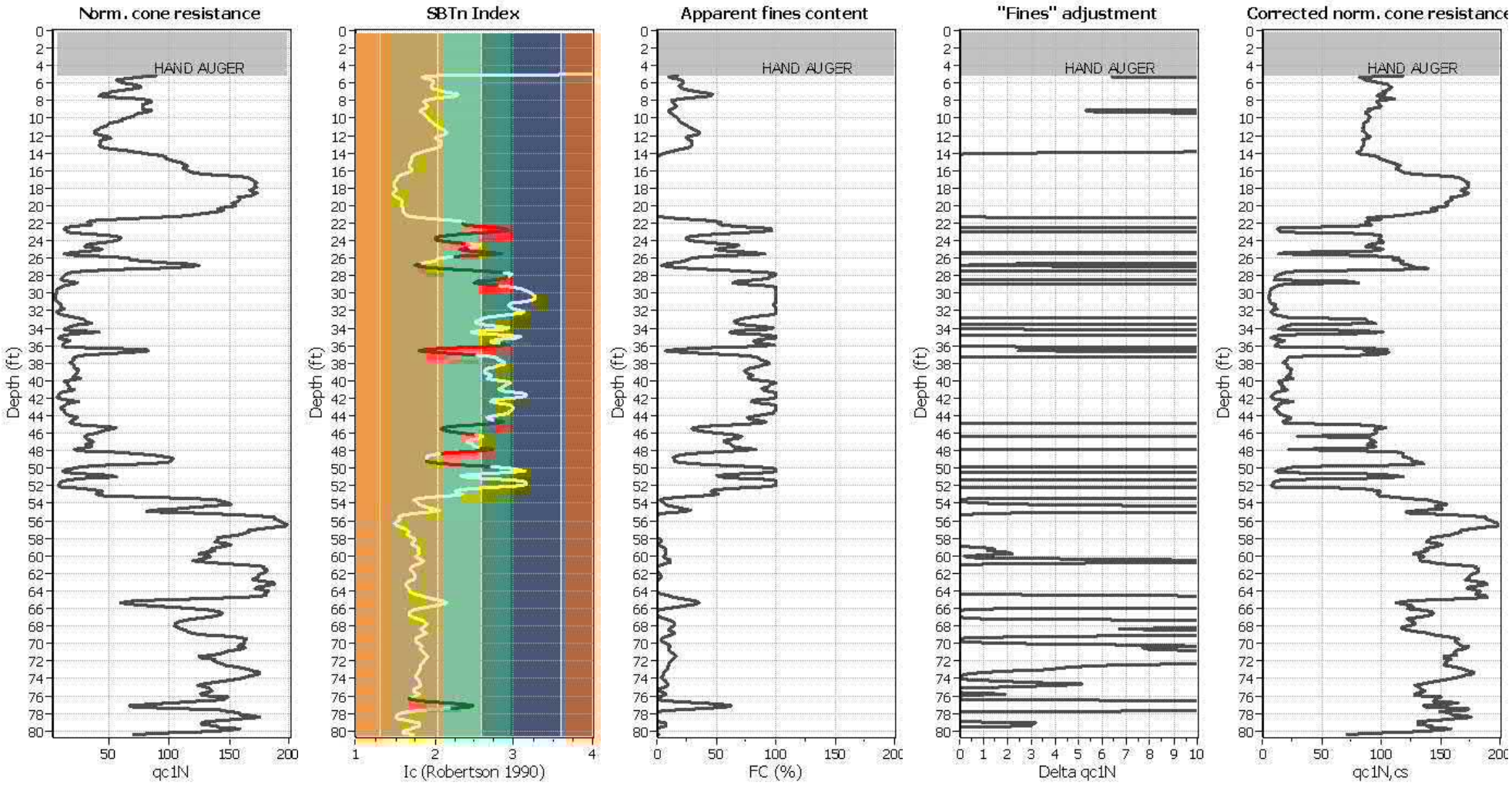
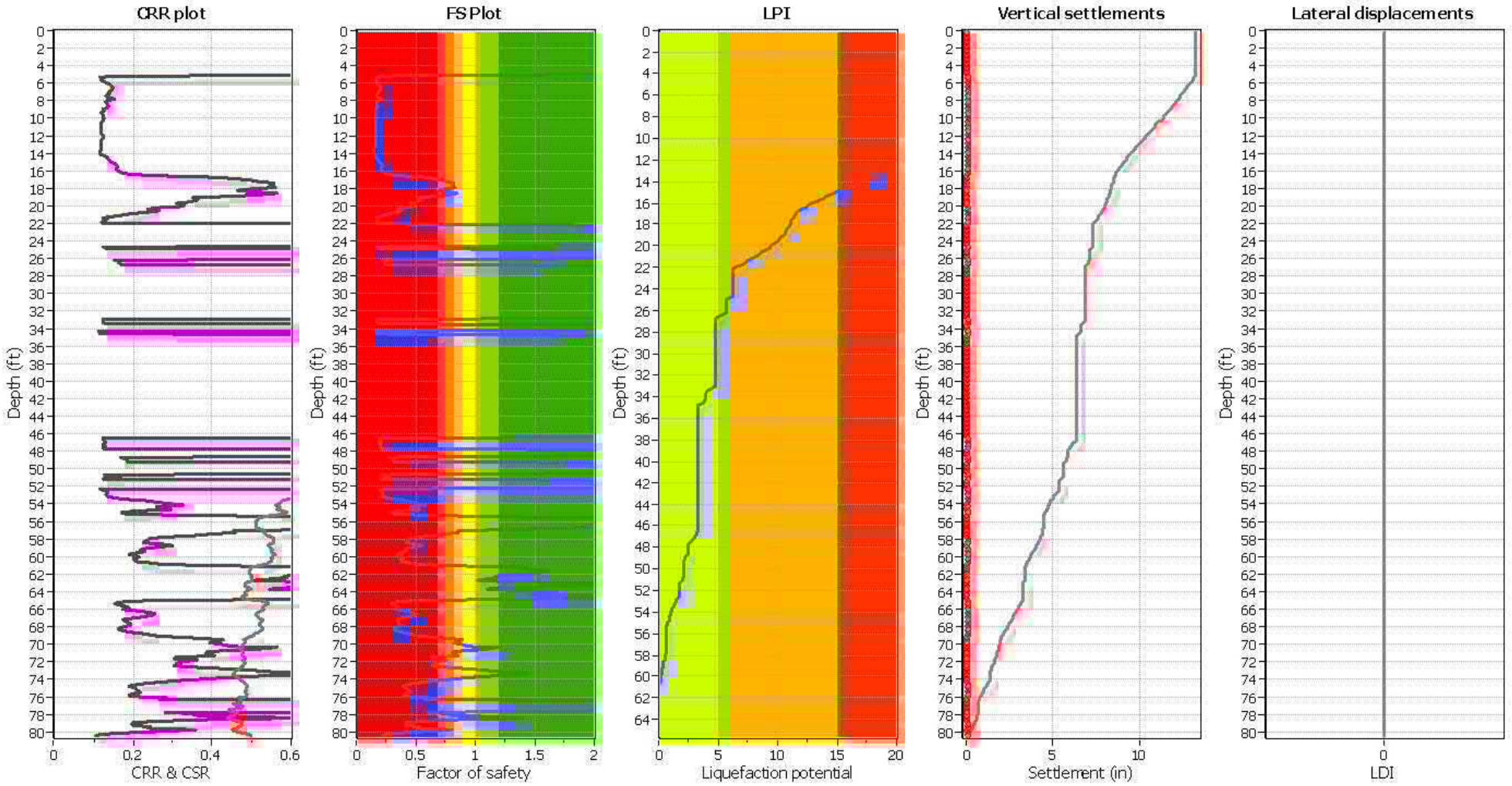
Liquefaction analysis overall plots (intermediate resu



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.59	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	9.00 ft	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plot



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Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
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F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
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LPI color scheme

- Very high risk
- High risk
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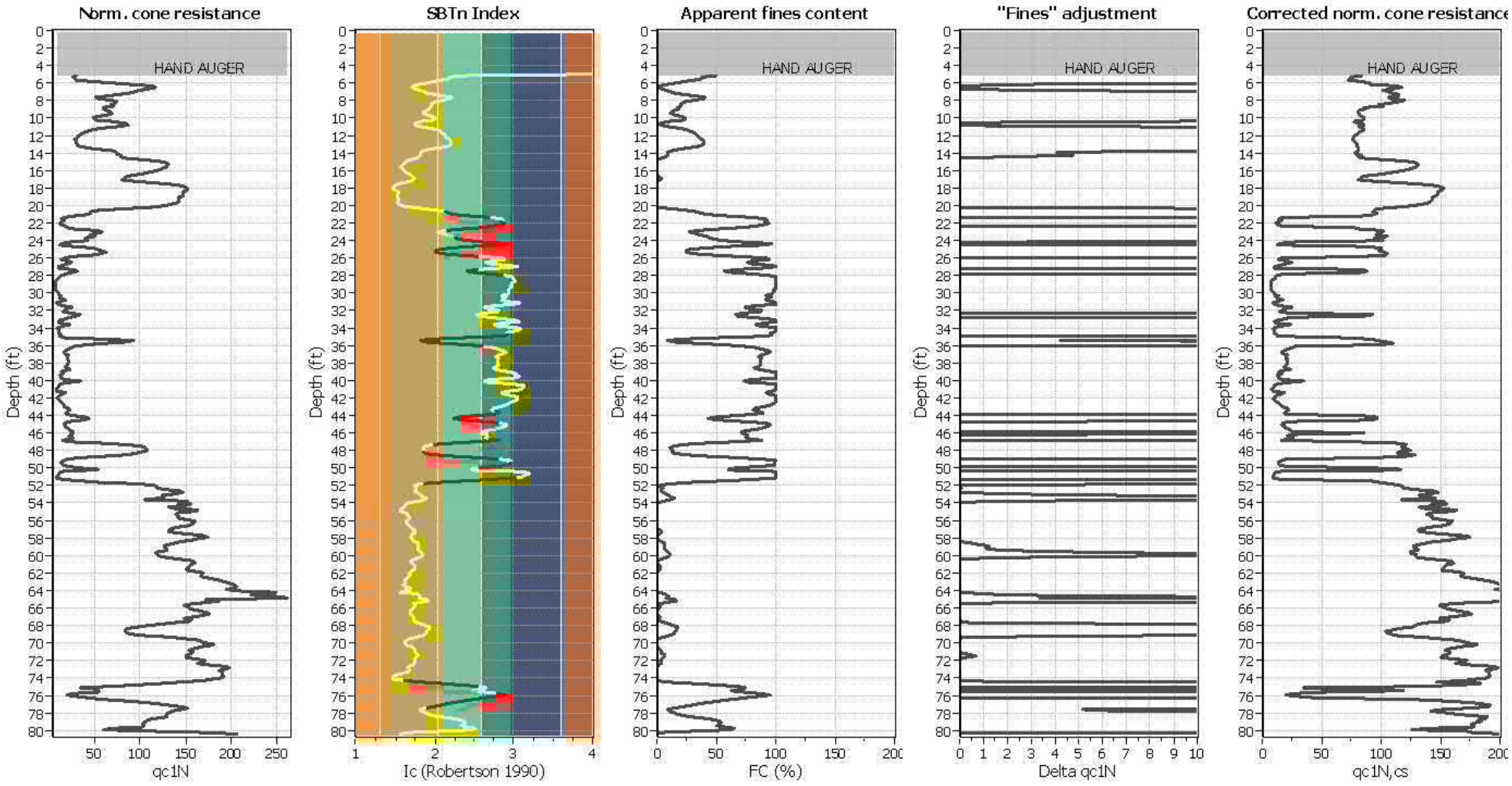
Liquefaction analysis overall plots (intermediate resu



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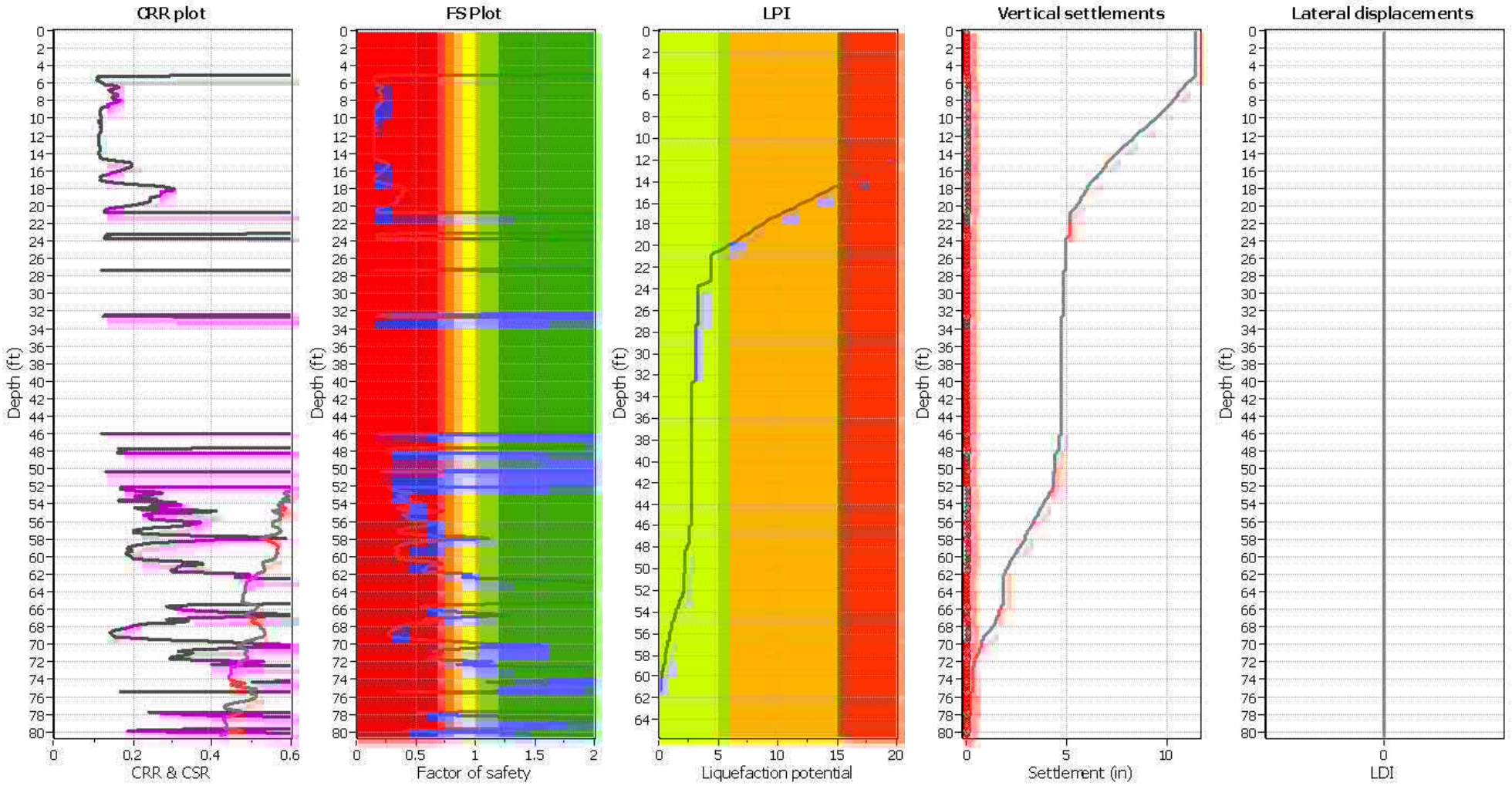

Input parameters and analysis data

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Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
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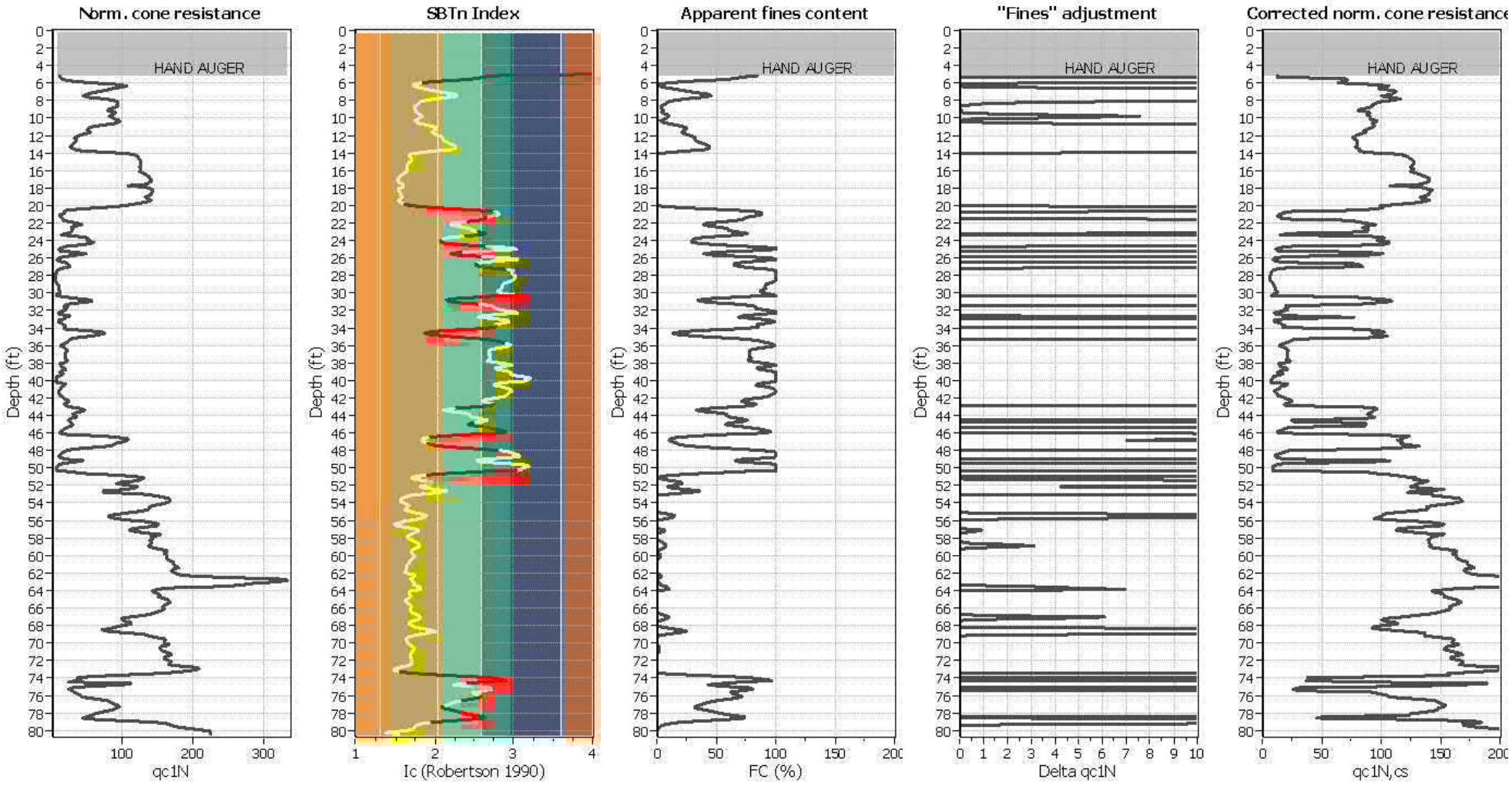

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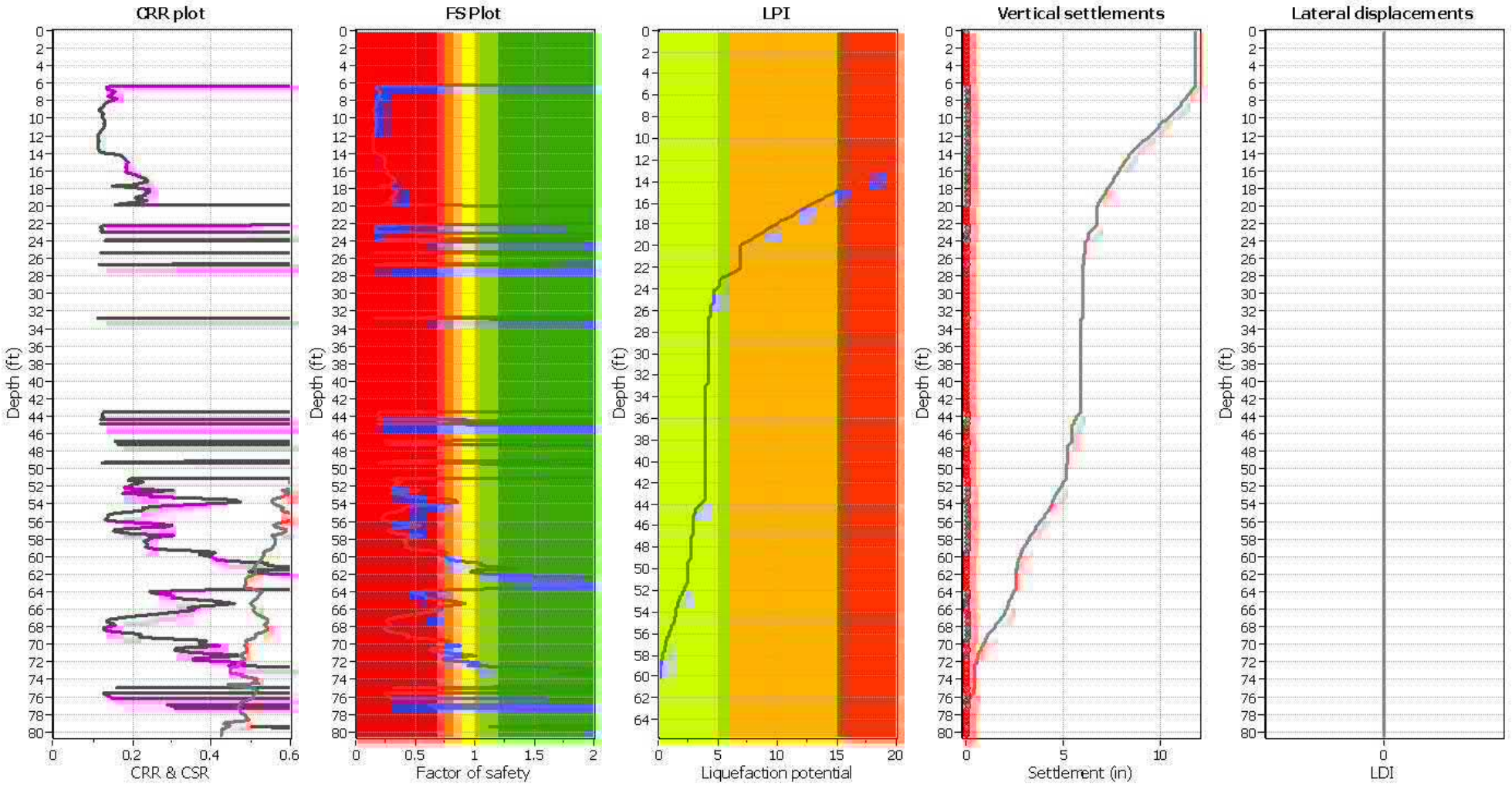

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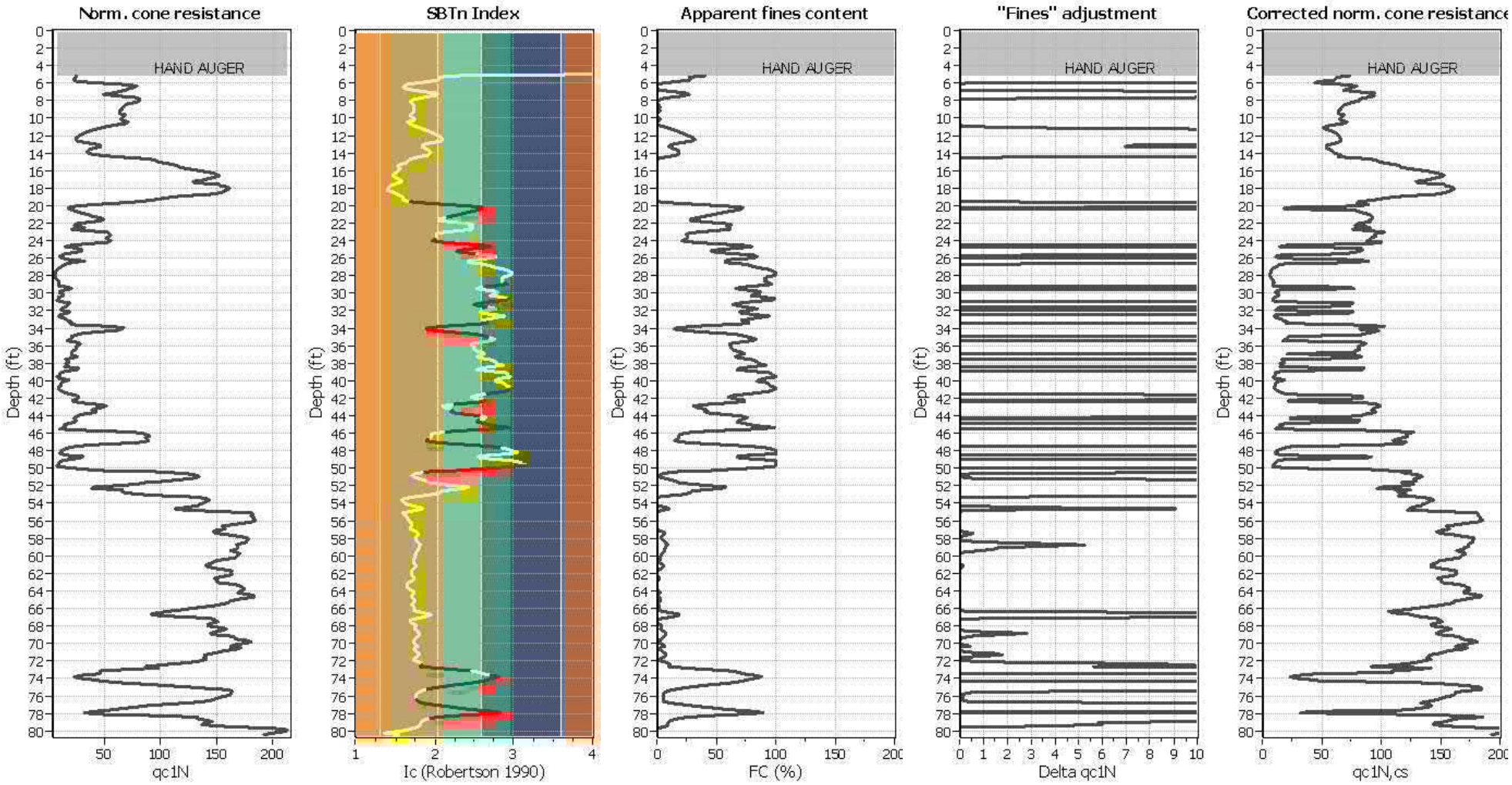

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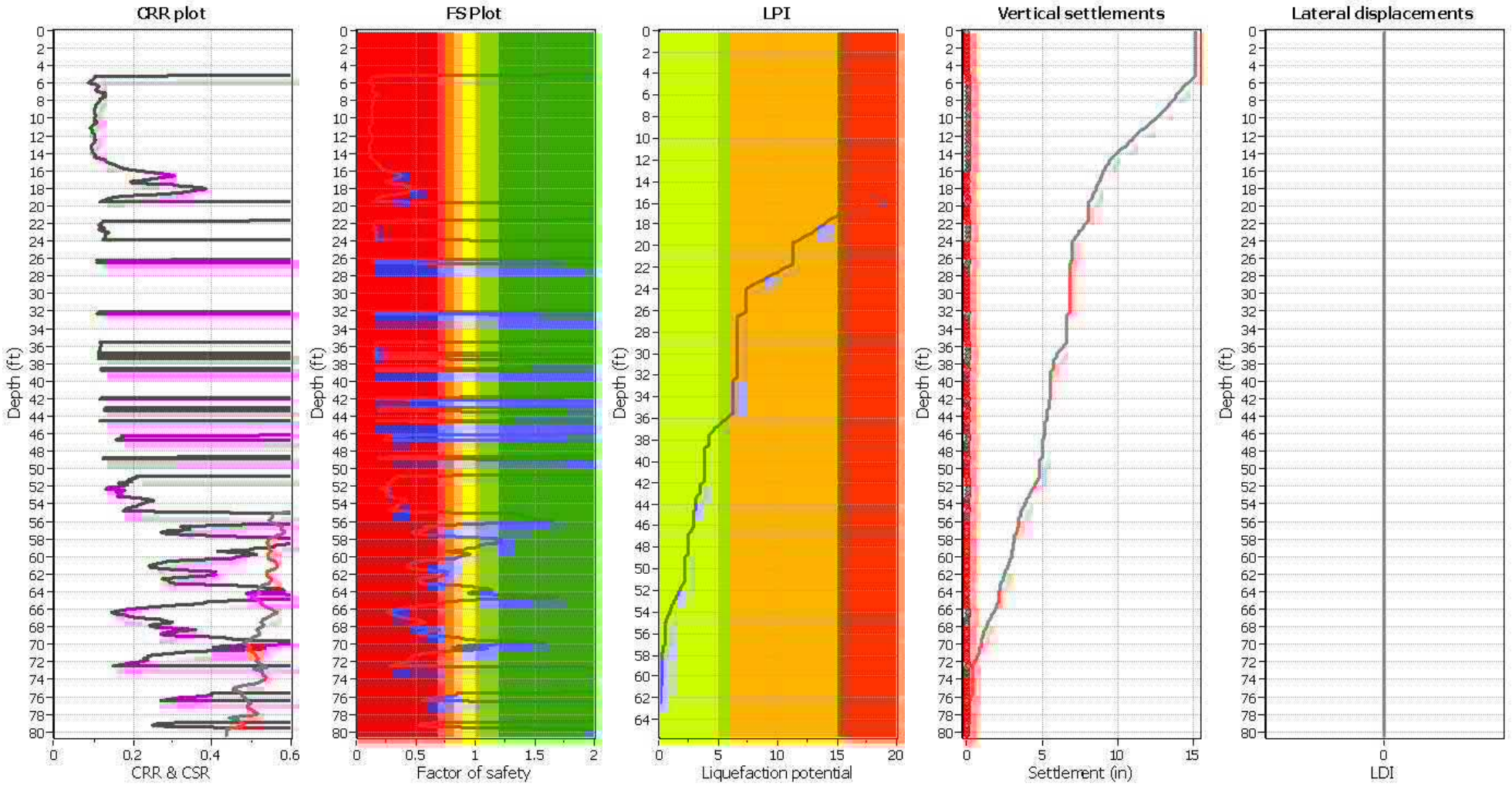

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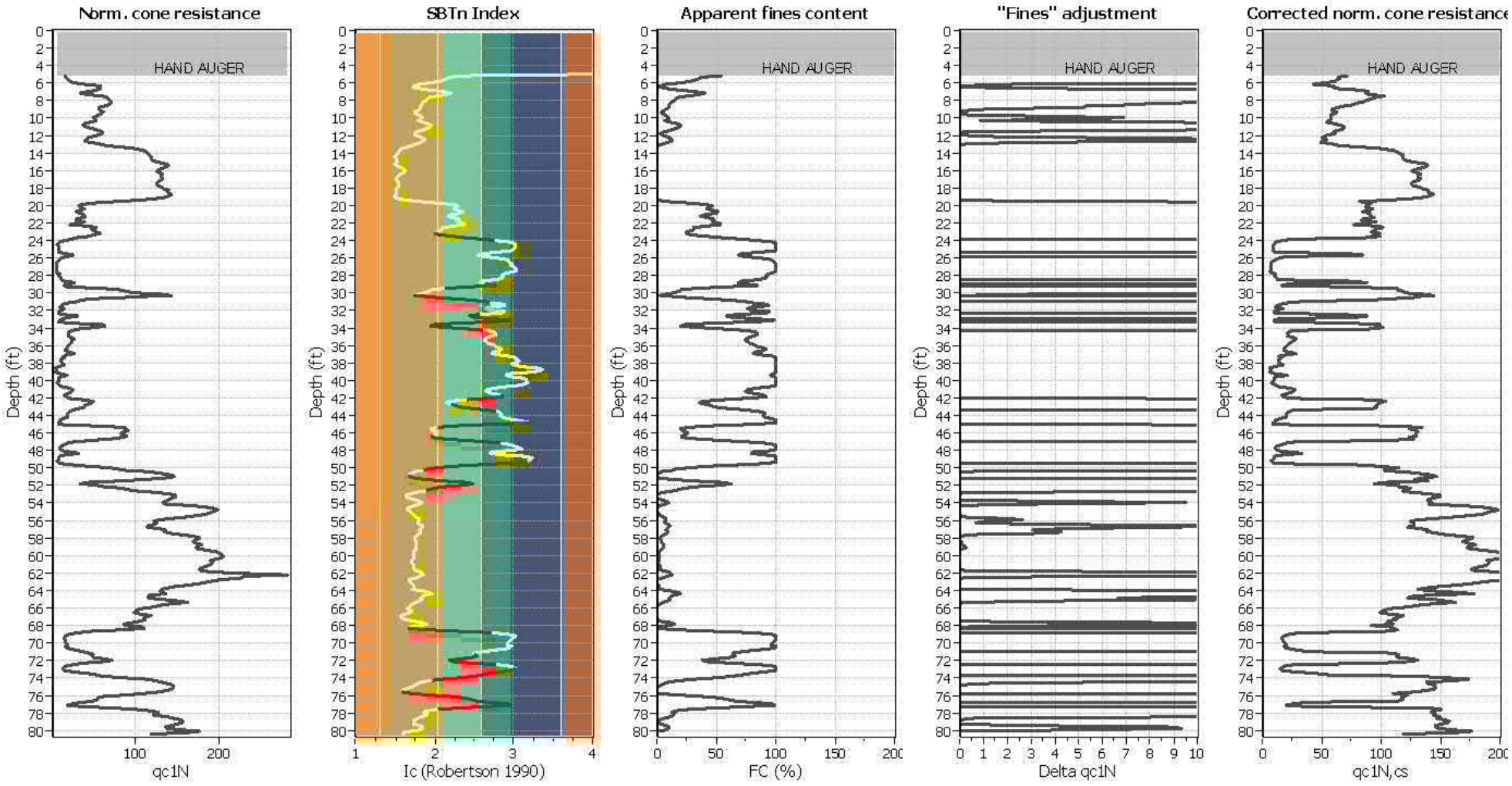

Input parameters and analysis data

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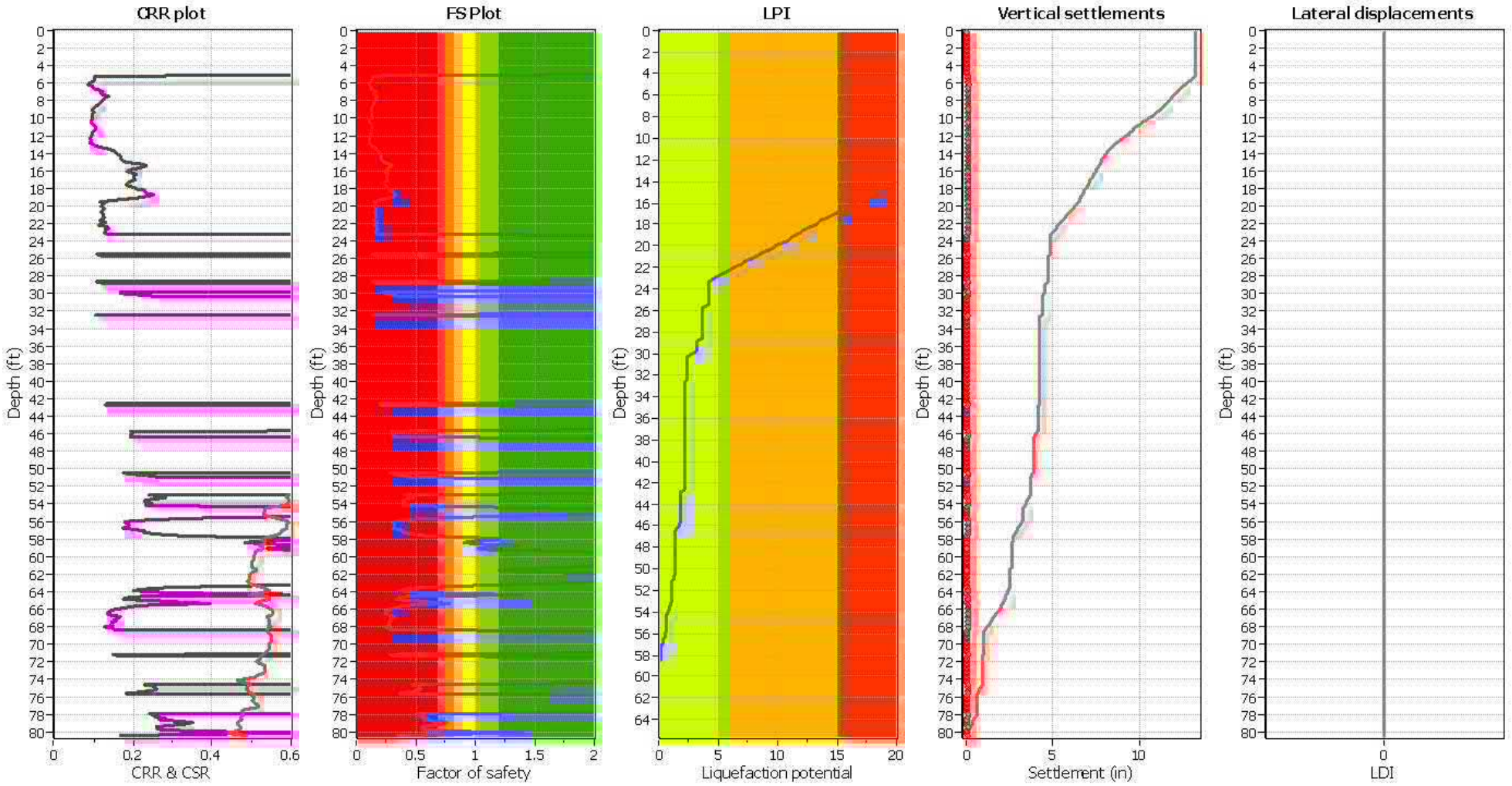

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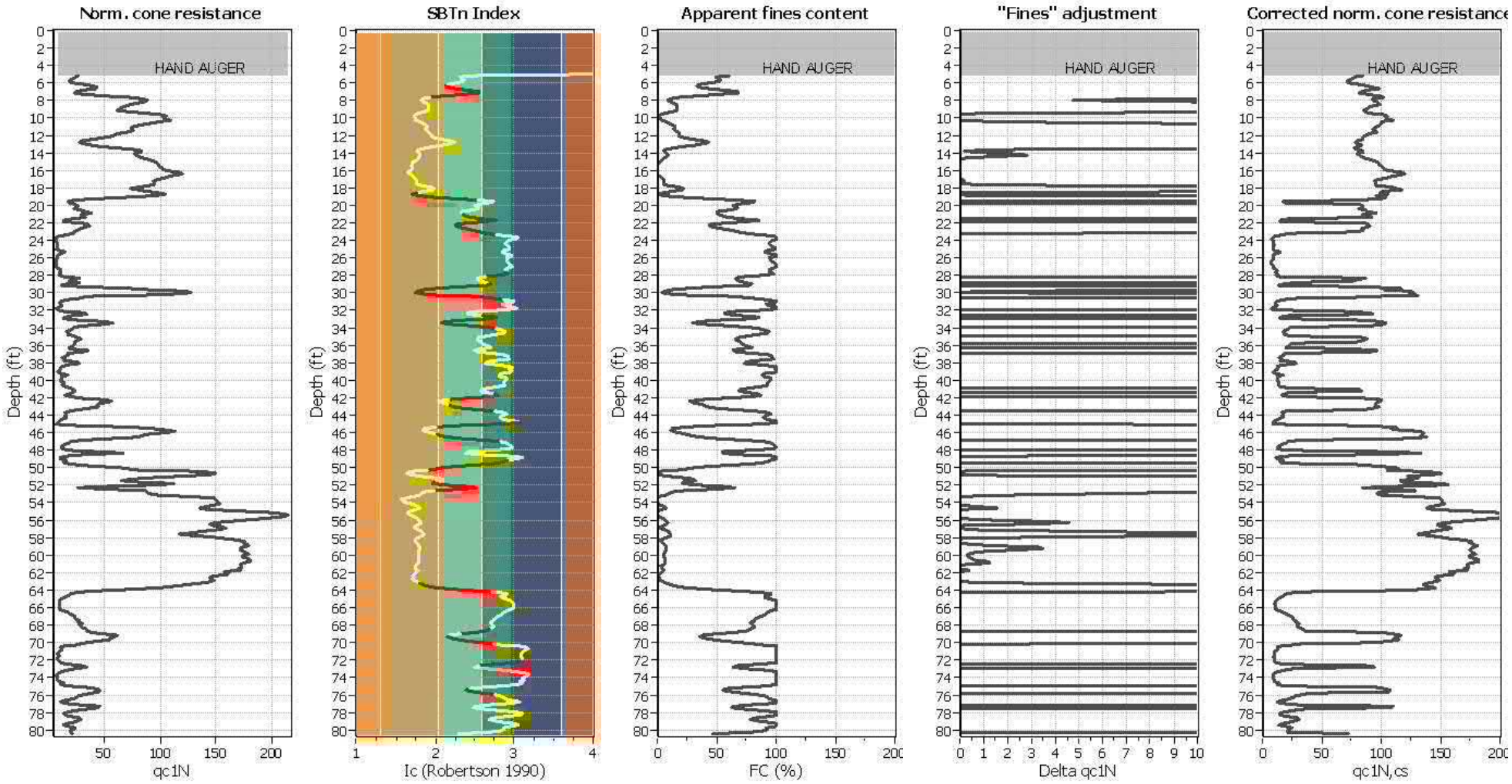

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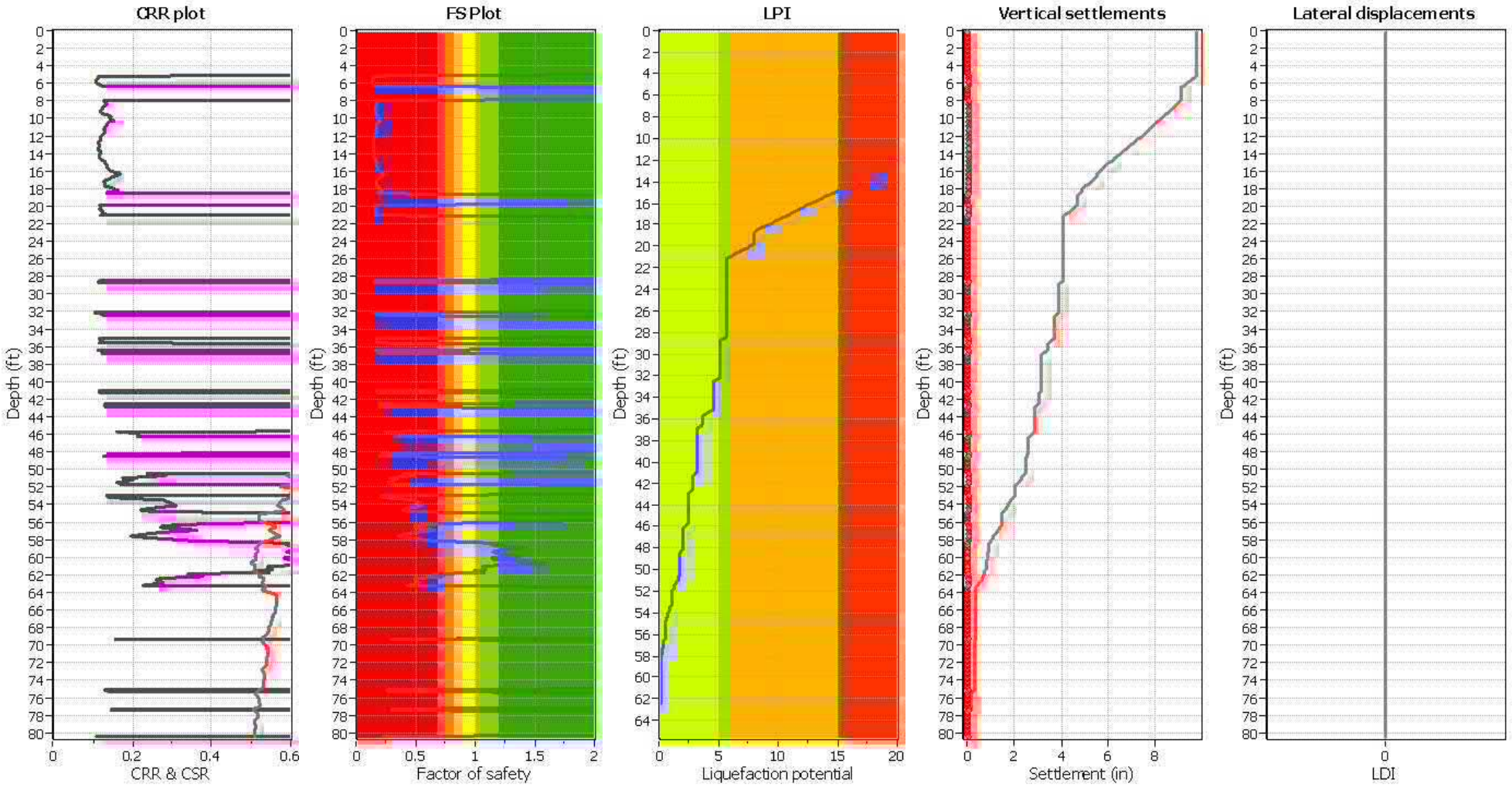

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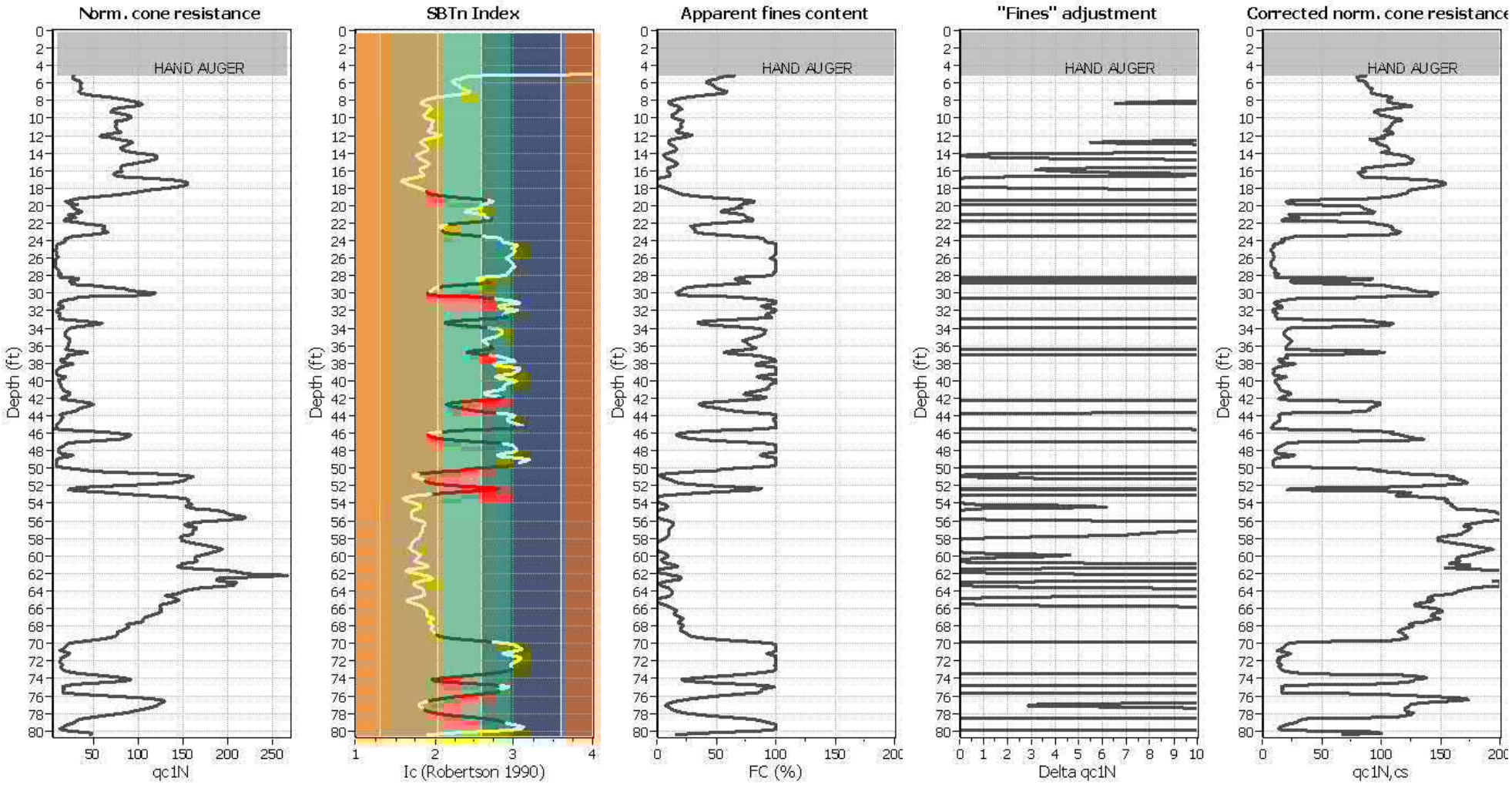

