ATTACHMENT O

ENGINEERING EVALUATIONS

O-1 Reinforced Rockfill Cofferdam Conceptual Design

O-2 Cofferdam Slope Stability Analysis

O-3 West Bank Erosion Potential Evaluation

O-4 River Bottom Erosion Potential Evaluation

dhec

Healthy People. Healthy Communities.

July 9, 2020

Mr. Paul Biery
Senior Project Manager
Dominion Energy South Carolina
400 Otarre Parkway
Cayce, SC 29033

RE: Reinforced Rockfill Cofferdam Conceptual Design
SCE&G Fleet Maintenance Site (Congaree River)
Columbia, South Carolina

Dear Mr. Biery,

The State Voluntary Cleanup Program has reviewed the Reinforced Rockfill Cofferdam Conceptual Design received by the Department on June 22nd, 2020. The Department approves of the submittal and the conclusions made in the report.

If you have any questions or comments please contact me at (803) 898-0747 or cassidga@dhec.sc.gov.

Sincerely,

Greg Cassidy
State Voluntary Cleanup Program
Bureau of Land and Waste Management

cc: File 52561
Lucas Berresford, BLWM
Veronica Barringer, Midlands EA Region
Al Peeples, Midlands EA Region

VIA ELECTRONIC MAIL

May 28, 2020

William Zeli, P.E., Environment Program Manager
Apex Companies, LLC
1600 Commerce Circle
Trafford, PA 15085

Subject: **Reinforced Rockfill Cofferdam Conceptual Design**
Congaree River Remediation Project
Columbia, South Carolina

Dear Mr. Zeli:

This Letter Report presents the results of WSP USA's (WSP) engineering evaluation and conceptual design of reinforced rockfill cofferdam options for the Congaree River Remediation project. Our services for this Project were performed in accordance with our December 31, 2019 proposal submitted to Apex Companies, LLC (Apex) authorized by Work Order #4, Change Order #1, dated December 17, 2019 and our April 28, 2020 proposal submitted to Apex authorized by Work Order #4, Change Order #4, dated April 30, 2020.

PROJECT UNDERSTANDING

In 2010, coal tar was discovered along the bottom of the Congaree River from the Gervais Street bridge to the Blossom Street bridge. Coal tar is a byproduct of a manufactured gas plant that once operated on Huger Street above the river. The manufacturing process left a residue that ultimately leaked into the Congaree River. Apex has prepared preliminary plans to remove the coal tar from the riverbed. The removal process will require the construction of a temporary cofferdam in the river to provide access for the construction equipment to remove the coal tar. Recent discussions held between WSP, Apex, and Dominion related to the revised design of the cofferdams to reflect the current removal plan resulted in a recommendation to evaluate various approaches to reinforcing the rockfill cofferdams in lieu of using cellular sheet pile cofferdams to mitigate the potential for catastrophic failure during flood flows. A catastrophic failure would result in distributing the rockfill within the river which may not be acceptable to the project stakeholders. This letter report presents descriptions for three reinforcement options and an evaluation of liner options for the rockfill cofferdam. Conceptual designs, associated budgetary cost estimates, and an evaluation matrix for the rockfill reinforcement concepts retained for evaluation are presented. Recommendations to proceed with a final design are also provided in this letter.

CONCEPTUAL DESIGN

This section presents a brief description of three cofferdam reinforcement options followed by an evaluation of liner options for the cofferdam. A conceptual design, including design sketch and budgetary cost estimate, are presented for each option retained for further evaluation. This information is used to complete the evaluation matrix. The conceptual designs consist of covering the outboard slope (wet side), crest, and the upper third of the inboard slope (dry side) of the rockfill cofferdam with

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reinforcement. The purpose of the reinforcement is to provide protection during overtopping, to prevent a catastrophic failure of the rockfill, and to limit deformations during flood loading conditions. Additional extensions of the reinforcement material further down the inboard slope will be subject to evaluation during final design. Engineering sketches of the conceptual designs are provided in Enclosure A.

ARTICULATED CONCRETE BLOCK MATS

This conceptual design consists of placing Articulated Concrete Block (ACB) mats on top of the rockfill throughout the outboard slope, crest, and the upper third of the inboard slope of the cofferdam. ACB mats are typically used for overtopping protection of earthen dams or earth lined spillways. Cable tied ACB mats are fabricated in the shop from pre-cast concrete blocks and steel cables. The height of the block ranges from 4 to 8 inches and the mats are generally 8-feet wide and up to 40-feet long (Contech, 2020). The mats can be transported to the site on a large flat-bed truck. A crane with spreader bar is required for installation. This concept includes potentially reusing the ACB mats at Area 2 after the coal tar has been removed from Area 1. However, this potential cost savings was not considered in the budgetary cost estimates due to uncertainties in the ability to successfully remove the ACB mats from Area 1 and the condition of the reclaimed ACBs. Since ACBs can resist flow velocities in excess of 25 feet per second, rip rap is not required along the outboard side of the cofferdam for erosion control.

ROCK MATTRESSES

This concept consists of placing rock mattresses on top of the rockfill throughout the outboard slope, crest, and the upper third of the inboard slope of the cofferdam. Rock mattresses are thin, flexible rectangular cages made from wire mesh. The mattresses are manufactured at an off-site facility and are delivered to the site where the baskets are formed, tied together, and then filled with appropriate sized crushed stone (rock). The wire cages are placed along the slope, tied together, filled with rock, and the top is placed and tied. Rock mattresses are typically used primarily for scour protection along river banks or embankment stability in channel linings. Typical mattress dimensions are 6 feet wide by 12 feet long. The height of the mattress ranges from 6 to 12 inches. The rock placed inside the mattress is hard, angular, and durable to prevent disintegration during the life of the project. Rock sizes range between 3 and 5 inches for 6 to 9-inch thick mattresses and between 4 and 8 inches for 12-inch thick mattresses. Rock mattresses can resist flow velocities in excess of 19 feet per second for slopes ranging from 2H:1V to 3H:1V. Due to the flow resistance of the rock mattresses, rip rap is not required along the outboard side of the cofferdam for erosion control.

STEEL REBAR MATS

This conceptual design consists of placing rectangular rebar mats on top of the rockfill. Rebar mats are typically used for constructing reinforced rockfill structures which include horizontal rows of rebar attached to the mats along the outside face. Our proposed design concept includes the mats along the outboard and inboard faces of the rockfill cofferdam. The spacing of the rebar is set to retain the rockfill dimensions placed along the face of the cofferdam. The Pit No. 7 Afterbay dam in California includes both internal and external rebar mats and has resisted flow velocities up to 12 feet per second but has experienced considerable material loss along the dam (FEMA, 2014). Therefore, we recommend that rip rap should be placed along the outboard side of the cofferdam for erosion control.

Horizontal reinforcement bars running through the cofferdam are required to increase the structural stability of the cofferdam, which would limit deformations of the rock fill and reduce the risk of a catastrophic failure during flood loading conditions. However, this design requirement presents a number of constructability issues. The horizontal bars would have to run through the liner along the outboard side of the cofferdam which would require watertight penetrations which are not practical. Also, the construction sequence of the cofferdam would require placing the horizontal bars along the rockfill lifts at predefined intervals, resulting in additional construction time compared with the other design concepts under consideration. Placing the horizontal rebar mats in the wet during construction is also challenging and would significantly increase construction cost. Based on the challenges of maintaining a watertight seal around the frequent liner penetrations for the horizontal reinforcement bars, and the additional construction time associated with this design concept, the steel rebar mat is considered to be the least practical and cost-effective design concept under consideration. Therefore, the steel rebar mat concept is discounted and not considered further in this evaluation.

LINER EVALUATION

Each conceptual design includes a geomembrane liner to minimize seepage through the cofferdam. The most commonly used materials used for geomembrane liners used for providing an impermeable barrier are linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE), and polyvinyl chloride (PVC). Other materials such as Hypalon, reinforced polypropylene and EPFM rubber are also used as geomembranes. However, based on discussions with Apex and Dominion, we have limited our evaluation to HDPE, PVC, and possibly Geosynthetic Clay Liners (GCLs).

GCLs are factory manufactured hydraulic barriers consisting of a layer of bentonite or other very low-permeability material supported by geotextiles and/or geomembranes mechanically held together by needling, stitching, or chemical adhesives. Typical applications for GCLs are for secondary lining systems for municipal or hazardous waste landfills when clay is not readily available. The use of GCL's for permanent dams or cofferdams is not mentioned in the United States Bureau of Reclamation's Design Standard No. 13 (USBR, 2018) and our discussions with geomembrane installers have indicated that GCLs need to be installed in the dry. Since our cofferdams will be installed in the wet, we do not believe that GCLs are suitable for the rockfill cofferdam.

HDPE geomembranes are used extensively in the US, have high UV resistance, and are very resistant to tearing and puncturing. HDPE seams must be thermally welded. However, HDPE is also very stiff so installation can be difficult especially in cold weather or tight corners. Typical applications are for landfill lining systems.

PVC geomembranes are more flexible than HDPE and have good tensile, elongation, and puncture resistance. PVC seams can be attached by solvent welding, adhesives, and heat or dielectric methods. PVC is used extensively in both US and Europe as an impermeable barrier in both embankment and concrete dams.

Based on this evaluation, our recommendation is to include a geomembrane liner (either PVC or HDPE) in the rockfill cofferdam with a minimum thickness of 50 mils. In addition, we will specify a minimum overlap distance of 5 feet or welding adjacent geomembrane panel seams.

ALTERNATIVE EVALUATION

The two remaining alternatives described in the previous section of the letter were ranked based on the key factors listed in ***Table 1***. The following factors used in previous evaluations conducted for the site were not included since the different reinforcement concepts do not have any significant differences:

- Practical to found on stream bottom
- Estimated leakage
- No Rise analysis
- Unexploded Ordnance impacts
- Availability of Contractors

Table 1

Cofferdam Alternatives Evaluation Matrix

REINFORCEMENT OPTION	**ACB MATS**	**ROCK MATTRESSES**
Overtopping Resistance	High	Medium
Proven Track Record for temporary installations	Yes	No
Estimated Installed Cost	$16/SF[a]	$12/SF[b]
Stability Enhancement	Yes (confirmed by stability analysis)	Possibly
Ease of Installation	Moderate	Less proven since mattresses need to be pre-filled
Ease of Removal	Moderate (recent temporary installation)	Challenging (no recent installations identified)
Installation and Removal Requirement	Common methods: crane with spreader bar required to lift and place/remove mats	Less proven methods: specialized equipment required to install in the wet
Duration of Installation and Removal	Medium	Long
Resistance to Catastrophic Failure	High	High
Compatibility with liner during construction	High (might be able to attach liner to bottom of ACB Mats)	Medium
Rank	**1**	**2**

Notes:

a. Cost information provided by ARMORTEC (2020).
b. Based on cost information provided by Elite Erosion Supply (2020).

BUDGETARY LEVEL COST ESTIMATES

Budgetary level cost estimates for the rockfill berm cofferdam including fabricating and installing the two reinforcement alternatives are provided in Enclosure B and summarized below. Installation costs are based on engineering judgement and recent correspondence with material suppliers for both ACBs (ARMORTEC) and rock mattresses (Elite Erosion Supply).

- ACB Mats: $5.3M
- Rock Mattresses: $4.9M

These budgetary costs for the reinforced rockfill berm include the base rockfill berm cost of $2.7M as described in WSP's July 17, 2019 letter report (WSP, 2019) and as summarized in the following paragraphs.

> *"These budgetary cost estimates are consistent for the current removal plan which consists of two separate work areas. The quantities of rock required for the rockfill berm have been calculated based on footprints of the stakeholder-developed MRA and the latest bathymetric data provided by APEX.*
>
> *A Digital Terrain Model (DEM) of the proposed cofferdams has been developed in ArcGIS software based on a 10-ft wide crest at elevation 124.5 ft NVGD29 and a side slope of 1V:1.3H. The bathymetric DEM has been subtracted from the cofferdam DEM, and the resulting DEM provides the depth of rockfill throughout Area 1 and Area 2. The DEMs are produced at a 1-ft by 1-ft resolution, which is appropriate for a budgetary level cost estimate.*
>
> *The cost estimates include a 20% contingency amount to reflect the associated uncertainty.*
>
> *The duration of dewatering is assumed to be 7 months for Area 1, and 2 months for Area 2."*

The estimated duration for installation and removal of the reinforced rockfill berms is approximately 8 weeks for Area 1 and approximately 5 weeks for Area 2.

RECOMMENDATIONS

Based on the results of the evaluation presented in this letter report, we recommend proceeding with preparing a final design using ACB mats to reinforce the rockfill cofferdam.

If you have any questions or need any additional information, please contact John Osterle at 412-535-9823 or john.osterle@wsp.com.

Kind regards,

John P. Osterle, P.E.
Project Manager

JPO:TE:

Enclosure

References

ARMORTEC, February 13, 2020, e-mail correspondence from Barrie King, PE.

Elite Erosion Supply, February 19, 2020, e-mail correspondence from Anamarie Stralla.

FEMA, 2014, “Technical Manual: Overtopping Protection for Dams”, FEMA P-1015.

CONTECH Engineered Solutions, 2020, “Articulating Concrete Block (ACB) System Specifications – Tapered Series Armor Flex, www.contech.com.

Maccaferri, 2017, “Reno Mattress, Galmac & PVC Coated, Technical Data Sheet”.

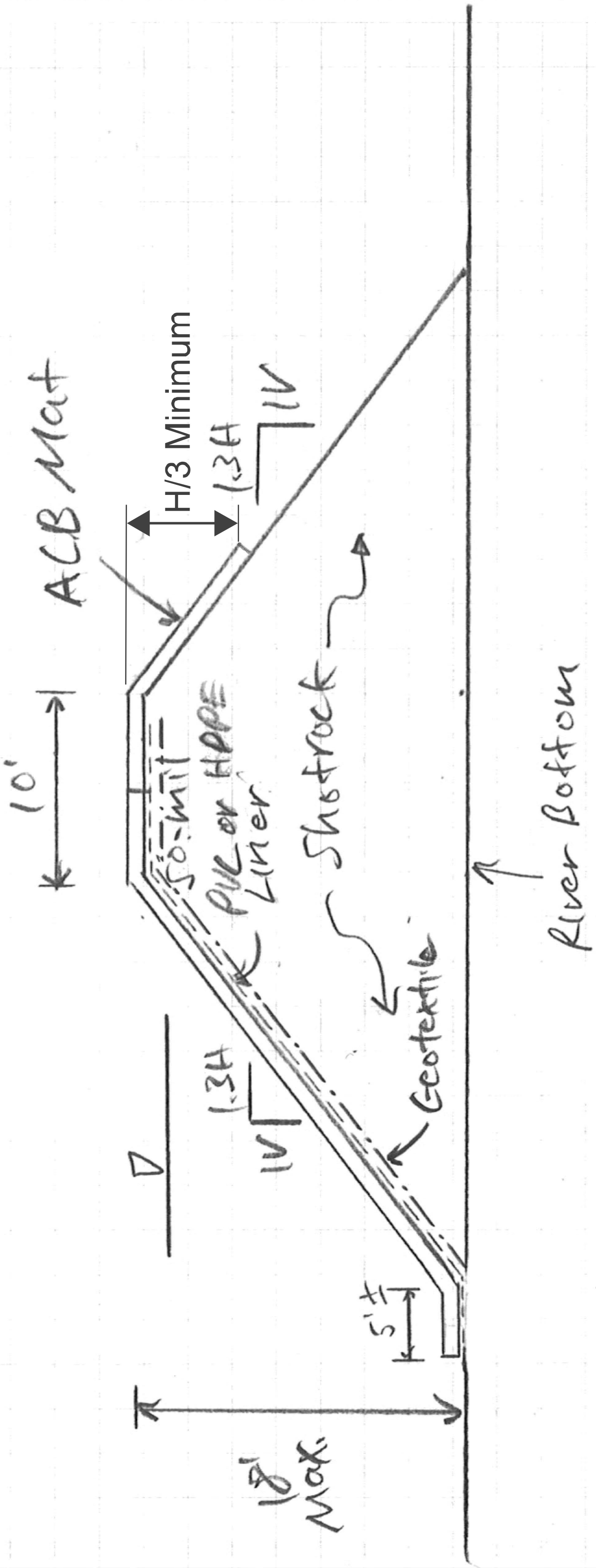
U.S. Bureau of Reclamation, 2018, “Design Standard No. 13, Embankment Dams, Chapter 20: Geomembranes”.

WSP, July 17, 2019, “Cellular Sheetpile Cofferdam Evaluation”, letter report submitted to Apex Companies, LLC.

ENCLOSURE A: ENGINEERING SKETCHES

Sheet No 1 of
Project # 31401700

Project: Congaree River Remediation
Subject: Reinforced Cofferdam
Computed by: JPO — Date: 5/15/2020
Checked by: TE — Date: 5/19/2020



Notes:

1. Provide a structural connection between both ACB mats at the crest of the cofferdam
2. Place shotrock in horizontal layers

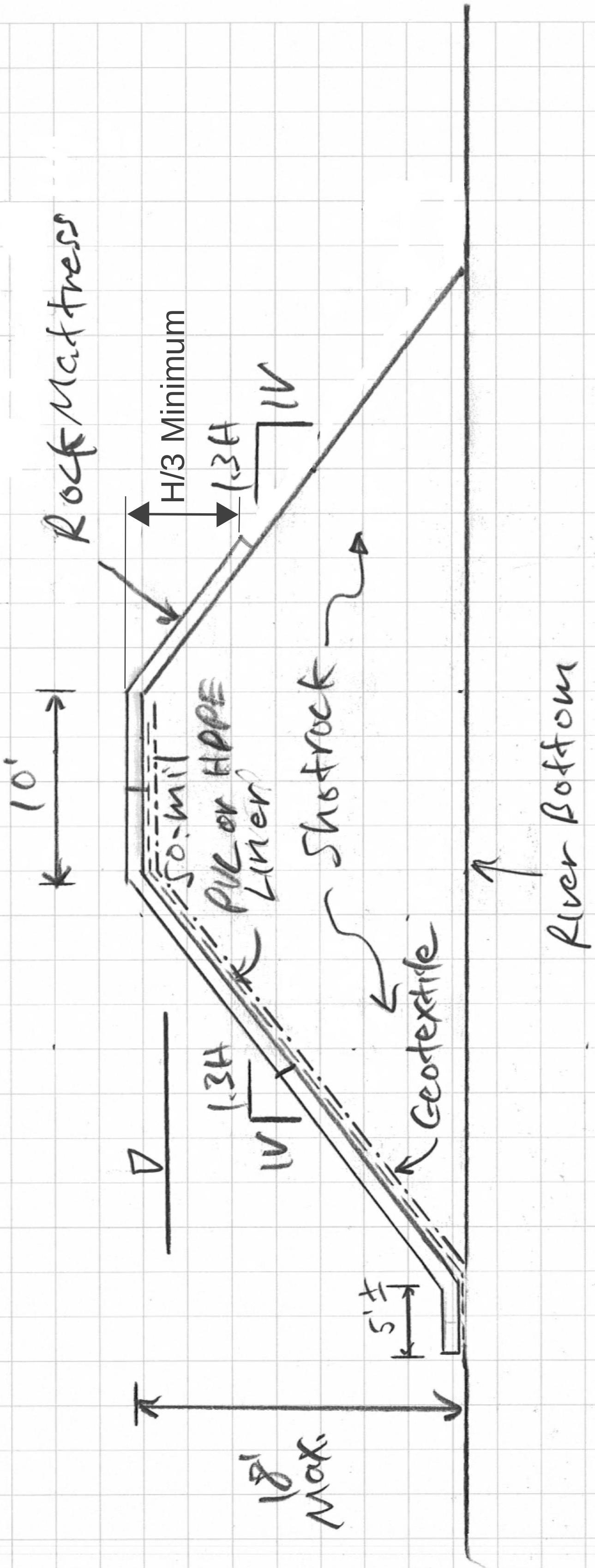
Scale 1" = 16'

wsp

Sheet No 2 of
Project # 31401700

Project: Congaree River Remediation
Subject: Reinforced Cofferdam

Computed by: JPO   Date: 5/15/2020
Checked by: TE   Date: 5/19/2020



Notes:

1. Provide a structural connection between both Rock mats at the crest and along slope of cofferdam
2. Place shotrock in horizontal layers

Scale

1" = 16'

ENCLOSURE B: BUDGETARY LEVEL COST ESTIMATES

CONGAREE RIVER REMEDIATION - ROCKFILL BERM WITH ACBs

Budgetary Cost Estimate

MAY 2020

Orig: JPO 5/15/20

Chk: TE 5/27/20

Item No.	Title	UNIT	QUANTITY	UNIT PRICE	ITEM PRICE
1.0	MOBILIZATION AND DEMOBILIZATION				
1.1	MOBILIZATION AND DEMOBILIZATION (10% of Cost)	LS	1	$405,000	$405,000
	SUB TOTAL 1.0				$405,000
2.0	AREA 1 BERM CONSTRUCTION (1215 FEET)				
2.1	GEOTEXTILE	SY	4,622	$3.50	$16,179
2.2	HDPE LINER	SF	41,602	$2.50	$104,005
2.3	SHOTROCK OR RIPRAP PLACEMENT	CY	16,380	$47.00	$769,860
2.4	DEWATERING	MONTH	7	$10,000	$70,000
2.5	ACBs (ARMORFLEX 45)	SF	62,942	$16.00	$1,007,072
2.6	ACB REMOVAL	SF	62,942	$4.00	$251,768
2.7	ACB DISPOSAL	TON	1,416	$50.00	$70,810
2.8	BERM REMOVAL	CY	16,380	$23.00	$376,740
2.9	OUTLET STRUCTURE	-	-	-	-
2.9.1	CHECK VALVE	EA	1	$6,000	$6,000
2.9.2	HDPE PIPE	FT	80	$125.00	$10,000
2.9.3	CATCH BASIN	EA	1	$2,500	$2,500
2.9.4	COLLARS AND MISC	EA	1	$6,000	$6,000
	SUB TOTAL 2.0				$2,690,933
3.0	AREA 2 BERM CONSTRUCTION (553 FT)				
3.1	GEOTEXTILE	SY	2,417	$3.50	$8,458
3.2	HDPE LINER	SF	21,749	$2.50	$54,373
3.3	SHOTROCK OR RIPRAP PLACEMENT	CY	8,600	$47.00	$404,200
3.4	DEWATERING	MONTH	2	$10,000	$20,000
3.5	ACBs (ARMORFLEX 45)	SF	30,300	$16.00	$484,800
3.6	ACB REMOVAL	SF	30,300	$4.00	$121,200
3.7	ACB DISPOSAL	TON	682	$50.00	$34,088
3.8	BERM REMOVAL	CY	8,600	$23.00	$197,800
3.9	OUTLET STRUCTURE	-	-	-	-
3.9.1	CHECK VALVE	EA	1	$6,000	$6,000
3.9.2	HDPE PIPE	FT	80	$125.00	$10,000
3.9.3	CATCH BASIN	EA	1	$2,500	$2,500
3.9.4	COLLARS AND MISC	EA	1	$6,000	$6,000
	SUB TOTAL 3.0				$1,349,418
	CONTINGENCY (20%)				$889,070
				TOTAL BASE BID PRICE	$5,334,422

CONGAREE RIVER REMEDIATION - ROCKFILL BERM WITH ROCK MATTRESSES

Budgetary Cost Estimate

MAY 2020

Orig: JPO 5/15/20

Chk: TE 5/27/20

Item No.	Title	UNIT	QUANTITY	UNIT PRICE	ITEM PRICE
1.0	MOBILIZATION AND DEMOBILIZATION				
1.1	MOBILIZATION AND DEMOBILIZATION (10% of Cost)	LS	1	$368,000	$368,000
	SUB TOTAL 1.0				$368,000
2.0	AREA 1 BERM CONSTRUCTION (1215 FT)				
2.1	GEOTEXTILE	SY	4,622	$3.50	$16,179
2.2	HDPE LINER	SF	41,602	$2.50	$104,005
2.3	SHOTROCK OR RIPRAP PLACEMENT	CY	16,380	$47.00	$769,860
2.4	DEWATERING	MONTH	7	$10,000	$70,000
2.5	ROCK MATTRESS (6" RENO)	SF	62,942	$12.00	$755,304
2.6	ROCK MATTRESS REMOVAL	SF	62,942	$4.00	$251,768
2.7	ROCK MATTRESS DISPOSAL	TON	1,574	$50.00	$78,678
2.8	BERM REMOVAL	CY	16,380	$23.00	$376,740
2.9	OUTLET STRUCTURE	-	-	-	-
2.9.1	CHECK VALVE	EA	1	$6,000	$6,000
2.9.2	HDPE PIPE	FT	80	$125.00	$10,000
2.9.3	CATCH BASIN	EA	1	$2,500	$2,500
2.9.4	COLLARS AND MISC	EA	1	$6,000	$6,000
	SUB TOTAL 2.0				$2,447,033
3.0	AREA 2 BERM CONSTRUCTION (553 FT)				
3.1	GEOTEXTILE	SY	2,417	$3.50	$8,458
3.2	HDPE LINER	SF	21,749	$2.50	$54,373
3.3	SHOTROCK OR RIPRAP PLACEMENT	CY	8,600	$47.00	$404,200
3.4	DEWATERING	MONTH	2	$10,000	$20,000
3.5	ROCK MATTRESS (6" RENO)	SF	30,300	$12.00	$363,600
3.6	ROCK MATTRESS REMOVAL	SF	30,300	$4.00	$121,200
3.7	ROCK MATTRESS DISPOSAL	TON	758	$50.00	$37,875
3.8	BERM REMOVAL	CY	8,600	$23.00	$197,800
3.9	OUTLET STRUCTURE	-	-	-	-
3.9.1	CHECK VALVE	EA	1	$6,000	$6,000
3.9.2	HDPE PIPE	FT	80	$125.00	$10,000
3.9.3	CATCH BASIN	EA	1	$2,500	$2,500
3.9.4	COLLARS AND MISC	EA	1	$6,000	$6,000
	SUB TOTAL 3.0				$1,232,005
	CONTINGENCY (20%)				$809,408
				TOTAL BASE BID PRICE	$4,856,446

July 9, 2020

Mr. Paul Biery
Senior Project Manager
Dominion Energy South Carolina
400 Otarre Parkway
Cayce, SC 29033

RE: Rockfill Cofferdam Slope Stability Analysis Memo
SCE&G Fleet Maintenance Site (Congaree River)
Columbia, South Carolina

Dear Mr. Biery,

The State Voluntary Cleanup Program has reviewed the Rockfill Cofferdam Slope Stability Analysis Memo received by the Department on July 2nd, 2020. The Department approves of the submittal and the conclusions made in the report.

If you have any questions or comments please contact me at (803) 898-0747 or cassidga@dhec.sc.gov.

Sincerely,

Greg Cassidy
State Voluntary Cleanup Program
Bureau of Land and Waste Management

cc: File 52561
Lucas Berresford, BLWM
Veronica Barringer, Midlands EA Region
Al Peeples, Midlands EA Region

S.C. Department of Health and Environmental Control
2600 Bull Street, Columbia, SC 29201 (803) 898-3432 www.scdhec.gov

Statement of Purpose

This calculation has been prepared to analyze the stability of the proposed rockfill cofferdams to be constructed in Area 1 and Area 2 of the Congaree River as shown on Figure 1. This analysis is required to evaluate the stability of the critical sections of the cofferdam for flood loading conditions.

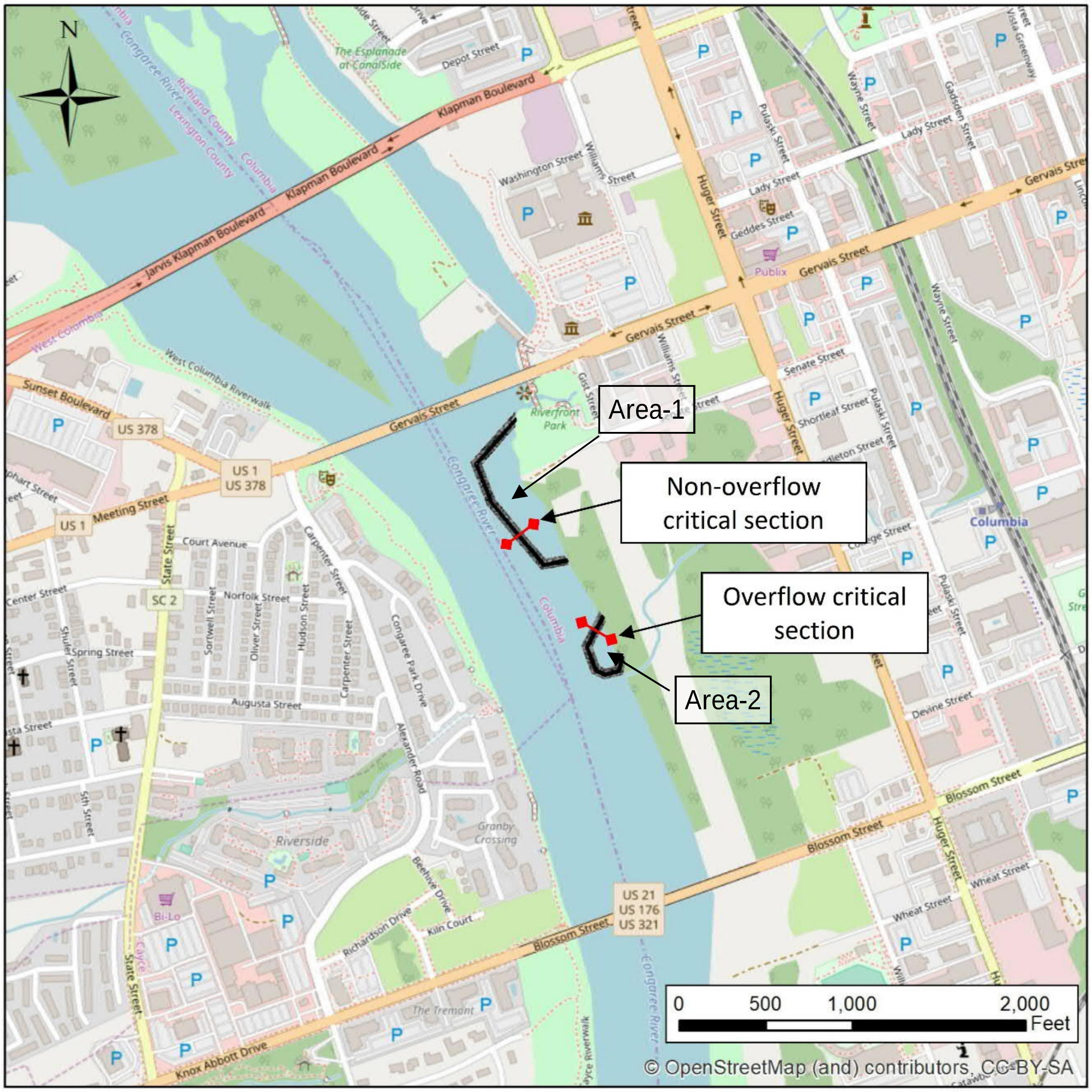


Figure 1: Plan View of Proposed Cofferdams

Approach

The slope stability of the proposed rockfill cofferdam was performed using the SLOPE/W computer program to evaluate the critical failure surfaces. The SLOPE/W software program is part of the GeoStudio software package and is produced by GEO-SLOPE International, Ltd. This program is a two-dimensional, limit equilibrium slope stability program which can model heterogeneous soil types, complex stratigraphic and slip Surface geometries, and variable pore-water pressure conditions using a wide range of soil models. The Spencer method was used to evaluate the slope stability of the proposed cofferdam.

The Spencer method is derived from the method of slices on the basis of limit equilibrium. It requires satisfying the equilibrium of forces and moments acting on individual slices. This method has been shown to be conservative and provide relatively accurate results.

The slope stability analysis was performed for flood loading conditions where the water level is assumed to be at the crest of the overflow structure of the Cofferdam. Section 3.2 of USACE EM-1110-2-1902 (Reference 1) states that stability computations must be performed when the consequences of the failure of a cofferdam, which is a temporary structure, is serious. A failure of the cofferdam during river remediation would introduce safety risks including equipment damage so a slope stability analysis is warranted and is good engineering practice. We have used a minimum required factor of safety of 1.3 (Reference 1, Table 3-1) since the cofferdam is a temporary structure that will only be used during construction activities (i.e., removing the contaminated sediment from the Congaree River). The analysis conditions and associated required minimum factors of safety are presented in Table 1.

