A Case Study of the Engineering and Design of the Cole's Bayou Marsh Restoration Project (TV-63)

Amanda Taylor, E.I.
Project Engineer
Coastal Protection and Restoration Authority

Dr. John D. Foret
Project Manager
NOAA National Marine Fisheries Service

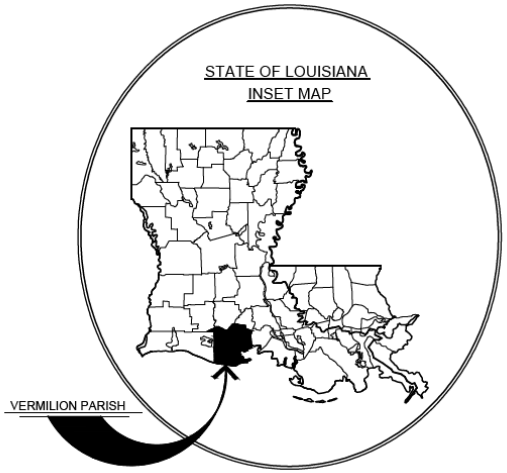
TV-63 Project Background and Marsh Loss

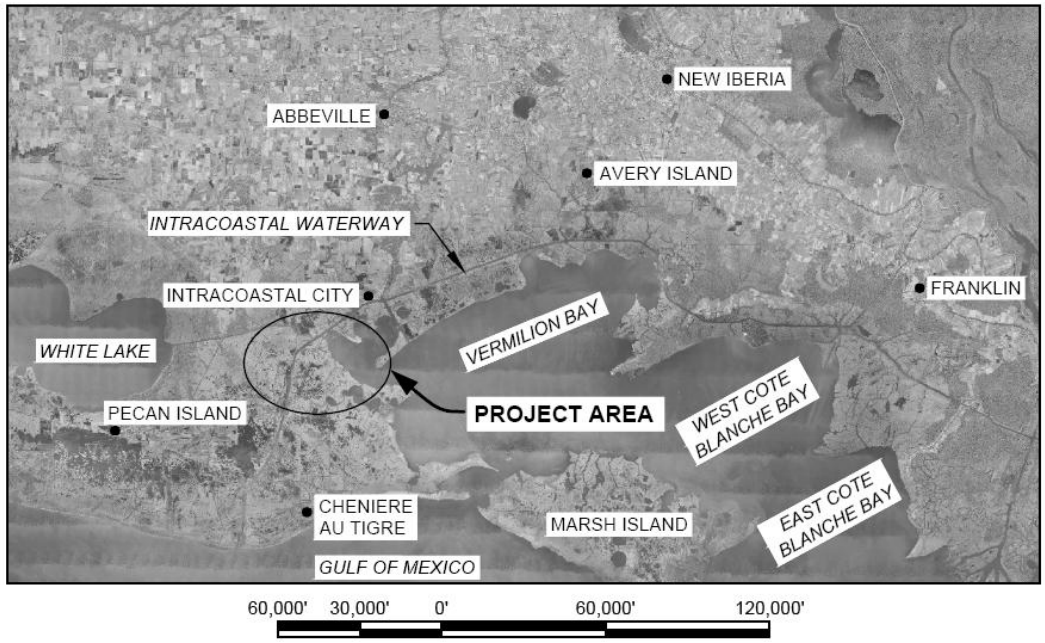
- Located in Lower Vermilion Parish about 5 miles Southwest of Intracoastal City, La

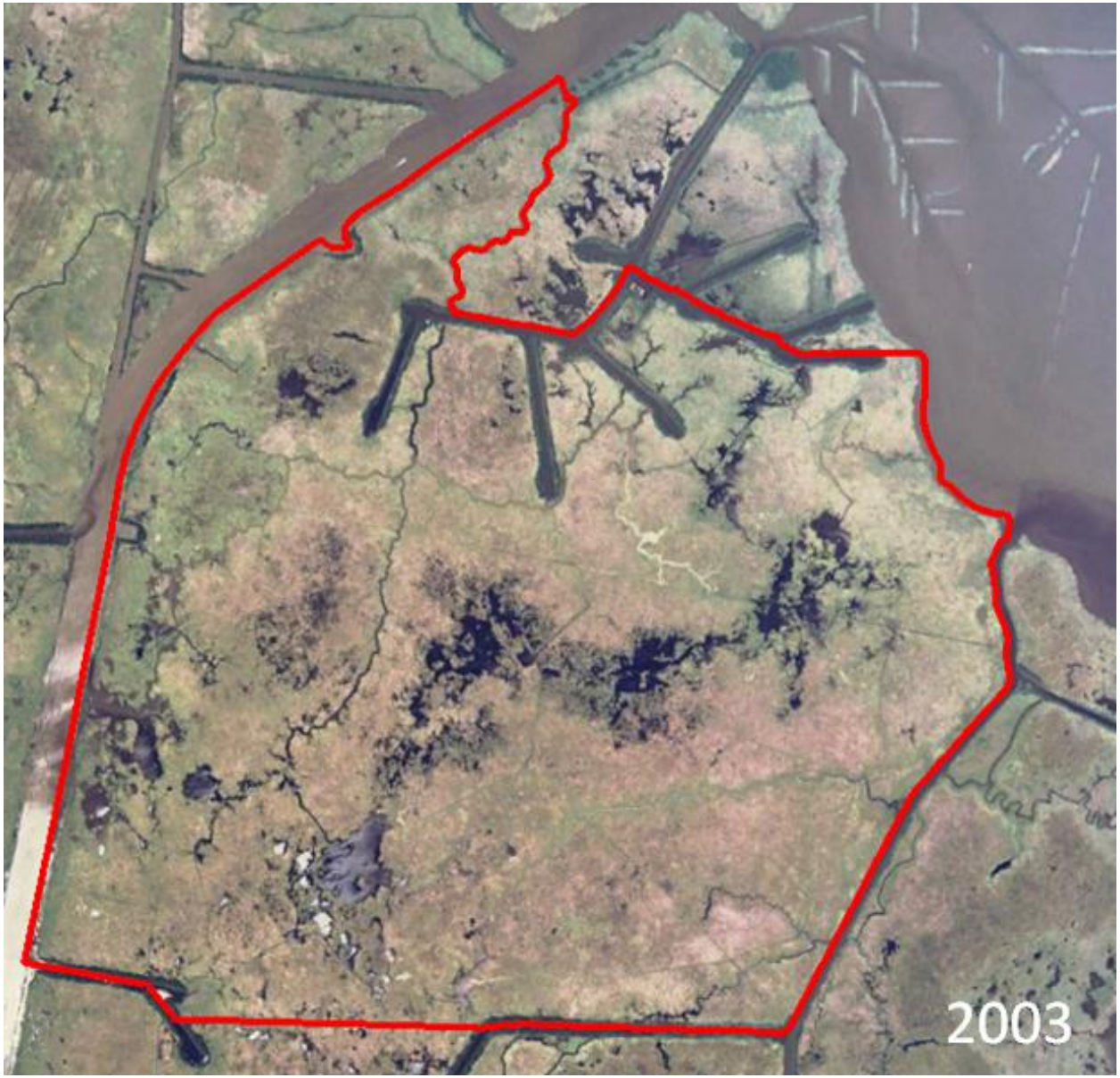
- Project area wetlands undergoing loss rate of -0.42% per year based on 1983 to 2011 USGS data

- Wetland loss processes include subsidence/sediment deficiency and storm impacts resulting in interior ponding and pond enlargement

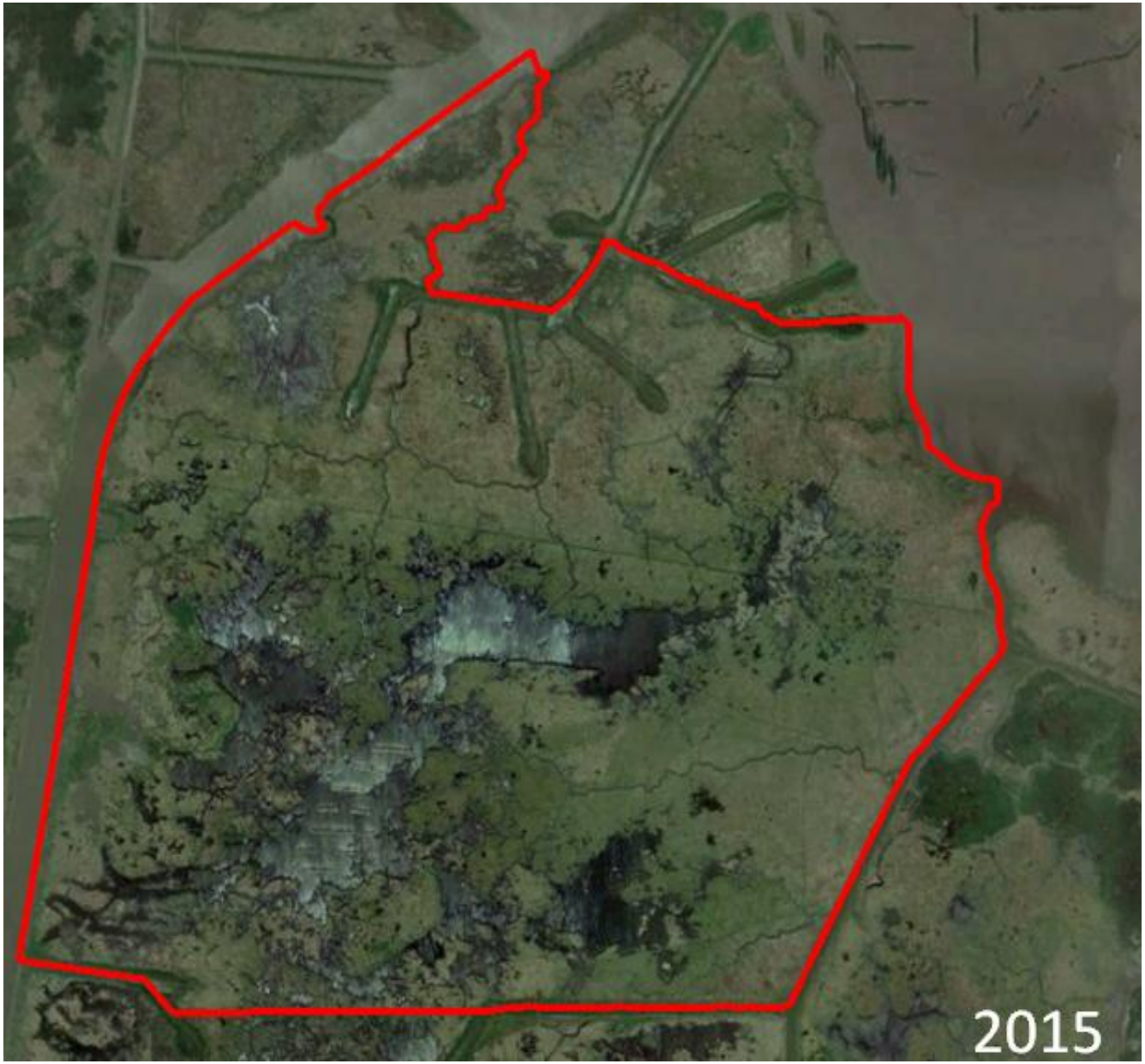
- Salt water intrusion and hydrologic changes have resulted in a more floatant marsh increasing susceptibility to tidal energy and storm damage.