Input parameters and analysis data

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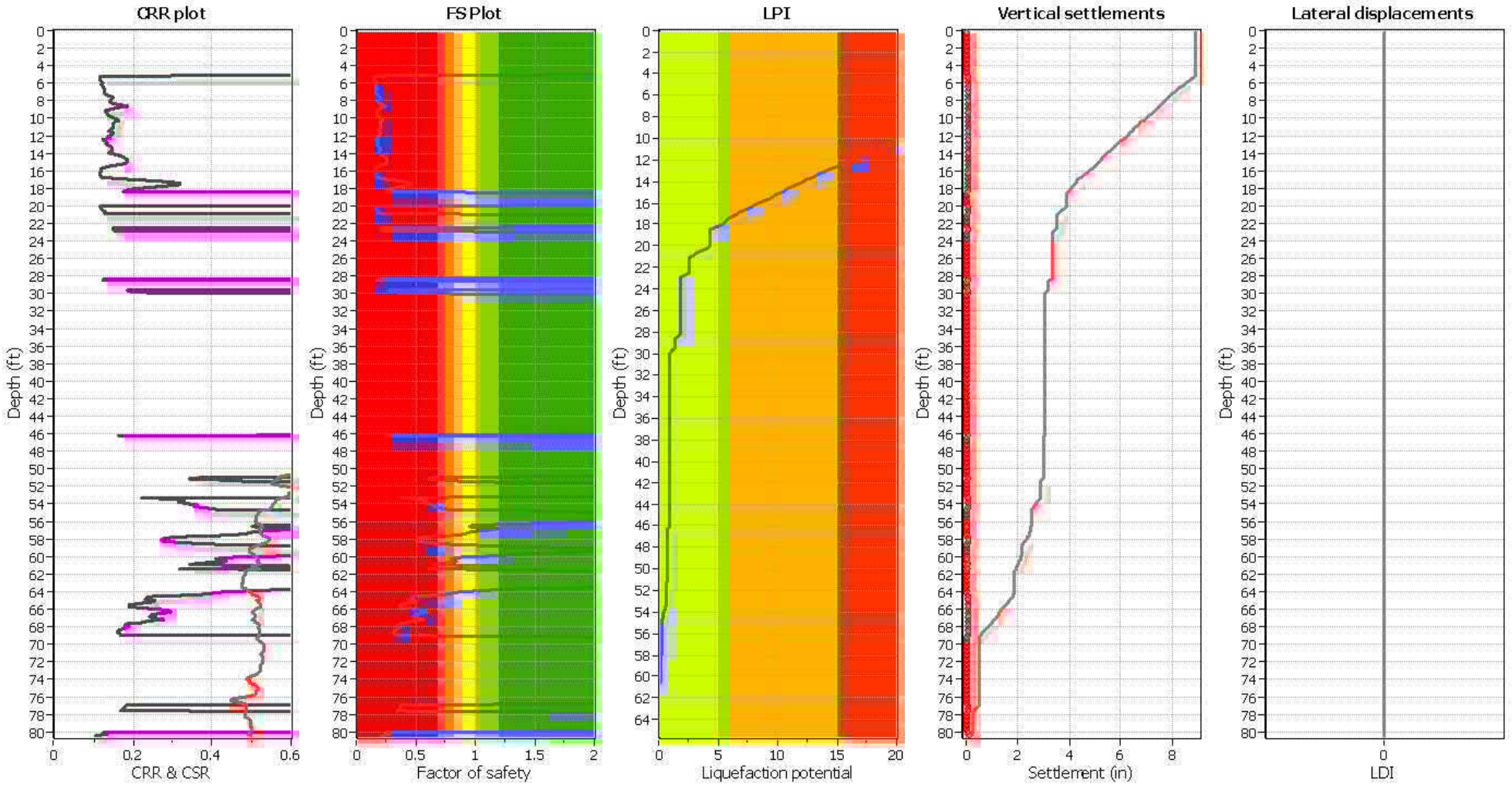
Liquefaction analysis overall plot



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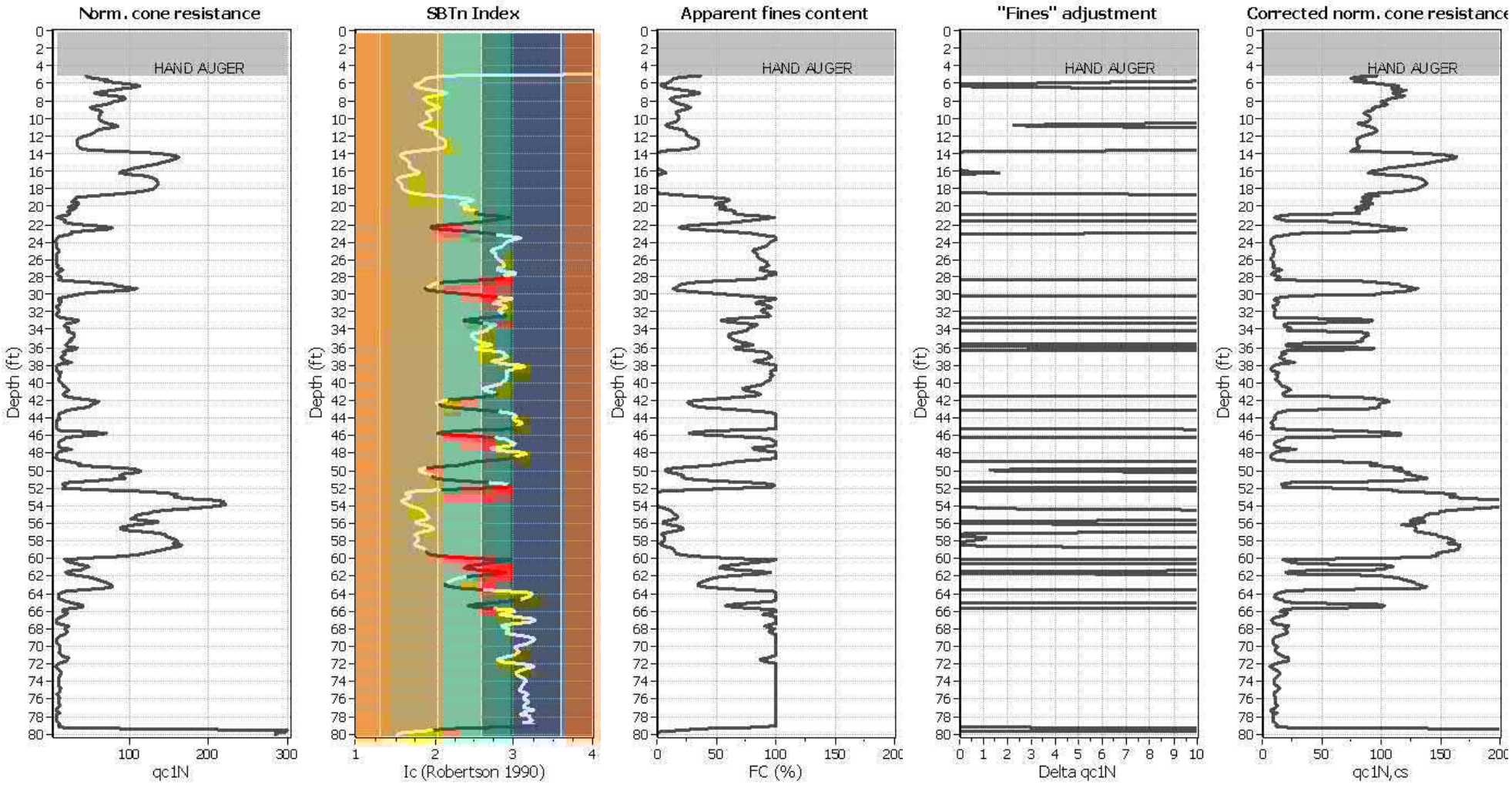

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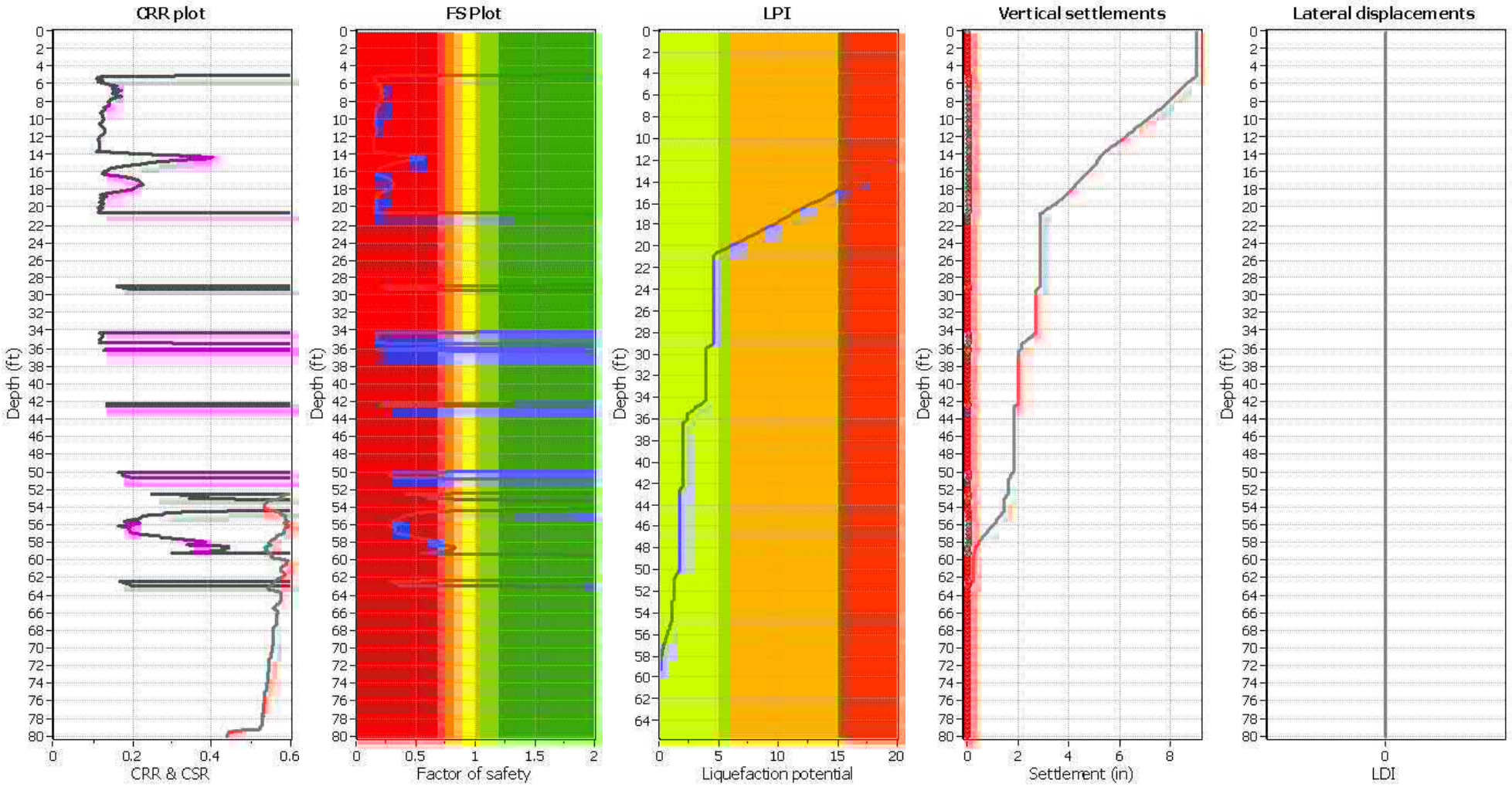

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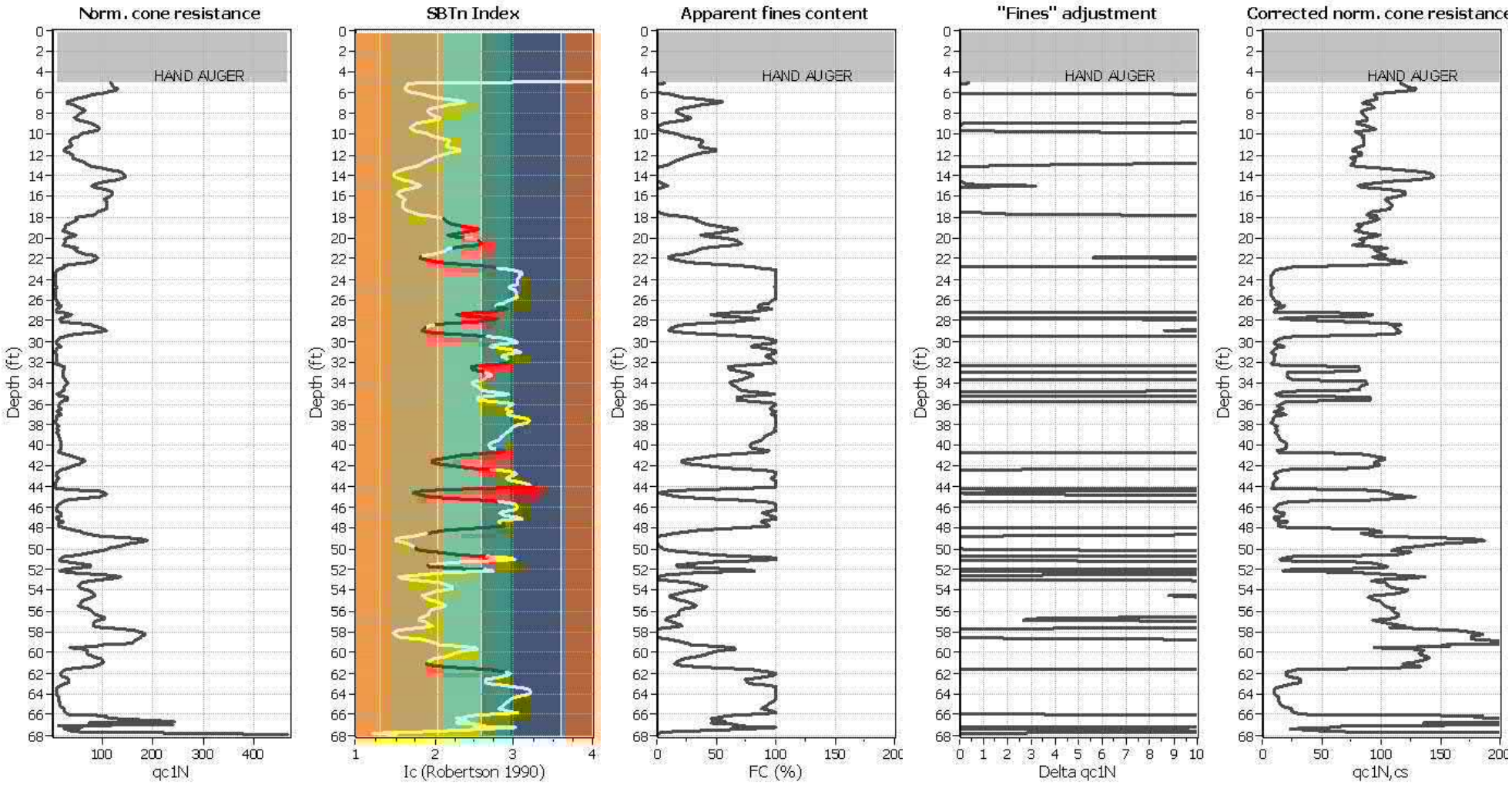

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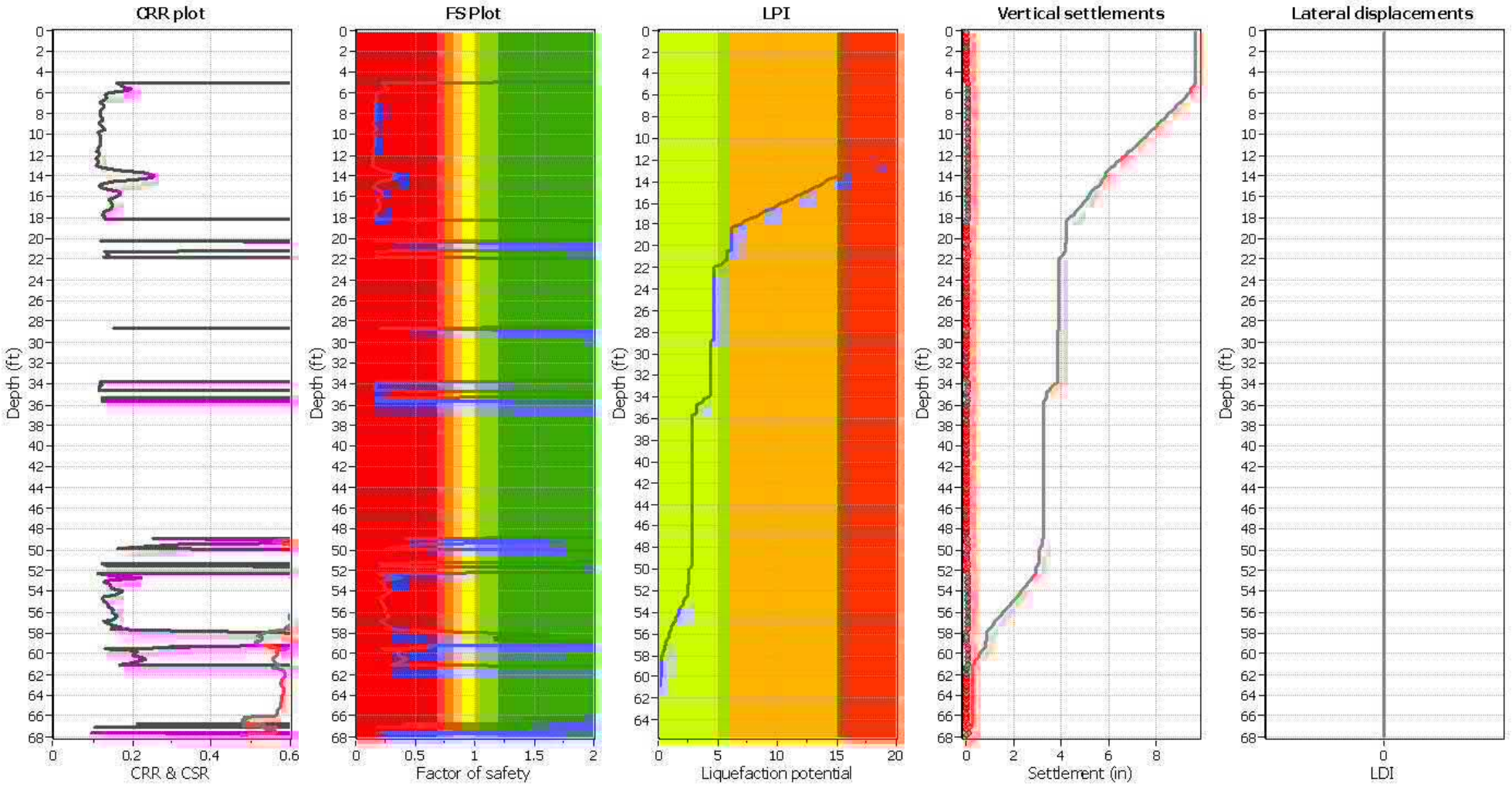

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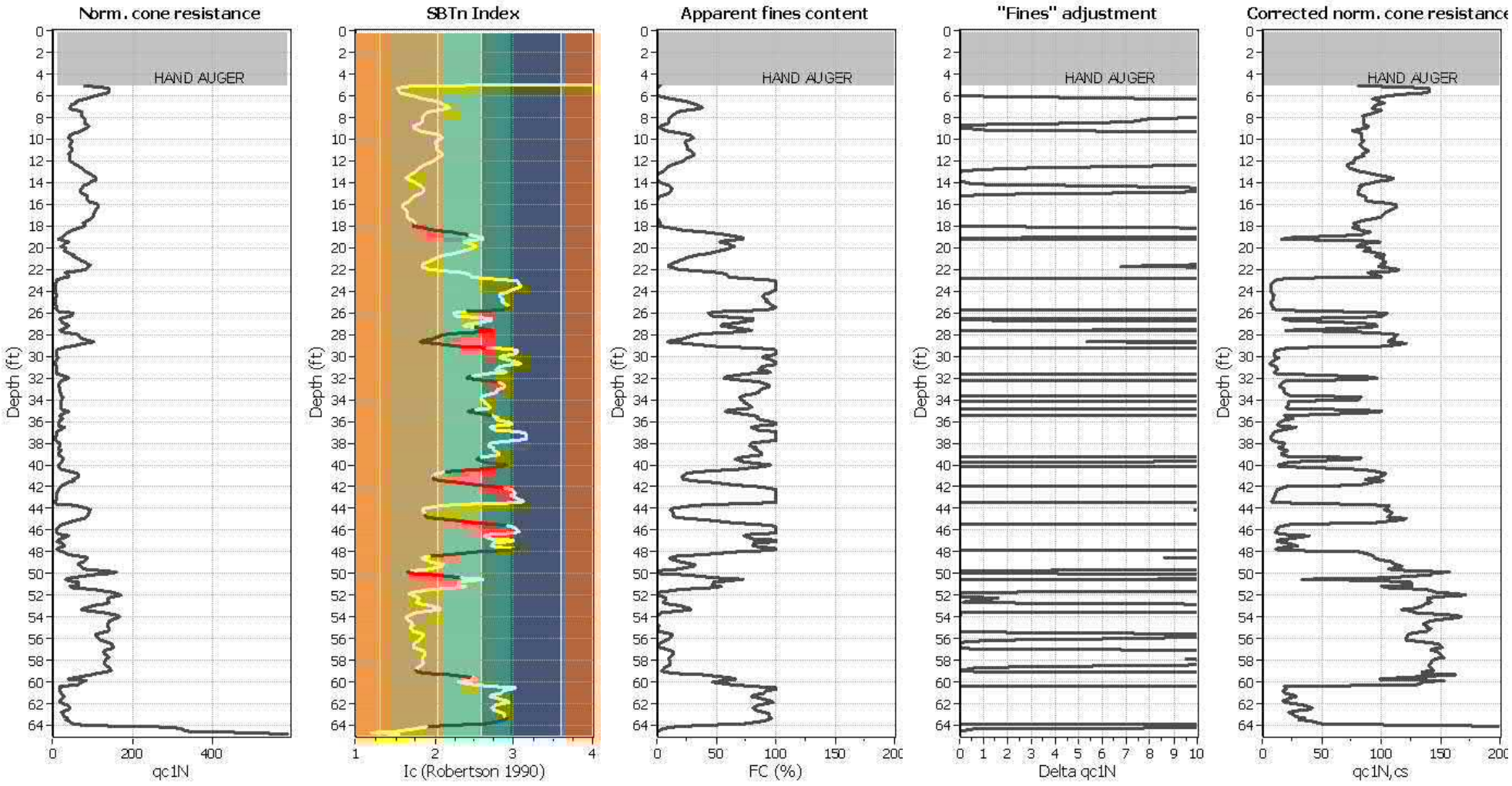

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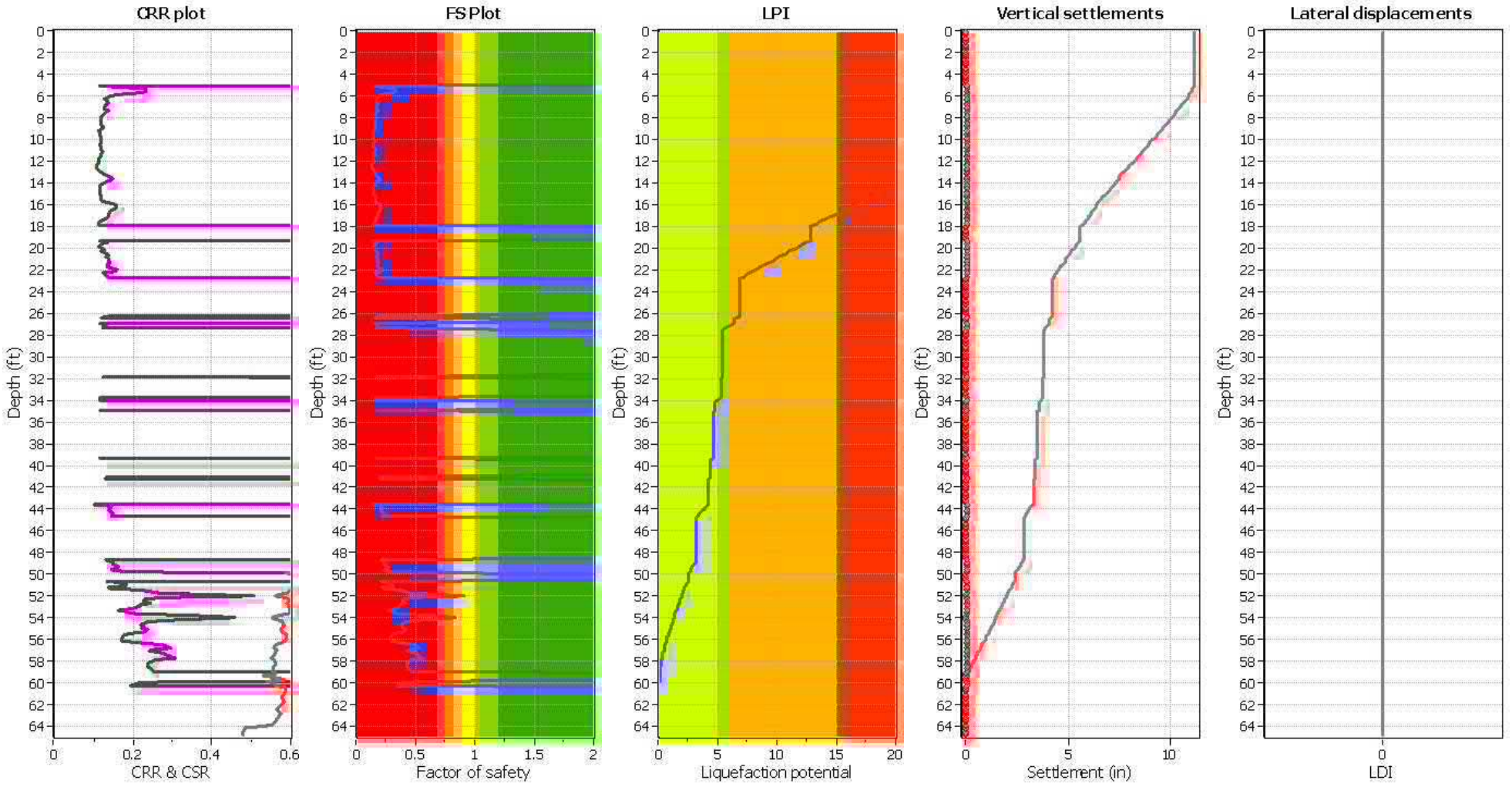

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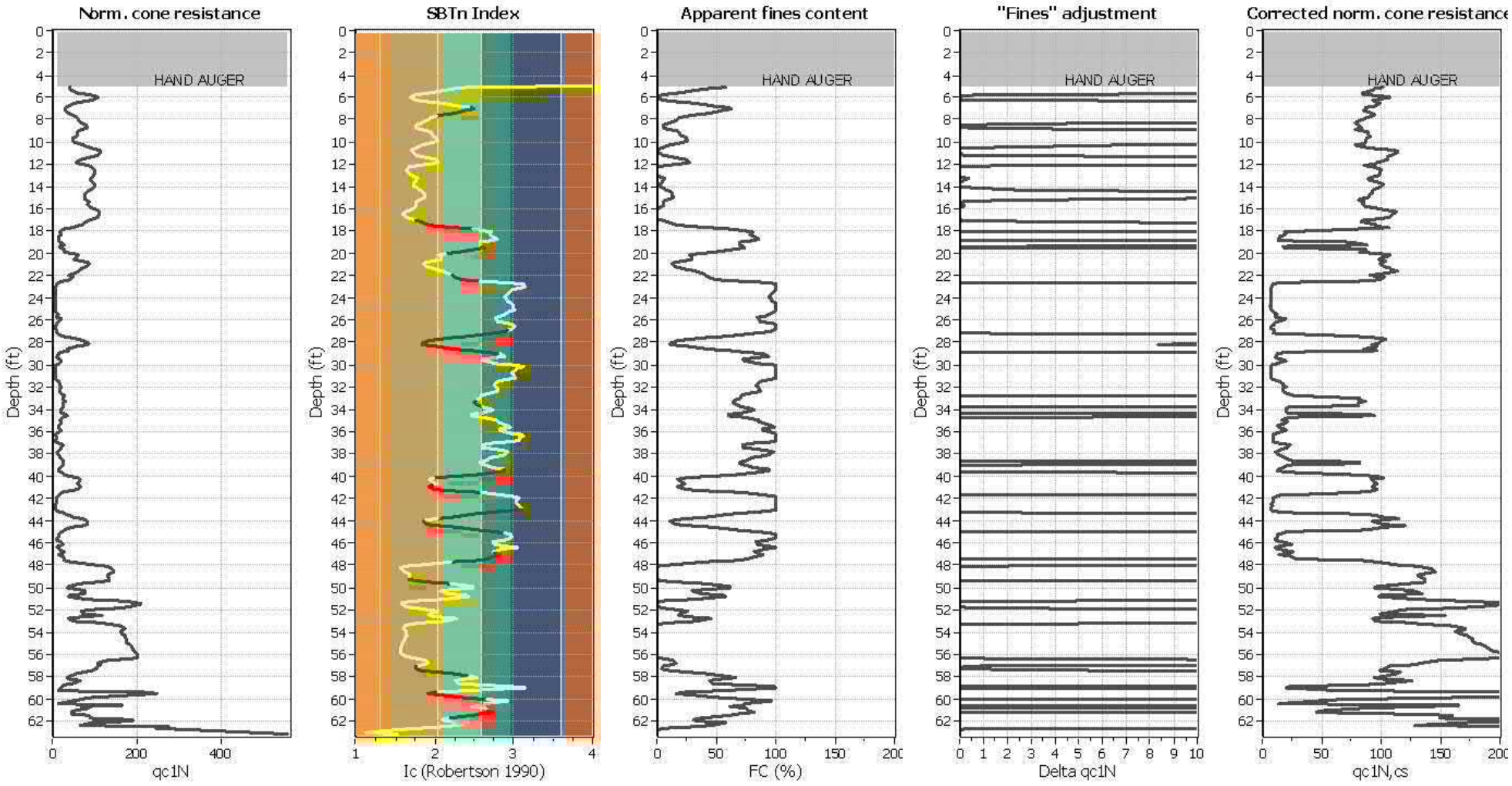

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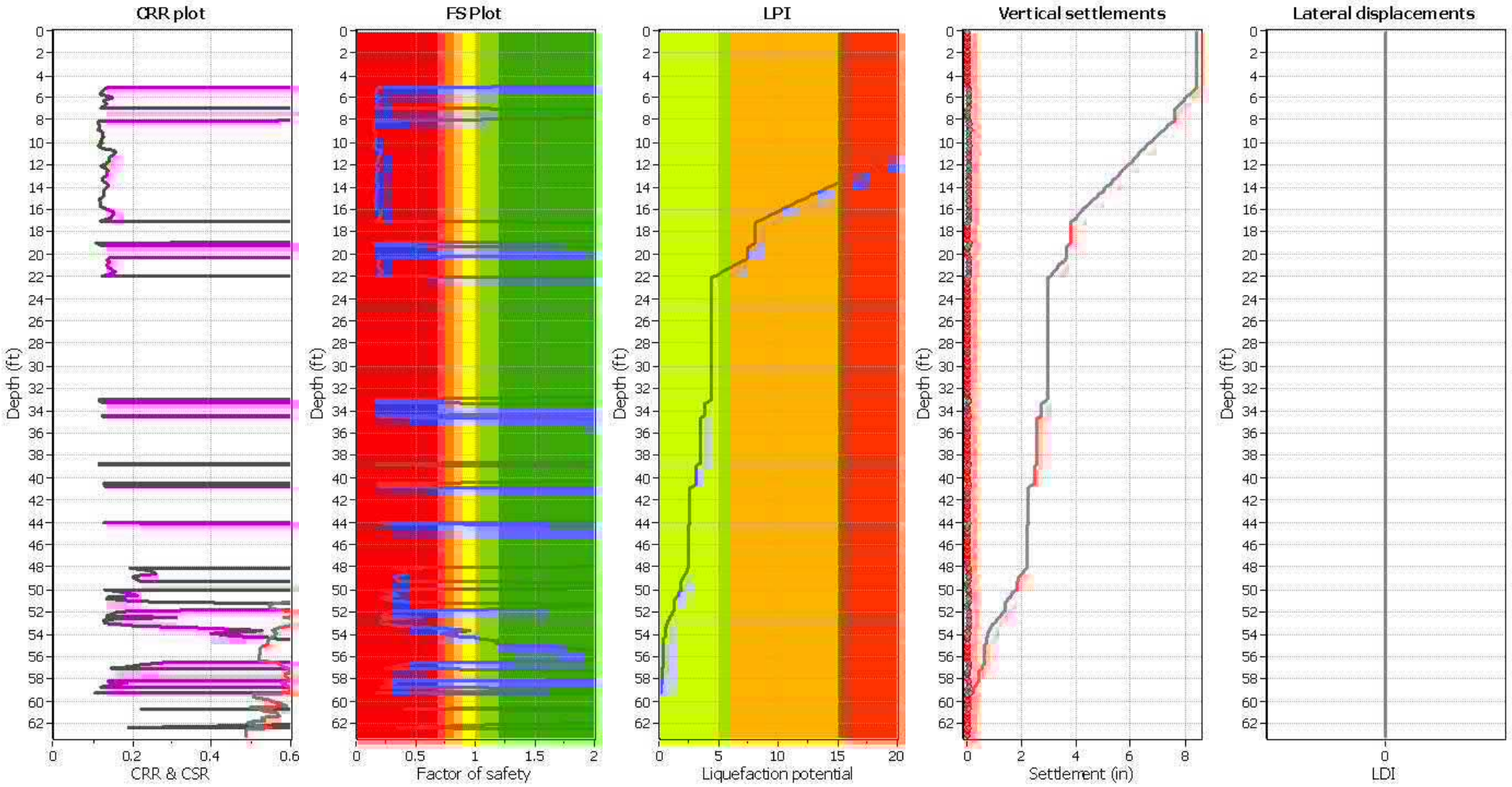

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Depth to water table (insitu):	9.00 ft	Fill height:	N/A	Limit depth:	N/A

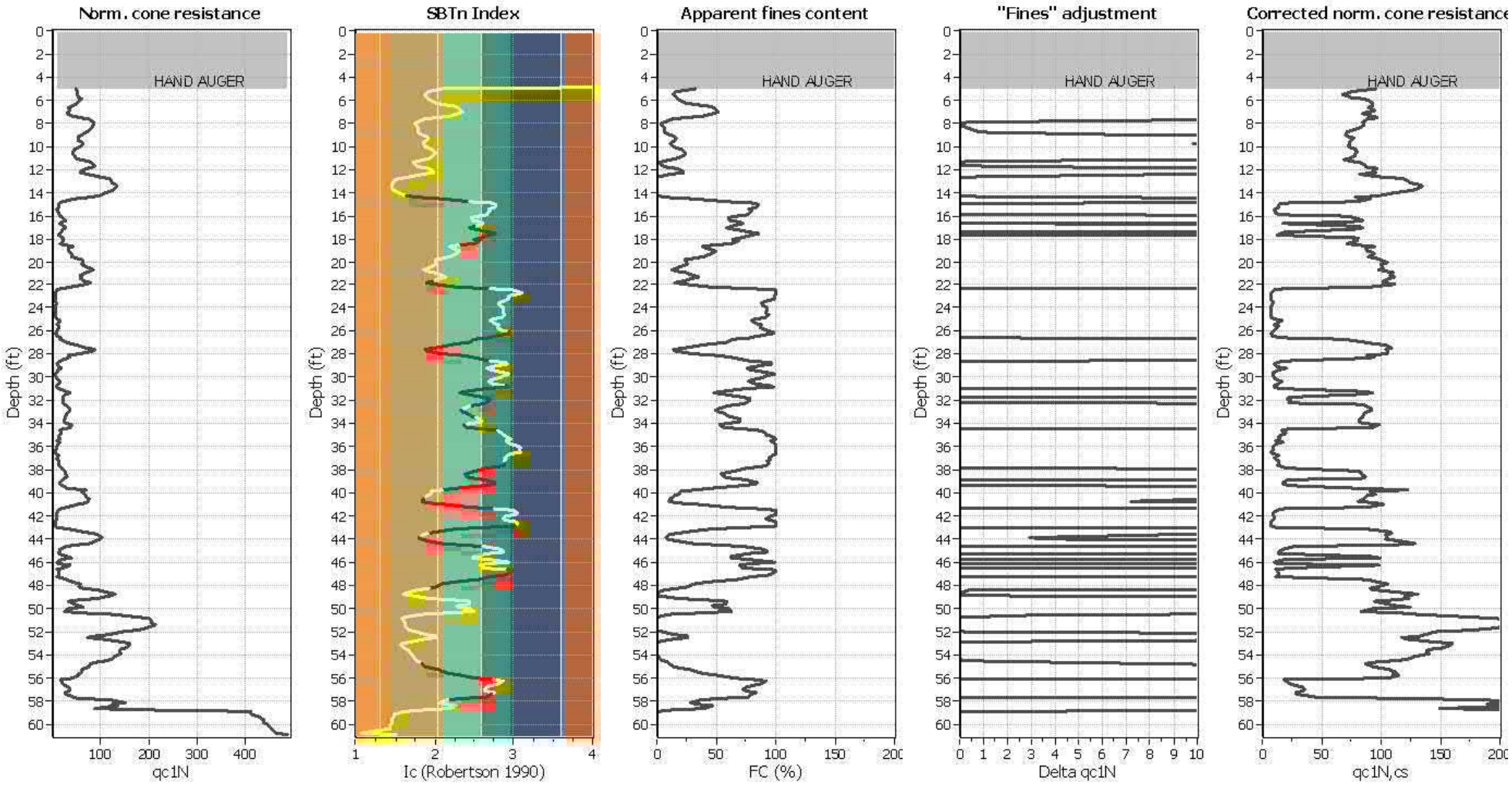
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis overall plots (intermediate resu



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.59	Use fill:	No	Limit depth applied:	No
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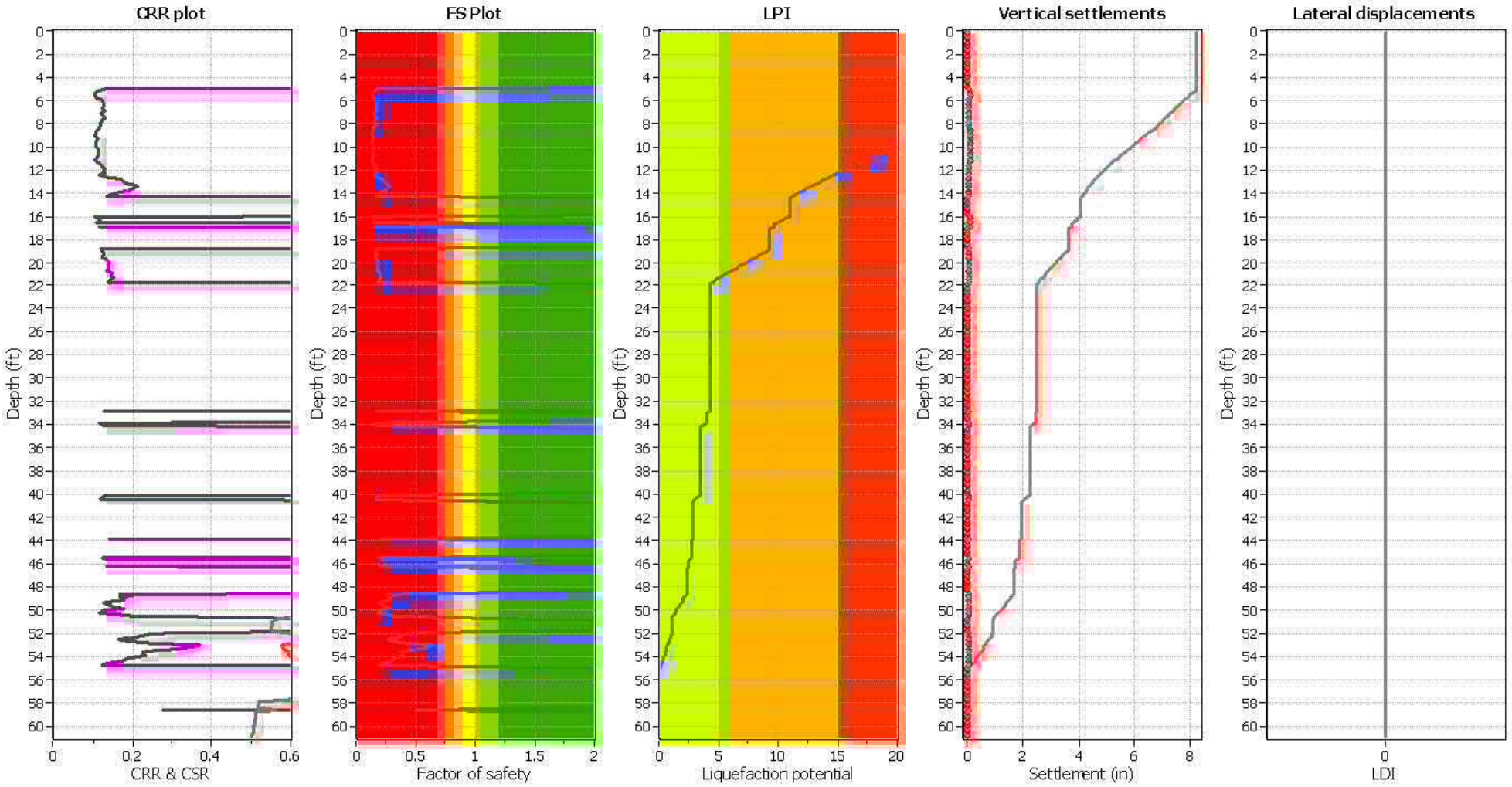
Liquefaction analysis overall plot



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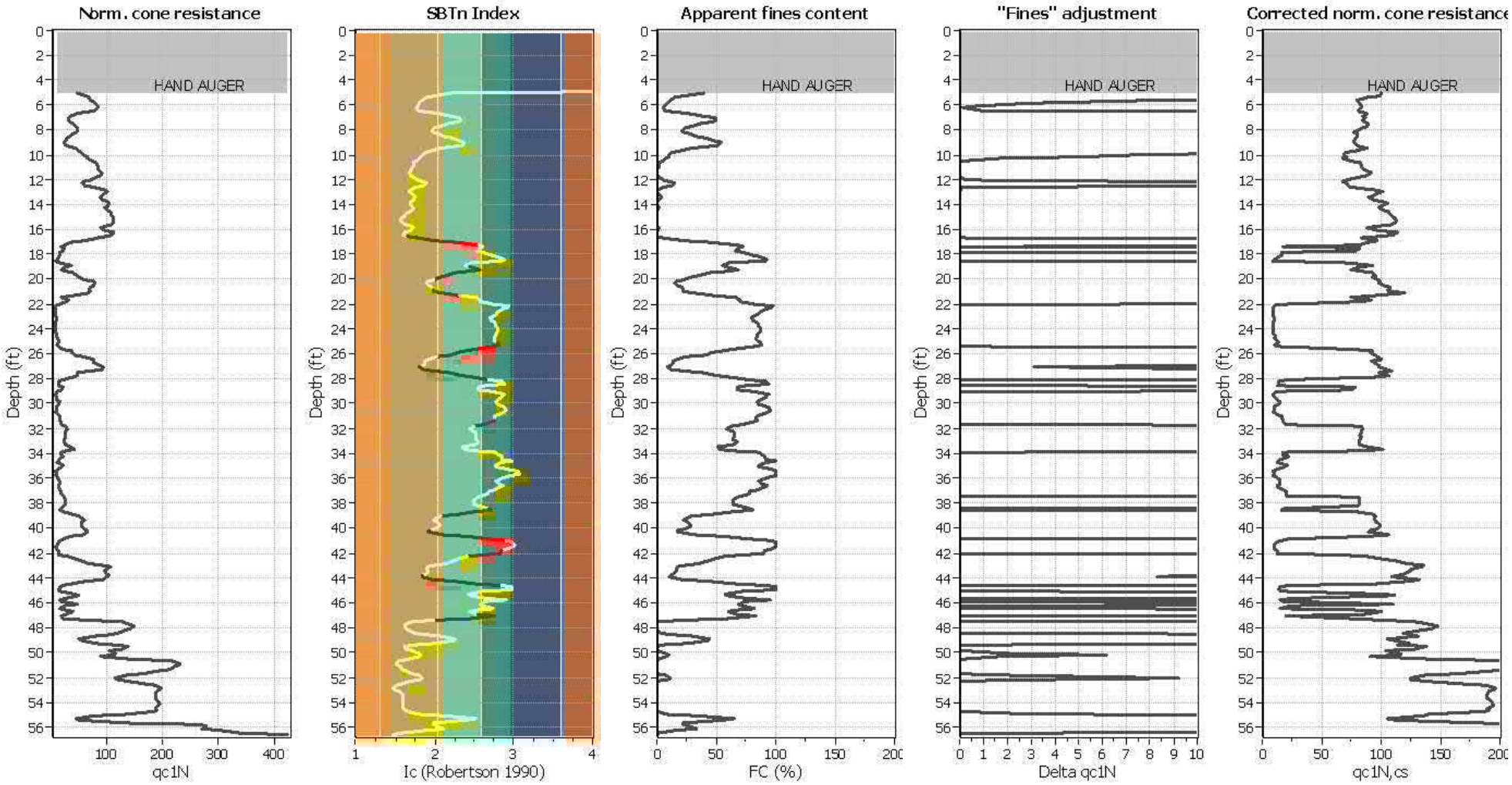

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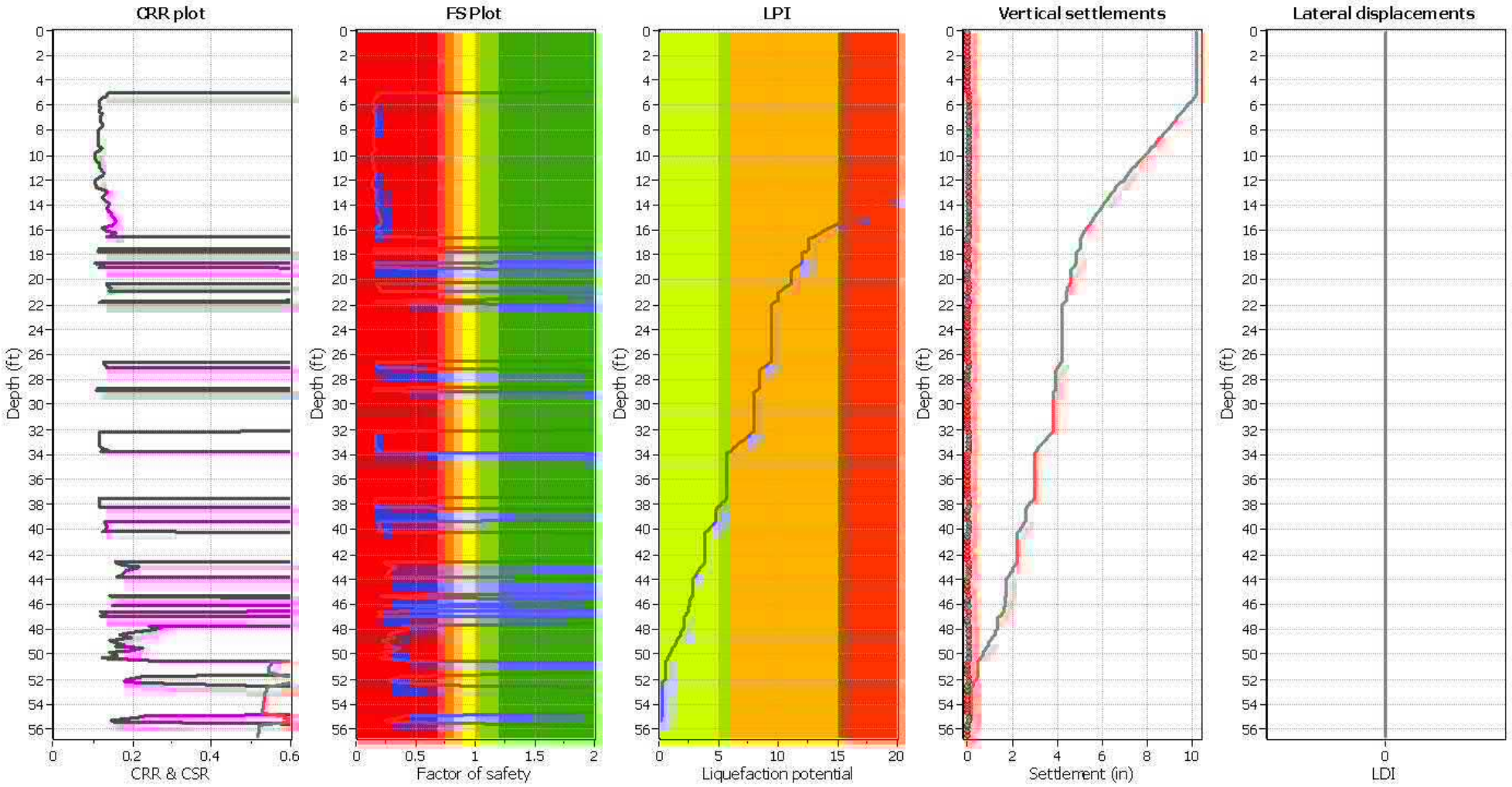
Liquefaction analysis overall plot