Table 1: Load Cases Considered in Slope Stability Analysis

Analysis Condition	Analyzed Slope	Required Factor of Safety
Water Level at EL 123.5 (Crest of Overflow Structure)	Outboard (wet)	1.3
Water Level at EL 123.5 (Crest of Overflow Structure)	Inboard (dry)	1.3

The slip surface for the inboard (dry) and outboard (wet) sides of the cofferdam was considered as a “circular” slip surface by checking the option to optimize the critical slip surface location in SLOPE/W. This type of slip surface is where the moment equilibrium is completely independent of the interslice shear forces. The interslice shear force can be assumed zero and still retain the ability for an acceptable factor of safety. (Reference 1).

An additional case was also considered for areas where significant sediment thickness (greater than 1 foot) is present on the river bottom beneath the cofferdam. A “circular” slip surface on the inboard slope was analyzed for this case with three different excavation scenarios behind the cofferdam.

Assumptions and Justification

1. The minimum depth of failure surfaces of interest are 3 feet from the top of the slope.
2. The material properties for the materials used to construct the proposed cofferdam are based on typical values for rockfill. The material properties are presented in Table 2.
3. The rockfill is assumed to be cohesionless and free draining.
4. Any water leaking through the HDPE liner is assumed to flow through the rockfill into a sump where it will be removed from the work area.

5. Phreatic surface assumed to have an initial height of H/4 from the foundation material, where H is the total height of the slope. The phreatic surface is assumed to build up after water flows through leaks in the liner.

6. Typical Cofferdam and Overtopping sections constructed on bedrock. Typical Full Articulated Concrete Block (ACB) Coverage section is constructed on a layer of river sediment. Bathymetric and sediment surveys show the maximum depth of sediment along the inboard toe of slope is 5.5 feet. 1 foot of settlement is assumed during placement of the shot rock, giving a revised sediment thickness of 4.5 feet for this analysis.

7. For the Reinforced Rockfill analysis, the Articulated Concrete Block (ACB) Mats extend to the toe of the cofferdam and onto the river bottom at the inboard/outboard sides for the typical overtopping section and the full ACB coverage section. Our slope stability model for these cases assumes that the mats terminate 2 feet above the bottom of the cofferdam. This prevents overestimating the shear resistance at the base of the cofferdam at the outboard side. In reality, the toe of the slope will move laterally if the driving forces exceed the frictional resistance from the ACB Mat/river bottom interface. This is not an issue for the typical cofferdam section, where the ACB Mats extend from the outboard toe of slope, up the outboard slope, across the crest and terminate one-quarter of the distance down the inboard slope.

Model Geometry

The locations of the critical cofferdam cross-sections are shown on Figure 1. The analysis of the proposed cofferdam was performed for the typical section shown on Figure 2, the typical overtopping section shown on Figure 3, and the full ACB coverage section shown on Figure 4.

The sections all have a 50-mil HDPE liner modeled between the shot rock and the planned 4-inch thick (ACB) on the outboard slope and crest. However, as discussed in the Assumptions and Justification section, the ACB mat was terminated 2 feet from the bottom of the cofferdam in the Slope/W model for the typical sections.

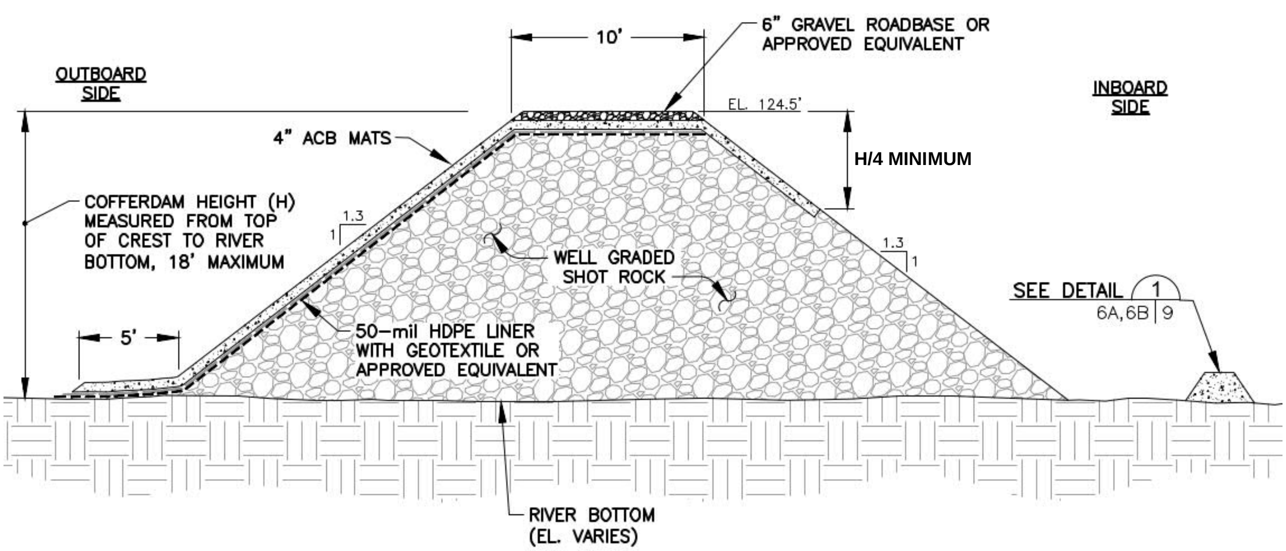


Figure 2: Typical Cofferdam Section

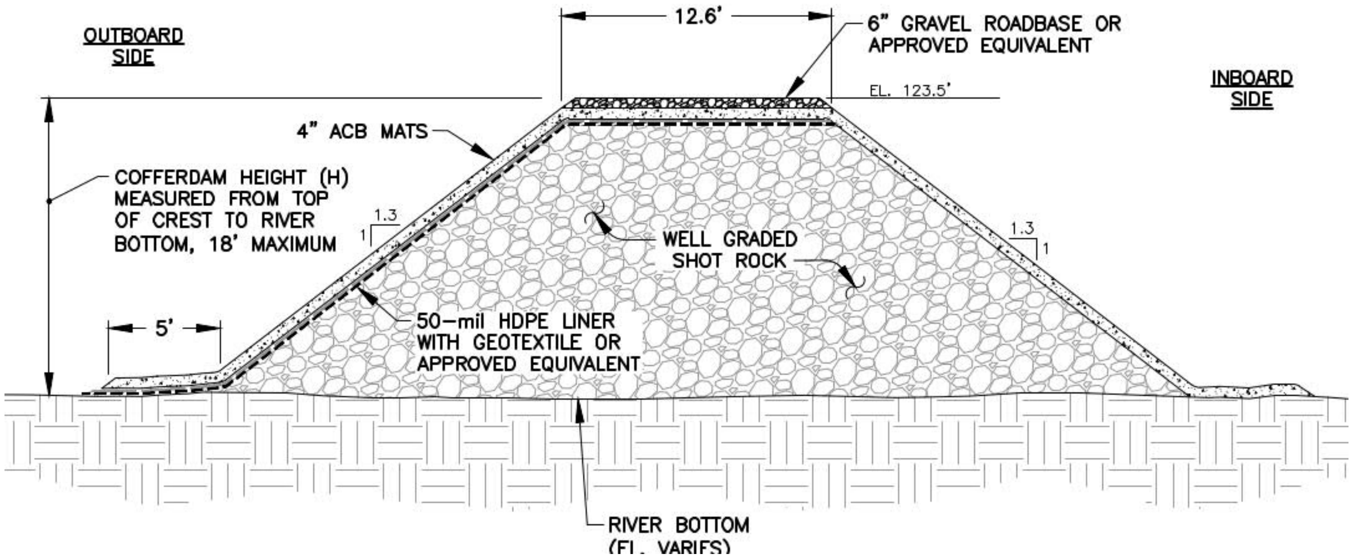


Figure 3: Typical Overflow Section

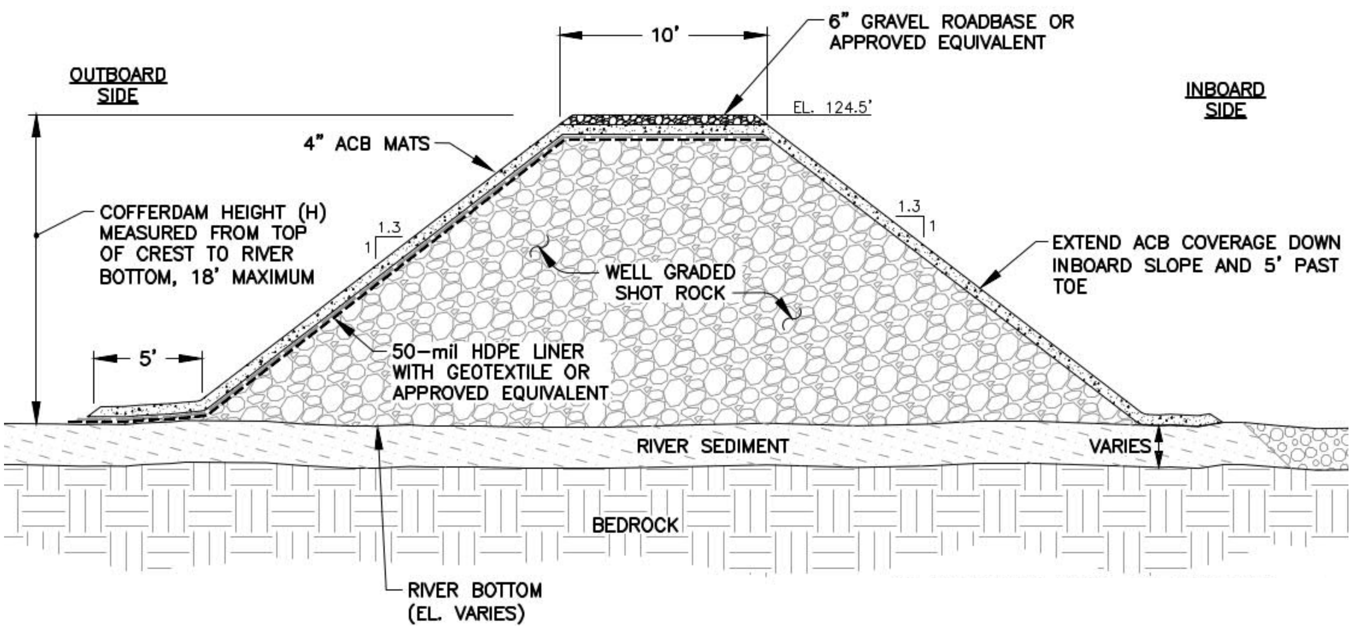


Figure 4: Full ACB Coverage Cofferdam Section

Material Properties

The unit weights, effective friction angles, and cohesion values of the various geotechnical materials are estimated based on standard properties used in the industry. The materials were assumed to be cohesionless and free draining (i.e., less than five percent of fine-grained materials in the rockfill). River sediment properties were based on the materials encountered during the sub-surface investigation.

Five materials are designated for specific regions within the cofferdam for this analysis — shot rock, native foundation rock, HDPE liner, ACB material, and river sediment.

Saturated unit weights are conservatively used in the model for the total unit weight. The model uses total unit weights in all locations and computes effective stresses based on stress calculations rather than unit weights.

The shear strength of the ACB material was estimated using an equivalent cohesion value. To determine the equivalent cohesion, shear capacity of the concrete material was calculated based on the ACI 318 (Eq. 22.8). The steel strands of the ACB elements were ignored in this analysis, conservatively. The unit weight for the ACB material was determined based off product information provided by contractors. Full calculations for ACB material properties can be referenced in Appendix B.

The estimated material properties used in the analysis are presented in Table 2.

Table 2: Material Properties Used in Slope Stability Analysis

Material	Unit Weight	Effective Friction Angle	Cohesion
	γ_{tot}	ϕ'	c
	(pcf)	(degrees)	(psf)
Shot Rock	150	45	0
HDPE Liner	150	30	0
Articulated Concrete Block (ACB)	114	0	5,000
Bedrock (Impenetrable)	-	-	-
River Sediment (silty sand)	110	30	0

Phreatic Surface and Pore Water Pressure

The slope stability analysis for the proposed cofferdam was performed with the water surface at the crest of the overflow section for the upstream side, which corresponds to El. 123.5'.

The phreatic surface is assumed to begin at height of H/4 (where H is the total height of the cofferdam) from the foundation materials. The phreatic surface is assumed to build up after water flows through leaks in the liner.

Results

The computed factors of safety of the critical cofferdam and overflow sections for flood loading conditions are summarized in Table 3. Results are presented for an unreinforced cofferdam, reinforced cofferdam, and for a reinforced cofferdam with limited (i.e., H/4) coverage along the inboard slope. Table 4 presents the results for the reinforced cofferdam with a 4.5 feet thick sediment layer on the river bottom beneath the cofferdam.

Table 3: Factors of Safety for Typical Sections

Section	Slip Surface	Analyzed Slope	Required Factor of Safety	Unreinforced Cofferdam FS	Reinforced FS	Reinforced FS (limited inboard coverage)
Typical	Circular	Outboard (wet)	1.3	1.5	2.6	N/A
Typical	Circular	Inboard (dry)	1.3	1.3	1.6	1.6
Overflow	Circular	Outboard (wet)	1.3	1.4	2.4	N/A
Overflow	Circular	Inboard (dry)	1.3	1.4	1.7	1.5

Table 4: Factors of Safety for Sediment Case

Section	Slip Surface	Analyzed Slope	Excavation Scenario	Required Factor of Safety	Reinforced FS
Full ACB Coverage	Circular	Inboard (dry)	Excavation starts 10 feet from toe of inboard slope	1.3	1.6
Full ACB Coverage	Circular	Inboard (dry)	Excavation starts 5 feet from toe of inboard slope	1.3	1.5
Full ACB Coverage	Circular	Inboard (dry)	Excavation starts 5 feet from toe of inboard slope; material is replaced with shot rock	1.3	1.7

Conclusion/Summary

The results from the slope stability analysis performed for the rockfill cofferdam as shown on Figures 2, 3, and 4 indicate that the upstream and downstream slopes meet the required factors of safety during flood loading conditions (water level at EL 123.5, crest of overflow structure). No additional analyses are required if the cofferdam is constructed as indicated and the design of the cofferdam is considered suitable for the conditions analyzed.

Key assumptions pertaining to the design of the cofferdam and validity of this analysis include:

- Rockfill is free draining and contains less than 5 percent of fine-grained materials (i.e., less than the No. 200 sieve).
- ACB mats cover the cofferdam as shown on Figures 2, 3, and 4, i.e., extend to at least H/4 along the inboard slope (where H is the height of the cofferdam measured from the crest to the inboard toe).
- The rockfill consist of angular crusher run material suitable for marine applications.
- The rockfill complies with SCDOT specifications for suitable rockfill.
- The maximum depth of sediment along the inboard toe of slope is 5.5 feet. 1 foot of settlement is assumed during placement of the shot rock, giving a revised sediment thickness of 4.5 feet for this analysis.

References

1. United States, Department of the Army, Army Corps of Engineers. Slope Stability. Washington, D.C.: USACE, October 2003. EM 1110-2-1902.

2. GEO-SLOPE International, Ltd. Stability Modeling with SLOPE/W 2007 Version. An Engineering Methodology. ed. Calgary, Alberta, CA: GEO-SLOPE International.

APPENDICES

Appendix A: SLOPE/W Output

Figure A1: Typical Section (Unreinforced); Model Configuration

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section 2-14-2020 unrein
Date: 04/03/2020
Kind: SLOPE/W
Method: Spencer

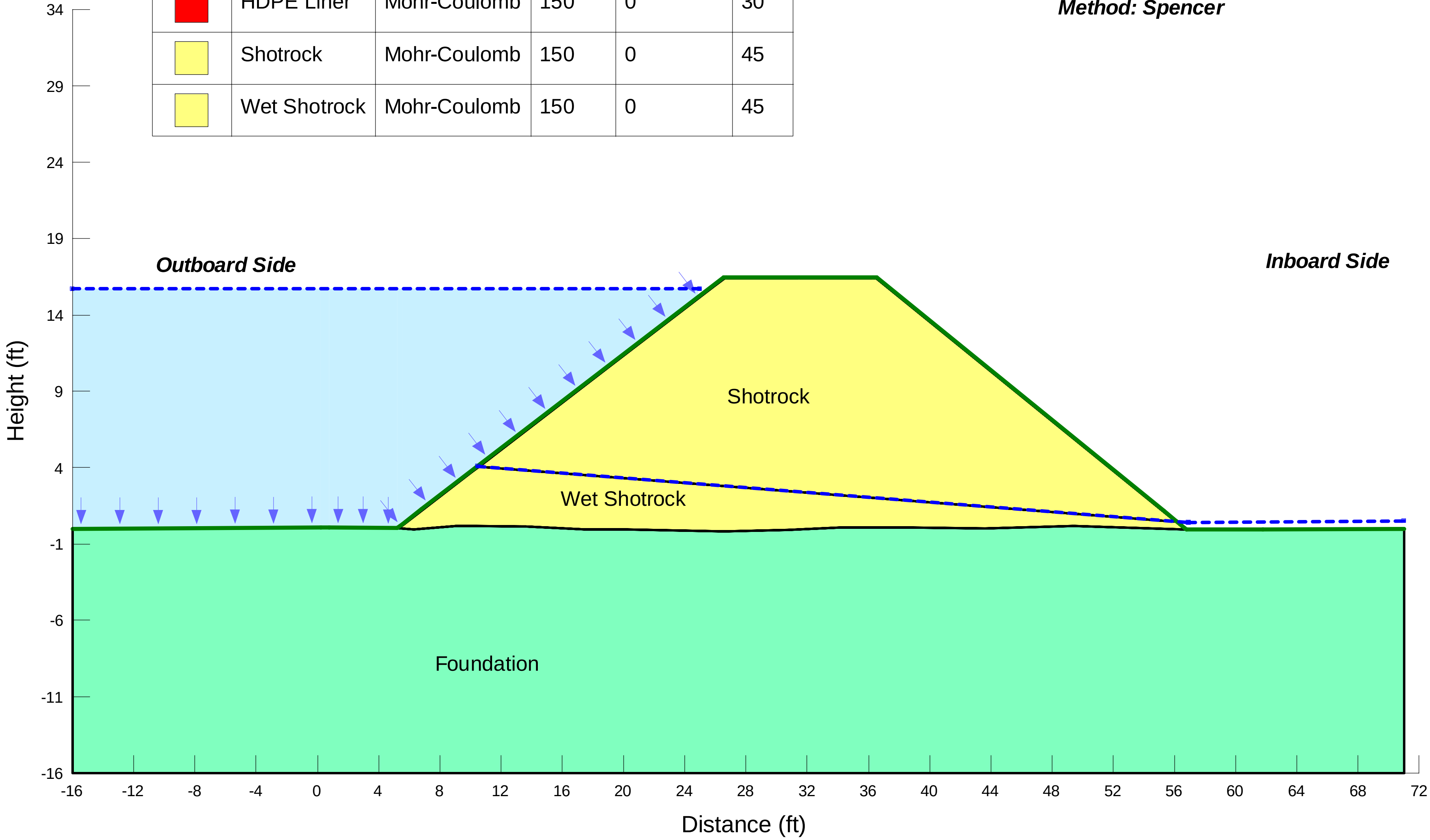


Figure A2: Typical Section (Unreinforced); Outboard Slope Failure Result

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section 2-14-2020 unreinforced.gsz
Date: 04/03/2020
Kind: SLOPE/W
Method: Spencer

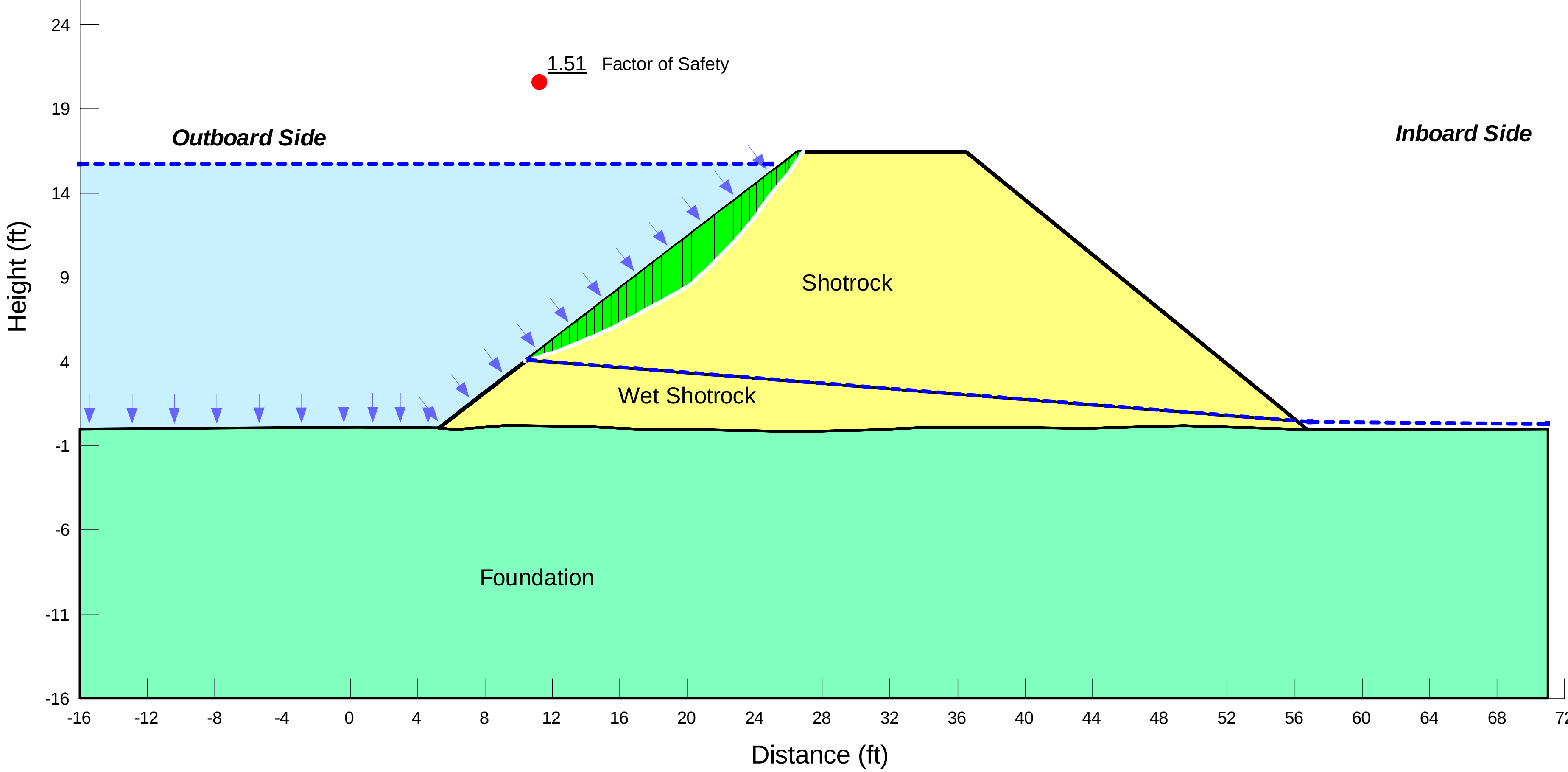


Figure A3: Typical Section (Unreinforced); Inboard Slope Failure Result

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

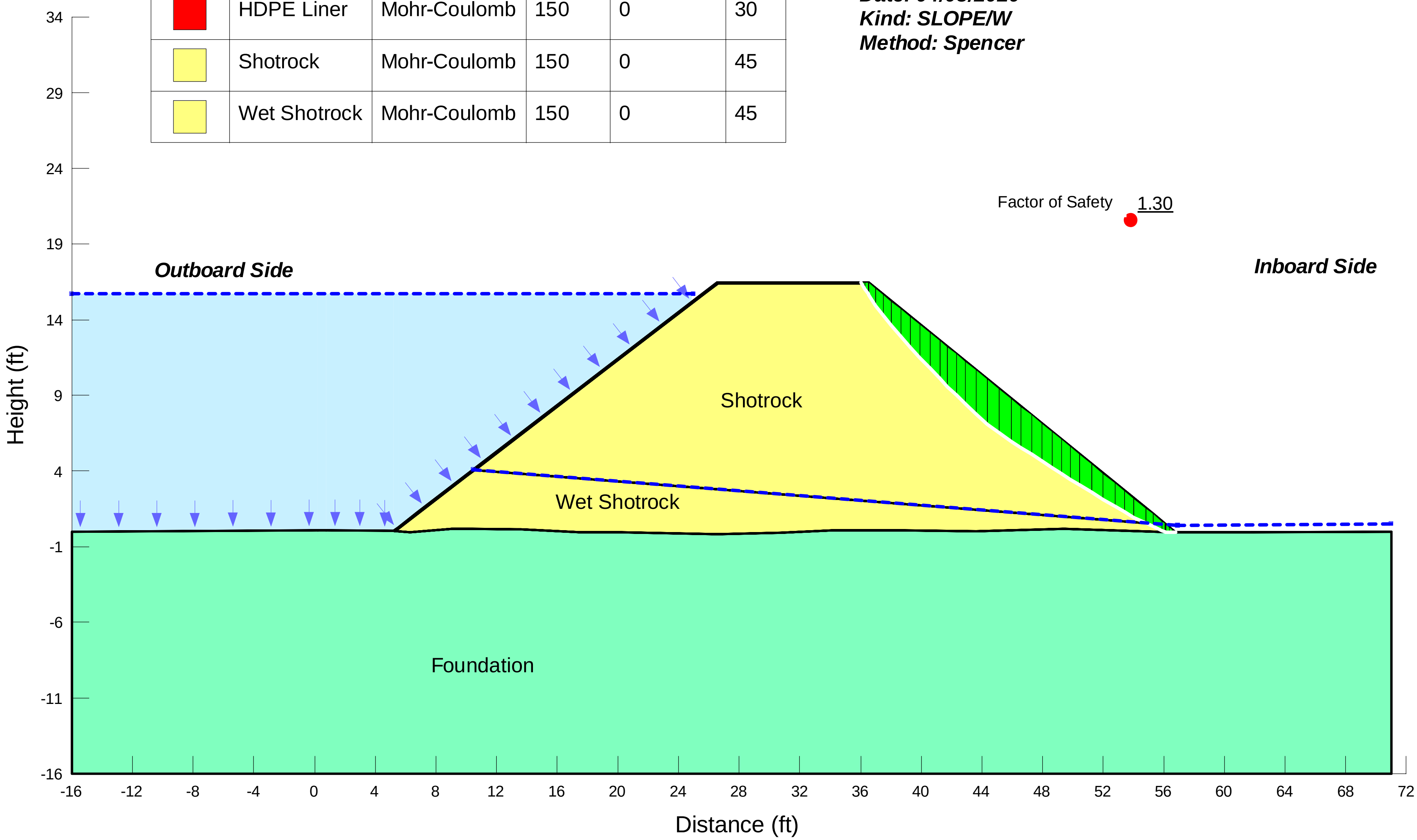
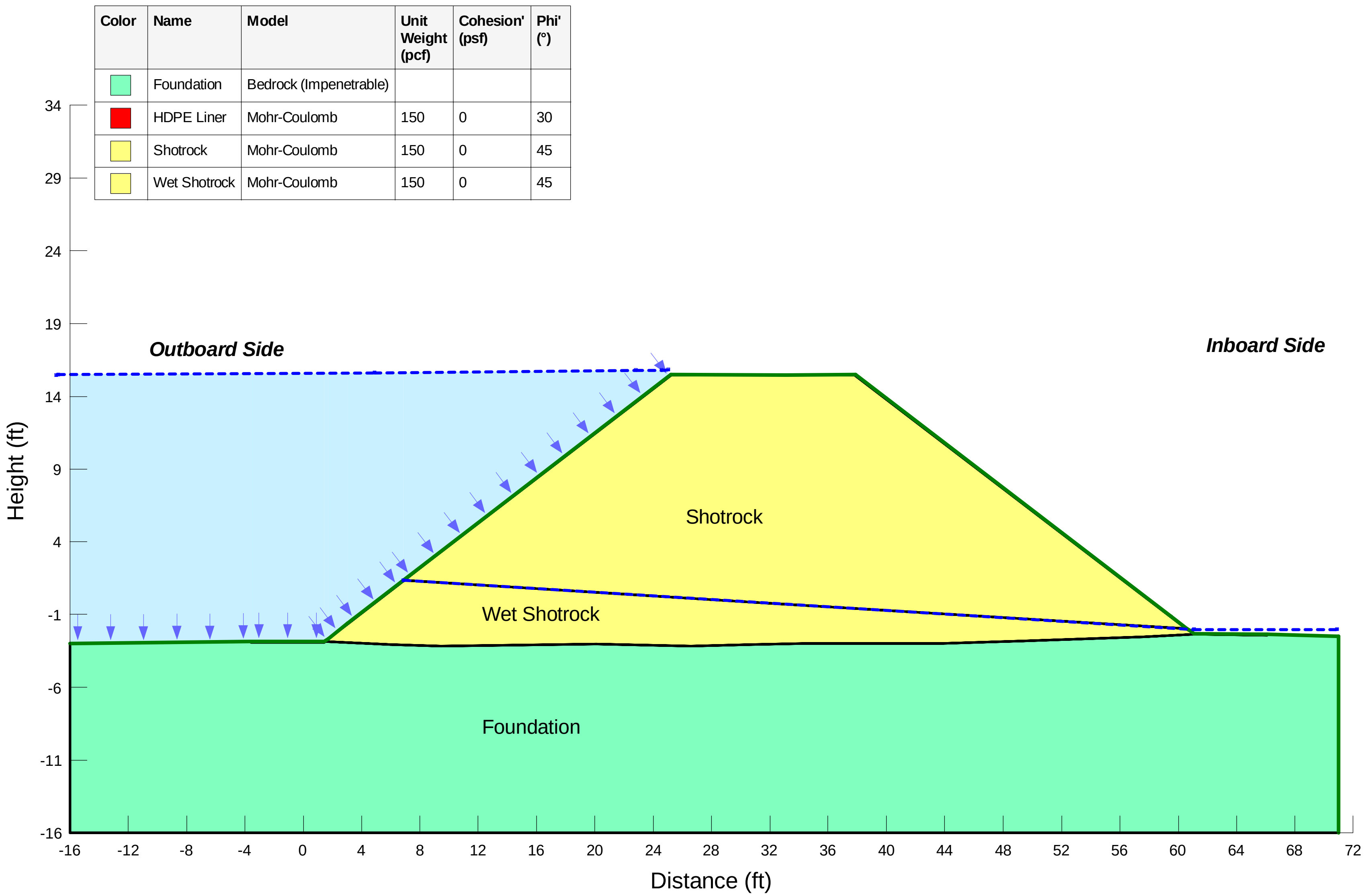


