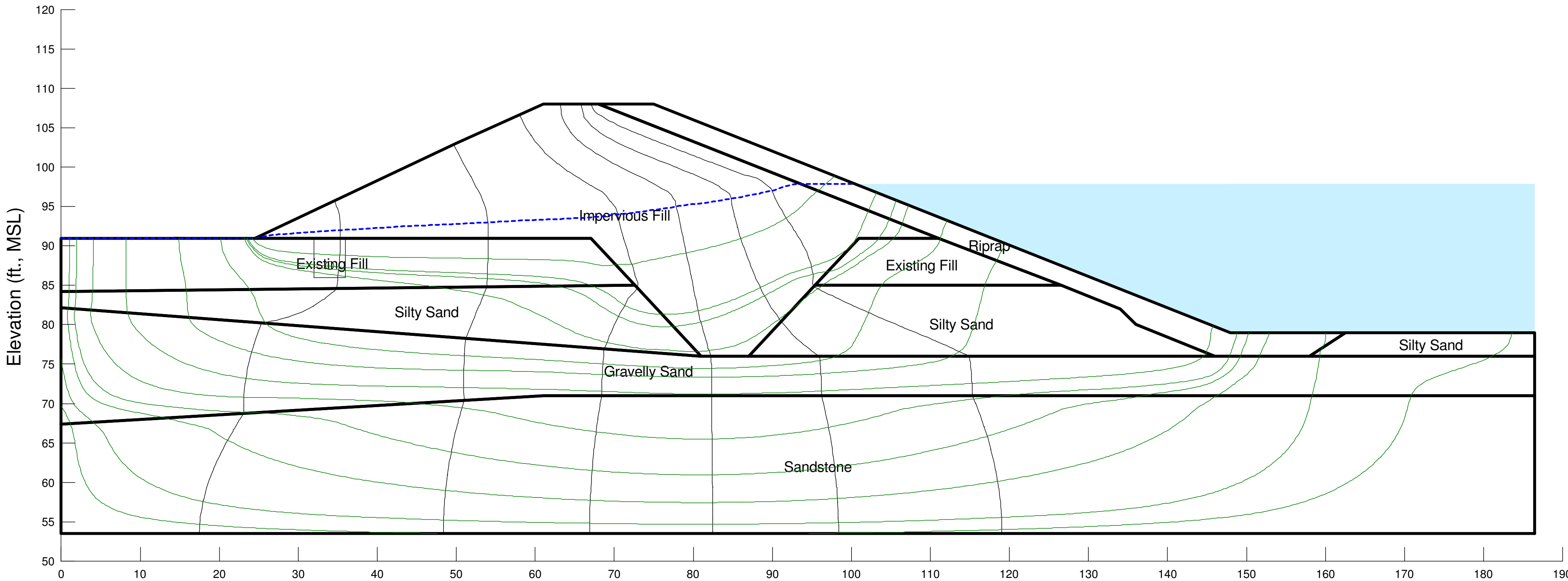
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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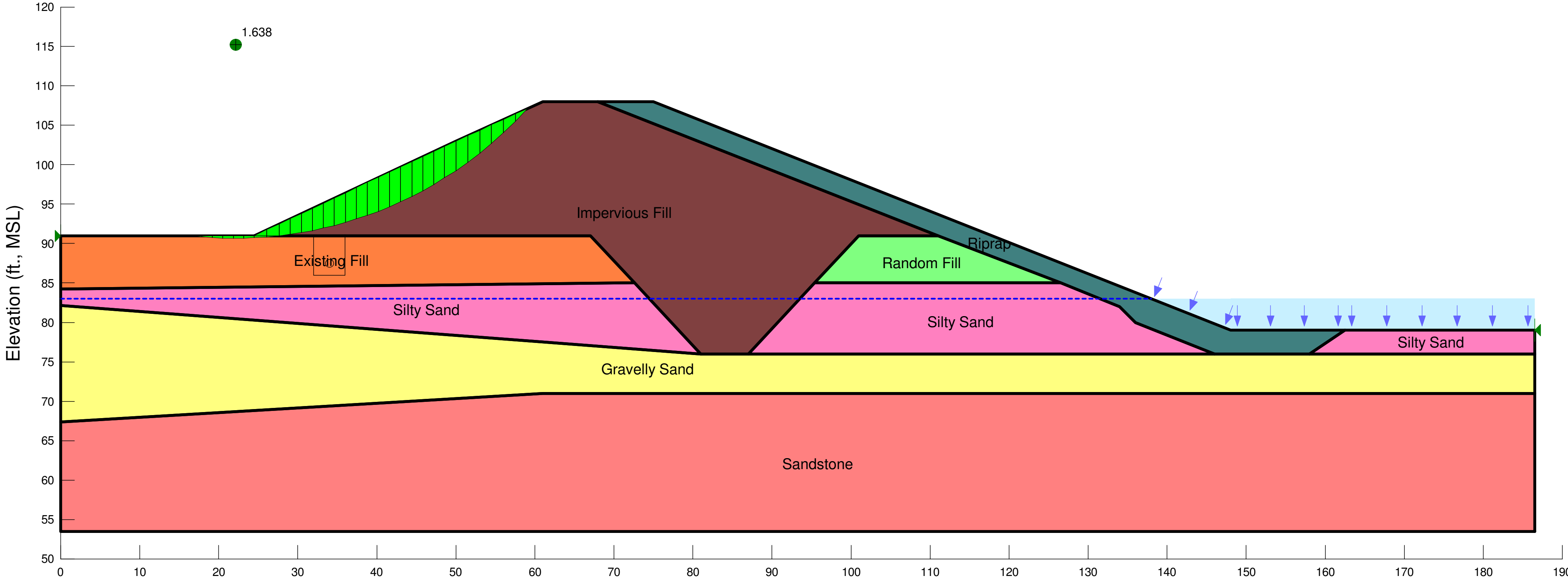
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Landside Slope Stability - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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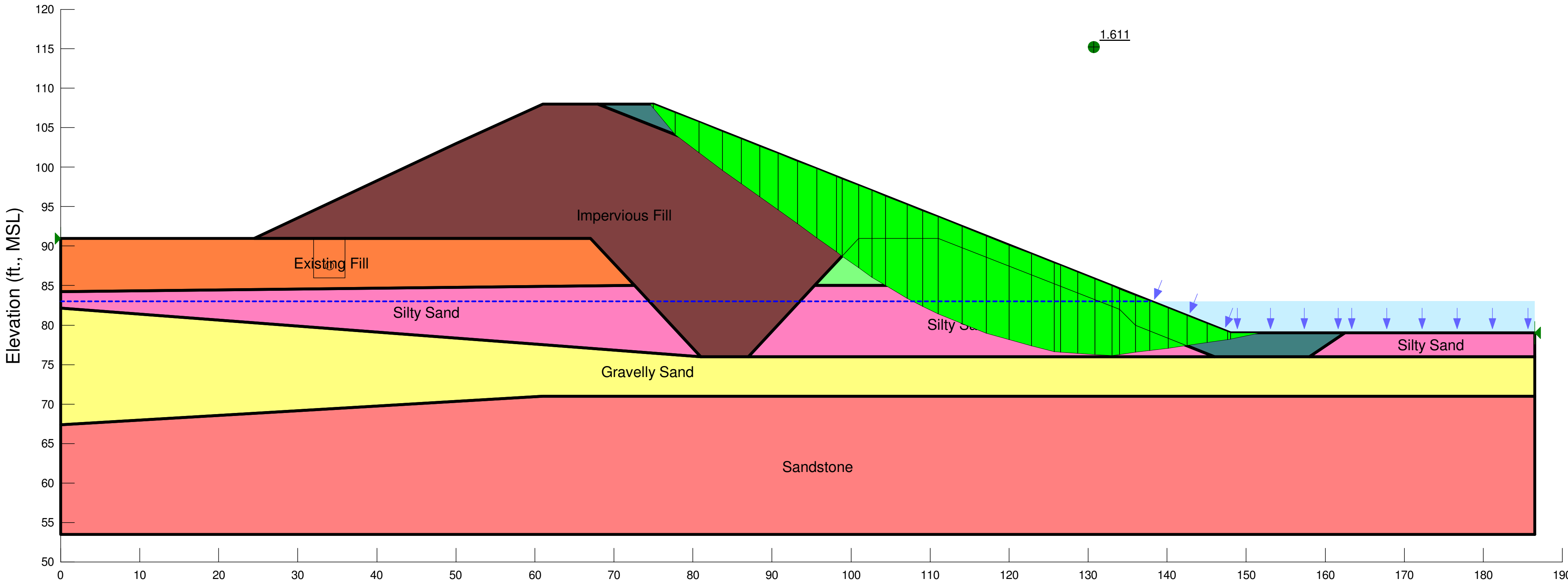
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Riverside Slope Stability - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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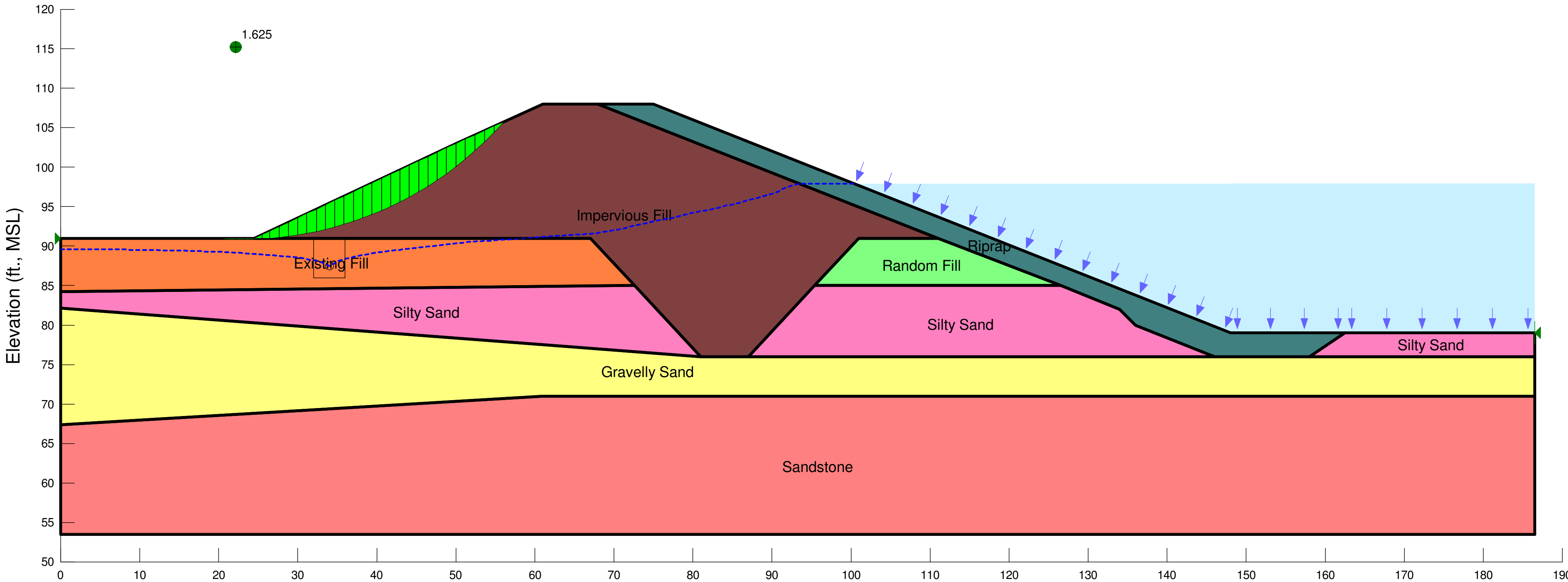
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Landside Slope Stability - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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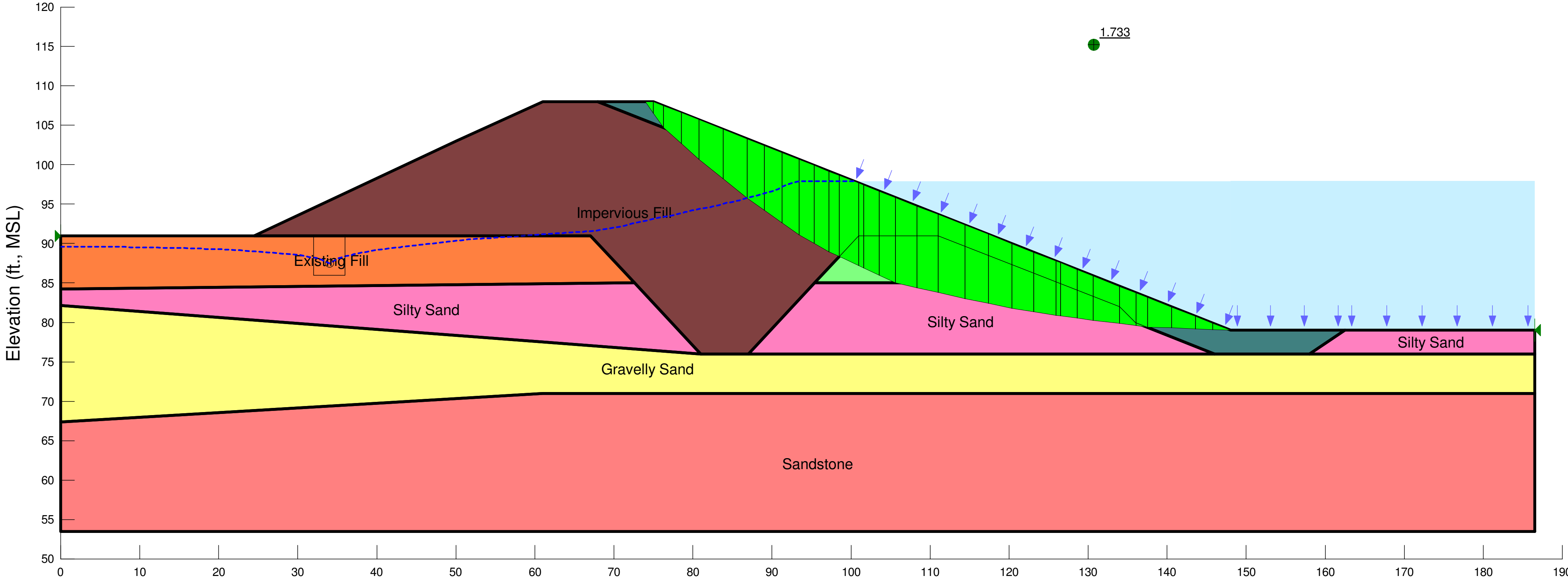
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Riverside Slope Stability - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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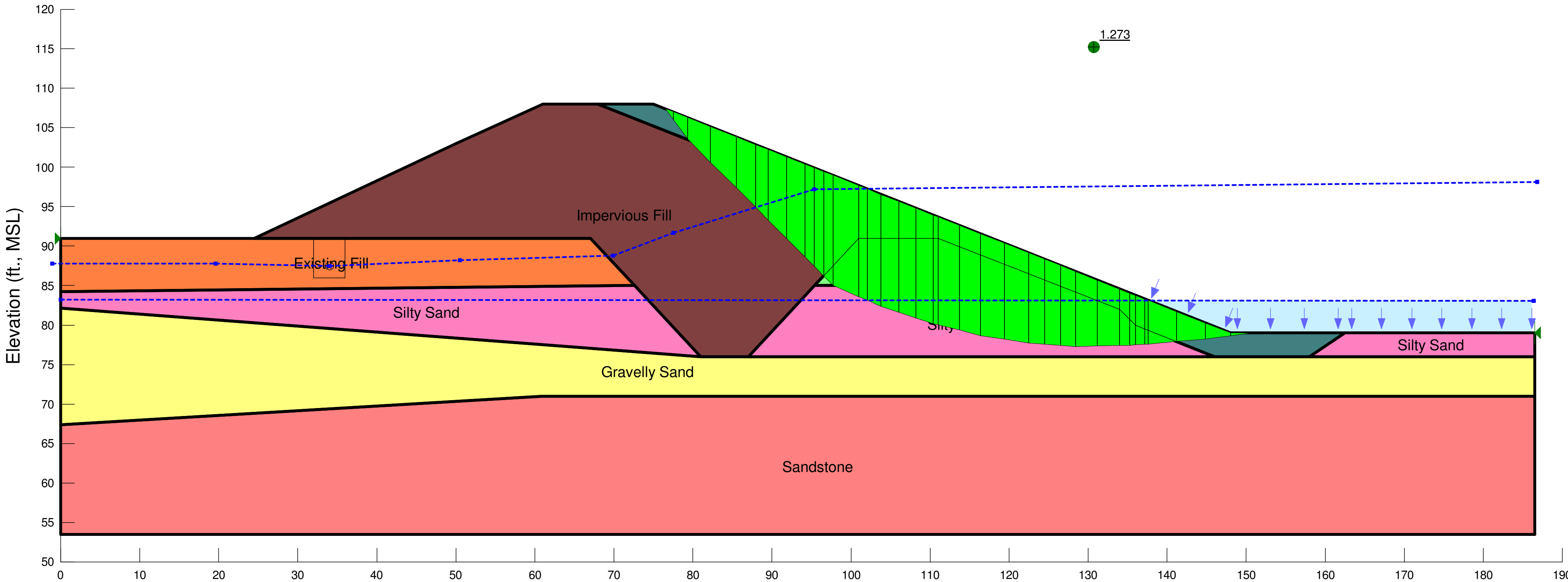
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Riverside Slope Stability - 100yr Drawdown