Input parameters and analysis data

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Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
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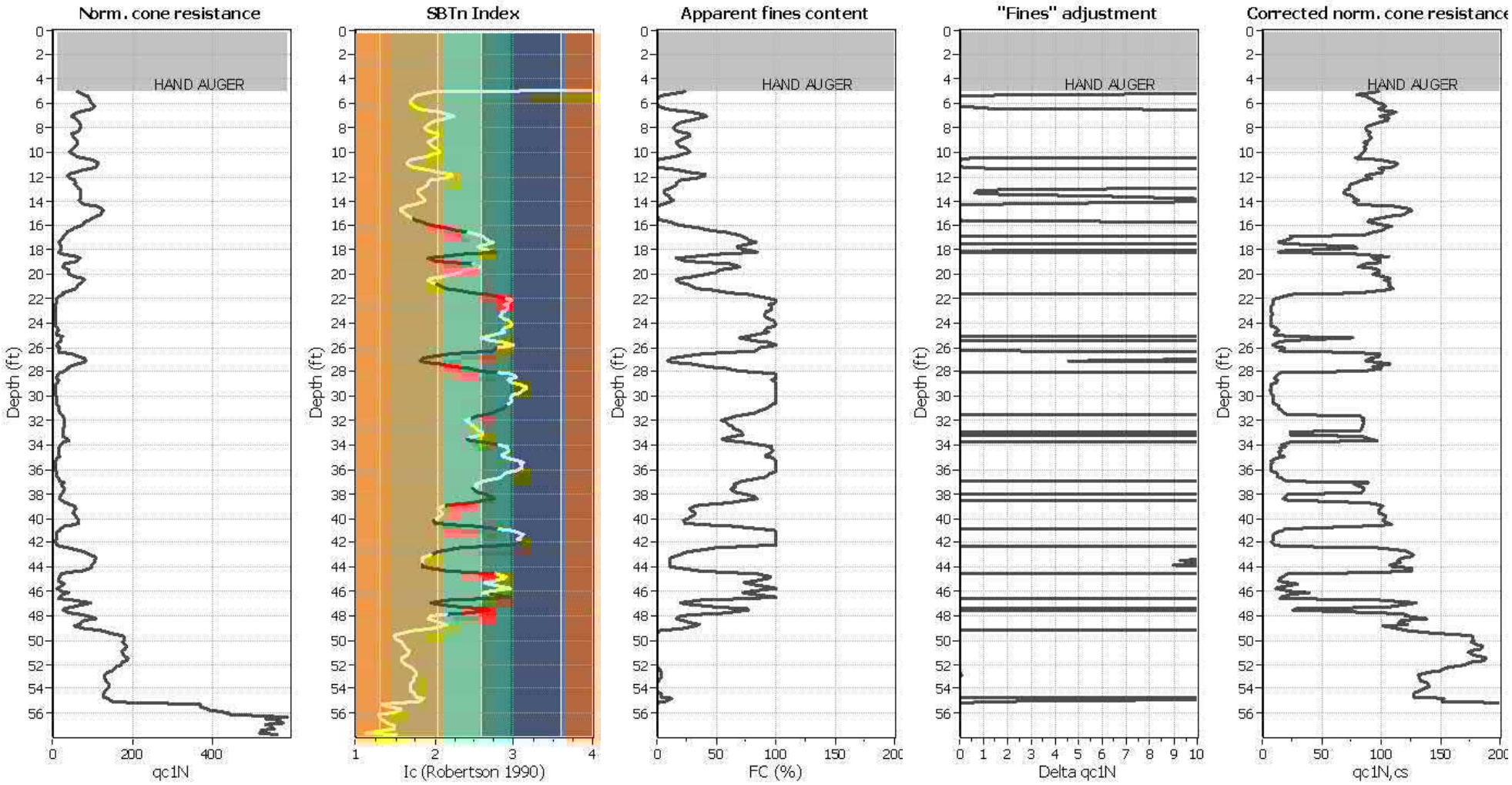

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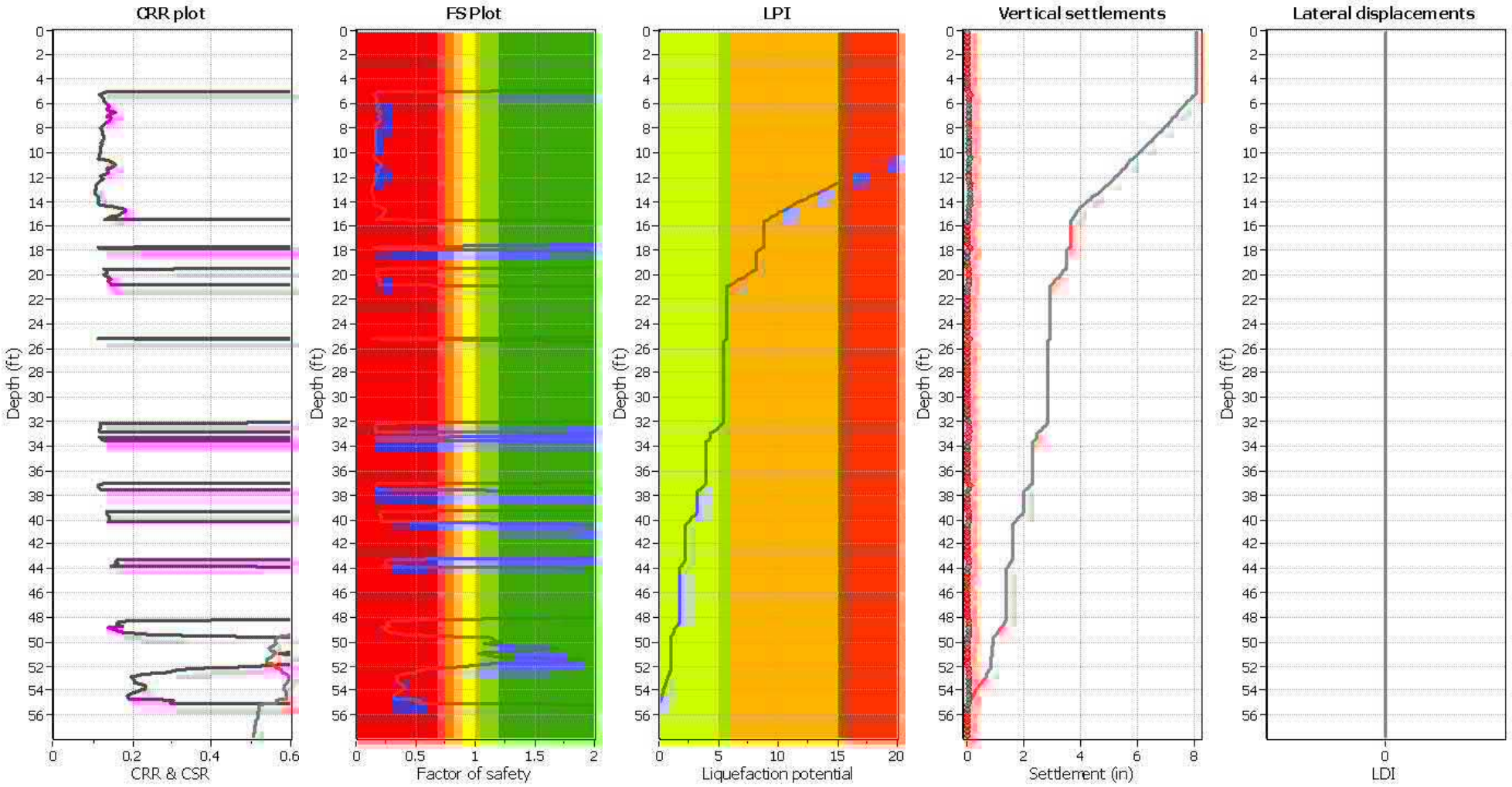

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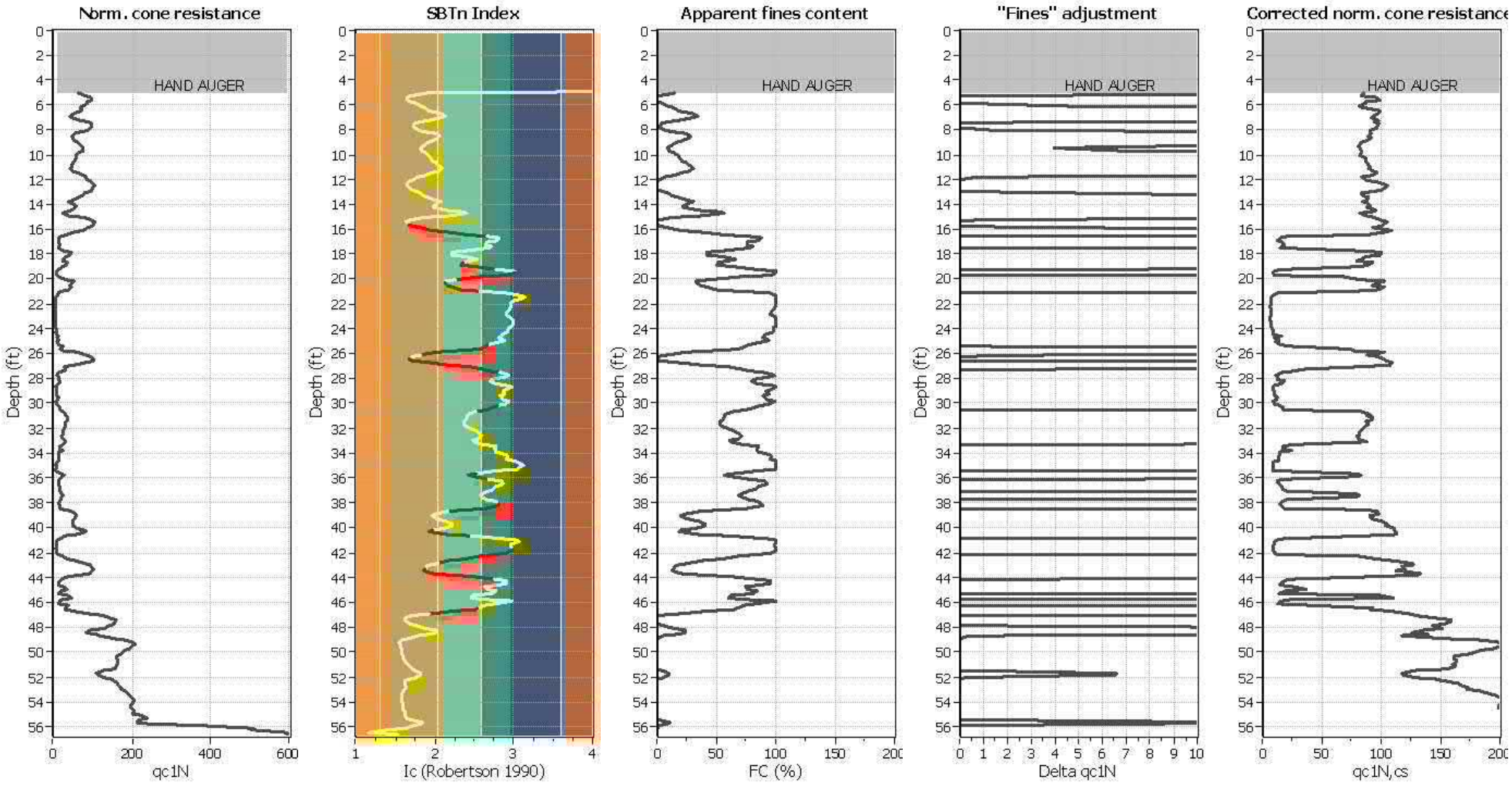

Input parameters and analysis data

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Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
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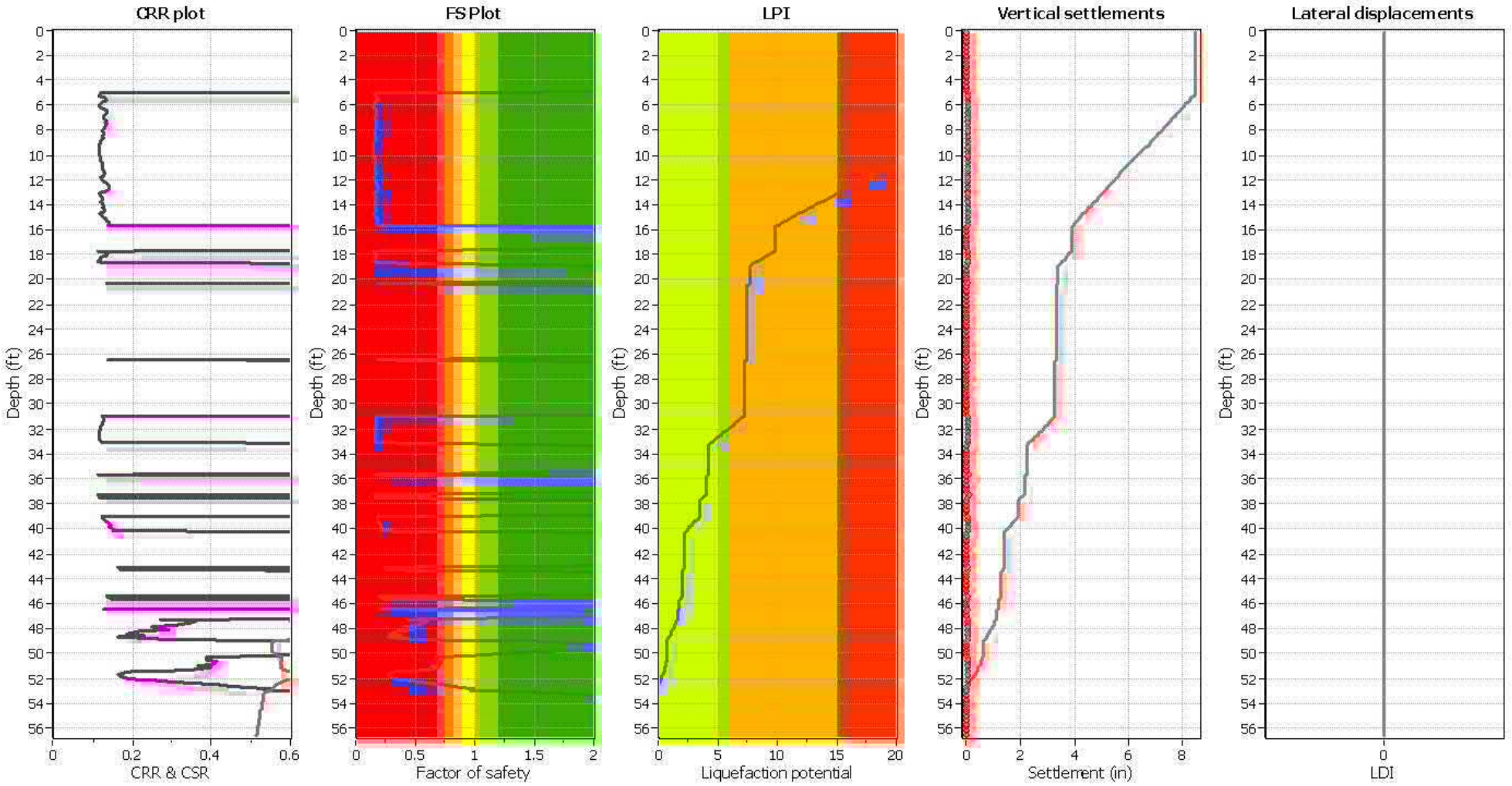
Liquefaction analysis overall plot



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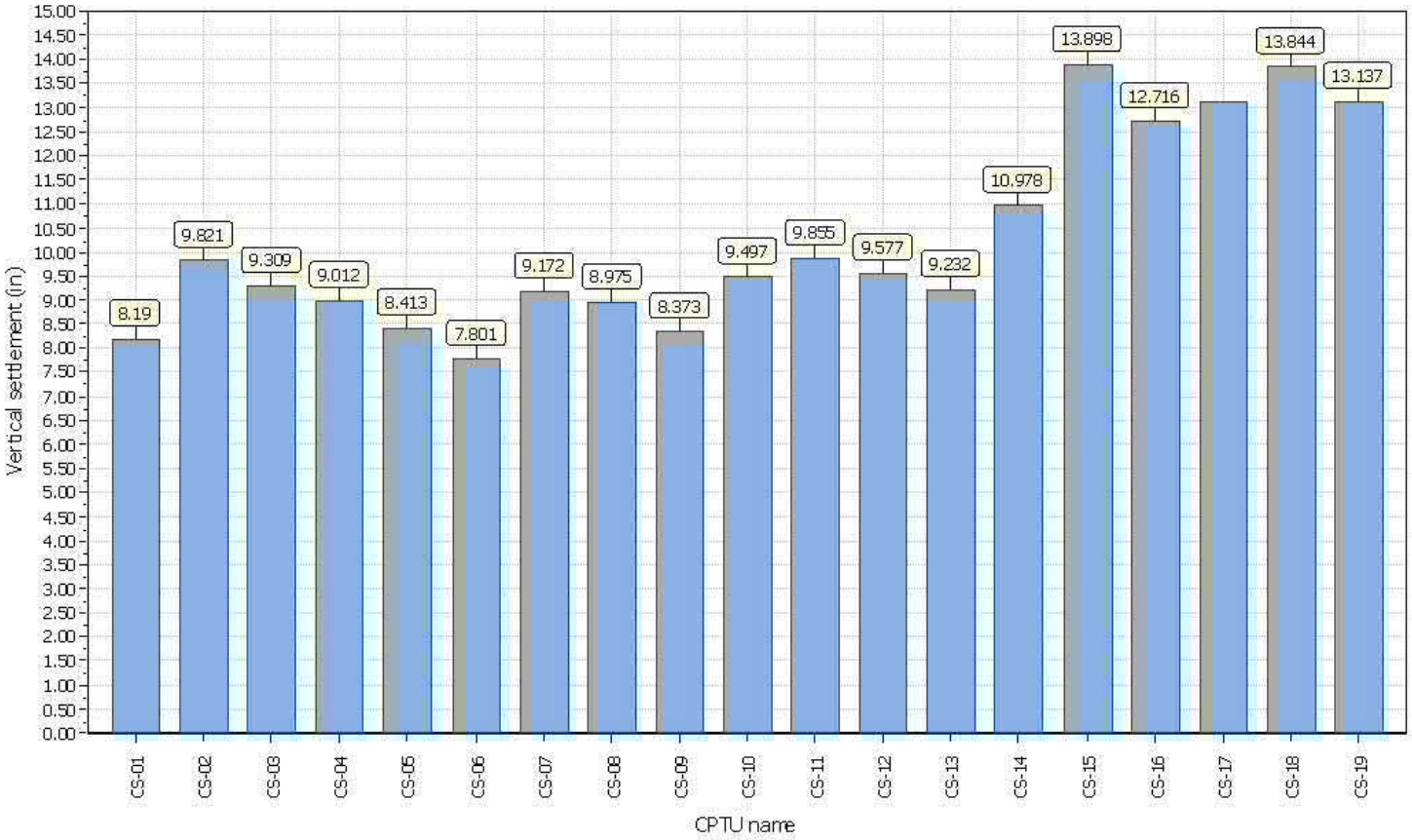
Liquefaction Analyses of CPTs Located on Custer Street

GeoLogismiki
Geotechnical Engineers
Merarhias 56
http://www.geologismiki.gr

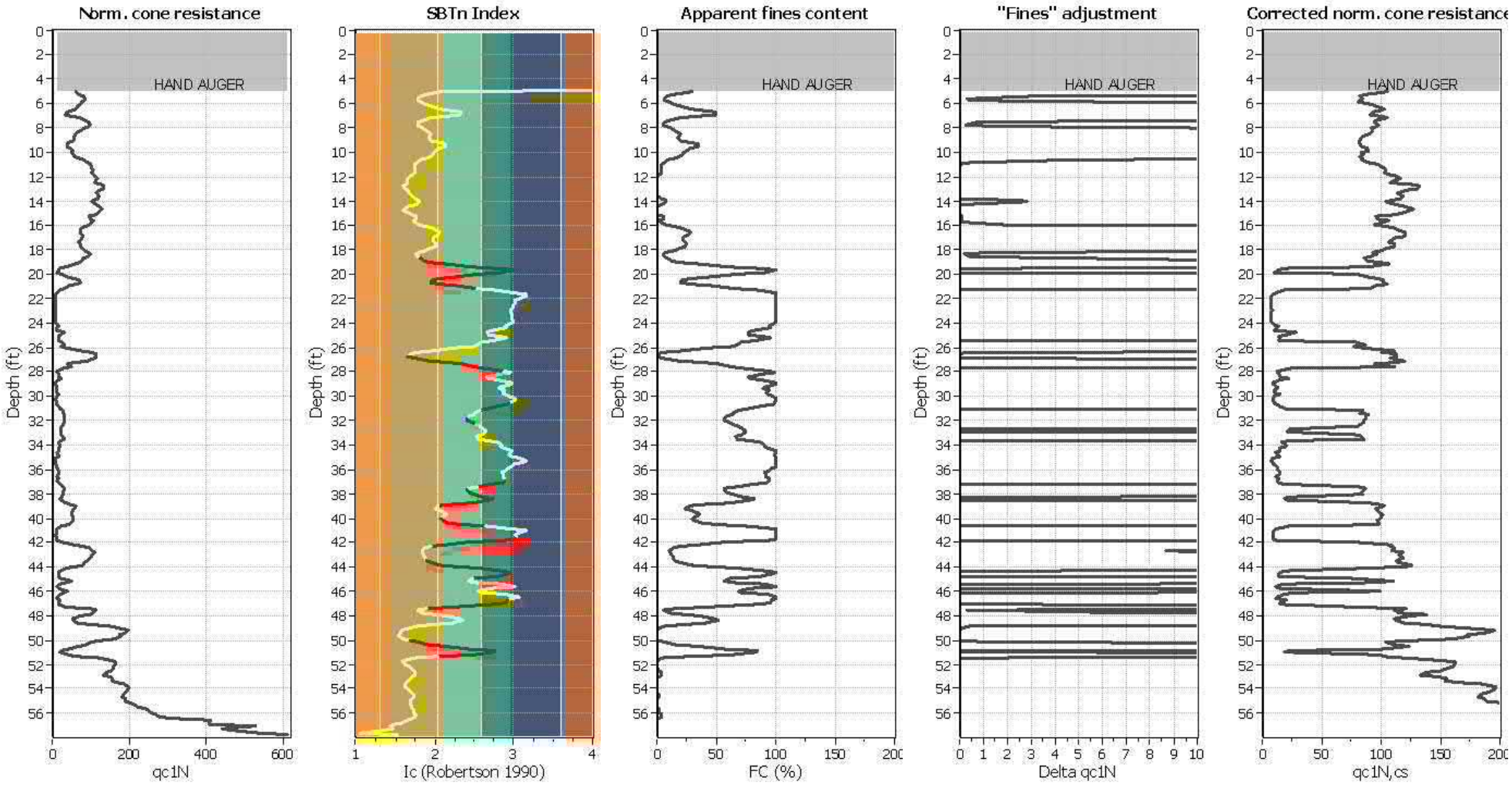
Project title :

Location :

Overall vertical settlements report



Liquefaction analysis overall plots (intermediate resu



Input parameters and analysis data

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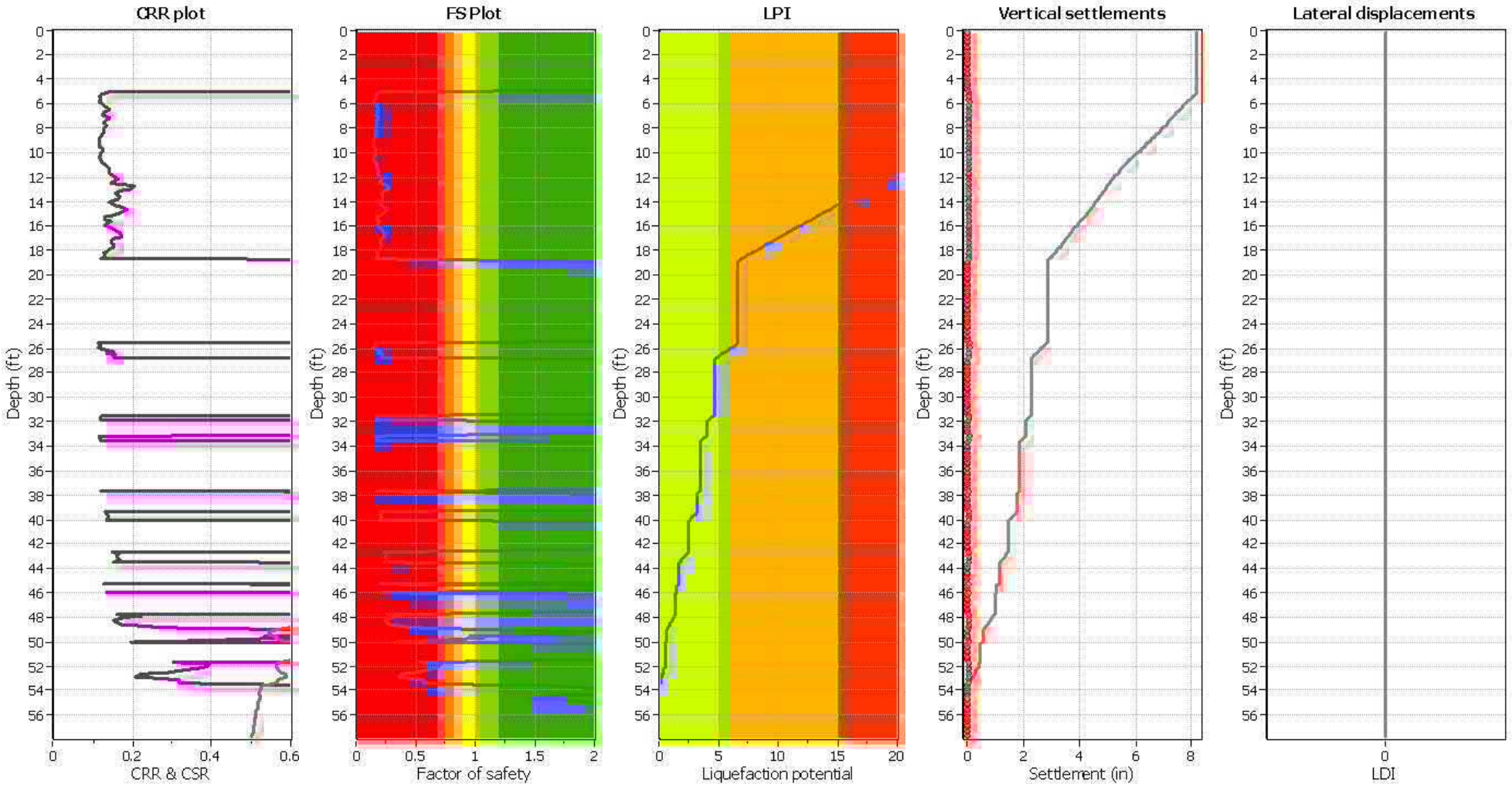
Liquefaction analysis overall plot



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LPI color scheme

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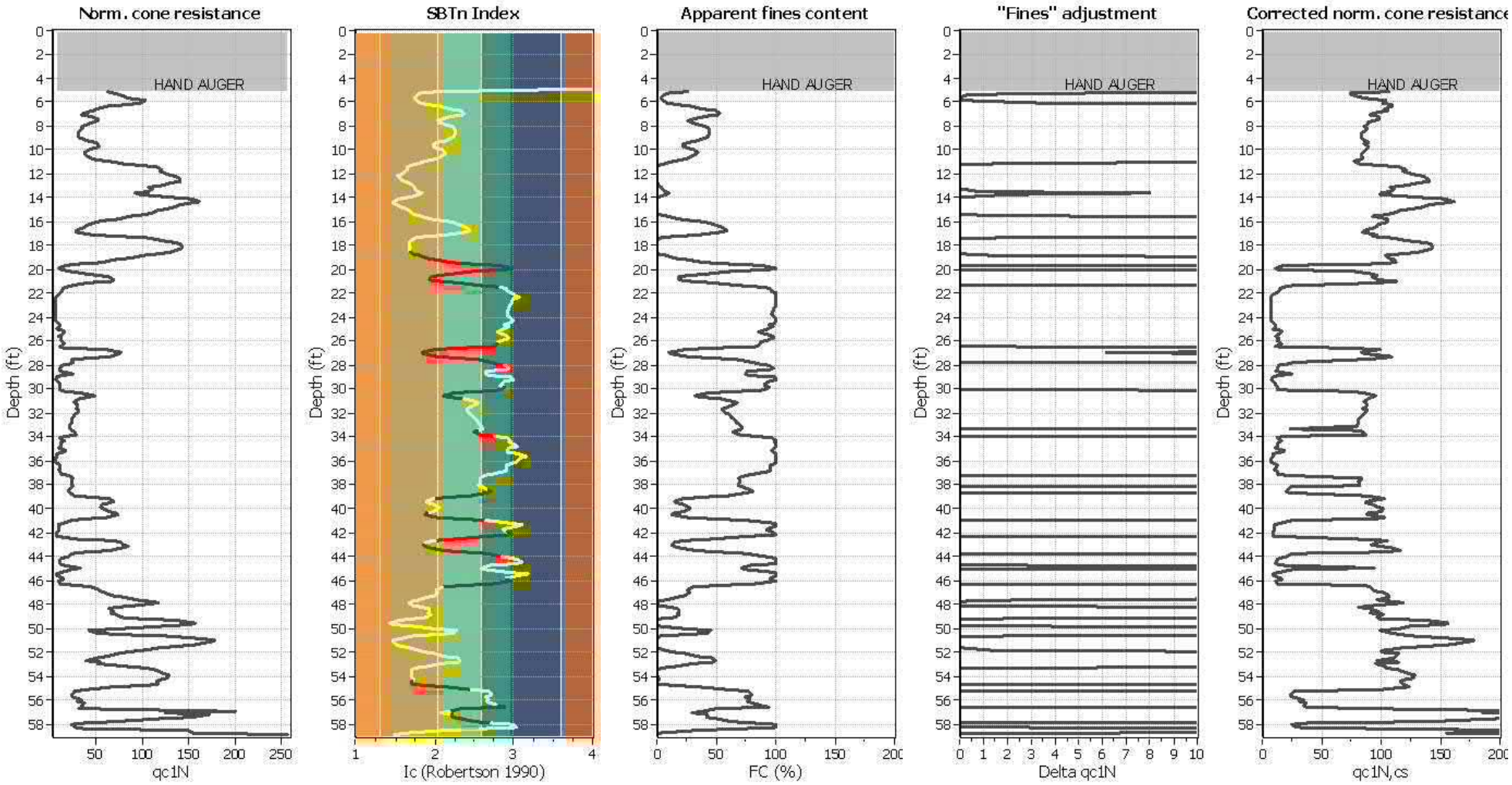
Liquefaction analysis overall plots (intermediate resu



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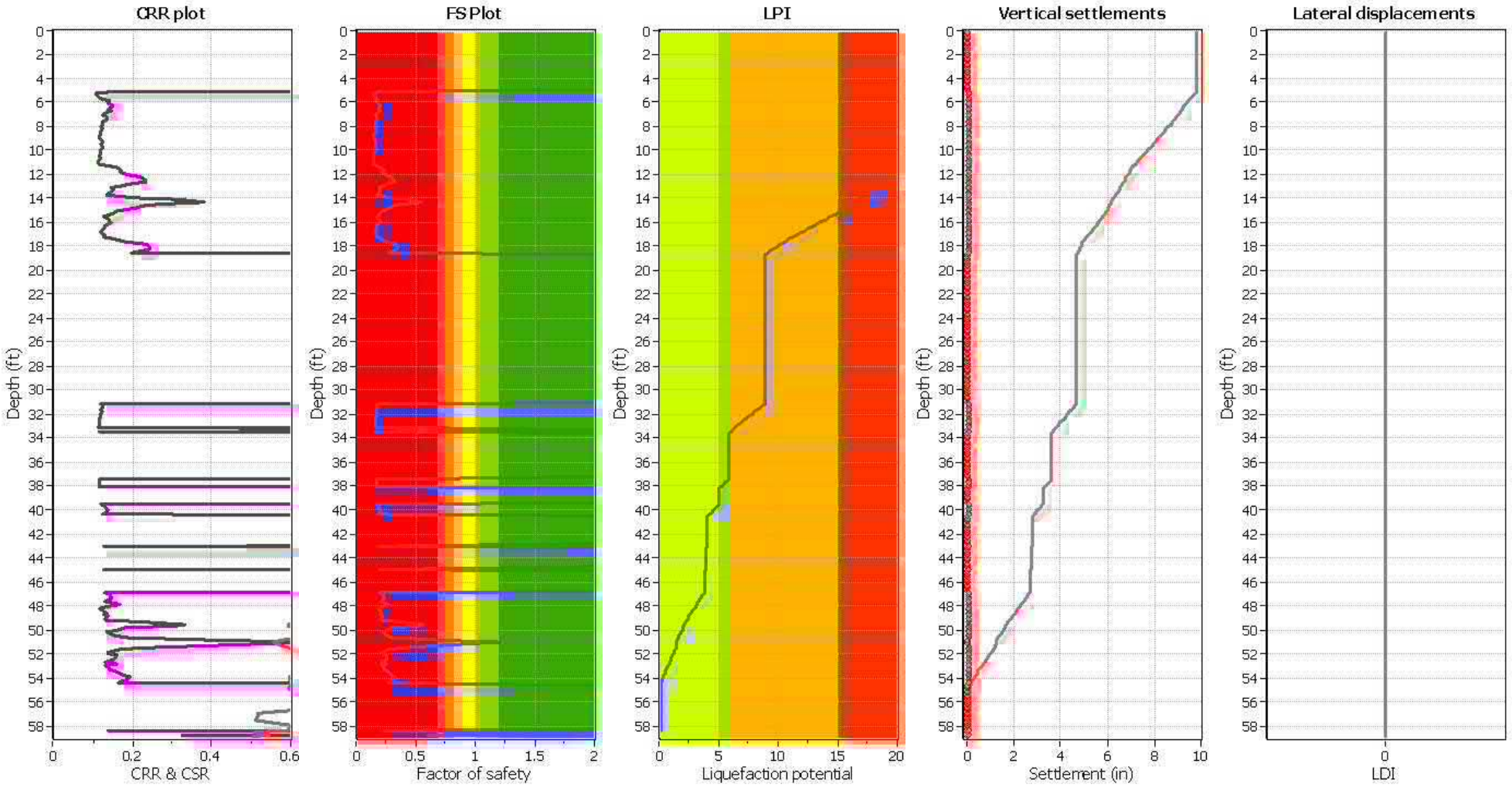
Liquefaction analysis overall plot



Input parameters and analysis data

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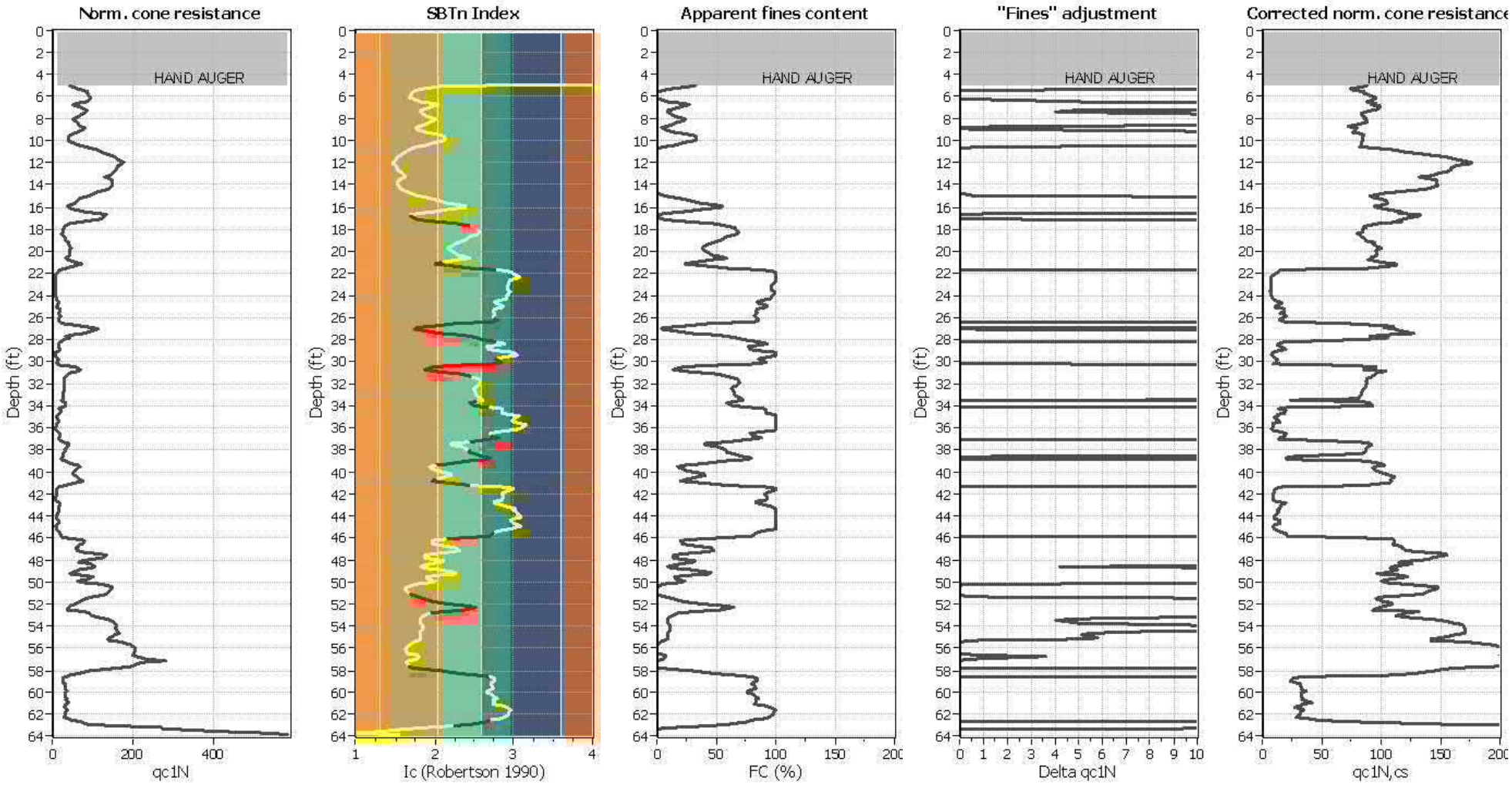
Liquefaction analysis overall plots (intermediate resu



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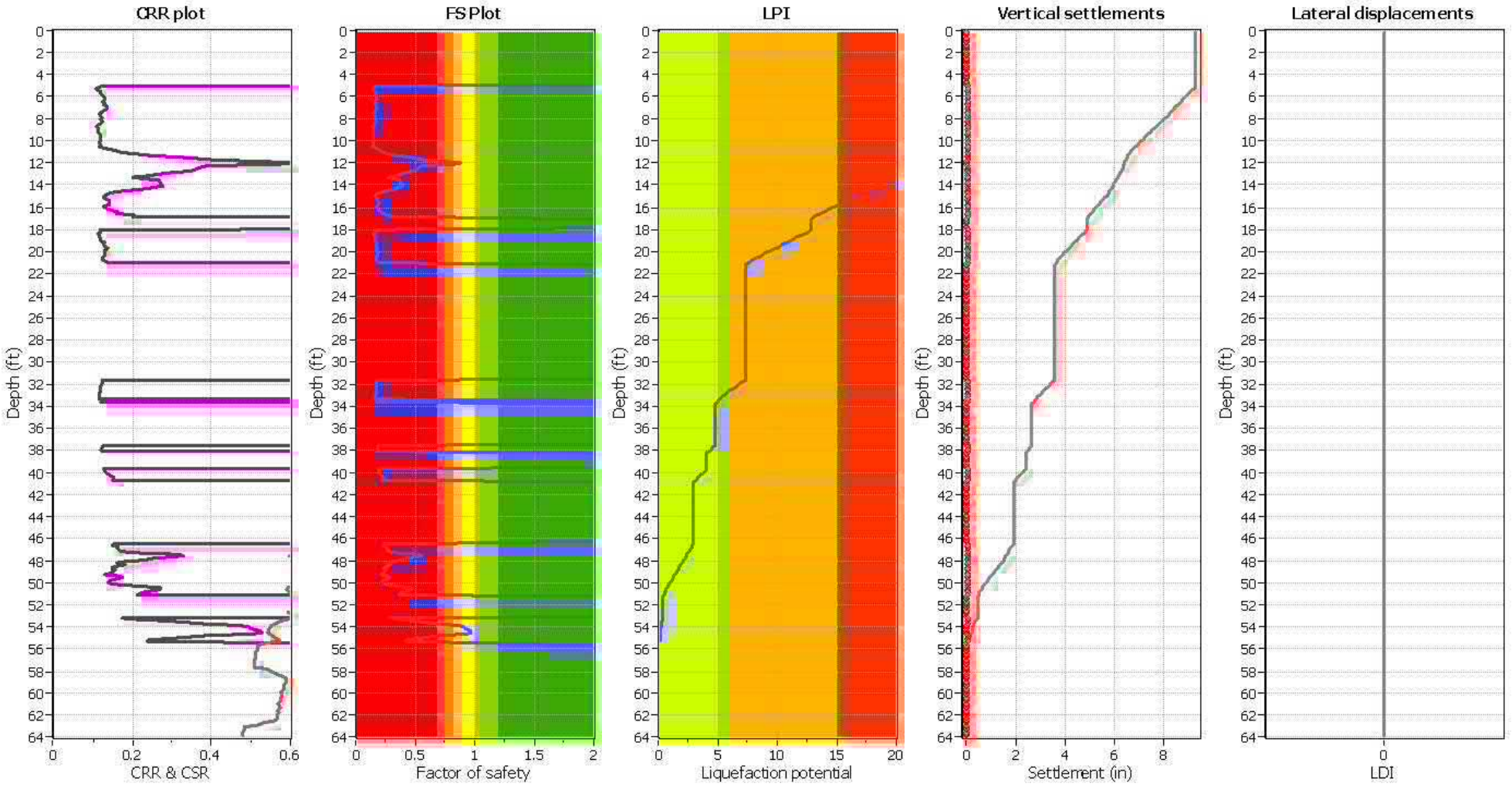

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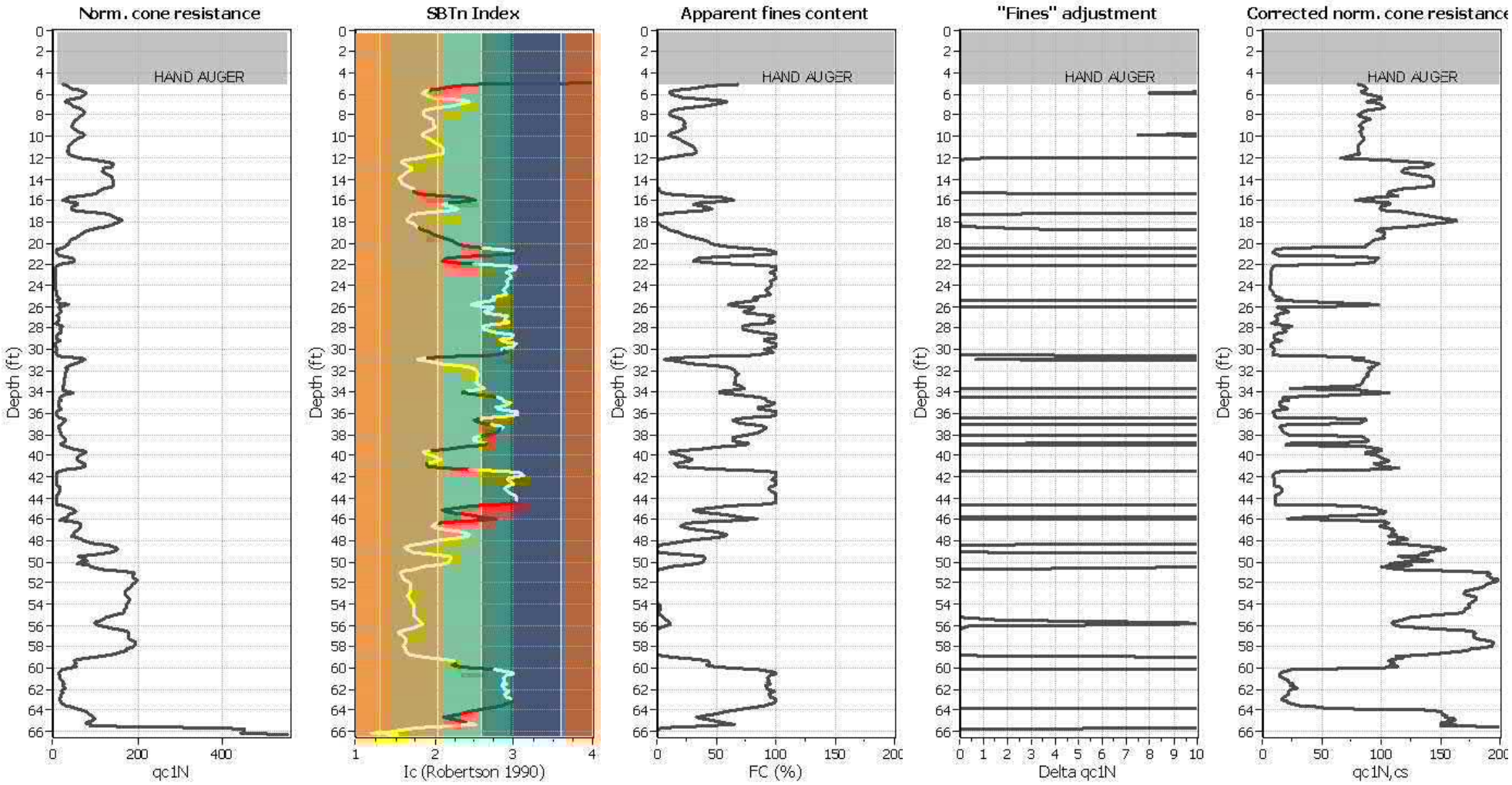

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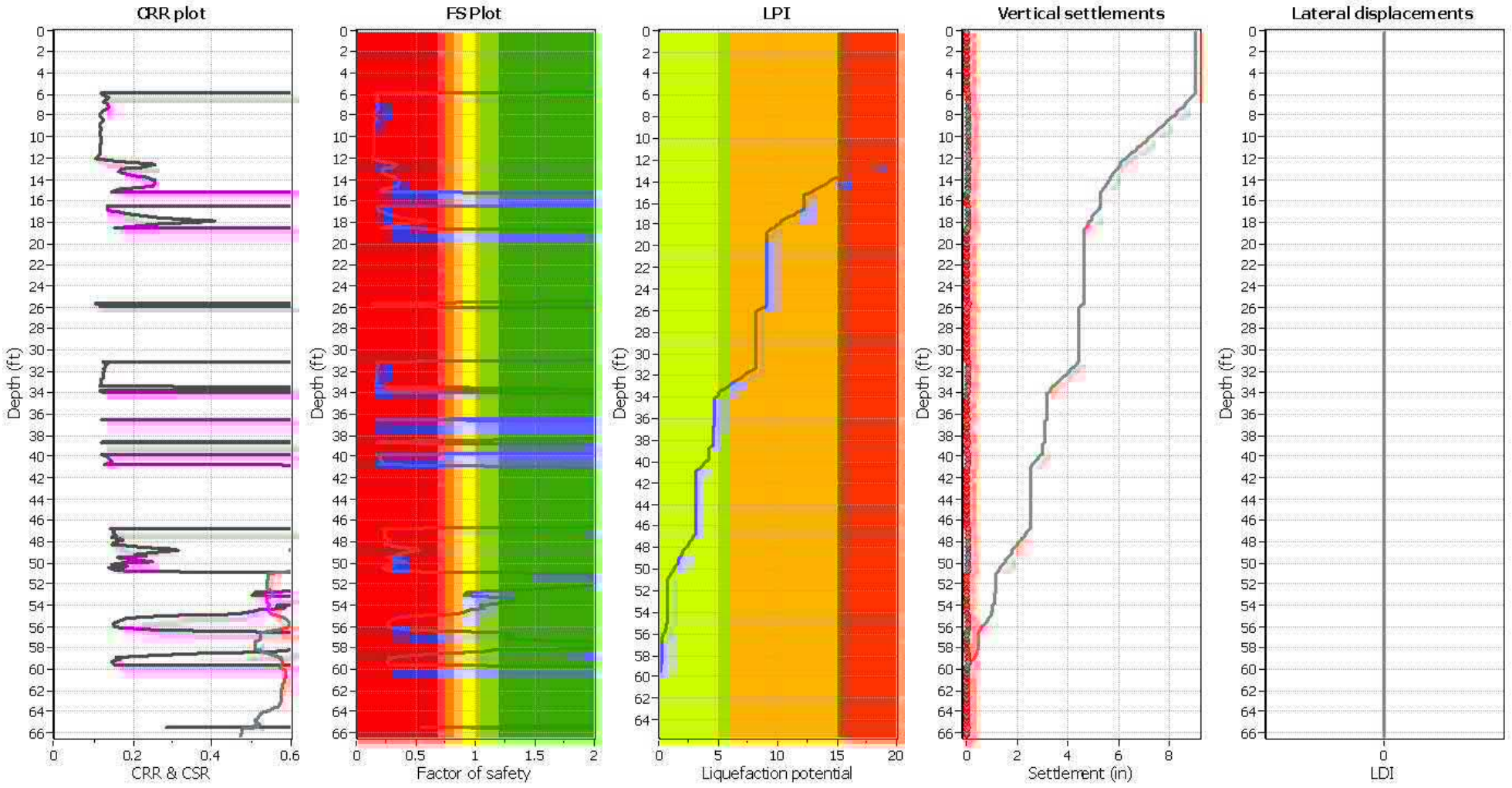