Figure A4: Overflow Section (Unreinforced); Model Configuration

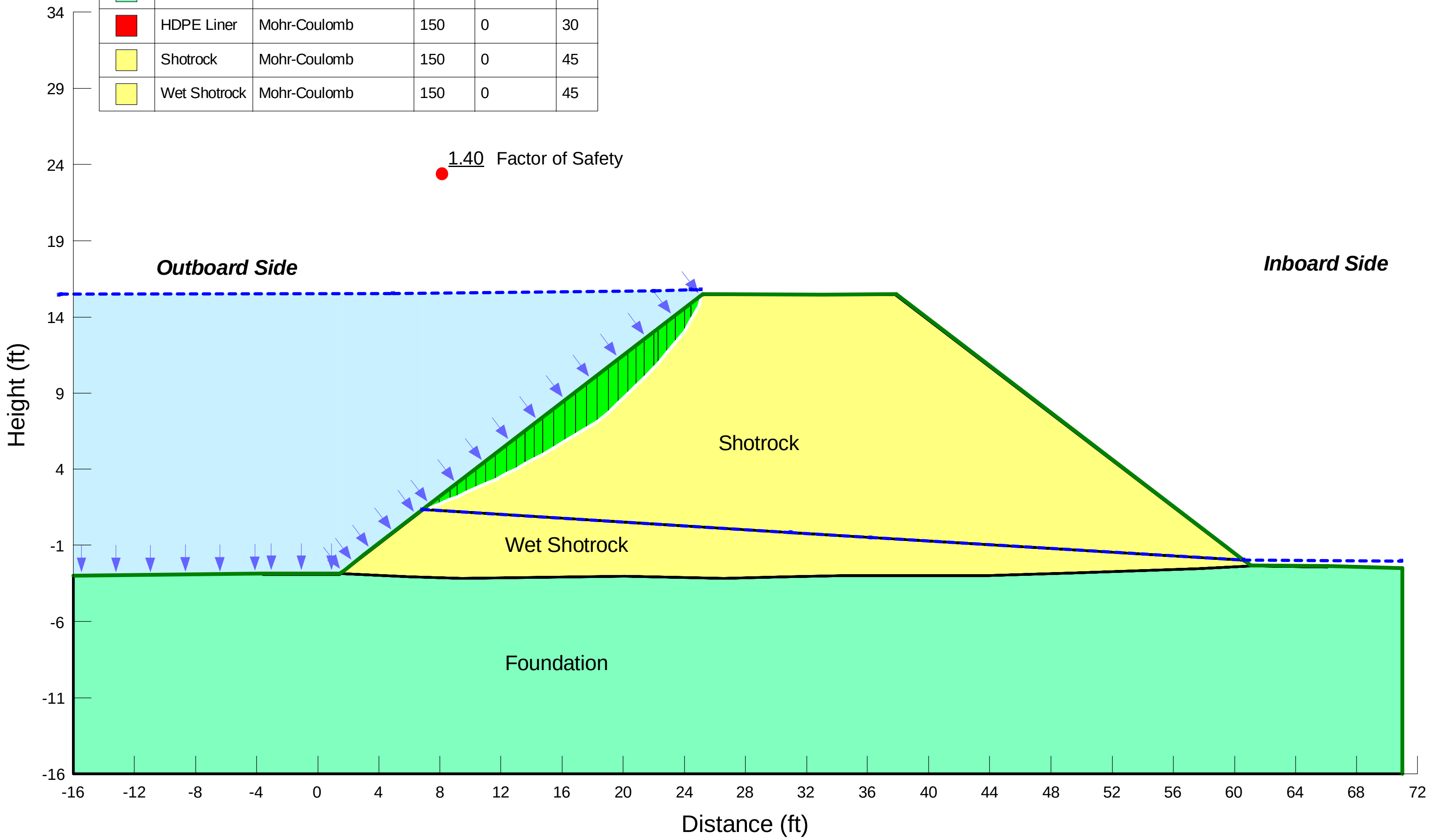


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Overflow Section 2-14-2020 unreinforced.gsz
Date: 04/03/2020
Kind: SLOPE/W
Method: Spencer

Figure A5: Overflow Section (Unreinforced); Outboard Slope Failure Result

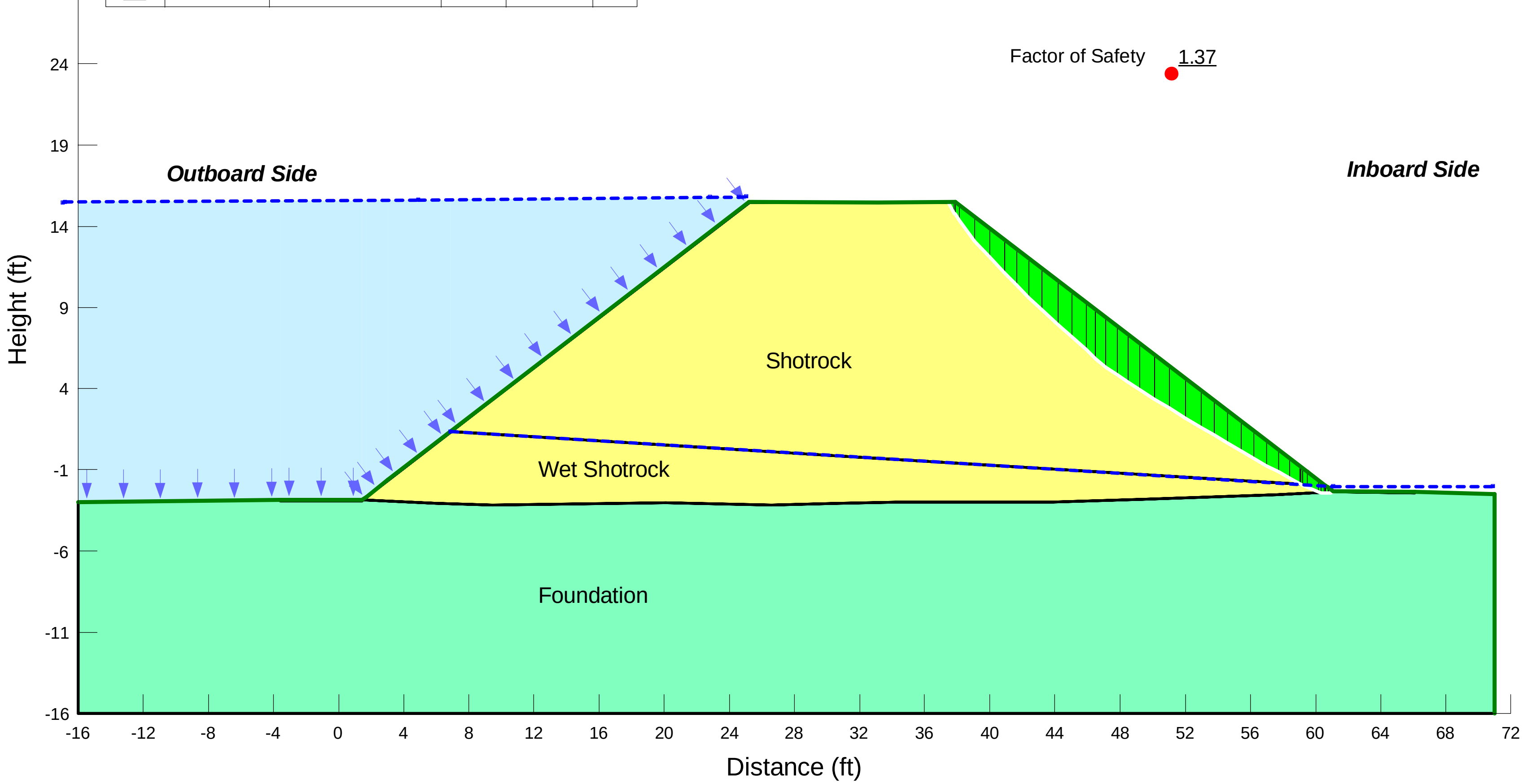
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45



Max Overflow Section 2-14-2020 unreinforced.gsz
Date: 04/03/2020
Kind: SLOPE/W
Method: Spencer

Figure A6: Overflow Section (Unreinforced); Inboard Slope Failure Result

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45



Max Overflow Section 2-14-2020 unreinforced.gsz
Date: 04/03/2020
Kind: SLOPE/W
Method: Spencer

Figure A7: Typical Section (Reinforced); Model Configuration

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section 2-14-2020.gsz
Date: 02/21/2020
Kind: SLOPE/W
Method: Spencer

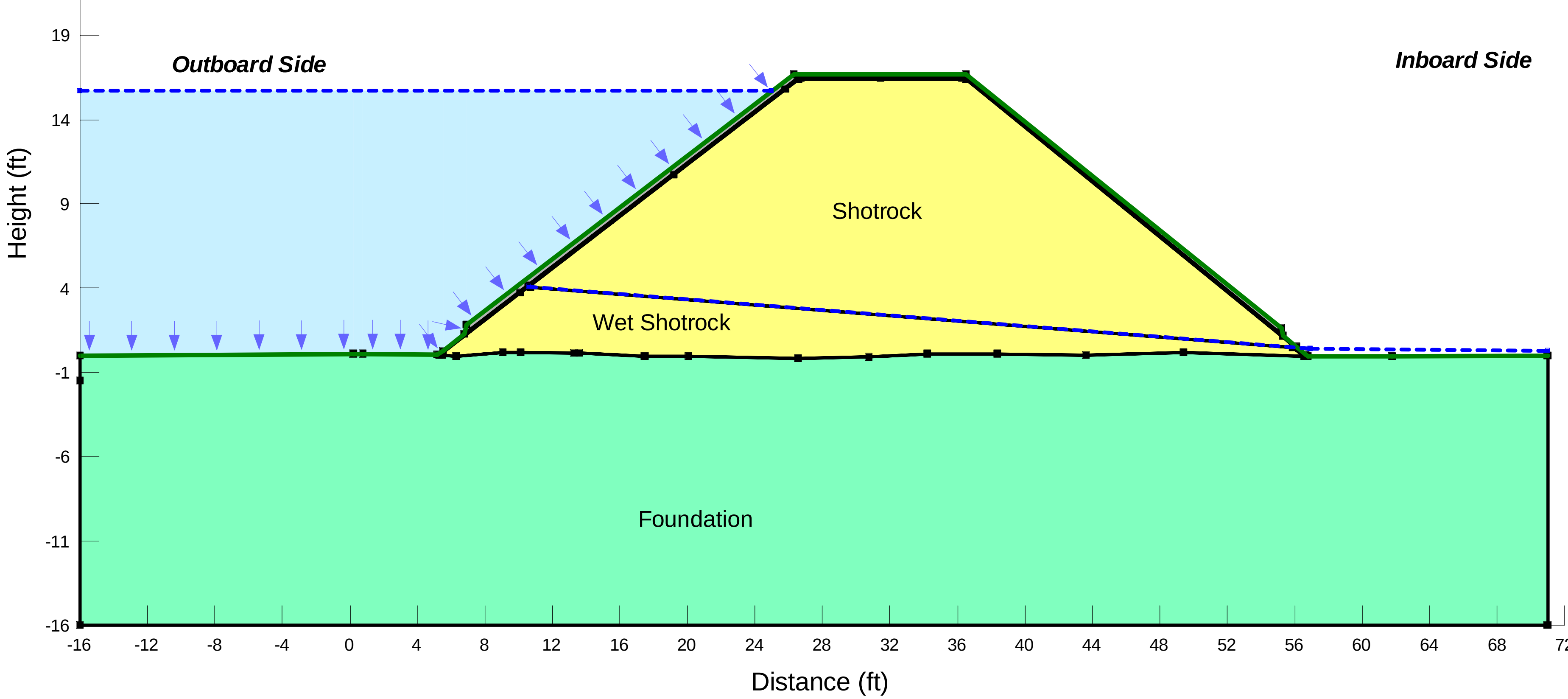


Figure A8: Typical Section (Reinforced); Outboard Slope Failure Result

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section 2-14-2020.gsz
Date: 02/21/2020
Kind: SLOPE/W
Method: Spencer

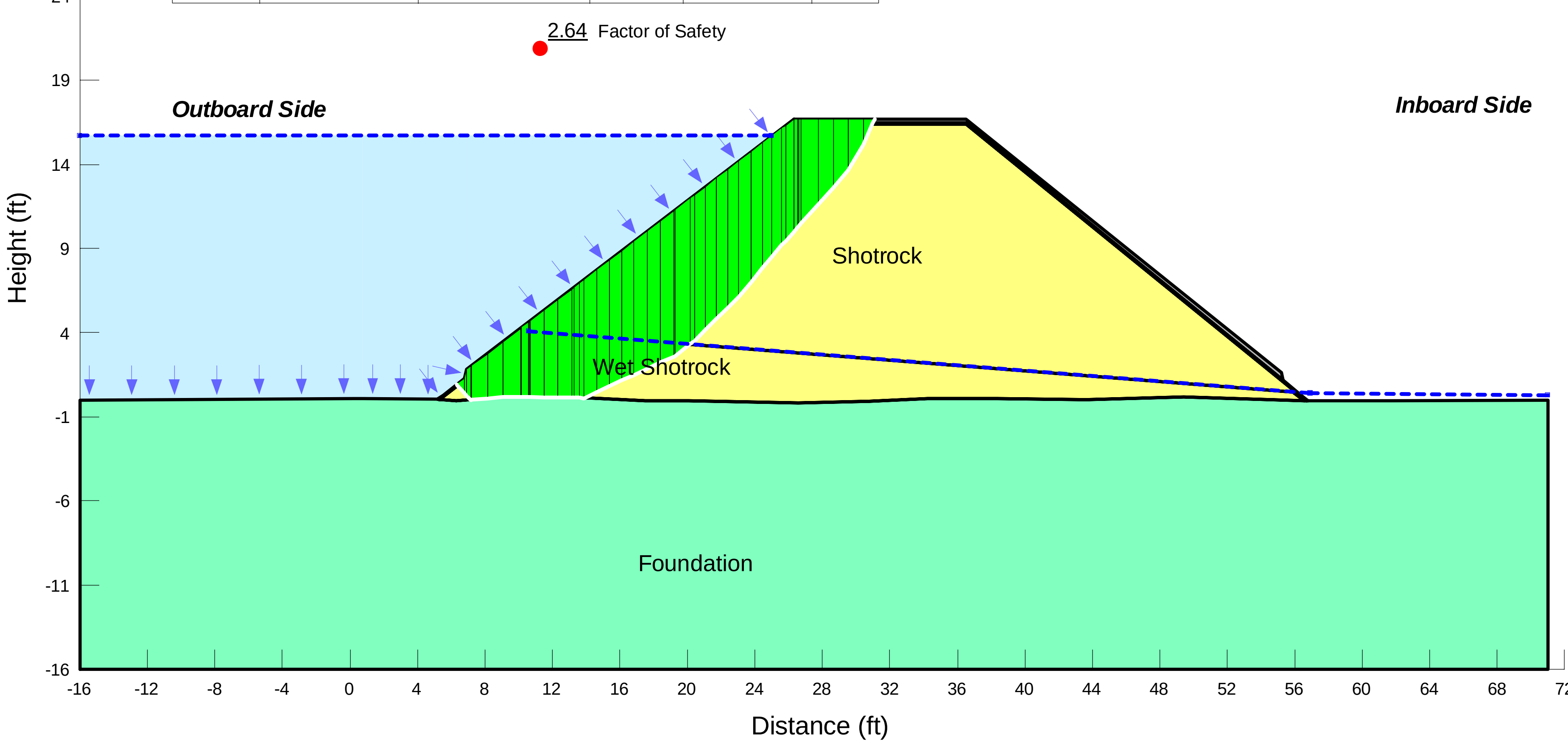


Figure A9: Typical Section (Reinforced); Inboard Slope Failure Result

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section 2-14-2020.gsz
Date: 02/21/2020
Kind: SLOPE/W
Method: Spencer

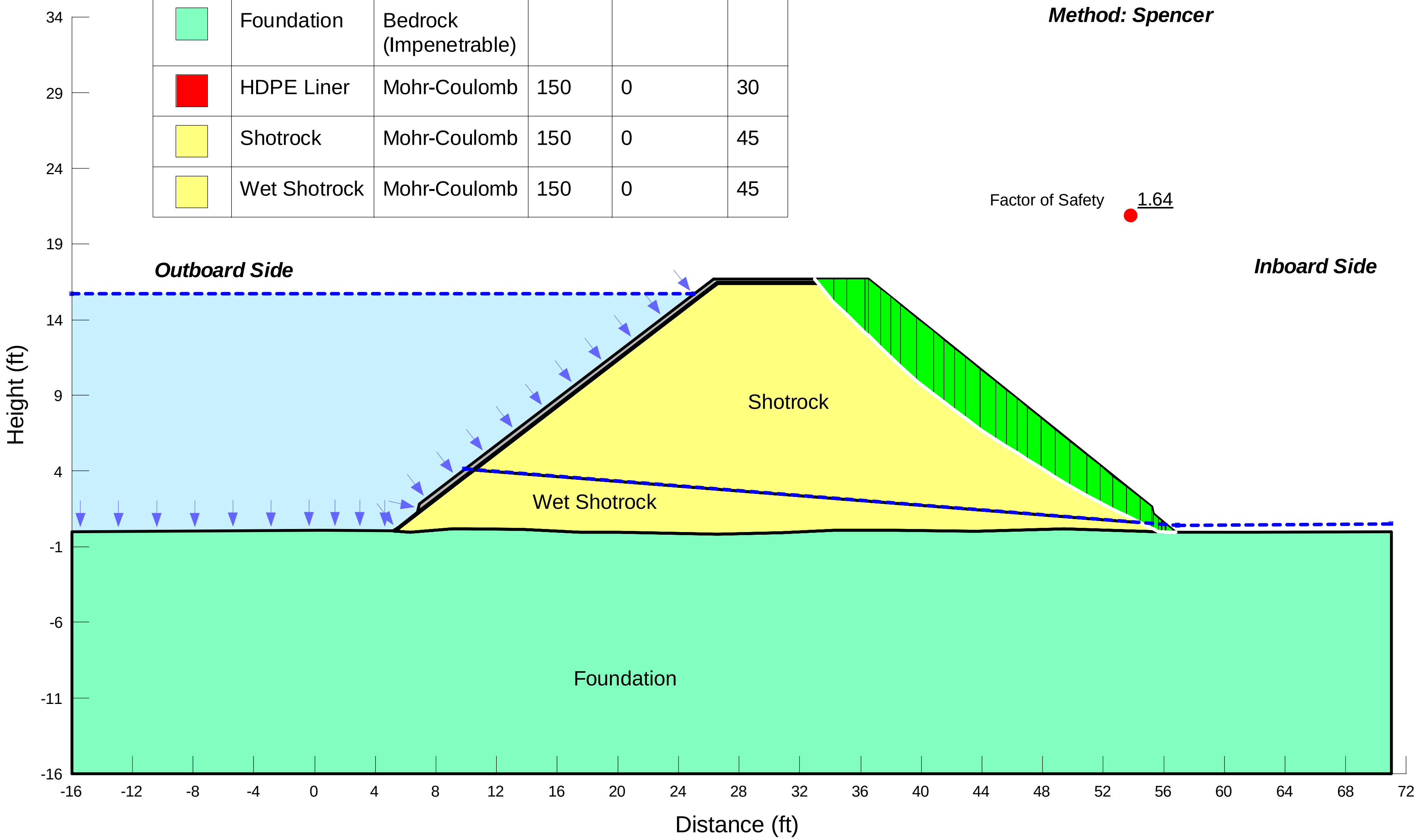
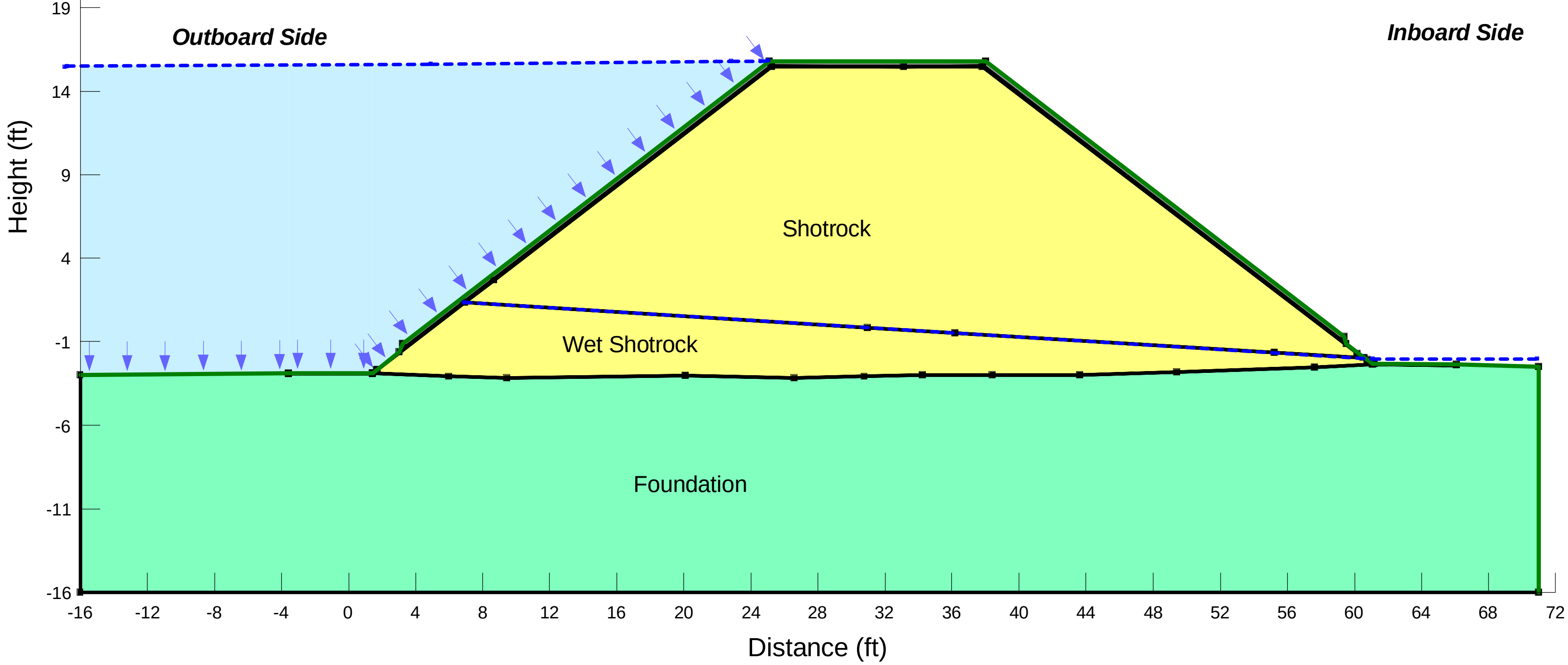


Figure A10: Overflow Section (Reinforced); Model Configuration

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB (Articulated Concrete Block)	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

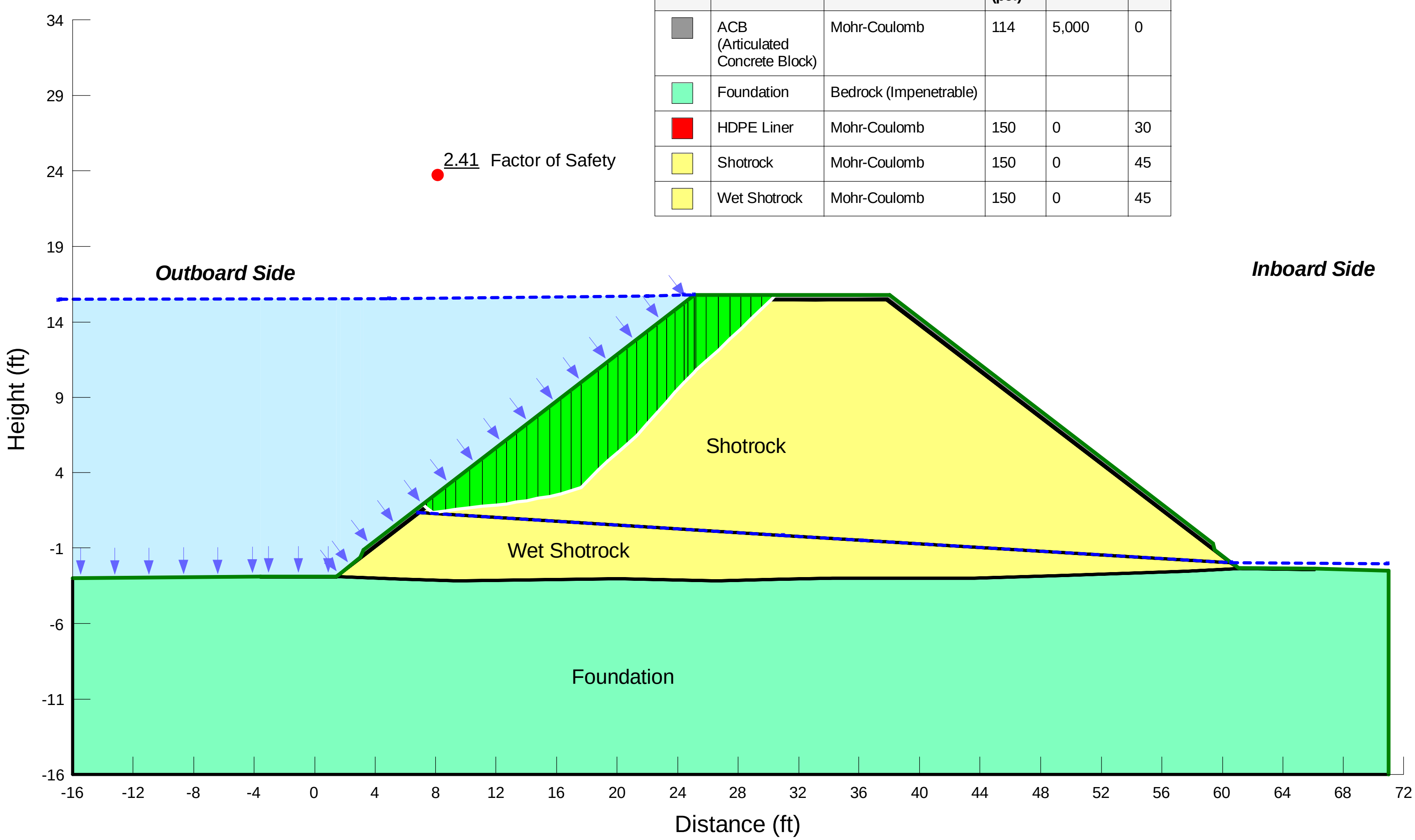


Max Overflow Section 2-14-2020.gsz
Date: 02/21/2020
Kind: SLOPE/W
Method: Spencer

Scale: 1:127.18208

Figure A11: Overflow Section (Reinforced); Outboard Slope Failure Result

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB (Articulated Concrete Block)	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

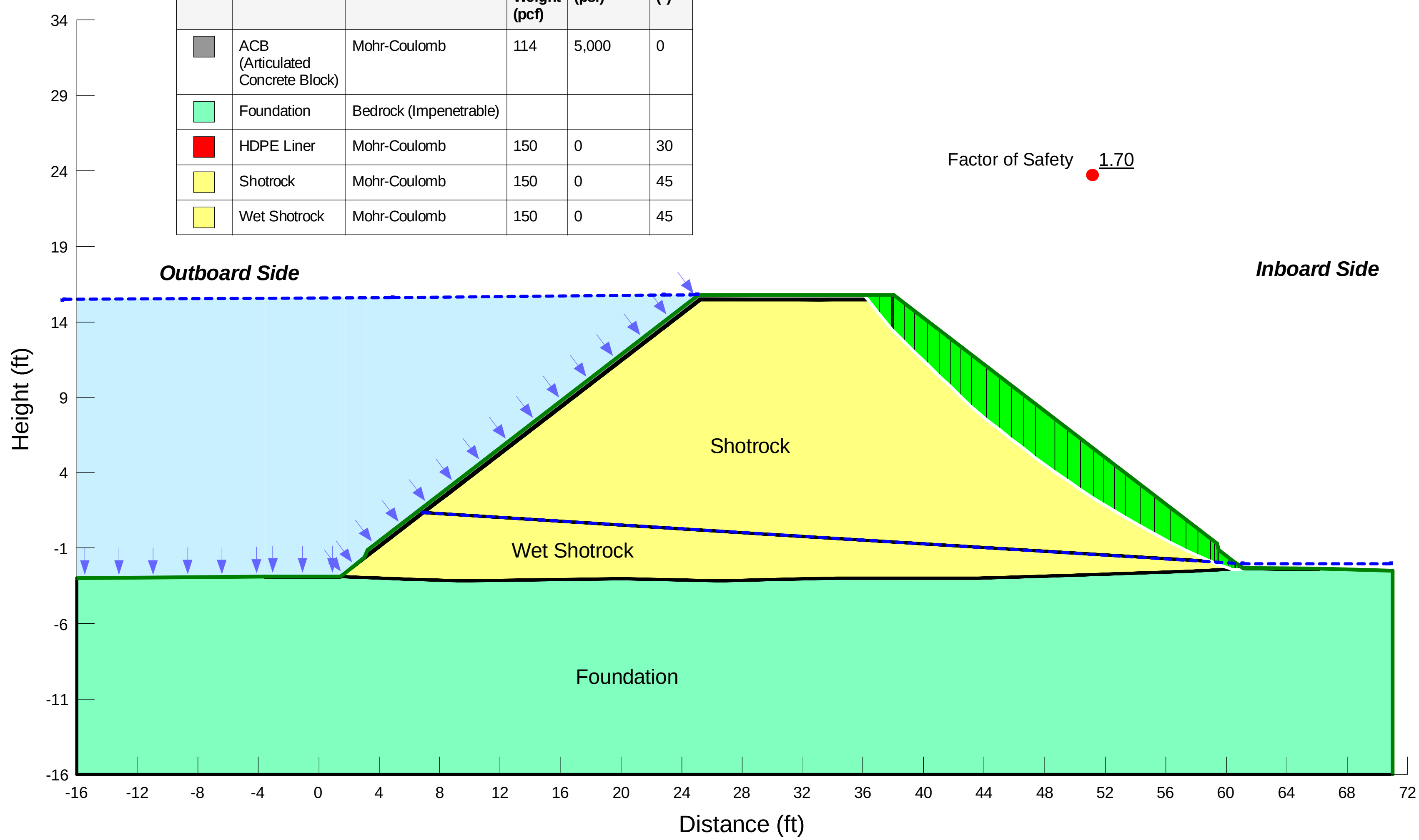


Max Overflow Section 2-14-2020.gsz
Date: 02/21/2020
Kind: SLOPE/W
Method: Spencer

Scale: 1:127.18208

Figure A12: Overflow Section (Reinforced); Inboard Slope Failure Result

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB (Articulated Concrete Block)	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45



Max Overflow Section 2-14-2020.gsz
Date: 02/21/2020
Kind: SLOPE/W
Method: Spencer

Scale: 1:127.18208

Figure A13: Typical Section (Limited Inboard Reinforcement Coverage); Model Configuration

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section H4 3-24-2020.gsz
Date: 04/03/2020
Kind: SLOPE/W
Method: Spencer

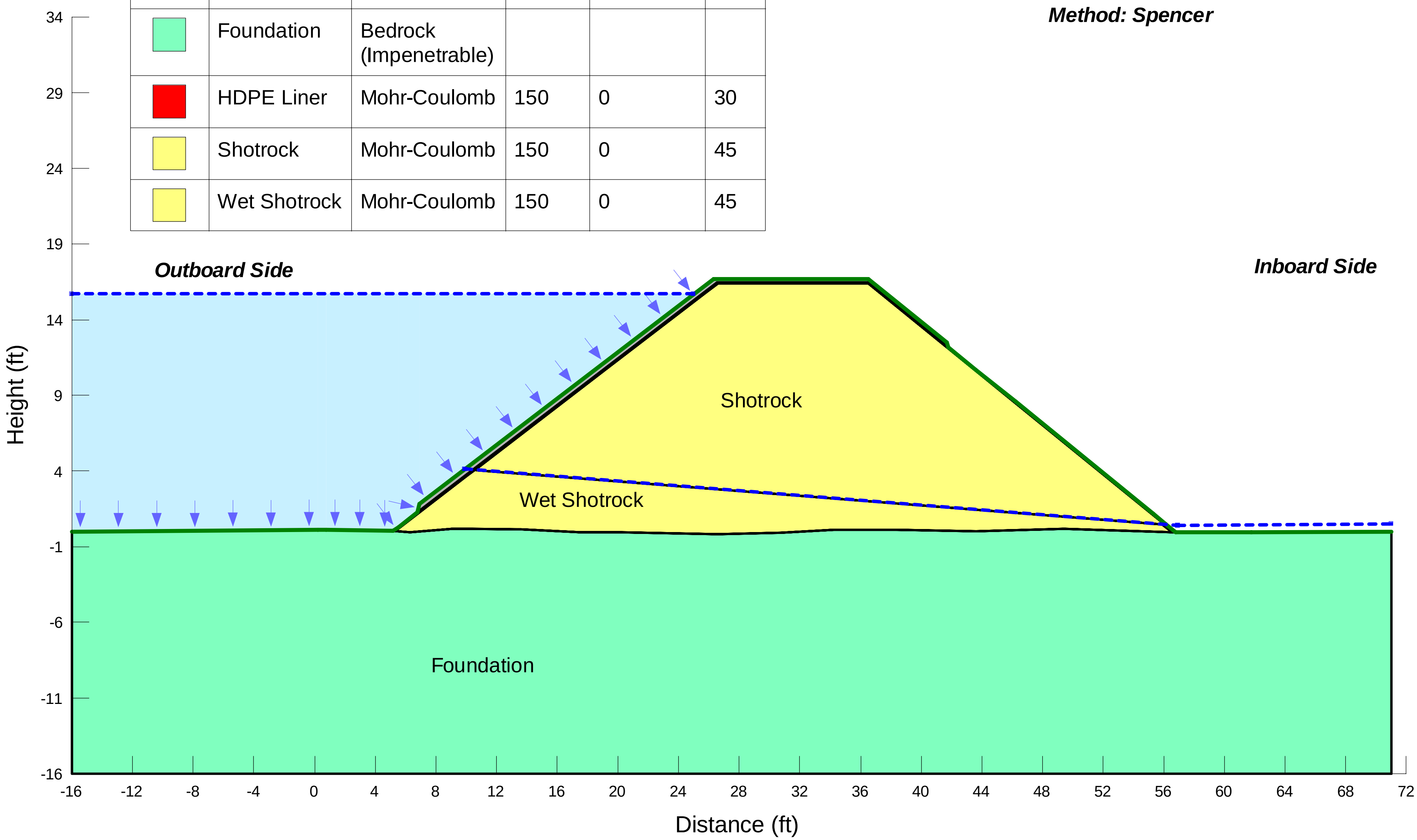


Figure A14: Typical Section (Limited Inboard Reinforcement Coverage); Inboard Slope Failure Result