2003


2007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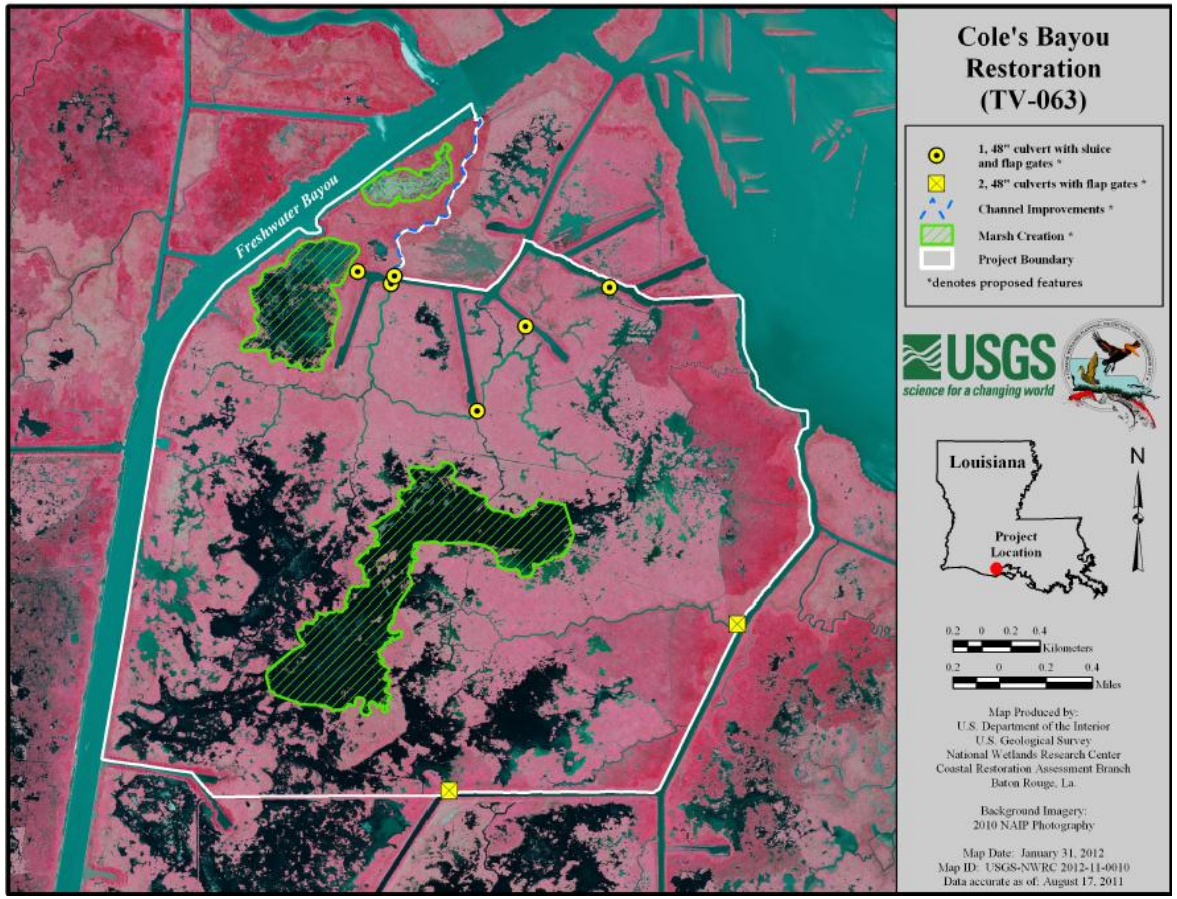
TV-63 Design Goals

- Create 365 acres of brackish marsh in recently formed open water areas
- Nourish 53 acres of existing brackish marsh
- Increase freshwater and sediment inflow into interior wetlands by improving project area's hydrology



Percent Inundation Determination

- Percentage of the year a certain elevation of land would be flooded based on water levels found in that region.

- Brackish marsh optimal range is flooded between 10% and 65% of the time.

TY0	Elevation (ft, NAVD88) - % inundation
10%	1.26
20%	0.96
30%	0.80
40%	0.68
50%	0.6
60%	0.50
65%	0.43
70%	0.42
80%	0.25
90%	-0.01

TY0

TY20	Elevation (ft, NAVD88) - % inundation
10%	1.95
20%	1.65
30%	1.49
40%	1.37
50%	1.29
60%	1.19
65%	1.12
70%	1.11
80%	0.94
90%	0.68

TY20

Project Surveys

- Bathymetric, Topographic, and Magnetometer surveys taken from April 2013 to June 2013 and from October 2014 to November 2014.

- Transect Spacing:
  - Marsh Fill Areas: 250 ft. grid format
  - Borrow Area: 500 ft.
  - Equipment Access Corridor and Dredge Pipeline Alignment: 1000 ft.

- Position and Elevation shots taken at 25 ft. intervals along transect.

- Magnetometer surveys taken in a 500 ft. grid format in the marsh fill and along the borrow area, equipment access corridor, and dredge pipeline alignment transects.

- Magnetometer surveys also located the existence of two (2) pipelines and one (1) flowline in project area vicinity.

Healthy Marsh Elevation Survey

- Five (5) locations
- 20 survey points taken at each location

Location	Elevation (ft NAVD88)
M-1	0.88
M-2	0.77
M-3	0.71
M-4	0.60
M-5	0.80
Average	**0.75**

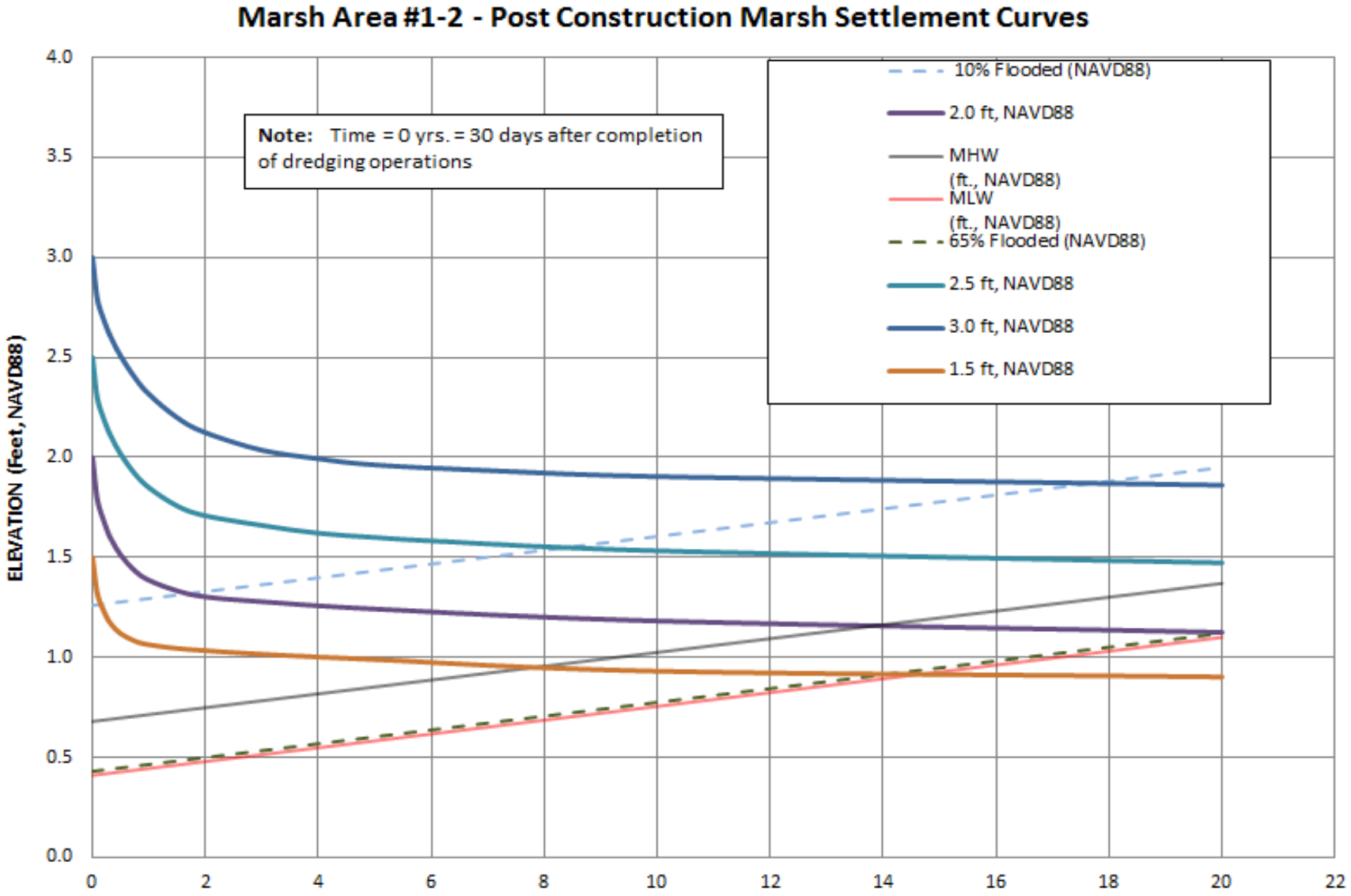
Geotechnical Investigation

- 26 soil borings taken from February 2013 to April 2013
  - 10 borings in Marsh Fill Area (20-80 ft. in depth)
  - 6 borings in Borrow Area (20 ft. in depth)
  - 8 borings at Water Control Structure locations (20-80 ft. in depth)
  - 2 borings along Freshwater Bayou shoreline (30 ft. in depth)