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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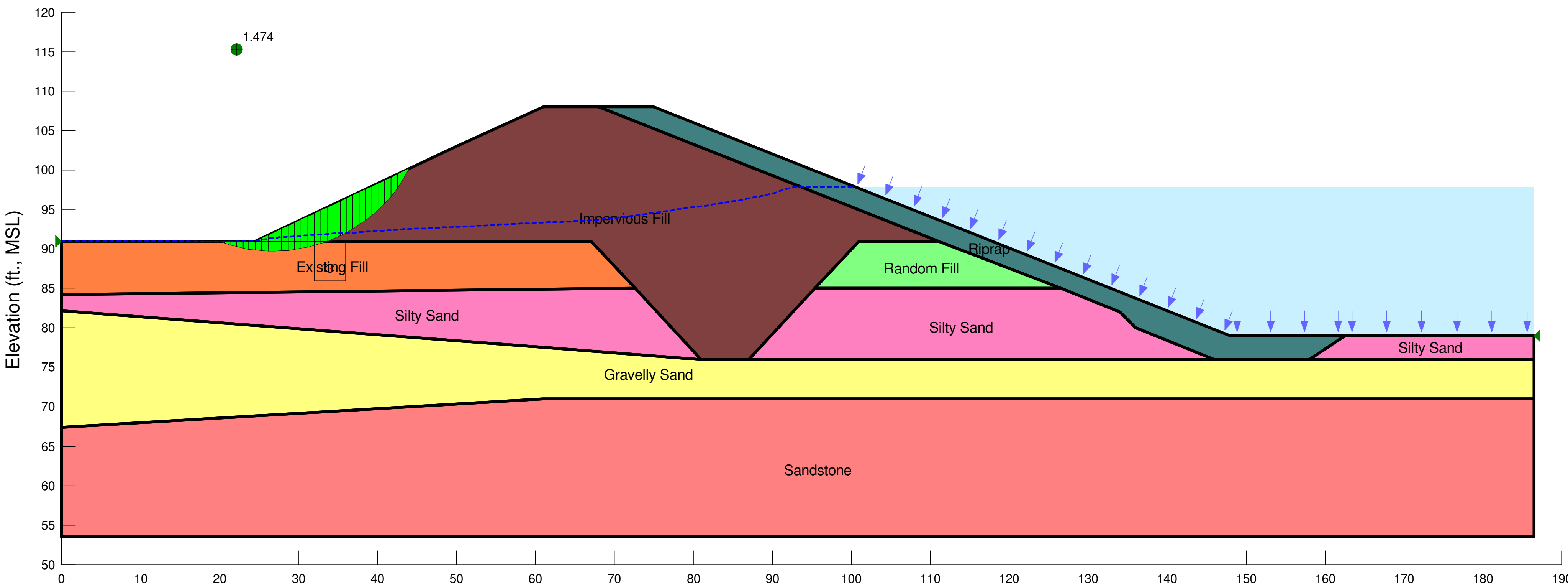
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Landside Slope Stability - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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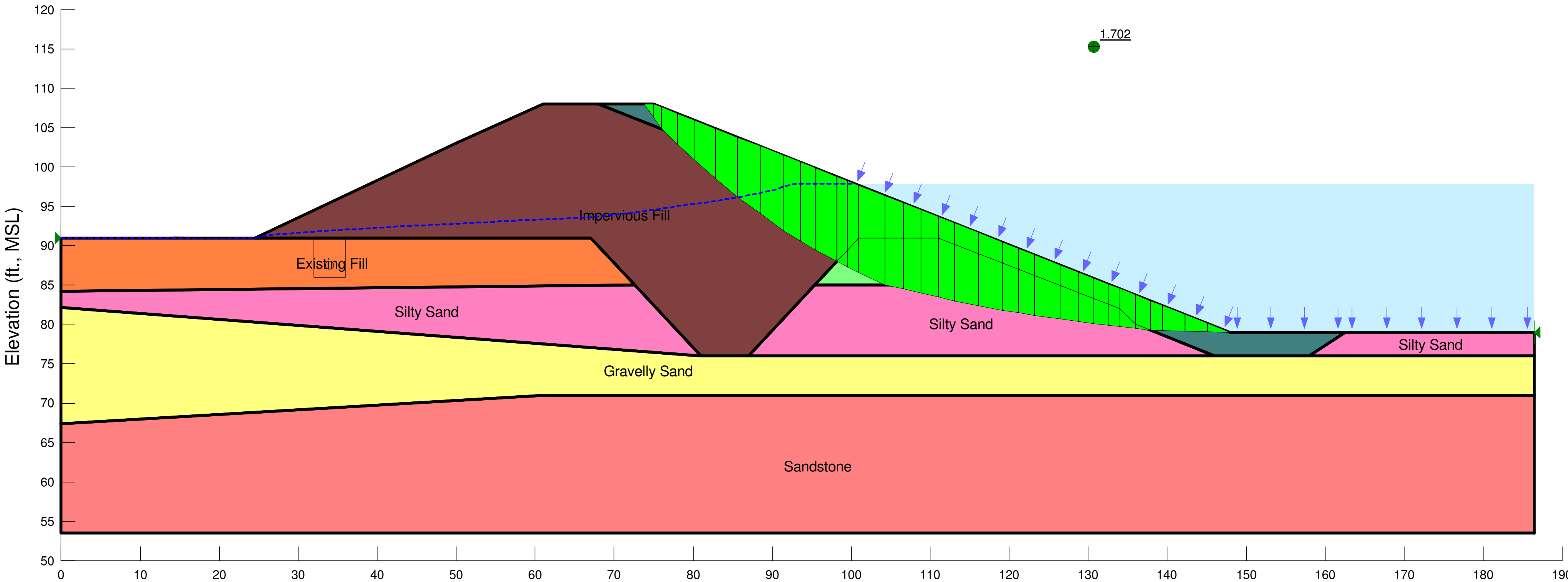
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Riverside Slope Stability - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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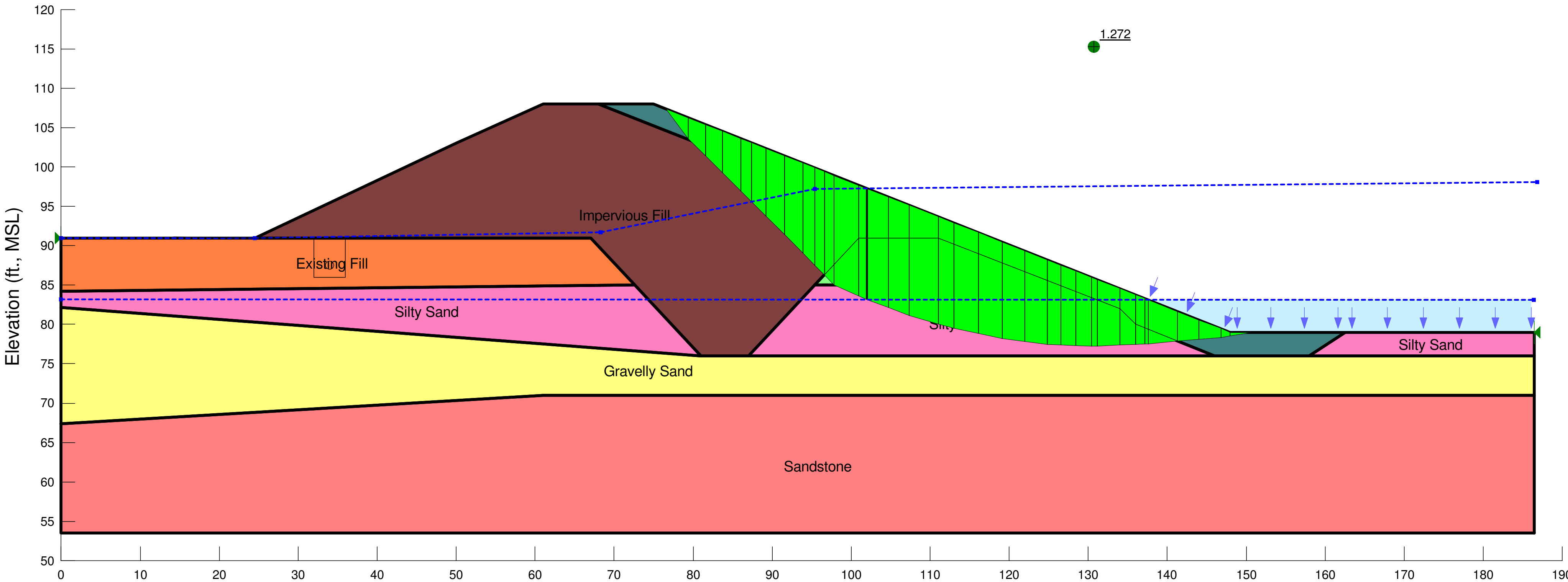
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Riverside Slope Stability - 100yr Drawdown (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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Engineers and Scientists