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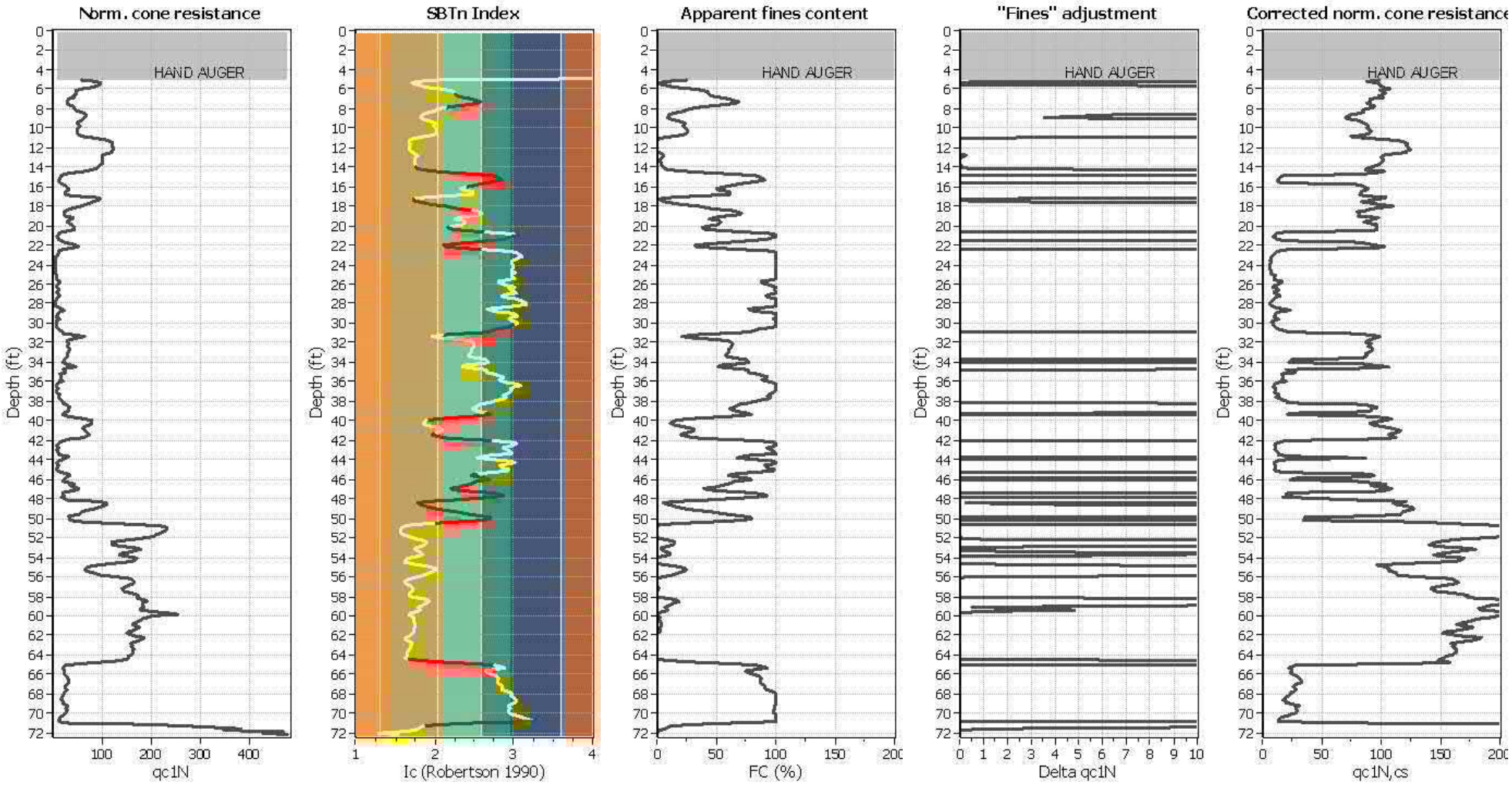

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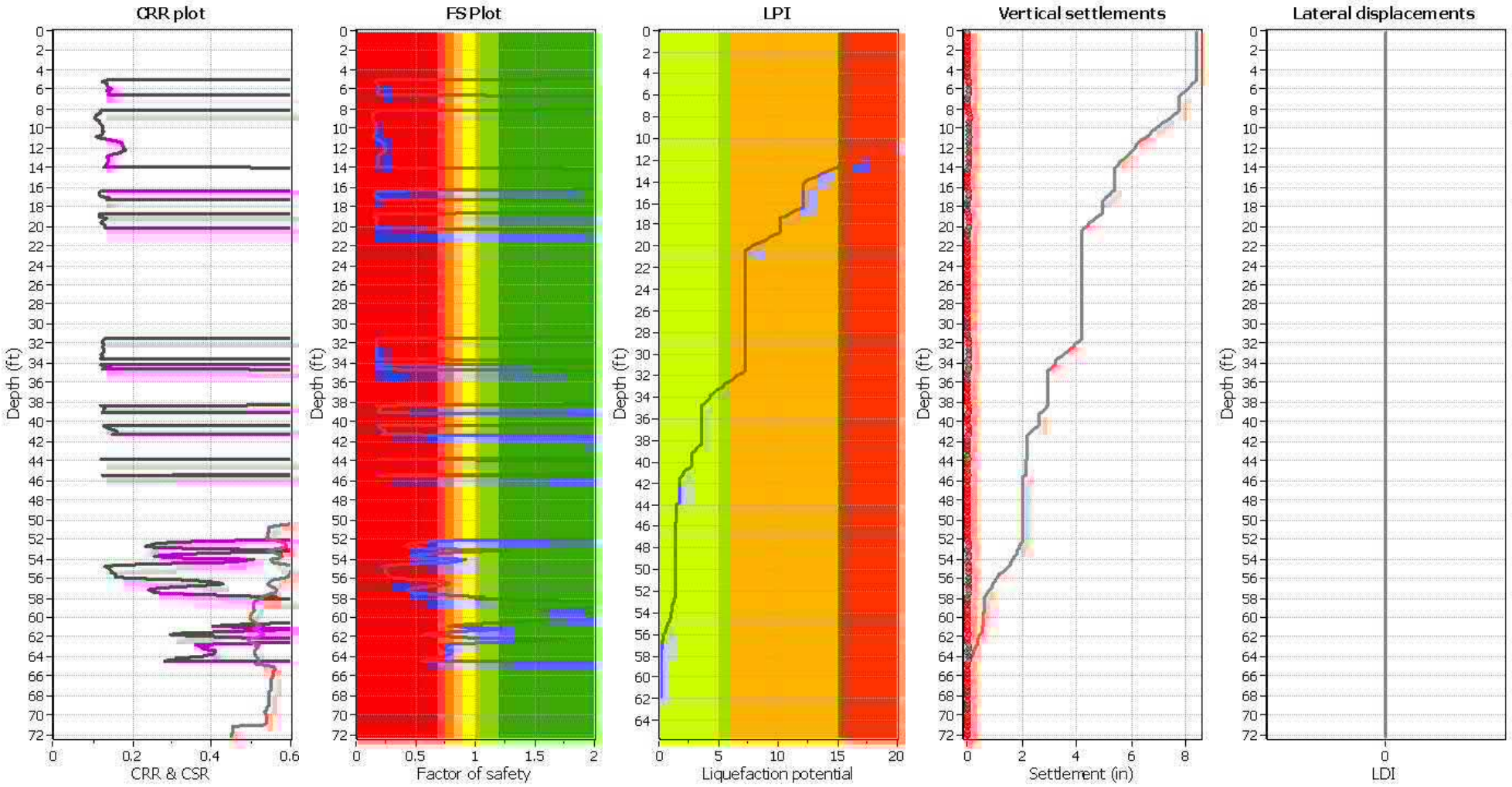

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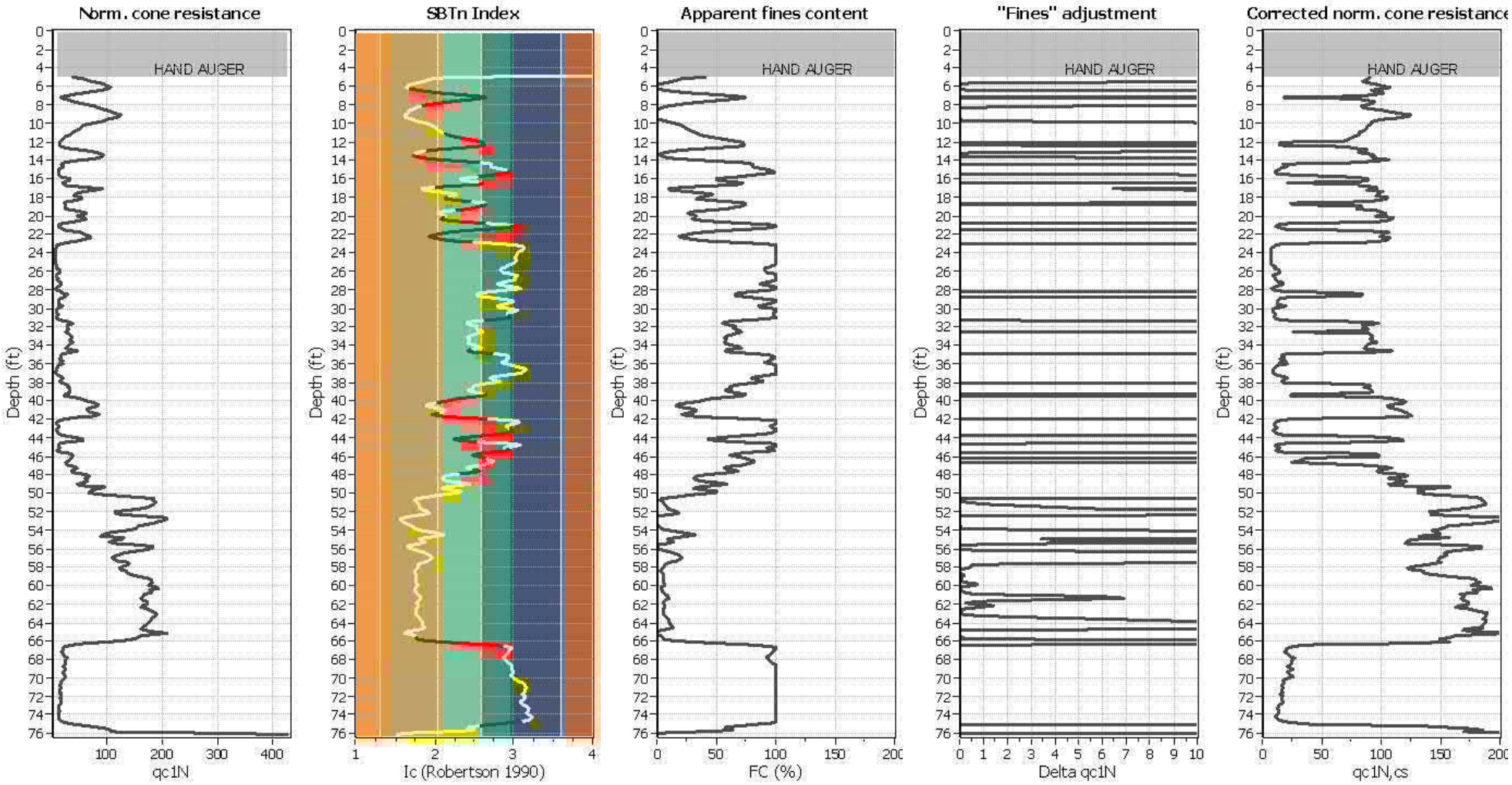

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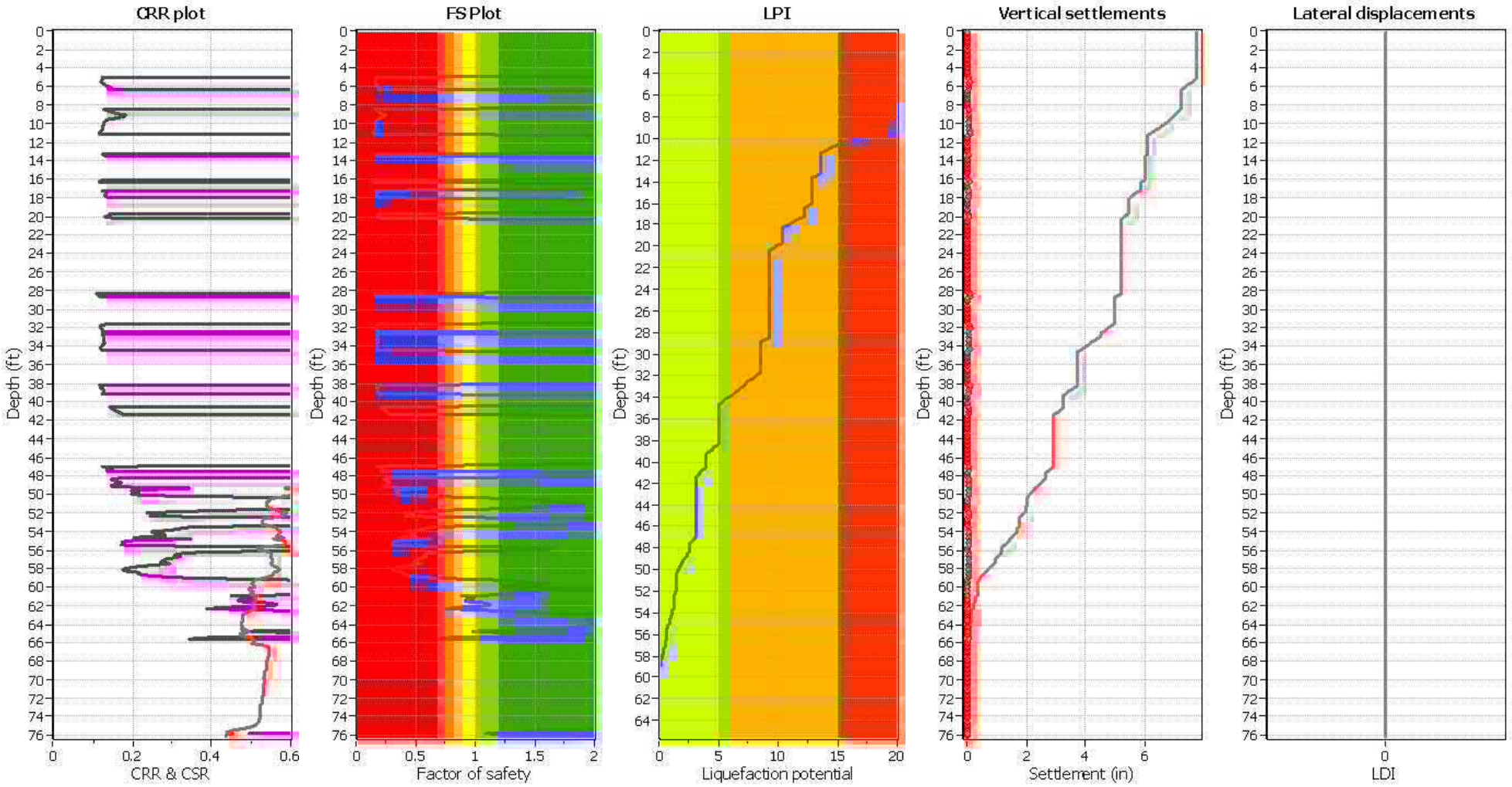

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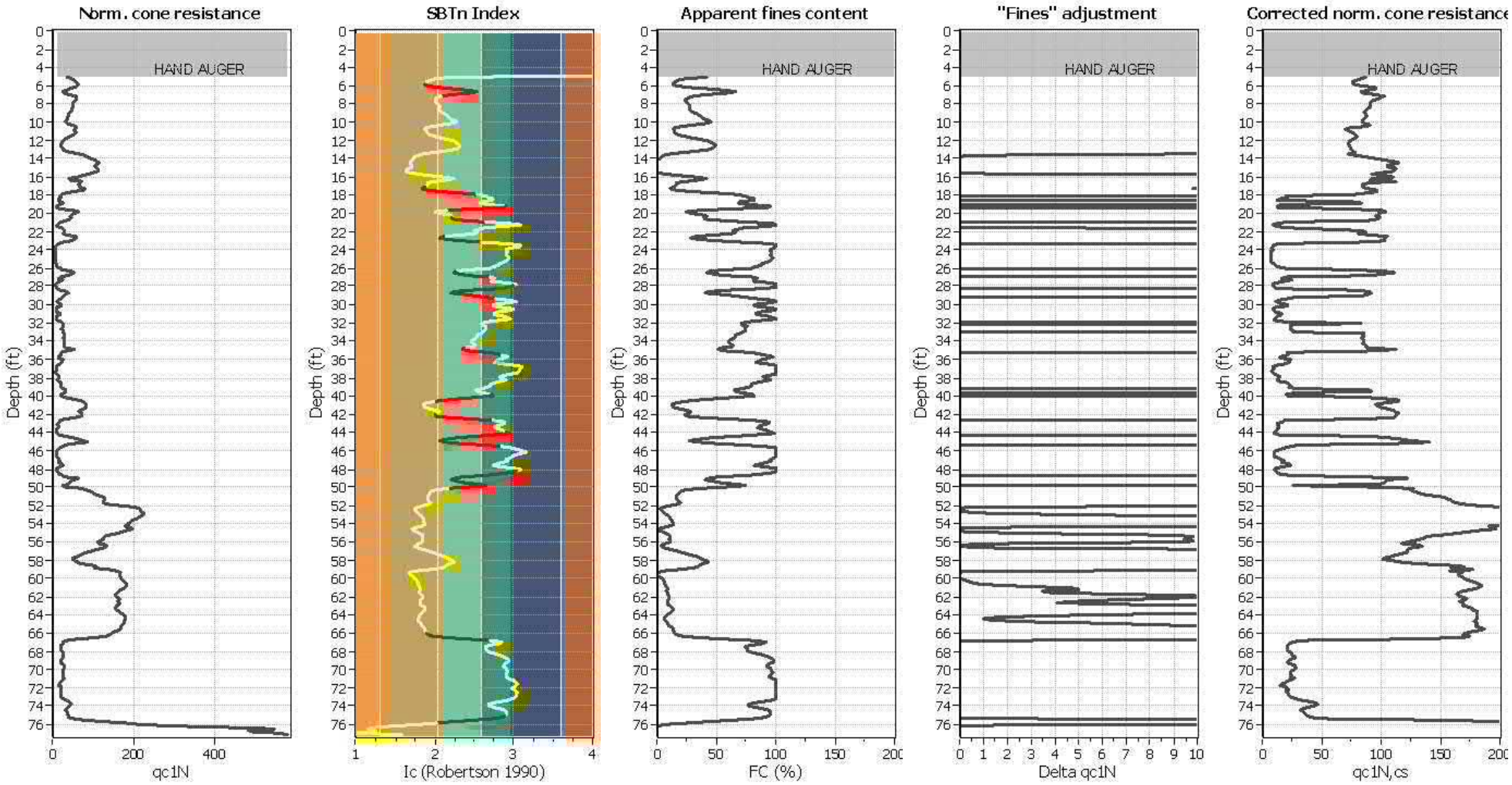

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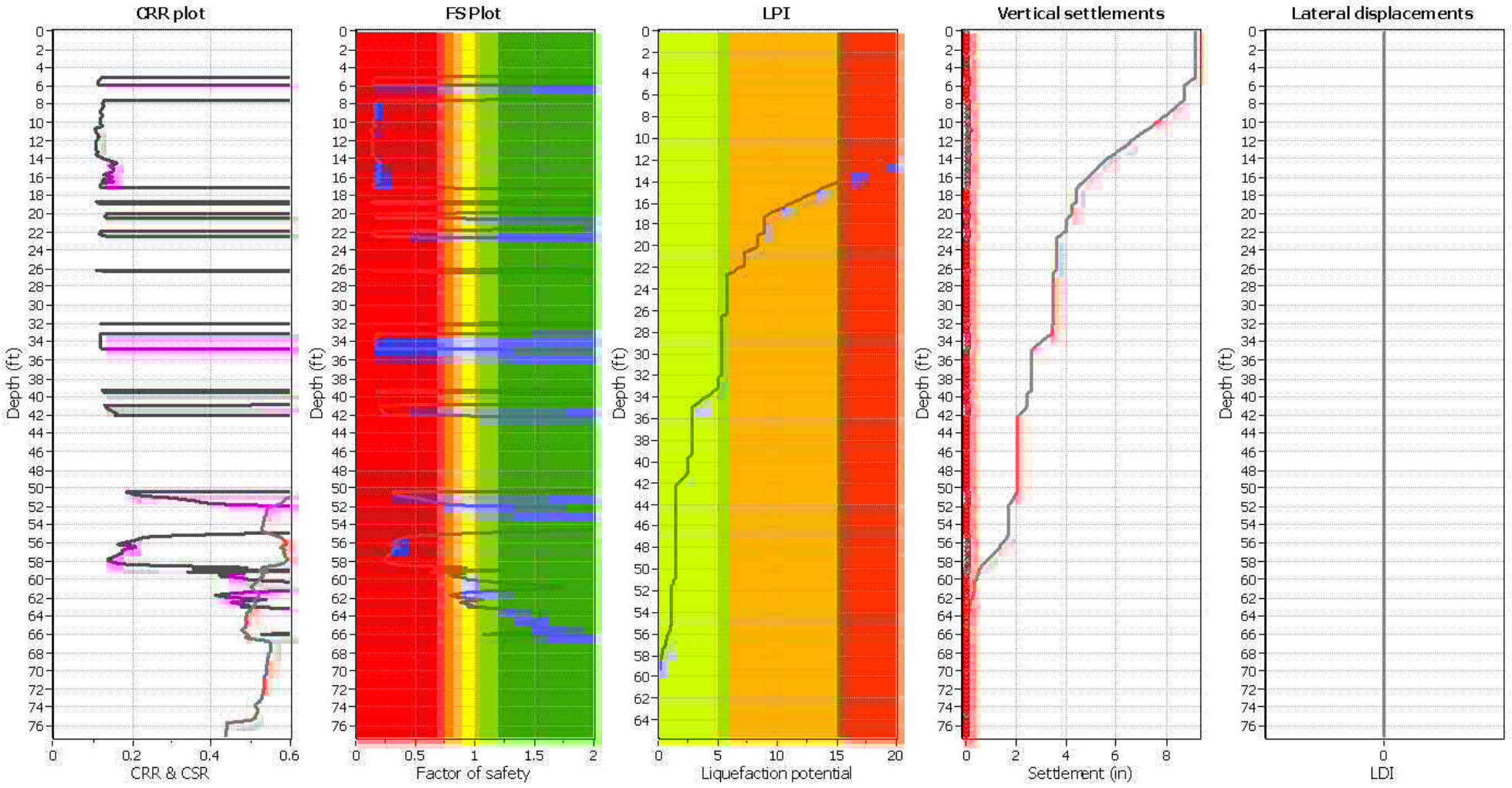
Peak ground acceleration:	0.59	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	9.00 ft	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plot



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.59	Use fill:	No	Limit depth applied:	No
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F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
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LPI color scheme

- Very high risk
- High risk
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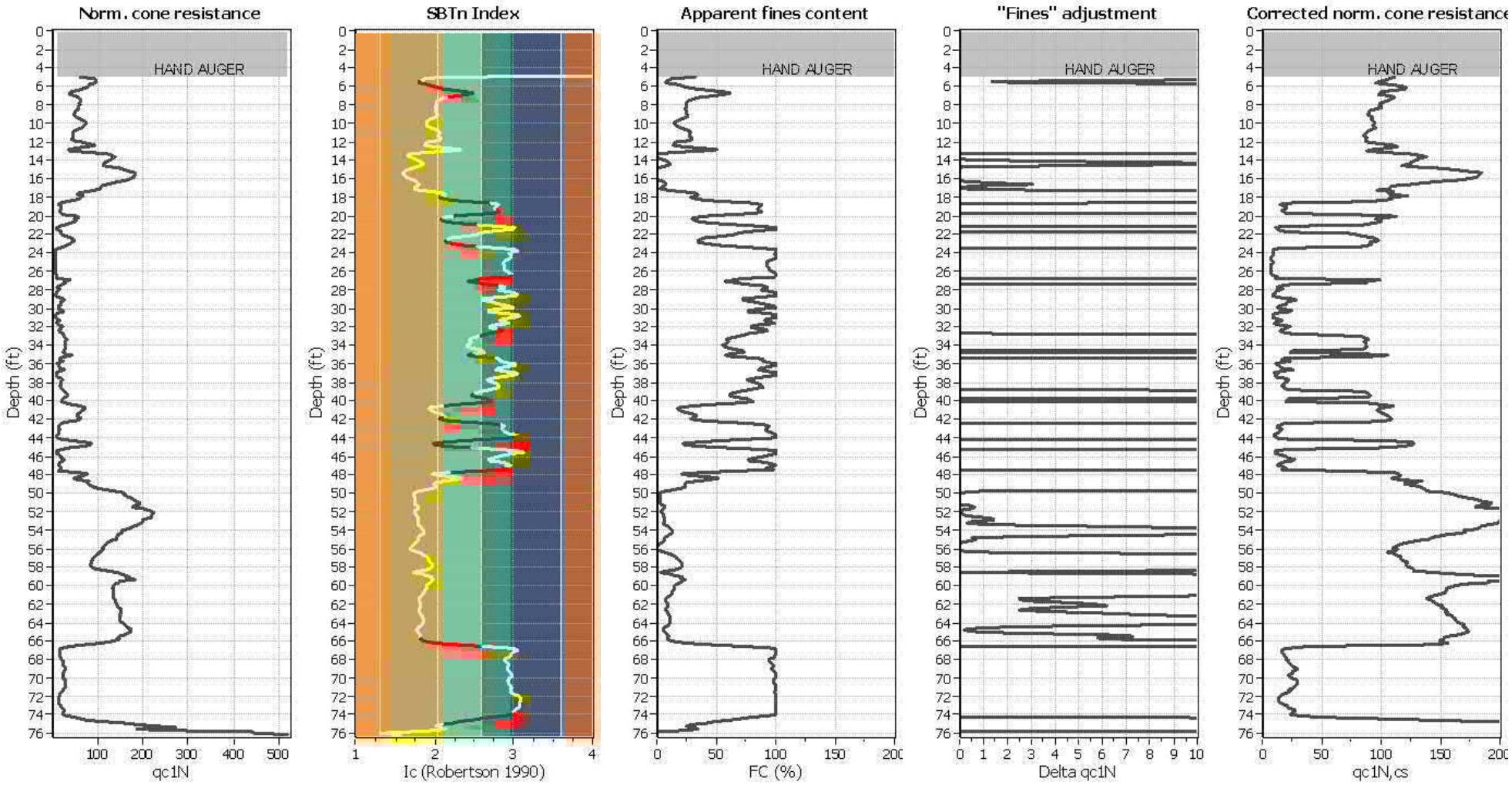
Liquefaction analysis overall plots (intermediate resu



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Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
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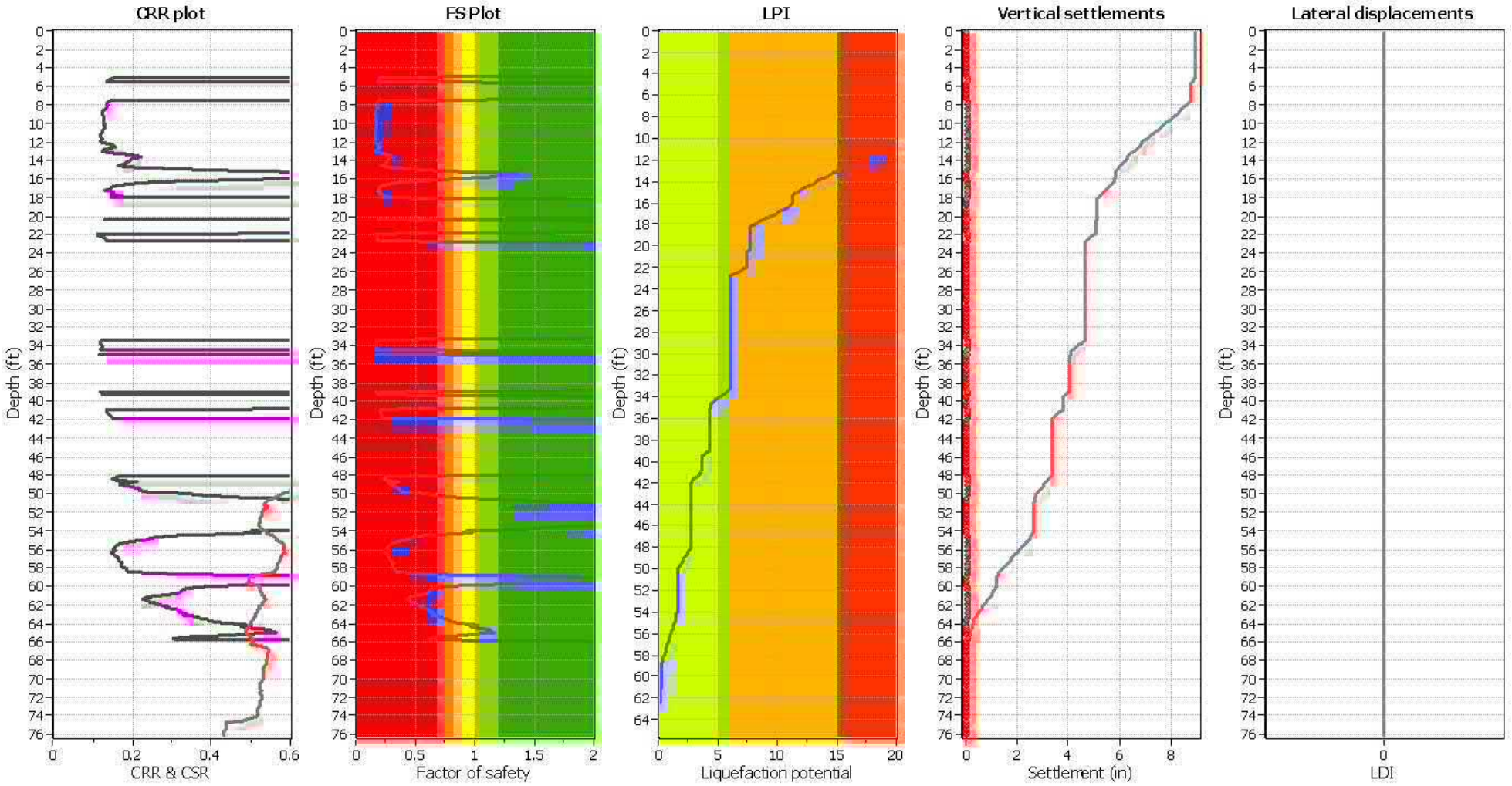

Input parameters and analysis data

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Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
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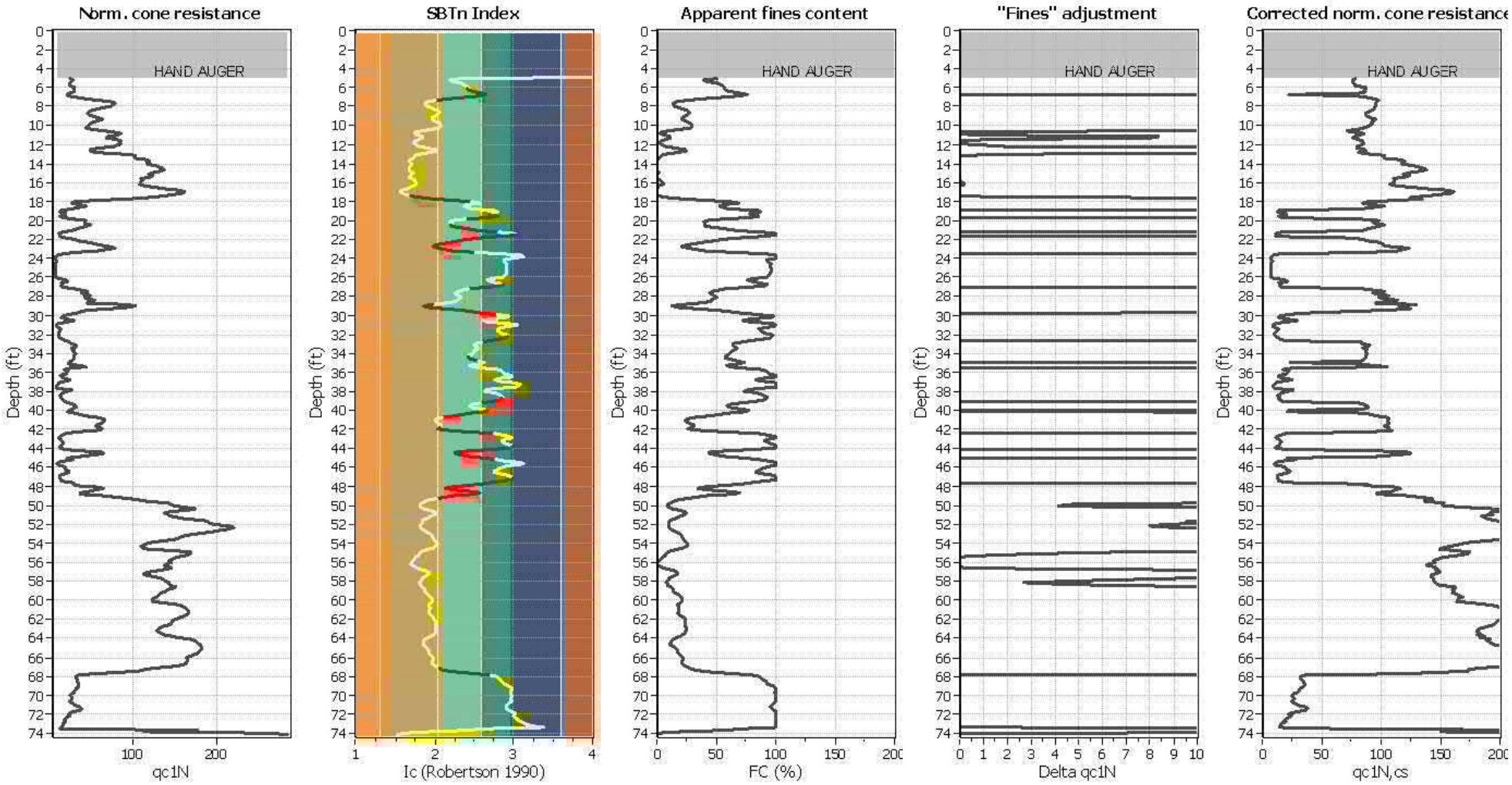
Liquefaction analysis overall plots (intermediate resu



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Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
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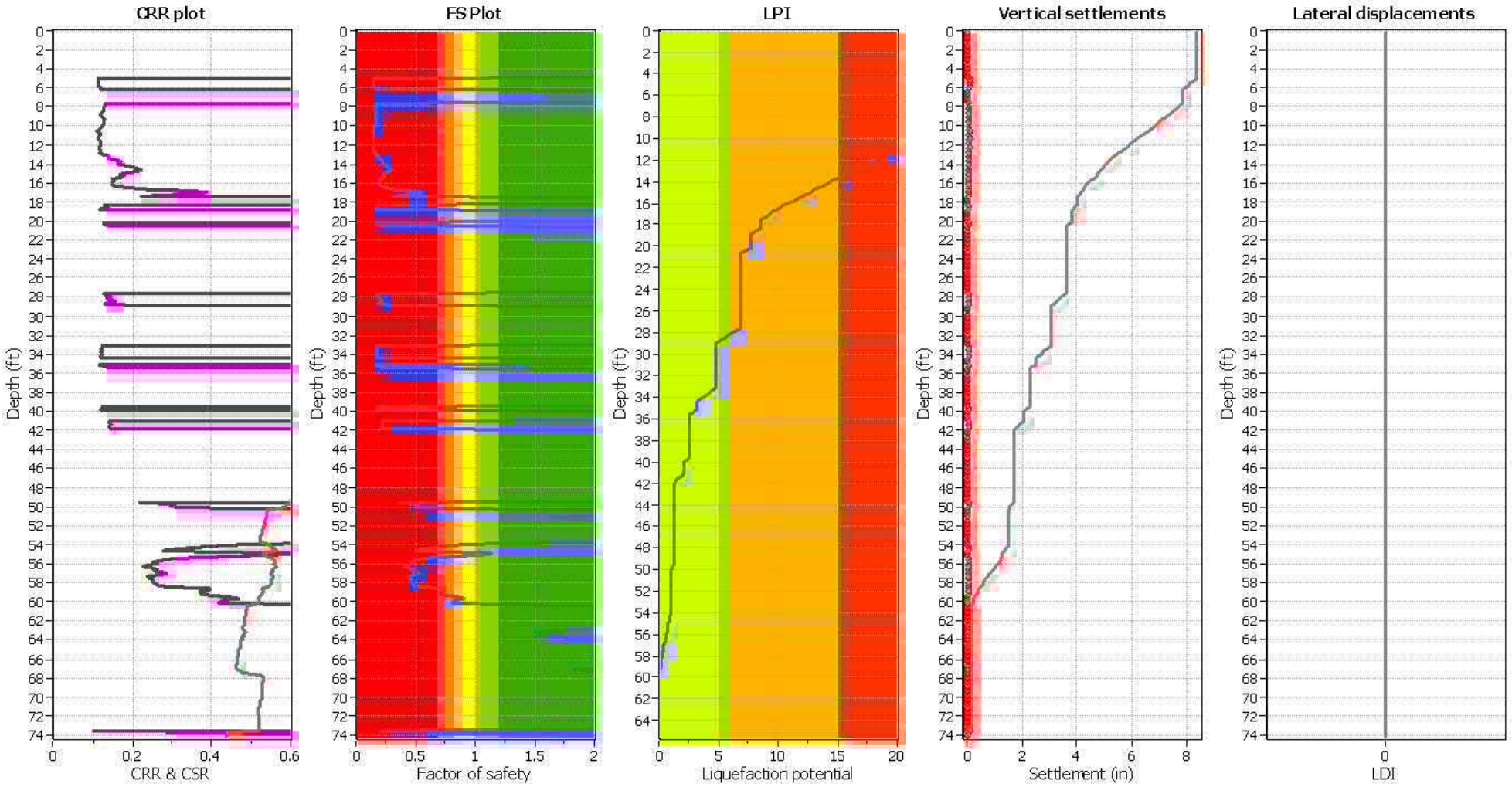

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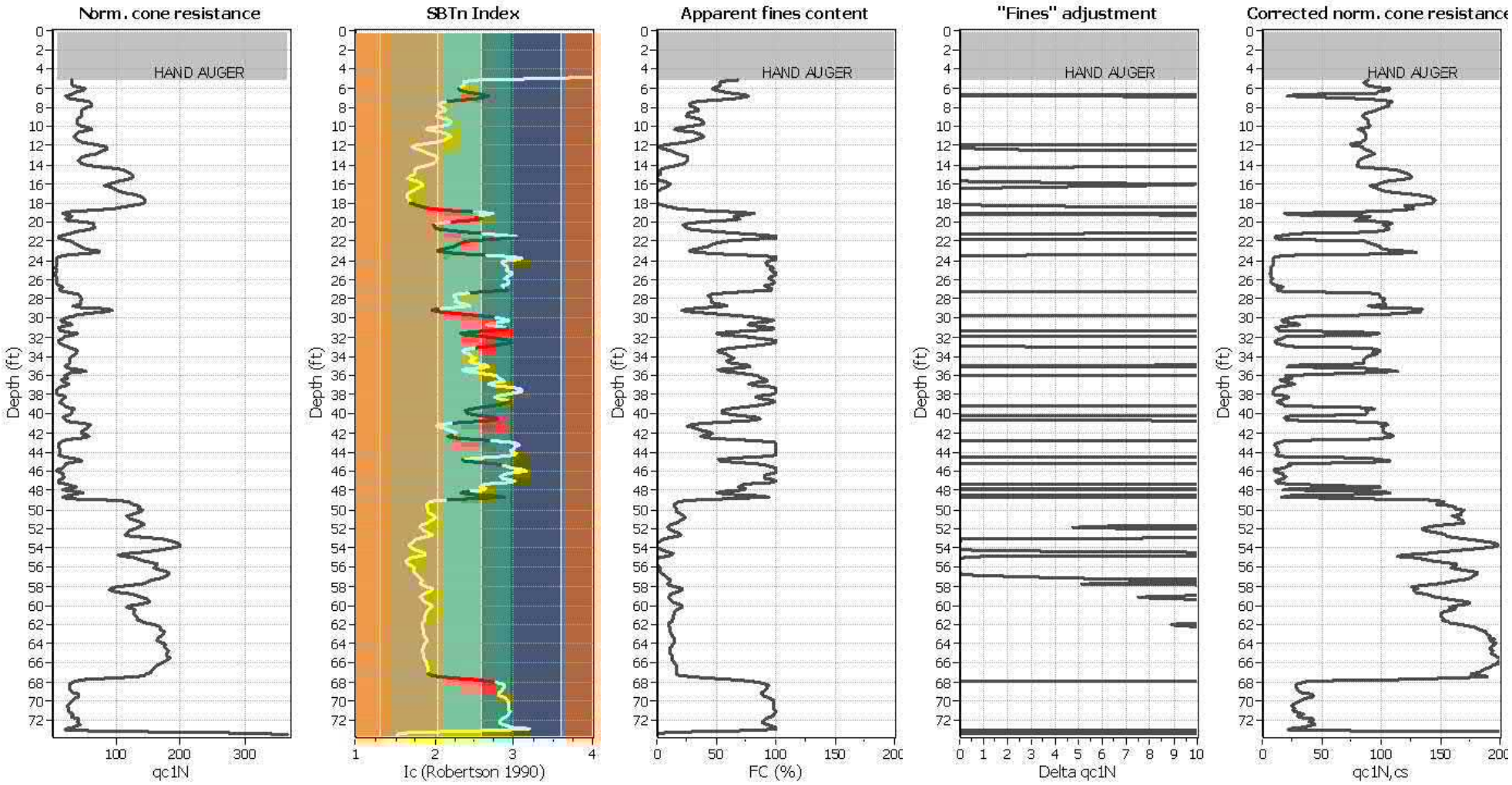

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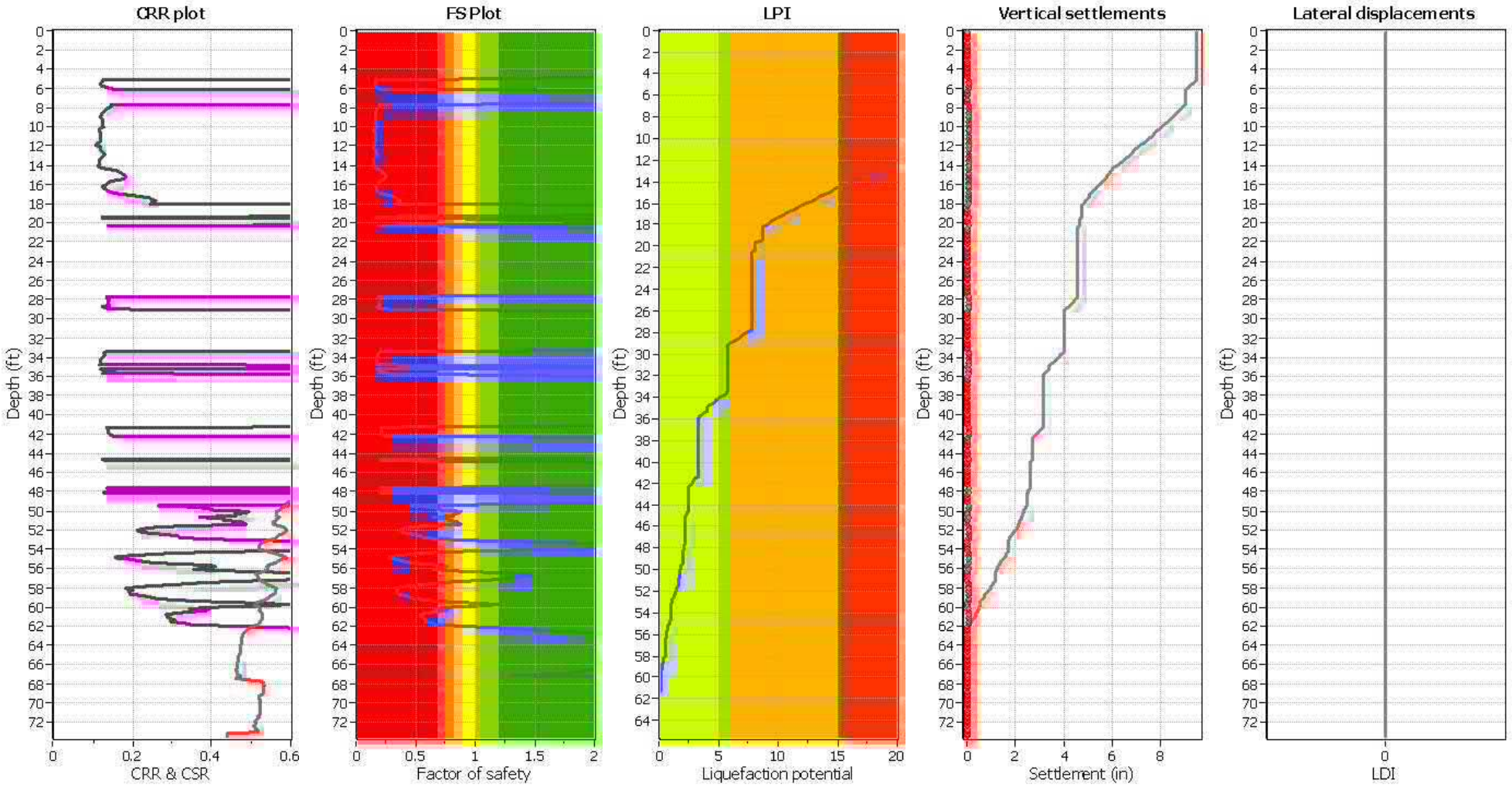

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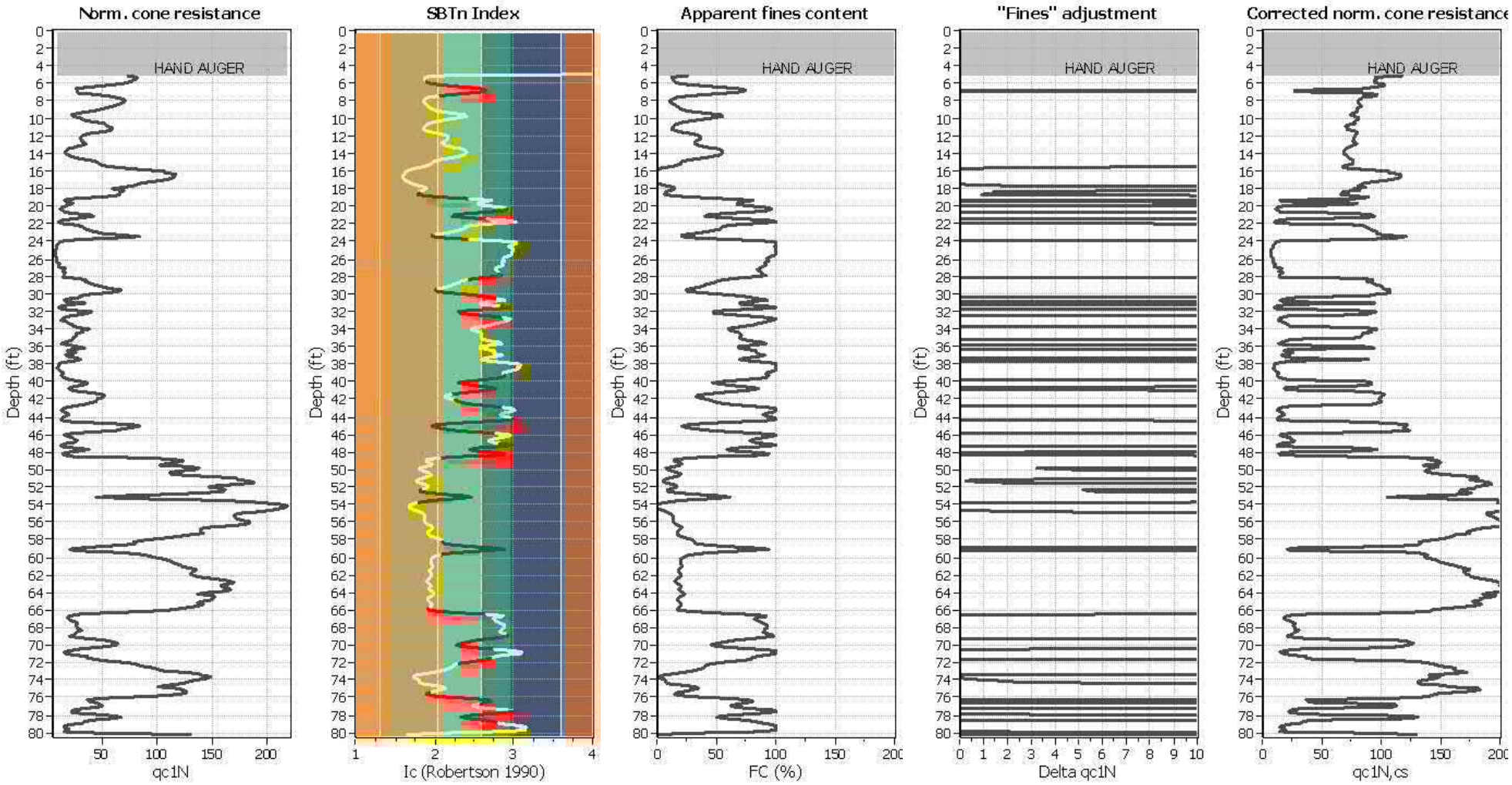