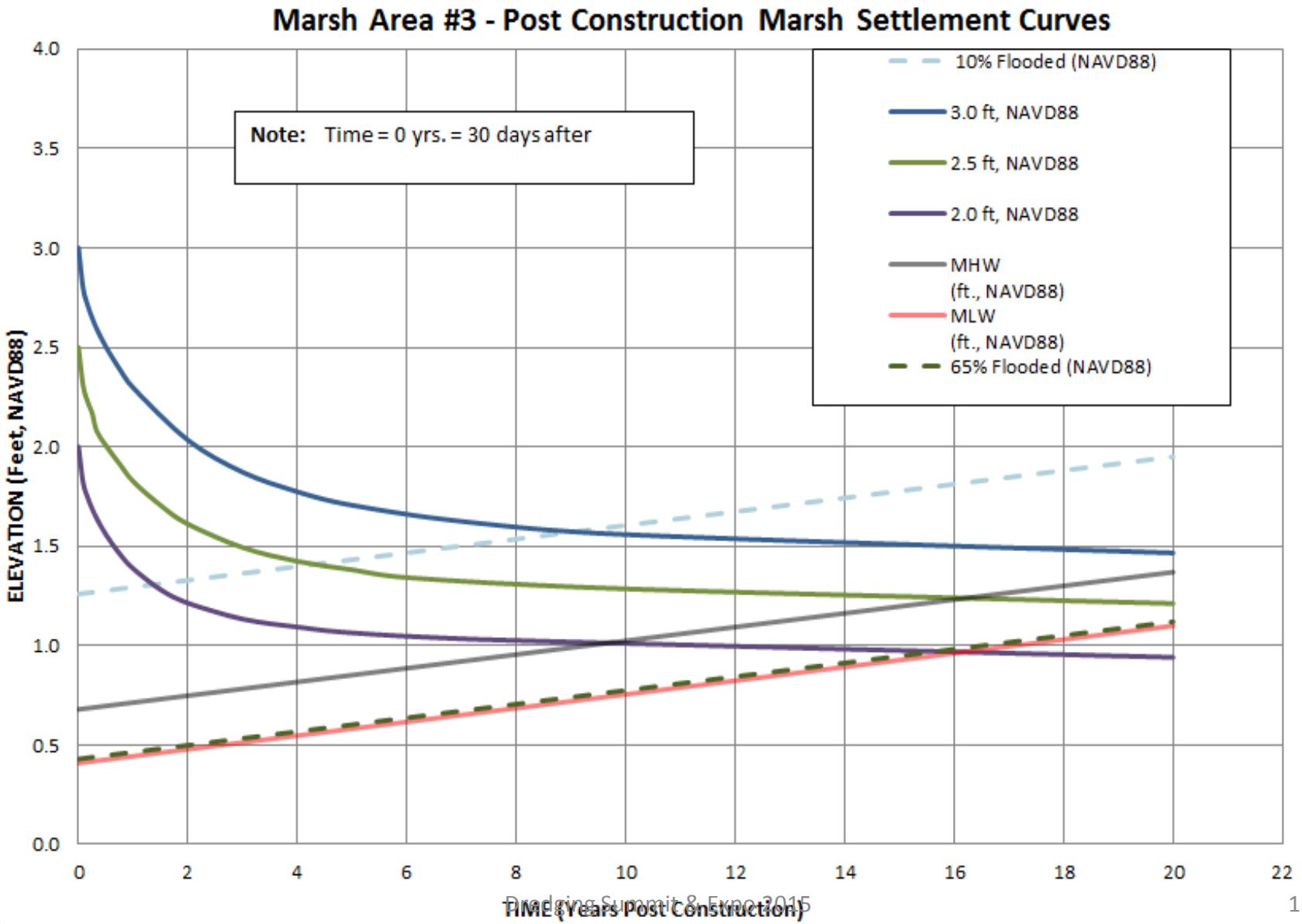
- Laboratory tests included:
  - Soil compressive strength, moisture content, organic content, grain size analysis, specific gravity, consolidation, and Atterberg limits

- Analysis of the samples included:
  - Determination of Soil Characteristics
  - Slope Stability Analysis for Earthen Containment Dikes
  - Settlement Analysis for Marsh Fill and Earthen Containment Dikes

Marsh Fill Settlement Curves



Marsh Fill Settlement Curves



Hydrodynamic Modeling

- Modeled the hydrodynamics of the project area and surrounding marshes
  - Adaptive Hydraulics Model (ADH)
  - Tracked water movement and salinity
  - Calibrated with data from monitoring stations set up in and around project area
    - Collected data on water levels, salinity, TSS, etc.

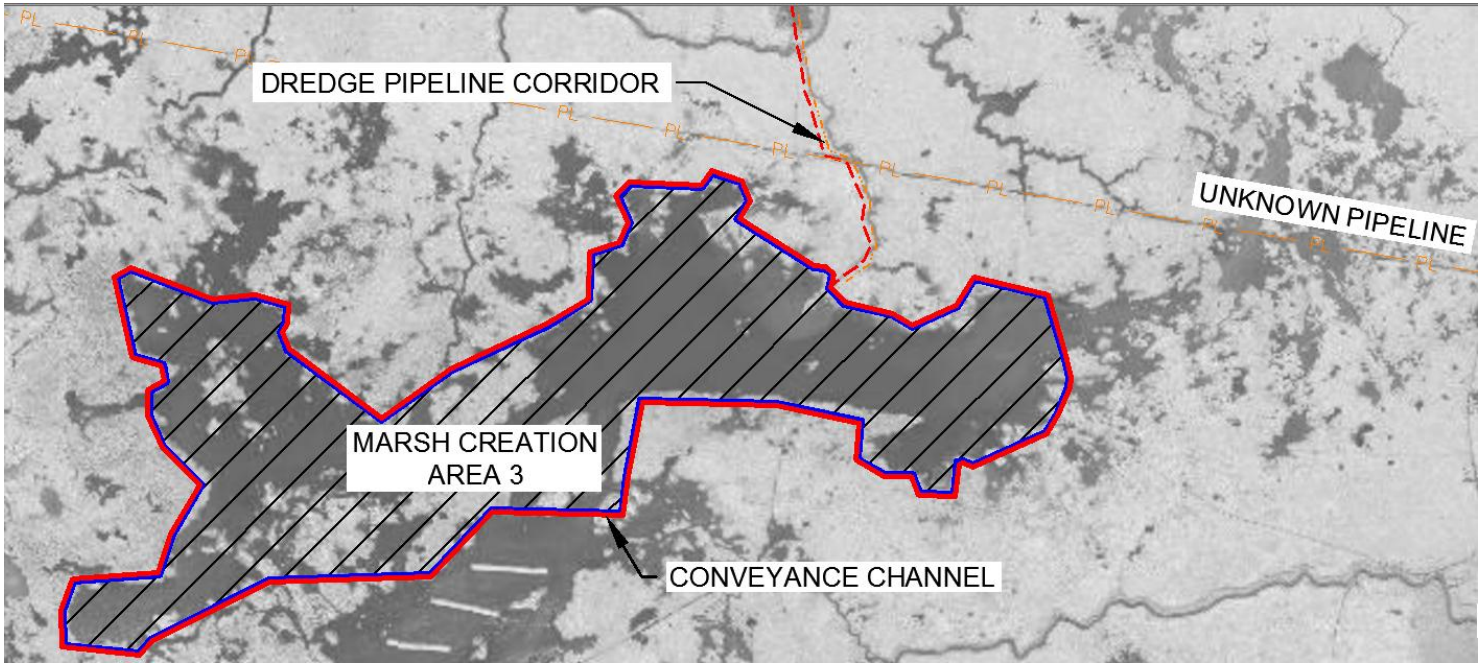
- Four (4) scenarios including existing conditions
  - Scenario 0-Existing Conditions
  - Scenario 1-Marsh Creation Only
  - Scenario 2-Marsh Creation plus Water Control Structures at Invert=0.0'
  - Scenario 3-Marsh Creation plus Water Control Structures at Invert=-2.0'

Scenario	Features	Flow In (cfs)	Flow Out (cfs)	Net Flow Out of Marsh(cfs)	Average Water Level (ft)
Existing	-	19.8	23.9	4.1	0.96
1	Marsh Fill at +1.3ft, NAVD88	15.9	19.6	3.7	0.99
2	Marsh Fill at +1.3ft, NAVD88				
	Conveyance Channel around MC3	6.2	10.6	4.4	1.22
	48in Culverts (Invert=0.0ft)				
3	Marsh Fill at +1.3ft, NAVD88				
	Conveyance Channel around MC3	40.5	43.8	3.3	1.02
	48in Culverts (Invert=-2.0ft)				

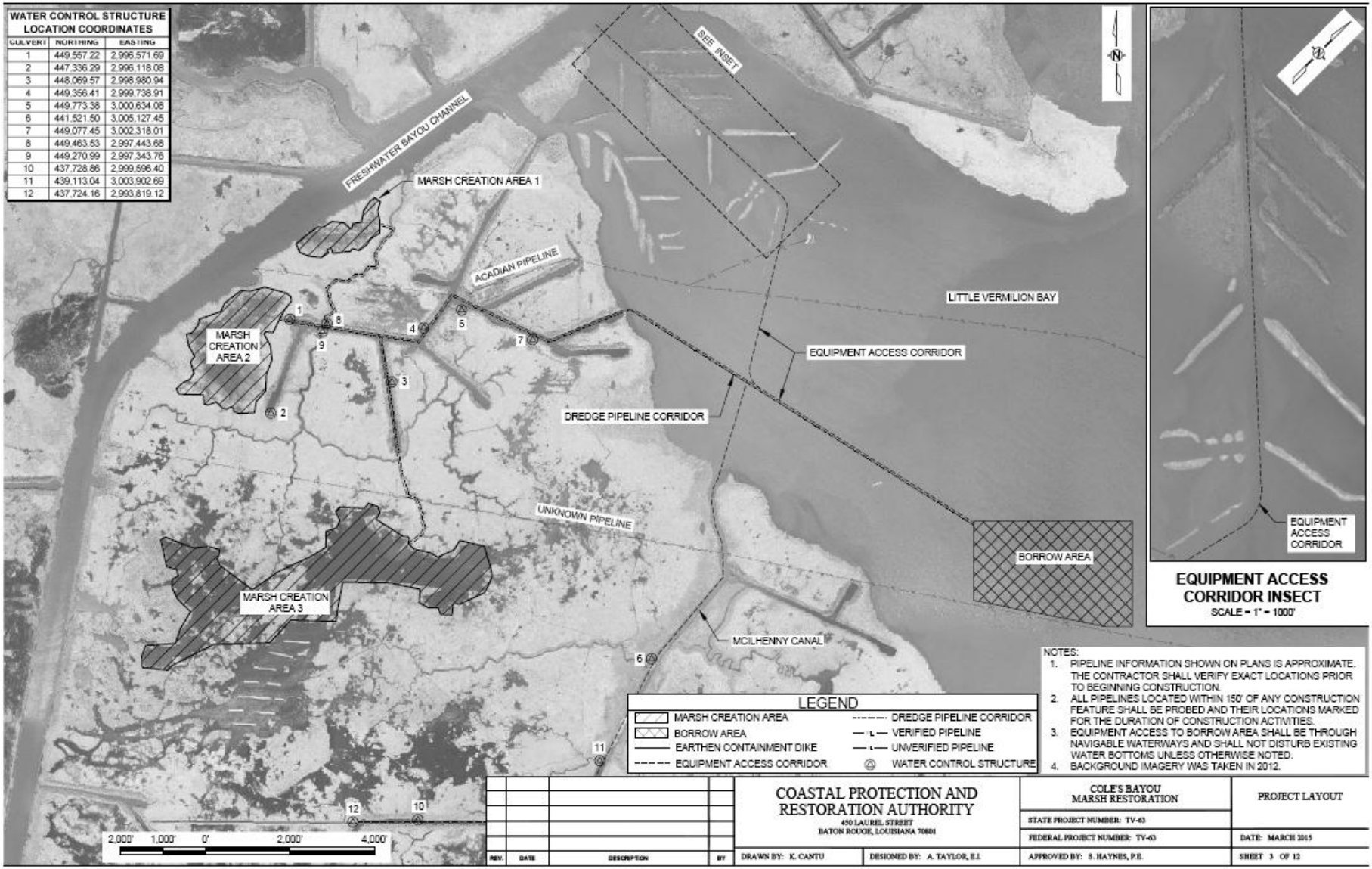
Hydrodynamic Modeling

- Conveyance Channel
  - Containment borrowed from outside of Marsh Creation Fill Area 3
  - Maximum bottom elevation=-5.0 ft NAVD88
  - Side Slopes= 1(V):4(H)