JOB	15.0702100.50 - Chicopee River Levee		
SHEET NO.	1	**OF**	2
CALCULATED BY	RDH/JGD	**DATE**	5/13/2010
CHECKED BY	JGD	**DATE**	5/13/2010
SCALE	N/A		

Objective: To assess seepage and stability of the **Chicopee Falls Section** of the Chicopee Flood Control Works

Method:

1) Develop typical cross section of levee at **Station 41+00, typical from Station 39+25 to 51+15** (See attached figure).
2) Determine material parameters from test borings and typical values of similar materials.
3) Calculate location of phreatic surface within levee for normal and flood conditions, using SEEP/W. Calculate factor of safety against piping failure (where applicable).
4) Using pore water data from SEEP/W, calculate factors of safety against slope failure for the following load cases defined by requirements of EM 1110-2-1913, Section 6-7302. Steady-state factors of safety calculated for both riverside and landside slopes using Spencer method. Rapid drawdown factor of safety calculated using USACE 3-stage method.

Case #1 - Steady-state seepage at normal pool
Case #2 - Steady-state seepage at 100 yr Flood
Case #3 - Rapid Drawdown from 100 yr Flood (Riverside only)

5) Where applicable, the above load cases were also checked for non-functioning drains

Subsurface Information:

- Test borings CF-8 through CF-11 and Exploration Location Plan by GZA (2009)
- "Chicopee River Flood Control - Chicopee Falls, Chicopee River, Massachusetts" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated April 1963
- "Chicopee Falls Local Protection Project - Design Memorandum No. 5 - Embankments and Foundations" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated March 1963

Assumptions:

- Soil strata interpreted from available test boring data and design drawings, actual configuration may vary.

Material Properties:

Strata	Total Unit Weight, γ_t	Effective Strength Cohesion,	Effective Strength Friction	Total Strength Cohesion, c	Total Strength Friction	K Ratio (k_v/k_h)	Saturated Horizontal Permeability, k_{sat}		Notes
Impervious Fill	118	0	35	0	35	1	4.6E-06	1.4E-04	(2),(3)
Random Fill	120	0	32	0	32	1	2.5E-03	7.6E-02	(1),(3)
Existing Fill	120	0	25	0	25	1	3.3E-04	1.0E-02	(4),(5)
Silty Sand	110	0	30	0	27	1	4.6E-06	1.4E-04	(2),(4)
Gravelly Sand	130	0	35	0	35	1	6.6E-05	2.0E-03	(2),(4)
Riprap	140	0	42	0	42	1	8.0E-03	2.4E-01	(1)

(1) - Unit weight and permeability values based on typical values for similar materials
(2) - Permeability values estimated from correlations with grain size distribution
(3) - Drained strength values based on correlations from SPT-N testing, total strength values are estimated
(4) - Drained strength based on values in USACE design
(5) - Permeability values based values used in USACE report
(6) - Strength of sandstone not included in slope stability analysis (assumed impenetrable)

Analysis Results:

SEEPAGE ANALYSIS RESULTS - EXISTING CONDITIONS

Case	River Elevation	Unit Flowrate, Q (1) (through slope into drain)	Exit Gradient, i_e (1)	Limiting Gradient(2)	OK?
1	Normal (El. ±80)	-	N/A	0.5	Y
2	100yr Flood (El. 93)	9.7E-05	0.05	0.5	Y
2a	100yr Flood (No Drain)	-	0.08	0.5	Y

- Note: Factor of safety values less than recommended values are shown in italics
(1) - Flow and exit gradient estimated from results of SEEP/W analysis at toe drain or landside face of the levee
(2) - Limiting gradient per requirements of US Army Corps Technical Letter ETL 1110-2-569 "DESIGN GUIDANCE FOR LEVEE UNDERSEEPAGE"

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Engineers and Scientists

JOB	15.0702100.50 - Chicopee River Levee		
SHEET NO.	2	**OF**	2
CALCULATED BY	RDH/JGD	**DATE**	5/13/2010
CHECKED BY	JGD	**DATE**	5/13/2010
SCALE	N/A		

SLOPE STABILITY ANALYSIS RESULTS - EXISTING CONDITIONS

Load Case	Loading Condition	Levee Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	Normal Conditions	Riverside	1.4	1.57	
		Landside		1.56	
2	100-year Flood (Steady State)	Riverside	1.4	1.71	
		Landside		1.56	
3	Sudden drawdown from 100yr Flood	Riverside	1.0 - 1.2[(1)]	1.51	

SLOPE STABILITY ANALYSIS RESULTS - EXISTING CONDITIONS - NON-FUNCTIONING DRAINS

Load Case	Loading Condition	Levee Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	Normal Conditions	Riverside	1.4	-	Same as Previous
		Landside		-	Same as Previous
2	100-year Flood (Steady State)	Riverside	1.4	1.70	
		Landside		1.55	
3	Sudden drawdown from 100yr Flood	Riverside	1.0 - 1.2[(1)]	1.51	

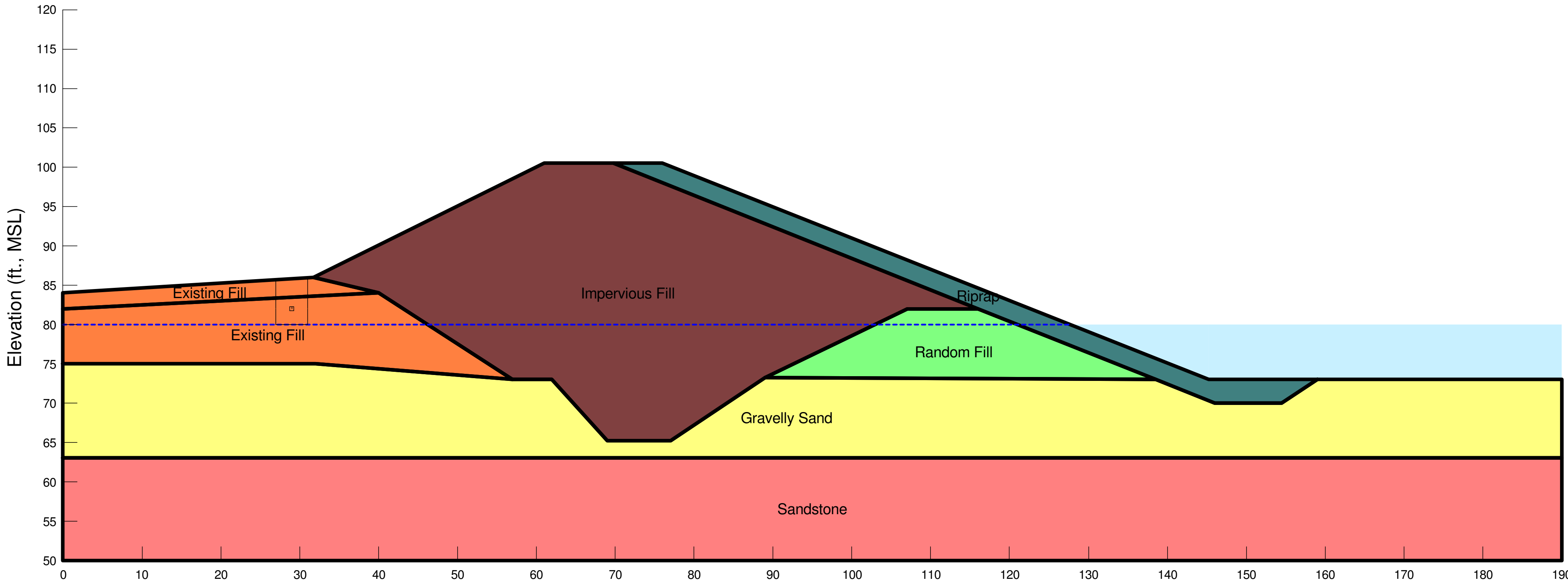
- Note: Factor of safety values less than recommended values are shown in italics

(1) - FS = 1.0 applies to flood levels unlikely to persist for long periods prior to drawdown, FS = 1.2 applies to levels likely to persist for long periods prior to drawdown.