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

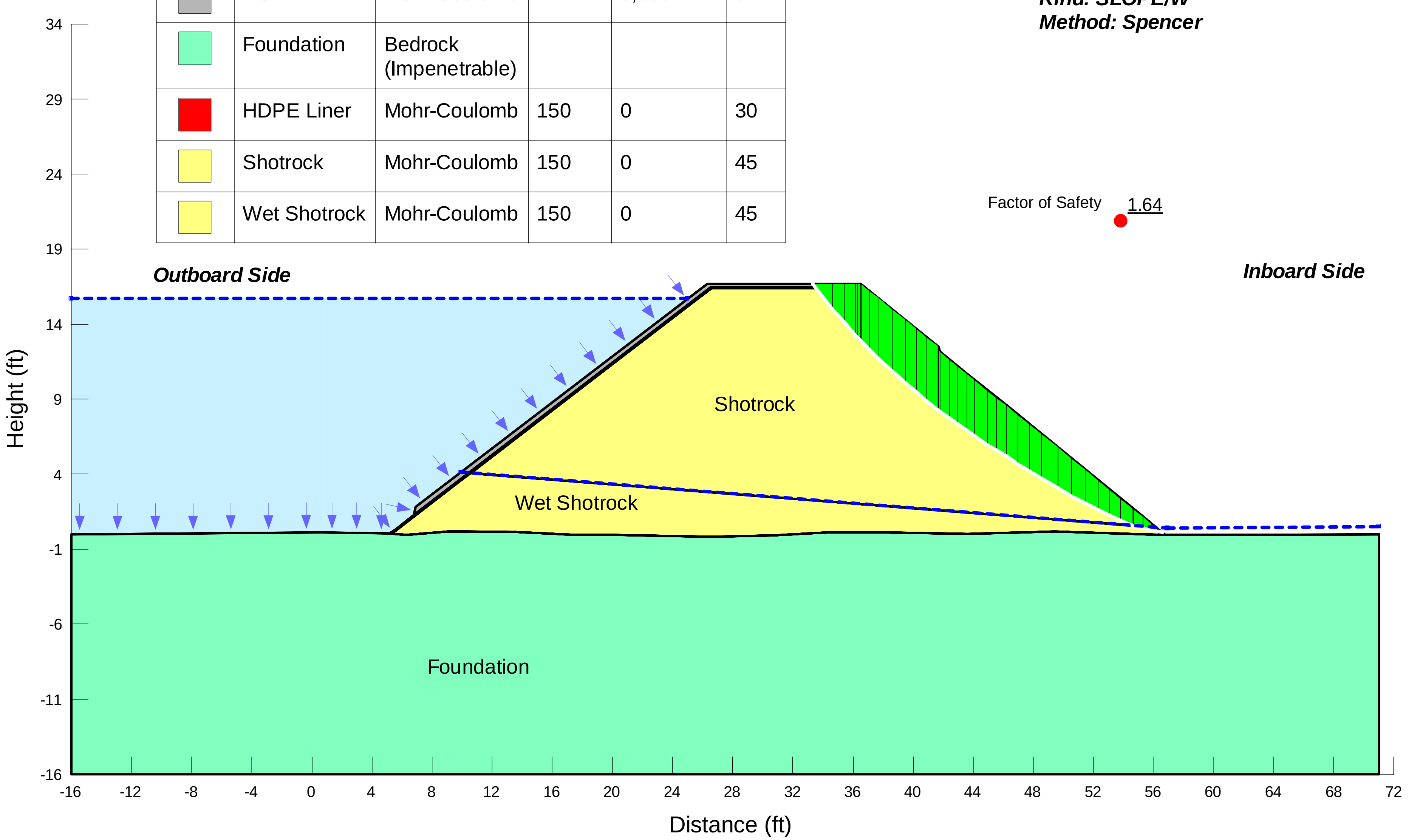
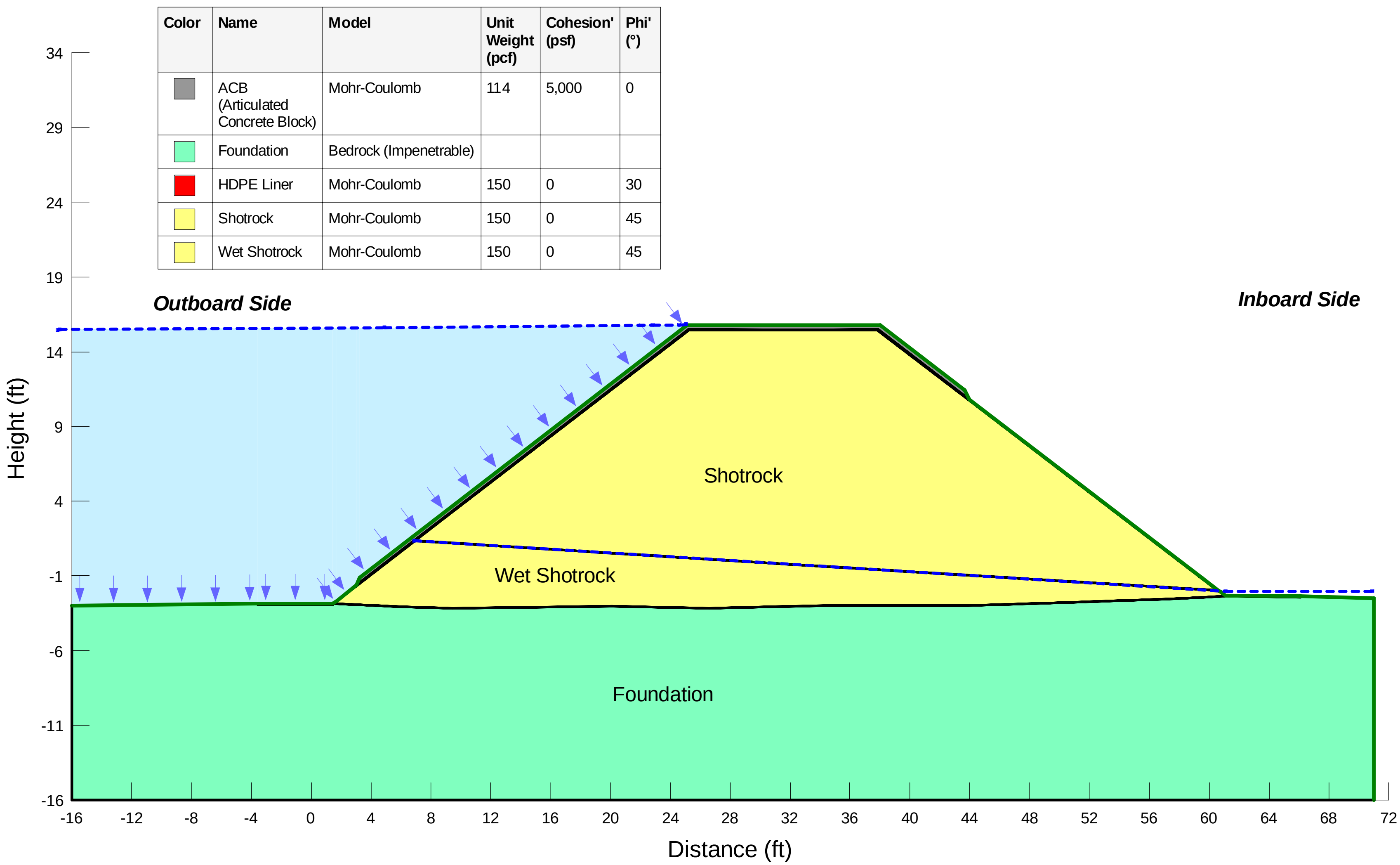


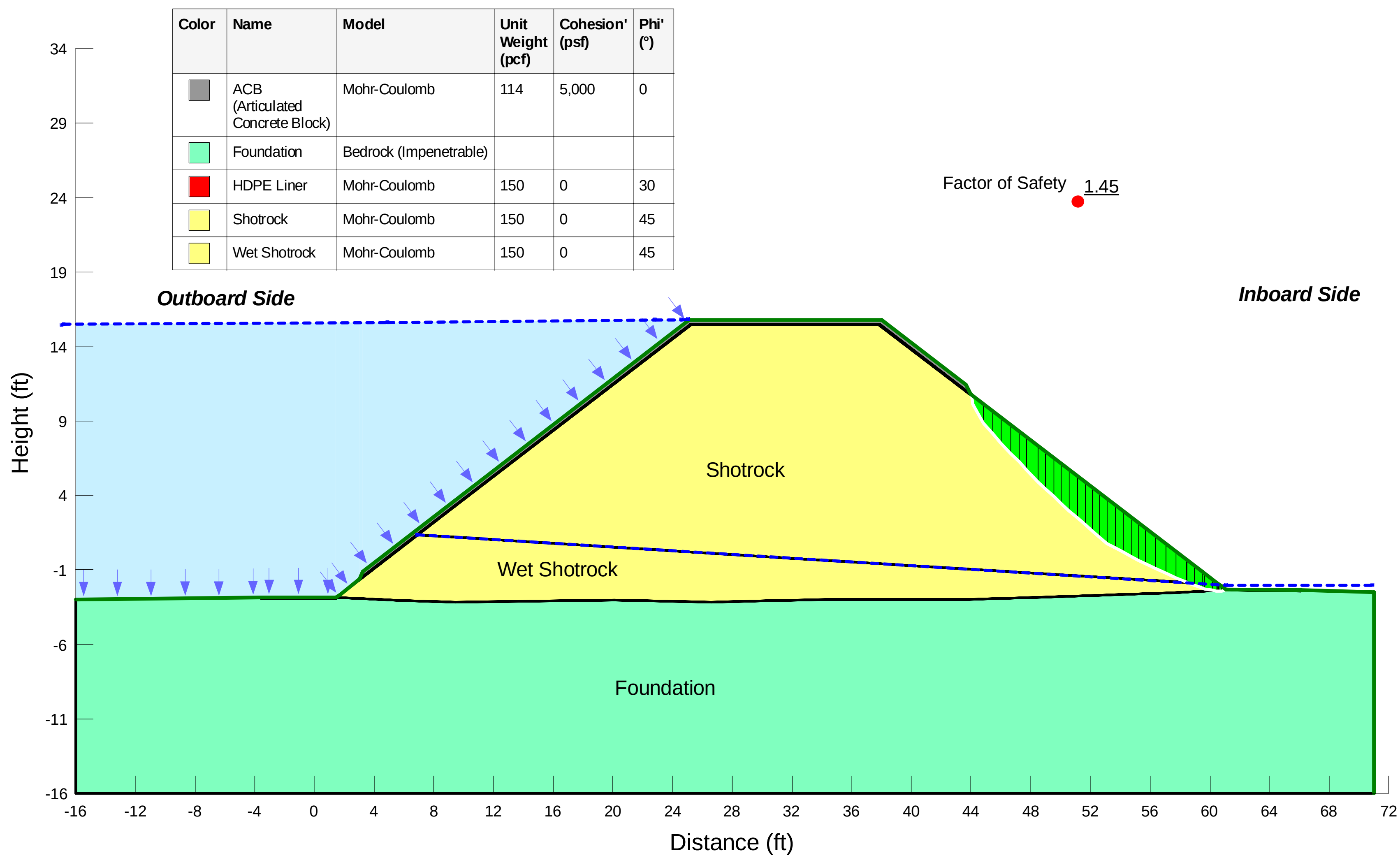
Figure A15: Overflow Section (Limited Inboard Reinforcement Coverage); Model Configuration



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB (Articulated Concrete Block)	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Overflow Section H4 3-24-2020.gsz
Date: 04/03/2020
Kind: SLOPE/W
Method: Spencer

Figure A16: Overflow Section (Limited Inboard Reinforcement Coverage); Inboard Slope Failure Result



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB (Articulated Concrete Block)	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Overflow Section H4 3-24-2020.gsz
Date: 04/03/2020
Kind: SLOPE/W
Method: Spencer

Figure A17: Typical Section (Full ACB Coverage); Model Configuration *[excavation starts 10 feet from toe of inboard slope]*

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	River Sediment	Mohr-Coulomb	110	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

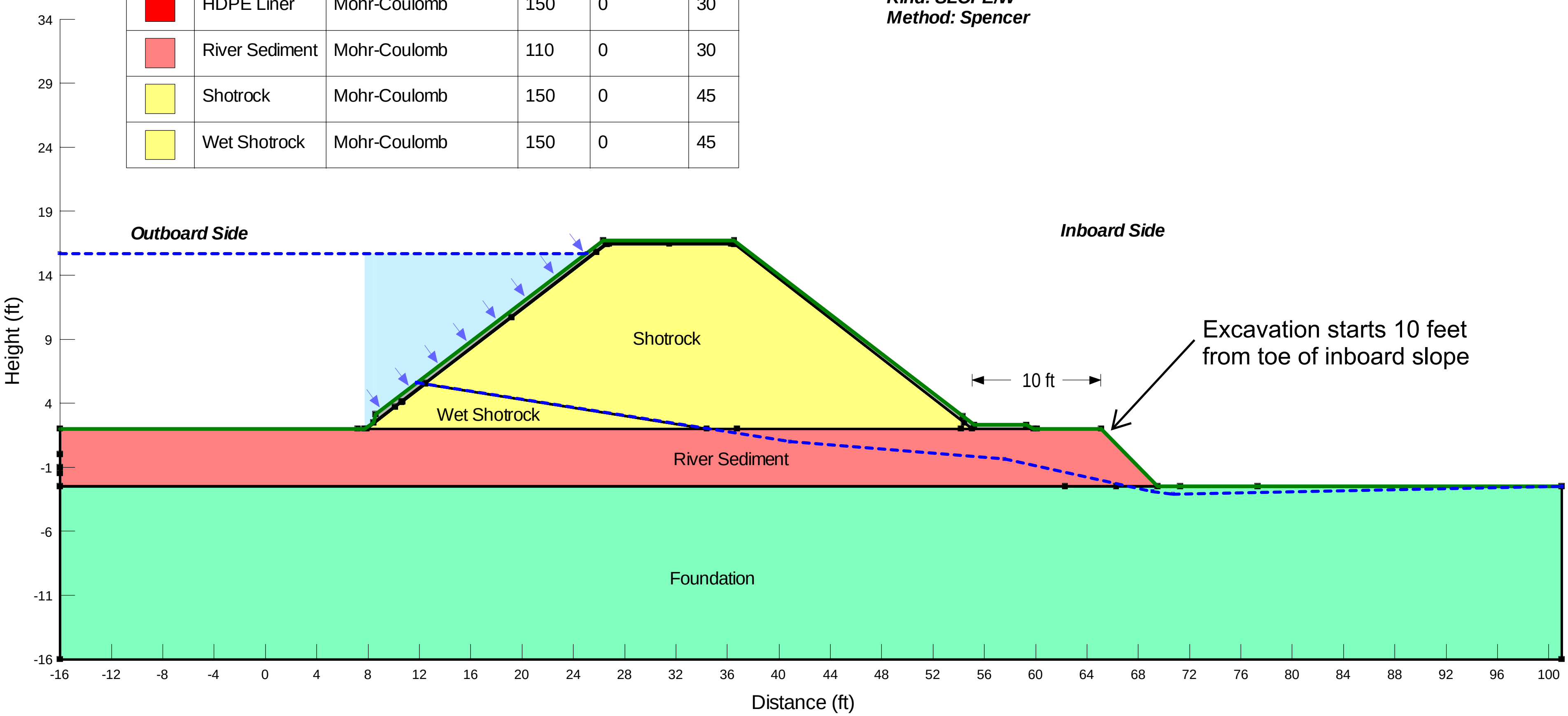


Figure A18: Typical Section (Full ACB Coverage);
Inboard Slope Failure Result *[excavation starts 10 feet from toe of inboard slope]*

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	River Sediment	Mohr-Coulomb	110	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section 4.5ft sediment full 6-1-2020.gsz
Date: 06/09/2020
Kind: SLOPE/W
Method: Spencer

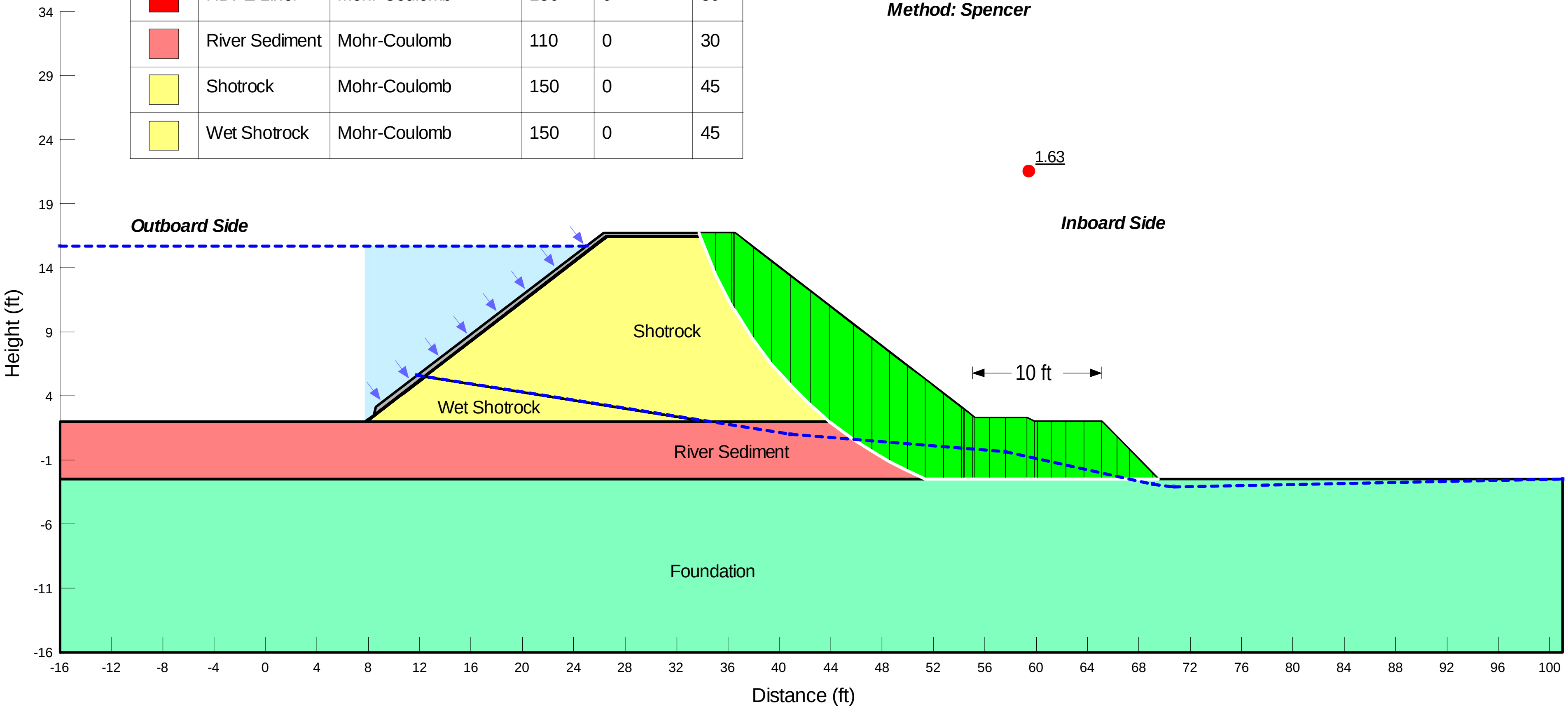


Figure A19: Typical Section (Full ACB Coverage); Model Configuration *[excavation starts 5 feet from toe of inboard slope]*

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	River Sediment	Mohr-Coulomb	110	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

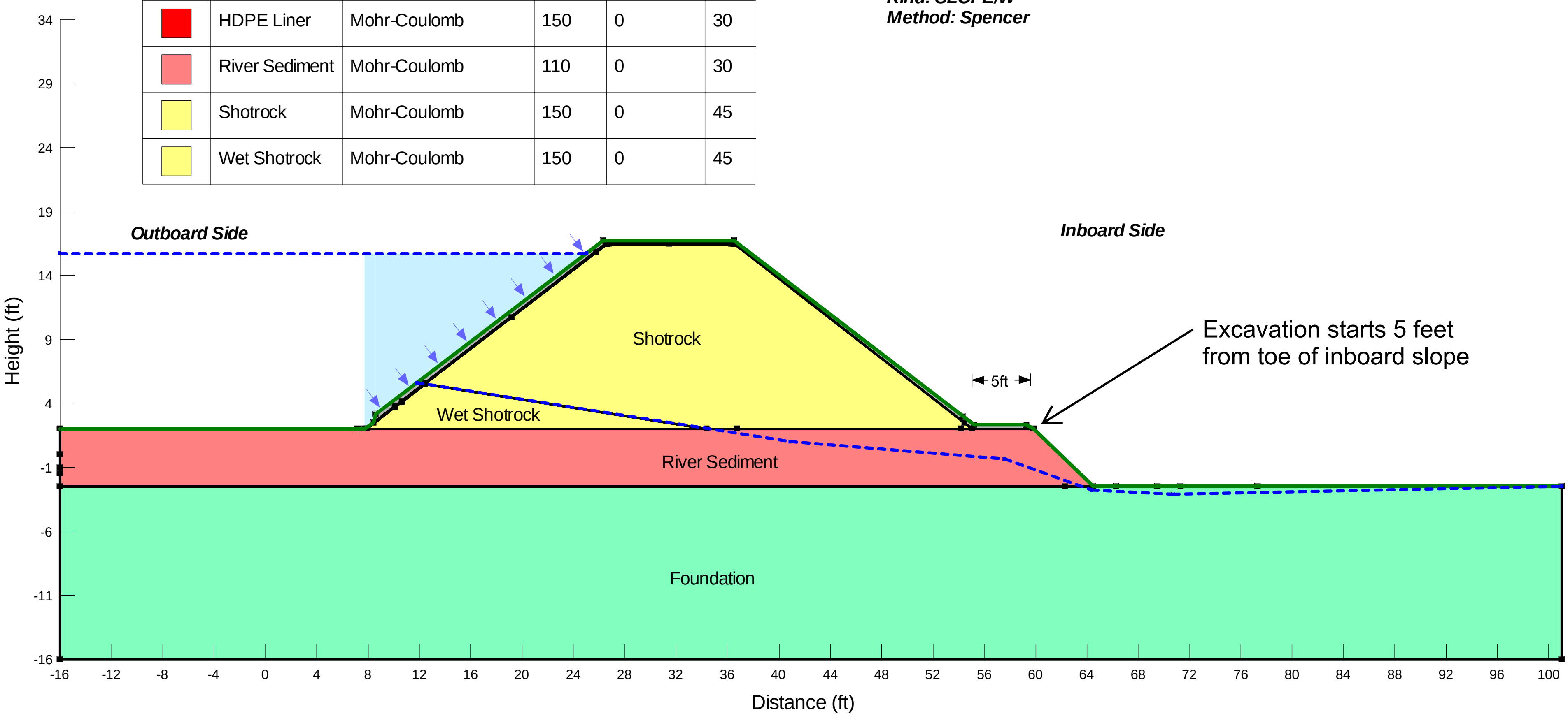


Figure A20: Typical Section (Full ACB Coverage); Inboard Slope Failure Result *[excavation starts 5 feet from toe of inboard slope]*

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	River Sediment	Mohr-Coulomb	110	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

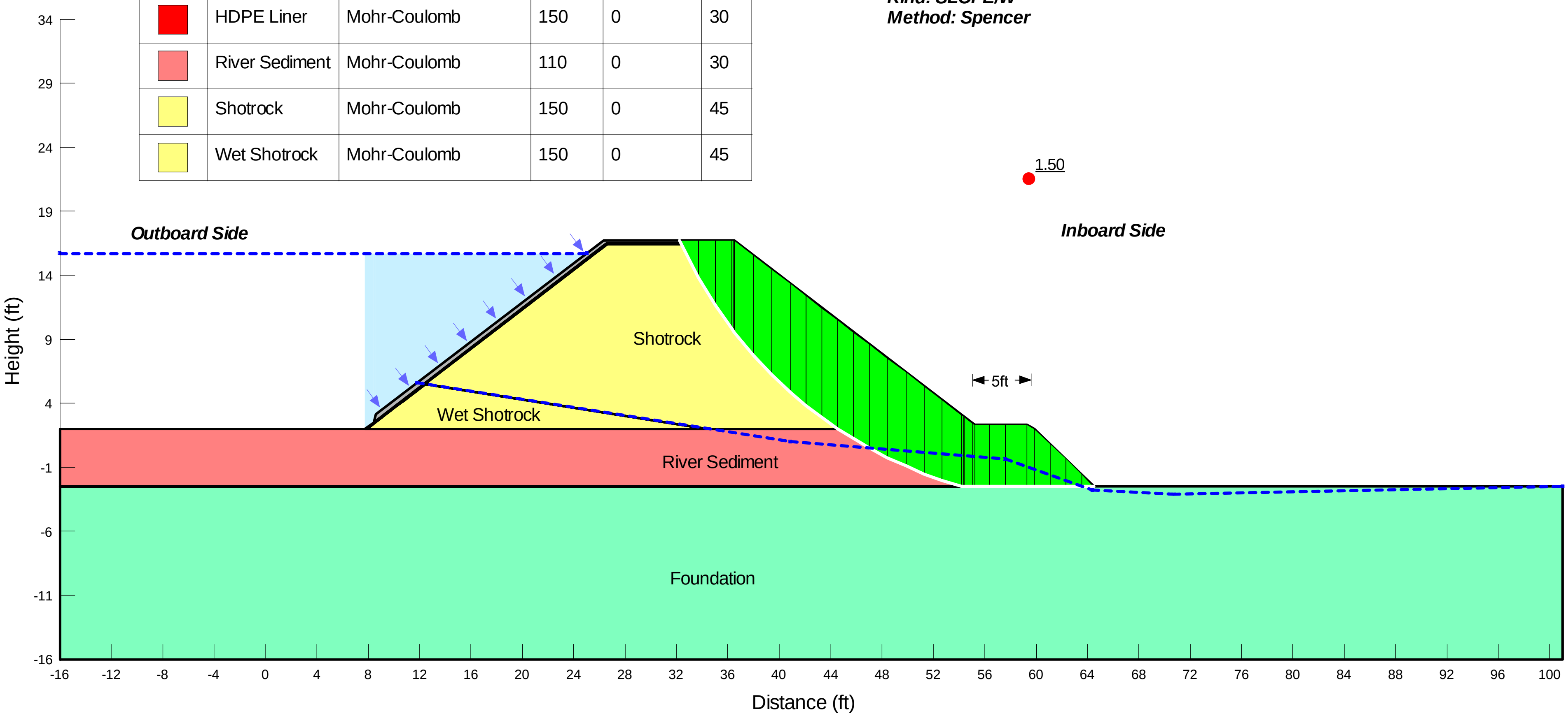


Figure A21: Typical Section (Full ACB Coverage); Model Configuration *[excavation starts 5 feet from toe of inboard slope, material is replaced with shot rock]*

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	River Sediment	Mohr-Coulomb	110	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section 4.5ft sediment full shotrock 6-1-2020.gsz
Date: 06/09/2020
Kind: SLOPE/W
Method: Spencer

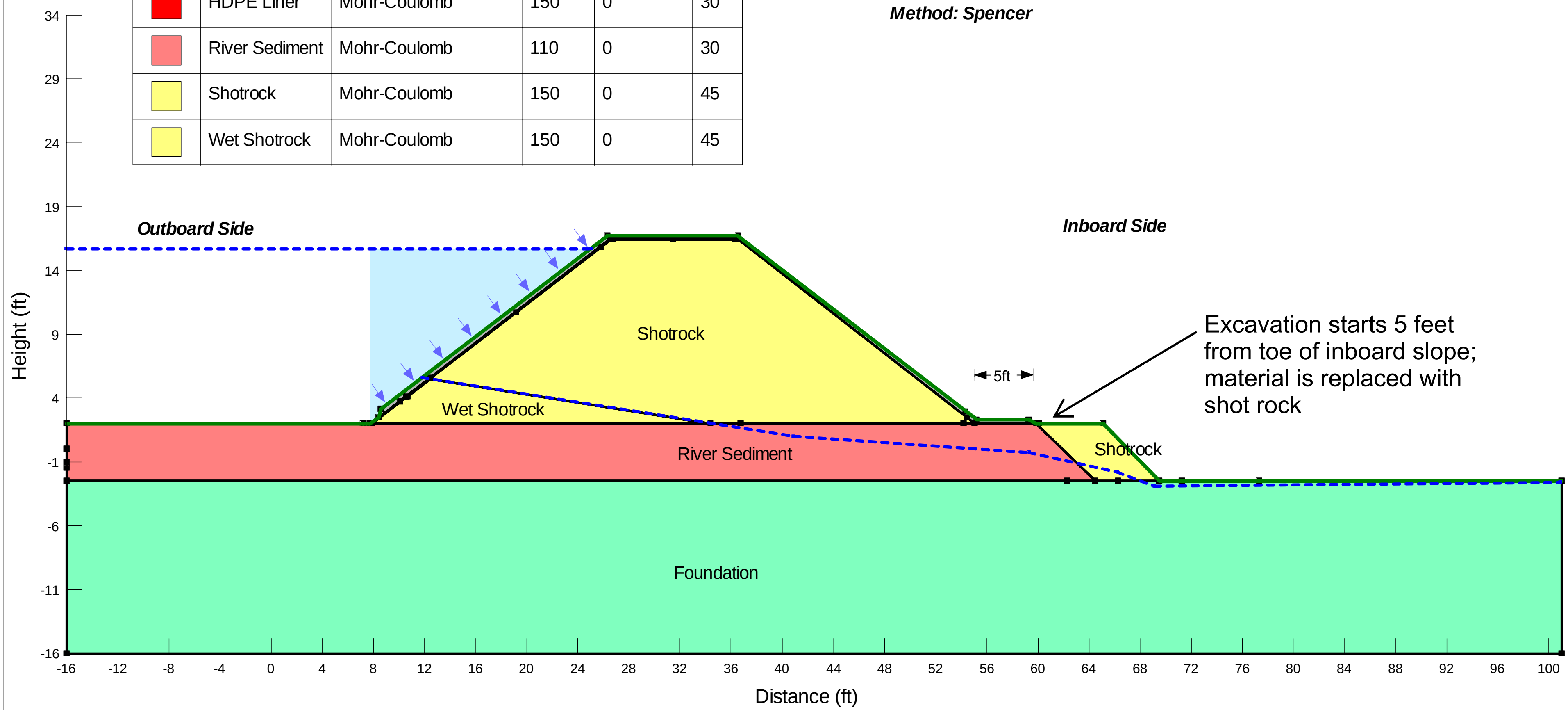
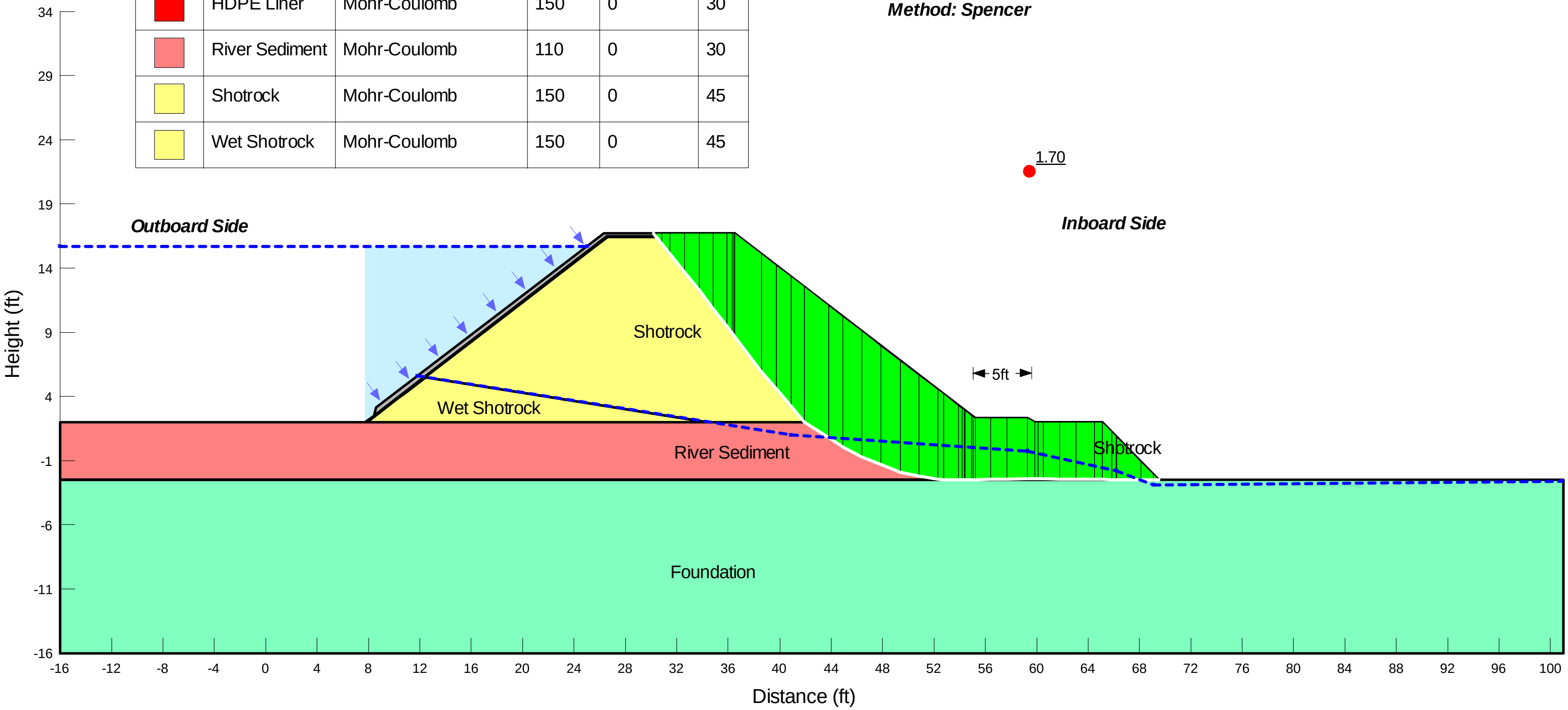


Figure A22: Typical Section (Full ACB Coverage); Inboard Slope Failure Result *[excavation starts 5 feet from toe of inboard slope, material is replaced with shot rock]*

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	ACB	Mohr-Coulomb	114	5,000	0
	Foundation	Bedrock (Impenetrable)			
	HDPE Liner	Mohr-Coulomb	150	0	30
	River Sediment	Mohr-Coulomb	110	0	30
	Shotrock	Mohr-Coulomb	150	0	45
	Wet Shotrock	Mohr-Coulomb	150	0	45

Max Cofferdam Section 4.5ft sediment full shotrock 6-1-2020.gsz
Date: 06/09/2020
Kind: SLOPE/W
Method: Spencer



Appendix B: Hand Calculations

Purpose

Estimate Unit weight and shear strengths of ACB blocks for Slope Stability Analysis

Shear Strength

calculate shear capacity for plain concrete

$$V_n = \frac{4}{3} \times 2 \times \sqrt{f'_c}\, b_w d$$

$$V_u = \phi V_n, \quad \phi = 0.65$$

ACI 318 chapter 22 eqn. 22.8, 9.3.5 for ϕ

Model shear strength of ACB blocks using an equivalent cohesion $= \frac{V_u}{b_w d}$

$$C = \frac{4}{3} \times 2 \times \sqrt{f'_c} \times 0.65$$

Use $f'_c = 4000$ psi, and a FS = 3.0 neglect shear capacity of steel cables

$$C = \frac{\frac{4}{3} \times 2 \times 0.65 \times \sqrt{4000}}{3.0} = 36.5 \text{ lb/in}^2$$

or 5261 lb/ft²

∴ use C = 5,000 psf

Project Congaree River Rem. Computed by JPO Date 2/13/20
Subject Checked by ASB Date 2/18/20

Unit Weight

#45 Armortex Mats weigh 45 lb/sf
(See Richard Hill e-mail on page 3)

Armortech details show a block height of 4.75 in. (0.396 ft)

$$\gamma = \frac{45\ lb/ft^2}{0.396\ ft} = \underline{\underline{114\ lb/ft^3}}$$

3/3

JPO 2/13/20

Osterle, John P.