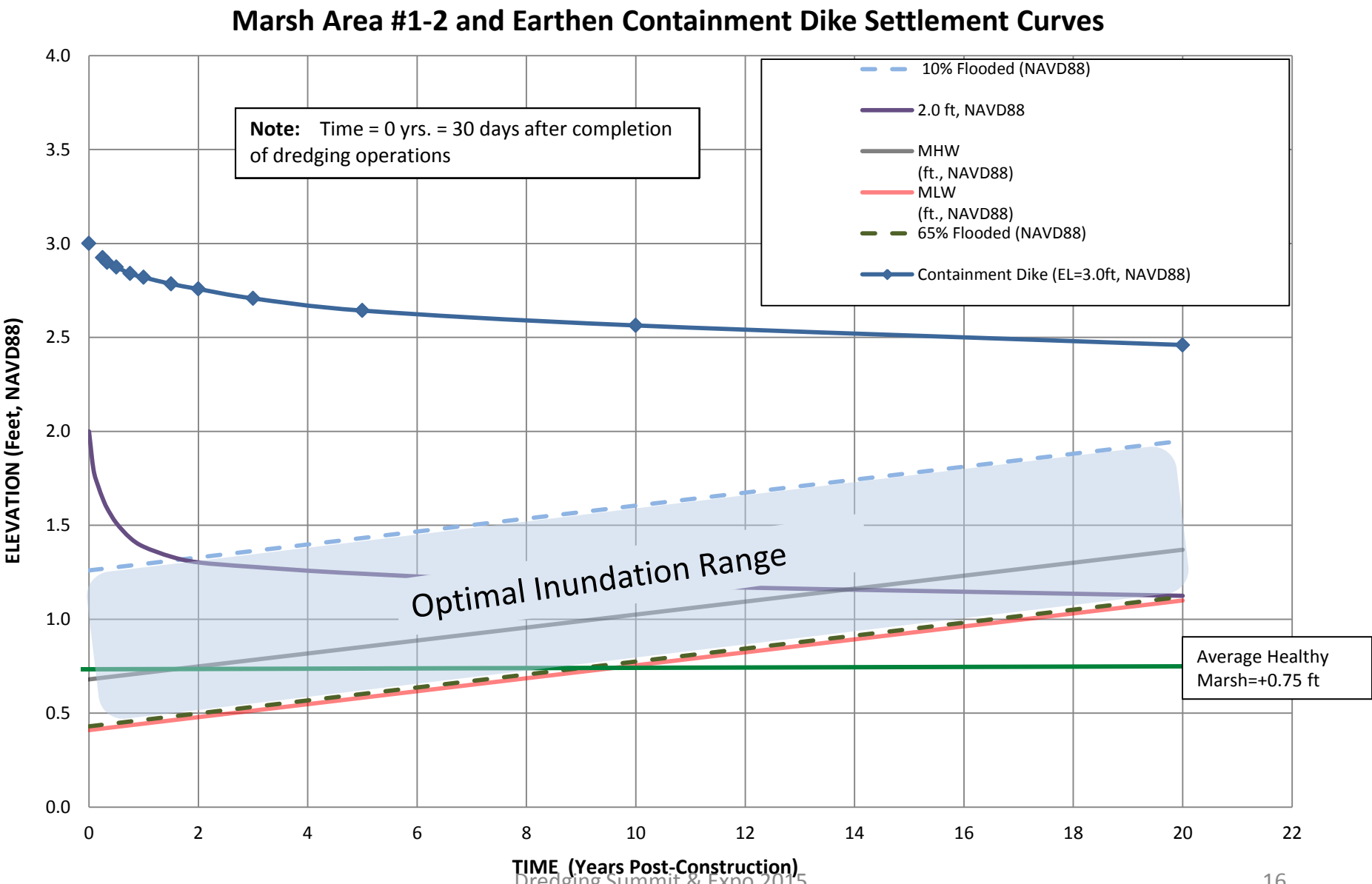
- Reconnects trenasses that would otherwise be cut off by the construction of Marsh Creation Fill Area 3