(2) - Factor of safety not provided in EM 1110-2-1913

- Refer to Attached SLOPE/W slope stability analysis graphical results

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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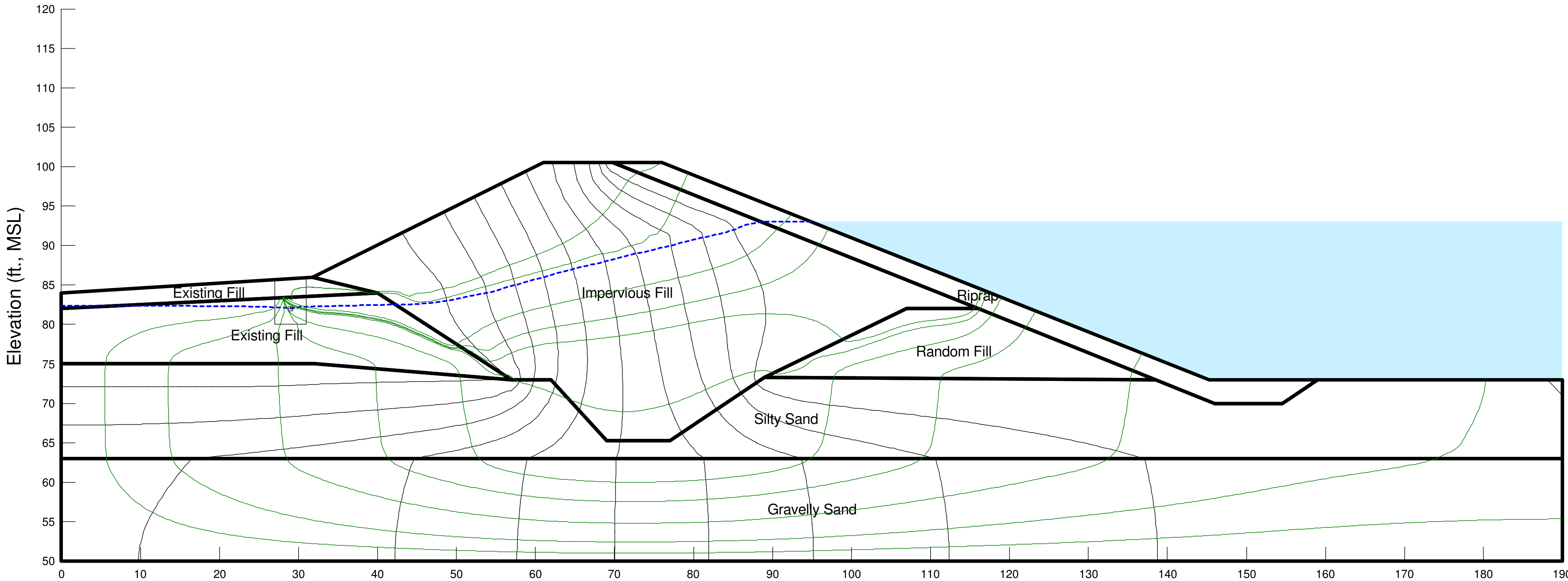
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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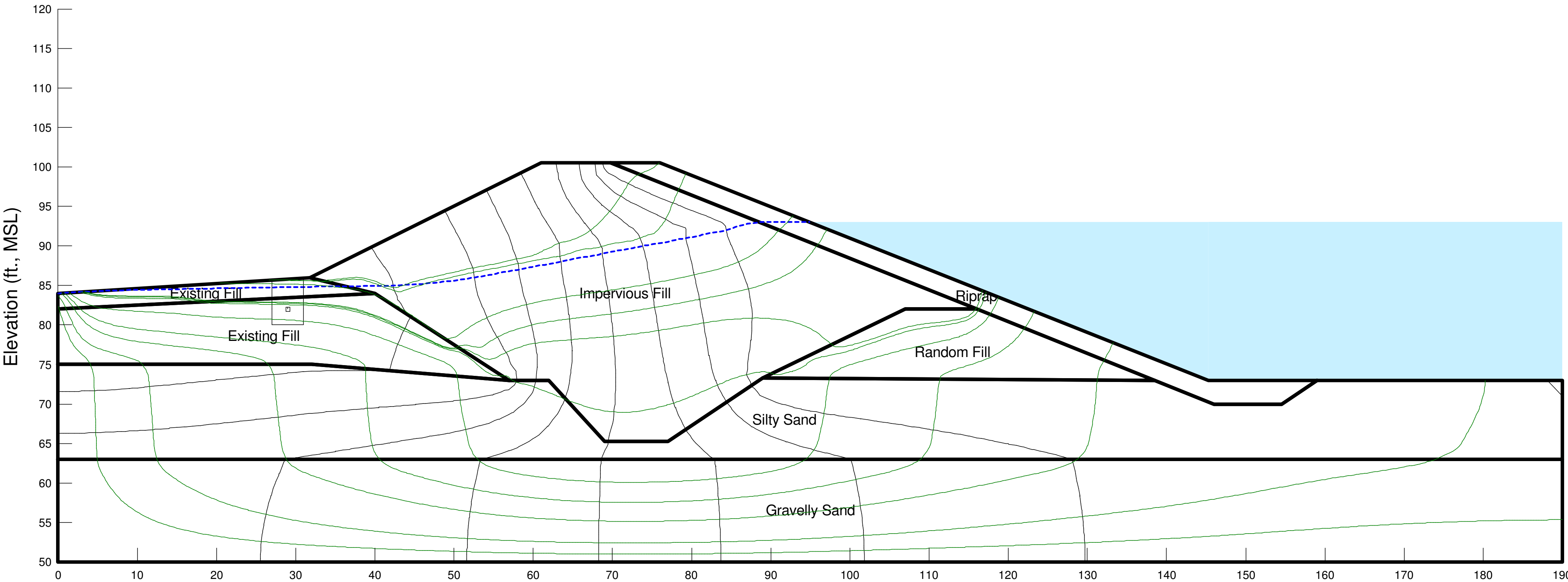
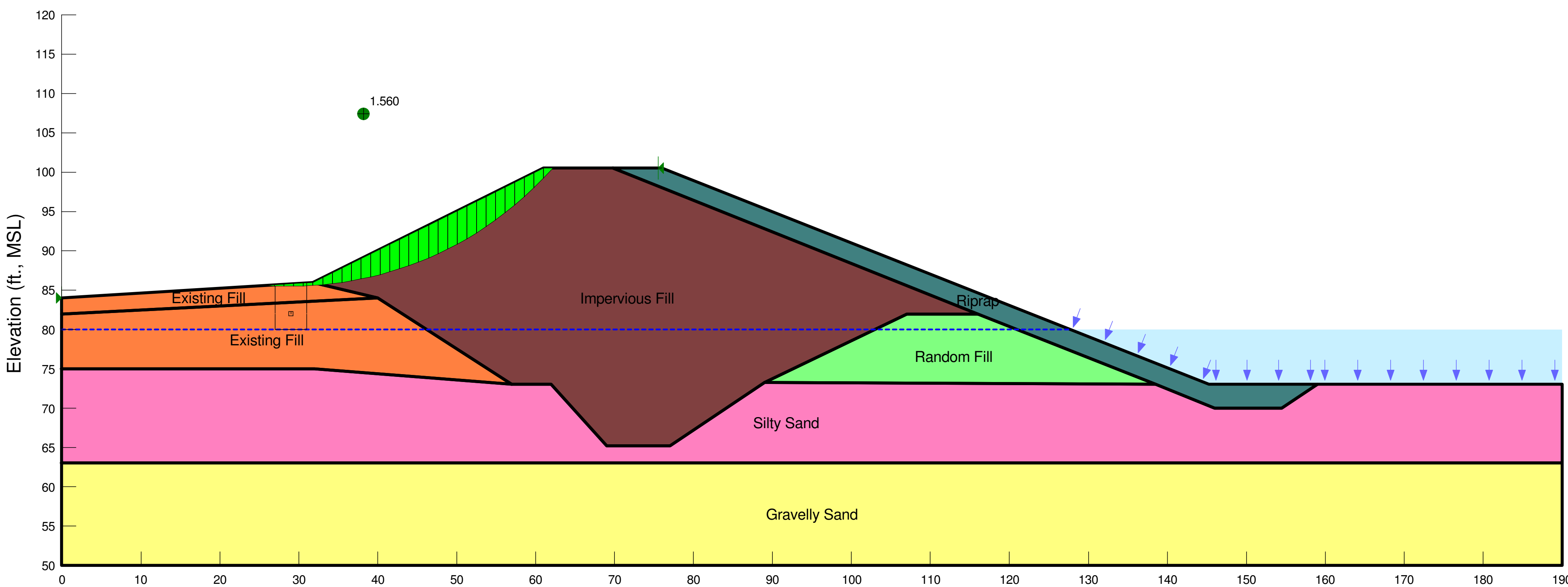
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