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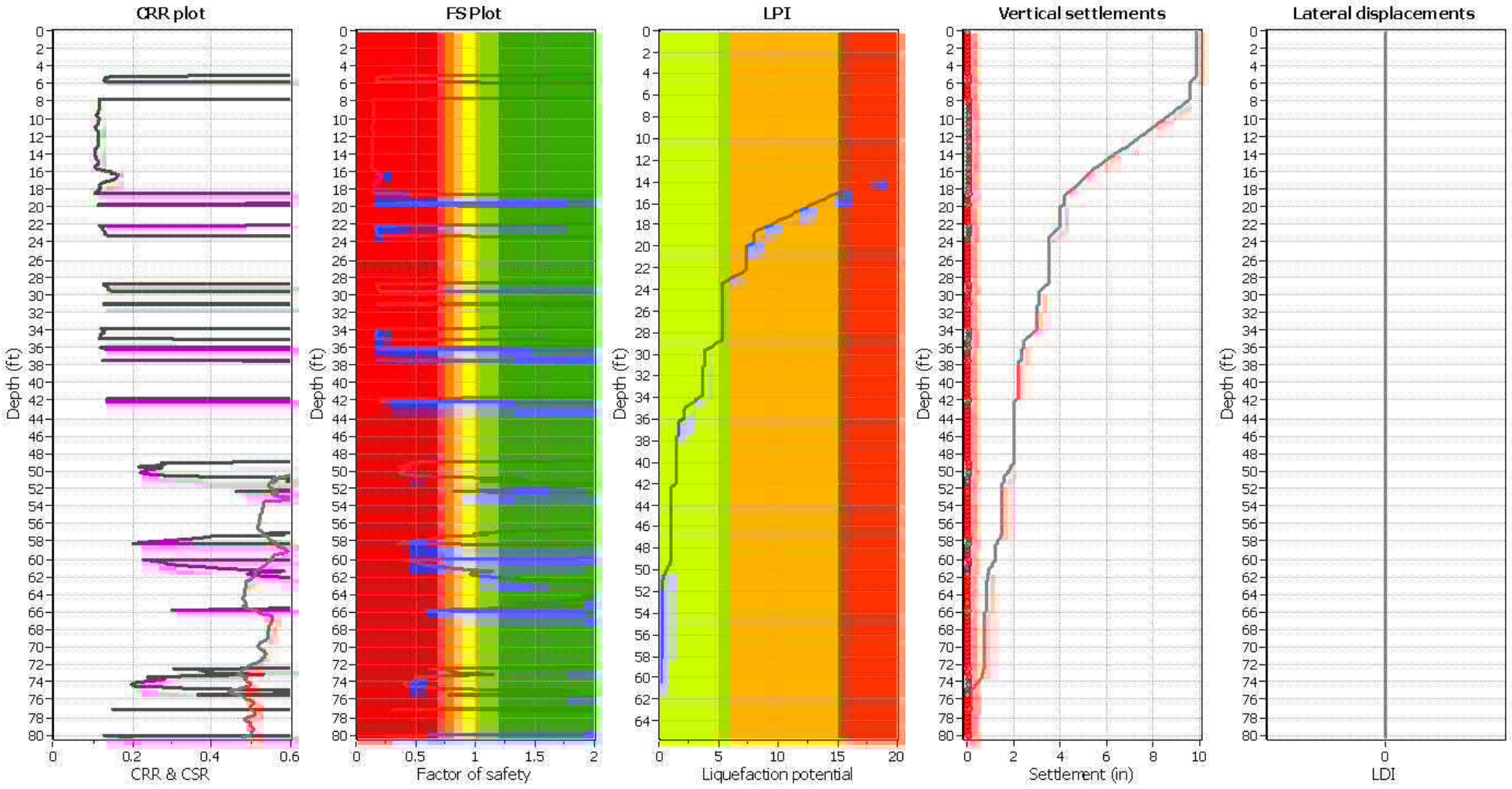
Liquefaction analysis overall plot



Input parameters and analysis data

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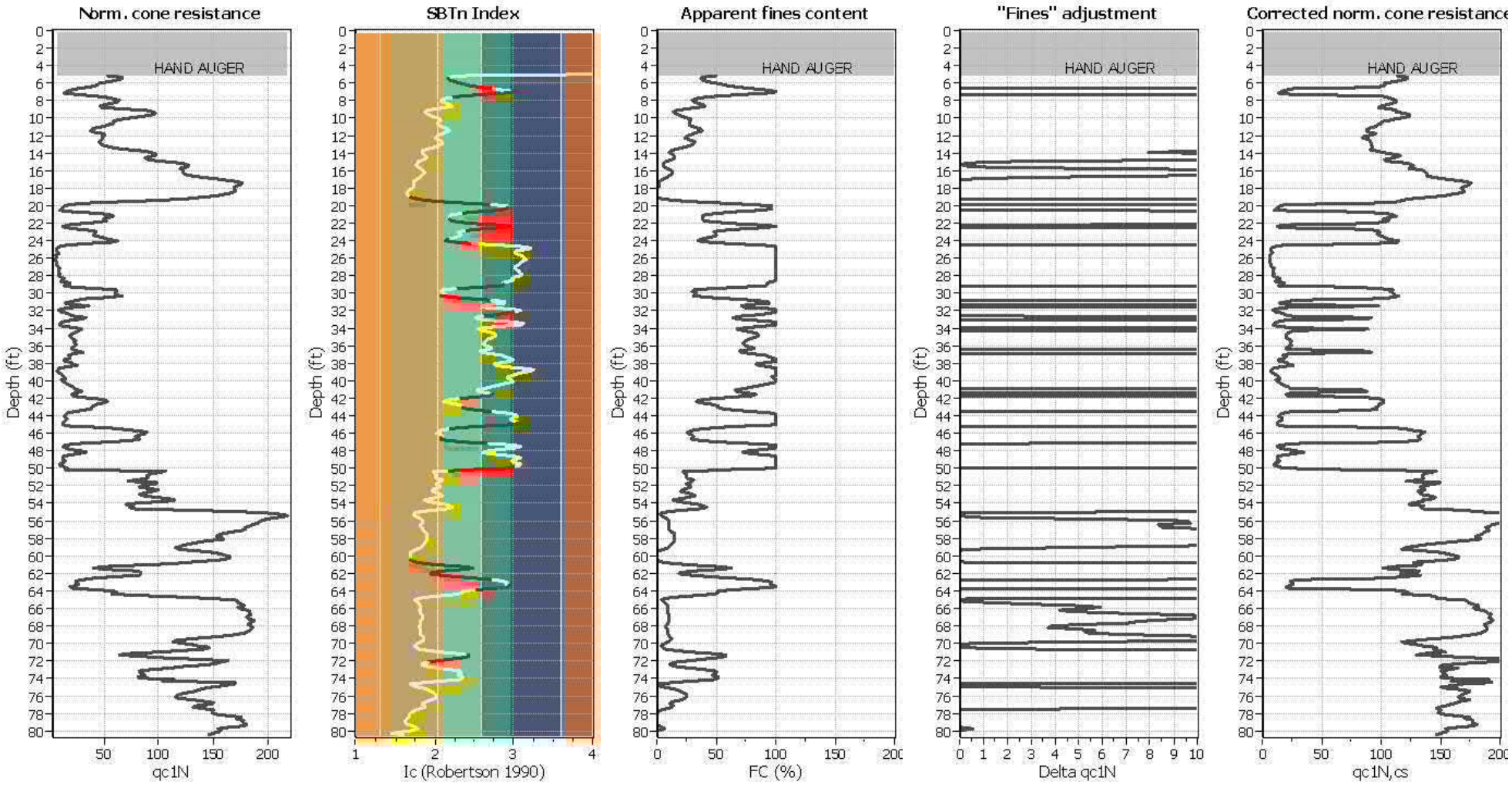
Liquefaction analysis overall plots (intermediate resu



Input parameters and analysis data

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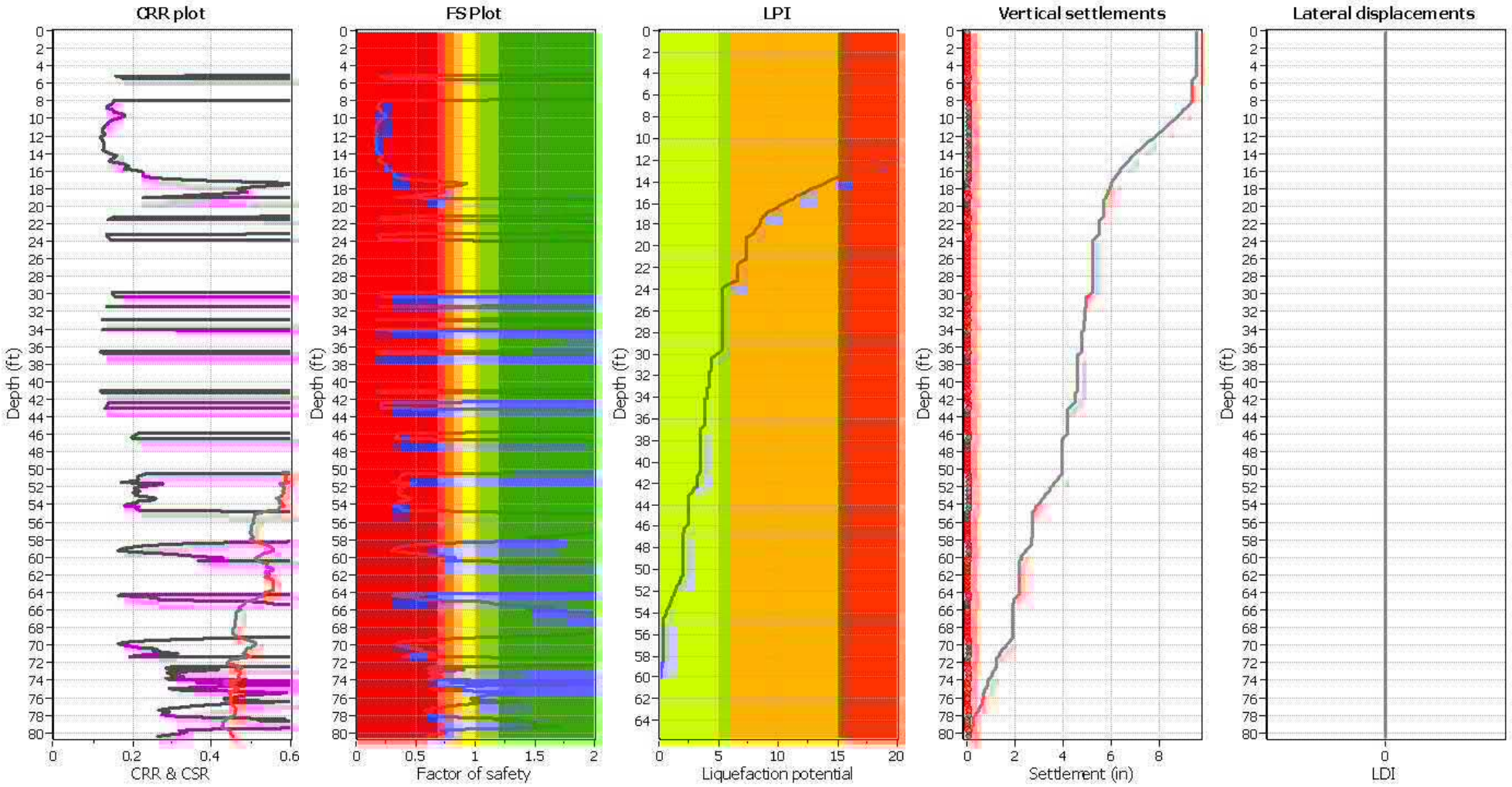
Liquefaction analysis overall plot



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
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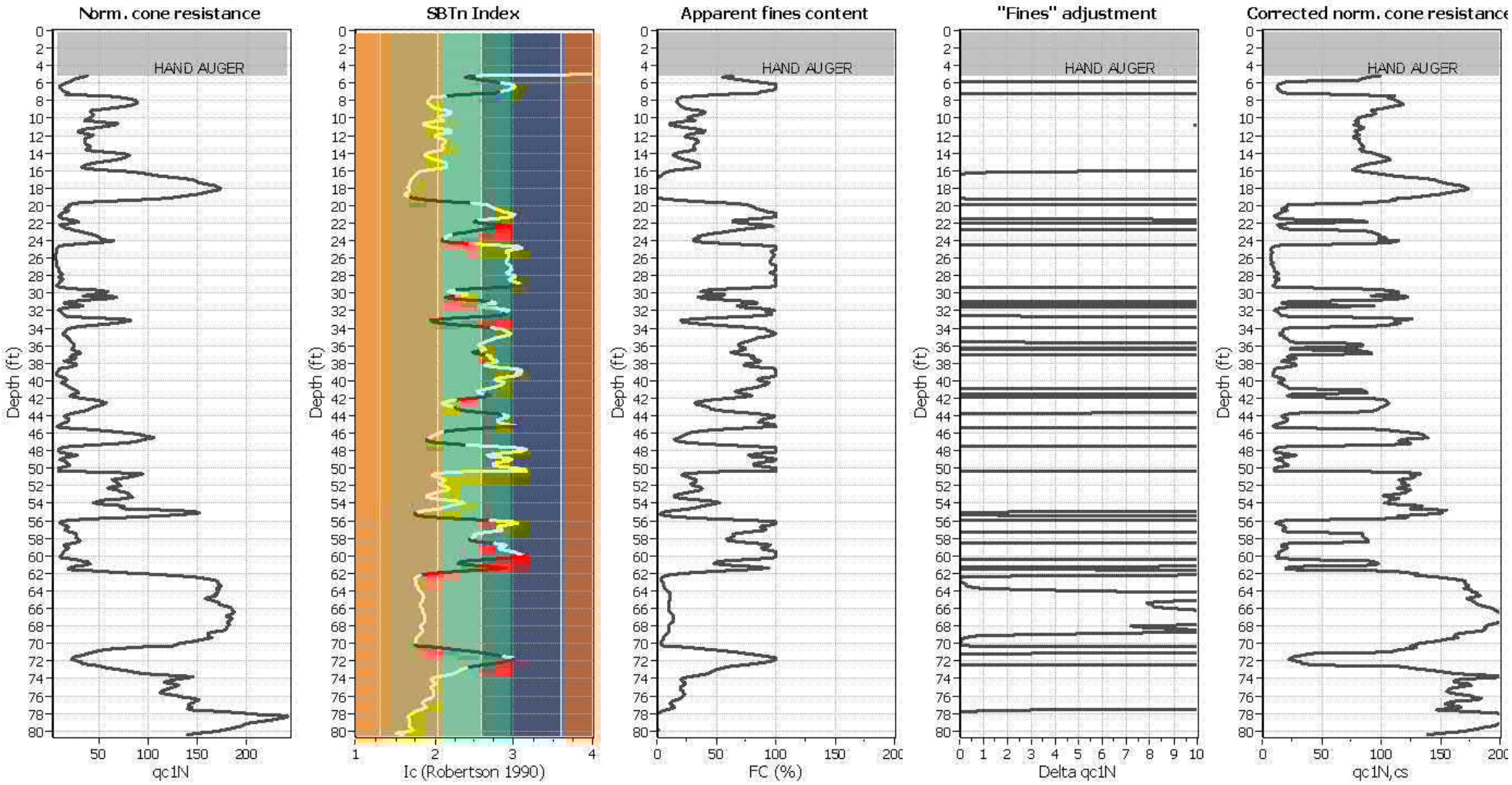
Liquefaction analysis overall plots (intermediate resu



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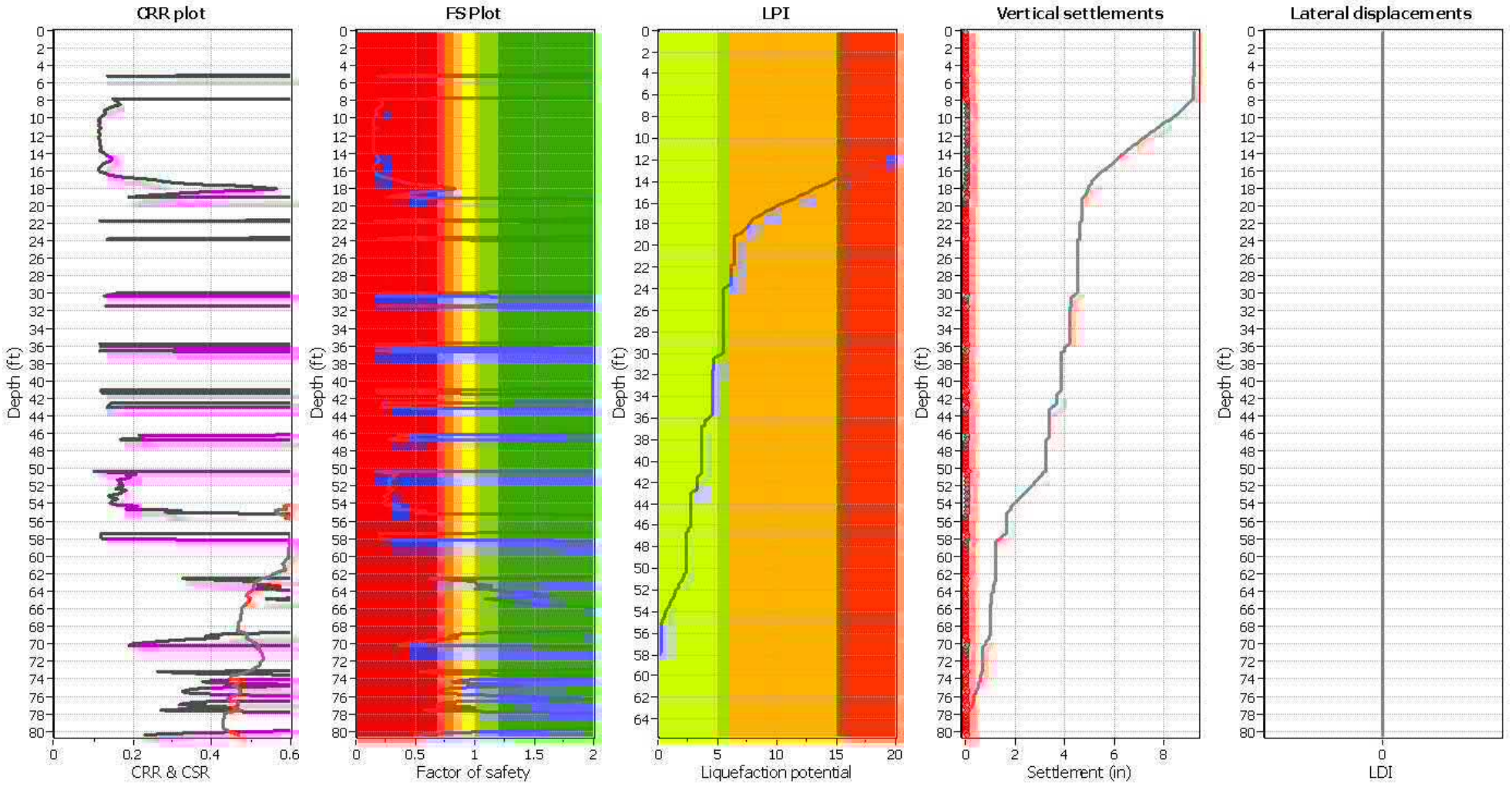
Liquefaction analysis overall plot



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
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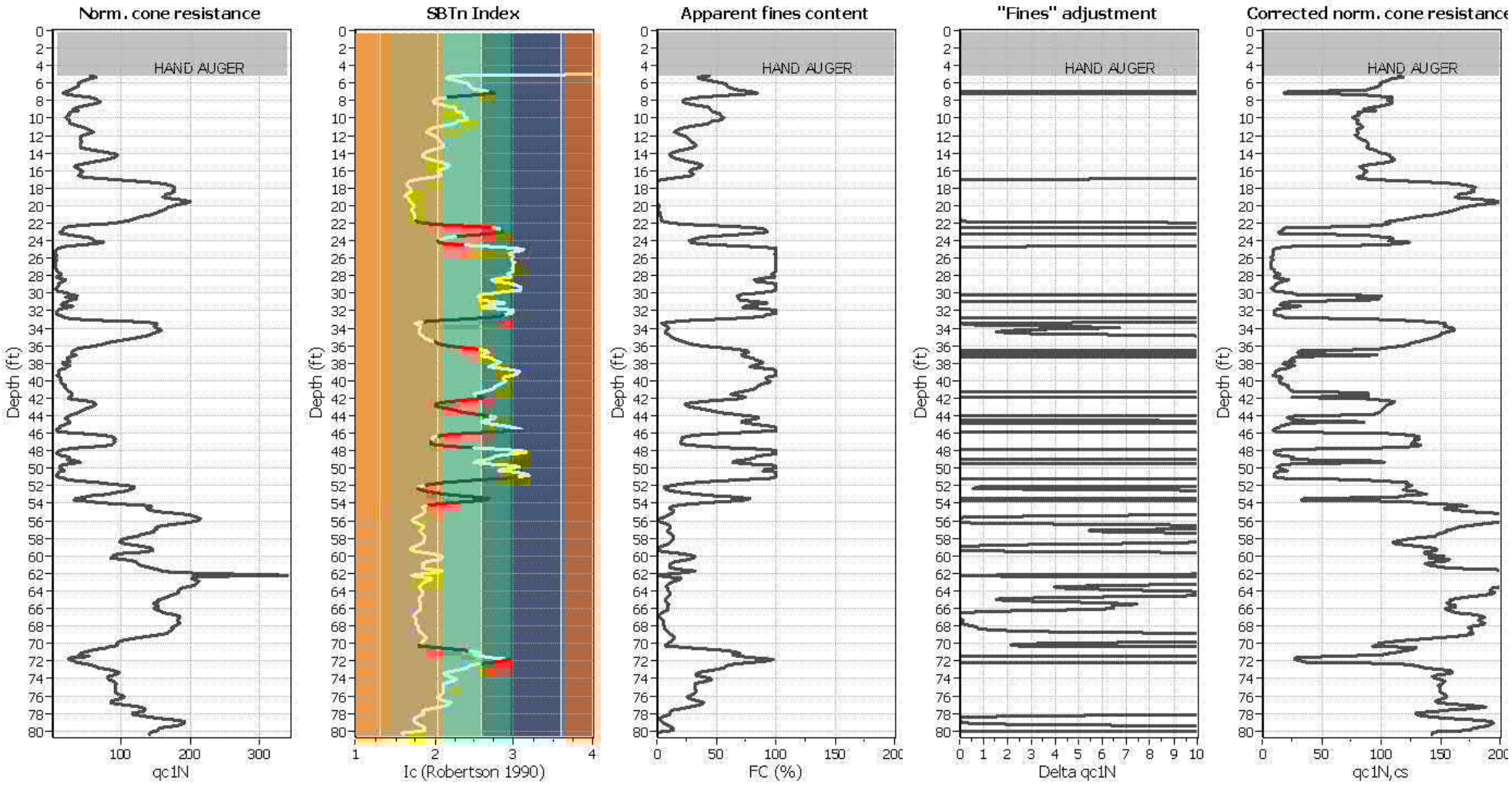
Liquefaction analysis overall plots (intermediate resu



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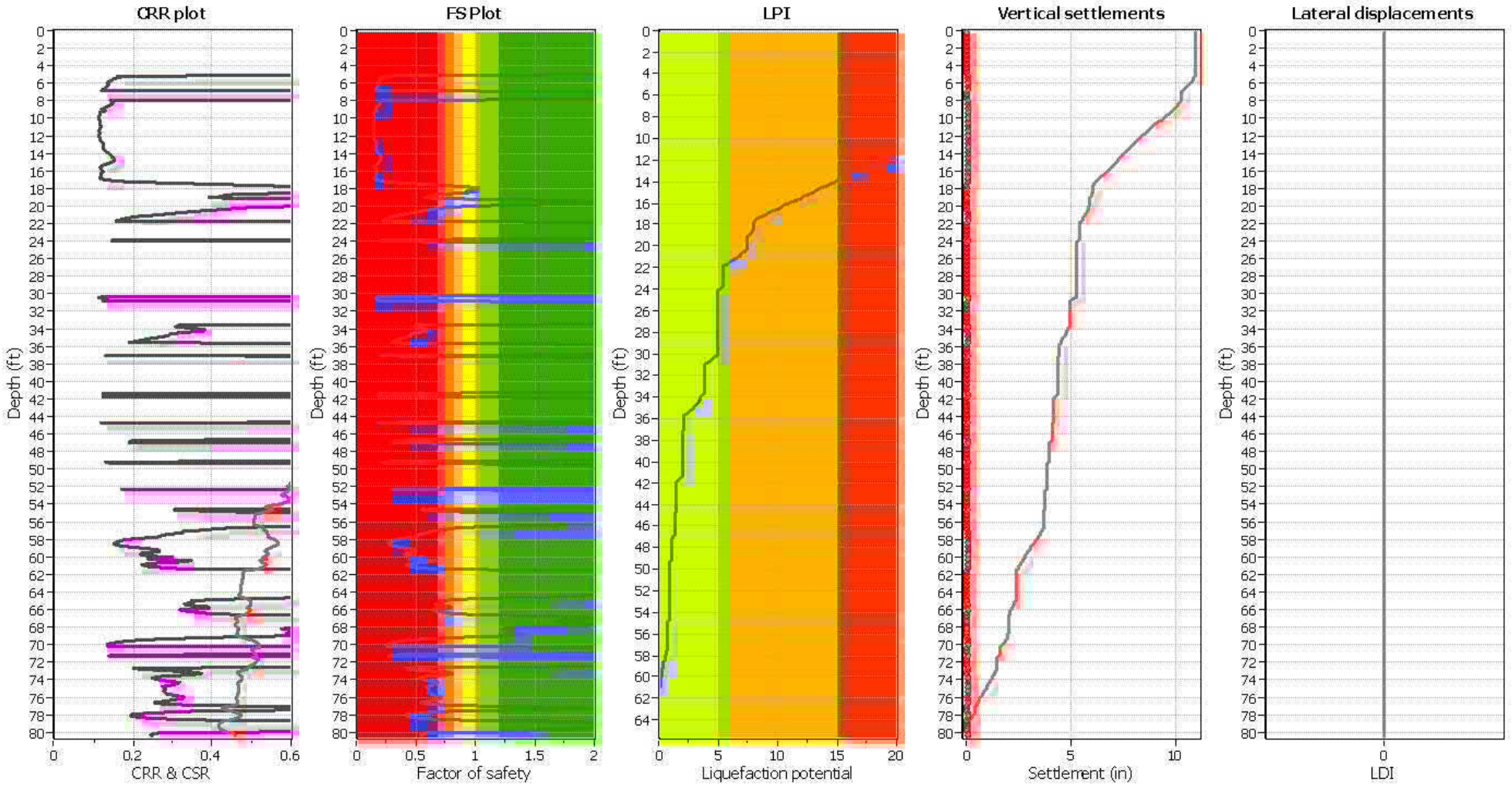

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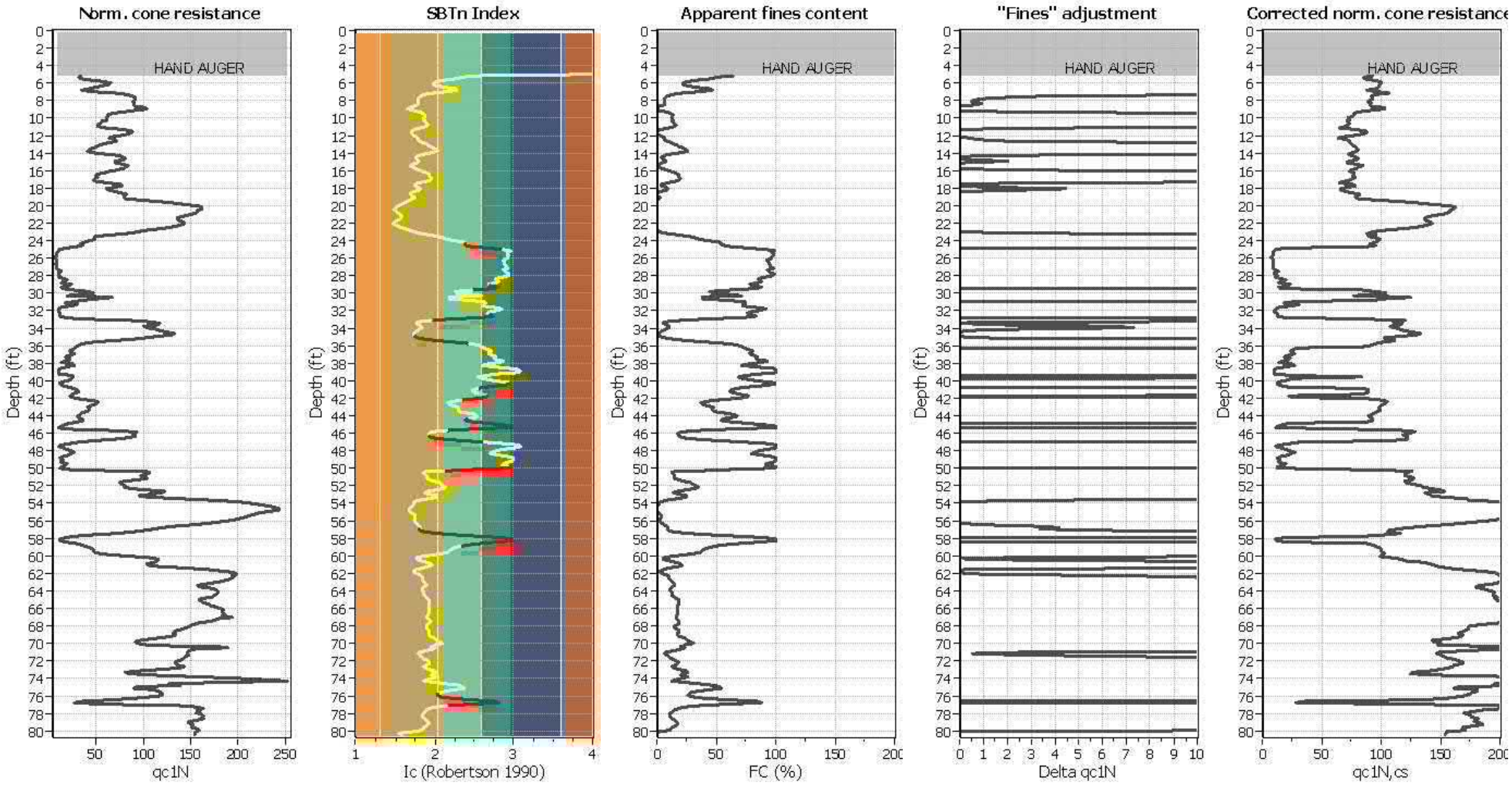

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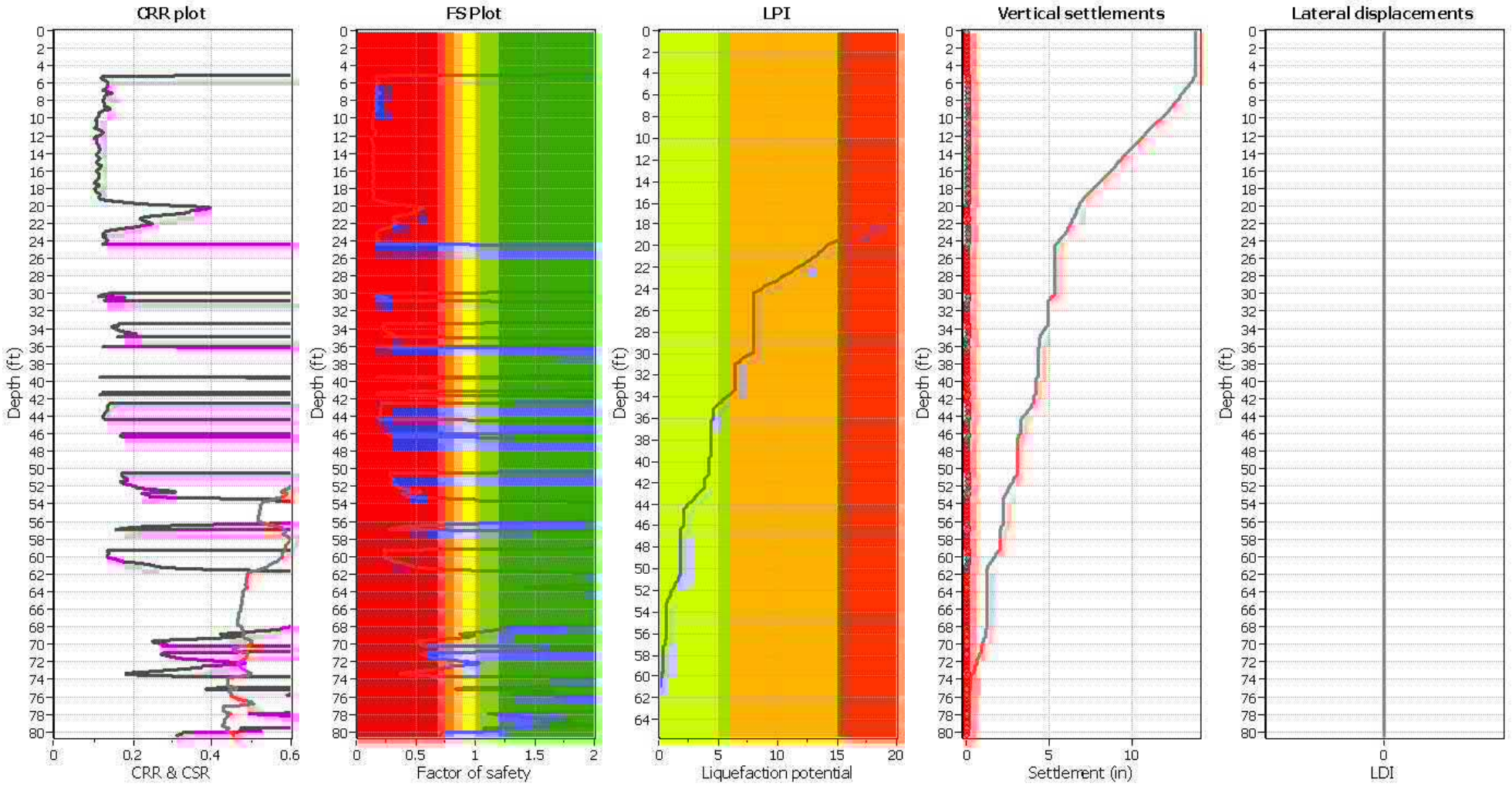

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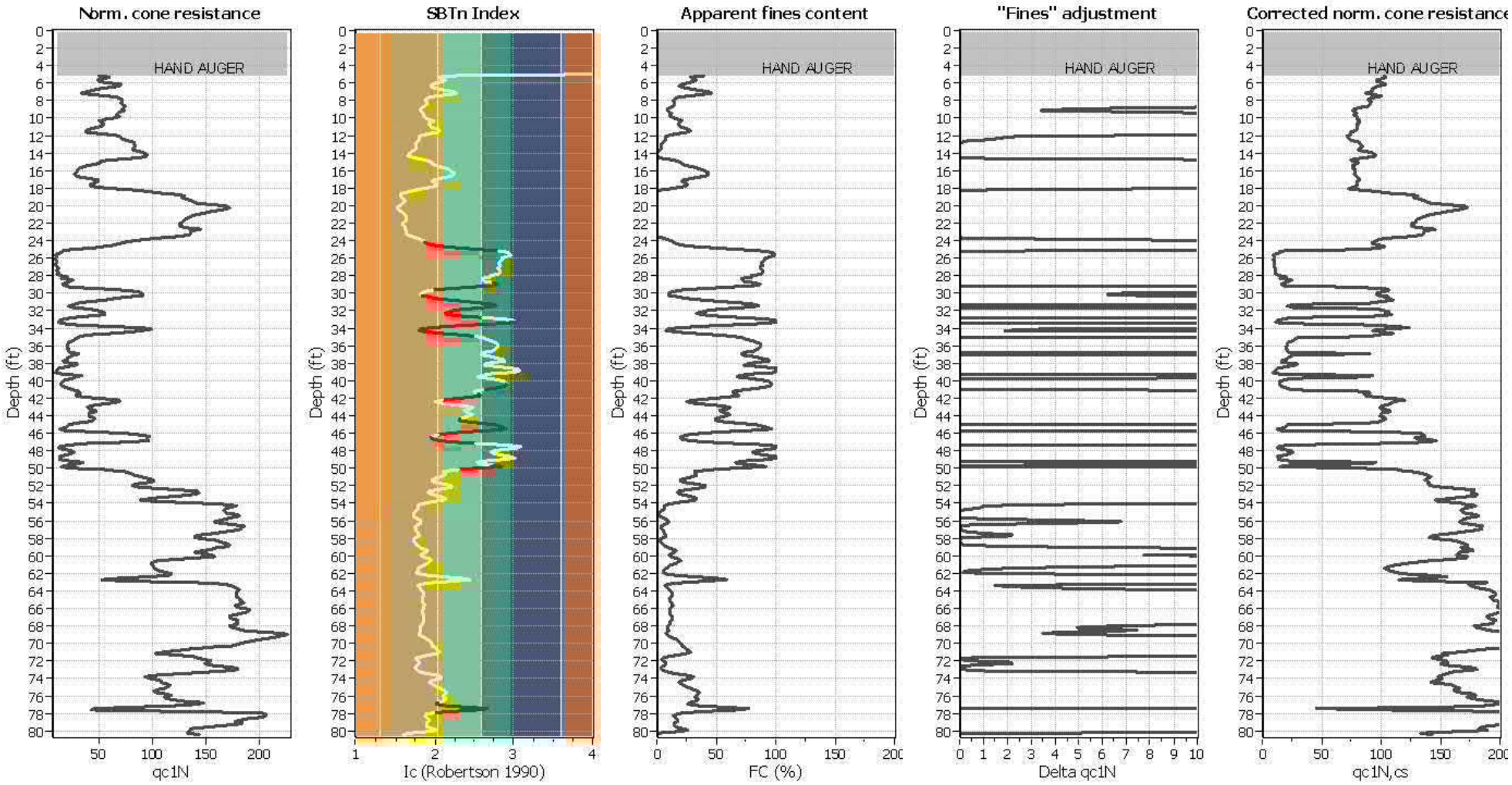

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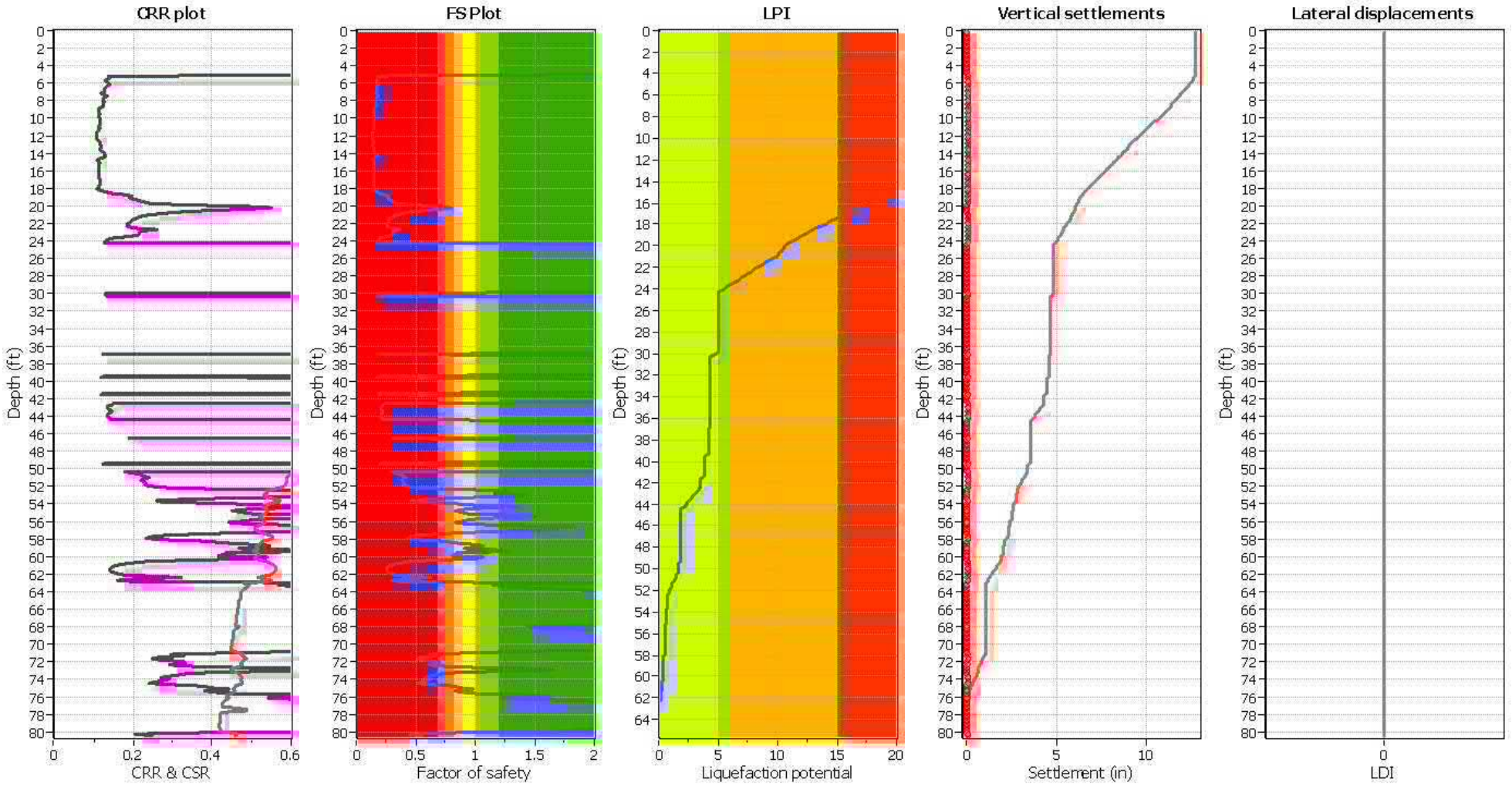

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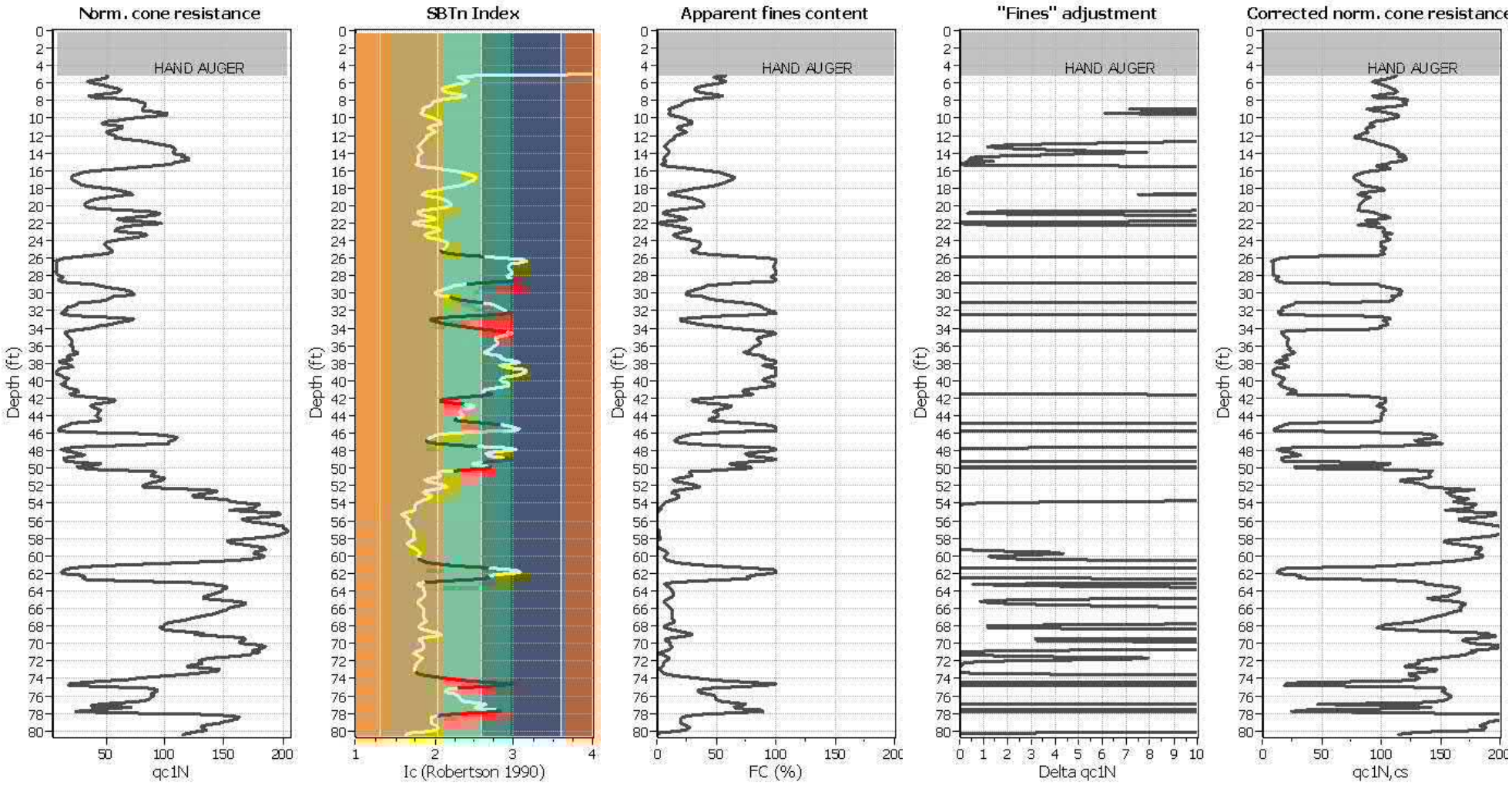

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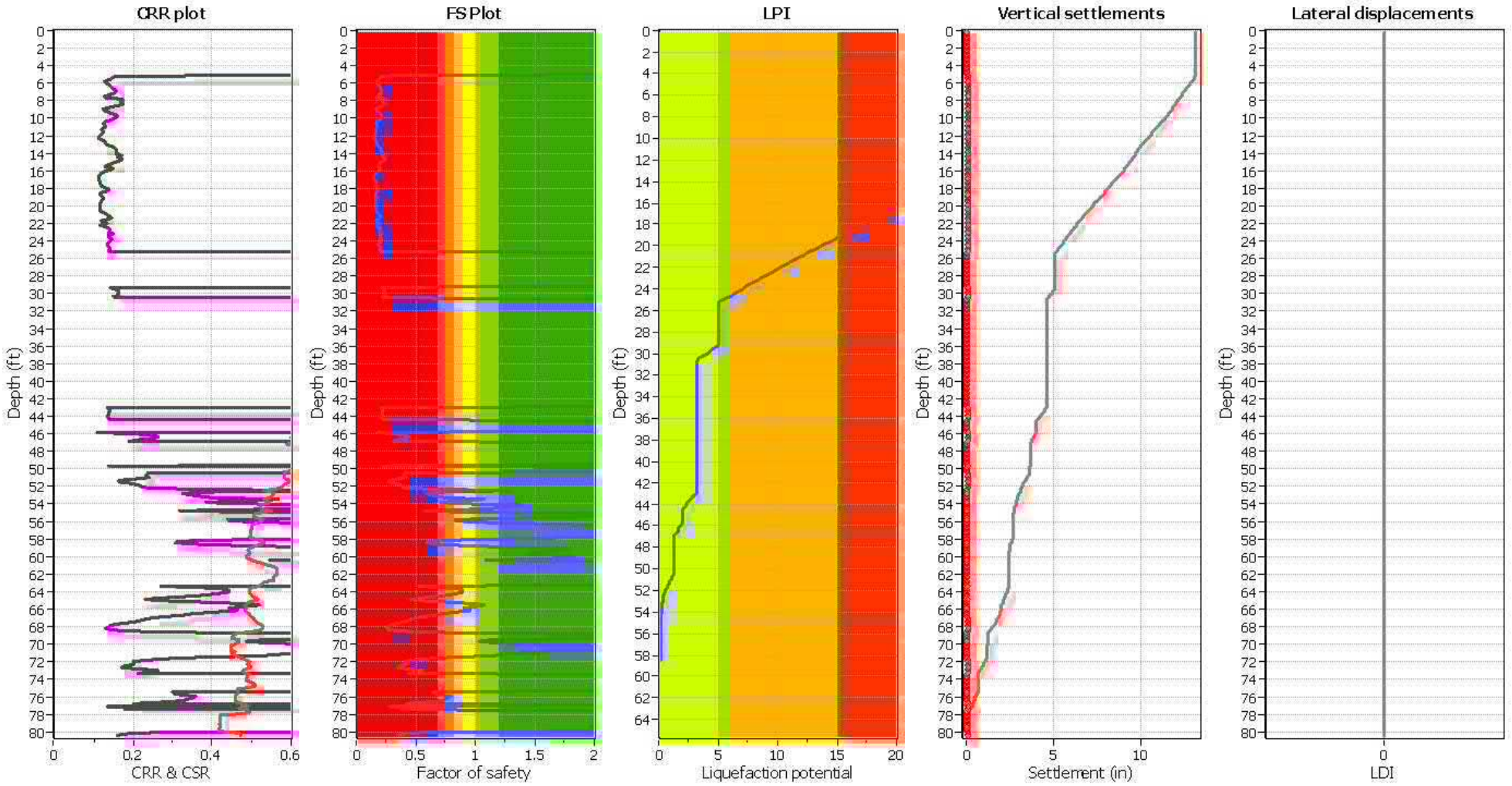