Marsh Creation Design

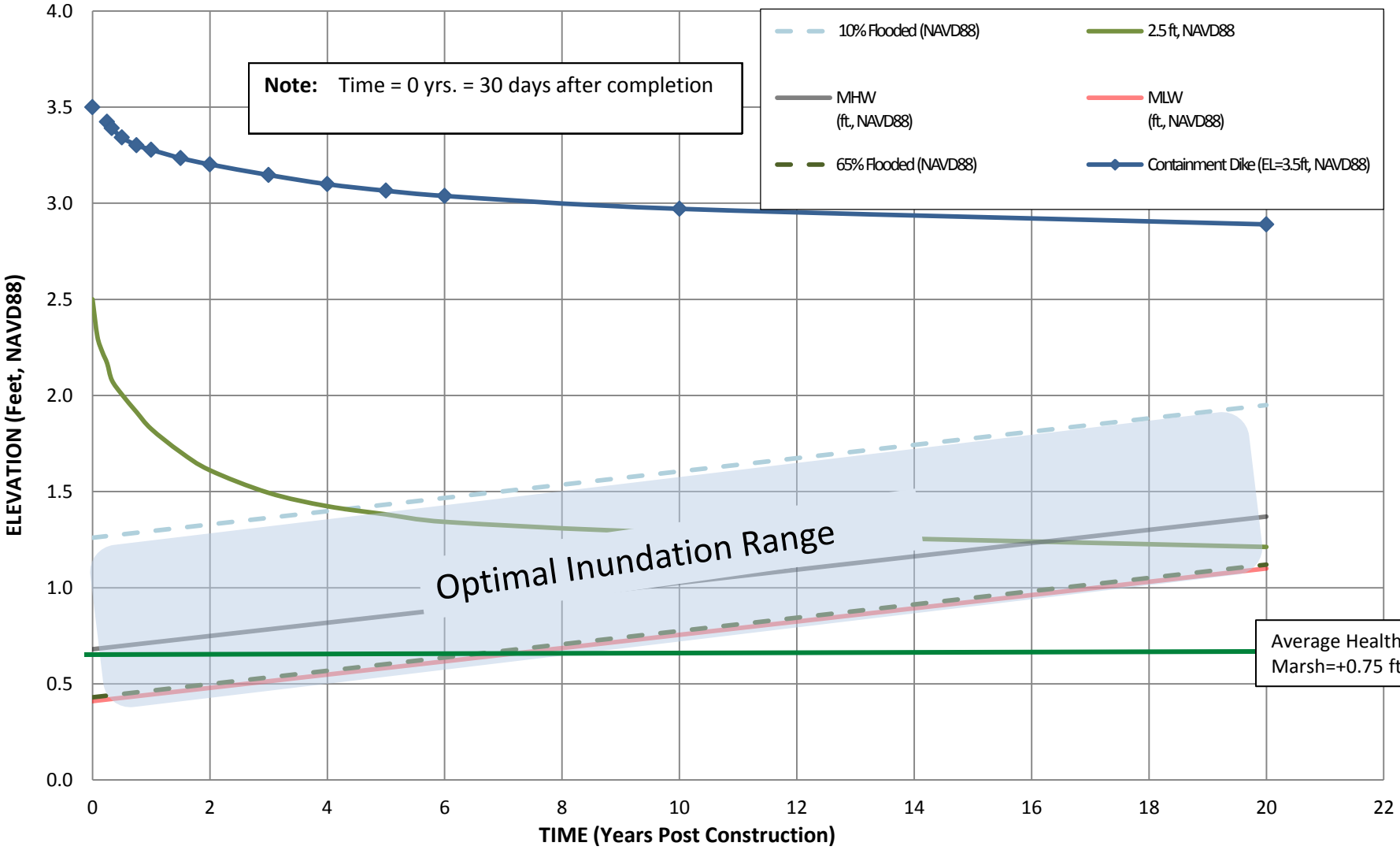


Target Marsh Elevation



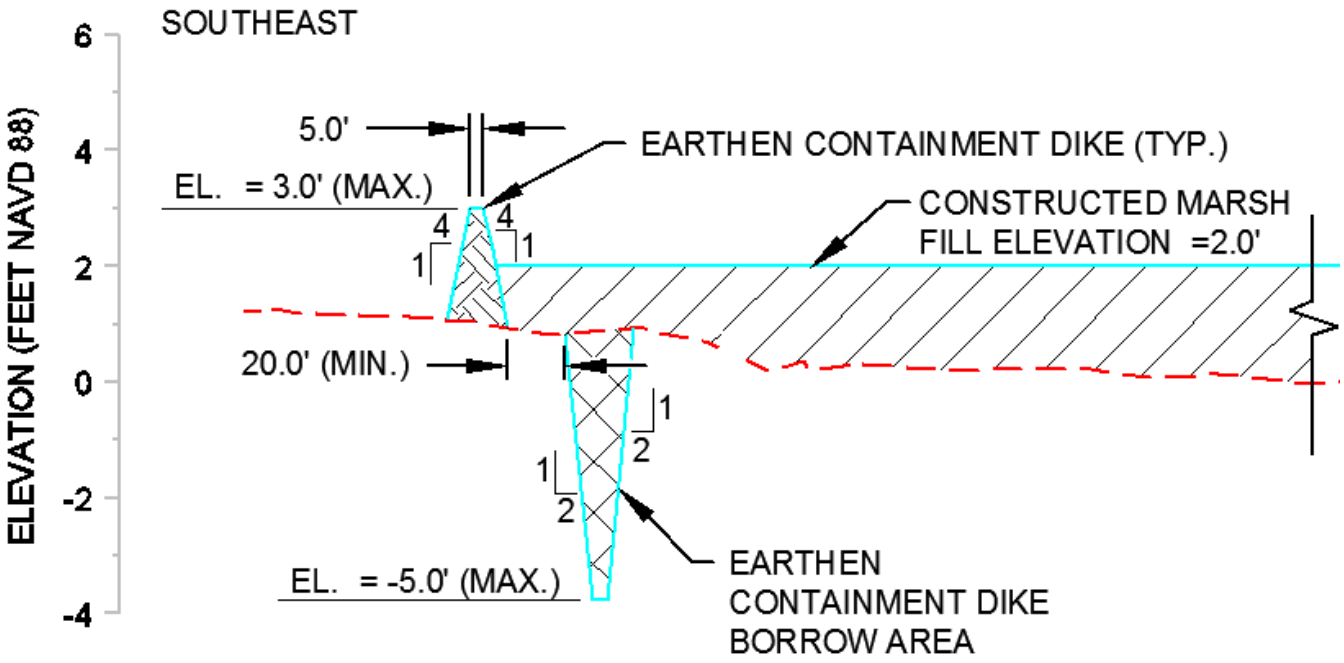
Target Marsh Elevation

Marsh Area #3 and Earthen Containment Dike Settlement Curves



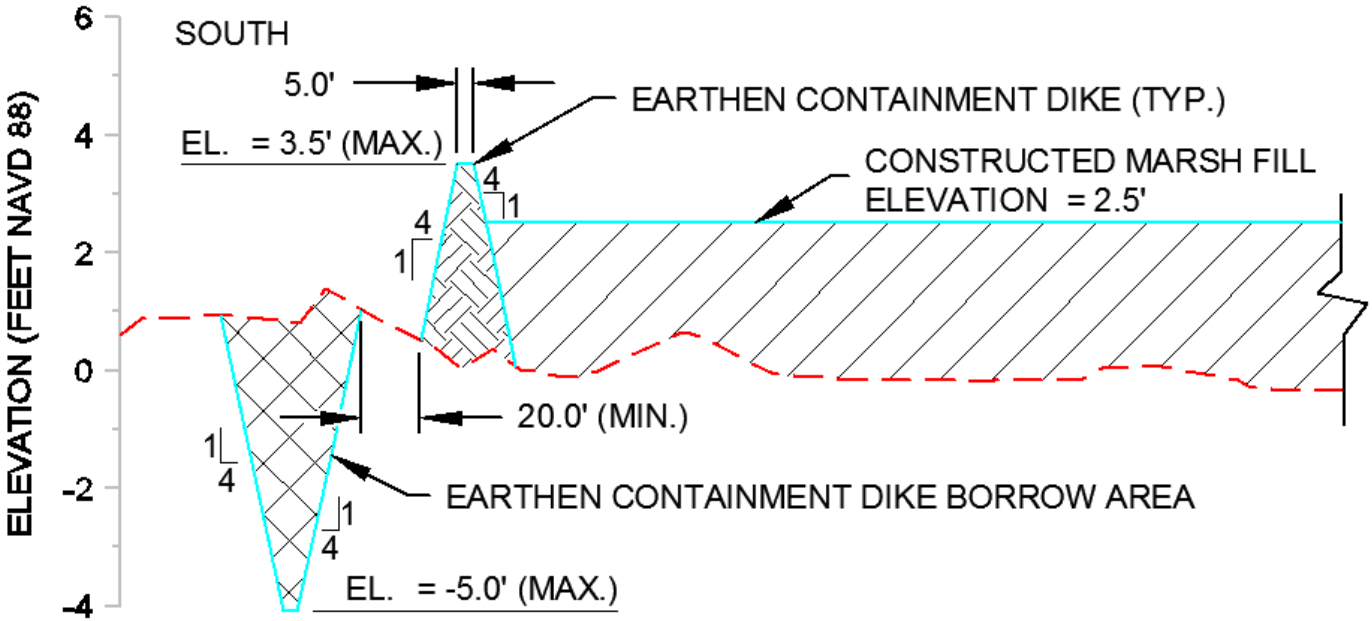
Earthen Containment Dike Design- Marsh Creation Fill Areas 1 & 2

- Crown Elevation:
  - +3.0 feet NAVD88
- Side Slope: 1(V):4(H)
- Top Width: 5.0 feet



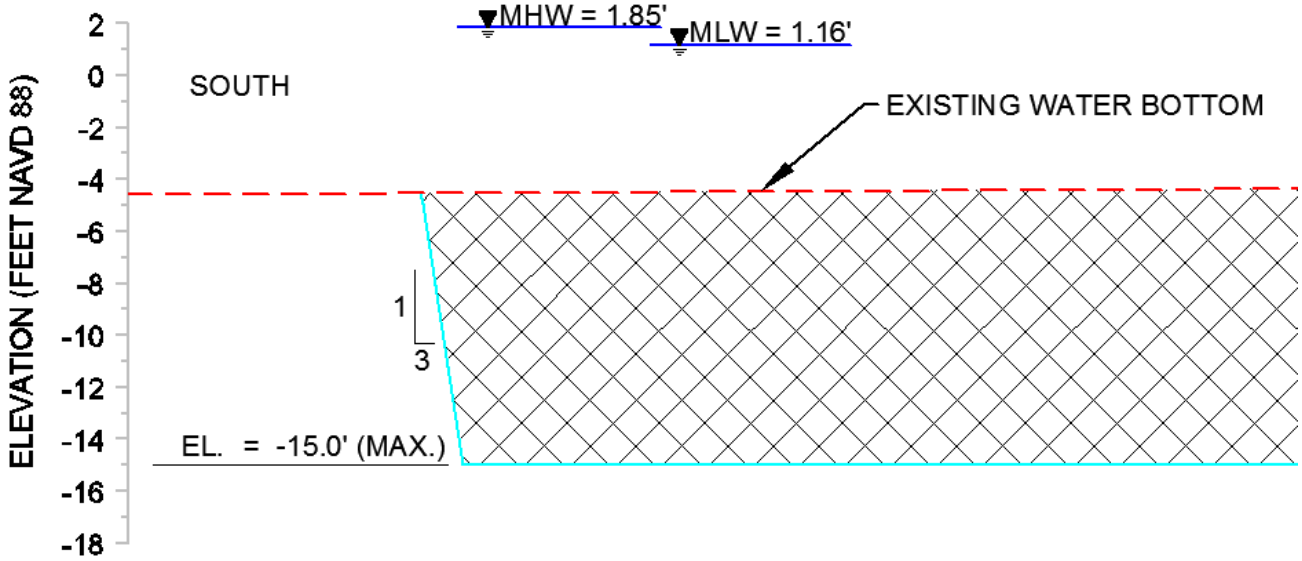
Earthen Containment Dike Design- Marsh Creation Fill Area 3

- Crown Elevation:
  - +3.5 feet NAVD88
- Side Slope: 1(V):4(H)
- Top Width: 5.0 feet
- Containment Borrowed from outside of fill area

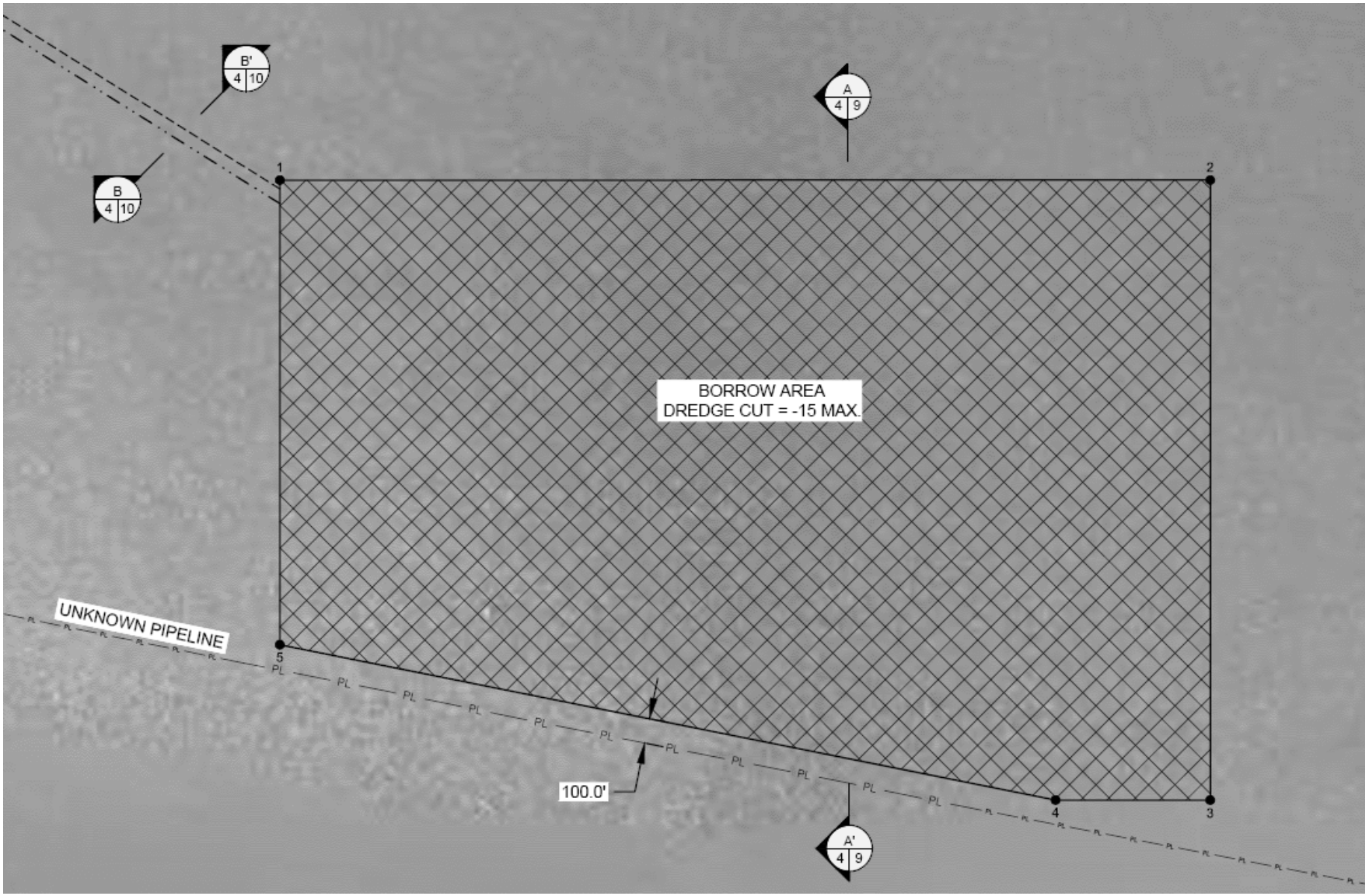


Borrow Area Design

- Proximity to Project Area
- Available vs. Required
  - Volumes computed using survey cross sections
  - Required volume = Fill Volume * C:F (1.5)
- Available: ~3.3 MCY
- Required: ~2.7 MCY