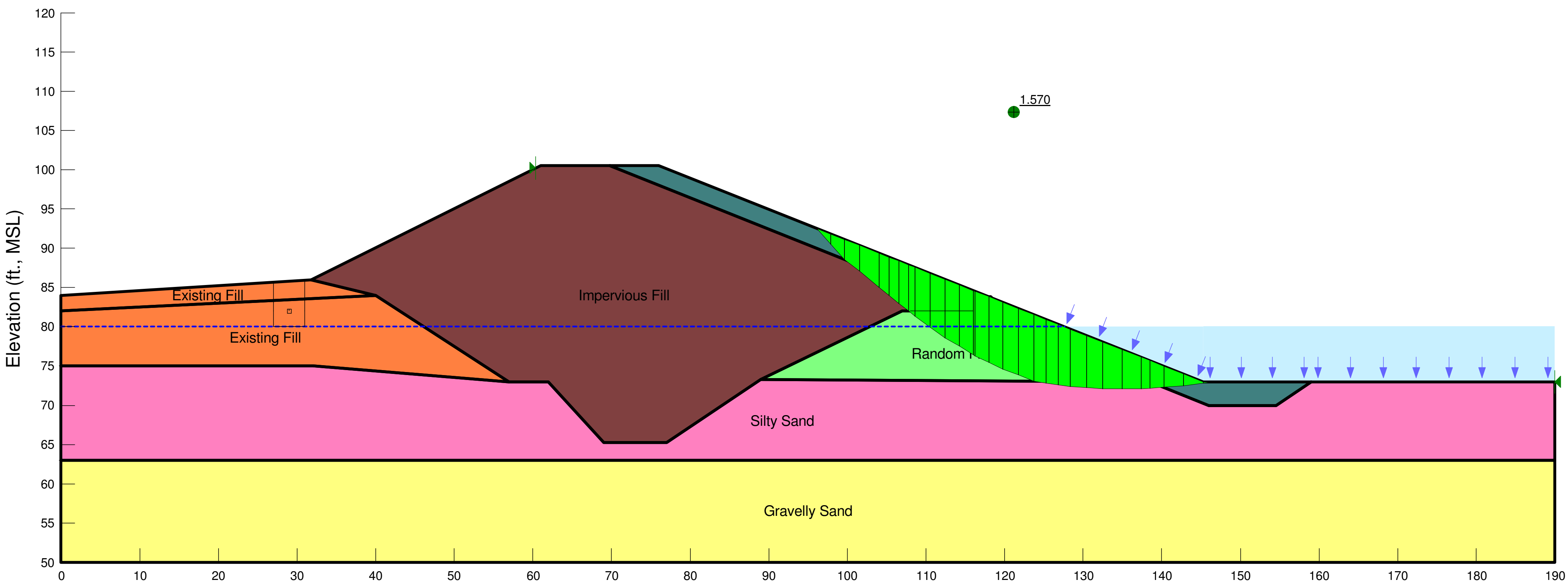
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Landside Slope Stability - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Riverside Slope Stability - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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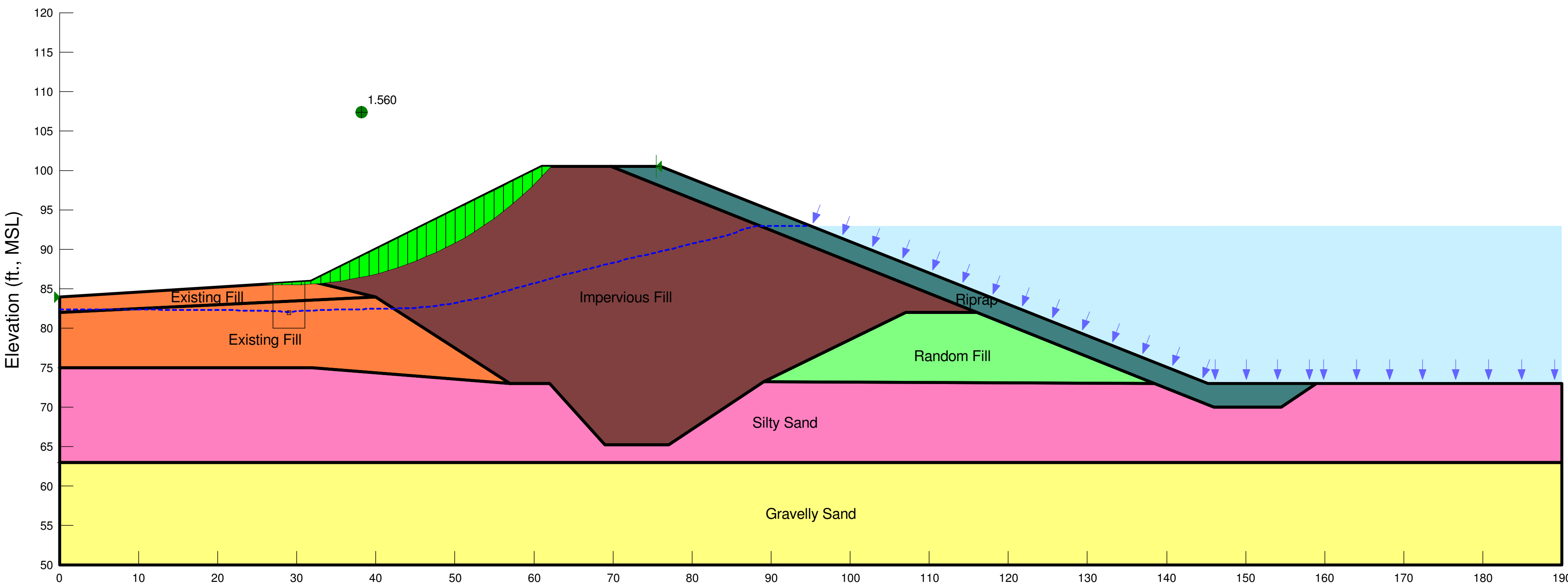
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Landside Slope Stability - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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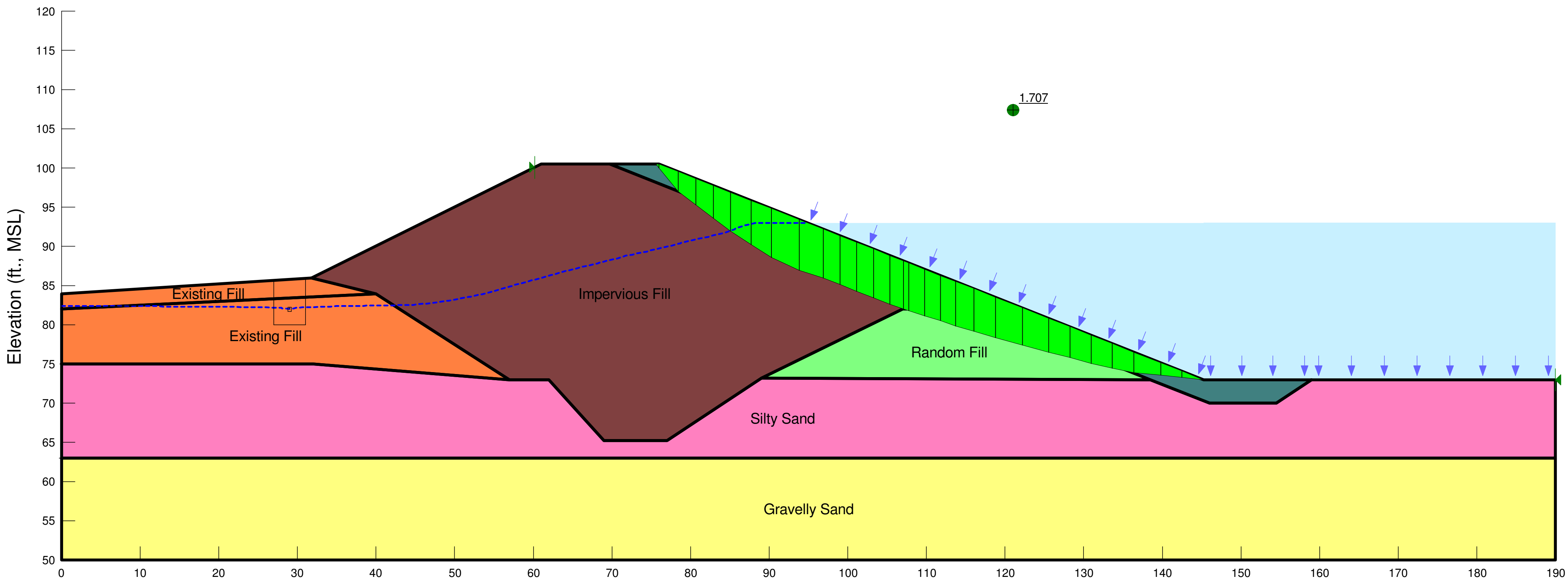
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Riverside Slope Stability - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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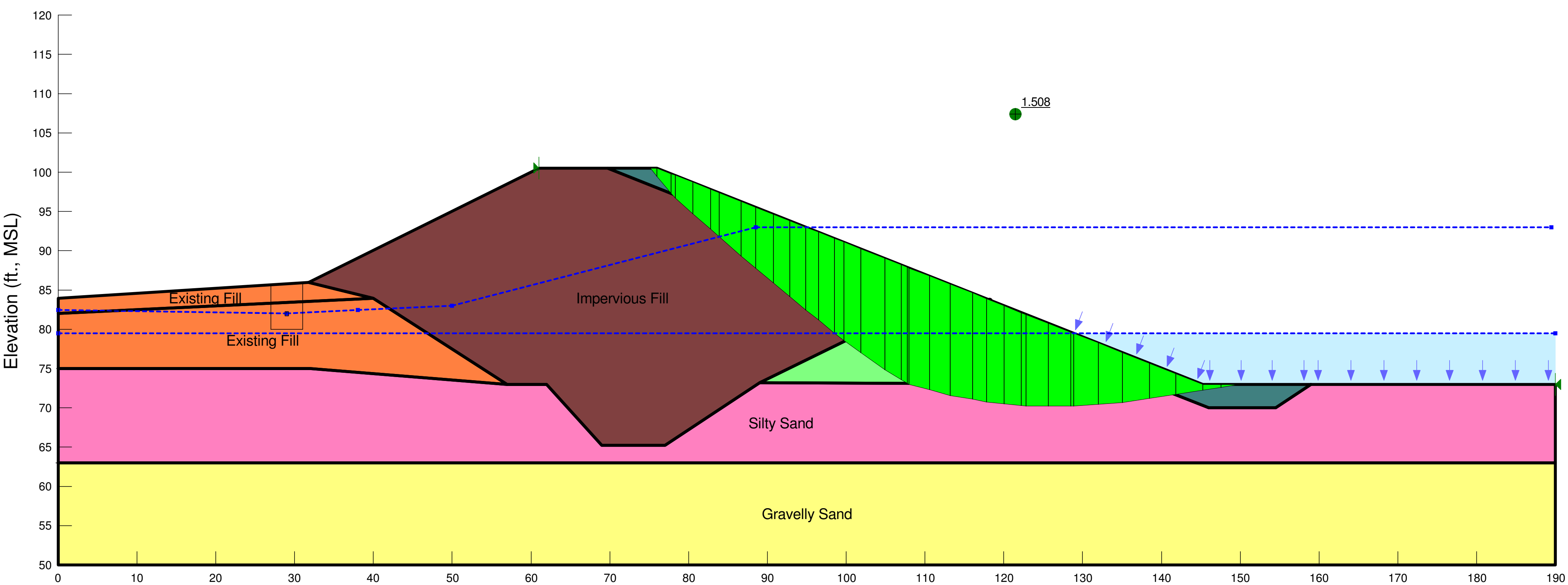
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Riverside Slope Stability - 100yr Drawdown