From: Hill, Richard <RHill@conteches.com>
Sent: Thursday, February 13, 2020 12:04 PM
To: Osterle, John P.
Cc: King, Barrie
Subject: RE: ACB Estimate - Columbia, SC

Hi John,

We typically use 45#/sq. ft. for the estimated handling weight for the #45 ArmorFlex cabled mats. The mat size you reference would be our max. size for shipping purposes. Therefore, the max. estimated individual mat weight would be 13,950#.

Let me know if you need specifications or any other detailed information.

Regards,

Richard A. Hill, P.E.
Bridge Consultant - Western PA and Northern WV (DOH Districts 4 & 6)
Contech Engineered Solutions
Email: RHill@conteches.com
Mobile: (412) 449-6610

From: Osterle, John P. <John.Osterle@wsp.com>
Sent: Thursday, February 13, 2020 11:36 AM
To: Hill, Richard <RHill@conteches.com>
Subject: RE: ACB Estimate - Columbia, SC

HI Richard,

Quick question for you. What is the total weight of a single ACB mat of closed cell #45 with dimensions of 7'-9"x 40'?

We are finalizing our conceptual design of the cofferdam using ACB mats now. Thanks.

John

From: Hill, Richard <RHill@conteches.com>
Sent: Wednesday, January 22, 2020 3:00 PM
To: Osterle, John P. <John.Osterle@wsp.com>
Subject: ACB Estimate - Columbia, SC

Good afternoon John,

Per your request, we offer the following recommended product and material only estimate for your use:

Approx. 109,021 sf ArmorFlex Closed Cell #45 ACB with Galv. Cabling – 40' lengths
- Delivered to Columbia, SC

Healthy People. Healthy Communities.

June 8, 2020

Mr. Paul Biery
Senior Project Manager
Dominion Energy South Carolina
400 Otarre Parkway
Cayce, SC 29033

RE: West Bank Erosion Potential Evaluation
SCE&G Fleet Maintenance Site (Congaree River)
Columbia, South Carolina

Dear Mr. Biery,

The State Voluntary Cleanup Program has reviewed the West Bank Erosion Potential Evaluation received by the Department on June 3, 2020. The Department approves of the submittal and the conclusions made in the report.

If you have any questions or comments please contact me at (803) 898-0747 or cassidga@dhec.sc.gov.

Sincerely,

Greg Cassidy
State Voluntary Cleanup Program
Bureau of Land and Waste Management

cc: File 52561
Lucas Berresford, BLWM
Veronica Barringer, Midlands EA Region
Al Peeples, Midlands EA Region

VIA ELECTRONIC MAIL

November 26, 2019

William Zeli, P.E., Environment Program Manager
Apex Companies, LLC
1600 Commerce Circle
Trafford, PA 15085

Subject: **West Bank Erosion Potential Evaluation**
Congaree River Remediation Project
Columbia, South Carolina

Dear Mr. Zeli:

This letter presents a summary of WSP USA's (WSP) west bank erosion potential evaluation completed using a two-dimensional (2D) HEC-RAS model of the Congaree River near the proposed Area 1 and Area 2 cofferdams.

2D MODEL DEVELOPMENT

A 2D HEC-RAS model was developed for the purposes of completing the erosion potential evaluation. The model was constructed using the same bathymetry, topographic survey, and LiDAR data used to develop a one-dimensional (1D) HEC-RAS model for the Hydraulic Analysis (WSP; April 12, 2019) and Low Flow Sensitivity Analysis (WSP; July 26, 2019). Boundary conditions were determined from the Low Flow Sensitivity Analysis model outputs.

The key characteristics of the 2D model are listed below:

- Upstream extent located approximately 1,000 feet (ft) upstream of Gervais Street bridge
- Downstream extent located approximately 500 ft upstream of Blossom Street bridge, at 1D model Sta. 282071
- Typical cell size of 5 ft x 5 ft, giving a total of approximately 225,000 cells
- Constant Manning's roughness value of 0.038 specified for existing river channel (as per 1D model) and proposed cofferdam structures.
- Upstream inflow boundary conditions for normal flow (8,564 cubic feet per second [cfs]) and crest flow (26,000 cfs) from 1D model. Flow split between left and right channels calculated based on flow area of

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11 Stanwix Street
Pittsburgh, PA 15222

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Fax: +1 412 281-2056
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each side of channel at normal/crest flow conditions from 1D model outputs. Results in approximately 50-50 split between channels.

- Downstream water level boundary conditions for normal and crest flow conditions determined from 1D model outputs as 115.0 and 121.8 ft NAVD 88, respectively.
- Separate Digital Elevation Models (DEMs) developed for Existing, Proposed Area-1 Cofferdam, and Proposed Area-2 Cofferdam scenarios. Cofferdams and river banks specified as break lines for all scenarios, ensuring a consistent 2D flow area with identical computation point locations is used for all models. Therefore, any changes in results can be attributed to elevation changes, not model schematization.
- Gervais Street bridge piers are represented in the models assuming an ellipse shape approximately 60 ft long and 20ft wide, based on Google Earth imagery.
- Final model simulations run using the full momentum equations and an adaptive computation interval with a maximum value of 30-seconds.

Figures 1 through 7 provide a summary of the model setup and input data.

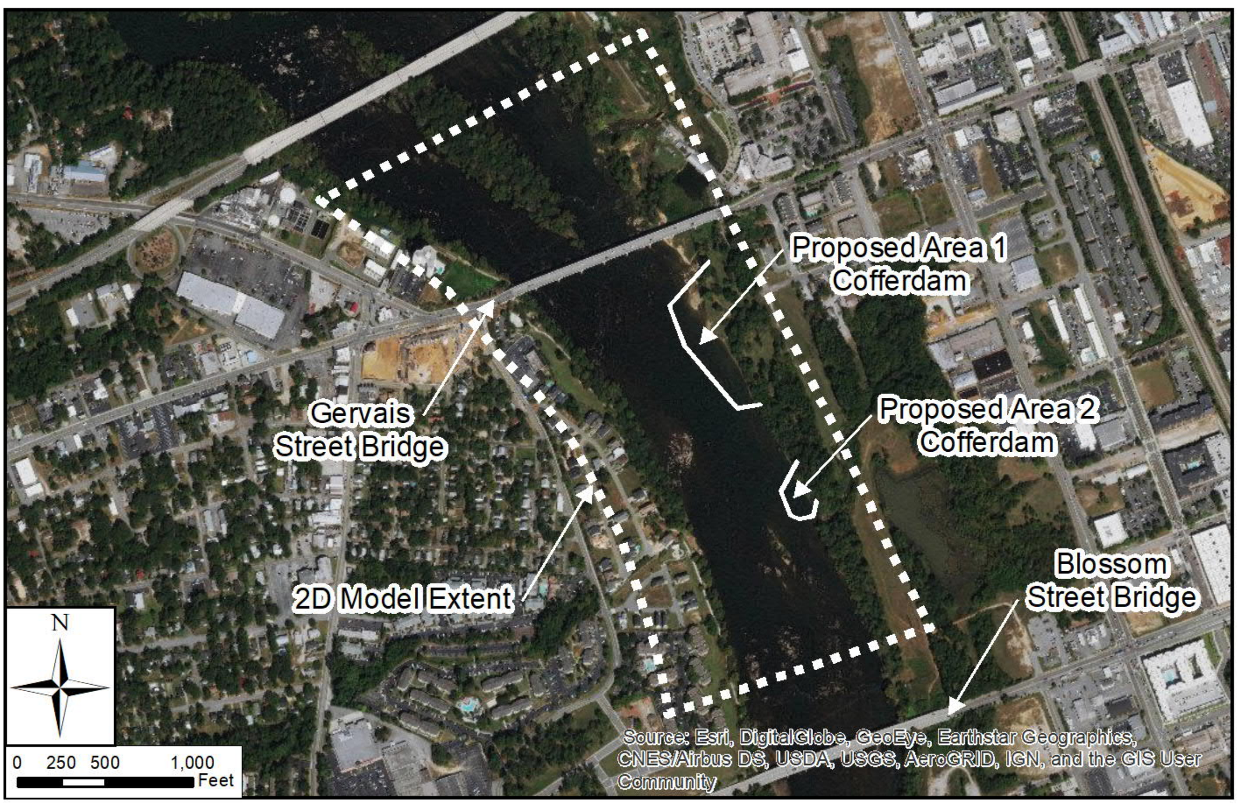


Figure 1: Model Extent

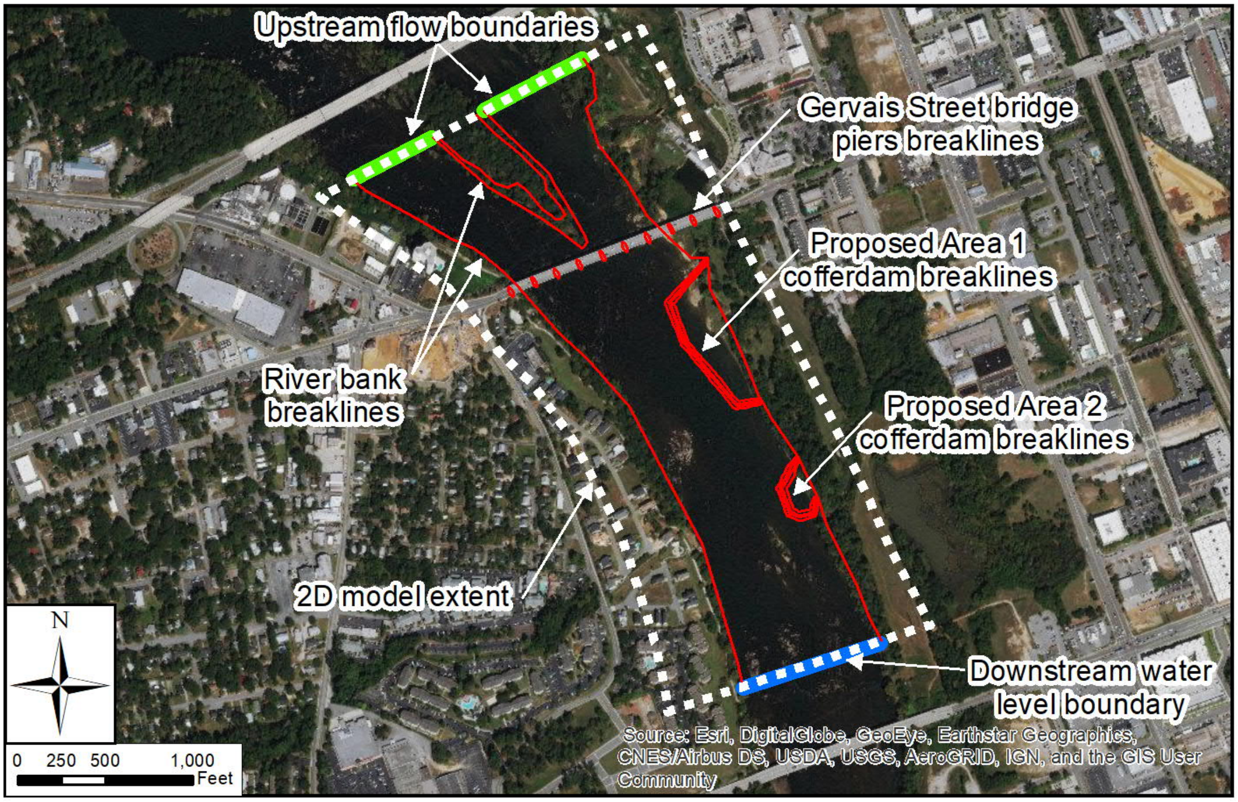


Figure 2: Model Details

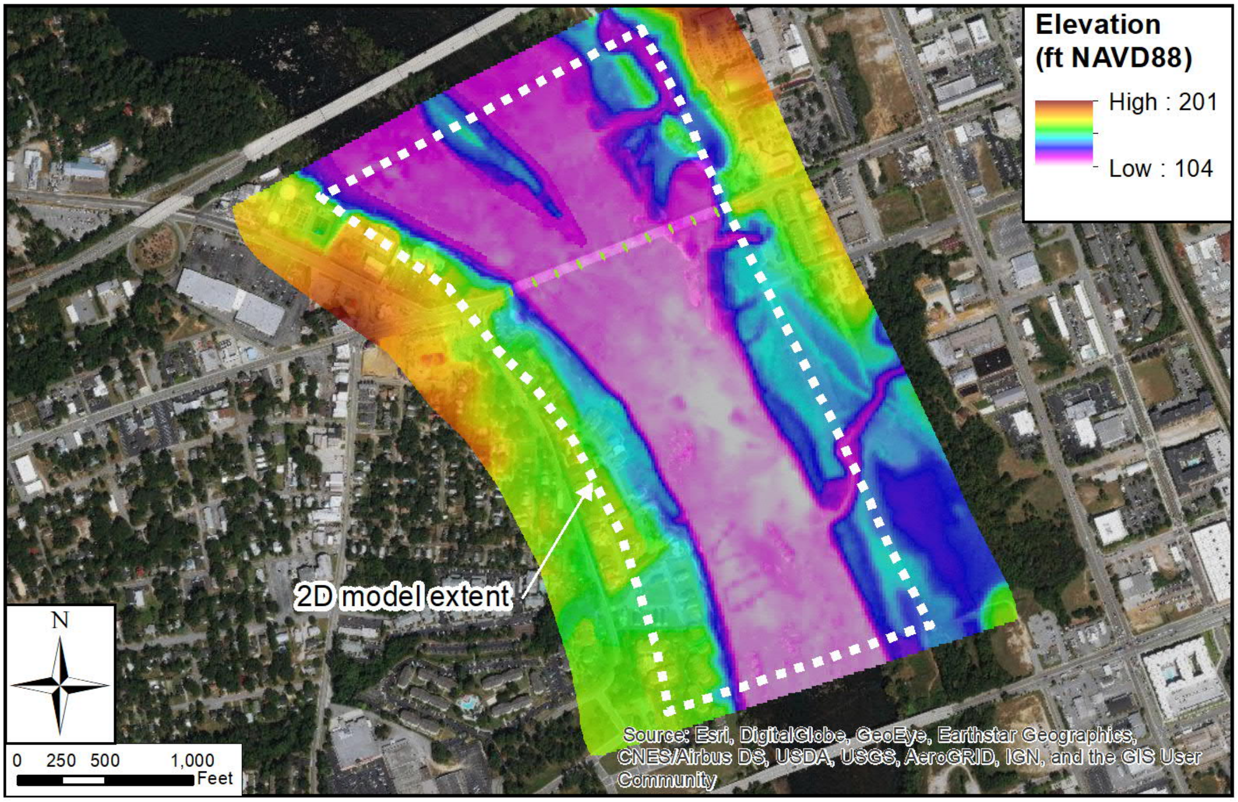


Figure 3: Existing Digital Elevation Model

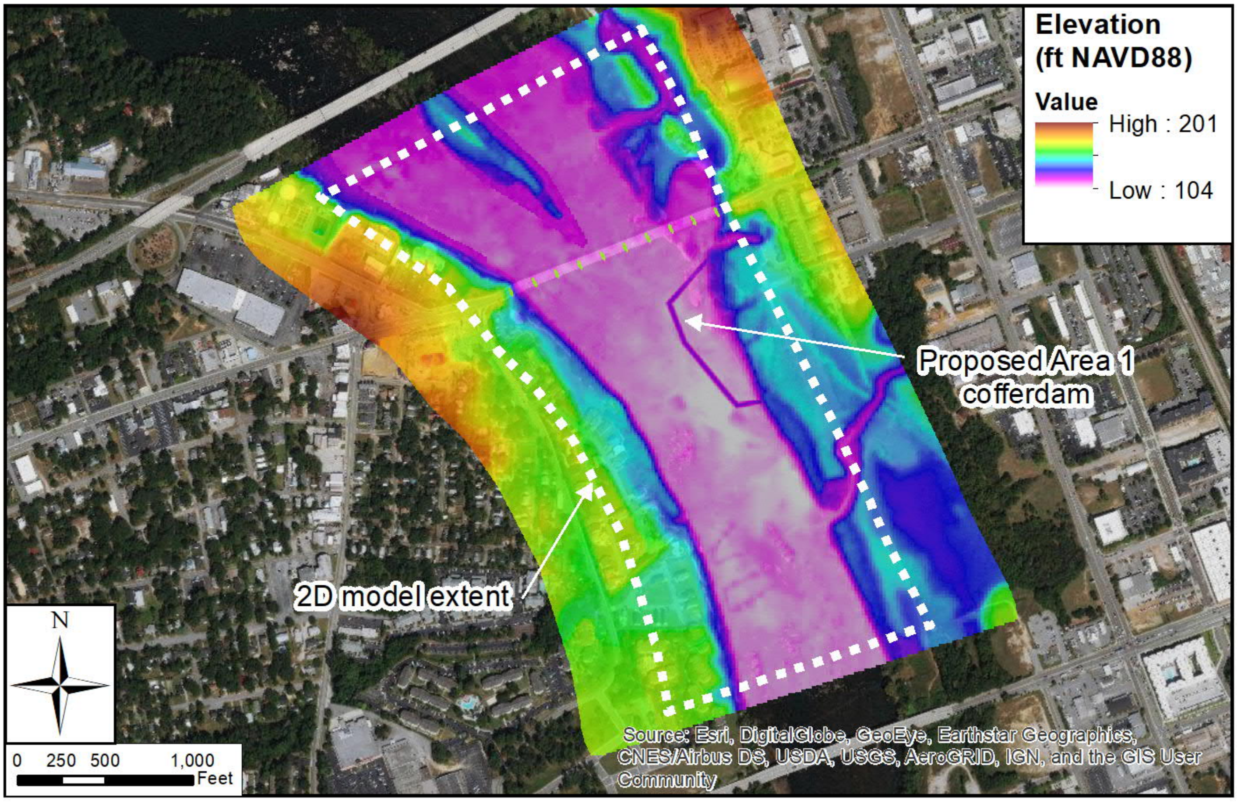


Figure 4: Proposed Area 1 Cofferdam Digital Elevation Model

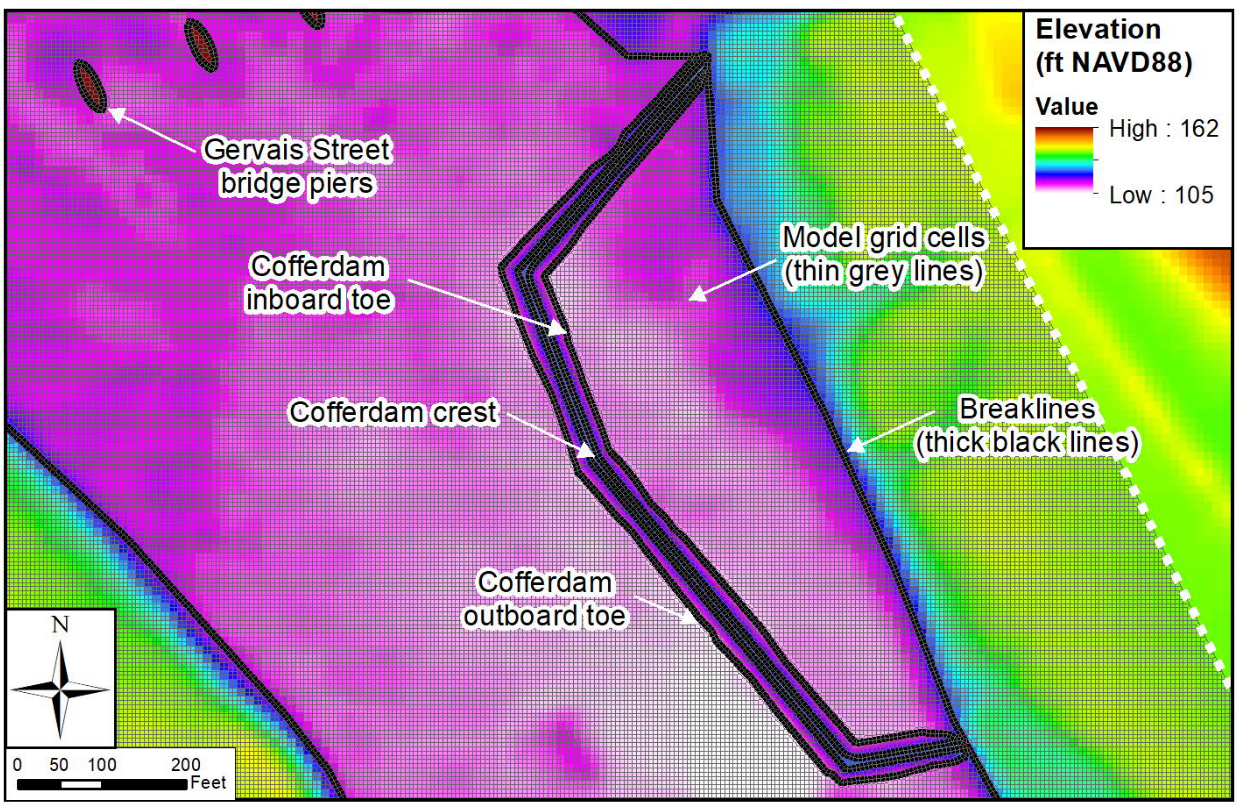


Figure 5: Proposed Area 1 Cofferdam Mesh Details

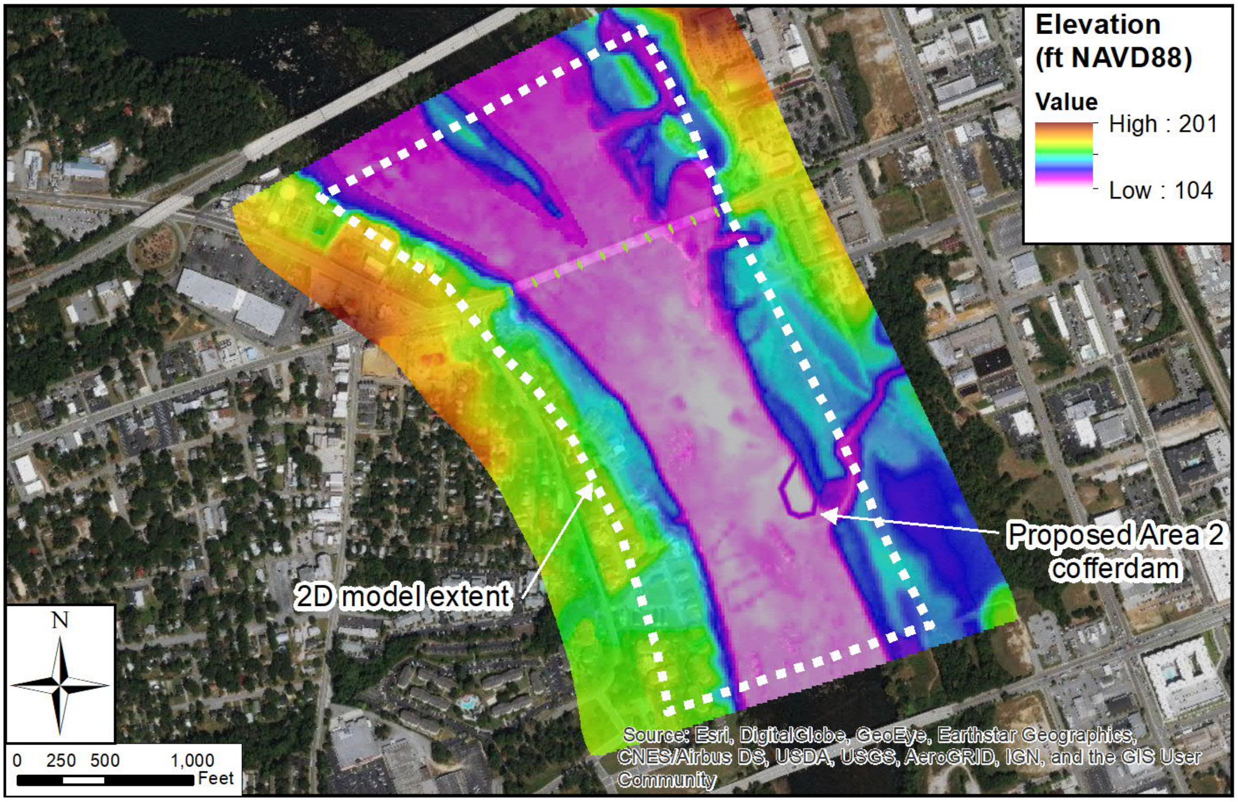


Figure 6: Proposed Area 2 Cofferdam Digital Elevation Model

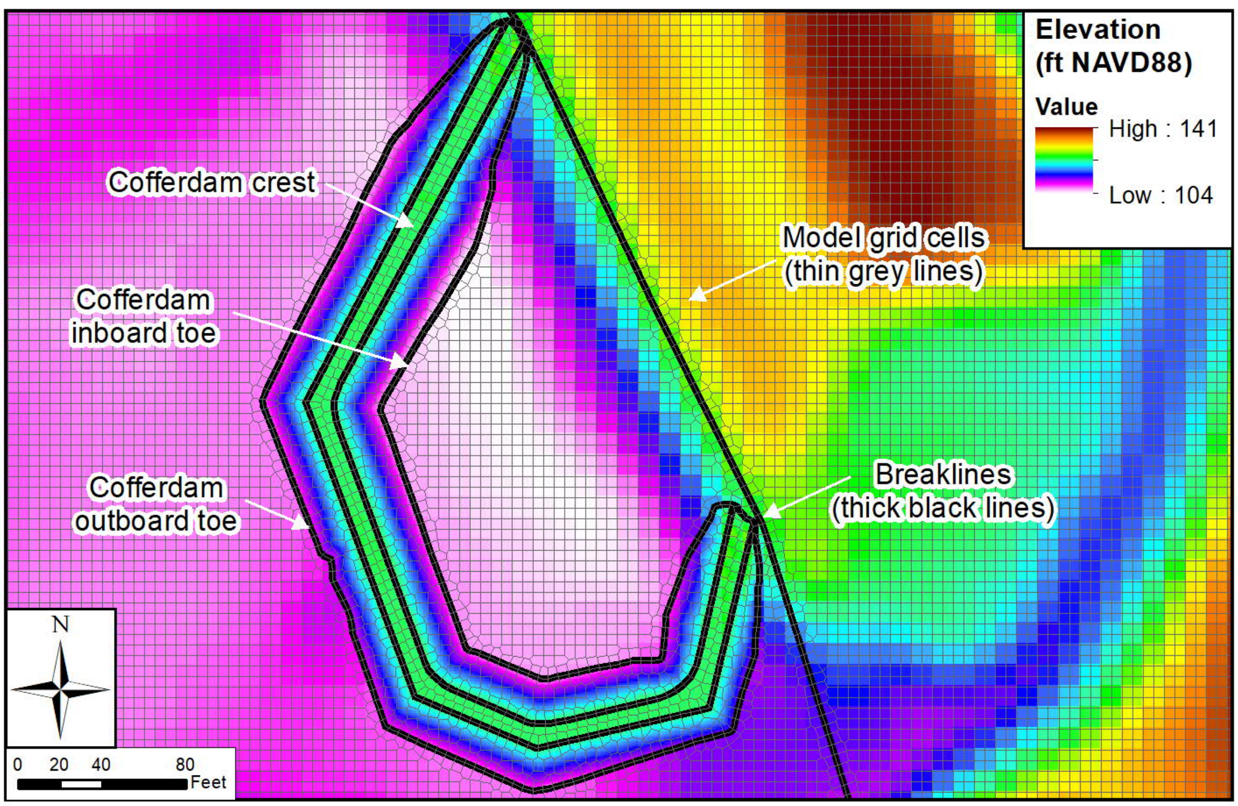


Figure 7: Proposed Area 2 Cofferdam Mesh Details

Figure 8 shows the upstream and downstream boundary conditions used for the model runs. The upstream inflow and downstream water level during the first hour of the run represents the “normal flow condition” of 8,564 cfs. Over the next four hours of the run, the boundary conditions ramp-up to the “crest flow condition” of 26,000 cfs, which is then maintained for the final two hours of the run. During development of the model, initial runs were completed to develop initial condition files at the start of the run for the Existing, Proposed Area 1 and Proposed Area 2 models.