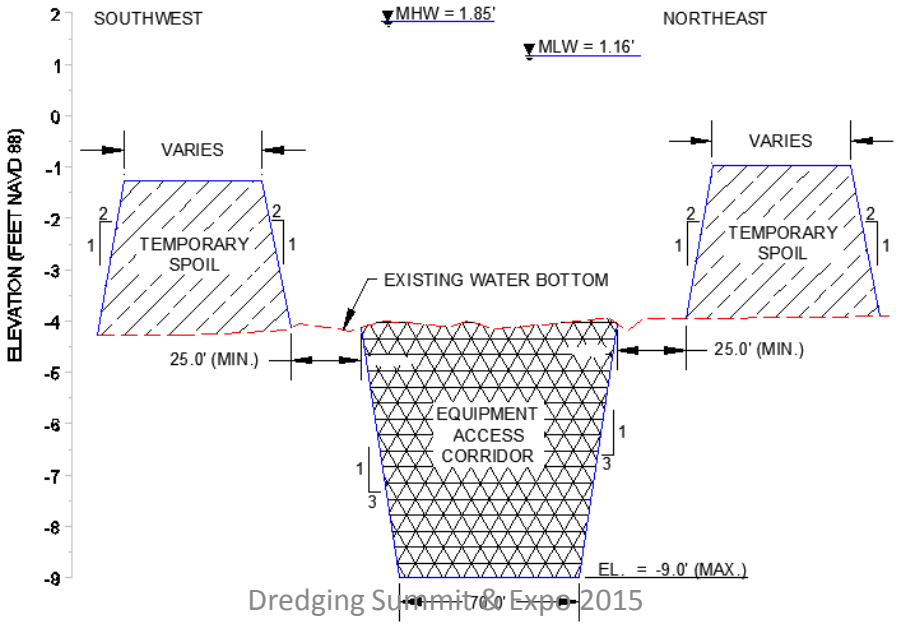


Borrow Area Design

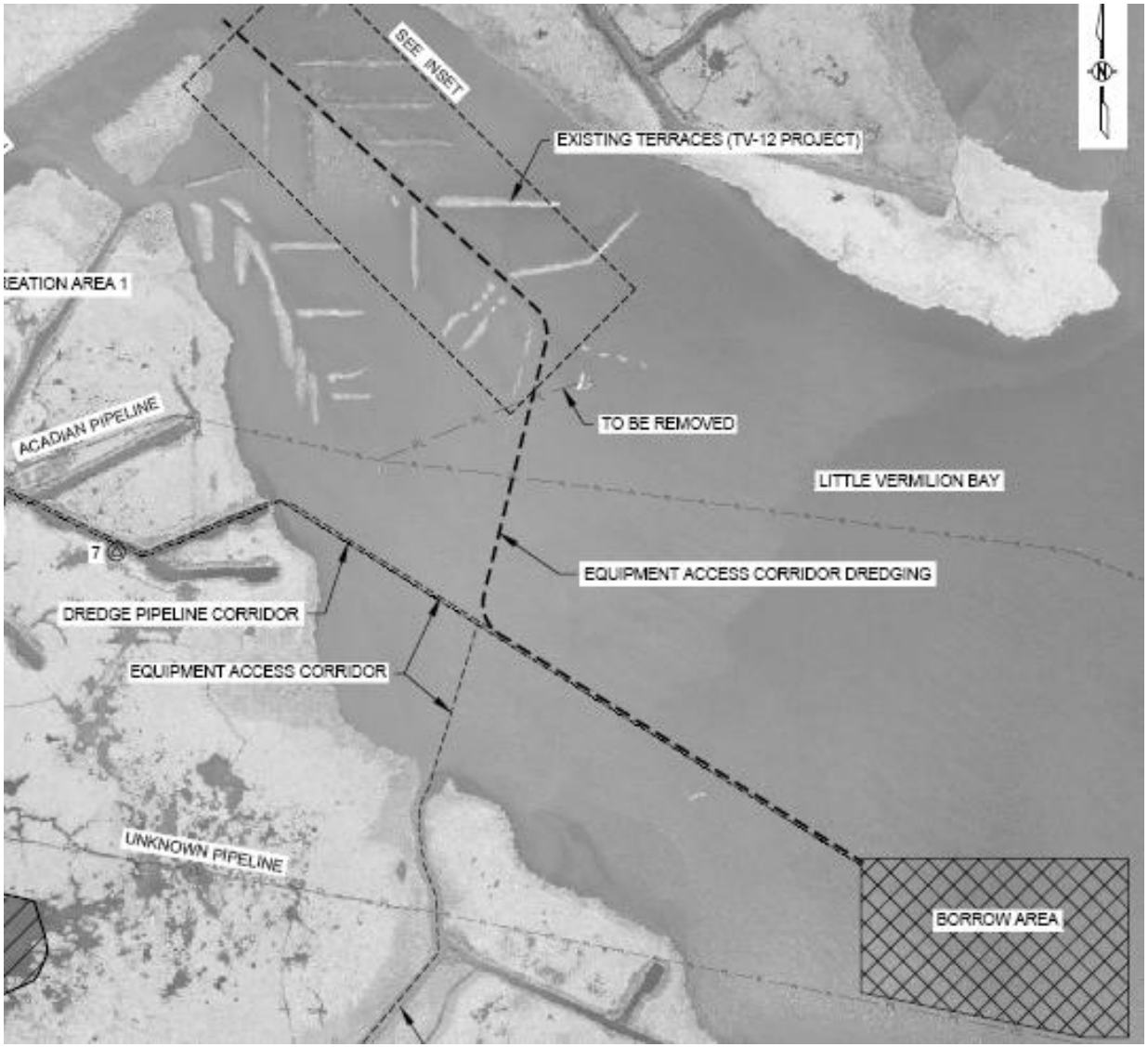


Equipment Access Corridor Design

- Maximum bottom elevation: -9 feet NAVD88
- Maximum bottom width: 70 feet
- Side Slopes: 1(V):3(H)
- Temporary disposal areas on either side of corridor will be backfilled once construction is completed

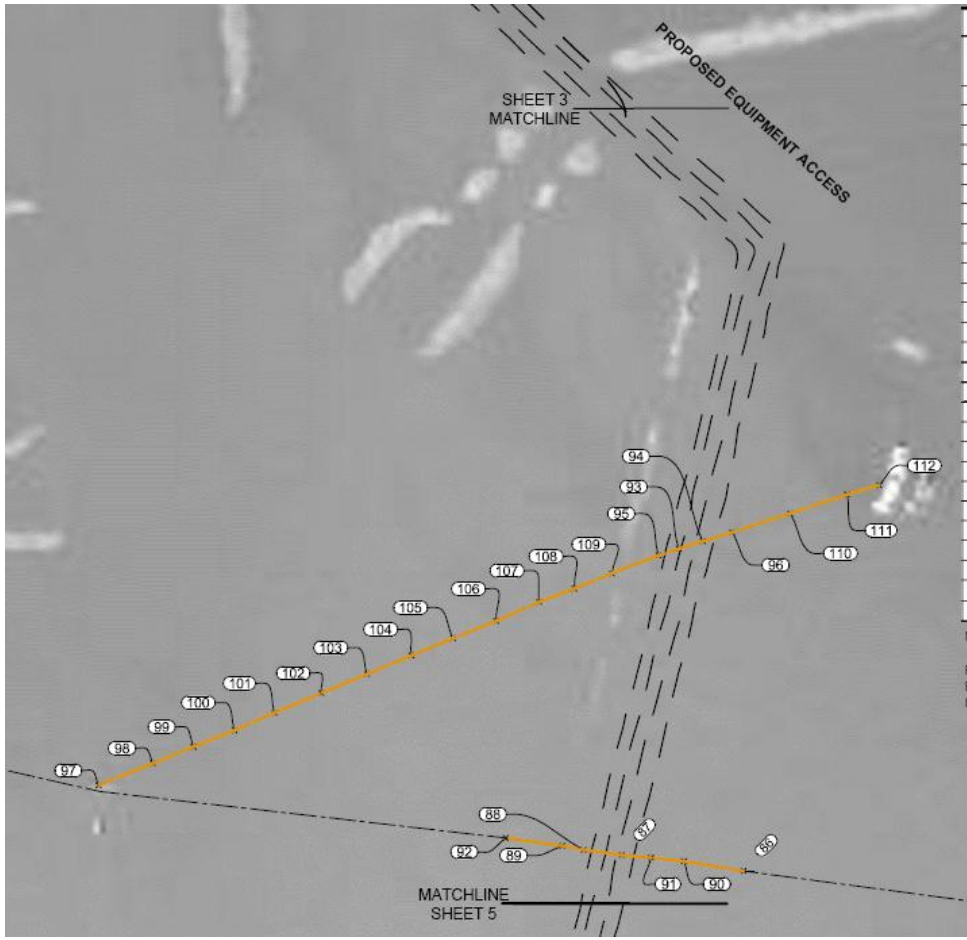


Equipment Access Corridor Design



Equipment Access Corridor Design

- 10 inch Acadian Pipeline crosses Equipment Access Corridor
- 2-3 inch Acadian Flow Line removed on 4/17/15



EQUIPMENT ACCESS PIPELINE PROBE LOCATION TABLE

REF	POINT NAME	NORTHING	EASTING	ELEVATION NATURAL GRADE	DEPTH OF BURIAL	ELEVATION TOP OF PIPE	DESCRIPTION
86	120814TJR007	450070.56	3008310.35	-0.9	13.9	-14.8	Acadian Pipeline
87	120814TJR001	450126.77	3007878.77	-2.6	11.5	-14.1	Acadian Pipeline
88	120814TJR002	450145.43	3007744.30	-2.6	11.3	-13.9	Acadian Pipeline
89	120814TJR003	450159.77	3007668.91	-2.6	9.7	-12.3	Acadian Pipeline
90	120814TJR004	450104.97	3008099.36	-2.8	10.2	-13.0	Acadian Pipeline
91	120814TJR006	450117.59	3007983.09	-3.4	10.6	-14.0	Acadian Pipeline
92	120814TJR008	450187.27	3007468.32	-3.2	6.9	-10.1	Acadian Pipeline
93	121714TJR001	451210.79	3008081.74	-2.1	7.0	-9.1	2" - 3" Flowline
94	121714TJR002	451237.20	3008166.63	-2.2	5.8	-8.0	2" - 3" Flowline
95	121714TJR003	451187.03	3008009.71	-2.8	8.8	-11.6	2" - 3" Flowline
96	121714TJR004	451268.86	3008270.74	-2.1	6.6	-8.7	2" - 3" Flowline
97	121714TJR005	450373.80	3006026.09	N/A	N/A	1.6	2" - 3" Flowline Riser
98	121714TJR007	450451.56	3006217.55	N/A	N/A	N/A	Radio Detection Signal
99	121714TJR008	450509.80	3006361.91	N/A	N/A	N/A	Radio Detection Signal
100	121714TJR009	450567.98	3006507.46	N/A	N/A	N/A	Radio Detection Signal
101	121714TJR010	450630.09	3006648.80	N/A	N/A	N/A	Radio Detection Signal
102	121714TJR011	450700.12	3006815.01	N/A	N/A	N/A	Radio Detection Signal
103	121714TJR012	450766.69	3006977.32	N/A	N/A	N/A	Radio Detection Signal
104	121714TJR013	450833.30	3007133.94	N/A	N/A	N/A	Radio Detection Signal
105	121714TJR014	450893.72	3007281.38	N/A	N/A	N/A	Radio Detection Signal
106	121714TJR015	450955.01	3007433.81	N/A	N/A	N/A	Radio Detection Signal
107	121714TJR016	451022.37	3007586.50	N/A	N/A	N/A	Radio Detection Signal
108	121714TJR017	451069.29	3007710.88	N/A	N/A	N/A	Radio Detection Signal
109	121714TJR018	451123.34	3007844.76	N/A	N/A	N/A	Radio Detection Signal
110	121714TJR019	451335.59	3008475.68	N/A	N/A	N/A	Radio Detection Signal
111	121714TJR020	451402.14	3008677.47	N/A	N/A	N/A	Radio Detection Signal
112	121714TJR021	451435.21	3008791.46	N/A	N/A	7.2	2" - 3" Flowline Riser

NOTE:

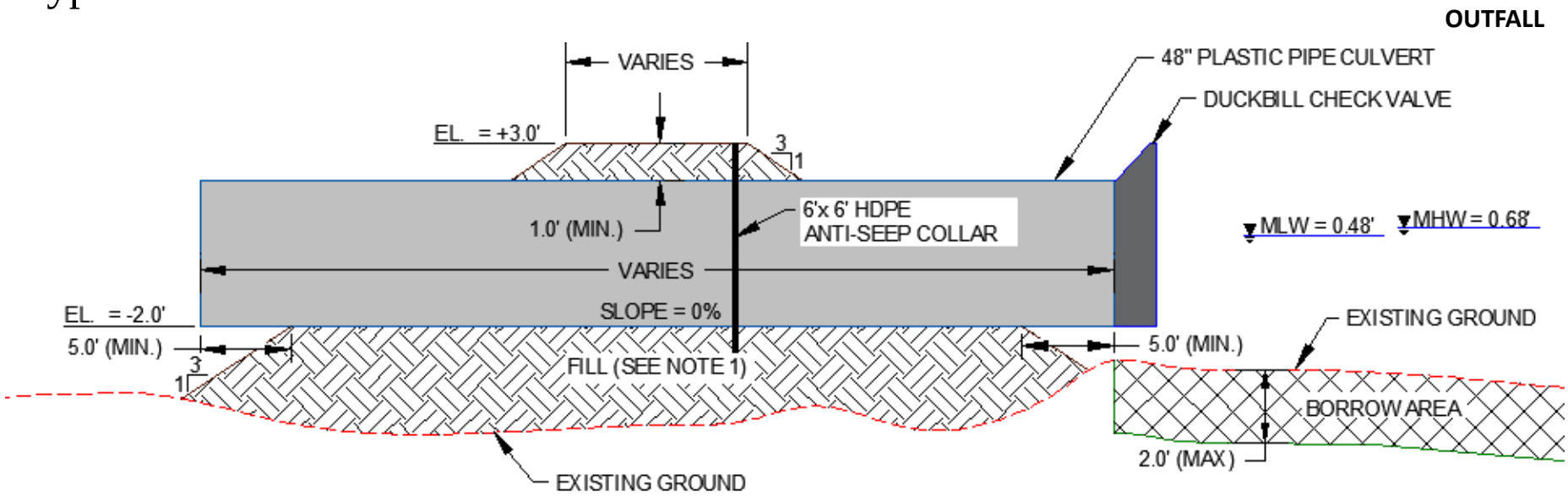
FLOWLINE IS TO BE REMOVED A WEEK FROM DECEMBER 17, 2014 AS INFORMED BY BRAMMER ENGINEERING REPRESENTATIVE AT JOB SITE. CONTACT MARK BARTON FOR FLOWLINE INFORMATION @ (337)232-2215 (EXT. 3115).

Hydrologic Restoration Design
Water Control Structure Design

- 48” corrugated HDPE pipe
  - Invert=-2.0 ft. NAVD88
  - Placed in existing breaches or through existing dike

- One way check valves to facilitate North to South flow

- Typical Section



Hydrologic Restoration Design
Duckbill Check Valve

- Duckbill check valves
  - Less maintenance required than with steel gate
  - Lightweight and durable
  - Easy to install

Conclusions

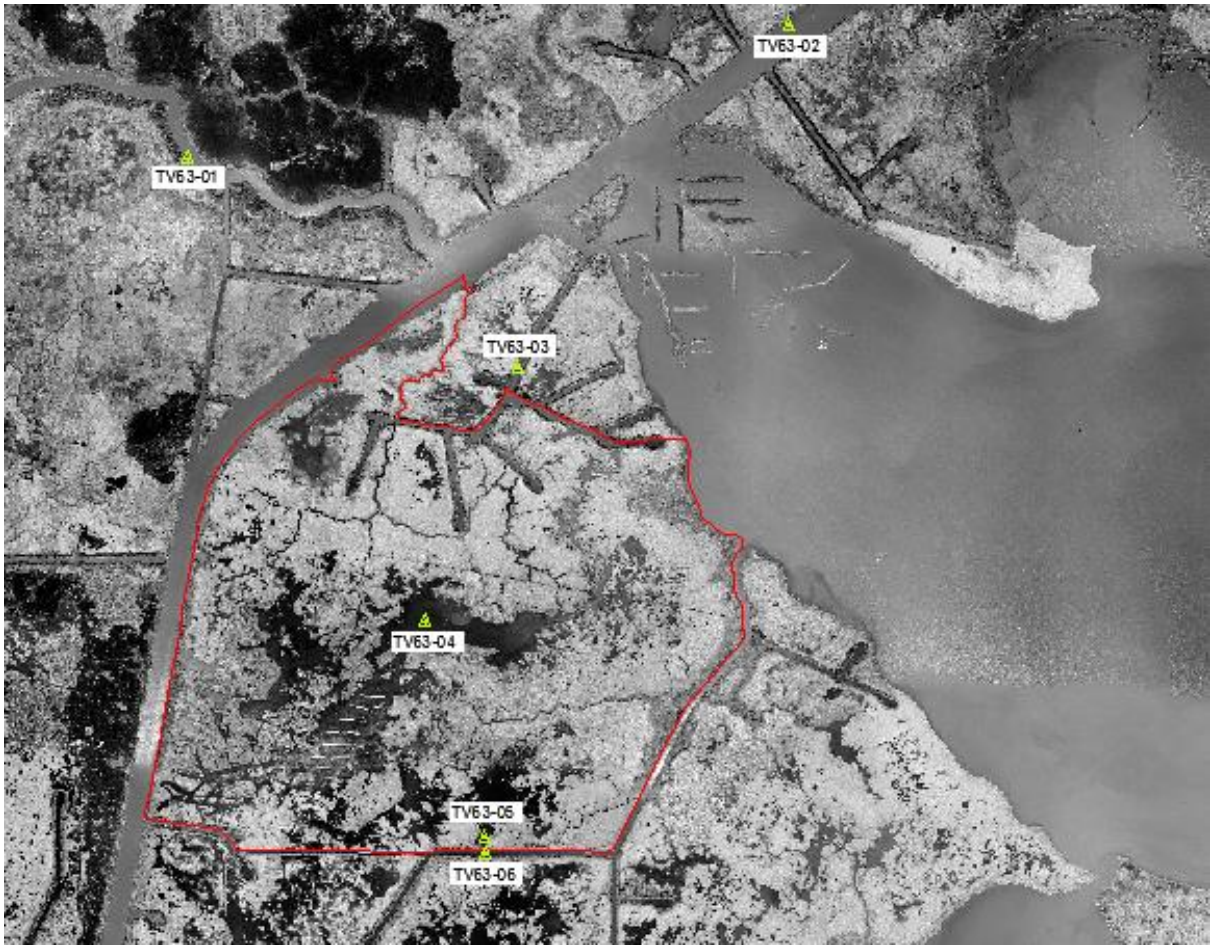
- Impounded and semi-impounded areas pose unique issues when designing marsh creation and hydrologic restoration projects.

- Unidirectional flow and consistent freshwater and sediment input are essential in maintaining the longevity of this and many other marsh creation projects.

Questions?

Hydrologic Monitoring Stations

- Six monitoring stations located in and around project area
- Monitored water levels, salinity, TSS, etc. from April 2013 to October 2013
- Data used to calibrate Hydrodynamic model and provide subordinate station data for Tidal Datum and Percent Inundation calculations



Tidal Gage Locations and Tidal Datum Determination

Subordinate Station

- TV63-04
- Set up for TV-63 project
- Located in center of largest marsh fill cell
- 6 months of continuous data (04/13 – 10/13)

Control Station

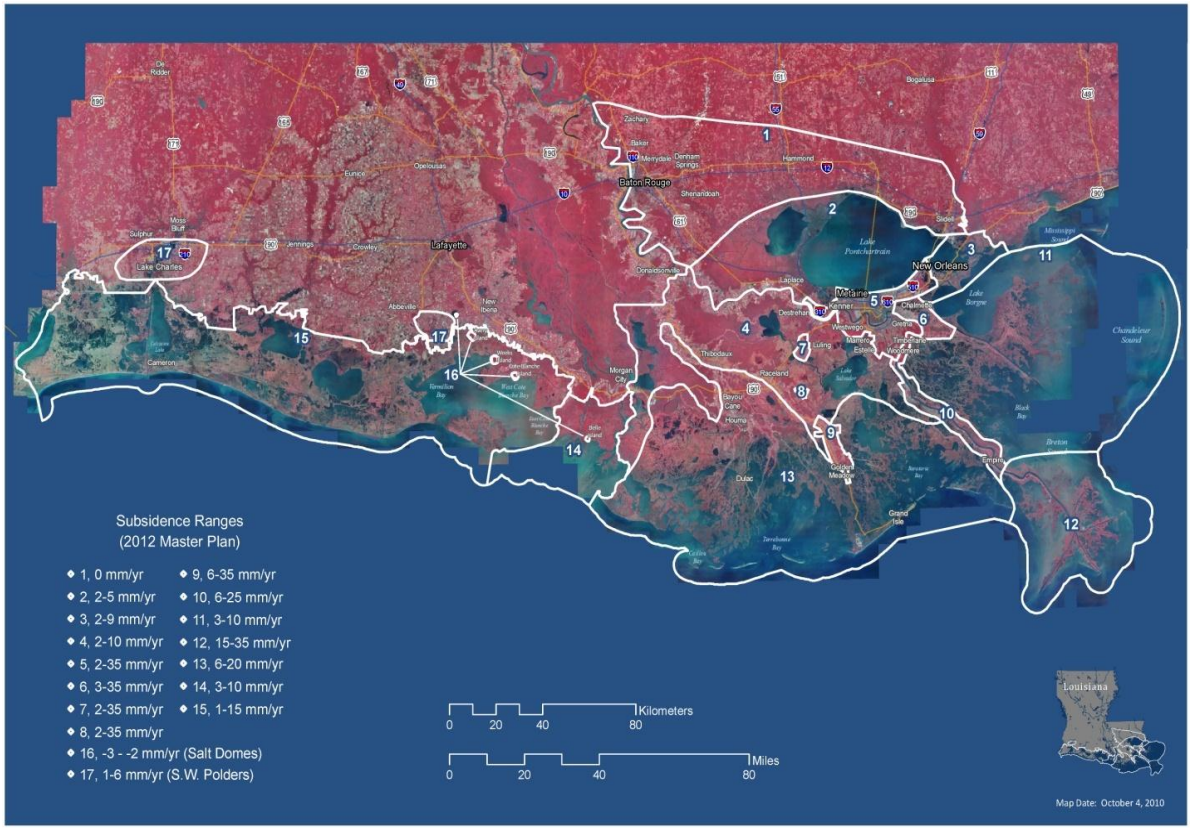
- CRMS2041
- Approximately 4 miles from TV-63
- 5 Years of Continuous Data (7/08-1/14)

KNOWN VARIABLES	ELEV. FT NAVD88
MHW_C= 5 Year Mean High Water At Control Station	1.86
MTL_C= 5 Year Mean Tide Level At Control Station	1.51
MLW_C= 5 Year Mean Low Water At Control Station	1.15
MR_C= 5 Year Mean Tide Range At Control Station	0.72
TL_C= Mean Tide Level For The Observation Period At Control Station	1.78
R_C= Mean Tide Range For The Observation Period At Control Station	0.72
TL_S= Mean Tide Level For The Observation Period At Subordinate Station	0.84
R_S= Mean Tide Range For The Observation Period At Subordinate Station	0.19
CALCULATED VARIABLES	
MHW_S= 5 Year Mean High Water At Subordinate Station (MHW = MTL + MR/2)	0.68
MTL_S= 5 Year Mean Tide Level At Subordinate Station (MTL = TL+MTL-TL)	0.57
MLW_S=5 Year Mean Low Water At Subordinate Station (MLW=MTL-MR/2)	0.48
MR_S=5 Year Mean Tide Range At Subordinate Station (MR=(MR*R)/R)	0.20

- MHW, MLW in surrounding marshes and Little Vermilion Bay
  - MHW= +1.85 ft. NAVD88
  - MLW= +1.16 ft. NAVD88

Relative Sea Level Rise (RSLR)

- CPRA utilizes its Planning Division to assist with calculating RSLR
- The RSLR rate estimated is 0.03451 ft/year (0.6902 ft at end of project life).