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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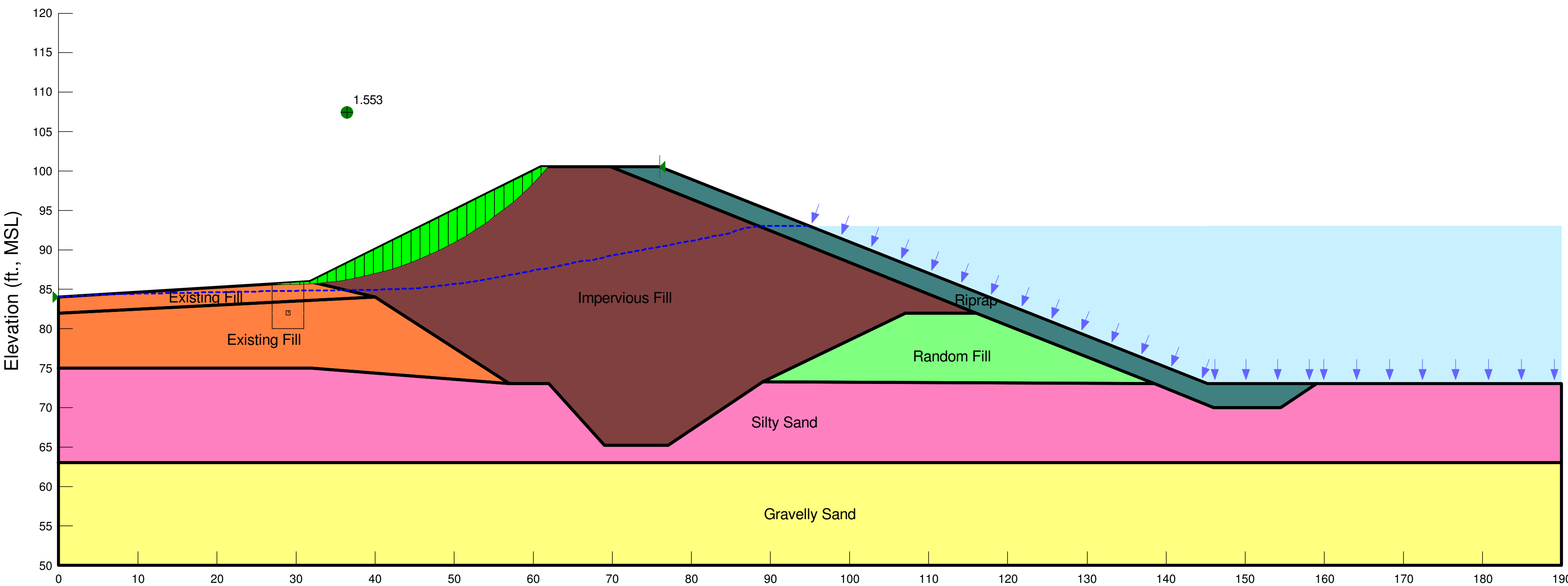
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Landside Slope Stability - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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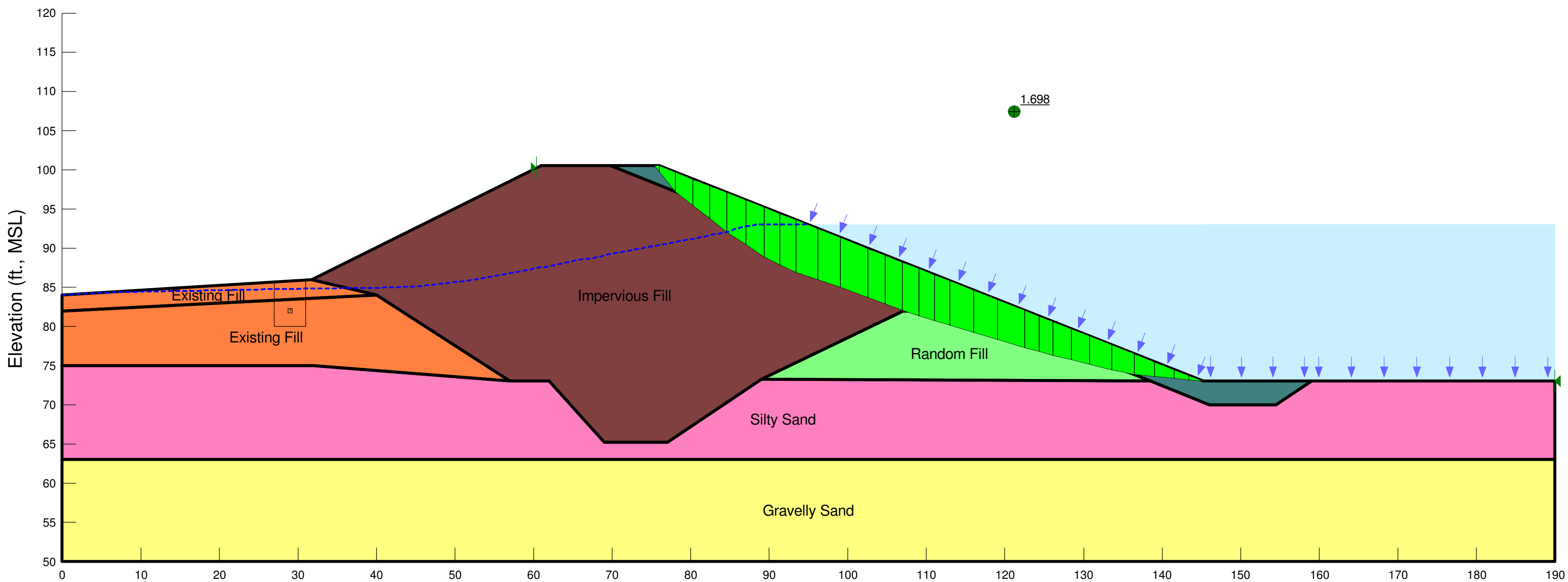
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Riverside Slope Stability - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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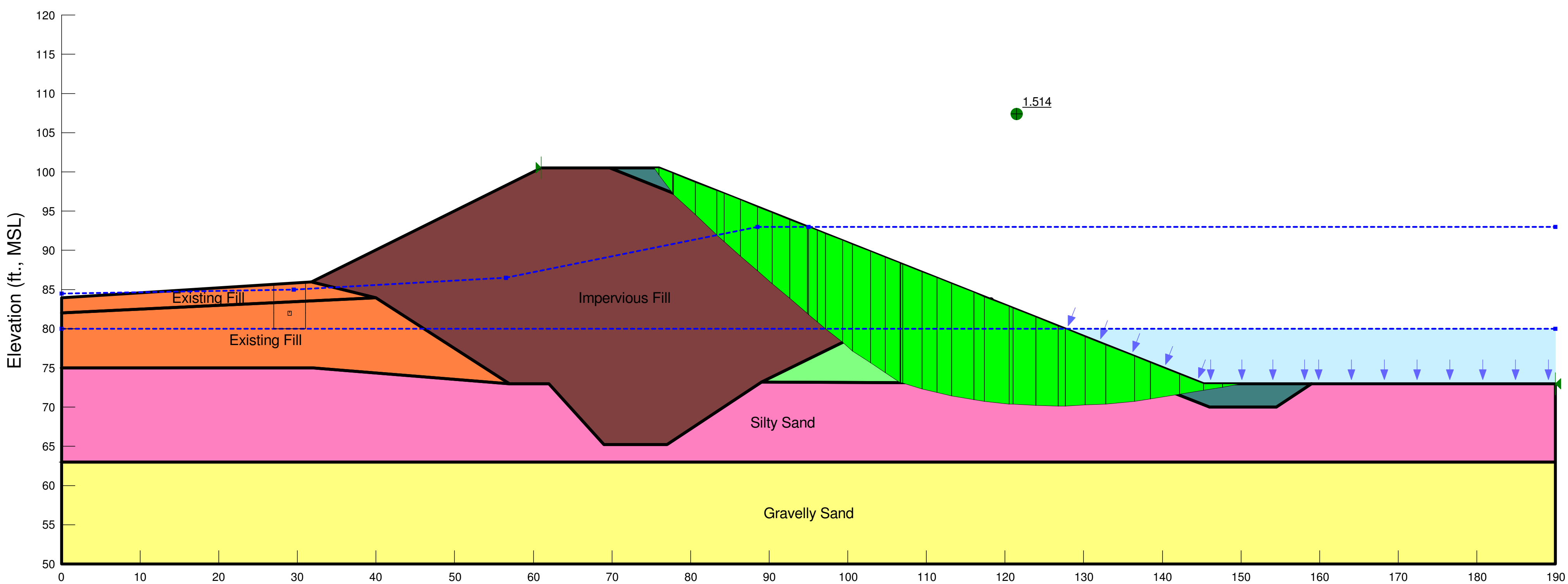
GZA Project No. 15.0702100.50



Station 41+00 - Riverside Slope Stability - 100yr Drawdown (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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Objective: To assess seepage FS for the flood walls of the **Chicopee Falls Section** of the Chicopee Flood Control Works

Method:

1) Develop typical cross section of flood wall at "worst-case" stations.
   a) Stations having the largest difference bewteen flood elevations and landside grade
   b) Stations having the largest difference bewteen the bottom of footing and top of bedrock.
2) Determine subsurface profile from closest test borings and Corps design drawings.
3) Using soil parameters developed for levee embankment analyses, calculate exit gradient using SEEP/W. If a soil layer exists for the wall section which wasn't used in the embankment analyses, estimate permeability using grain-size correlations (if tested) or typical values for similar materials.
4) The following cases were analyzed and compared to the USACE limiting gradient of 0.5:

Case #1 - 100-yr Flood - Operating Drain
Case #2 - 100-yr Flood - No Drain

Subsurface Information:

- Test borings CF-1 through CF-11 and Exploration Location Plan by GZA (2009)
- "Chicopee River Flood Control - Chicopee Falls, Chicopee River, Massachusetts" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated April 1963
- "Chicopee Falls Local Protection Project - Design Memorandum No. 5 - Embankments and Foundations" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated March 1963

Assumptions:

- Soil strata interpreted from available test boring data and design drawings, actual configuration may vary.

Material Properties:

Strata	K Ratio (k_v/k_h)	Saturated Horizontal Permeability, k_{sat} ft/s	cm/s	Notes
Random Fill	1	3.3E-04	1.0E-02	(3)
Existing Fill	1	3.3E-05	1.0E-03	(1)
Silty Sand	1	4.6E-06	1.4E-04	(2)
Gravelly Sand	1	6.6E-05	2.0E-03	(2)
Riprap	1	8.0E-03	2.4E-01	(1)
Sandstone	1	1.6E-06	5.0E-05	(1)
Concrete	1	3.3E-11	1.0E-09	(1)

(1) - Permeability values based on typical values for similar materials
(2) - Permeability values estimated from correlations with grain size distribution
(3) - Permeability values based values used in USACE report

Analysis Results:

SEEPAGE ANALYSIS RESULTS - STATION 9+00 (TYPICAL FROM STATION 0+00 TO 9+50)

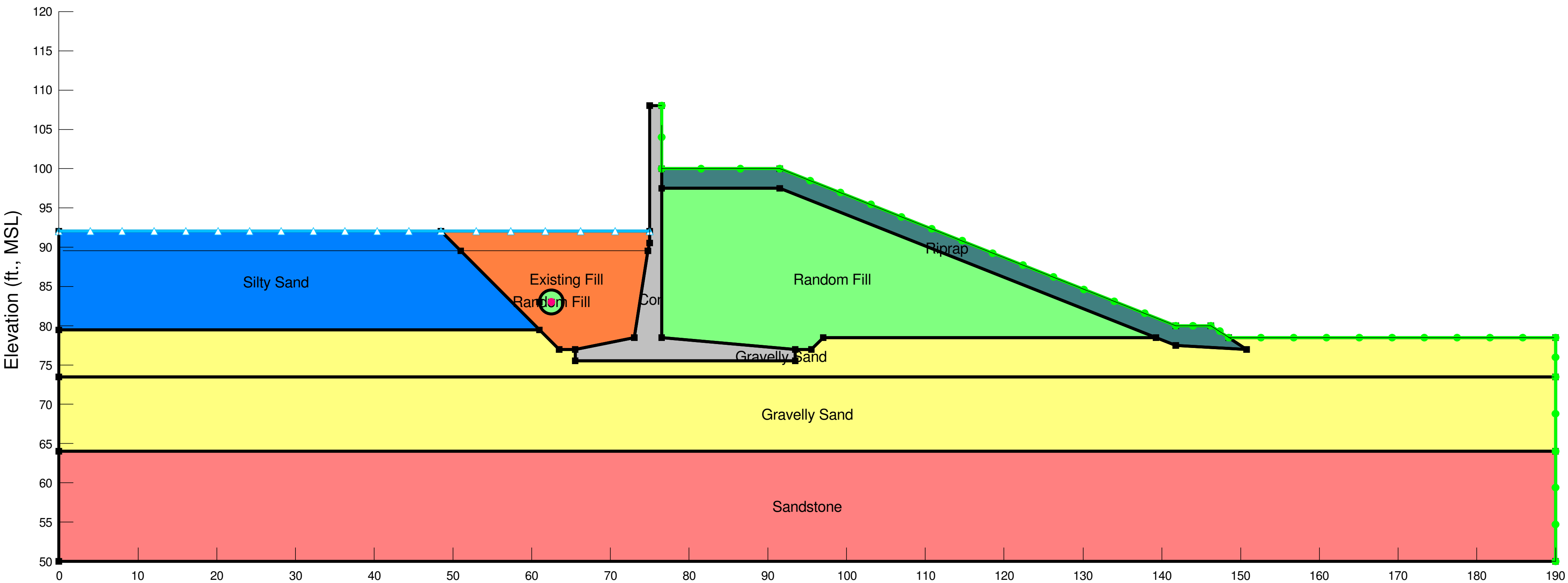
Case	River Elevation	Landside Elevation(1)	Max. Exit Gradient, i_e(2)	Limiting Gradient(3)	OK?
1	100yr Flood (El. 99.3)	83	0.03	0.5	OK
2	100yr Flood (No Drain)	92	0.13	0.5	OK