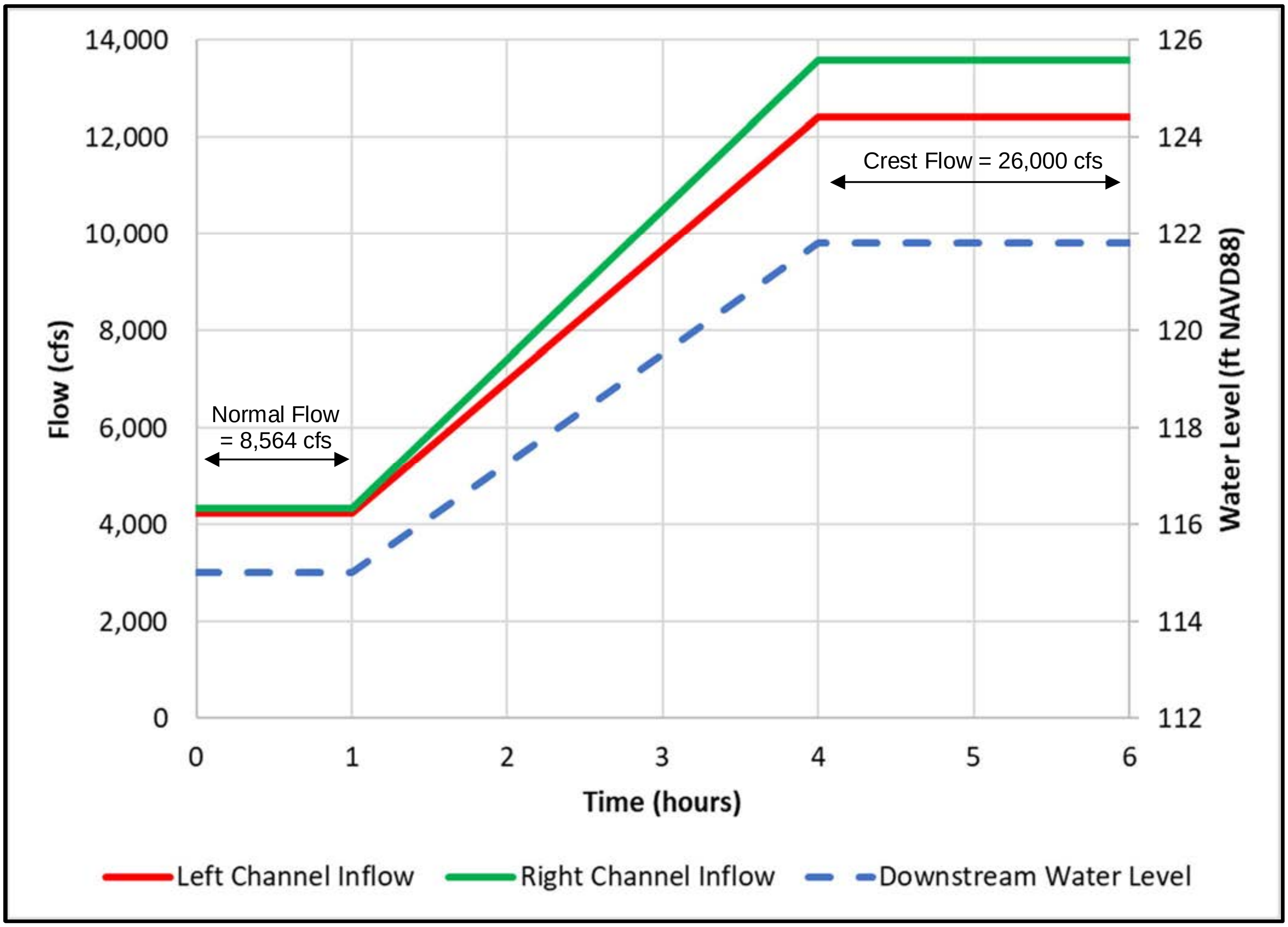


Figure 8: Upstream and Downstream Boundary Conditions

2D MODEL RESULTS

Separate two-dimensional unsteady flow analyses were performed for the Existing, Proposed Area 1, and Proposed Area 2 models. Additional trial analyses were also performed to test the model’s sensitivity to the computational timestep interval and the application of the full momentum equations. After our initial quality assurance review, we determined that the adaptive computational interval and the full momentum equations should be utilized for the final model runs, in accordance with the HEC-RAS 2D Modeling User’s Manual.

The velocity and shear stress results were extracted from all of the models after one hour to represent the normal flow condition of 8,564 cfs, and after six hours to represent the crest flow condition of 26,000 cfs. The results were used to develop figures that show the spatial variation of flow velocity/shear stress throughout the Congaree River channel and to show changes in velocity due to the construction of the Area 1 and Area 2 cofferdams.

The following figures are provided in Attachment A:

- Figure A1: Normal Flow (8,564 cfs) Existing Scenario – Flow Velocity
- Figure A2: Crest Flow (26,000 cfs) Existing Scenario – Flow Velocity
- Figure A3: Normal Flow (8,564 cfs) Proposed Area-1 Scenario – Flow Velocity
- Figure A4: Crest Flow (26,000 cfs) Proposed Area-1 Scenario – Flow Velocity
- Figure A5: Normal Flow (8,564 cfs) Proposed Area-1 Scenario – Change in Flow Velocity
- Figure A6: Crest Flow (26,000 cfs) Proposed Area-1 Scenario – Change in Flow Velocity
- Figure A7: Normal Flow (8,564 cfs) Proposed Area-2 Scenario – Flow Velocity
- Figure A8: Crest Flow (26,000 cfs) Proposed Area-2 Scenario – Flow Velocity
- Figure A9: Normal Flow (8,564 cfs) Proposed Area-2 Scenario – Change in Flow Velocity
- Figure A10: Crest Flow (26,000 cfs) Proposed Area-2 Scenario – Change in Flow Velocity
- Figure A11: Crest Flow (26,000 cfs) Existing Scenario – Shear Stress
- Figure A12: Crest Flow (26,000 cfs) Proposed Area-1 Scenario – Shear Stress
- Figure A13: Crest Flow (26,000 cfs) Proposed Area-2 Scenario – Shear Stress

The following sections discuss the velocity and shear stress results for the west bank of the Congaree River in the vicinity of the project area for the Existing, Proposed Area-1, and Proposed Area-2 scenarios.

EXISTING SCENARIO

The velocity results along the west bank show that during normal flow conditions (8,564 cfs), the river velocity ranges between 2 to 4 feet per second (ft/s) approximately 550 feet downstream of the Gervais Street Bridge. The river velocity for the next 1,200 feet downstream ranges between 0.5 to 2 ft/s. The river velocity throughout the remaining 800 feet of the model ranges from 2 to 4 ft/s, with some localized areas of 5 ft/s. Upstream of the Gervais Street bridge, the river velocity ranges between 3 to 5 ft/s.

The velocity results along the west bank during crest flow conditions (26,000 cfs) range between 2 to 4 ft/s downstream of the Gervais Street bridge. Upstream of the bridge, the river velocity ranges between 4 to 5 ft/s.

PROPOSED AREA-1 SCENARIO

During normal flow conditions, the construction of the Area-1 cofferdam increases the river velocity between 0.1 to 1 ft/s for approximately 1,400 feet of the west bank area opposite the structure. During crest flow conditions, the river velocity increases up to 0.5 ft/s on the west bank upstream of the Gervais Street Bridge. The river velocity increases between 0.1 to 1 ft/s for approximately 1,600 feet of the west bank area opposite the structure. There are some localized areas along the bank which show a river velocity increase up to 1.5 ft/s.

PROPOSED AREA-2 SCENARIO

During normal flow conditions, the construction of the Area-2 cofferdam increases the river velocity between 0.1 to 0.5 ft/s for approximately 1,000 feet of the west bank area opposite the structure. During crest flow conditions, the river velocity increases between 0.5 to 1 ft/s for approximately 700 feet of the west bank opposite the structure. Upstream and downstream of Area 2, the river velocity increases between 0.1 to 0.5 ft/s, for bank lengths ranging from 300 to 400 feet.

WEST BANK EROSION POTENTIAL EVALUATION

The river velocities along the west bank of the Congaree River during normal (8,564 cfs) and crest (26,000 cfs) flow conditions range between 3 to 5 ft/s upstream of the Gervais Street Bridge and range between 0.5 to 4 ft/s downstream of the bridge.

The river velocity along the west bank after the construction of the Area 1 cofferdam increases up to 1 ft/s during normal flow conditions. The area affected is opposite the cofferdam structure and the velocities in this area remain within the 2 to 4 ft/s range. During crest flow conditions, there are some localized increases of up to 1.5 ft/s due to the construction of the Area-1 cofferdam. Similar to normal flow conditions, this increase also occurs opposite the proposed structure and the velocities remain within the 2 to 4 ft/s range during crest flow conditions.

The river velocity along the west bank after the construction of the Area 2 cofferdam increases up to 0.5 ft/s during normal conditions and up to 1 ft/s during crest flow conditions. The area affected is opposite the cofferdam structure and the velocities in this area remain within the 2 to 4 ft/s range for normal and crest flow conditions. However, there is a localized area that has a river velocity up to 4.5 ft/s.

The change in velocity due to construction of the cofferdams is relatively small (i.e., less than 1.5 ft/s) and the velocities along the west bank of the Congaree River remain relatively low (i.e., 2 to 4 ft/s). Based on the flow velocities, erosion protection measures such as riprap or bank stabilization revetments are not necessary to provide river bank protection during the construction period.

Additional evaluation of the shear stress values near the west bank also confirms that erosion protection is not required. Table 6.2 of the Pennsylvania Department of Environmental Protection's "Erosion and Sediment Pollution Control Program Manual" provides maximum permissible shear stresses for various channel liners. The maximum permissible shear stress for non-reinforced vegetation is 1.0 lb/ft^2 and the average value for unlined soils is approximately 0.1 lb/ft^2. The model results show the shear stress along the west bank is typically less than 0.1 lb/ft^2 for the Existing, Proposed Area 1, and Proposed Area 2 scenarios.

If you have any questions or need any additional information, please contact John Osterle at 412-535-9823 or john.osterle@wsp.com, or Tom Edwards at 412-535-9889 or thomas.edwards@wsp.com.

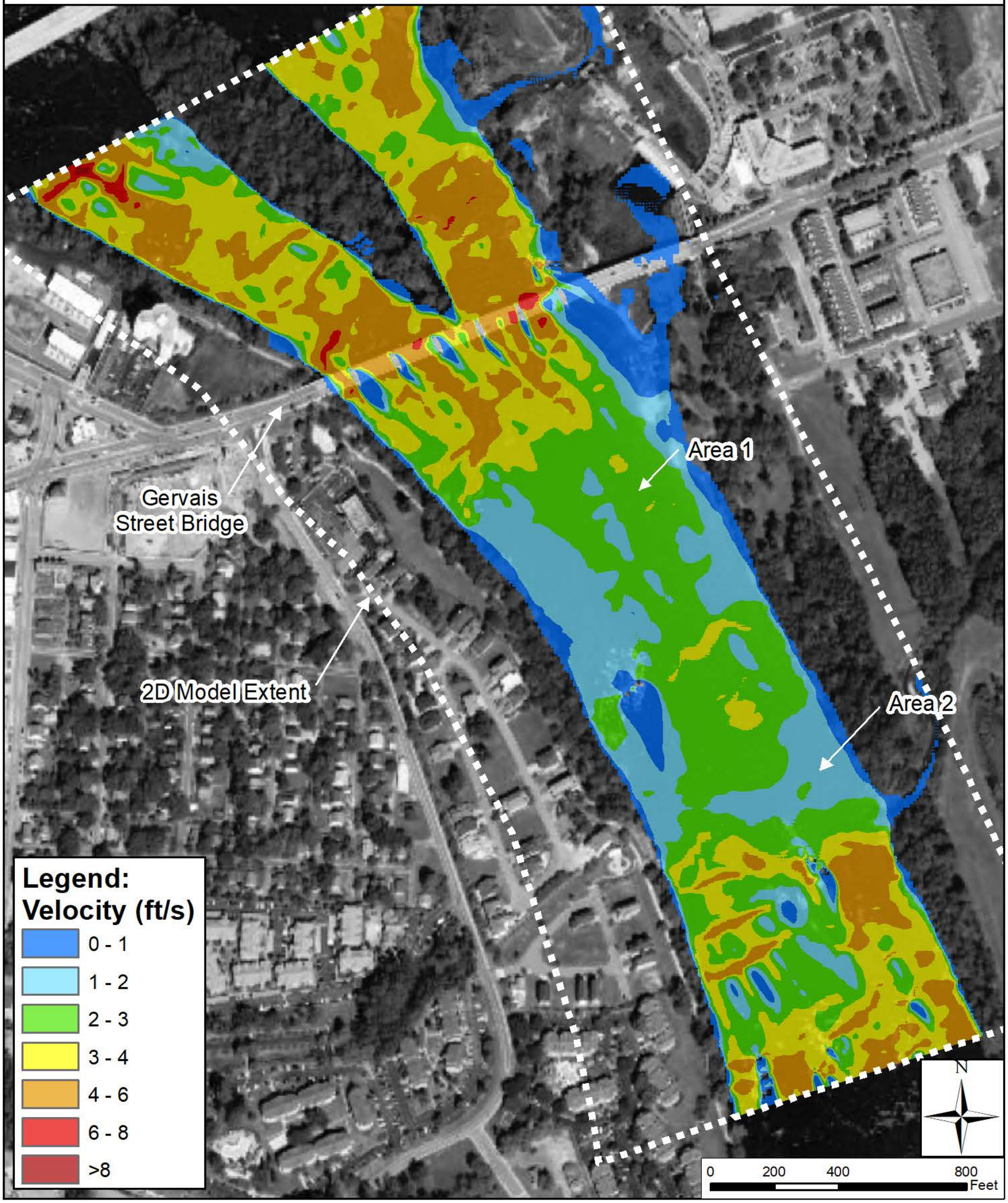
Kind regards,

John P. Osterle, P.E. Project Manager	Tom Edwards, P.E. Water Resources Engineer

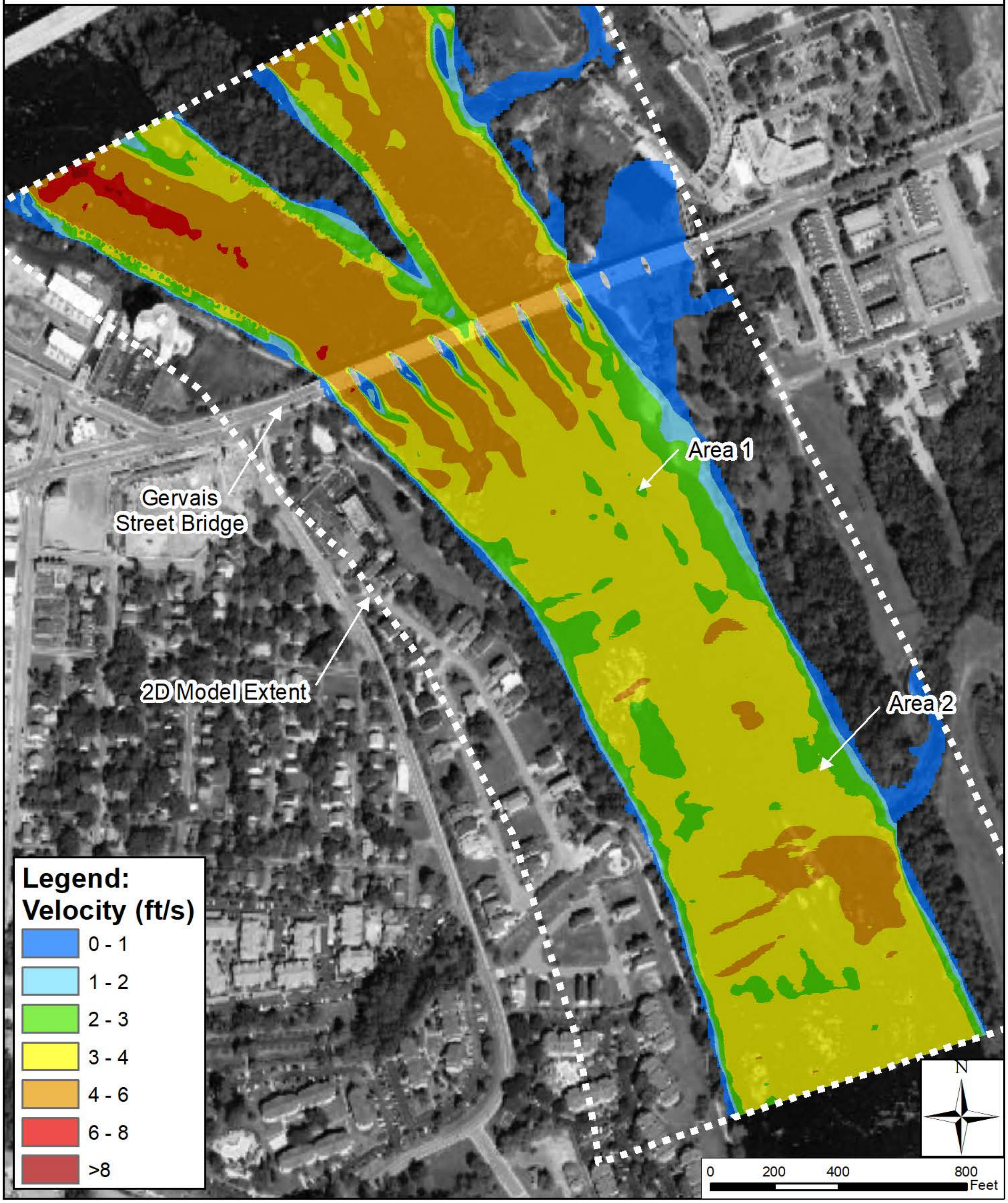
TE: JPO

ATTACHMENT A: FIGURES

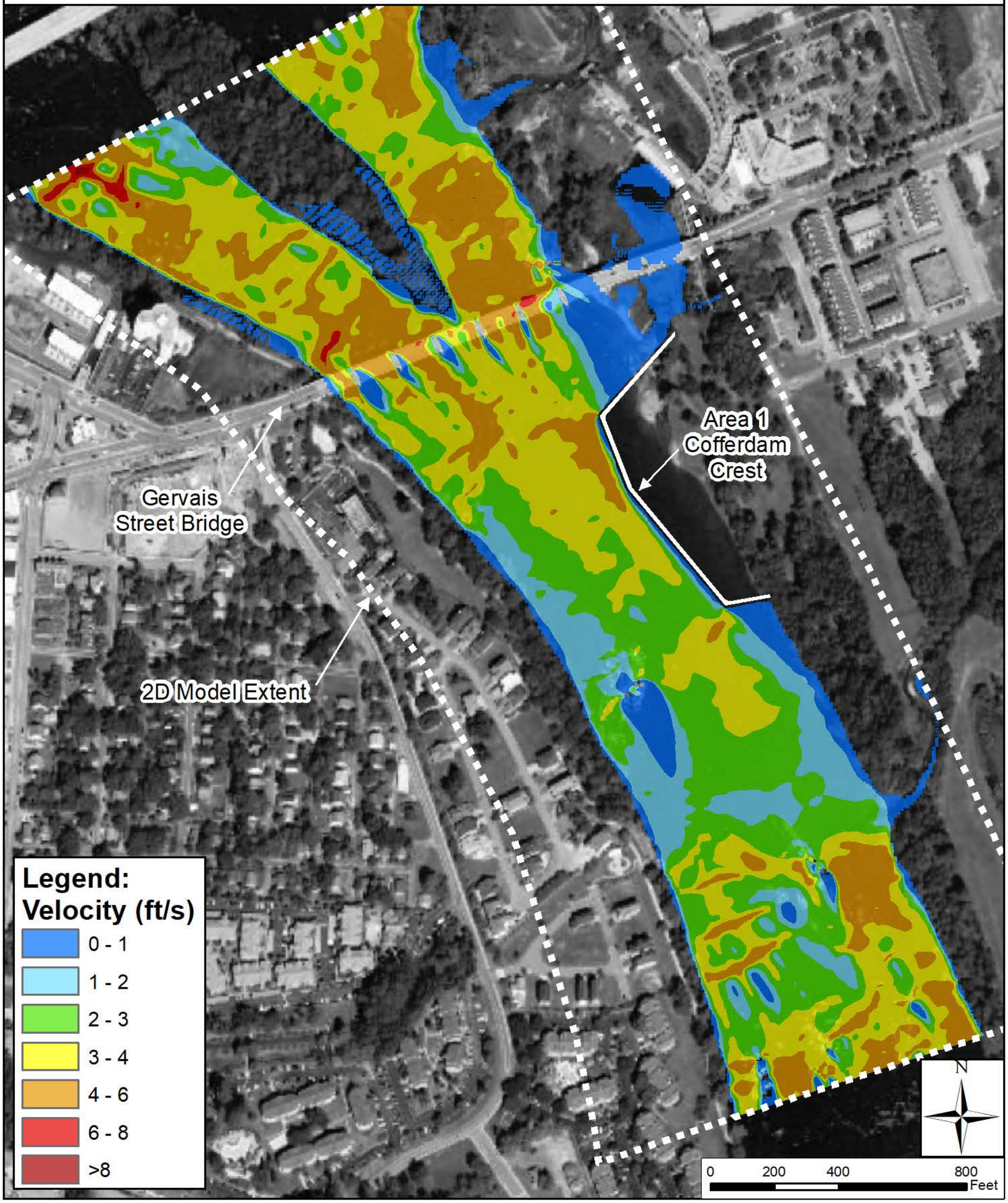
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A1: Normal Flow (8,564 cfs)
Existing Scenario: Flow Velocity



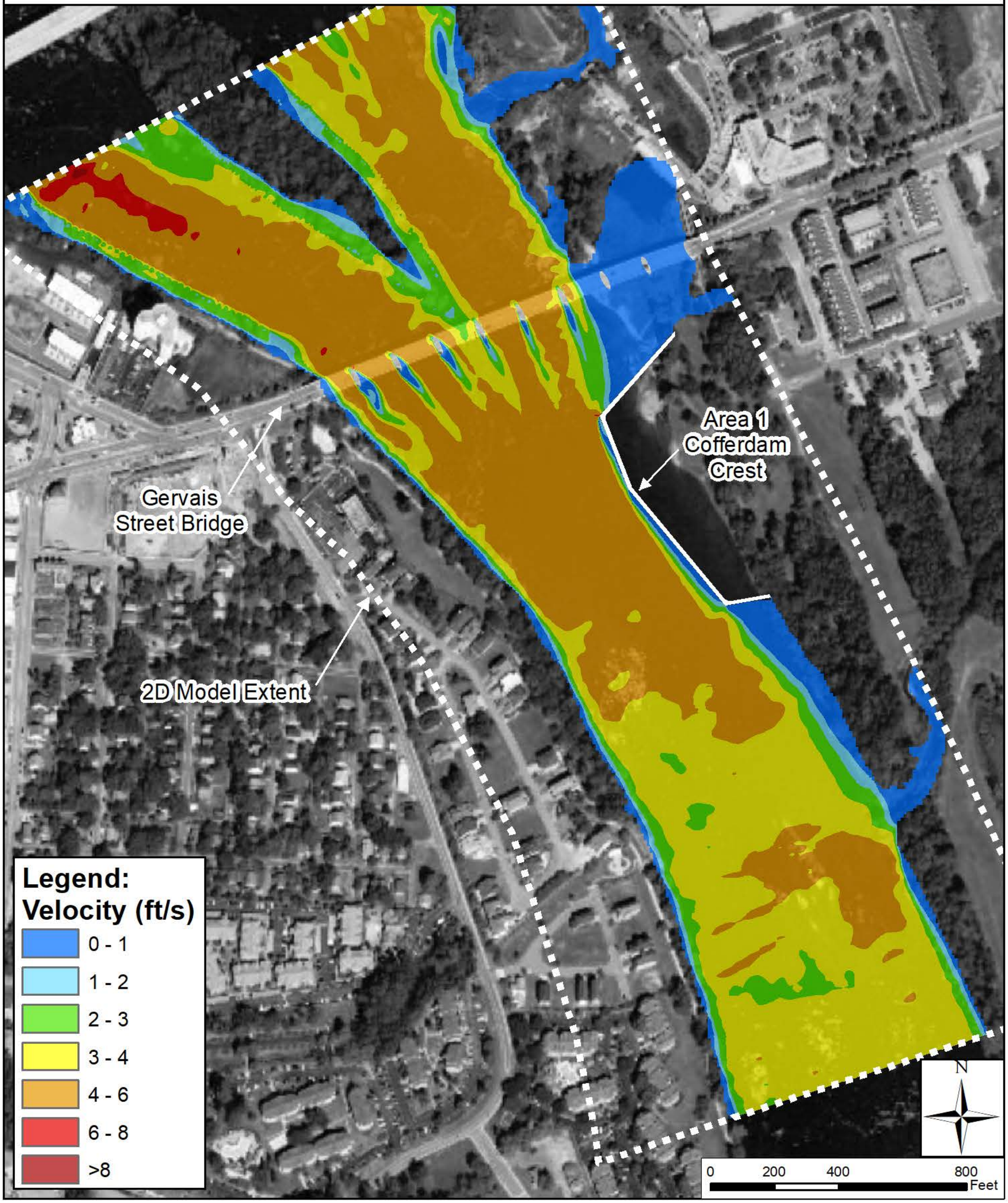
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A2: Crest Flow (26,000 cfs)
Existing Scenario: Flow Velocity



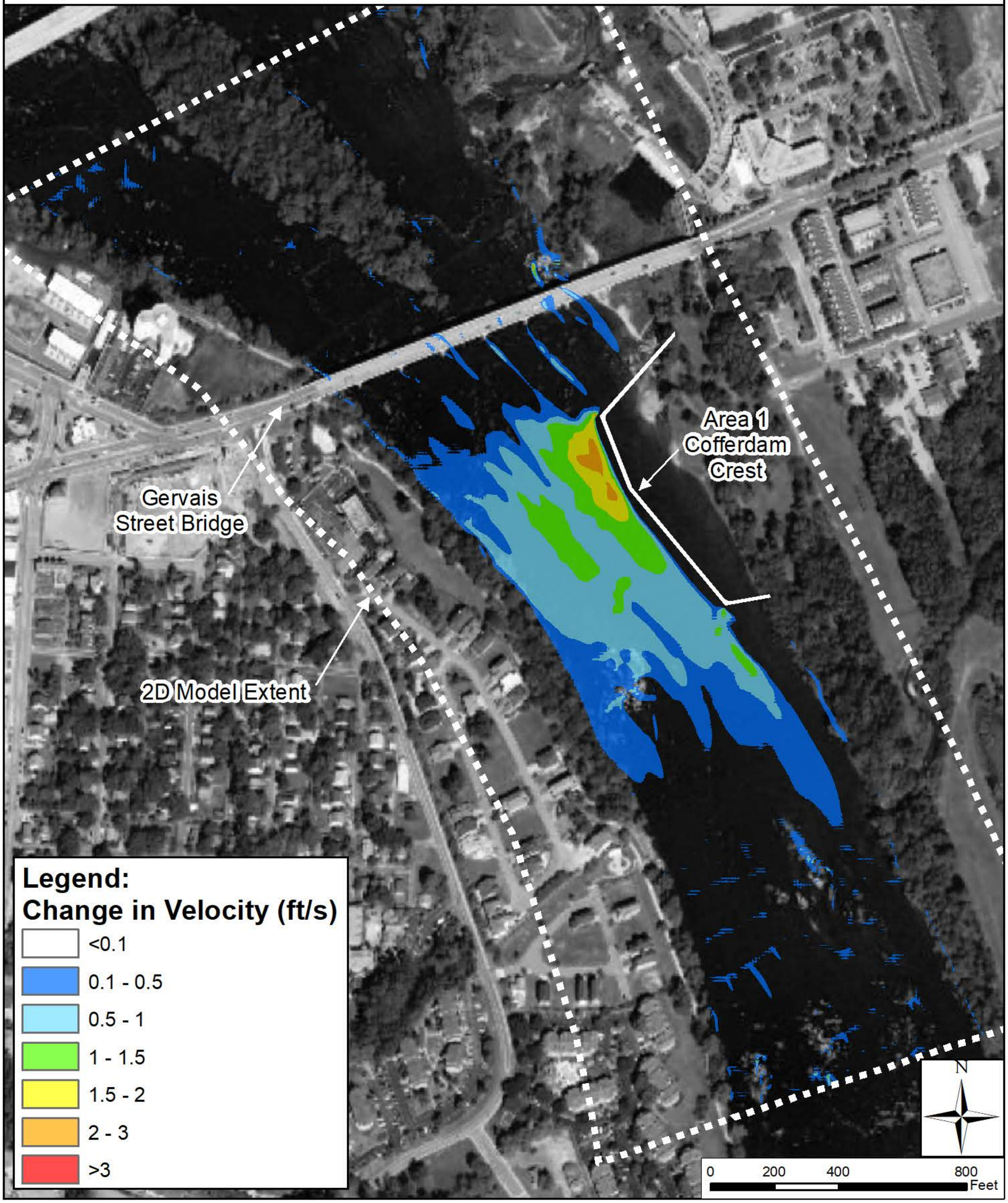
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A3: Normal Flow (8,564 cfs)
Proposed Area-1 Scenario: Flow Velocity



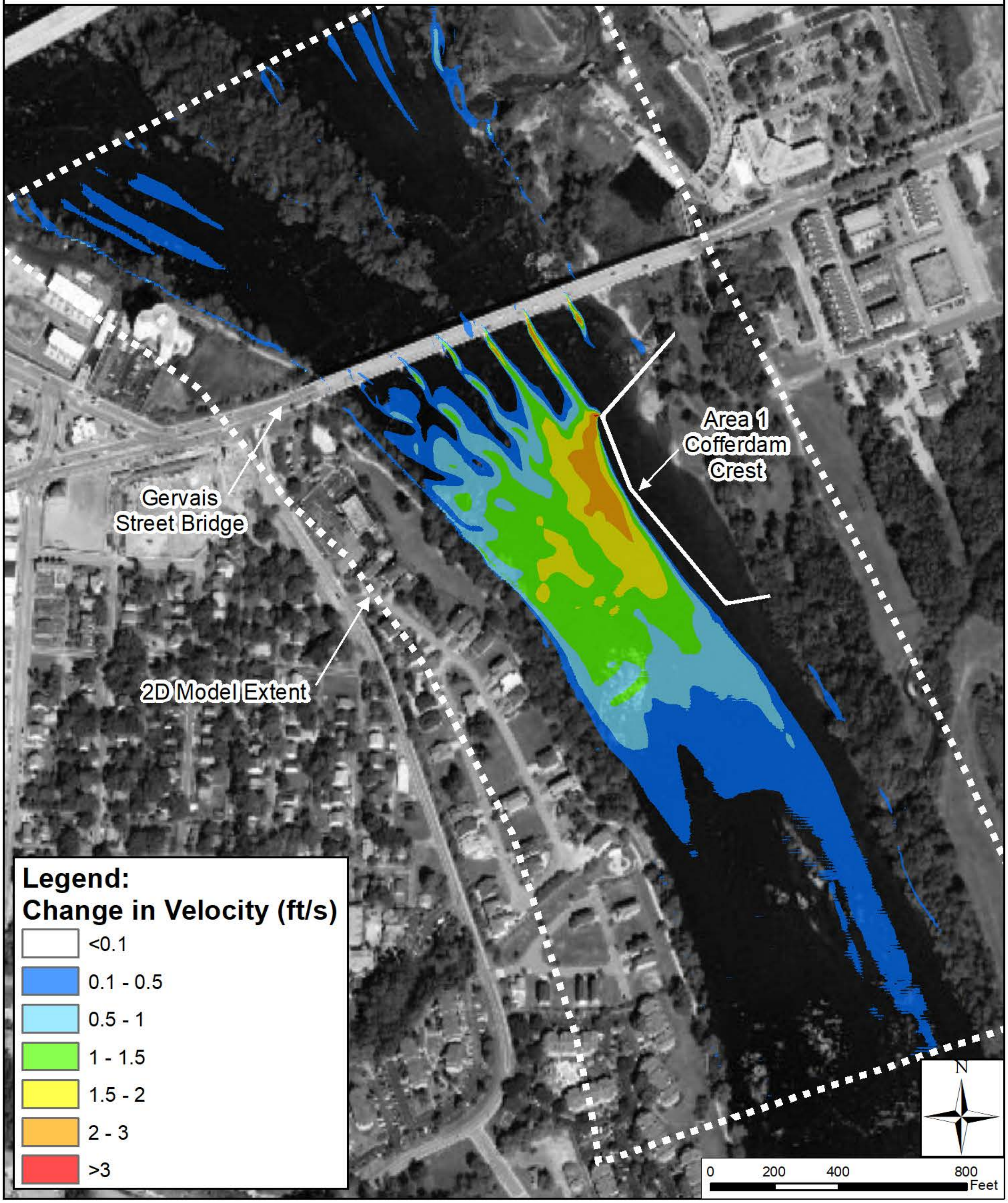
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A4: Crest Flow (26,000 cfs)
Proposed Area-1 Scenario: Flow Velocity