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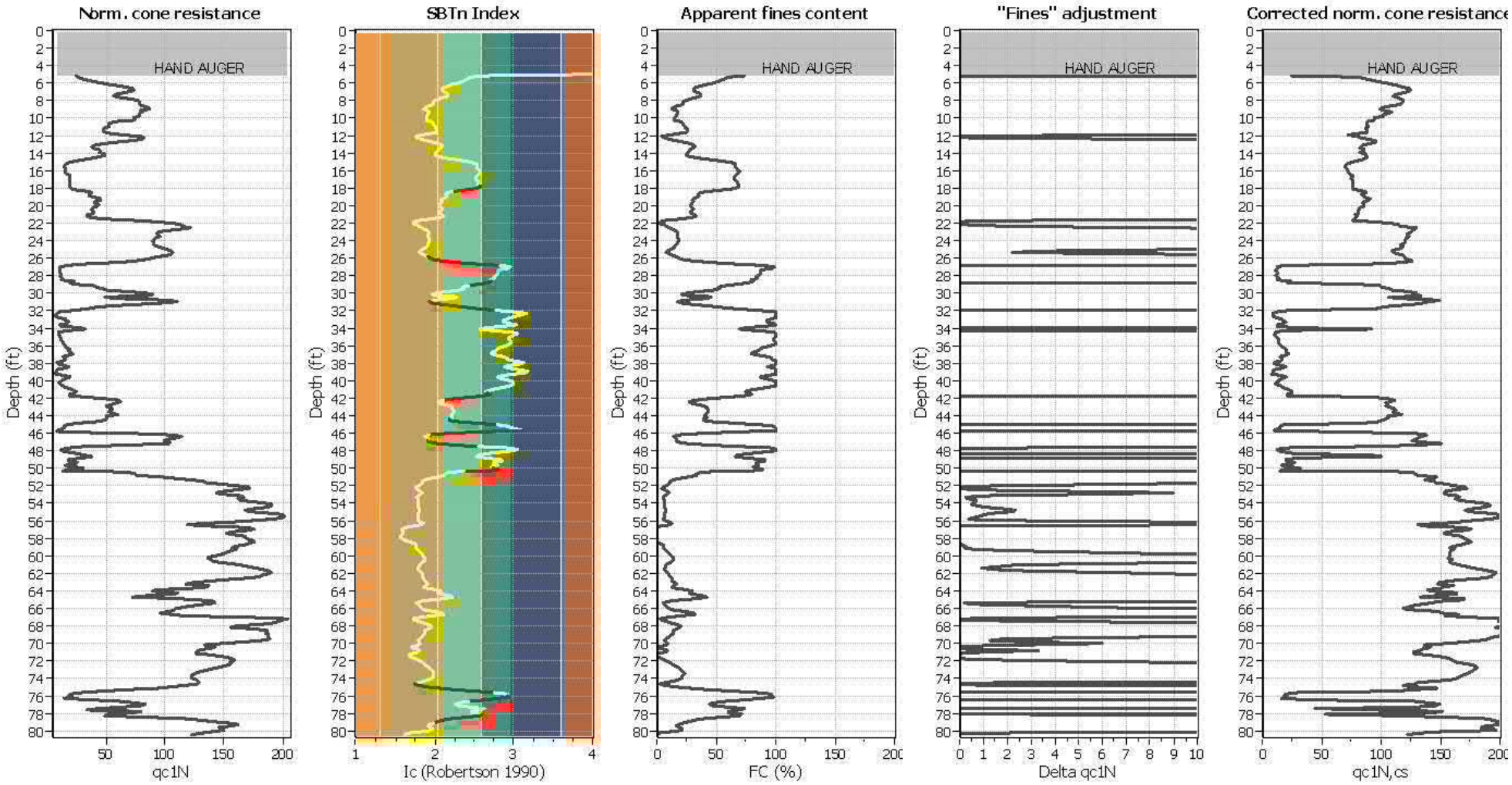
- Low risk

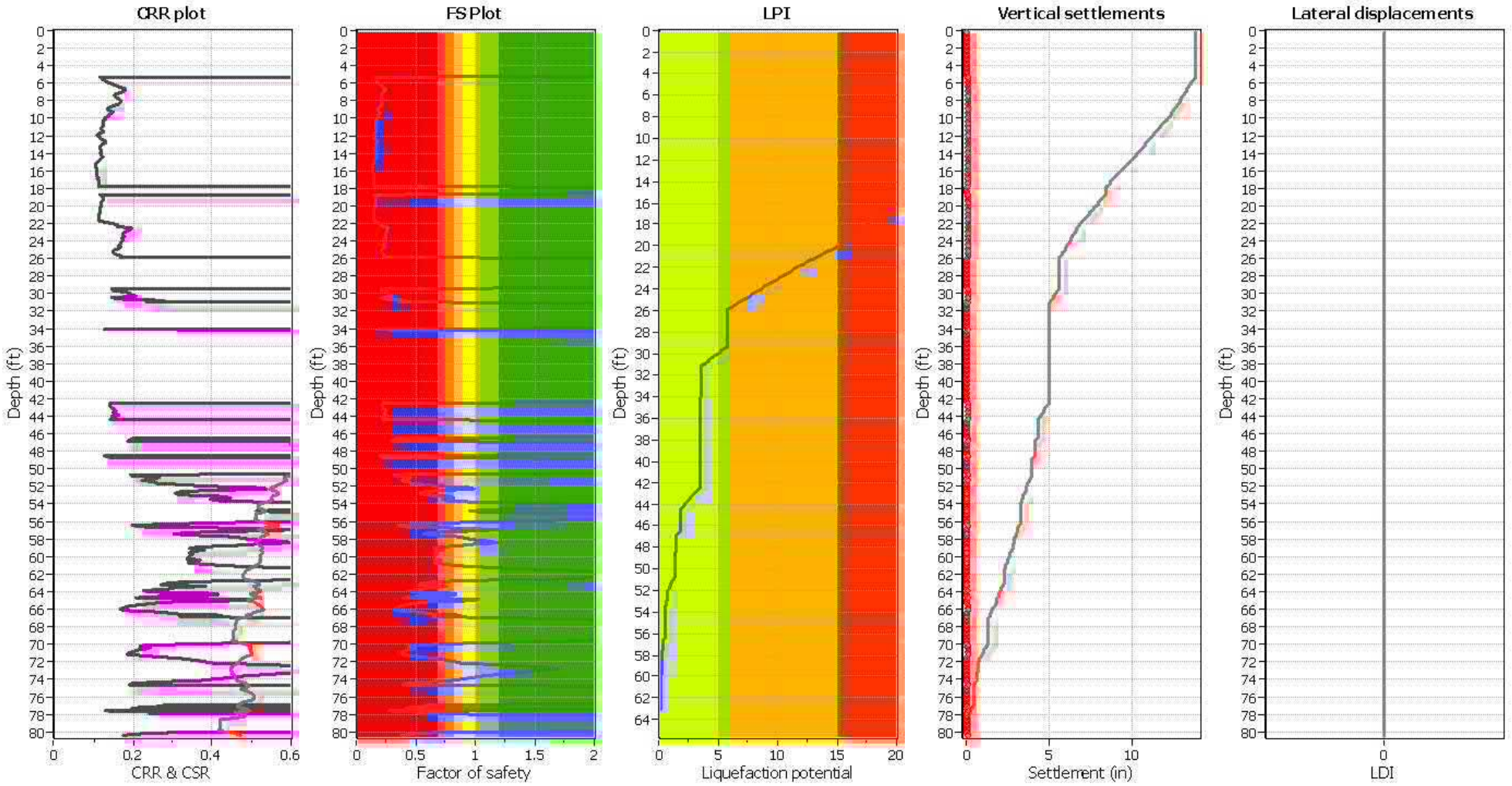
Liquefaction analysis overall plots (intermediate resu



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.59	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	9.00 ft	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plot



Input parameters and analysis data

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Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.59	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	9.00 ft	Fill height:	N/A	Limit depth:	N/A

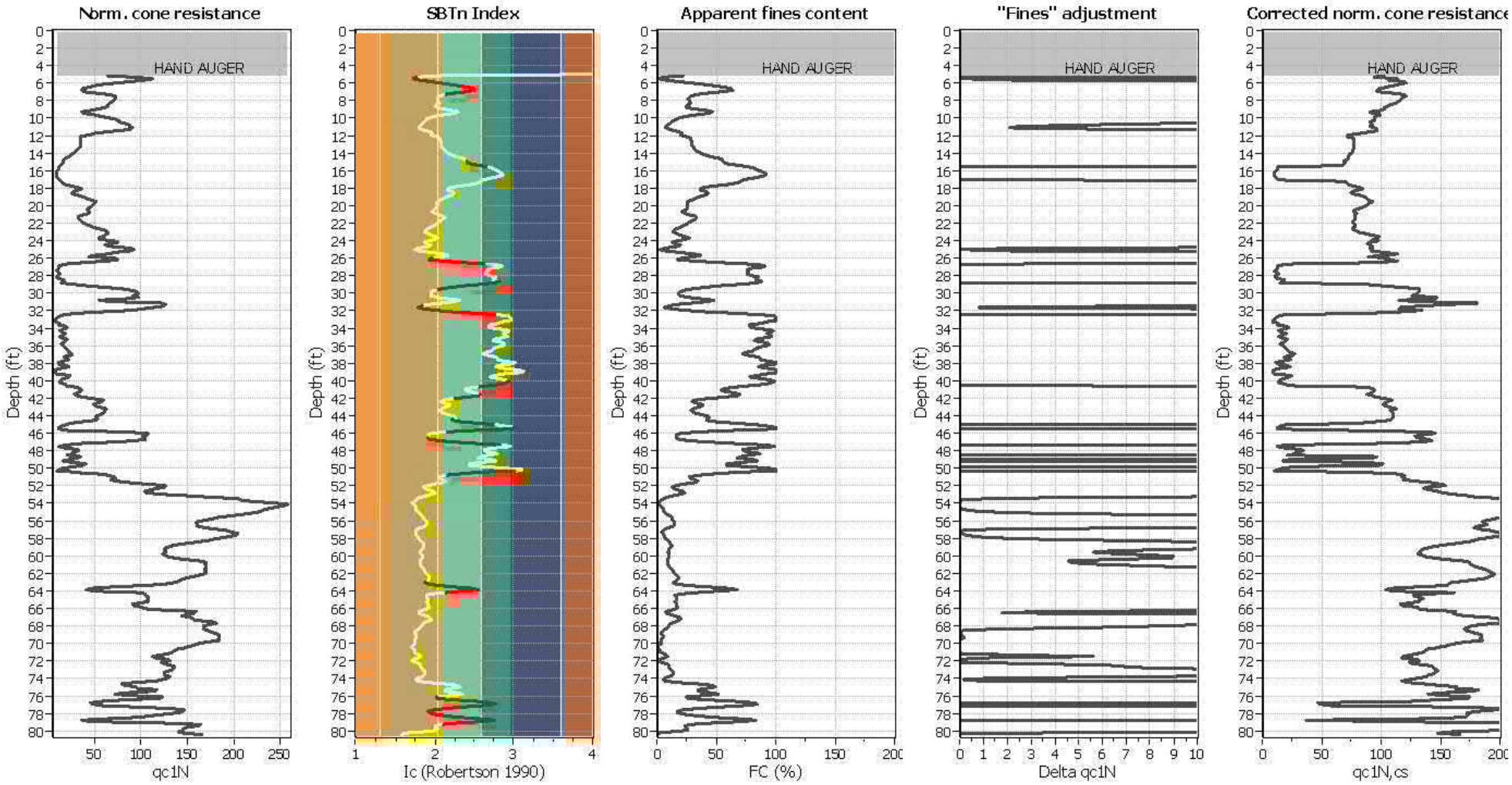
F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

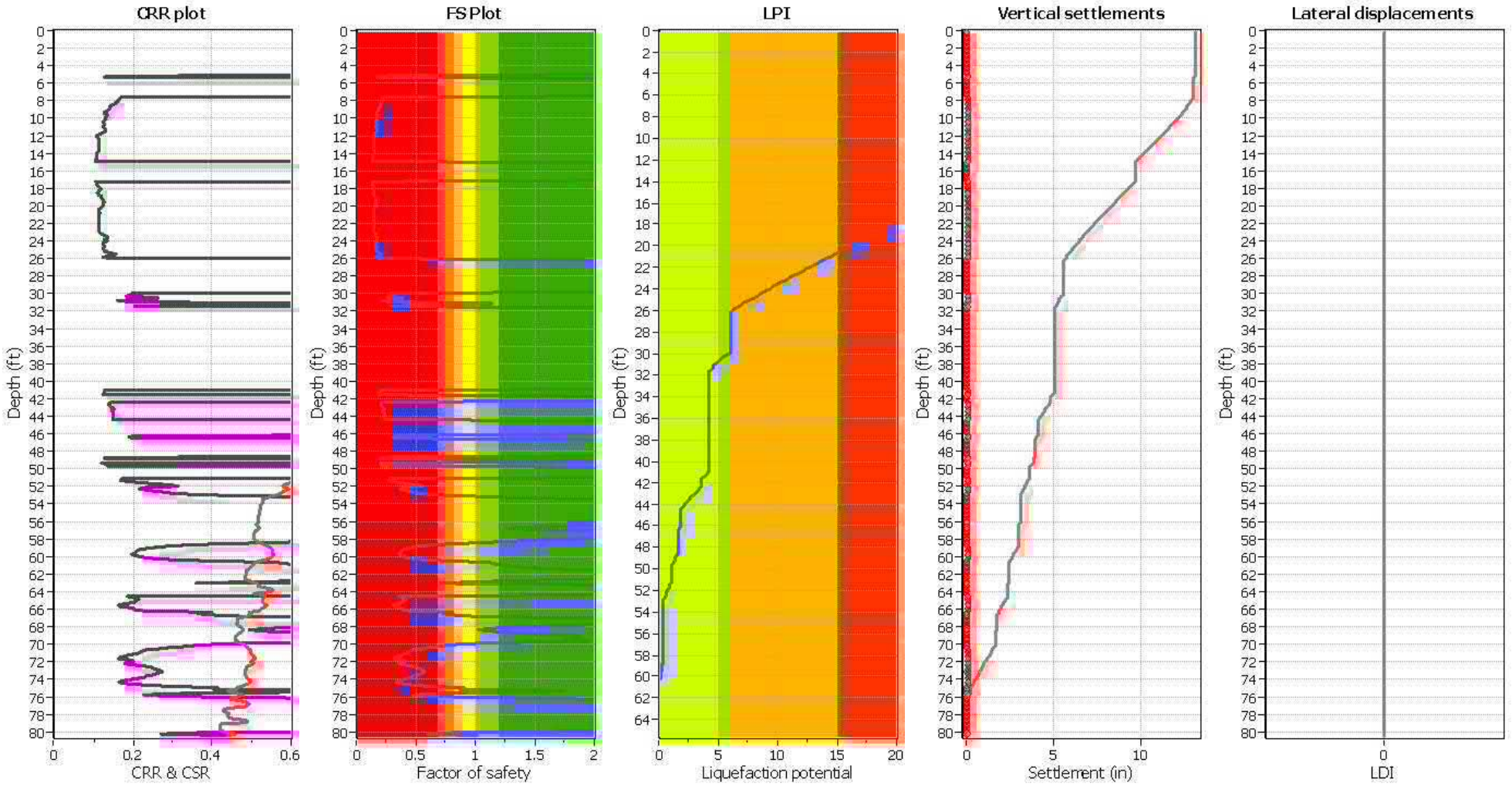
Liquefaction analysis overall plots (intermediate resu



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.59	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	9.00 ft	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plot



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.59	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	9.00 ft	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

APPENDIX F

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APPENDIX F – Dewatering Analyses Results

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AECOM

CALCULATION COVER PAGE

BASIC INFORMATION

Project	Job No.	TTP No. (if req'd)	Total pages includes attachments
Morena Pump Station	60530732-1.01.05.20.00		Page 1 of 1
Client	Department/Discipline		Calculation No.
	Geotechnical		1

Subject / Title

Calculation Rev. No.	Originator	Discipline Reviewer	Technical Peer Reviewer (if req'd)	Confirmation Req'd Y/N
0	T. Kanax	Ben Choy BYC 7/26/17		

Calculation Objective:
Dewatering Wells and flow calculations

Calculation Methodology and data to be confirmed:
Flow rates

References / Inputs/ Field Data:
L:\Projects\Legacy\IE_Xdrive\x_geo\Kanax\Others\Morena Pump Station\

Conclusions including confirmations to be obtained:
Estimated flow rates

This calculation is complete and ready for Discipline Review:

Originator _____
Signature / Date

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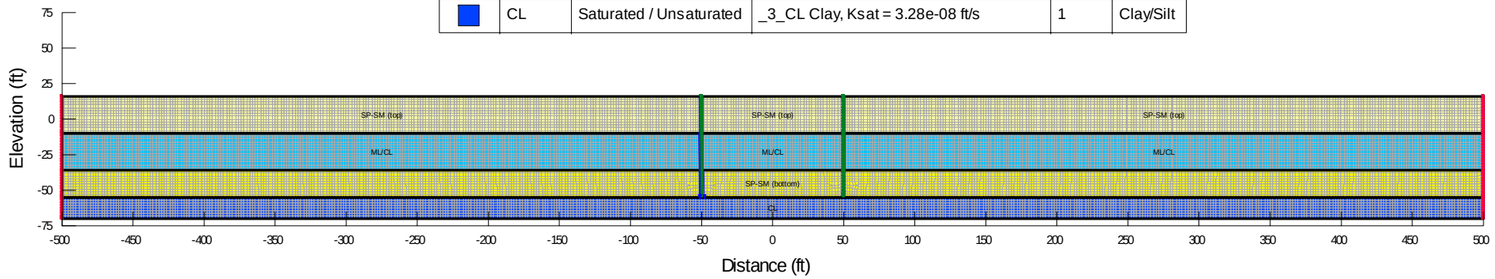
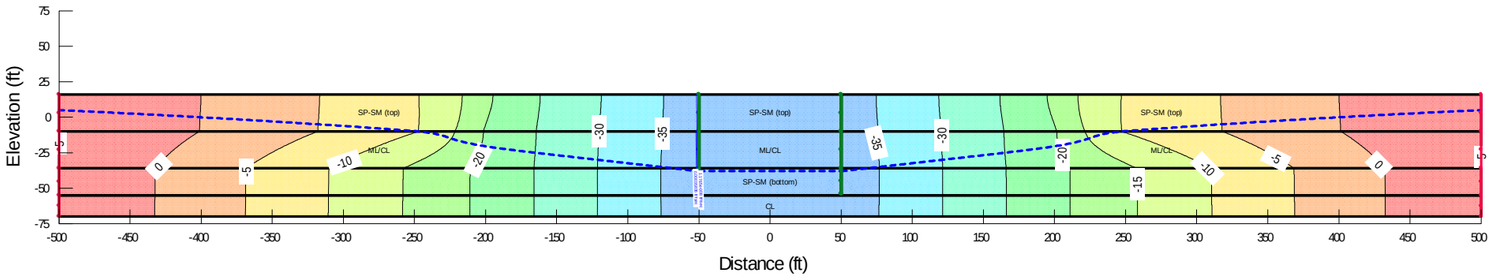
Date: 7/27/2017 Project: Morena Pump Station Pepared by: T. Kanax Checked by: NOT CHECKED

Preliminary SEEP/W Analysis Results –2D Model for Stady State Condition

(1) Model 1: Model width 1000 ft

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Vol. WC. Function
	SP-SM (top)	Saturated / Unsaturated	_1_SP-SM sand, Ksat = 1.64e-4 ft/s	1	Sand
	ML/CL	Saturated / Unsaturated	_2_CL/ML, Silty Clay, Ksat = 3.28e-06 ft/s	1	Clay/Silt
	SP-SM (bottom)	Saturated / Unsaturated	_1_SP-SM sand, Ksat = 1.64e-4 ft/s	1	Sand
	CL	Saturated / Unsaturated	_3_CL Clay, Ksat = 3.28e-08 ft/s	1	Clay/Silt

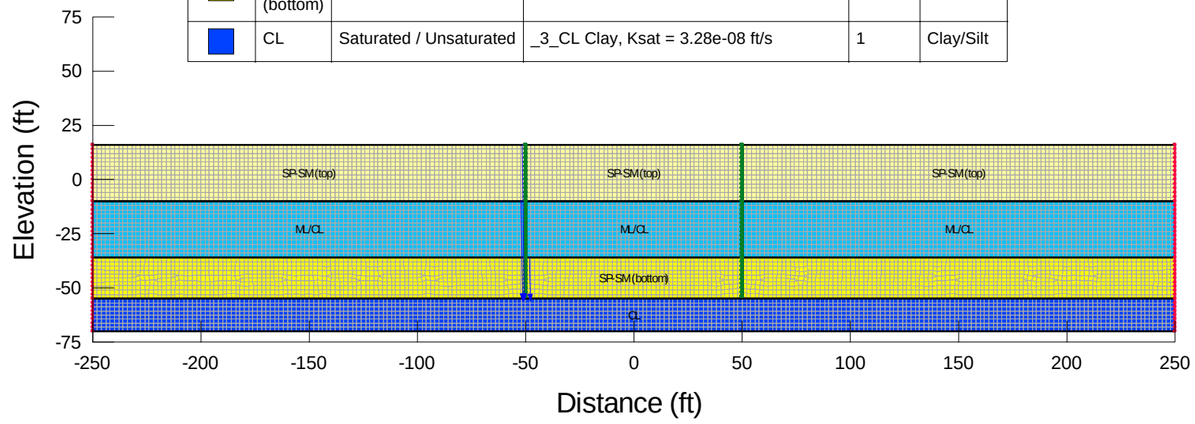


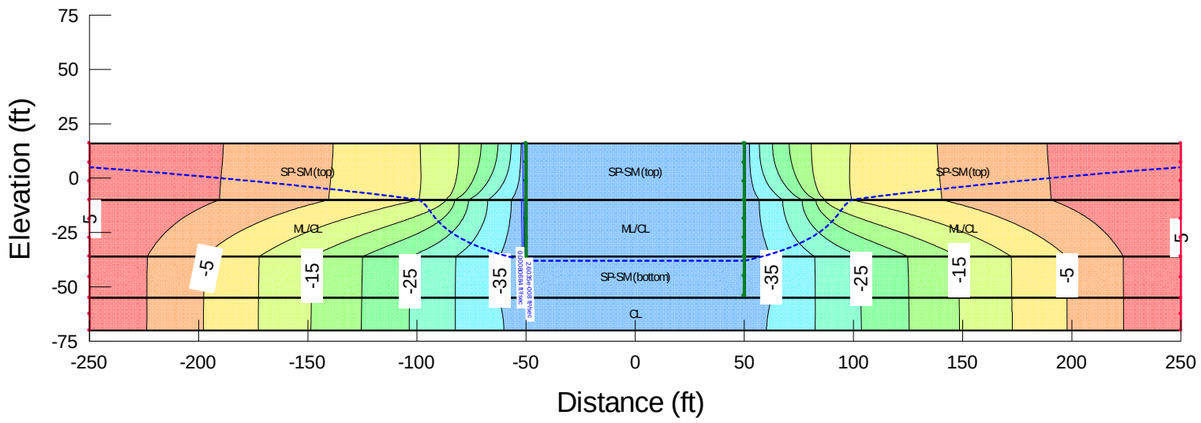


Results for Model 1: 20170725_Morena_2D_Model_R500ft_W1000ft.gsz								
Flow per foot per line of wells	=	0.00036	$ft^3/s/ft$ =	31.1	$ft^3/day/ft$	0.16	gpm/ft =	233 gpd/ft
Flow per foot for 2-lines of wells	=	0.00072	$ft^3/s/ft$ =	62.2	$ft^3/day/ft$	0.32	gpm/ft =	465 gpd/ft

(2) Model 2: Model width 500 ft

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Vol. WC. Function
	SP-SM (top)	Saturated / Unsaturated	_1_SP-SM sand, Ksat = 1.64e-4 ft/s	1	Sand
	ML/CL	Saturated / Unsaturated	_2_CL/ML, Silty Clay, Ksat = 3.28e-06 ft/s	1	Clay/Silt
	SP-SM (bottom)	Saturated / Unsaturated	_1_SP-SM sand, Ksat = 1.64e-4 ft/s	1	Sand
	CL	Saturated / Unsaturated	_3_CL Clay, Ksat = 3.28e-08 ft/s	1	Clay/Silt

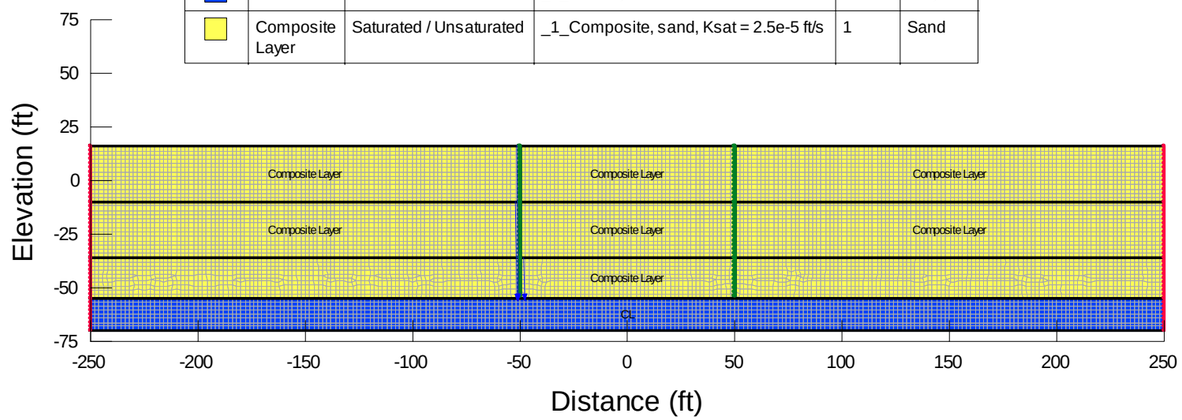


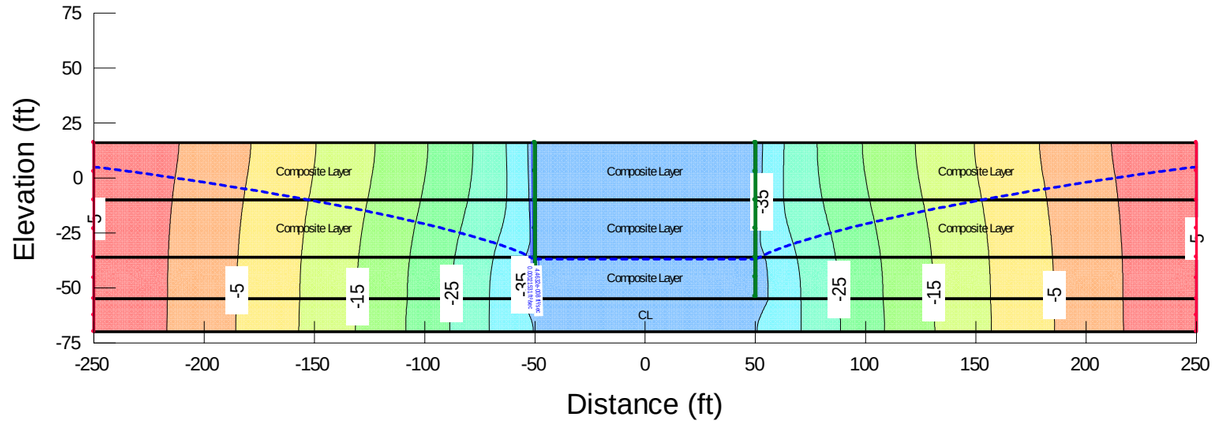


Results for Model 2: 20170725_Morena_2D_Model_R250ft_W500ft.gsz								
Flow per foot per line of wells =	0.00081	$ft^3/s/ft$ =	69.7	$ft^3/day/ft$ =	0.36	gpm/ft =	522	gpd/ft
Flow per foot for 2-lines of wells =	0.00161	$ft^3/s/ft$ =	139.4	$ft^3/day/ft$ =	0.72	gpm/ft =	1043	gpd/ft

(3) Model 3: Model width 500 ft and Composite Permeability

Color	Name	Model	K-Function	Ky'/Kx' Ratio	Vol. WC. Function
	CL	Saturated / Unsaturated	_3_CL Clay, Ksat = 3.28e-08 ft/s	1	Clay/Silt
	Composite Layer	Saturated / Unsaturated	_1_Composite, sand, Ksat = 2.5e-5 ft/s	1	Sand





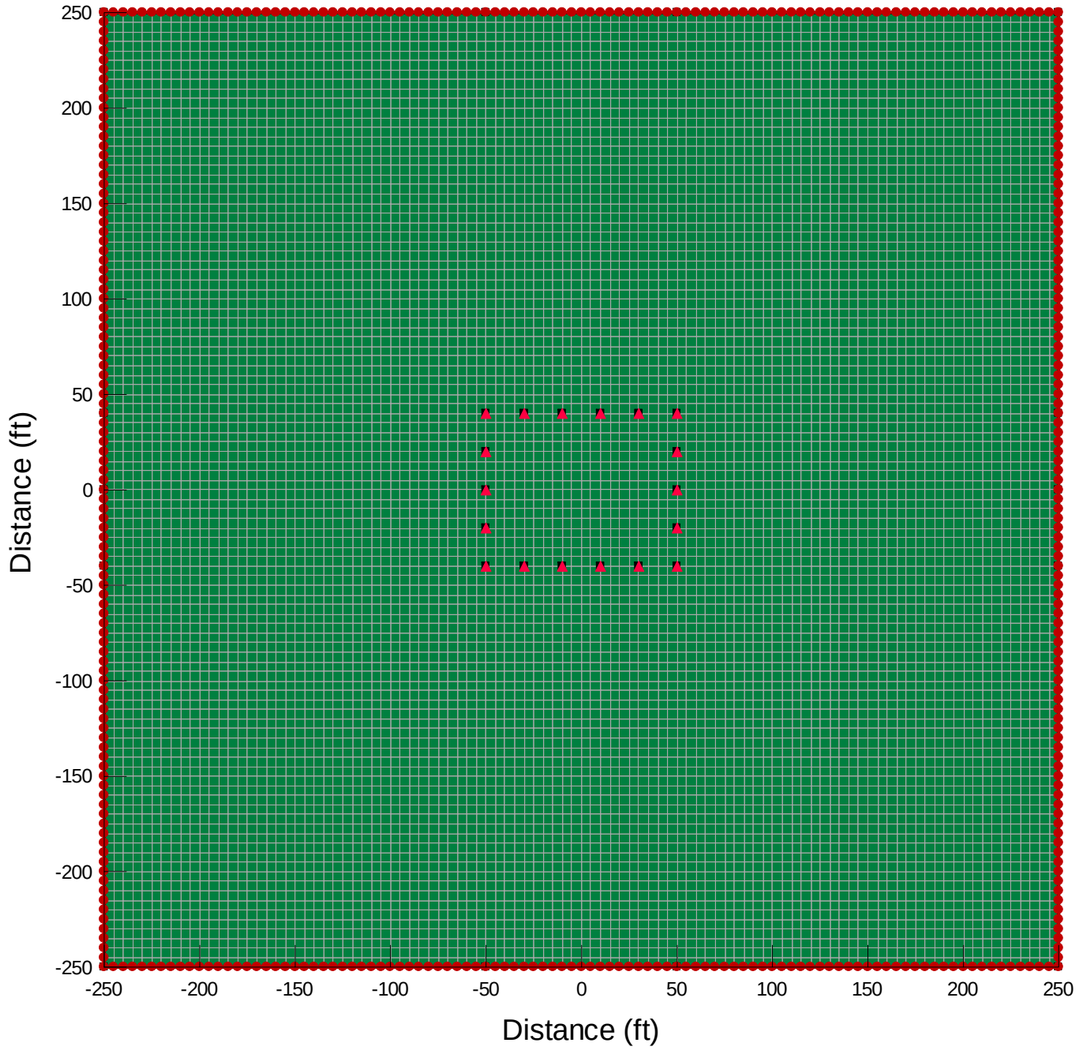
Results for Model 3: 20170727_Morena_2D_Model_R250ft_W500ft_k2.5e-5ftpersec.gsz								
Flow per foot per line of wells =	0.00022	$ft^3/s/ft$ =	19.0	$ft^3/day/ft$ =	0.10	gpm/ft =	142	gpd/ft
Flow per foot for 2-lines of wells =	0.00044	$ft^3/s/ft$ =	38.0	$ft^3/day/ft$ =	0.20	gpm/ft =	284	gpd/ft

Date: 7/27/2017 Project: Morena Pump Station Pepared by: T. Kanax Checked by: NOT CHECKED

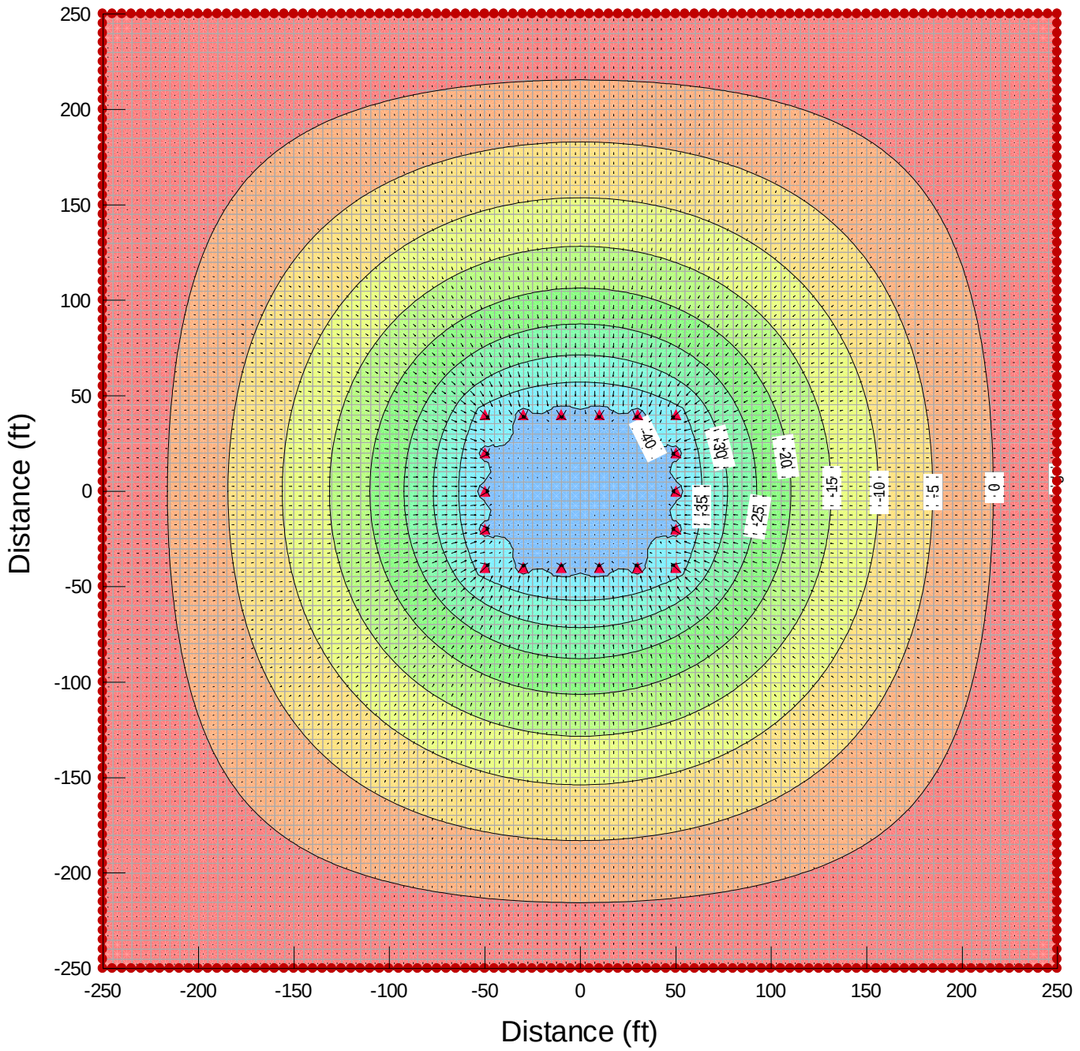
Preliminary SEEP/W Analysis Results –Plan View Model for Stady State Condition

(4) Model 4: Plan View Model with Model width of 500 ft and Composite Permeability (kh/kv= 1)

Wells spaced at 20 ft along 80 ft x100 ft rectangle; pumps operate at same pumping rate; thickness of the comosite saturated aquifer 60 ft; Composite permeability = **2.5e-5** ft/s; kh/kv = 1



Model



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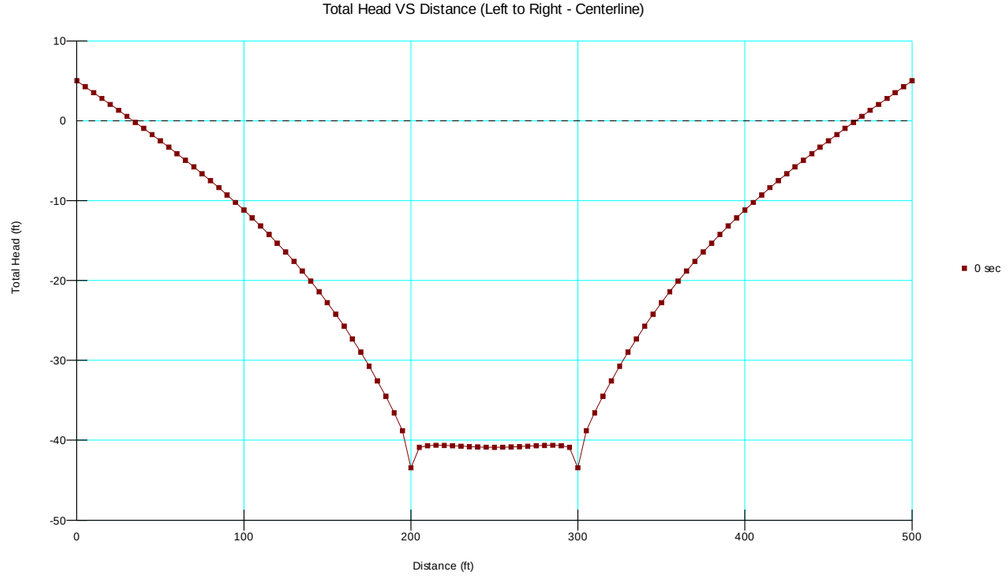
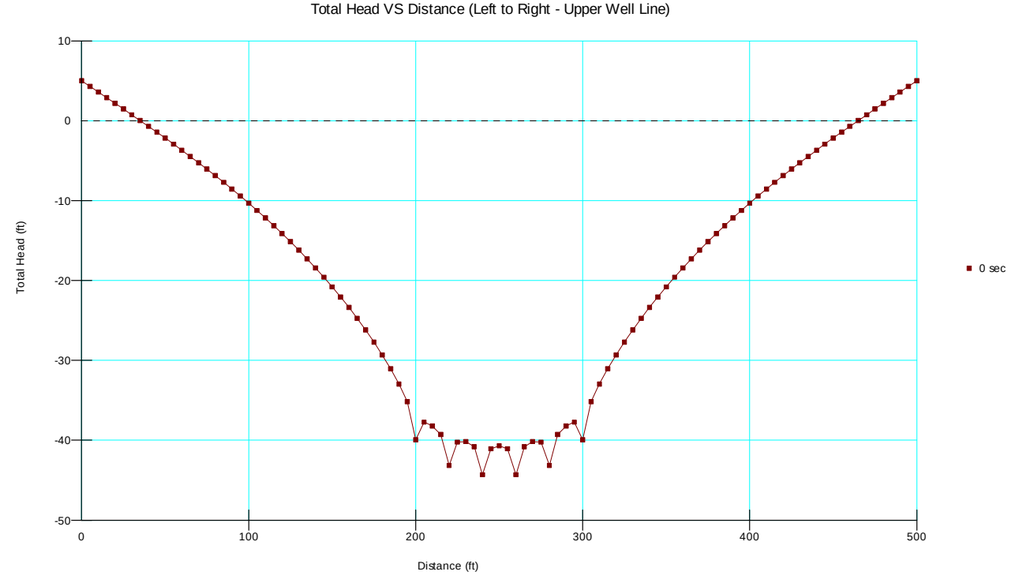
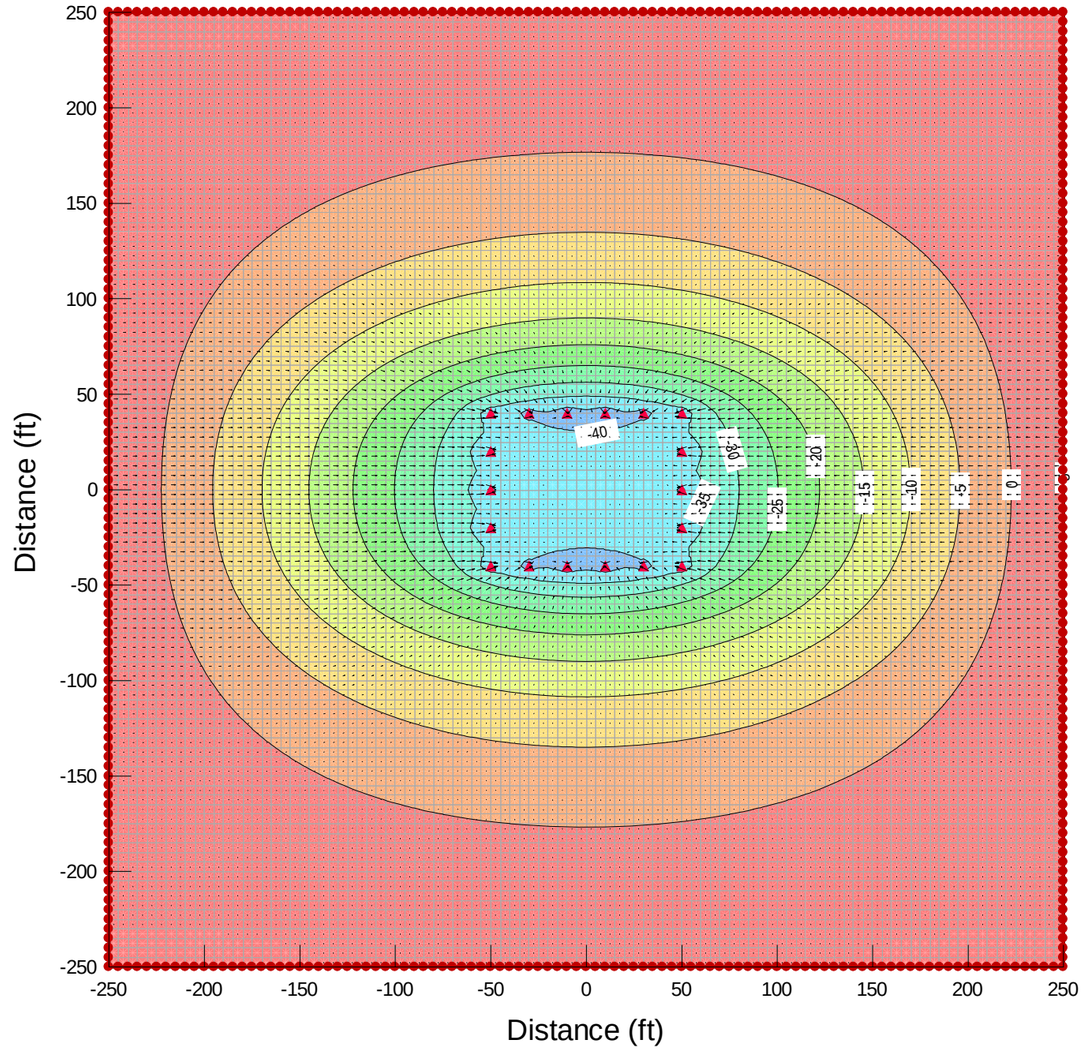




Results for Model 4:									
Pumping Rate	=	0.0145	ft^3/s per pump						
Total number of pumps	=	18							
Total flow extracted	=	0.261	ft3/s =	22550	ft^3/day =	117	gpm	=	168689 gpd

(5) Model 5: Plan View Model with Model width of 500 ft and Composite Permeability (kh/kv= 5)

Wells spaced at 20 ft along 80 ft x100 ft rectangle; pumps operate at same pumping rate; thickness of the comosite saturated aquifer 60 ft; Horizontal composite permeability (kh) = **1.25e-4** ft/s; kh/kv=5



Results for Model 5:									
Pumping Rate	=	0.037	ft^3/s per pump						
Total number of pumps	=	18							
Total flow extracted	=	0.666	ft3/s =	57542	ft^3/day =	299	gpm =	430447	gpd

APPENDIX G

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APPENDIX G – Worksheet C.4-1

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Worksheet C.4-1: Categorization of Infiltration Feasibility Condition

Categorization of Infiltration Feasibility Condition	Worksheet C.4-1

Part 1 - Full Infiltration Feasibility Screening Criteria

Would infiltration of the full design volume be feasible from a physical perspective without any undesirable consequences that cannot be reasonably mitigated?

Note that it is not necessary to investigate each and every criterion in the worksheet if infiltration is precluded. Instead a letter of justification from a geotechnical professional familiar with the local conditions substantiating any geotechnical issues will be required.

Criteria	Screening Question	Yes	No
1	**Is the estimated reliable infiltration rate below proposed facility locations greater than 0.5 inches per hour?** The response to this Screening Question must be based on a comprehensive evaluation of the factors presented in Appendix C.2 and Appendix D.		X

Provide basis:

The site is mapped in Hydraulic Soil Group D near the border of that zone. The explorations performed to date indicate that the site is underlain by interbedded sands, silts and clays. The soil is considered to have a potential infiltration rate below 0.5 inches per hour, but in the partial infiltration range. In addition groundwater has been measured at 9 feet below ground surface.

Summarize findings of studies; provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.

2	**Can infiltration greater than 0.5 inches per hour be allowed without increasing risk of geotechnical hazards (slope stability, groundwater mounding, utilities, or other factors) that cannot be mitigated to an acceptable level?** The response to this Screening Question must be based on a comprehensive evaluation of the factors presented in Appendix C.2.		X

Provide basis:

The alluvial soils underlying the site and the adjacent sites is potentially liquefiable. Full infiltration could cause mounding of the groundwater increasing the loose soils below the groundwater level that are potentially liquefiable in the area.

Summarize findings of studies; provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.

Worksheet C.4-1 Page 2 of 4			
Criteria	Screening Question	**Yes**	**No**
3	**Can infiltration greater than 0.5 inches per hour be allowed without increasing risk of groundwater contamination (shallow water table, storm water pollutants or other factors) that cannot be mitigated to an acceptable level?** The response to this Screening Question must be based on a comprehensive evaluation of the factors presented in Appendix C.3.		X
Provide basis: An environmental release occurred at the Lloyd's Pest control about 200 feet upgradient of the project site has been reported and closed. Groundwater was sampled in the monitoring well performed for this project. The analytical laboratory testing indicated TPH and VOCs in the groundwater. Full infiltration could cause contaminants to migrate downgradient towards the San Diego River. Summarize findings of studies; provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.			
4	**Can infiltration greater than 0.5 inches per hour be allowed without causing potential water balance issues such as change of seasonality of ephemeral streams or increased discharge of contaminated groundwater to surface waters?** The response to this Screening Question must be based on a comprehensive evaluation of the factors presented in Appendix C.3.	X	
Provide basis: Downstream water rights should not be affected. Summarize findings of studies; provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.			
Part 1 Result*	If all answers to rows 1 - 4 are "**Yes**" a full infiltration design is potentially feasible. The feasibility screening category is **Full Infiltration** If any answer from row 1-4 is "**No**", infiltration may be possible to some extent but would not generally be feasible or desirable to achieve a "full infiltration" design. Proceed to Part 2		

*To be completed using gathered site information and best professional judgment considering the definition of MEP in the MS4 Permit. Additional testing and/or studies may be required by County staff to substantiate findings.

Worksheet C.4-1 Page 3 of 4

Part 2 – Partial Infiltration vs. No Infiltration Feasibility Screening Criteria

Would infiltration of water in any appreciable amount be physically feasible without any negative consequences that cannot be reasonably mitigated?