SEEPAGE ANALYSIS RESULTS - STATION 20+00 (TYPICAL FROM STATION 16+82 TO 25+50)

Case	River Elevation	Landside Elevation(1)	Max. Exit Gradient, i_e(2)	Limiting Gradient(3)	OK?
1	100yr Flood (El. 99.3)	84	<0.01	0.5	**OK**
2	100yr Flood (No Drain)	88.5	0.03	0.5	OK

- Note: Factor of safety values less than recommended values are shown in italics
(1) - Landside elevation refers to grade or toe drain, depending on the case
(2) - Flow and exit gradient estimated from results of SEEP/W analysis at toe drain or landside ground surface
(3) - Limiting gradient per requirements of US Army Corps Technical Letter ETL 1110-2-569 "DESIGN GUIDANCE FOR LEVEE UNDERSEEPAGE'

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 9+00 (Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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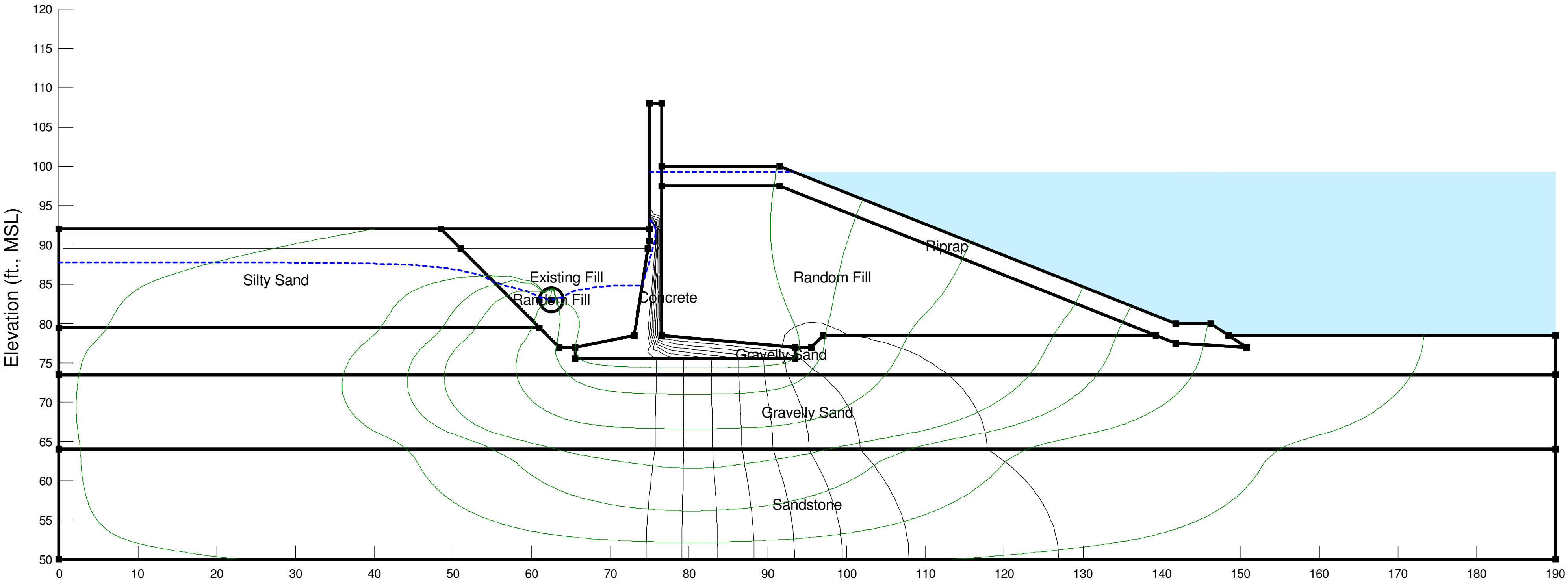
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 9+00 - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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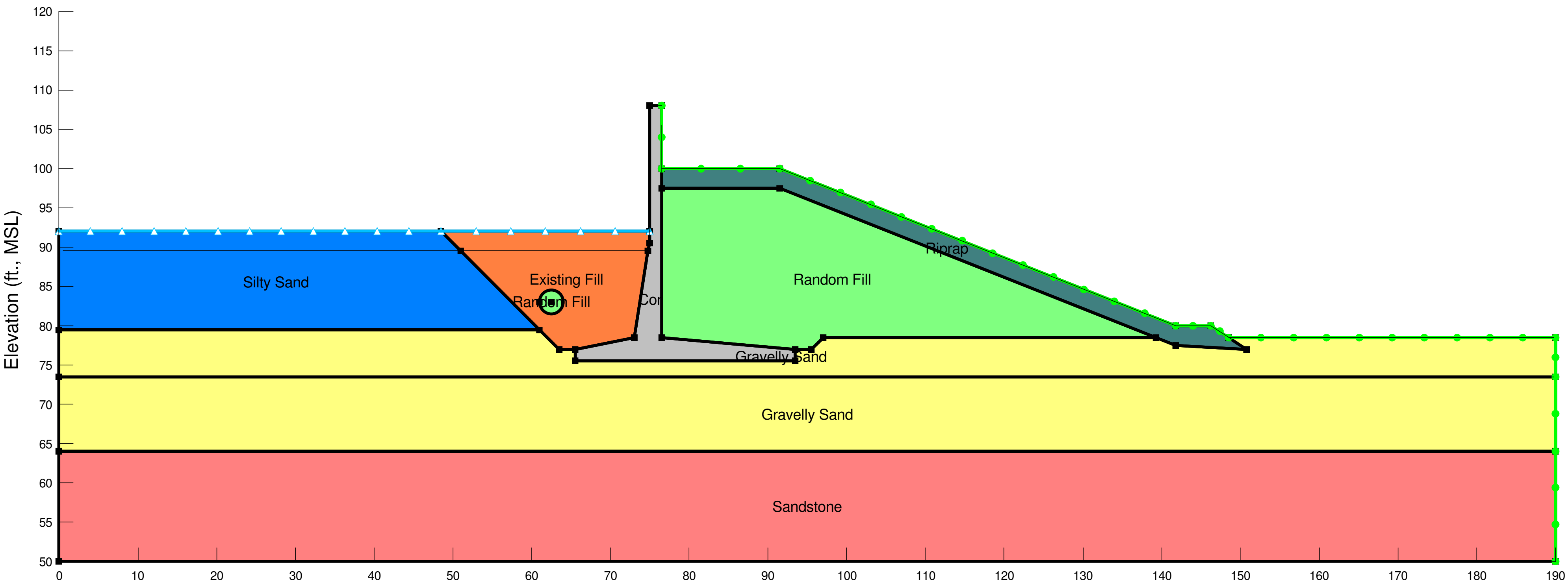
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 9+00 (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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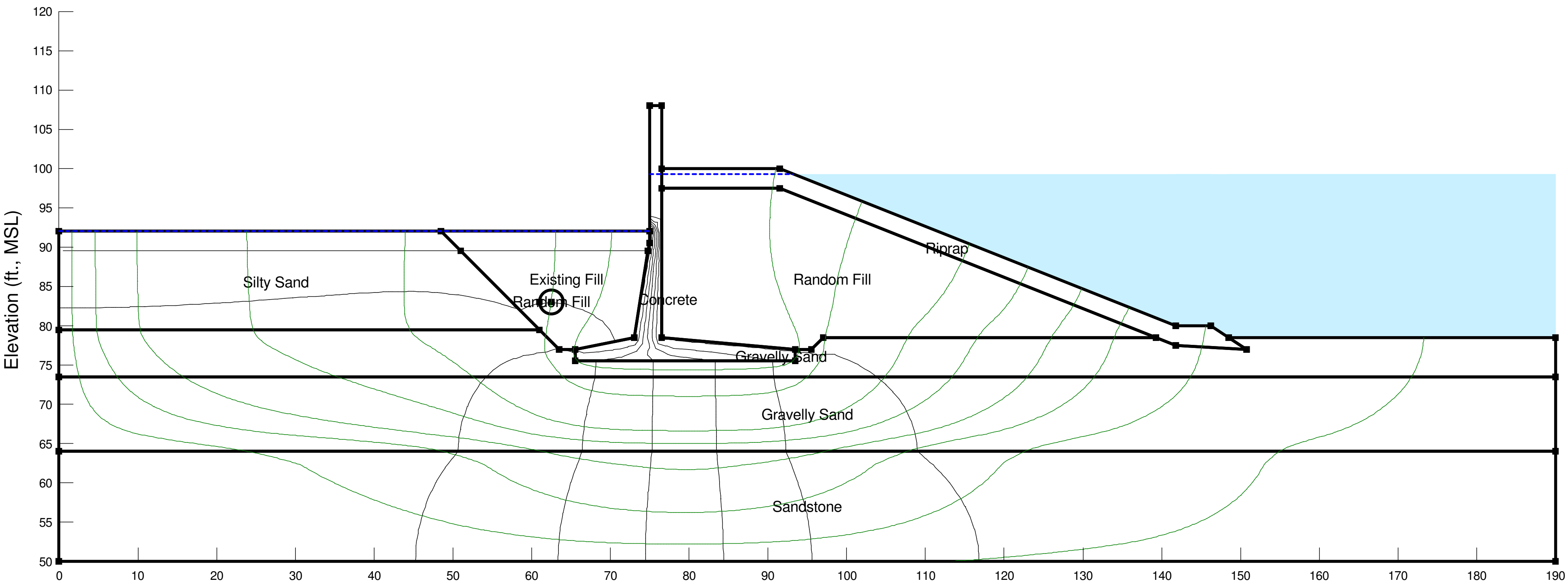
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 9+00 - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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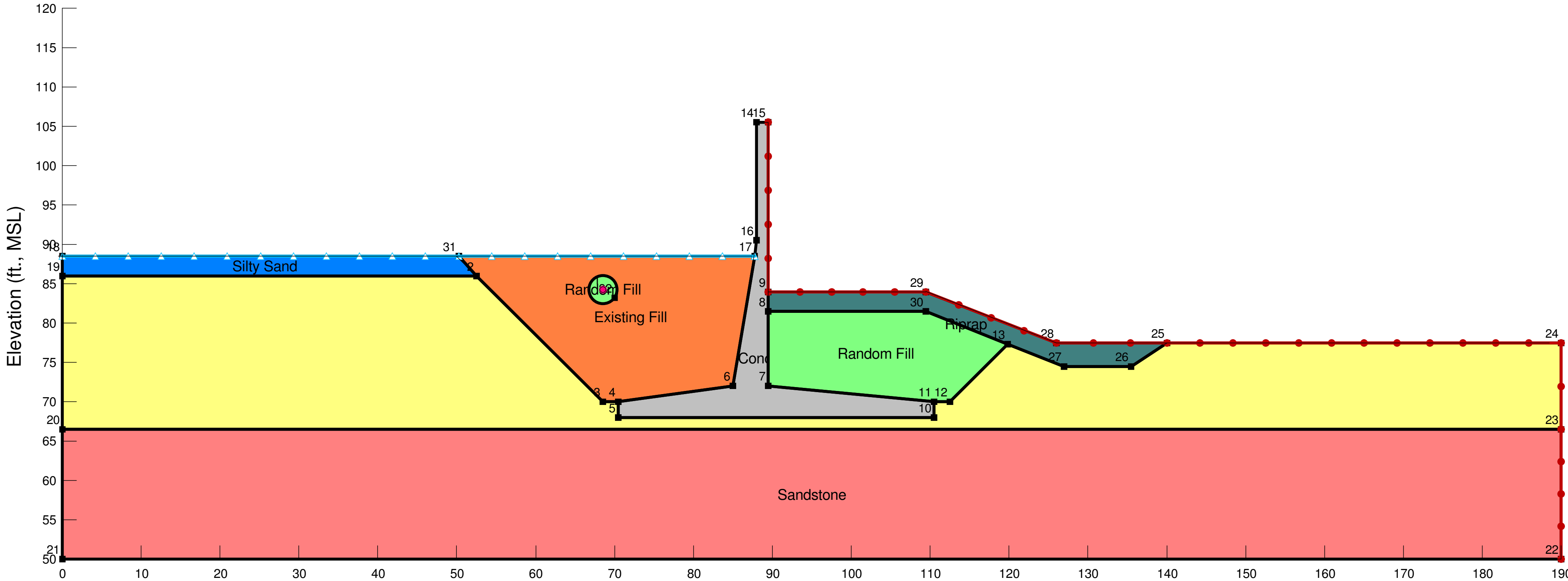
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 20+00 (Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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Chicopee Flood Control - Chicopee Falls Section
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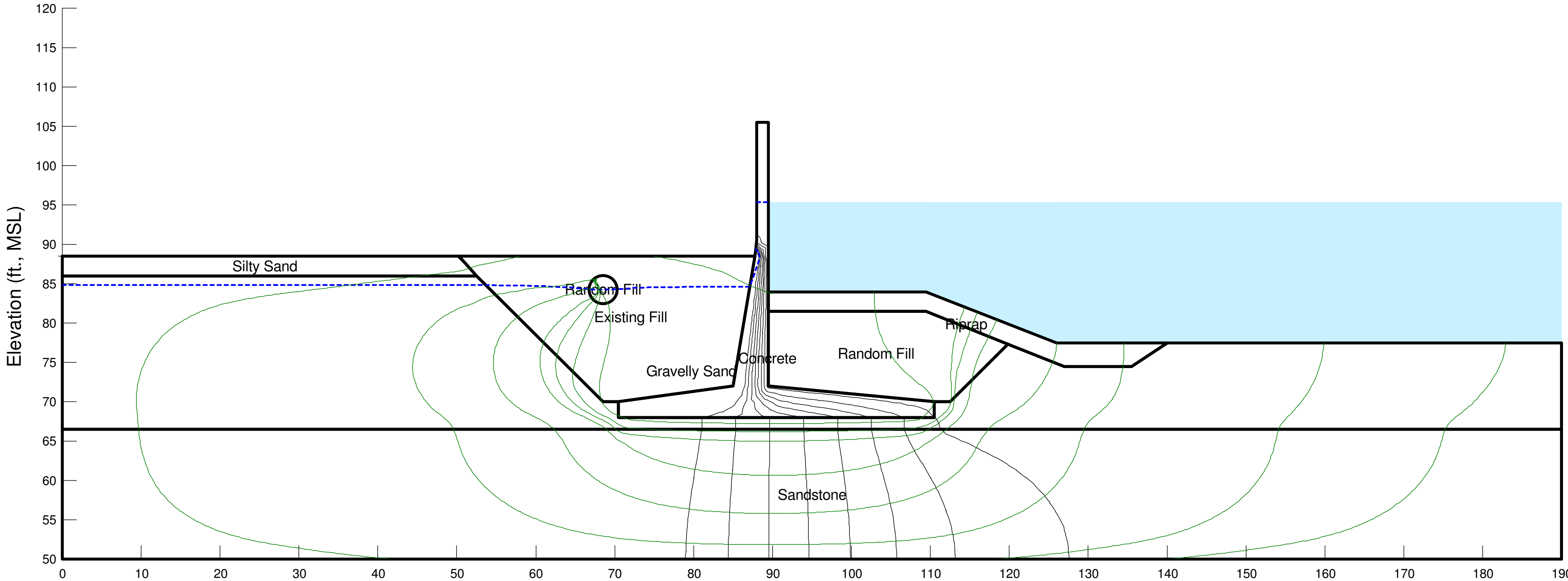