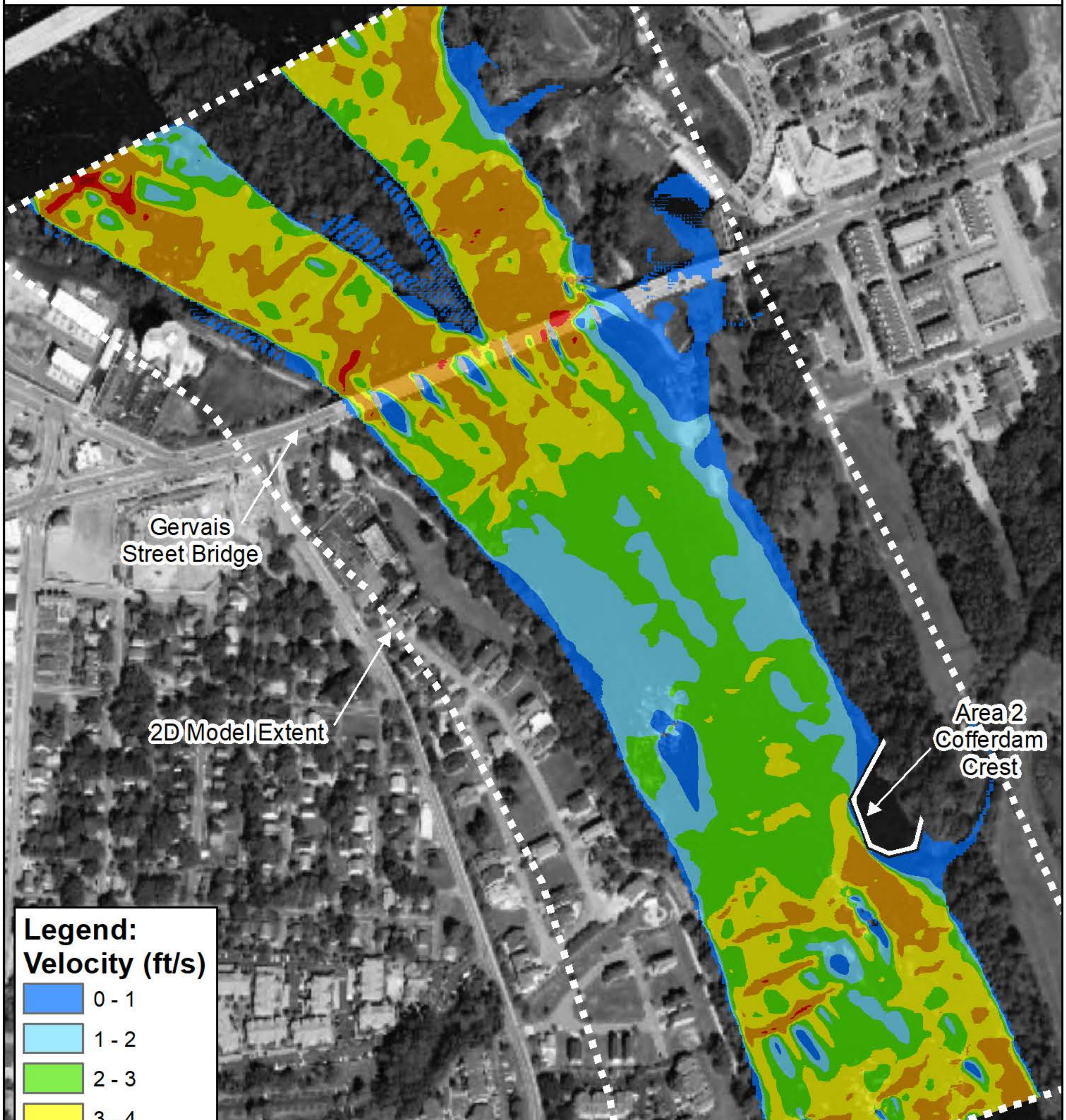
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A5: Normal Flow (8,564 cfs)
Proposed Area-1 Scenario: Change in Flow Velocity



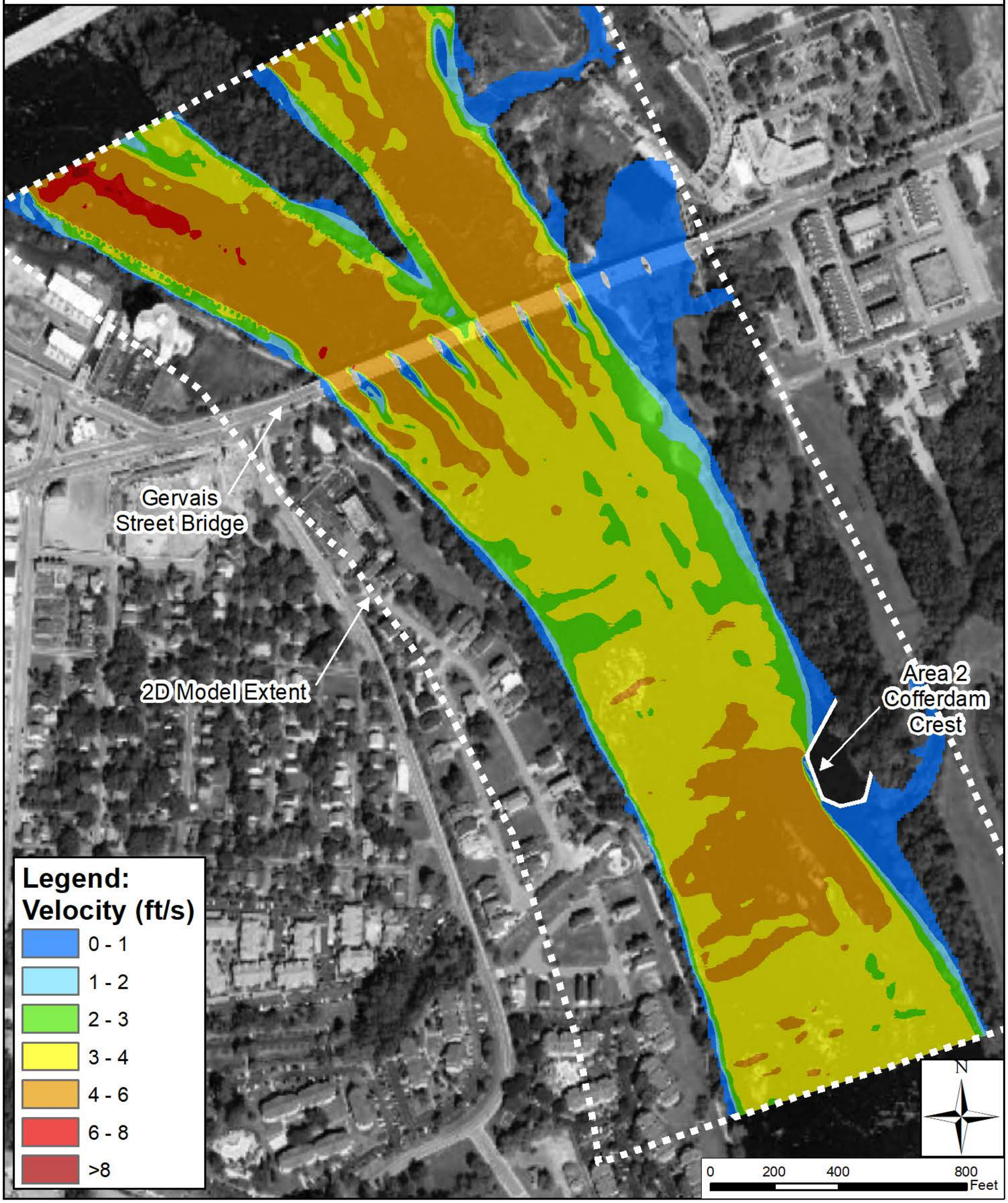
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A6: Crest Flow (26,000 cfs)
Proposed Area-1 Scenario: Change in Flow Velocity



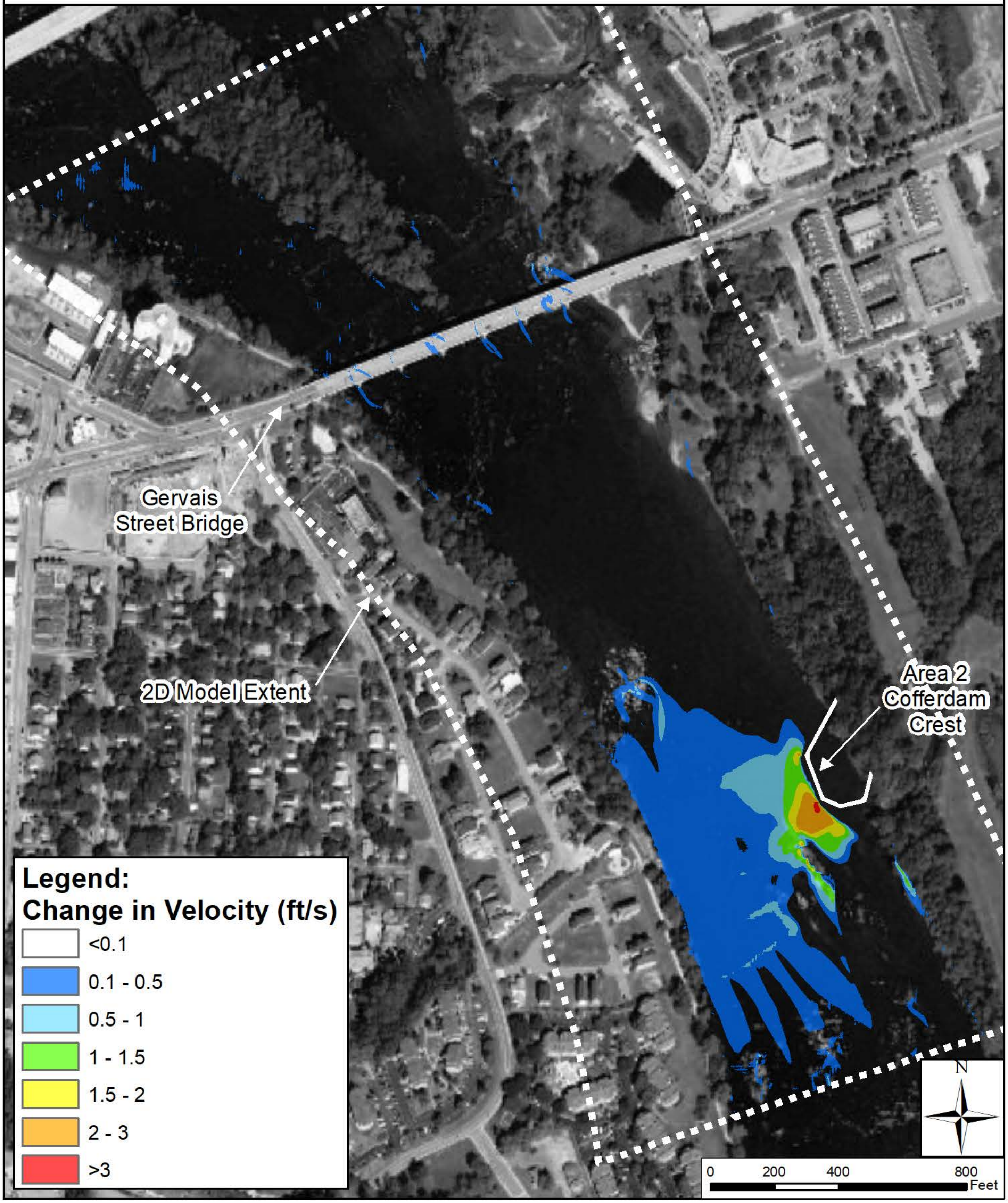
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A7: Normal Flow (8,564 cfs)
Proposed Area-2 Scenario: Flow Velocity



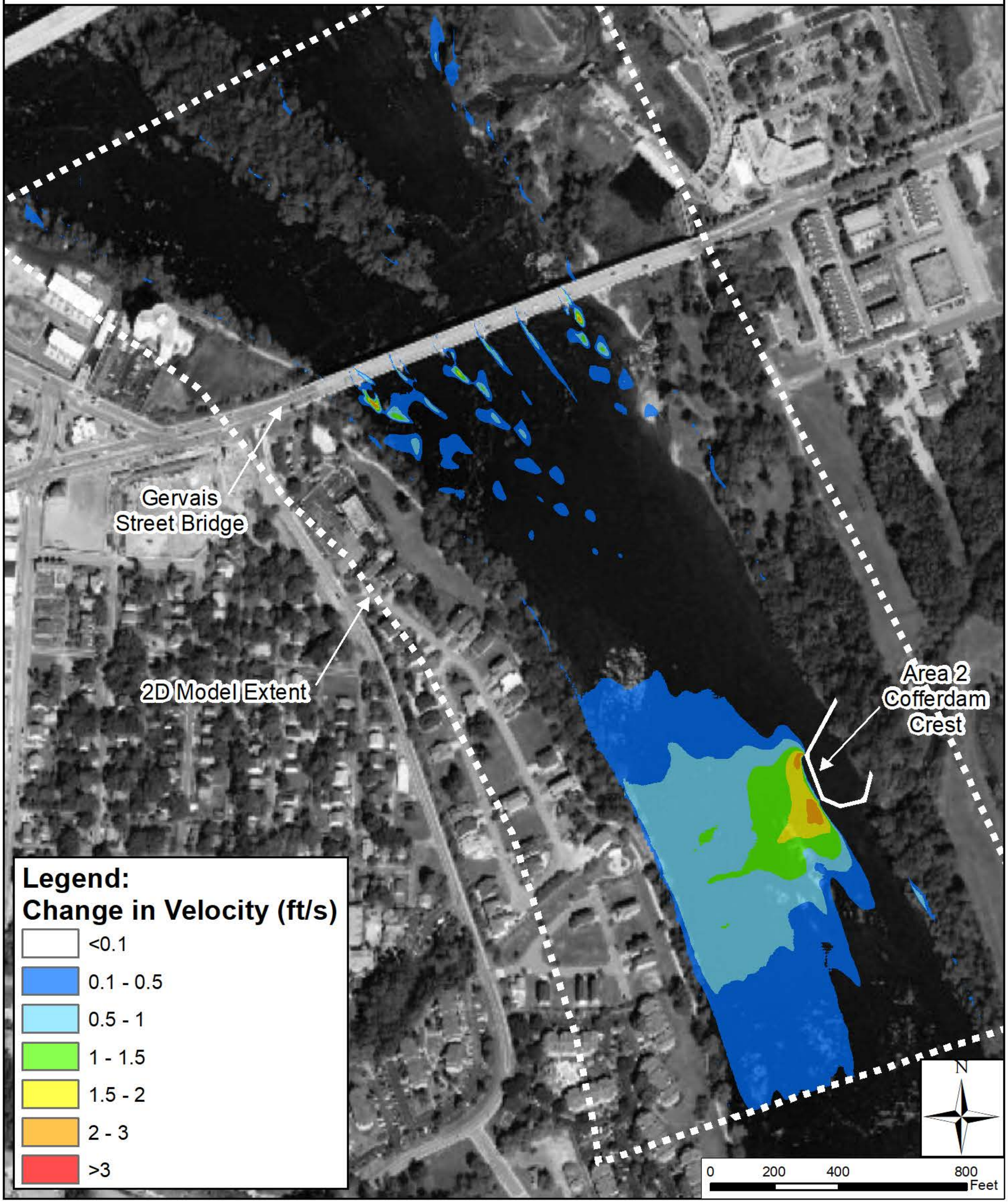
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A8: Crest Flow (26,000 cfs)
Proposed Area-2 Scenario: Flow Velocity



Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A9: Normal Flow (8,564 cfs)
Proposed Area-2 Scenario: Change in Flow Velocity



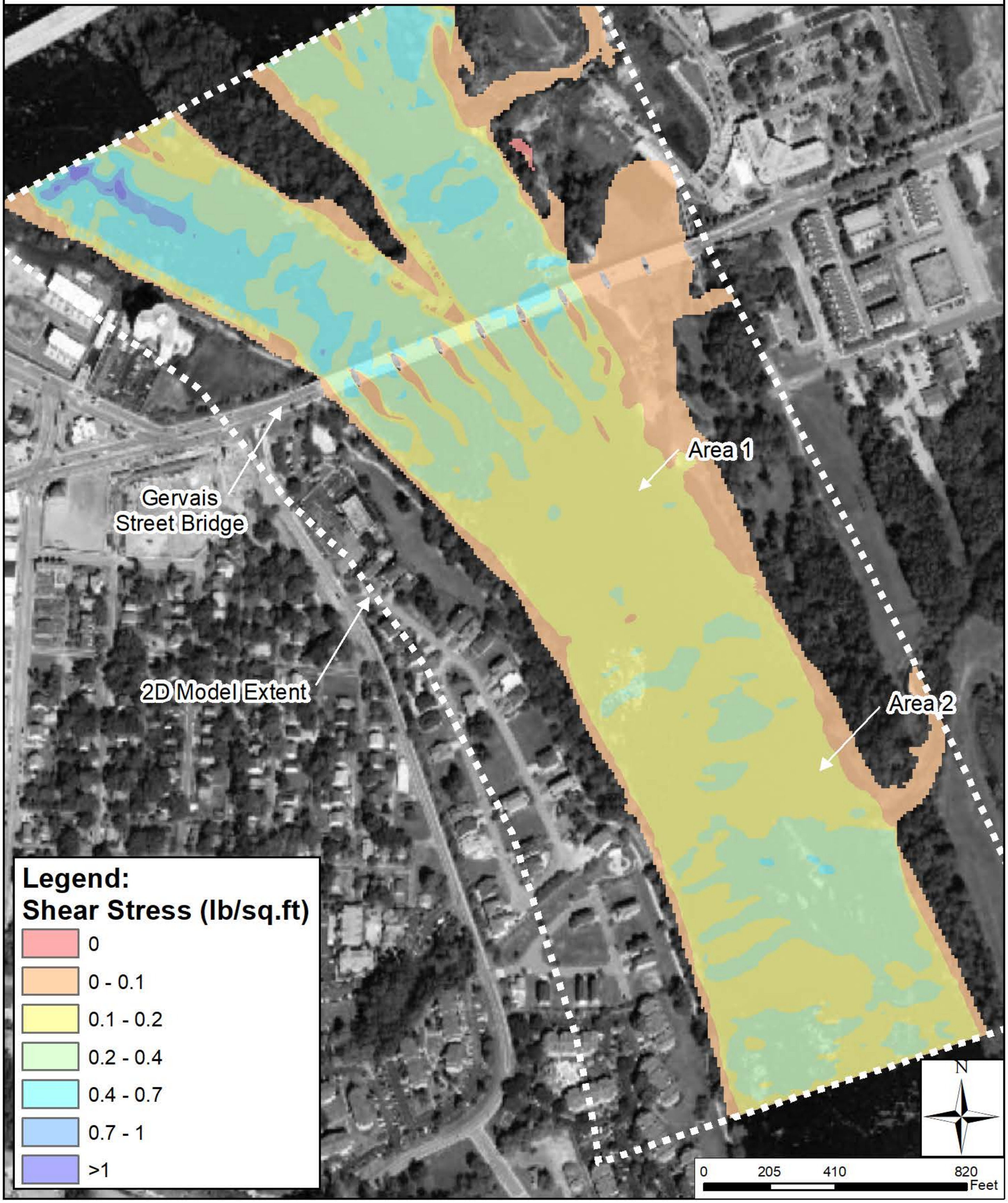
Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A10: Crest Flow (26,000 cfs)
Proposed Area-2 Scenario: Change in Flow Velocity



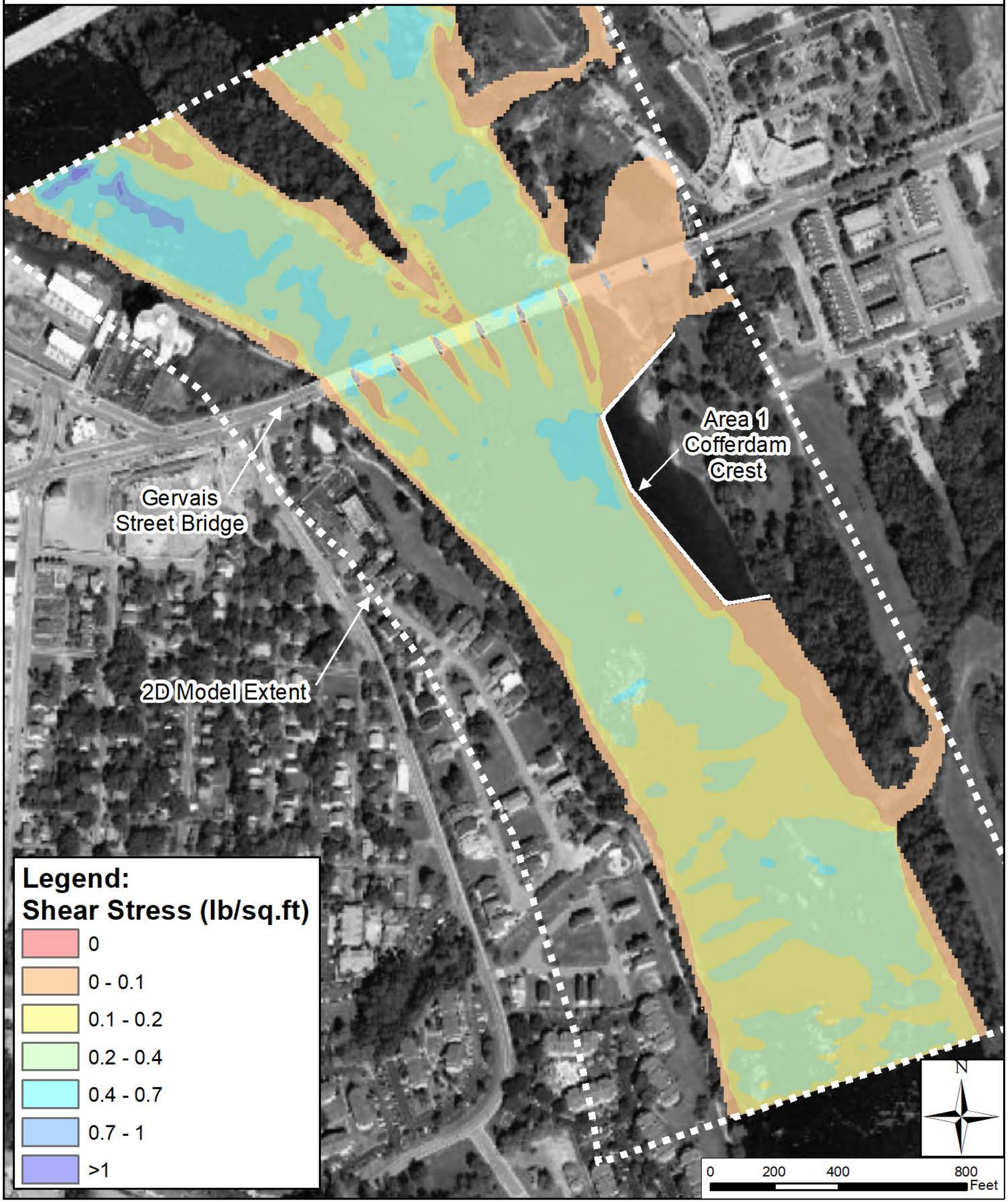
Legend:
Change in Velocity (ft/s)

- <0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- >3

Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A11: Crest Flow (26,000 cfs)
Existing Scenario: Shear Stress



Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A12: Crest Flow (26,000 cfs)
Proposed Area-1 Scenario: Shear Stress



Congaree River Remediation Project
West Bank Erosion Potential Evaluation
Figure A13: Crest Flow (26,000 cfs)
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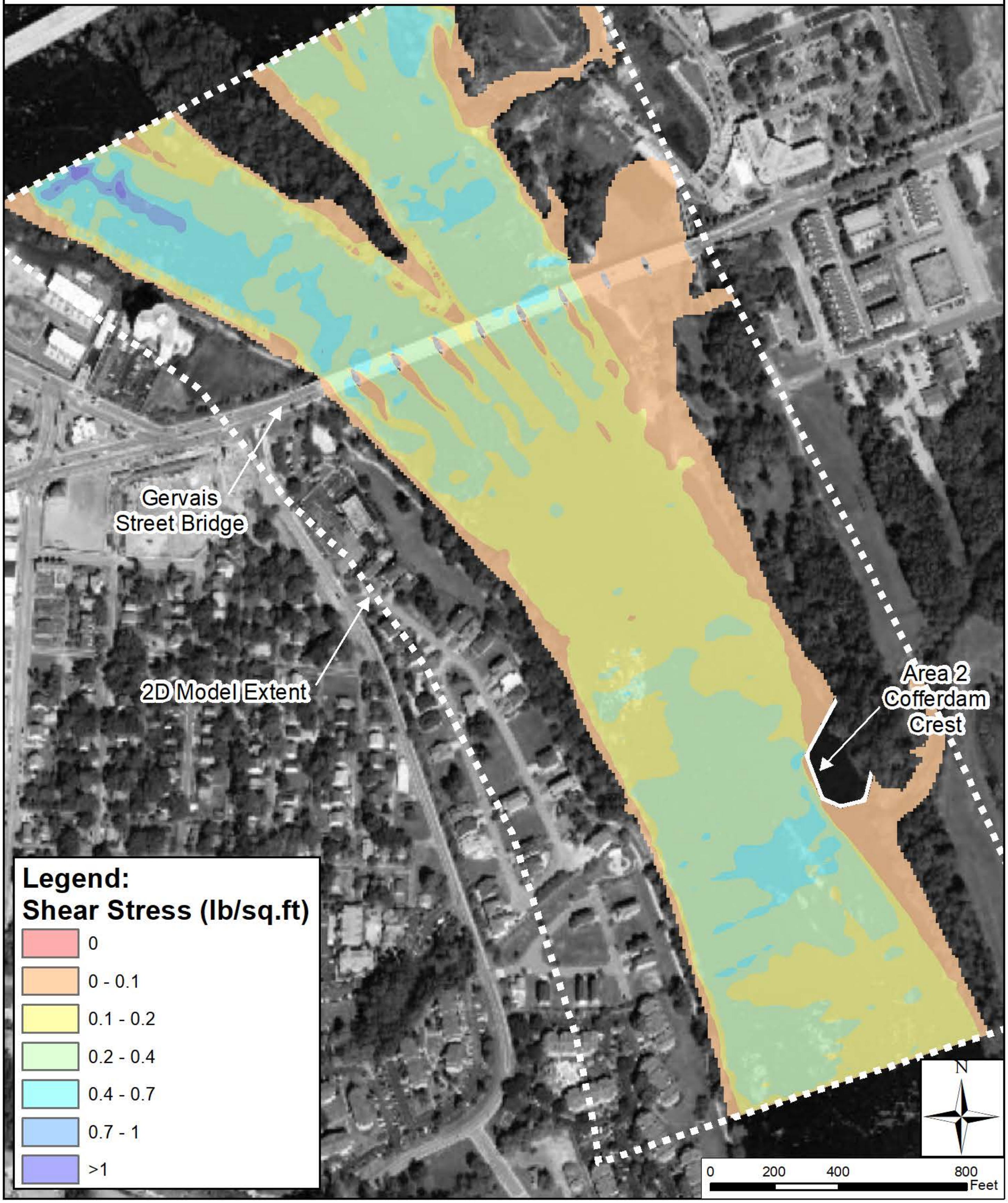

Healthy People. Healthy Communities.

June 8, 2020

Mr. Paul Biery
Senior Project Manager
Dominion Energy South Carolina
400 Otarre Parkway
Cayce, SC 29033

RE: River Bottom Erosion Potential Evaluation
SCE&G Fleet Maintenance Site (Congaree River)
Columbia, South Carolina

Dear Mr. Biery,

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If you have any questions or comments please contact me at (803) 898-0747 or cassidga@dhec.sc.gov.