Earthen Containment Dike Slope Stability

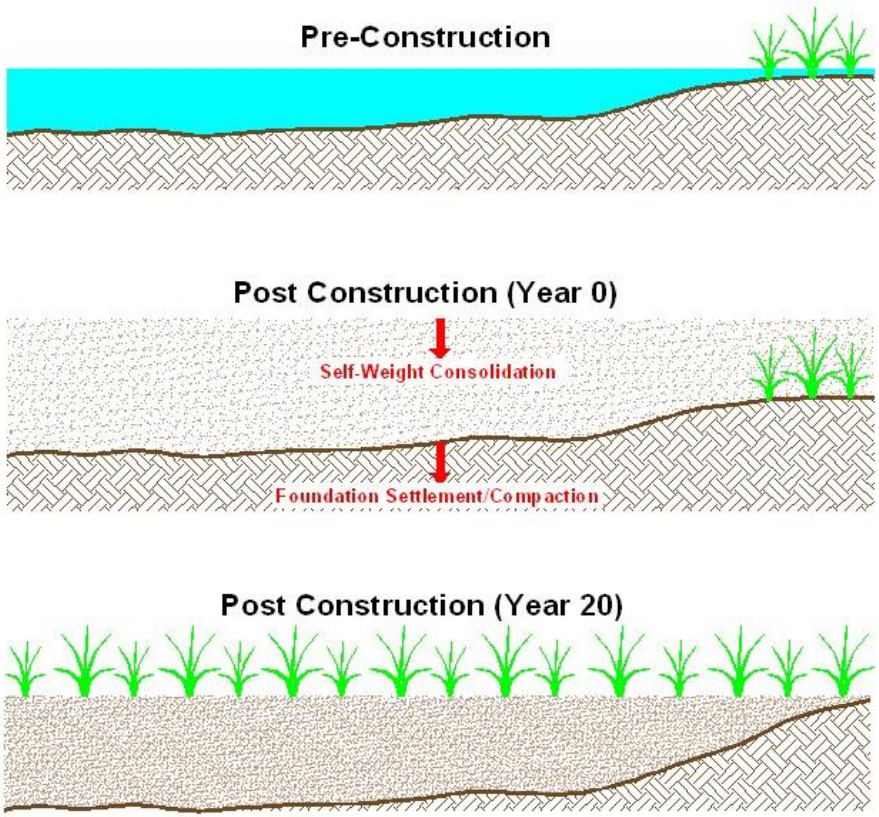
- Slope/W used to compute factors of safety
- Minimum acceptable factor of safety for this area determined to be 1.5

Marsh Area	Estimated Berm Crest El. (ft. NAVD88)	Borrow Excavation Offset (ft.)	Berm Side Slope	Factors of Safety		
				Circular Arc In Berm Slope	Circular Arc Bearing Capacity	Global Sliding Toward Borrow Pit
1	+3.0	20	4H:1V	2.02	2.74	2.66
	+4.0			1.61	2.22	2.18
2	+3.0	20	4H:1V	3.97	4.89	3.31
	+4.0			2.71	2.86	2.62
3	+3.0	20	4H:1V	2.02	3.10	2.65
	+4.0			1.61	2.38	2.08

Marsh Fill Settlement Analysis

- Utilized Terzaghi's 1-D linear Consolidation Theory and PSDDF

- Goals:
  1. Determine target marsh fill elevation
     - Settlement of underlying soils (compaction)
     - Self weight consolidation
  2. Settle to optimal brackish marsh range (10%-65% inundated) within first few years after construction and remain within range until end of project life



Earthen Containment Dike Design

Marsh Creation Area	Design Height (ft)	Side Slopes	Crown Width (ft)	Factor of Safety	Minimum Offset (ft)	Cut to Fill	Volume of Fill (yd^3)	Volume of Cut (yd^3)
1	3.0	4H : 1V	5	2.02	20	1.3	7,244	9,417
2	3.0	4H : 1V	5	3.97	20	1.3	9,226	11,994
3	3.5	4H : 1V	5	1.61	20	1.3	62,614	81,398
Total							**79,084**	**102,809**

*1.3 Cut to Fill recommended by Ardaman & Associates

Marsh Fill Area Design

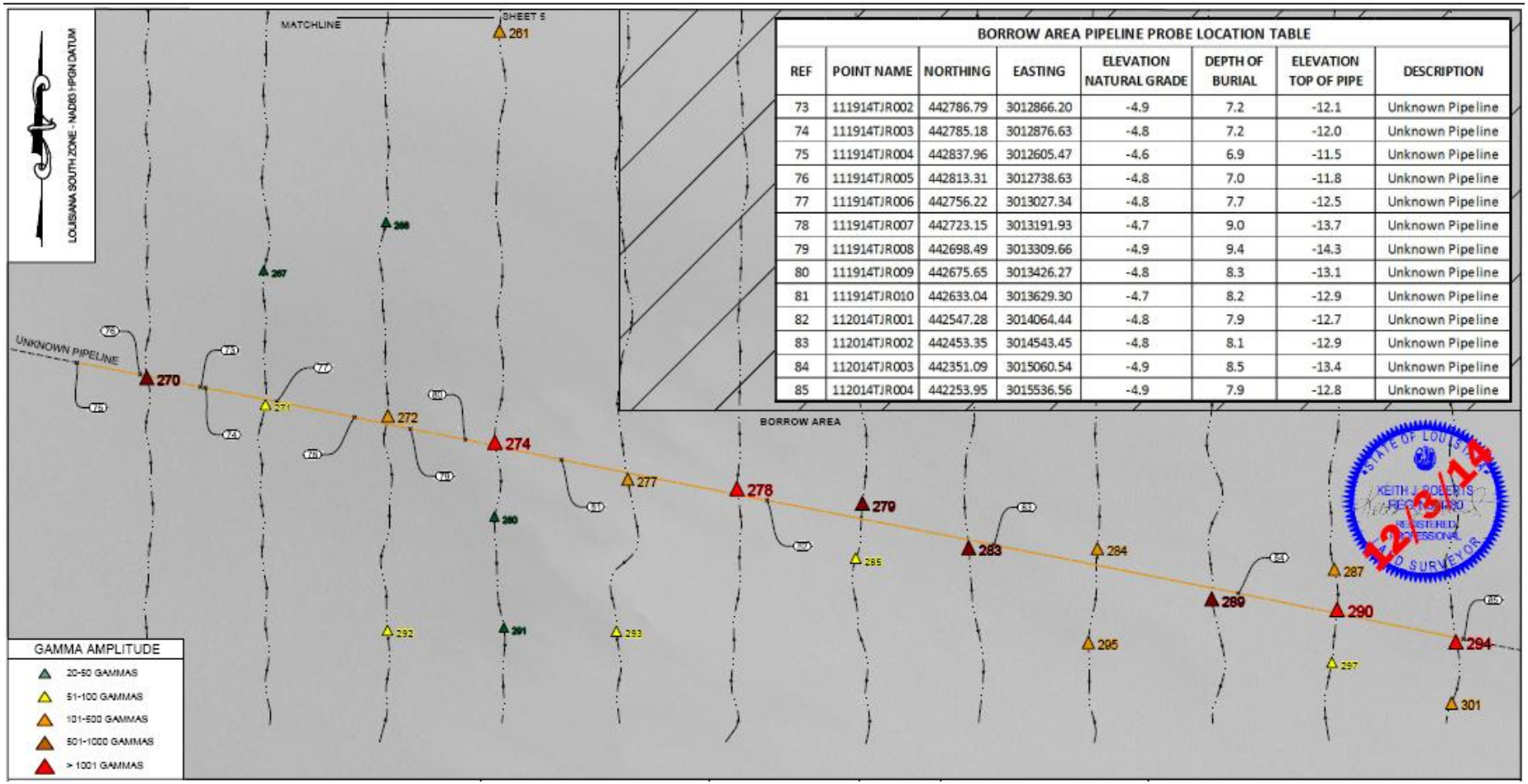
- Determined final and constructed target marsh elevations from settlement curves.
- Goal: To maintain healthy marsh that is flooded between 10% and 65% of the year during the majority of the project life.

Marsh Creation Area	Fill Height (ft)	Area (Acres)	Cut to Fill	Volume of Fill (yd^3)	Volume of Cut (yd^3)
1	2.0	28	1.5	85,288	127,932
2	2.0	108	1.5	318,163	477,244
3	2.5	282	1.5	1,373,450	2,060,175
Totals		**418**		**1,776,901**	**2,665,352**

*Volumes for Marsh Creation Cells 1 and 2 include filling of containment dike borrow areas.

Borrow Area Design

- Pipeline of unknown diameter located near southwest corner of borrow area
  - 100 ft. buffer from edge of borrow area



BORROW AREA PIPELINE PROBE LOCATION TABLE

REF	POINT NAME	NORTHING	EASTING	ELEVATION NATURAL GRADE	DEPTH OF BURIAL	ELEVATION TOP OF PIPE	DESCRIPTION
73	111914TJR002	442786.79	3012866.20	-4.9	7.2	-12.1	Unknown Pipeline
74	111914TJR003	442785.18	3012876.63	-4.8	7.2	-12.0	Unknown Pipeline
75	111914TJR004	442837.96	3012605.47	-4.6	6.9	-11.5	Unknown Pipeline
76	111914TJR005	442813.31	3012738.63	-4.8	7.0	-11.8	Unknown Pipeline
77	111914TJR006	442756.22	3013027.34	-4.8	7.7	-12.5	Unknown Pipeline
78	111914TJR007	442723.15	3013191.93	-4.7	9.0	-13.7	Unknown Pipeline
79	111914TJR008	442698.49	3013309.66	-4.9	9.4	-14.3	Unknown Pipeline
80	111914TJR009	442675.65	3013426.27	-4.8	8.3	-13.1	Unknown Pipeline
81	111914TJR010	442633.04	3013629.30	-4.7	8.2	-12.9	Unknown Pipeline
82	112014TJR001	442547.28	3014064.44	-4.8	7.9	-12.7	Unknown Pipeline
83	112014TJR002	442453.35	3014543.45	-4.8	8.1	-12.9	Unknown Pipeline
84	112014TJR003	442351.09	3015060.54	-4.9	8.5	-13.4	Unknown Pipeline
85	112014TJR004	442253.95	3015536.56	-4.9	7.9	-12.8	Unknown Pipeline

Dredge Pipeline Alignment