Criteria	Screening Question	Yes	No
5	**Do soil and geologic conditions allow for infiltration in any appreciable rate or volume?** The response to this Screening Question must be based on a comprehensive evaluation of the factors presented in Appendix C.2 and Appendix D.	X	

Provide basis:

Infiltration testing will be performed if infiltration is required. Partial infiltration is suspected feasible from a soils conditions based on the subsurface soils encountered as part of the field investigation performed for this project. However, groundwater has been measured at 9 feet below the ground surface at the site.

Summarize findings of studies; provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability and why it was not feasible to mitigate low infiltration rates.

6	**Can Infiltration in any appreciable quantity be allowed without increasing risk of geotechnical hazards (slope stability, groundwater mounding, utilities, or other factors) that cannot be mitigated to an acceptable level**? The response to this Screening Question must be based on a comprehensive evaluation of the factors presented in Appendix C.2.	X	

Provide basis:

Partial infiltration would be possible without much risk of mounding of the groundwater.

Summarize findings of studies; provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability and why it was not feasible to mitigate low infiltration rates.

Worksheet C.4-1 Page 4 of 4			
Criteria	Screening Question	**Yes**	**No**
7	**Can Infiltration in any appreciable quantity be allowed without posing significant risk for groundwater related concerns (shallow water table, storm water pollutants or other factors)?** The response to this Screening Question must be based on a comprehensive evaluation of the factors presented in Appendix C.3.		X
Provide basis: The groundwater contamination in the area would preclude infiltration of stormwater at the site. Summarize findings of studies; provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability and why it was not feasible to mitigate low infiltration rates.			
8	**Can infiltration be allowed without violating downstream water rights**? The response to this Screening Question must be based on a comprehensive evaluation of the factors presented in Appendix C.3.	X	
Provide basis: Downstream water rights should not be affected. Summarize findings of studies; provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability and why it was not feasible to mitigate low infiltration rates.			
Part 2 Result*	If all answers from row 5-8 are yes then partial infiltration design is potentially feasible. The feasibility screening category is **Partial Infiltration.** If any answer from row 5-8 is no, then infiltration of any volume is considered to be **infeasible** within the drainage area. The feasibility screening category is **No Infiltration.**		

*To be completed using gathered site information and best professional judgment considering the definition of MEP in the MS4 Permit. Additional testing and/or studies may be required by Agency/Jurisdictions to substantiate findings

R E P O R T

FAULT INVESTIGATION
MORENA PUMP STATION, WW FORCE MAIN, AND BRINE/CENTRATE CONVEYANCE PREDESIGN (NC01)

SAN DIEGO, CALIFORNIA

Prepared for

City of San Diego
Public Utilities Department
San Diego, California

September 19, 2017

AECOM Project No. 60530732

Prepared by

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F 1-619-610-7601

September 19, 2017

Ms. Laila Nasrawi
City of San Diego
Public Utilities Department
9192 Topaz Way
San Diego, California

Subject: Fault Hazard Investigation Report
Morena Pump Station, WW Force Main, and
Brine/Centrate Conveyance Predesign (NC01)
San Diego, California
AECOM Project No. 60530732

Dear Ms. Nasrawi:

AECOM Technical Services, Inc. has prepared the attached Fault Hazard Investigation Report for the Morena Pump Station, Wastewater Force Main and Brine/Centrate Conveyance Pipeline for Pure Water San Diego. The purpose of this investigation is to evaluate potential fault hazards for design. Close-spaced subsurface explorations (Cone Penetration Test [CPT]) soundings were performed to investigate possible faults at the Morena Pump Station. The assessment of potential fault hazards for the pipelines was based on review of published geologic maps, previous investigations and interpreting historical air photos, as discussed in the report. Separate geotechnical investigation reports were prepared for the Morena Pump Station and cut-and-cover pipelines and for the proposed tunnels.

Sincerely,

AECOM Technical Services, Inc.

Michael E. Hatch C.E.G. 1925
Principal Engineering Geologist

David L. Schug, C.E.G. 1212
Principal Engineering Geologist

Steven M. Fitzwilliam, G.E. 2501
Principal Geotechnical Engineer

TABLE OF CONTENTS

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LIST OF TABLES

APPENDICES

List of Acronyms and Abbreviations

AECOM	AECOM Technical Services, Inc.
ASCE	American Society of Civil Engineers
ASTM	ASTM International, formerly American Society for Testing and Materials
bgs	below ground surface
CBC	California Building Code
CGS	California Geological Survey
CPT	Cone Penetrometer Test
EQFZ	Earthquake Fault Zone
ft	feet
g	Gravitational Acceleration
ka	Thousand years (Kilo annum)
IBC	International Building Code
MCE	Maximum Considered Earthquake
MPS	Morena Pump Station
NGVD 29	National Geodetic Mean Datum of 1929
pcf	pounds per cubic foot
pci	pounds per cubic inch
Project	Morena Pump Station, WW Force Main, and Brine/Centrate Conveyance Predesign (NC01) Project
psf	pounds per square foot
RCFZ	Rose Canyon Fault Zone
SPT	Standard Penetration Test
URS	URS Corporation
USA	Underground Service Alert
USGS	United States Geological Survey

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1.0 INTRODUCTION

This fault investigation report was prepared for the Morena Pump Station, WW Force Main, and Brine/Centrate Conveyance Predesign (NC01) Project ("Project") for Pure Water San Diego. Specifically, the report provides a summary of the fault hazard investigation performed for the Morena Pump Station. Fault hazard evaluations are also provided for the pipeline portions of the project based on available data and interpretations of historic aerial photography. The planned locations of the pump station and waste water and brine/centrate pipelines are shown on Figure 1.

1.1 PROJECT DESCRIPTION

The layout of the primary components of the Morena Pump Station is shown on Figure 2. The proposed finished grade for the Morena Pump Station (MPS) is approximately elevation 16 feet National Geodetic Mean Datum of 1929 (NGVD 29). The Intake Screening Building has a proposed bottom of foundation elevation of -18.25 feet NGVD 29, which will require an approximate excavation depth of 34 feet. The Pump Station Building will require an excavation depth of about 51 feet to accommodate the foundation (bottom elevation of -32.5 feet NGVD 29) and underlying base layer. The Energy Dissipator Structure has a proposed bottom of foundation elevation of -7.33 feet NGVD 29, which will require an excavation of about 25 feet deep. Other supporting facilities, including the Electrical/Maintenance Building, electrical transformers, Odor Control System and a High Purity Oxygen Injection Facility will be constructed at or near finished grade. Based on the planned operations of the MPS, it is expected that there will not be continuous human occupancy needed for general operations of the facility. Routine maintenance will be accomplished on a periodic basis with maintenance personnel being dispatched to the site. Maintenance activities will include the removal of screening debris containers from the Screenings Building along with general maintenance of the odor control systems, pumping facilities and inspections of said facilities.

The wastewater and brine/centrate pipelines will continue from the Morena Pump Station in a north and east direction to the North City Water Reclamation Plant, located in the northeast corner of Miramar Road and I-805. The general alignment is shown on Figure 1; minor deviations from this alignment are also being considered to address specific construction constraints such as utility conflicts and addressing constructability issues at Tecolote Creek, San Clemente Canyon and Rose Canyon/NCTD crossings. The majority of the proposed pipeline will be installed through traditional open cut/cover construction methods with the exception proposed tunnels at San Clemente Canyon, Rose Canyon at Rose Creek/NCTD Railroad, and Executive Drive at I-805. Additional tunnel crossings are proposed for the diversion structure pipelines south of the MPS. The proposed pipe invert depths for the cut-and-cover portions of the pipelines generally range from 10 to 30 feet below grade dependent on specific locations and existing infrastructure conflicts.

1.2 PREVIOUS STUDIES

Our understanding of the site geologic conditions and fault hazards is based on a review of available information and investigations performed by AECOM as part of this project. Selected portions of significant previous projects are included in Appendix A. Projects that provided important background for the fault hazard portion of this project included:

- Mid-Coast Corridor Transit Project – Geotechnical, Geologic and Seismic Impacts Technical Report. Kleinfelder Report dated August 2014.
- Mid-Coast Corridor Transit Project – Earthquake Fault Rupture Field Investigation. Kleinfelder Report dated April 9, 2014.
- Fault Hazard Investigation, Proposed Hilton Garden Inn, 4200 Taylor Street, San Diego. CTE report dated May 22, 2012 (revised).
- Paleoseismic Assessment of the Late Holocene Rupture History of the Rose Canyon Fault Zone in San Diego. Report to Southern California Edison, prepared by team led by Dr. T. K. Rockwell, dated December, 2012.

Appendix A includes selected portions of previous and current subsurface investigation.

Figure 1
Alignment Map
Morena Pipeline Project
San Diego, CA

Alignments

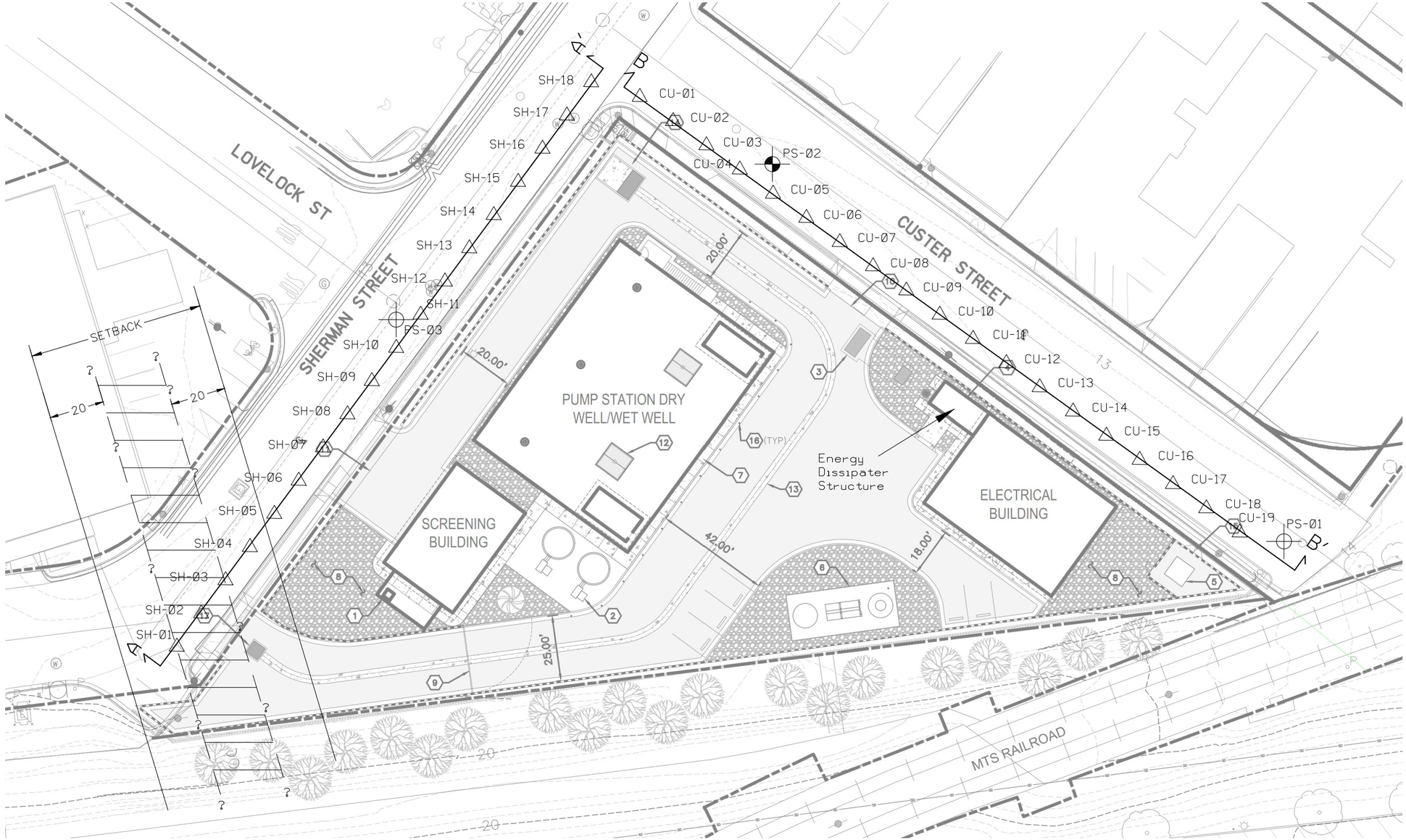
- City Alternative No. 1a (20151123)
- City Alternative No. 2 (20151123)
- Alvarado Morena Distribution and Transmission Water Pipelines
- Tunnel Crossing
- MTS Tunnel Crossings

0 1,750 3,500 ft

1:42,000 1 inch = 3,500 feet

AECOM

AECOM SD, U:\Projects_GIS\60530732\map_docs\mxd\alignment_tunnels.mxd, 9/14/2017, paul.moreno



Reference: KEH 60% Design 7-25-17

LEGEND

△ SH-01	Cone Penetration Test (CPT), 2017
⊕ PS-01	Exploratory Boring, 2017
⊕ PS-02	Exploratory Boring with Monitoring Well, 2017
A — A′	Location of Geologic Cross Section

Possible Fault Zone With Setback

MORENA PUMP STATION SITE PLAN
MORENA PIPELINE PROJECT
SAN DIEGO, CALIFORNIA

AECOM

20 0 20 40
SCALE: 1"= 40'

CHECKED BY: MEH	DATE: 7-25-17	FIG. NO: 2
PM: JL	PROJ. NO: 60530732	

2.0 FAULT HAZARD INVESTIGATION

This section of the report summarizes the fault hazard investigation at the Morena Pump Station (MPS). Site specific explorations were performed adjacent to MPS along Sherman Street and Custer Street within 50 feet of the property line of said parcel. Currently, the City of San Diego is in the process of acquiring the property for the MPS which is occupied by the San Diego Humane Society. Until the City has obtained ownership rights to the property, on-site investigations cannot be conducted. Literature review and air photos interpretations were performed for the force main and brine/centrate pipeline alignments, including the proposed Alvarado Morena Transmission and Distribution Water Pipelines, as described below.

2.1 REVIEW, COMPILATION AND AERIAL PHOTOGRAPHY REVIEW

The investigation included review and evaluation of published and unpublished geotechnical, geologic, and geologic hazard information in the project area. The primary sources of published fault hazard information include California Geologic Survey (CGS) Earthquake Fault Zone (EFZ) information, the CGS publication on the Rose Canyon Fault Zone (Treiman 1993), and the City of San Diego Seismic Safety Study. Other significant studies include the published geologic mapping of the area by Kennedy (1975) and by Kennedy and Tan (2008). The City of San Diego Seismic Safety Study represents a compilation of data that draws from the mapping by Kennedy augmented by consulting studies aimed at updating hazard input into the City map.

Faults on Figure 3a and 3b are compiled from reviewed sources and rely primarily on the City Seismic Safety Study, CGS EFZ, and recent detailed studies along the Rose Canyon fault performed for the Mid Coast Corridor Project. The faults compiled include active and potentially active faults without differentiation, except for the CGS EFZ faults which are interpreted to be active.

Fault lines as shown on maps are represented as dotted, dashed and solid line segments denoting concealed, inferred or approximately located. This is the typical convention for faults as shown on geologic and geologic hazard maps and is presented for the various mapped faults, depending on the map source.

Faults located based on terrain analysis performed on historic aerial photography are similarly depicted using solid and dashed lines to show continuity of geomorphic features and confidence level based on geomorphic expression of faulting. These mapped features are suspected active faults, but their presence and level of activity have not been confirmed by field investigations.

The historic aerial photographs reviewed include vertical stereographic photographs from 1928, 1937, 1941 and 1953.

2.2 MORENA PUMP STATION FIELD INVESTIGATION

2.2.1 Cone Penetrometer Tests

Thirty seven (37) Cone Penetrometer Test (CPT) soundings were performed by Gregg Drilling along Sherman and Custer Streets as shown of Figure 2. CPT soundings were spaced

approximately 15 feet apart and extended to depths of 80 feet or refusal. Eighteen CPT soundings were performed along Sherman Street and 19 along Custer Street and are designated SH-1 through SH-18 and CU-1 through CU-19, respectively. Logs of these CPTs are presented in Appendix B along with a summary of the field activity and a description of the CPT methodology.

2.2.2 Geotechnical Borings

Three geotechnical borings were performed in the City streets adjacent to the MPS as shown on Figure 2 and designated PS-1, -2, and -3. These borings were drilled using hollow stem auger methods and extended to depths of 62 to 81 feet. The logs of borings for the pump station are presented in AECOM's Geotechnical Report for the project.

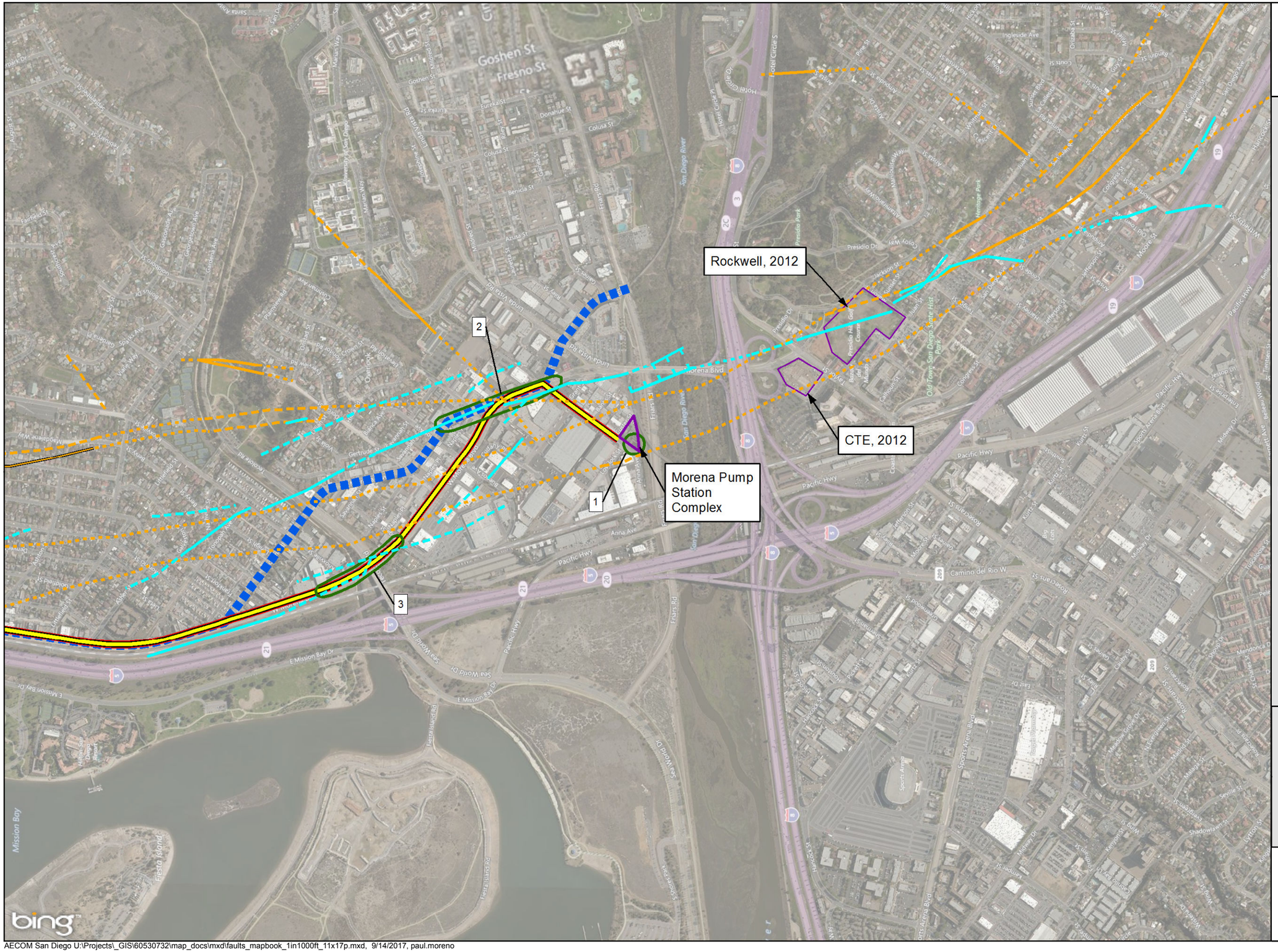


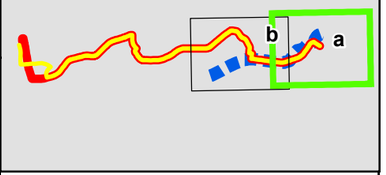
Figure 3a
Project Fault Hazard Map
Morena Pipeline Project
San Diego, CA

Alignments
- City Alternative No. 1a (20151123)
- City Alternative No. 2 (20151123)
- Alvarado Morena Distribution and Transmission Water Pipelines

Alquist Priolo (EFZ) Faults
- Accurately Located Fault Trace
- Approximately Located Fault Trace
- Inferred Fault Trace
- Concealed Fault Trace
- Alquist-Priolo Earthquake Fault Zone

Faults (SanGIS)
- FAULT
- INFERRED FAULT
- CONCEALED ZONE
- SHEAR ZONE

Faults (Compiled interpretations)
- Distinct geomorphic features in historic aerial photos
- Moderately expressed geomorphic features in historic aerial photos
- Concealed
- Graben
- Fault Hazard Location



Sources: SanGIS; CGS; Kleinfelder.

0 1,000 Feet

1:12,000 1 inch = 1,000 feet

AECOM

AECOM San Diego U:\Projects_GIS\60530732\map_docs\mxd\faults_mapbook_1in1000ft_11x17p.mxd, 9/14/2017, paul.moreno

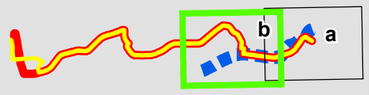
Figure 3b
Project Fault Hazard Map
Morena Pipeline Project
San Diego, CA

Alignments
- City Alternative No. 1a (20151123)
- City Alternative No. 2 (20151123)
- Alvarado Morena Distribution and Transmission Water Pipelines

Alquist Priolo (EFZ) Faults
- Accurately Located Fault Trace
- Approximately Located Fault Trace
- Inferred Fault Trace
- Concealed Fault Trace
- Alquist-Priolo Earthquake Fault Zone

Faults (SanGIS)
- FAULT
- INFERRED FAULT
- CONCEALED ZONE
- SHEAR ZONE

Faults (Compiled interpretations)
- Distinct geomorphic features in historic aerial photos
- Moderately expressed geomorphic features in historic aerial photos
- Concealed
- Graben
- Fault Hazard Location



Sources: SanGIS; CGS; Kleinfelder.

0 1,000 Feet

1:12,000 1 inch = 1,000 feet

AECOM

3.0 GEOLOGIC AND SEISMIC SETTING

3.1 GEOLOGIC SETTING

Coastal San Diego lies within the Peninsular Ranges physiographic province that is characterized by northwesterly trending mountains and intervening valleys. The western portion of the province, which includes the site area, is generally characterized as a coastal plain subprovince that includes broad mesas and terraces that have been cut into Tertiary age sedimentary deposits. These terraces are capped by thin Quaternary age sedimentary deposits that reflect former high stands of sea level during Pleistocene glacial epochs. These coastal terraces are incised by westerly trending drainages. The project alignments cross a series of secondary drainages including; Tecolote Canyon, Rose Canyon, and San Clemente Canyon.

The San Diego River is the main drainage course which has shaped and modified the central-western San Diego metropolitan area. The southern portion of the Project is located adjacent to the northern margin of San Diego River and lies within the ancient confines of this river system.

3.2 SITE GEOLOGY

3.2.1 Pump Station

Subsurface conditions at the Morena Pump Station were interpreted based on the results of subsurface borings PS-1 through PS-3 and CPTs SH-01 through SH-18 and CU-01 through CU19, performed by AECOM in March and April 2017. CPT logs are included in the Appendix B. Approximate locations of the borings and CPTs are shown on Figure 2. Due to access limitations at the proposed Morena Pump Station site, all explorations were performed in the city streets around the perimeter of the site.

The preliminary available data indicates that within the depth of the explorations (maximum depth about 80 feet below ground surface [bgs]), the site is underlain by a thin fill layer over a thick sequence of young alluvium. The fill ranges from about 3 to 5 feet in depth and consists primarily of silty sand. The underlying alluvium varies significantly, and is highly interlayered in some zones. Three generally distinct units have been identified within the alluvial deposits and are described below. These units are very similar in thickness, depth and CPT signature to units identified in a study to the south of the Project area in the Old Town area for a Hilton Garden Hotel (CTE, 2012). This site occupies a very similar geologic and geomorphic setting as that of the pump station.

Unit 1. Sandy fluvial deposits. Unit 1 is present across the site as a continuous unit comprised primarily of silty sands and poorly graded sands with lesser amounts of sandy silt and fine grained layers. The layer extends to a depth of approximately 21 to 30 feet along Sherman Street and 22 to 26 feet along Custer Street.

Unit 2. Thinly bedded silts, clays, and sands. Unit 2 is a shallow estuarine and lagoonal deposit. Shell fragments are present and a sandy lower subunit is interpreted as shown on the site cross sections. The units are laterally continuous and extend to a depth of approximately 48 to 55 feet along the Sherman Street section and 48 to 51 feet along Custer Street.

Unit 3. Sandy fluvial deposits. Unit 3 represents a distinct geologic change with denser, sandy deposits underlying the thin bedded and generally fine-grained estuarine and lagoonal deposits of Unit 2. Unit 3 contains gravels and refusal to CPT advancement was encountered in approximately half of the CPT locations (see Appendix B).

Preliminary Age Assessment. Based on correlation to the dated lithologic and stratigraphic units to the south of the San Diego River channel in the Old Town area (CTE, 2012), AECOM interprets the sequence of deposits at the pump station to range in age from late Pleistocene to mid- Holocene. Pump Station Unit 2 correlates to the Hilton Unit 3 that dates to approximately 7 to 7.5 thousand years (ka). Pump Station unit three correlates to Hilton Unit 4 dated at 9.2 ka at a depth of 61 feet. The pump station CPTs encountered refusal in gravelly or cobbly materials that likely correlate to Hilton Unit 4 and Hilton Unit 5 in the deeper refusals. Hilton Unit 5 was estimated to range from 10.5 to 20 ka (CTE, 2012).

3.2.2 Pipeline

The project can be divided into three reaches with regard to geologic setting and subsurface conditions. Along most of the southerly pipeline reach (between Clairemont Drive and Friars Road) the combined thickness of fill and alluvium is greater than the anticipated pipeline trench depths, except for short reaches within the Older Paralic Deposits (formerly Bay Point Formation), a semi consolidated sedimentary formation.

A second reach for the project can be defined where the pipeline route ascends up along Clairemont Drive from the coastal plain to the mesa top. This reach traverses primarily Pleistocene age terrace deposits (Very Old Paralic Deposits – formerly Lindavista Formation).

A third reach can be described extending along the mesa tops and ending at the North City Water Reclamation Plant. This portion of the route is mostly within dense Tertiary sedimentary formations including the Scripps Formation and Quaternary sedimentary deposits including various units of the Very Old Paralic Deposits.

More description of the geologic units and a geologic strip map of the project are provided in the 30% Design Geotechnical Report.

3.3 TECTONIC SETTING

The tectonic setting of the San Diego area is influenced by plate boundary interaction between the Pacific and North American lithospheric plates. This crustal interaction occurs along a broad zone of northwest striking, predominantly right slip faults that span the width of the Peninsular Ranges and extend offshore into the California Continental Borderland Province. At the latitude of San Diego, this zone extends from the San Clemente fault zone, located approximately 60 miles offshore of the San Diego coastline to the San Andreas Fault, located about 70 miles east of San Diego, (CGS, 2010, http://maps.conservation.ca.gov/cgs/fam/).

Geologic, geodetic, and seismic data indicate that the faults along the eastern margin of the plate boundary, including the San Andreas, San Jacinto, and Imperial faults, including their associated branches, are currently the most active and appear dominant in accommodating the majority of the motion between the two adjacent plates. A smaller portion of the relative plate motion is being accommodated by northwest-striking faults to the west, including the Elsinore, Rose

Canyon, and offshore faults. Many of these faults have experienced historic seismic activity, as shown on Figure 4. The following is a general description of the Rose Canyon Fault Zone and its interaction with the proposed project improvements associated with the Morena Pump Station and Conveyance System.

3.3.1 Rose Canyon Fault Zone

The Morena Pump Station and the southern portion of the pipeline alignment along Morena Boulevard are considered to lie within the active Rose Canyon Fault Zone (RCFZ). The on-shore portion of the RCFZ extends along the northeast flank of Mount Soledad at La Jolla and continues southward along the eastern margins of Mission Bay (just west of Interstate 5) towards downtown San Diego. Between Mission Bay and San Diego Bay, the zone appears to widen and diverge. Active faults (i.e. Holocene-age fault rupture) and potentially active faults (i.e. Quaternary-age fault rupture) are present in the Project area.

The pump station lies within the RCFZ and concealed fault strands have been mapped on the City maps as lying to east and west of the pump station site as shown on Figure 3a. Mapped faults in the project area trend (strike) predominantly north-northwest; these trends are consistent with the overall trend of the RCFZ along the eastern margin of Mission Bay.

3.3.2 Other Faults

Other faults in the area include inactive and potentially active faults mapped in the project vicinity east of the RCFZ (City of San Diego, 2008). None of these faults cross the Project alignment and therefore are not considered potential fault hazards to the project limits.

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Figure 4
Regional Fault and Epicenter Map
Morena Pipeline Project
San Diego, CA

Project Alignment
County Boundary
State Boundary

Earthquake Epicenter Magnitude
2.91 - 4.0
4.01 - 5.0
5.01 - 6.0
6.01 - 7.0
7.01 - 8.0

Alquist Priolo (EFZ) Faults
Accurately Located Fault Trace
Approximately Located Fault Trace
Concealed Fault Trace
Inferred Fault Trace

Quaternary & Pre-quaternary Faults
Accurately Located Fault Trace
Approximately Located Fault Trace
Concealed Fault Trace

Sources: ESRI; CGS.

0 6.5 13 Miles

1:823,680 1 inch = 13 miles

AECOM

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4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 FAULT CONSIDERATIONS

Earthquake fault rupture is a hazard associated with active faults during sizable seismic events. The CGS and the City of San Diego consider a fault active if it displays evidence of activity within the Holocene epoch, i.e., in the last approximately 11,000 years (Hart and Bryant, 2008). Potentially active faults are classified as having exhibited activity prior to 11,000 years but within the past 1.6 million years (City of San Diego, 1999).

Significant ground rupture generally does not occur until earthquake magnitudes reach M6 or greater. Faulting events which do rupture the ground surface can have a significant effect on existing infrastructure and development improvements that crosses the ruptured area.

The RCFZ is considered capable of maximum earthquake magnitudes on the order of M6.8 to 7.2. Slip rate estimates based on paleoseismic studies (fault trenching, geomorphic analysis) in the Rose Creek area estimate a minimum slip rate of 1.5 mm/year (Lindvall and Rockwell, 1995). Subsequent studies by Rockwell (2010) provides a best estimate of slip rate for the Rose Canyon at 2 mm/yr.

The paleoseismic studies in Rose Creek noted evidence for at least 3 displacement events in the past 8,000 years. More recent studies in Old Town suggest that there have been more than three events. Current estimates of recurrence suggest an interval on the order of 500 to 1,000 years for displacement events. Displacement per event for the Rose Canyon fault is estimated at 3 to 6 feet of lateral (strike-slip) movement.

4.2 FAULT HAZARD ASSESSMENT

4.2.1 Morena Pump Station

Two lines of closely spaced (15 feet on center) CPTs were performed to provide an evaluation of possible faulting within the site. Figures 5 and 6 present cross sections along Sherman and Custer Streets, respectively. The layered stratigraphy across the site provides for a basis to evaluate the presence or absence of possible faulting. Based on our interpretation of subsurface layering, there is an anomaly at the western end of the Sherman section. The interpreted layers correlated from CPT to CPT along the section show relationships varying from relatively flat lying to very shallowly dipping for a series of six or seven contacts between CPTs SH-03 and SH-18. Between SH-02 and SH-03 all of these contacts drop in elevation. This pattern is inferred to represent a fault with west-side-down vertical separation. The apparent vertical separation of the subsurface units also appears to increase slightly with depth, which would be consistent with a fault that has had repeated movement resulting in greater displacement of the older, deeper units.

Based on the CPT data (Figure 5), Units 1 and 2 appear to be offset by a fault between SH-02 and SH-03. Unit 2 correlates with sediments that date to approximately 7 to 7.5 ka, i.e., the sediments were deposited during the early Holocene. In our opinion, the offset layers represent Holocene age deposits that appear to have been displaced by a fault. Therefore the fault is considered active (City of San Diego, 1999).

An active fault poses a surface rupture hazard. The City requires setbacks from active faults (City of San Diego, 1999). A 20-foot setback from the fault zone is recommended at Morena Pump Station to reduce the risk of surface rupture during the design life of the structure.

The recommended 20-foot structural setback considers the approximate distance between adjacent CPTs (about 15 feet) and CPT location accuracy (up to about 5 feet). The north-northwest location trend of the fault (about N15W) mapped on Figure 2 reflects the general trend of the RCFZ and faults mapped in the pump station site vicinity as shown on Figure 3a. The 20-foot setback also provides a structural setback if the fault were to trend more northwesterly within the site limits.

The remainder of the site, as evidenced by the relatively flatlying and continuous stratigraphy shown along the Sherman Street section east of CPT SH-03 (Figure 5), and all of the Custer Street section (Figure 6), does not appear to be crossed by active faults.

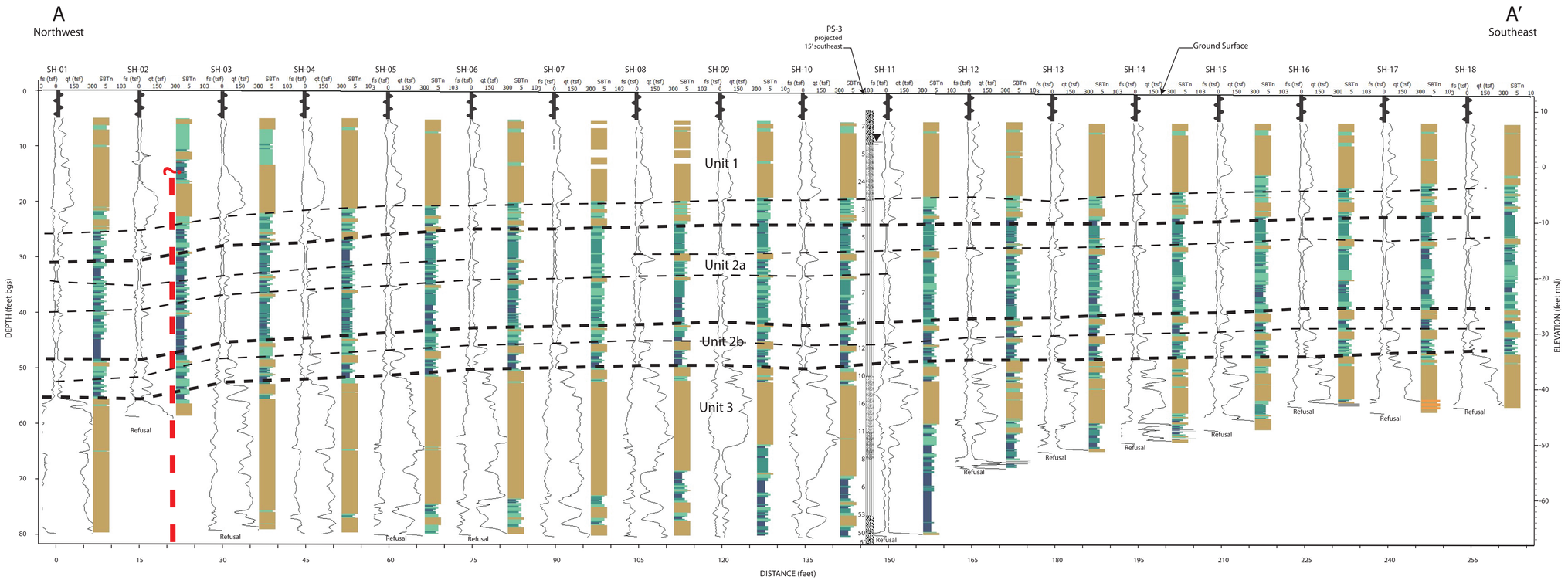
The Morena Pump Station building and associated facilities are not considered habitable structures and therefore seismic danger exposure to humans is limited. In addition, the Morena Pump Station does not have public access and is an electronic controlled security site. Based on review of the anticipated operational procedures by City Operations staff, pump station operations are anticipated to require less than 2,000 man hours per year. Therefore the proposed project structures are not for human occupancy as defined in Section 3601(e) of the California Code of Regulations, Title 14, Division 2.

4.2.2 Pipeline Alignments

The pipeline routes along Morena and West Morena Boulevard generally parallel the active RCFZ along east Mission Bay. Locations of active strands of the RCFZ are known near Balboa Avenue, at Buenos Avenue, and at Old Town; otherwise active faults in the Morena pipeline reach are generally mapped as suspected or “concealed” (i.e., not well located) on geologic and fault maps by the City of San Diego and the CGS. Fault locations are shown on Figures 3a and 3b.

Geomorphic features evident on historical air photos are suggestive of faults that may cross the pipeline route. If active faults are present, as suggested by the air photo interpretations, fault rupture may pose a potential hazard at pipeline-fault crossings. Faults at locations shown as concealed, inferred or approximately located were judged to have a low potential to intersect the pipeline, especially if geomorphic features were not present. Locations of possible active faults that appear to cross the proposed pipeline are shown on Figures 3a and 3b.

Table 1 is a summary of suspected active faults that are mapped as crossing the alignment, and/or mapped very near the alignment. These faults appear to be active and may be a potential source of fault rupture.



LEGEND

TYPICAL SOIL GRAPHIC SYMBOLS

- Silty SAND (SM)
- Poorly graded SAND with silt (SP-SM)
- FILL
- SILT (ML)
- Gravel (GP)
- Fat CLAY (CH)

TYPICAL SAMPLER GRAPHIC SYMBOLS

50 Sampler Blowcounts for 12" interval

CPT GRAPHIC SYMBOL

HAND AUGER

OTHER GRAPHIC SYMBOLS

- Geologic Unit Contact
- Geologic Subunit Contact
- Inferred Fault
- First Groundwater encounter at time of drilling and sampling (ATD)
- Stabilized Groundwater

SBTn Legend

- Sensitive fine grained
- Organic soil
- Clay to silty clay
- Clayey silt to silty clay
- Silty sand to sandy silt
- Clean sand to silty sand
- Gravely sand to sand
- Very stiff sand to clayey sand
- Very stiff fine grained

Notes:
Scale 1:10

GENERALIZED GEOLOGIC CROSS SECTION A-A′ (SHERMAN ST.)
MORENA PIPELINE PROJECT
SAN DIEGO, CALIFORNIA

AECOM		CHECKED BY: MEH	DATE: 7-31-17	FIG. NO.
		PM: JL	NO: 60530732	5

B
Northeast

B′
Southwest

PS-2 projected 10' southwest

PS-1 projected 2.5' southwest

Ground Surface

CU-01 CU-02 CU-03 CU-04 CU-05 CU-06 CU-07 CU-08 CU-09 CU-10 CU-11 CU-12 CU-13 CU-14 CU-15 CU-16 CU-17 CU-18 CU-19

Unit 1

Unit 2a

Unit 2b

Unit 3

Refusal

DEPTH (feet bgs)

ELEVATION (feet msl)

DISTANCE (feet)

LEGEND

TYPICAL SOIL GRAPHIC SYMBOLS

- Silty SAND (SM)
- Poorly graded SAND (SP)
- Poorly graded SAND with silt (SP-SM)
- FILL
- SILT (ML)
- Sandy CLAY (CL)
- Fat CLAY (CH)

TYPICAL SAMPLER GRAPHIC SYMBOLS

50 Sampler Blowcounts for 12" interval

CPT GRAPHIC SYMBOL

HAND AUGER

OTHER GRAPHIC SYMBOLS

- Geologic Unit Contact
- Geologic Subunit contact
- First Groundwater encounter at time of drilling and sampling (ATD)
- Stabilized Groundwater

SBTn Legend

- Sensitive fine grained
- Organic soil
- Clay to silty clay
- Clayey silt to silty clay
- Silty sand to sandy silt
- Clean sand to silty sand
- Gravely sand to sand
- Very stiff sand to clayey sand
- Very stiff fine grained

Notes:
Scale 1:10

GENERALIZED GEOLOGIC CROSS SECTION B-B' (CUSTER ST.)
MORENA PIPELINE PROJECT
SAN DIEGO, CALIFORNIA

AECOM

CHECKED BY: MEH | DATE: 4-20-17 | FIG. NO. 6

PM: JL | NO: 60530732

Table 1. Summary of Pipeline Fault Hazards

Fault Hazard Location	Proposed Structure	Fault Data Source	Anticipated Displacement Style	Comments
1	Morena Pump Station	Cone Penetration Tests	Strike-slip with east-side-down apparent vertical separation.	Fault appears to underlie westernmost portion of site.
2	All pipelines	Historical air photos	Strike-slip; possible shear and/or compression.	Relatively continuous fault appears to align very near and along proposed alignments for over 1,000 lineal ft.
3	All pipelines including proposed tunnels below Tecolote Creek	Historical air photos	Strike-slip; possible shear and/or extension.	Pipeline-fault crossing appears to be within step-over features.
4	All pipelines	Historical air photos	Strike-slip; possible extension component	Possible minor faults within step-over
5	Force main and brine/centrate pipelines	Published geologic maps, historical air photos	Strike-slip, possible shear and/or compression.	Alignment crosses possible major fault strand
6	Alvarado Morena pipeline	Published geologic maps, including EQFZ, historical air photos	Strike-slip, possible shear and/or compression.	Relatively continuous fault appears to align very near and along proposed alignment for approx 3,000 lineal ft.
7	Alvarado Morena pipeline	Historical air photos	Strike-slip, possible shear and/or compression.	Pipeline alignment becomes northerly, possible relatively narrow pipeline-fault crossing.

The project seismic setting presents a risk of pipeline damage and resulting interruption of the project. Options for mitigating and/or reducing the vulnerability of pipelines to fault rupture hazards generally include: 1) operational options that would implement changes to system monitoring and responses to seismic events; 2) upgrades such as modifying soil conditions and pipeline physical characteristics to reduce the level of earthquake hazard and increase the pipeline resistance to the impact of earthquake hazards; 3) avoidance such as altering the pipeline alignment to reduce seismic hazards.

The project design will incorporate operational measures including system monitoring and responses to seismic events. The generalized operational measure being incorporated into the design of the Morena Pump Station and Conveyance System are as follows:

- Forcemain Pipe Break – Triggers a Low-Head Pump Signal, triggers a pump station shutdown.
- Forcemain Pipe Blockage – Triggers a High-Head Pump Signal, triggers a pump station shutdown.
- Brine/Centrate Return Pipe Break – Triggers a low pressure condition, triggers a Advance Water Purification Facility shutdown.

These design features will mitigate seismic risk by stopping flow and allowing investigations of pipeline integrity following a seismic event. The proposed operational measures would mitigate

fault rupture hazards without the need for site specific fault characterizations. Therefore site specific fault investigations were not performed for design.

4.3 ADDITIONAL INVESTIGATIONS

The primary pump station components are located more than double the recommended structural setback zone, which further mitigates potential northwesterly fault trends within the site. In our opinion, additional geologic investigation is not necessary at this time to define the location of active faulting across the site or to delineate an appropriate structural setback zone for the purposes of environmental review.

An as-graded or as-built geologic/geotechnical report will be required according to City of San Diego Guidelines for Geotechnical reports (2011) to document geologic and geotechnical conditions encountered during construction of the pump station. Logs of additional subsurface explorations (especially CPTs, if performed during construction) with geologic cross sections will be provided in the as-built report to confirm the location of the inferred fault along the western portion of the site.

5.0 REFERENCES

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APPENDIX A

APPENDIX A— PREVIOUS STUDIES

Previous studies that provided specific information relied upon in this study include the compiled fault hazard information presented by Kleinfelder for the Mid-Coast Corridor Transit Project. Attached here are the figures from the technical report that present the compiled fault data including the geomorphic assessment based on historical aerial photographs from 1928 and 1953. Two figures from the 2014 Technical Report are attached here as A-1 and A-2.

Subsurface information and interpretations presented by CTE (2012) for a proposed Hilton Garden Hotel include age-dated deposits in a geologic and geomorphic setting that is very similar to the Morena Pump Station. Attached here is an interpreted section from the CTE report as A-3.

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Figure 4-10. Detail Fault Map (Approximate Stations 185–295)

Mid-Coast Corridor Transit Project

- Trolley - Future Blue Line Service on Existing Tracks
- Trolley Station
- Transit Center
- Future Trolley Station
- Transit Center with a Future Trolley Station
- Existing Substation
- Fault Hazard 1 — Fault Location

City of San Diego
- Fault
- Shear Zone
- Inferred Fault
- Concealed Zone

Faults (Kleinfelder, 2011)
- Fault - Identified by distinct geomorphic features in vintage aerial photos
- Fault - Identified by moderately expressed geomorphic features in vintage aerial photos
- Fault, concealed
- Graben

Alquist-Priolo Earthquake Fault Zones
- Accurately located fault trace
- Approximately located fault trace
- Inferred fault trace
- Concealed fault trace
- Earthquake Fault Zone Boundary
- Interpretive Area

Projection: State Plane Coordinate System, California, Zone VI, NAD 1983
Corridor Aerial photo base provided by provided by Parsons Brinckerhoff
Background Aerial photo base- (c) 2010 Microsoft Corporation and its data suppliers

N

0 500 1,000 2,000 Feet

SANDAG

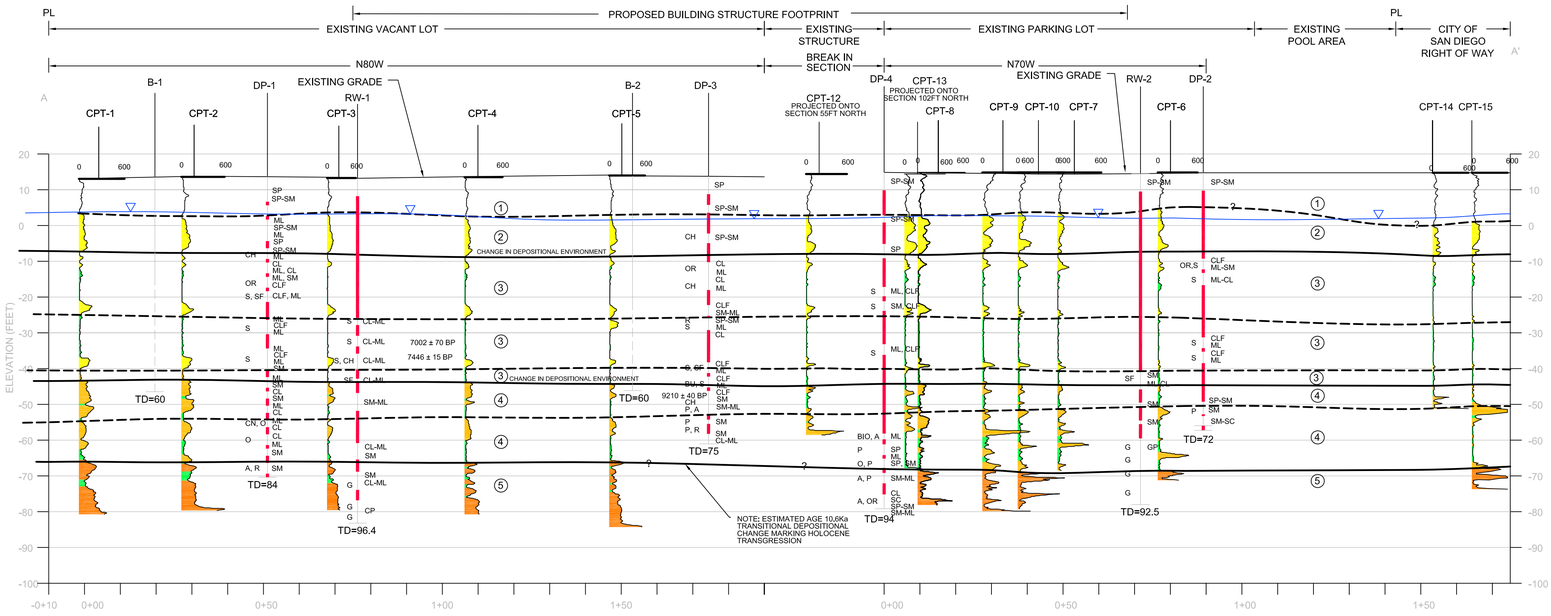
Sources: City of San Diego Faults- from the SanGIS Database (www.sangis.org) Alquist-Priolo Earthquake Fault Zones- Modified from California Geological Survey CD-ROM 2001-05 (2002), Official Map of Alquist-Priolo Earthquake Fault Zones, La Jolla Quadrangle (1991)

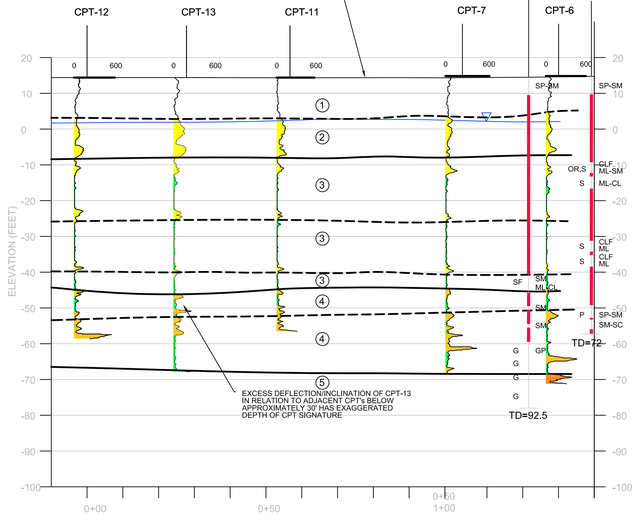
Alignment/stationing drawing is based on electronic drawing files provided by Parsons Brinckerhoff dated 4-18-11 and consistent with the 2012 Draft SEIS/SEIR Plan Set

Figure 4-11. Detail Fault Map (Approximate Stations 260–418)

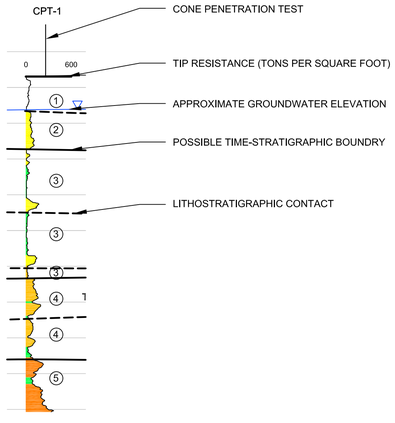
Sources: City of San Diego Faults- from the SanGIS Database (www.sangis.org). Alquist-Priolo Earthquake Fault Zones- Modified from California Geological Survey CD-ROM 2001-05 (2002), Official Map of Alquist-Priolo Earthquake Fault Zones, La Jolla Quadrangle (1991)

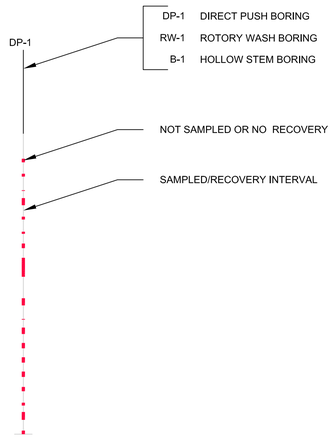
Alignment/stationing drawing is based on electronic drawing files provided by Parsons Brinckerhoff dated 4-18-11 and consistent with the 2012 Draft SEIS/SEIR Plan Set.