Station 20+00 - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
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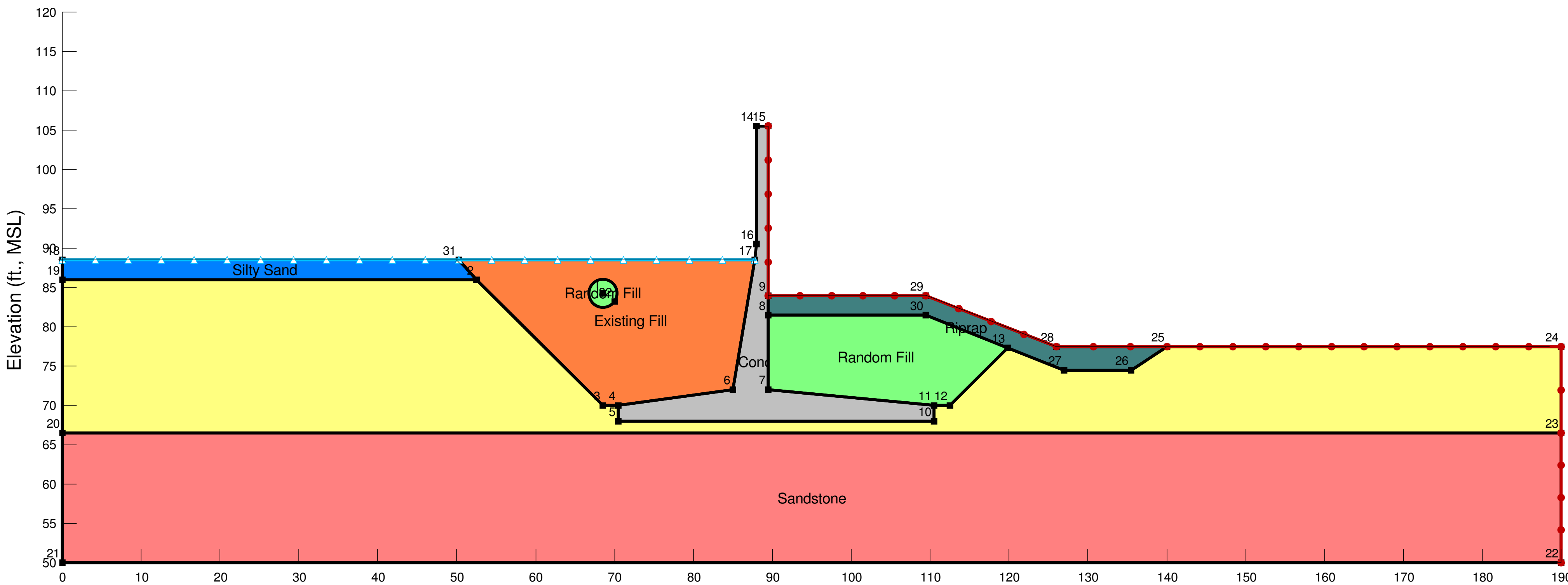

Station 20+00 (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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Chicopee Flood Control - Chicopee Falls Section
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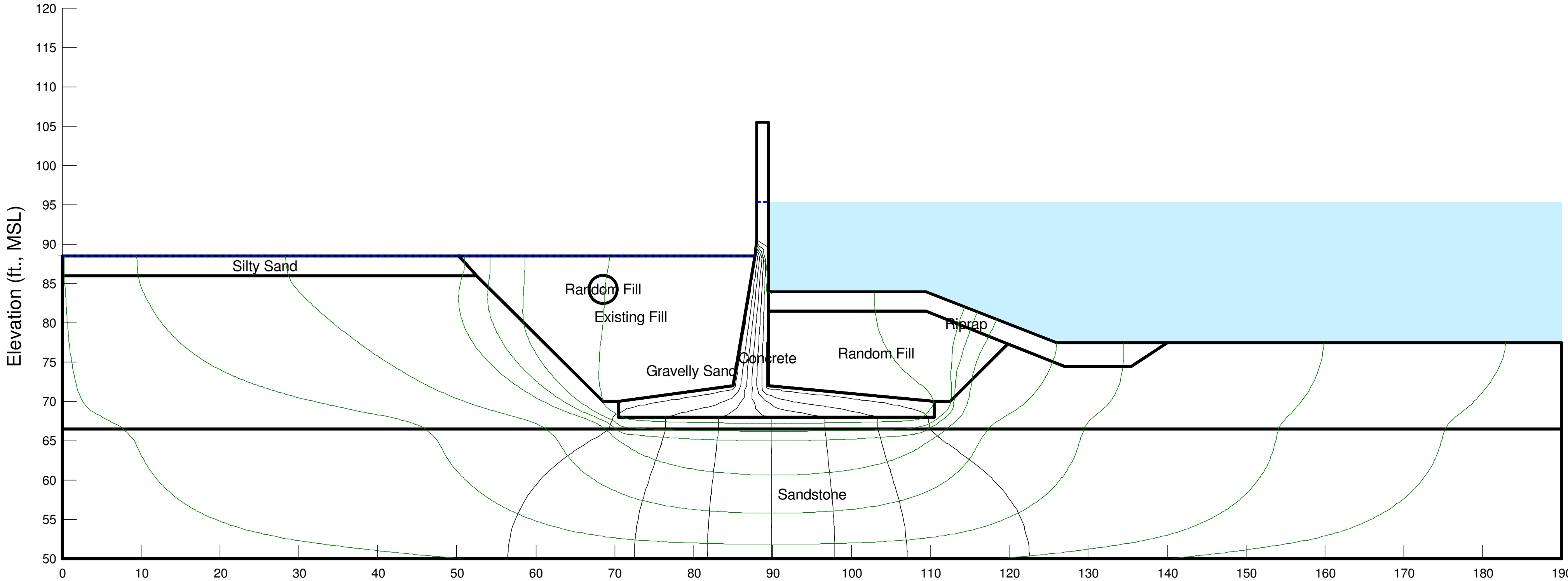

Station 20+00 - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').