LEGEND





LEGEND

CL	CLAY
CLF	FISSLE CLAY
ML	SILT
SM	SILTY SAND
SP-SM	POORLY GRADED SAND W/ SILT
SP	POORLY GRADED SAND
GP	POORLY GRADED GRAVELS
CH	CHARCOAL
OR	ORGANICS
S	SHELLS
SF	SHELL FRAGMENTS
P	PEBBLES
G	GRAVEL
A	POSSIBLE A-HORIZON
CN	CARBONATE NODULES
R	ROOTS
BU	BURROWS

CPT-1	CONE PENETRATION TEST
DP-1	DIRECT PUSH BORING
RW-1	ROTORY WASH BORING
B-1	DIRECT PUSH BORING
0 — 600	TIP RESISTANCE (TONS PER SQUARE FOOT)
	POSSIBLE TIME-STRATIGRAPHIC BOUNDRY
	LITHOSTRATIGRAPHIC CONTACT
	APPROXIMATE GROUNDWATER ELEVATION
7002 ± 70 BP	CONVENTIONAL RADIOCARBON AGE

QUATERNARY HOLOCENE DEPOSITS

① UNIT 1: The Recent mechanical fill material consisted of an approximately ten to twelve foot thick section of loose, dry, yellow gray poorly graded sand to poorly graded sand with silt. This unit extended down to and slightly below the observed groundwater elevations continuously across the site at approximate elevations 2-to 4-feet msl.

② UNIT 2: Deposits of Unit 2 consisted of a sequence of loose to medium dense, planar laminated light and dark gray poorly graded sands, to weakly laminated, massive poorly graded sands and silty sands. Sands where generally micaceous, with occasional pebbles, and contained charcoal, and organic fragments of wood. This unit extended to depths of approximately 21 to 22 feet bgs and could be correlated continuously across the entire site.

③ UNIT 3: A marked change in depositional environment was observed between the overlying predominately sandy Unit 2 and the underlying Unit 3. Unit 3 consists of a series of alternating silt and clay layers to laminations, with occasional silty sands that contained a high percentage of silt. Sandy intervals occur on approximate 10-foot intervals separated by alternating clays and silts. Based on the CPT logs it appears there are a series of stacked finning upwards sequences within this map unit. An absence of shells was apparent in the upper portion of the unit above approximately 30 to 35 feet in depth and wood and charcoal was more abundant. Below this depth shells were readily observed and consisted of, mollusks including gastropods and bivalvia, such as snails, turritella, varieties of clams, and oysters. Clays were highly organic, fissile with crude cross-laminations to planar wavey laminations. Our sample frequency was not frequent enough over this change to define a map contact, but there appears to be a change in environment from the upper and lower portions of Unit 3, possibly a change from predominately salt water to fresh water up section.

④ UNIT 4: Another change in depositional environment was recognized between Unit 3 and Unit 4, possibly representing a hiatus or unconformity. This change was the marked by the disappearance of the shells, marked increase of silty sands and decrease in the dark, fissile, organic-rich clays. Also, an increase of pebbles was noticed, increasing both vertically downward and laterally to the east. Sands were coarser grained, with slight oxidation or glaying, and possible local development of A-soil horizonations. This surface could also represent a depositional hiatus representing a environment with local areas exposed to the surface for a substantial time. The unit consists of interlayered clays, silts and sands, with pebble floaters to stringers.

QUATERNARY PLEISTOCENE DEPOSITS

⑤ UNIT 5: Unit 5 is similar to unit 4 with an increase in the amount of gravel that increases in abundance and size to the east and south across the site. The gravels consist of fine gravel to cobble sized clasts and interbedded sand layers. Clasts are almost exclusively volcanic in origin, with rhyolitic, andesitic, "Poway type" clasts. The clasts were well-rounded within a sand matrix that typically washed-out during the drilling process. These clasts are interpreted to be Pleistocene fluvial gravels and not part of Eocene deposits with similar gravel populations.

MODIFIED 5-6-12

CONSTRUCTION TESTING & ENGINEERING, INC.
PLANNING - CIVIL ENGINEERING - LAND SURVEYING - GEOTECHNICAL
1441 MONTIEL ROAD, SUITE 115 ESCONDIDO CA. 92026, PH:(760) 746-4955

GEOLOGIC CROSS SECTION

OLD TOWN SAN DIEGO, PADRE SITE
4200 TAYLOR STREET
SAN DIEGO, CALIFORNIA

SCALE:	DATE:
1"=20'	3/12
CTE JOB NO.:	PLATE:
10-11003G	1

\\ESC_SERVER\Projects\10-11003G\Plate 1(Mod 5-6-12).dwg

APPENDIX B

APPENDIX B — CONE PENETROMETER TESTING

The field program for this project took place along Sherman and Custer Streets near the proposed Morena Pump Station in San Diego, California. A number of permits were required including boring permits, encroachment permits and a traffic control plan. Underground Service Alert (USA or DigAlert) was also notified prior to beginning work.

CPTs and Direct Push Borings

Gregg Drilling of Signal Hill, California advanced 37 CPT soundings and 3 direct push holes between March 14 and March 24, 2017. The CPT program was cleared to 5 feet below ground surface (bgs) using a hand auger. Prior to beginning the field program, all the CPTs were permitted through the County of San Diego Department of Environmental Health. Upon completion, the holes were backfilled with bentonite grout and resurfaced with concrete or asphalt to match the existing ground.

The CPTs were performed in two lines, along the south side of Sherman Street and along the west side of Custer Street, approximately 5 feet off the curb. CPTs were generally spaced at 15 feet on center.

The first phase of work included CPT soundings along Sherman Street. Many of the soundings reached the target depth of 80 feet bgs, but a number of attempts reached refusal on a gravel/cobble layer at approximately 55 feet to 70 feet bgs. The second phase included a line of CPTs along Custer Street. Many of these soundings towards the south side of Custer Street reached the target depth of 80 feet bgs, but a number of attempts reached refusal on a gravel/cobble layer between approximately 55 feet to 75 feet bgs. The gravel layer was the shallowest at the intersection of Sherman and Custer Streets.

During the second phase of work three direct push borings were advanced at new locations in order to obtain a visual classification at selected depth intervals. The sampler was pushed 12 inches into the subsurface and samples were obtained at various intervals as determined by the Project Geologist. An AECOM geotechnical engineer observed and sampled the direct push borings. The direct push borings were advanced to depths ranging from 53 to 71 feet bgs. Copies of the field notes are retained in our files. Direct push borings CU-11a, CU-1a, and SH-09a were located 3 feet south of CU-11, 3 feet north of CU-01, and 3 feet east of SH-09, respectively.

The CPT soundings and direct push borings were conducted using a full-sized 30-ton rig. The cone on each rig has a 30-ton capacity with a tip area of 15 cm^2 and a friction sleeve area of 225 cm^2. The cone is designed with an equal end area friction sleeve and a tip end area ratio of 0.85. The cone takes measurements of cone bearing, sleeve friction, and dynamic pore water pressure at 5-cm intervals during penetration to provide a nearly continuous geologic log. The CPT soundings were performed generally in accordance with ASTM D5778. Further details on methods and data interpretation are presented in a report by Gregg Drilling in this appendix.

The CPT sounding data were reviewed for changes in inclination (tilt). The only appreciable tilt (greater than 10 degrees) was noted on CPT SH-02 and so the sounding for that CPT was corrected for depth.

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GREGG DRILLING & TESTING, INC.
GEOTECHNICAL AND ENVIRONMENTAL INVESTIGATION SERVICES

March 21, 2017

AECOM
Attn: Kelsey Martin

Subject: CPT Site Investigation
Morena Pump Station
San Diego, California
GREGG Project Number: 17-035MA

Dear Ms. Martin:

The following report presents the results of GREGG Drilling & Testing's Cone Penetration Test investigation for the above referenced site. The following testing services were performed:

1	Cone Penetration Tests	(CPTU)	☒
2	Pore Pressure Dissipation Tests	(PPD)	☒
3	Seismic Cone Penetration Tests	(SCPTU)	☐
4	UVOST Laser Induced Fluorescence	(UVOST)	☐
5	Groundwater Sampling	(GWS)	☐
6	Soil Sampling	(SS)	☐
7	Vapor Sampling	(VS)	☐
8	Membrane Interface Probe	(MIP)	☐
9	Vane Shear Testing	(VST)	☐
10	Dilatometer Testing	(DMT)	☐

A list of reference papers providing additional background on the specific tests conducted is provided in the bibliography following the text of the report. If you would like a copy of any of these publications or should you have any questions or comments regarding the contents of this report, please do not hesitate to contact our office at (925) 313-5800.

Sincerely,
GREGG Drilling & Testing, Inc.

Mary Walden
Operations Manager

Cone Penetration Test Sounding Summary

-Table 1-

CPT Sounding Identification	Date	Termination Depth (feet)	Depth of Groundwater Samples (feet)	Depth of Soil Samples (feet)	Depth of Pore Pressure Dissipation Tests (feet)
SH-01	3/16/17	80	-	-	-
SH-02	3/14/17	62	-	-	-
SH-03	3/14/17	80	-	-	-
SH-04	3/14/17	80	-	-	-
SH-05	3/15/17	80	-	-	-
SH-06	3/14/17	80	-	-	55.1
SH-07	3/15/17	80	-	-	-
SH-08	3/15/17	80	-	-	-
SH-09	3/16/17	80	-	-	-
SH-10	3/16/17	80	-	-	-
SH-11	3/16/17	80	-	-	-
SH-12	3/17/17	67	-	-	-
SH-13	3/15/17	64	-	-	-
SH-14	3/17/17	63	-	-	-
SH-15	3/15/17	60	-	-	-
SH-16	3/17/17	56	-	-	-
SH-17	3/17/17	57	-	-	-
SH-18	3/17/17	56	-	-	-

Cone Penetration Test Sounding Summary

-Table 1-

CPT Sounding Identification	Date	Termination Depth (feet)	Depth of Groundwater Samples (feet)	Depth of Soil Samples (feet)	Depth of Pore Pressure Dissipation Tests (feet)
CU-01	3/20/17	57	-	15.5, 21.5, 30.5, 32.5, 39.5, 40.5, 43.5, 52.5	-
CU-02	3/20/17	58	-	-	-
CU-03	3/20/17	63	-	19.5, 24.5, 32.5, 42.5, 43.5, 50.5, 53.5, 62.5	-
CU-04	3/20/17	66	-	-	-
CU-05	3/20/17	72	-	-	-
CU-06	3/21/17	76	-	-	-
CU-07	3/21/17	77	-	-	-
CU-08	3/21/17	76	-	-	-
CU-09	3/21/17	74	-	-	-
CU-10	3/21/17	73	-	-	-
CU-11	3/22/17	80	-	15.5, 22.5, 33.5, 41, 49.5, 52.5, 69.5NR, 71	-
CU-12	3/22/17	80	-	-	-
CU-13	3/22/17	80	-	-	-
CU-14	3/22/17	80	-	-	-
CU-15	3/22/17	80	-	-	-
CU-16	3/23/17	80	-	-	-
CU-17	3/23/17	80	-	-	-
CU-18	3/23/17	80	-	-	-
CU-19	3/23/17	80	-	-	-

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Woeller, D.J., P.K. Robertson, T.J. Boyd and Dave Thomas, "Detection of Polyaromatic Hydrocarbon Contaminants Using the UVIF-CPT", 53rd Canadian Geotechnical Conference Montreal, QC October pp. 733-739, 2000.

Zemo, D.A., T.A. Delfino, J.D. Gallinatti, V.A. Baker and L.R. Hilpert, "Field Comparison of Analytical Results from Discrete-Depth Groundwater Samplers" BAT EnviroProbe and QED HydroPunch, Sixth national Outdoor Action Conference, Las Vegas, Nevada Proceedings, 1992, pp 299-312.

Copies of ASTM Standards are available through www.astm.org

Cone Penetration Testing Procedure (CPT)

Gregg Drilling carries out all Cone Penetration Tests (CPT) using an integrated electronic cone system, *Figure CPT*.

The cone takes measurements of tip resistance (q_c), sleeve resistance (f_s), and penetration pore water pressure (u_2). Measurements are taken at either 2.5 or 5 cm intervals during penetration to provide a nearly continuous profile. CPT data reduction and basic interpretation is performed in real time facilitating on-site decision making. The above mentioned parameters are stored electronically for further analysis and reference. All CPT soundings are performed in accordance with revised ASTM standards (D 5778-12).

The 5mm thick porous plastic filter element is located directly behind the cone tip in the u_2 location. A new saturated filter element is used on each sounding to measure both penetration pore pressures as well as measurements during a dissipation test (*PPDT*). Prior to each test, the filter element is fully saturated with oil under vacuum pressure to improve accuracy.

When the sounding is completed, the test hole is backfilled according to client specifications. If grouting is used, the procedure generally consists of pushing a hollow tremie pipe with a "knock out" plug to the termination depth of the CPT hole. Grout is then pumped under pressure as the tremie pipe is pulled from the hole. Disruption or further contamination to the site is therefore minimized.

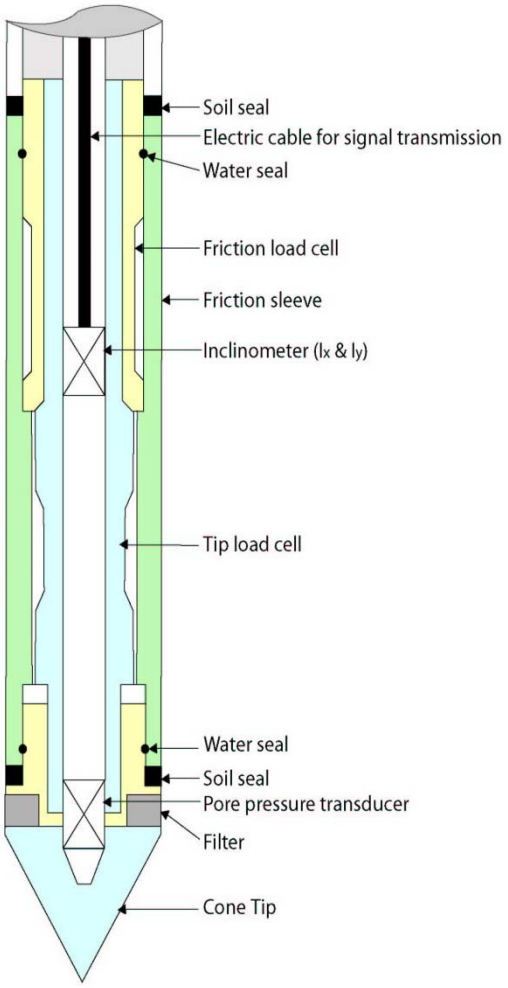


Figure CPT

Gregg 15cm^2 Standard Cone Specifications

Dimensions	
Cone base area	15 cm^2
Sleeve surface area	225 cm^2
Cone net area ratio	0.80
Specifications	
Cone load cell	
Full scale range	180 kN (20 tons)
Overload capacity	150%
Full scale tip stress	120 MPa (1,200 tsf)
Repeatability	120 kPa (1.2 tsf)
Sleeve load cell	
Full scale range	31 kN (3.5 tons)
Overload capacity	150%
Full scale sleeve stress	1,400 kPa (15 tsf)
Repeatability	1.4 kPa (0.015 tsf)
Pore pressure transducer	
Full scale range	7,000 kPa (1,000 psi)
Overload capacity	150%
Repeatability	7 kPa (1 psi)

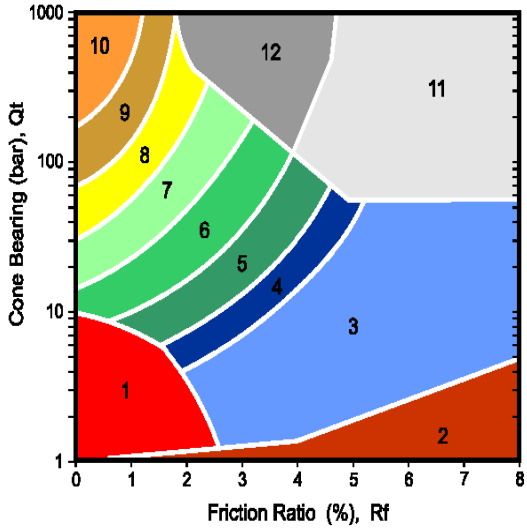
Note: The repeatability during field use will depend somewhat on ground conditions, abrasion, maintenance and zero load stability.

Cone Penetration Test Data & Interpretation

The Cone Penetration Test (CPT) data collected are presented in graphical and electronic form in the report. The plots include interpreted Soil Behavior Type (SBT) based on the charts described by Robertson (1990). Typical plots display SBT based on the non-normalized charts of Robertson et al (1986). For CPT soundings deeper than 30m, we recommend the use of the normalized charts of Robertson (1990) which can be displayed as SBTn, upon request. The report also includes spreadsheet output of computer calculations of basic interpretation in terms of SBT and SBTn and various geotechnical parameters using current published correlations based on the comprehensive review by Lunne, Robertson and Powell (1997), as well as recent updates by Professor Robertson (Guide to Cone Penetration Testing, 2015). The interpretations are presented only as a guide for geotechnical use and should be carefully reviewed. Gregg Drilling & Testing Inc. does not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the software and does not assume any liability for use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used in the software. Some interpretation methods require input of the groundwater level to calculate vertical effective stress. An estimate of the in-situ groundwater level has been made based on field observations and/or CPT results, but should be verified by the user.

A summary of locations and depths is available in Table 1. Note that all penetration depths referenced in the data are with respect to the existing ground surface.

Note that it is not always possible to clearly identify a soil type based solely on q_t, f_s, and u_2. In these situations, experience, judgment, and an assessment of the pore pressure dissipation data should be used to infer the correct soil behavior type.



ZONE		SBT
1		Sensitive, fine grained
2		Organic materials
3		Clay
4		Silty clay to clay
5		Clayey silt to silty clay
6		Sandy silt to clayey silt
7		Silty sand to sandy silt
8		Sand to silty sand
9		Sand
10		Gravely sand to sand
11		Very stiff fine grained*
12		Sand to clayey sand*

*over consolidated or cemented

Figure SBT (After Robertson et al., 1986) – Note: Colors may vary slightly compared to plots

Cone Penetration Test (CPT) Interpretation

Gregg uses a proprietary CPT interpretation and plotting software. The software takes the CPT data and performs basic interpretation in terms of soil behavior type (SBT) and various geotechnical parameters using current published empirical correlations based on the comprehensive review by Lunne, Robertson and Powell (1997). The interpretation is presented in tabular format using MS Excel. The interpretations are presented only as a guide for geotechnical use and should be carefully reviewed. Gregg does not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the software and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used in the software.

The following provides a summary of the methods used for the interpretation. Many of the empirical correlations to estimate geotechnical parameters have constants that have a range of values depending on soil type, geologic origin and other factors. The software uses 'default' values that have been selected to provide, in general, conservatively low estimates of the various geotechnical parameters.

Input:

1 Units for display (Imperial or metric) (atm. pressure, p_a = 0.96 tsf or 0.1 MPa)
2 Depth interval to average results (ft or m). Data are collected at either 0.02 or 0.05m and can be averaged every 1, 3 or 5 intervals.
3 Elevation of ground surface (ft or m)
4 Depth to water table, z_w (ft or m) – input required
5 Net area ratio for cone, a (default to 0.80)
6 Relative Density constant, C_{Dr} (default to 350)
7 Young's modulus number for sands, α (default to 5)
8 Small strain shear modulus number
  a. for sands, S_G (default to 180 for SBT_n 5, 6, 7)
  b. for clays, C_G (default to 50 for SBT_n 1, 2, 3 & 4)
9 Undrained shear strength cone factor for clays, N_{kt} (default to 15)
10 Over Consolidation ratio number, k_{ocr} (default to 0.3)
11 Unit weight of water, (default to γ_w = 62.4 lb/ft^3 or 9.81 kN/m^3)

Column

1 Depth, z, (m) – CPT data is collected in meters
2 Depth (ft)
3 Cone resistance, q_c (tsf or MPa)
4 Sleeve resistance, f_s (tsf or MPa)
5 Penetration pore pressure, u (psi or MPa), measured behind the cone (i.e. u_2)
6 Other – any additional data
7 Total cone resistance, q_t (tsf or MPa) $q_t = q_c + u\,(1-a)$

8	Friction Ratio, R_f (%)	$R_f = (f_s/q_t) \times 100\%$
9	Soil Behavior Type (non-normalized), SBT	see note
10	Unit weight, γ (pcf or kN/m^3)	based on SBT, see note
11	Total overburden stress, σ_v (tsf)	$\sigma_{vo} = \sigma\, z$
12	In-situ pore pressure, u_o (tsf)	$u_o = \gamma_w (z - z_w)$
13	Effective overburden stress, σ'_{vo} (tsf)	$\sigma'_{vo} = \sigma_{vo} - u_o$
14	Normalized cone resistance, Q_{t1}	$Q_{t1} = (q_t - \sigma_{vo}) / \sigma'_{vo}$
15	Normalized friction ratio, F_r (%)	$F_r = f_s / (q_t - \sigma_{vo}) \times 100\%$
16	Normalized Pore Pressure ratio, B_q	$B_q = u - u_o / (q_t - \sigma_{vo})$
17	Soil Behavior Type (normalized), SBT_n	see note
18	SBT_n Index, I_c	see note
19	Normalized Cone resistance, Q_{tn} (n varies with I_c)	see note
20	Estimated permeability, k_{SBT} (cm/sec or ft/sec)	see note
21	Equivalent SPT N_{60}, blows/ft	see note
22	Equivalent SPT $(N_1)_{60}$ blows/ft	see note
23	Estimated Relative Density, D_r, (%)	see note
24	Estimated Friction Angle, ϕ', (degrees)	see note
25	Estimated Young's modulus, E_s (tsf)	see note
26	Estimated small strain Shear modulus, Go (tsf)	see note
27	Estimated Undrained shear strength, s_u (tsf)	see note
28	Estimated Undrained strength ratio	s_u/σ_v'
29	Estimated Over Consolidation ratio, OCR	see note

Notes:

1 Soil Behavior Type (non-normalized), SBT (Lunne et al., 1997 and table below)

2 Unit weight, γ either constant at 119 pcf or based on Non-normalized SBT (Lunne et al., 1997 and table below)

3 Soil Behavior Type (Normalized), SBT_n Lunne et al. (1997)

4 SBT_n Index, I_c $I_c = ((3.47 - \log Q_{t1})^2 + (\log F_r + 1.22)^2)^{0.5}$

5 Normalized Cone resistance, Q_{tn} (n varies with Ic)

$Q_{tn} = ((q_t - \sigma_{vo})/pa)\ (pa/(\sigma'_{vo})^n$ and recalculate I_c, then iterate:

When $I_c < 1.64$, n = 0.5 (clean sand)
When $I_c > 3.30$, n = 1.0 (clays)
When $1.64 < I_c < 3.30$, $n = (I_c - 1.64)0.3 + 0.5$
Iterate until the change in n, $\Delta n < 0.01$

6 Estimated permeability, k_{SBT} based on Normalized SBT_n (Lunne et al., 1997 and table below)

7 Equivalent SPT N_{60}, blows/ft Lunne et al. (1997)

$$\frac{(q_t/p_a)}{N_{60}} = 8.5\left(1 - \frac{I_c}{4.6}\right)$$

8 Equivalent SPT $(N_1)_{60}$ blows/ft $(N_1)_{60} = N_{60}\, C_N$,
where $C_N = (pa/\sigma'_{vo})^{0.5}$

9 Relative Density, D_r, (%) $D_r^2 = Q_{tn} / C_{Dr}$
Only SBT_n 5, 6, 7 & 8 *Show 'N/A' in zones 1, 2, 3, 4 & 9*

10 Friction Angle, ϕ', (degrees) $\tan\phi' = \frac{1}{2.68}\left[\log\left(\frac{q_c}{\sigma'_{vo}}\right) + 0.29\right]$
Only SBT_n 5, 6, 7 & 8 *Show'N/A' in zones 1, 2, 3, 4 & 9*

11 Young's modulus, E_s $E_s = \alpha\, q_t$
Only SBT_n 5, 6, 7 & 8 *Show 'N/A' in zones 1, 2, 3, 4 & 9*

12 Small strain shear modulus, Go

a. $G_o = S_G\,(q_t\ \sigma'_{vo}\ pa)^{1/3}$ *For SBT_n 5, 6, 7*

b. $G_o = C_G\, q_t$ *For SBT_n 1, 2, 3& 4*

Show 'N/A' in zones 8 & 9

13 Undrained shear strength, s_u $s_u = (q_t - \sigma_{vo}) / N_{kt}$
Only SBT_n 1, 2, 3, 4 & 9 *Show 'N/A' in zones 5, 6, 7 & 8*

14 Over Consolidation ratio, OCR $OCR = k_{ocr}\, Q_{t1}$
Only SBT_n 1, 2, 3, 4 & 9 *Show 'N/A' in zones 5, 6, 7 & 8*

The following updated and simplified SBT descriptions have been used in the software:

SBT Zones		**SBT_n Zones**	
1	sensitive fine grained	1	sensitive fine grained
2	organic soil	2	organic soil
3	clay	3	clay
4	clay & silty clay	4	clay & silty clay
5	clay & silty clay		
6	sandy silt & clayey silt		

7	silty sand & sandy silt	5	silty sand & sandy silt
8	sand & silty sand	6	sand & silty sand
9	sand		
10	sand	7	sand
11	very dense/stiff soil*	8	very dense/stiff soil*
12	very dense/stiff soil*	9	very dense/stiff soil*

*heavily overconsolidated and/or cemented

Track when soils fall with zones of same description and print that description (i.e. if soils fall only within SBT zones 4 & 5, print 'clays & silty clays')

Estimated Permeability (see Lunne et al., 1997)

SBT_n	Permeability (ft/sec)	(m/sec)
1	$3x\ 10^{-8}$	$1x\ 10^{-8}$
2	$3x\ 10^{-7}$	$1x\ 10^{-7}$
3	$1x\ 10^{-9}$	$3x\ 10^{-10}$
4	$3x\ 10^{-8}$	$1x\ 10^{-8}$
5	$3x\ 10^{-6}$	$1x\ 10^{-6}$
6	$3x\ 10^{-4}$	$1x\ 10^{-4}$
7	$3x\ 10^{-2}$	$1x\ 10^{-2}$
8	$3x\ 10^{-6}$	$1x\ 10^{-6}$
9	$1x\ 10^{-8}$	$3x\ 10^{-9}$

Estimated Unit Weight (see Lunne et al., 1997)

SBT	Approximate Unit Weight (lb/ft^3)	(kN/m^3)
1	111.4	17.5
2	79.6	12.5
3	111.4	17.5
4	114.6	18.0
5	114.6	18.0
6	114.6	18.0
7	117.8	18.5
8	120.9	19.0
9	124.1	19.5
10	127.3	20.0
11	130.5	20.5
12	120.9	19.0

Pore Pressure Dissipation Tests (PPDT)

Pore Pressure Dissipation Tests (PPDT's) conducted at various intervals can be used to measure equilibrium water pressure (at the time of the CPT). If conditions are hydrostatic, the equilibrium water pressure can be used to determine the approximate depth of the ground water table. A PPDT is conducted when penetration is halted at specific intervals determined by the field representative. The variation of the penetration pore pressure (*u)* with time is measured behind the tip of the cone and recorded.

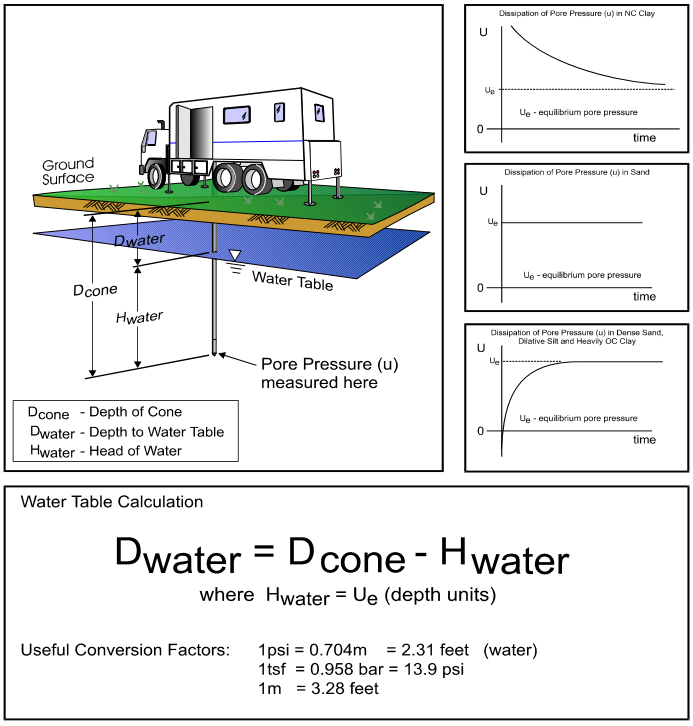
Pore pressure dissipation data can be interpreted to provide estimates of:

- Equilibrium piezometric pressure
- Phreatic Surface
- In situ horizontal coefficient of consolidation (c_h)
- In situ horizontal coefficient of permeability (k_h)

In order to correctly interpret the equilibrium piezometric pressure and/or the phreatic surface, the pore pressure must be monitored until it reaches equilibrium, *Figure PPDT*. This time is commonly referred to as t_{100}, the point at which 100% of the excess pore pressure has dissipated.

A complete reference on pore pressure dissipation tests is presented by Robertson et al. 1992 and Lunne et al. 1997.

A summary of the pore pressure dissipation tests are summarized in Table 1.



Water Table Calculation

$$D_{water} = D_{cone} - H_{water}$$

where $H_{water} = U_e$ (depth units)

Useful Conversion Factors: 1psi = 0.704m = 2.31 feet (water)
1tsf = 0.958 bar = 13.9 psi
1m = 3.28 feet

Figure PPDT

Seismic Cone Penetration Testing (SCPT)

Seismic Cone Penetration Testing (SCPT) can be conducted at various intervals during the Cone Penetration Test. Shear wave velocity (Vs) can then be calculated over a specified interval with depth. A small interval for seismic testing, such as 1-1.5m (3-5ft) allows for a detailed look at the shear wave profile with depth. Conversely, a larger interval such as 3-6m (10-20ft) allows for a more average shear wave velocity to be calculated. Gregg's cones have a horizontally active geophone located 0.2m (0.66ft) behind the tip.

To conduct the seismic shear wave test, the penetration of the cone is stopped and the rods are decoupled from the rig. An automatic hammer is triggered to send a shear wave into the soil. The distance from the source to the cone is calculated knowing the total depth of the cone and the horizontal offset distance between the source and the cone. To calculate an interval velocity, a minimum of two tests must be performed at two different depths. The arrival times between the two wave traces are compared to obtain the difference in time (Δt). The difference in depth is calculated (Δd) and velocity can be determined using the simple equation: $v = \Delta d/\Delta t$

Multiple wave traces can be recorded at the same depth to improve quality of the data.

A complete reference on seismic cone penetration tests is presented by Robertson et al. 1986 and Lunne et al. 1997.

A summary the shear wave velocities, arrival times and wave traces are provided with the report.

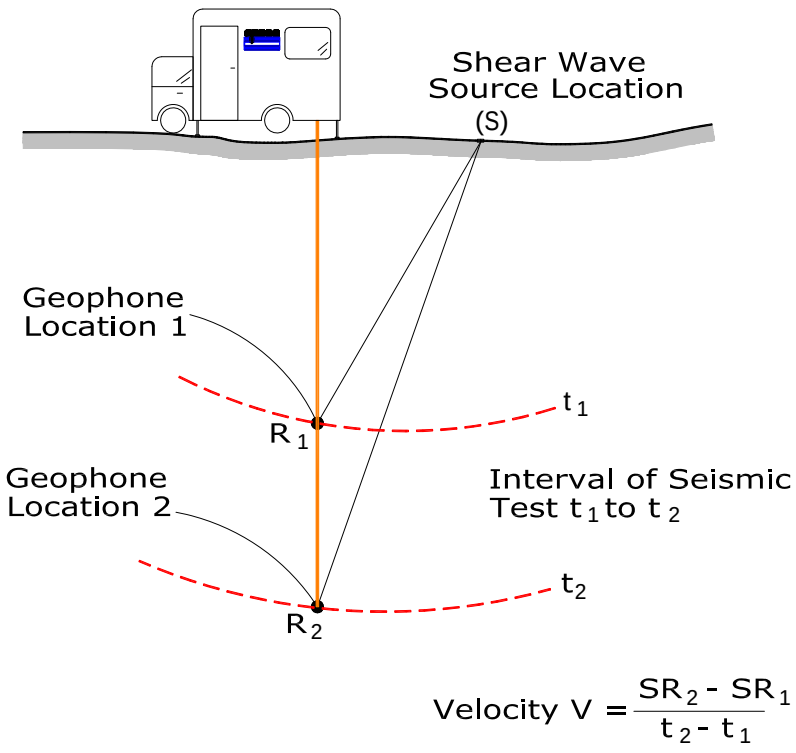


Figure SCPT

Groundwater Sampling

Gregg Drilling & Testing, Inc. conducts groundwater sampling using a sampler as shown in *Figure GWS*. The groundwater sampler has a retrievable stainless steel or disposable PVC screen with steel drop off tip. This allows for samples to be taken at multiple depth intervals within the same sounding location. In areas of slower water recharge, provisions may be made to set temporary PVC well screens during sampling to allow the pushing equipment to advance to the next sample location while the groundwater is allowed to infiltrate.

The groundwater sampler operates by advancing 44.5mm (1¾ inch) hollow push rods with the filter tip in a closed configuration to the base of the desired sampling interval. Once at the desired sample depth, the push rods are retracted; exposing the encased filter screen and allowing groundwater to infiltrate hydrostatically from the formation into the inlet screen. A small diameter bailer (approximately ½ or ¾ inch) is lowered through the push rods into the screen section for sample collection. The number of downhole trips with the bailer and time necessary to complete the sample collection at each depth interval is a function of sampling protocols, volume requirements, and the yield characteristics and storage capacity of the formation. Upon completion of sample collection, the push rods and sampler, with the exception of the PVC screen and steel drop off tip are retrieved to the ground surface, decontaminated and prepared for the next sampling event.

For a detailed reference on direct push groundwater sampling, refer to Zemo et. al., 1992.

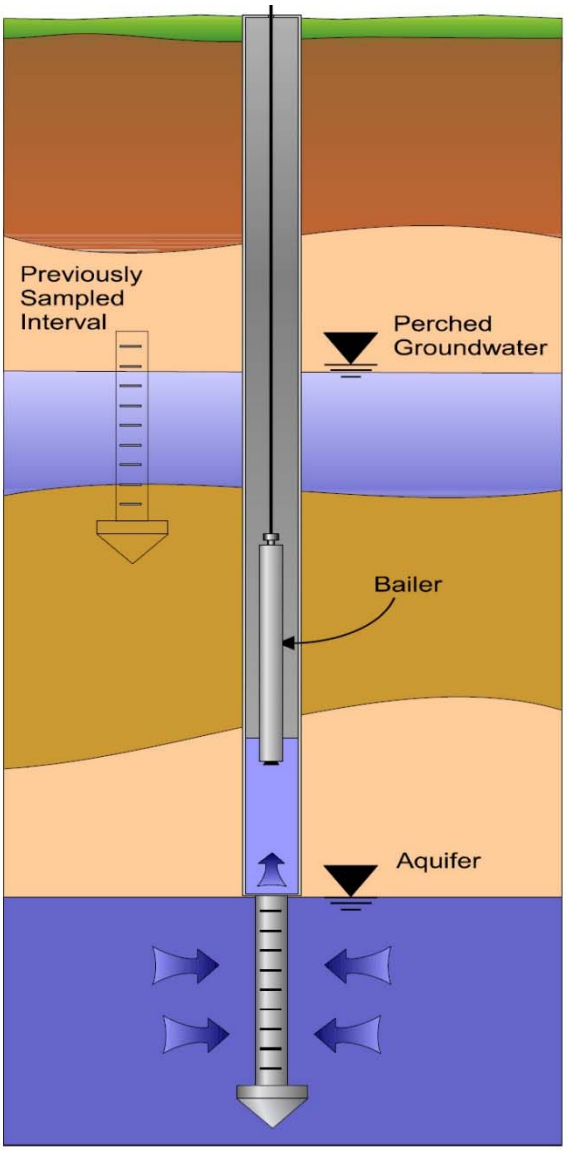


Figure GWS

Soil Sampling

Gregg Drilling & Testing, Inc. uses a piston-type push-in sampler to obtain small soil samples without generating any soil cuttings, *Figure SS*. Two different types of samplers (12 and 18 inch) are used depending on the soil type and density. The soil sampler is initially pushed in a "closed" position to the desired sampling interval using the CPT pushing equipment. Keeping the sampler closed minimizes the potential of cross contamination. The inner tip of the sampler is then retracted leaving a hollow soil sampler with inner 1¼" diameter sample tubes. The hollow sampler is then pushed in a locked "open" position to collect a soil sample. The filled sampler and push rods are then retrieved to the ground surface. Because the soil enters the sampler at a constant rate, the opportunity for 100% recovery is increased. For environmental analysis, the soil sample tube ends are sealed with Teflon and plastic caps. Often, a longer "split tube" can be used for geotechnical sampling.

For a detailed reference on direct push soil sampling, refer to Robertson et al, 1998.

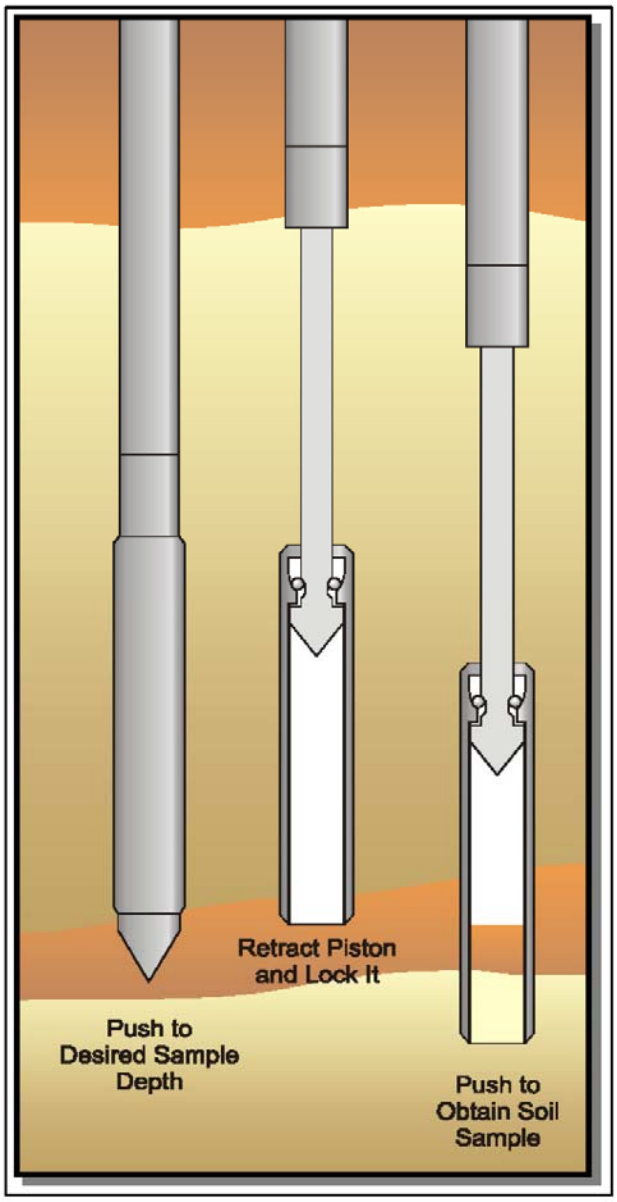


Figure SS

Ultra-Violet Induced Fluorescence (UVOST)

Gregg Drilling conducts Laser Induced Fluorescence (LIF) Cone Penetration Tests using a UVOST module that is located behind the standard piezocone, *Figure UVOST*. The laser induced fluorescence cone works on the principle that polycyclic aromatic hydrocarbons (PAH's), mixed with soil and/or groundwater, fluoresce when irradiated by ultra violet light. Therefore, by measuring the intensity of fluorescence, the lateral and vertical extent of hydrocarbon contamination in the ground can be estimated.

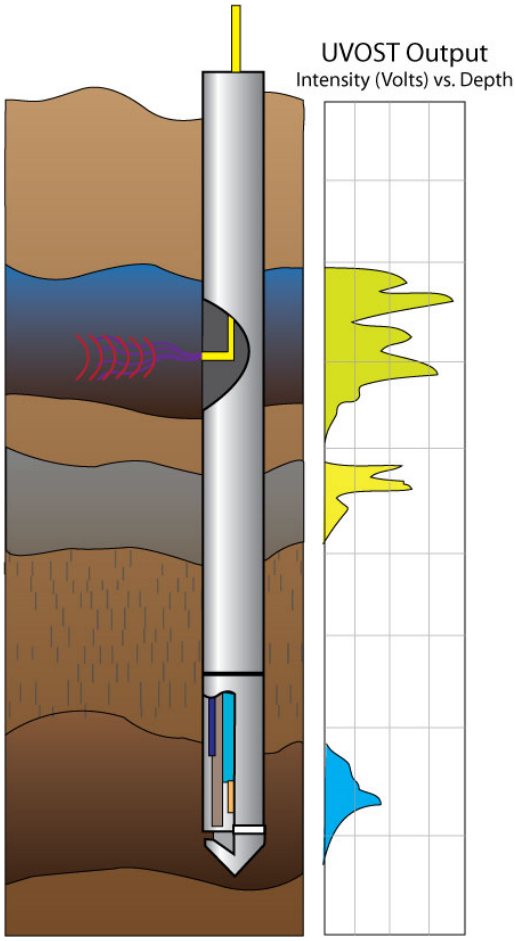


Figure UVOST

The UVOST module uses principles of fluorescence spectrometry by irradiating the soil with ultra violet light produced by a laser and transmitted to the cone through fiber optic cables. The UV light passes through a small window in the side of the cone into the soil. Any hydrocarbon molecules present in the soil absorb the light energy during radiation and immediately re-emit the light at a longer wavelength. This re-emission is termed fluorescence. The UVOST system also measures the emission decay with time at four different wavelengths (350nm, 400nm, 450nm, and 500nm). This allows the software to determine a product "signature" at each data point. This process provides a method to evaluate the type of contaminant. A sample output from the UVOST system is shown in *Figure Output*. In general, the typical detection limit for the UVOST system is <100 ppm and it will operate effectively above and below the saturated zone.

With the capability to push up to 200m (600ft) per day, laser induced fluorescence offers a fast and efficient means for delineating PAH contaminant plumes. Color coded logs offer qualitative information in a quick glance and can be produced in the field for real-time decision making. Coupled with the data provided by the CPT, a complete site assessment can be completed with no samples or cuttings, saving laboratory costs as well as site and environmental impact.

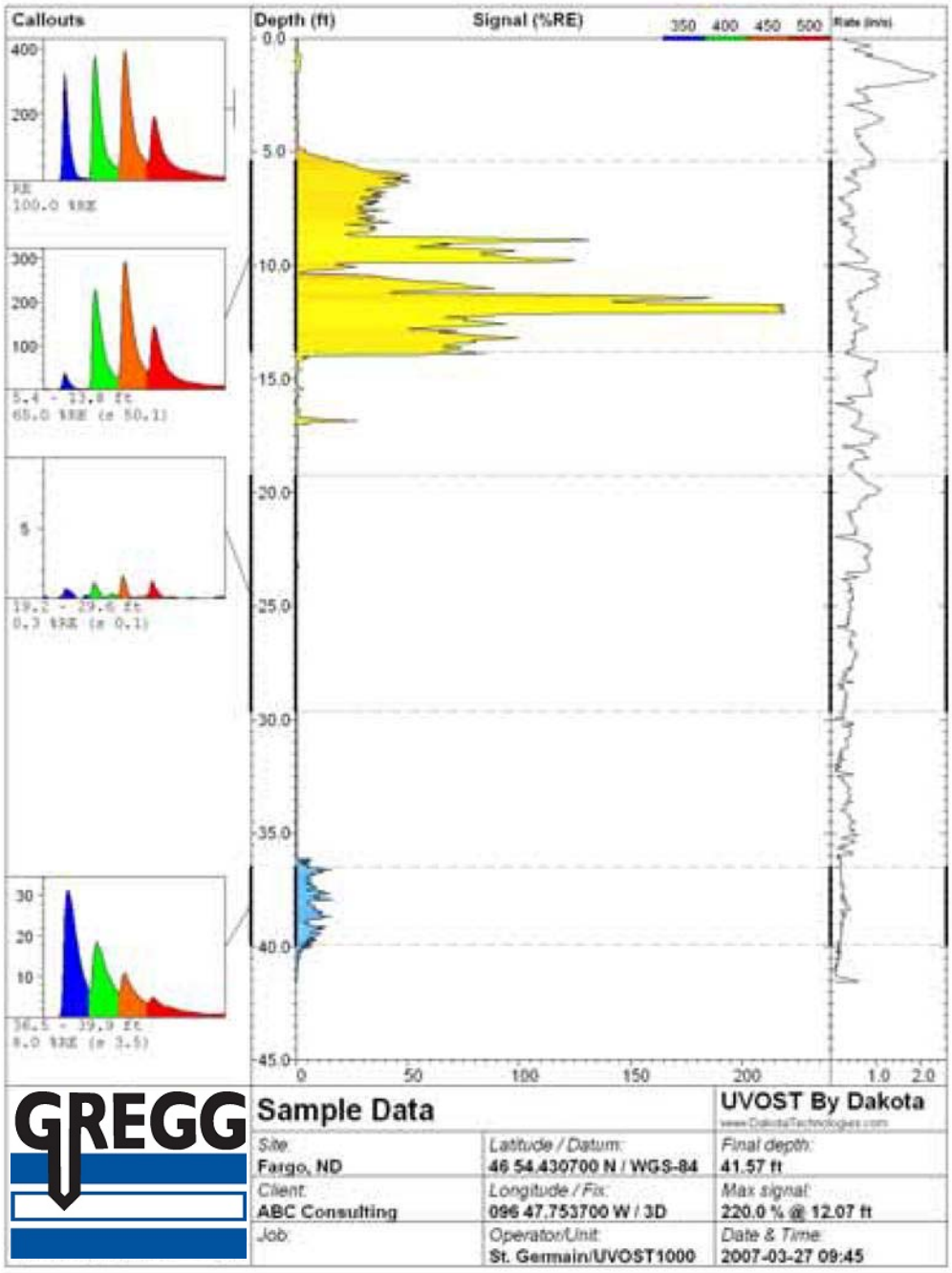


Figure Output