Sincerely,

Greg Cassidy
State Voluntary Cleanup Program
Bureau of Land and Waste Management

cc: File 52561
Lucas Berresford, BLWM
Veronica Barringer, Midlands EA Region
Al Peeples, Midlands EA Region

VIA ELECTRONIC MAIL

March 10, 2020

William Zeli, P.E., Environment Program Manager
Apex Companies, LLC
1600 Commerce Circle
Trafford, PA 15085

Subject: **River Bottom Erosion Potential Evaluation**
Congaree River Remediation Project
Columbia, South Carolina

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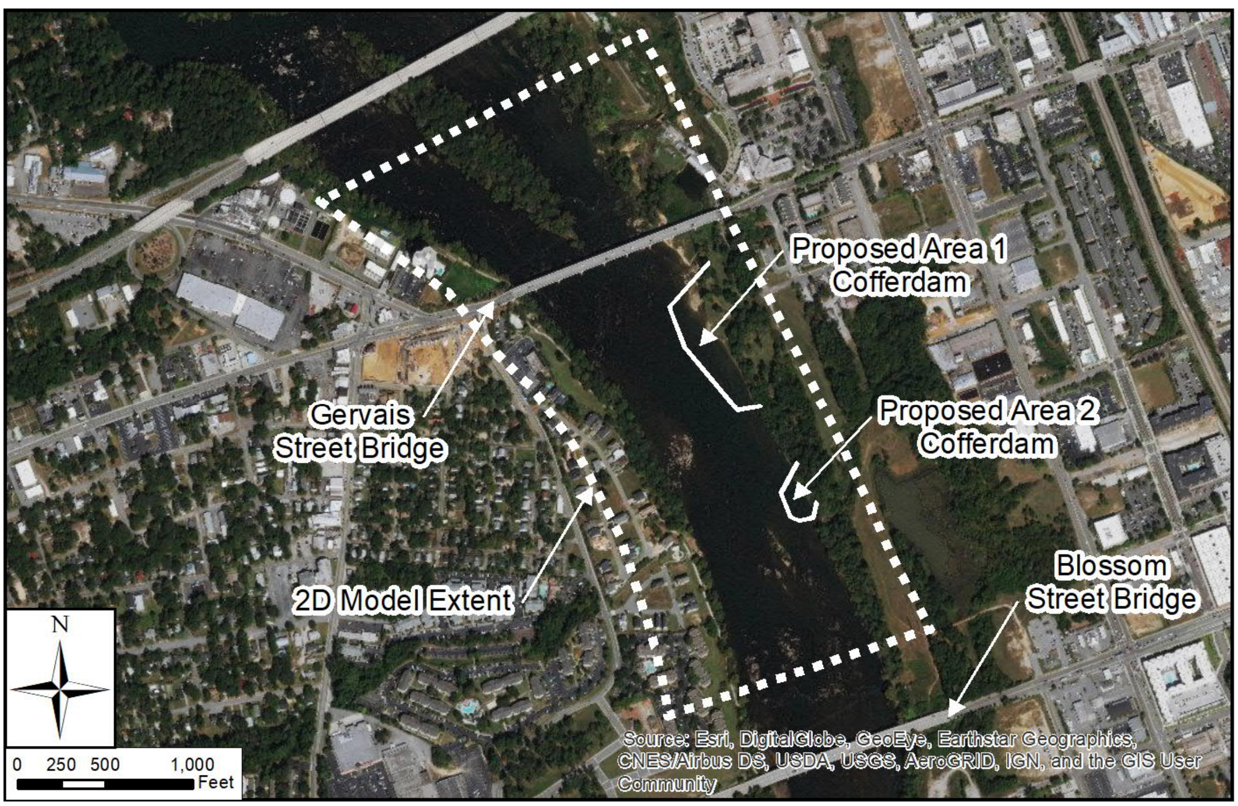

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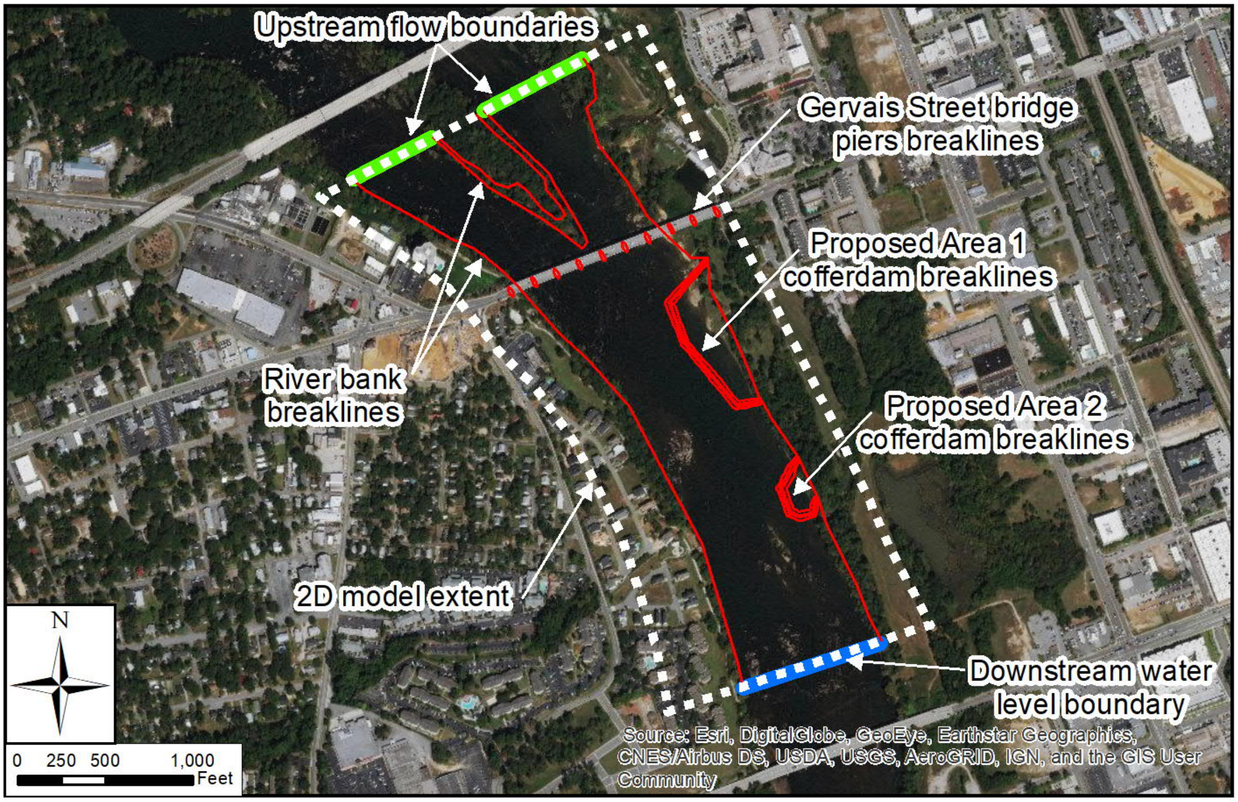

Figure 2: Model Details

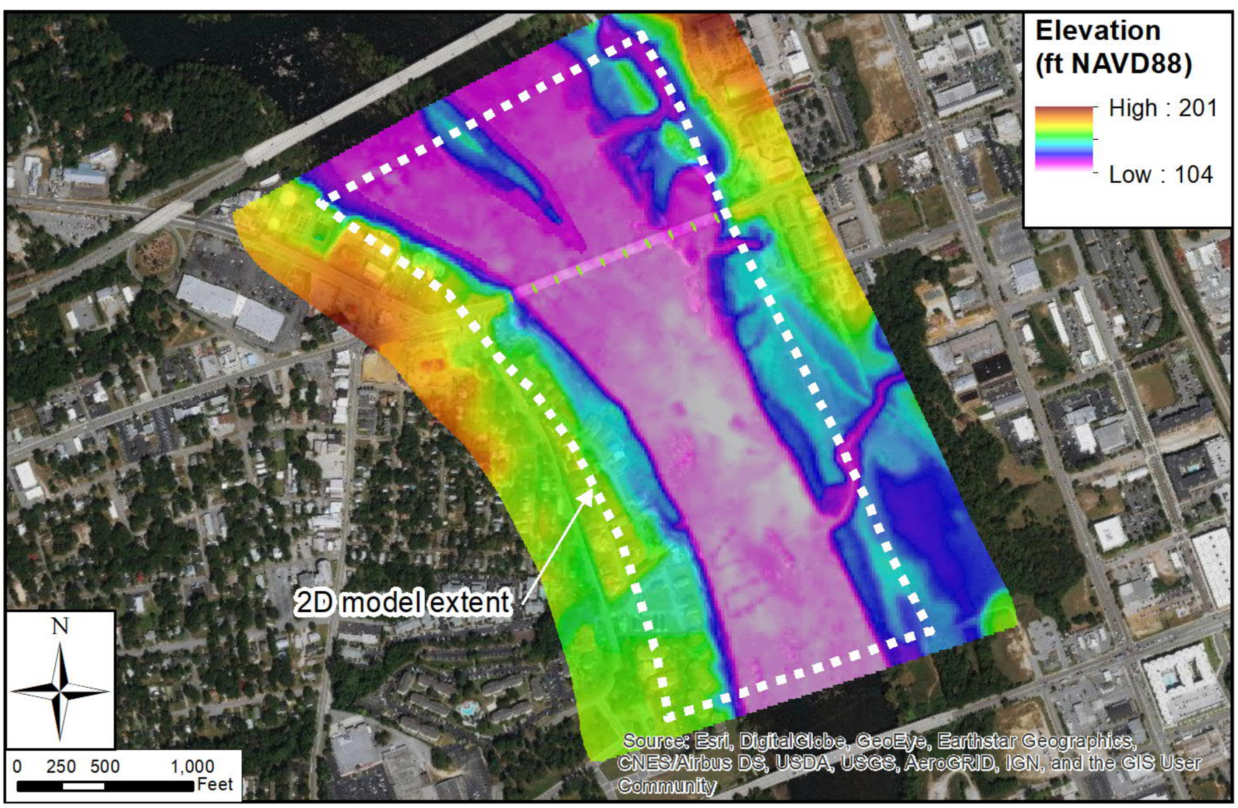

Figure 3: Existing Digital Elevation Model

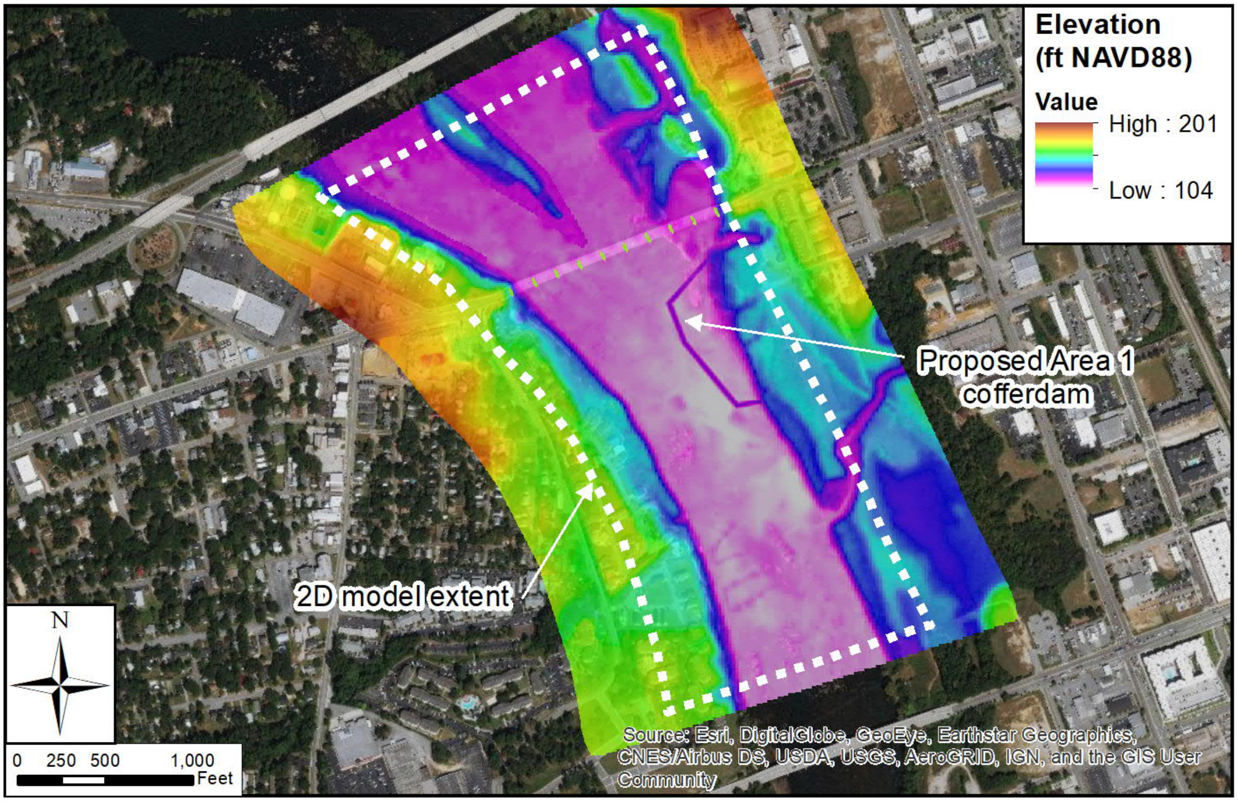

Figure 4: Proposed Area 1 Cofferdam Digital Elevation Model

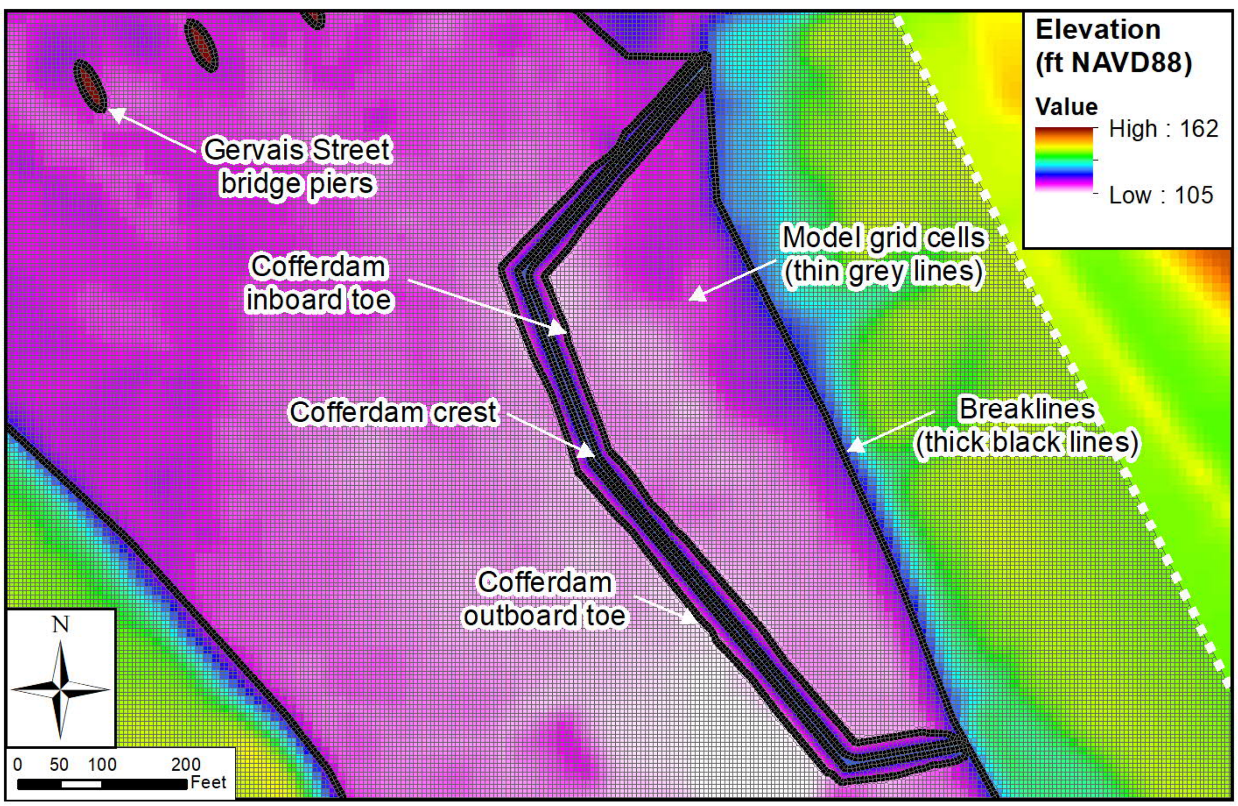

Figure 5: Proposed Area 1 Cofferdam Mesh Details

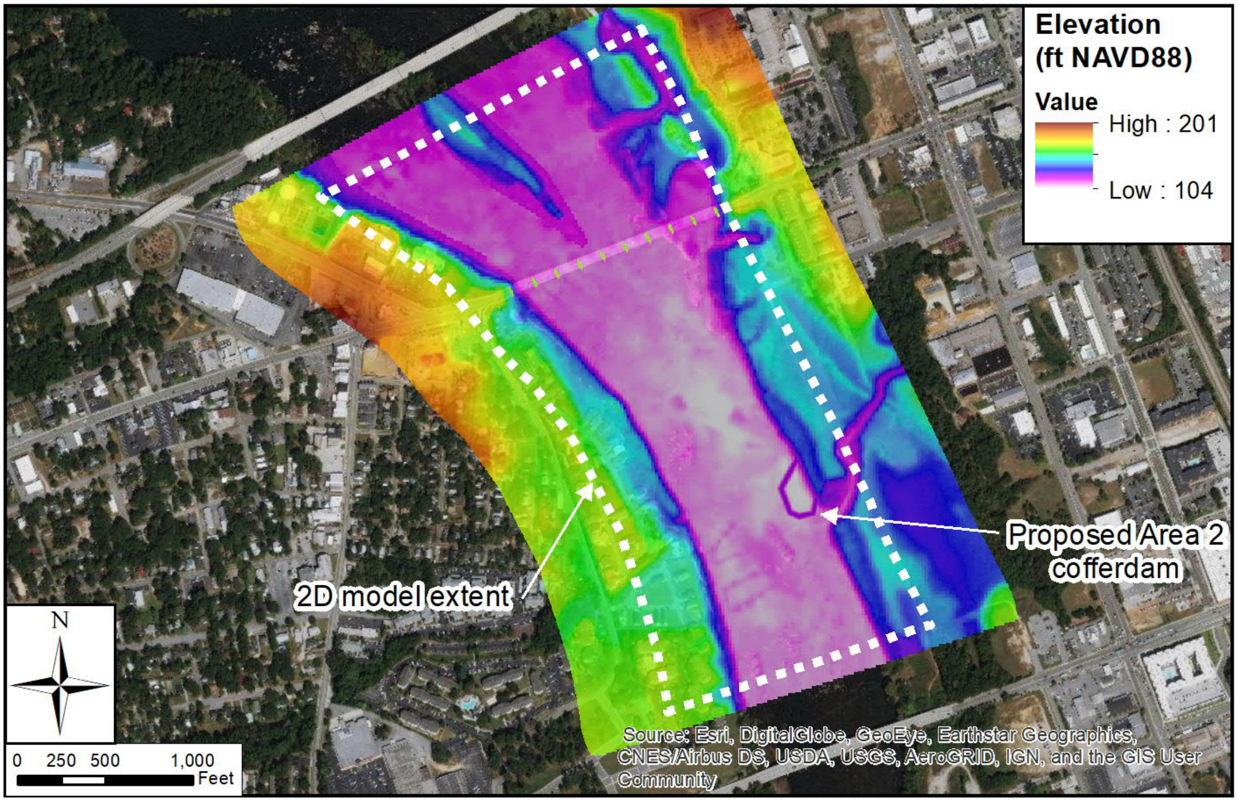

Figure 6: Proposed Area 2 Cofferdam Digital Elevation Model

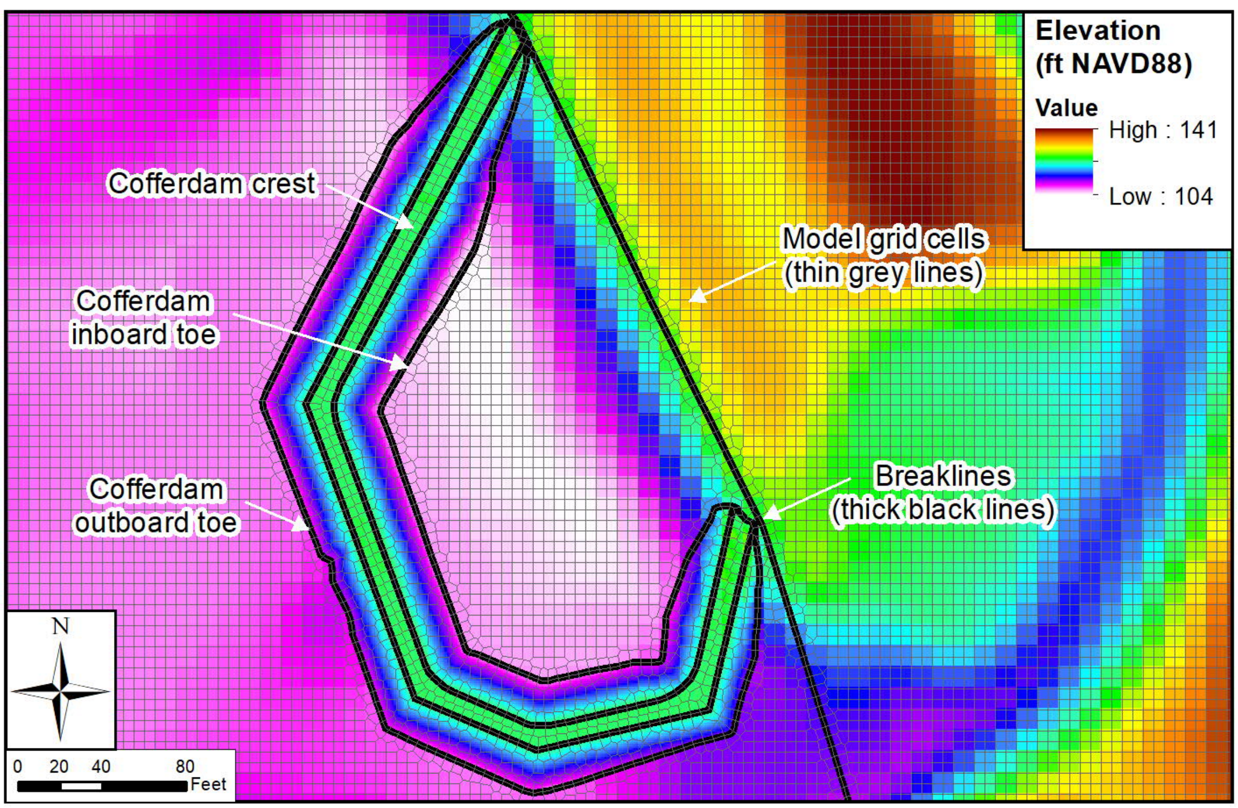

Figure 7: Proposed Area 2 Cofferdam Mesh Details

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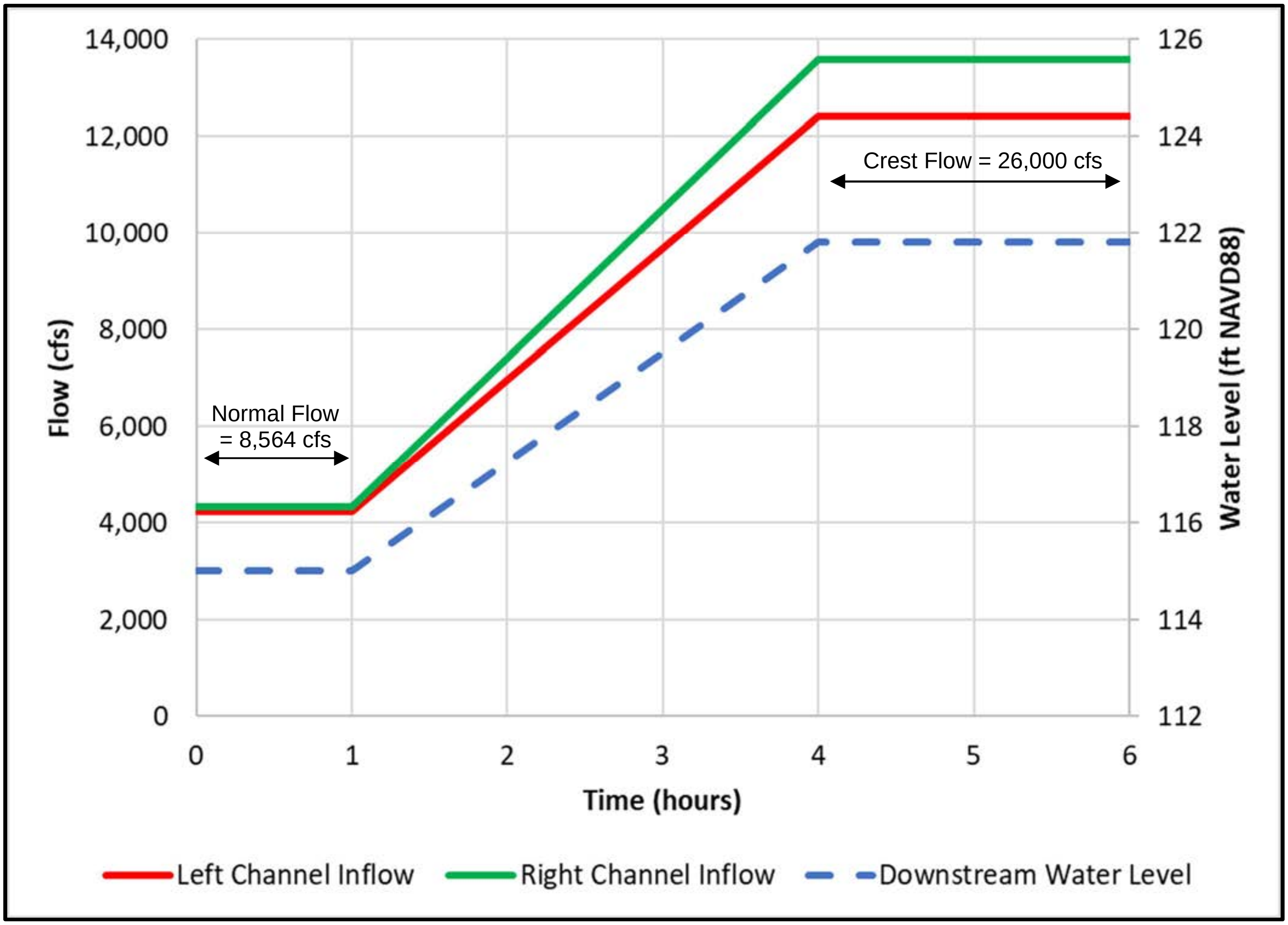


Figure 8: Upstream and Downstream Boundary Conditions

2D MODEL RESULTS

Separate two-dimensional unsteady flow analyses were performed for the Existing, Proposed Area 1, and Proposed Area 2 models. Additional trial analyses were also performed to test the model’s sensitivity to the computational timestep interval and the application of the full momentum equations. After our initial quality assurance review, we determined that the adaptive computational interval and the full momentum equations should be utilized for the final model runs, in accordance with the HEC-RAS 2D Modeling User’s Manual.

The velocity and shear stress results were extracted from all of the models after one hour to represent the normal flow condition of 8,564 cfs, and after six hours to represent the crest flow condition of 26,000 cfs. The results were used to develop figures that show the spatial variation of flow velocity/shear stress throughout the Congaree River channel and to show changes in velocity due to the construction of the Area 1 and Area 2 cofferdams.

The following figures are provided in Attachment A:

- Figure A1: Normal Flow (8,564 cfs) Existing Scenario – Flow Velocity
- Figure A2: Crest Flow (26,000 cfs) Existing Scenario – Flow Velocity
- Figure A3: Normal Flow (8,564 cfs) Proposed Area-1 Scenario – Flow Velocity
- Figure A4: Crest Flow (26,000 cfs) Proposed Area-1 Scenario – Flow Velocity
- Figure A5: Normal Flow (8,564 cfs) Proposed Area-1 Scenario – Change in Flow Velocity
- Figure A6: Crest Flow (26,000 cfs) Proposed Area-1 Scenario – Change in Flow Velocity
- Figure A7: Normal Flow (8,564 cfs) Proposed Area-2 Scenario – Flow Velocity
- Figure A8: Crest Flow (26,000 cfs) Proposed Area-2 Scenario – Flow Velocity
- Figure A9: Normal Flow (8,564 cfs) Proposed Area-2 Scenario – Change in Flow Velocity
- Figure A10: Crest Flow (26,000 cfs) Proposed Area-2 Scenario – Change in Flow Velocity
- Figure A11: Normal Flow (8,564 cfs) Existing Scenario – Shear Stress
- Figure A12: Crest Flow (26,000 cfs) Existing Scenario – Shear Stress
- Figure A13: Normal Flow (8,564 cfs) Proposed Area-1 Scenario – Shear Stress
- Figure A14: Crest Flow (26,000 cfs) Proposed Area-1 Scenario – Shear Stress
- Figure A15: Normal Flow (8,564 cfs) Proposed Area-1 Scenario – Change in Shear Stress
- Figure A16: Crest Flow (26,000 cfs) Proposed Area-1 Scenario – Change in Shear Stress
- Figure A17: Normal Flow (8,564 cfs) Proposed Area-2 Scenario – Shear Stress
- Figure A18: Crest Flow (26,000 cfs) Proposed Area-2 Scenario – Shear Stress
- Figure A19: Normal Flow (8,564 cfs) Proposed Area-2 Scenario – Change in Shear Stress
- Figure A20: Crest Flow (26,000 cfs) Proposed Area-2 Scenario – Change in Shear Stress

The following sections discuss the **velocity and shear stress results for the Congaree River in the vicinity of the project area** for the Existing, Proposed Area-1, and Proposed Area-2 scenarios. A summary of the velocity and shear stress results is provided in Table 1 and 2, respectively.

Table 1: Velocity Results Summary

Velocity (ft/s)	Reference Values (USBR, 2015)	Existing Scenario		Proposed Area-1 Scenario		Proposed Area-2 Scenario	
		Normal Flow (8,564 cfs)	Crest Flow (26,000 cfs)	Normal Flow (8,564 cfs)	Crest Flow (26,000 cfs)	Normal Flow (8,564 cfs)	Crest Flow (26,000 cfs)
Upstream and immediately downstream of Gervais St Bridge	1.5 – 6	3 – 5	4 – 6	3 – 5	4 – 6	3 – 5	4 – 6
Next 1,200 feet		1 – 3	2 – 4, some localized 5	2 – 4, some localized 4.5	4 – 6, some localized 6.5	1 – 3	2 – 4, some localized 5
Final 800 feet		2 – 4, some localized 5	2 – 4, some localized 5	2 – 4, some localized 5	2 – 4, some localized 5	2 – 4, some localized 6	3.5 – 5.5, some localized 6

Table 2: Shear Stress Results Summary

Shear Stress (lb/ft^2)	Reference Values (USBR, 2015)	Existing Scenario		Proposed Area-1 Scenario		Proposed Area-2 Scenario	
		Normal Flow (8,564 cfs)	Crest Flow (26,000 cfs)	Normal Flow (8,564 cfs)	Crest Flow (26,000 cfs)	Normal Flow (8,564 cfs)	Crest Flow (26,000 cfs)
Upstream and immediately downstream of Gervais St Bridge	0.02 – 0.67	0.2 – 0.5, some localized 0.7	0.3 – 0.5, some localized >0.7	0.2 – 0.5, some localized 0.7	0.3 – 0.5, some localized >0.7	0.2 – 0.5, some localized 0.7	0.3 – 0.5, some localized >0.7
Next 1,200 feet		0.05 – 0.2	0.1 – 0.2	0.1 – 0.4, some localized 0.6	0.2 – 0.5, some localized 0.7	0.05 – 0.2	0.1 – 0.2
Final 800 feet		0.1 – 0.5, some localized 0.7	0.1 – 0.4, some localized 0.5	0.1 – 0.5, some localized 0.7	0.1 – 0.4, some localized 0.5	0.1 – 0.4, some localized >0.9	0.2 – 0.5, some localized 0.7

RIVER BOTTOM EROSION POTENTIAL EVALUATION

For existing conditions, the river velocities within the Congaree River during normal (8,564 cfs) and crest (26,000 cfs) flow conditions vary between 1 and 6 ft/s. Shear stresses range between 0.05 and 0.5 lb/ft^2, with some localized areas of increased shear of approximately 0.7 lb/ft^2. Note that the annual probability of exceedance for crest flow conditions is approximately 50%, i.e., a 1 in 2-year flood event.

The maximum increase in flow velocity across the river after cofferdam construction is up to 1.5 ft/s during normal and crest flow conditions. However, the velocities in this area remain within the 4 to 6 ft/s range. The maximum flow velocity increase within the immediate vicinity of the cofferdams is up to 3 ft/s but the velocities remain within the 5.5 to 6.5 ft/s range.

The change in shear stress after cofferdam construction follows a similar pattern, with increases between 0.1 and 0.4 lb/ft^2 adjacent to the structures, and the highest increases in close proximity to the structure, with peak values typically up to 0.5 lb/ft^2. Further out into the main river channel, the increase in shear stress typically ranges between 0 and 0.2 lb/ft^2. Some localized areas of higher shear values are located where rock outcrops are visible in the aerial imagery. The velocities suddenly increase at these locations to account for a reduced flow depth.

The U.S Department of the Interior, Bureau of Reclamation's (USBR's) Bank Stabilization Guidelines, Report No. SRH-2015-25 provides shear and velocity resistance values for various liner materials in Table 4-2. The table indicates that 'Soils' can withstand a shear stresses ranging between 0.02 to 0.67 lb/ft^2 and velocities ranging between 1.5 and 6 ft/s before eroding, depending upon the specific soil type. The sands and clays encountered in the soil samples and borings advanced along the river bottom at the project location can withstand velocities and shear stresses towards the lower end of the published range. Therefore, during existing flow conditions, some erosion of the river bottom should be anticipated. This is consistent with visual observations of the river that show cloudy water from suspended sediment during higher than normal flow conditions.

Figure B1 provided in Attachment B shows the anticipated depth of sediment in the river at the location of the proposed cofferdams based on a 2018 bathymetric survey and top of bedrock estimates from soil borings advanced between 2010 to 2012. The figure shows that the sediment depth around the perimeter of the cofferdam structures varies between 0 and 3 feet before top of rock is encountered.

The results of our hydraulic analyses indicate that the construction of the proposed cofferdams during normal and crest flow conditions will result in some localized increases in flow velocity and shear stress in the channel. However, the maximum reported values are already experienced in close proximity to the project site under existing conditions; therefore, the proposed cofferdams are unlikely to result in any significant changes to the river morphology in the area which is currently constantly changing and evolving over time in response to current flows and storm events. Therefore, in our professional opinion, erosion protection measures are not necessary for the river bottom or toe of the cofferdam during the construction period.

The proposed cofferdam design includes erosion protection provided by Articulated Concrete Block (ACB) Mats or Rock Mattresses along the outboard slope and extend onto the river bottom. Rock mattresses and ACB's can withstand maximum flow velocities of 19 and 25 ft/s respectively, which is significantly greater than the maximum values between 5.5 to 6.5 ft/s located in the vicinity of the cofferdams. The ACBs or rock mattresses will provide an additional factor of safety against erosion at the toe of the cofferdam and will also account for any complex localized three-dimensional flow patterns that are not represented using a 2D depth-averaged model.

If you have any questions or need any additional information, please contact John Osterle at 412-535-9823 or john.osterle@wsp.com, or Tom Edwards at 412-535-9818 or thomas.edwards@wsp.com.

Kind regards,

John P. Osterle
T Edwards

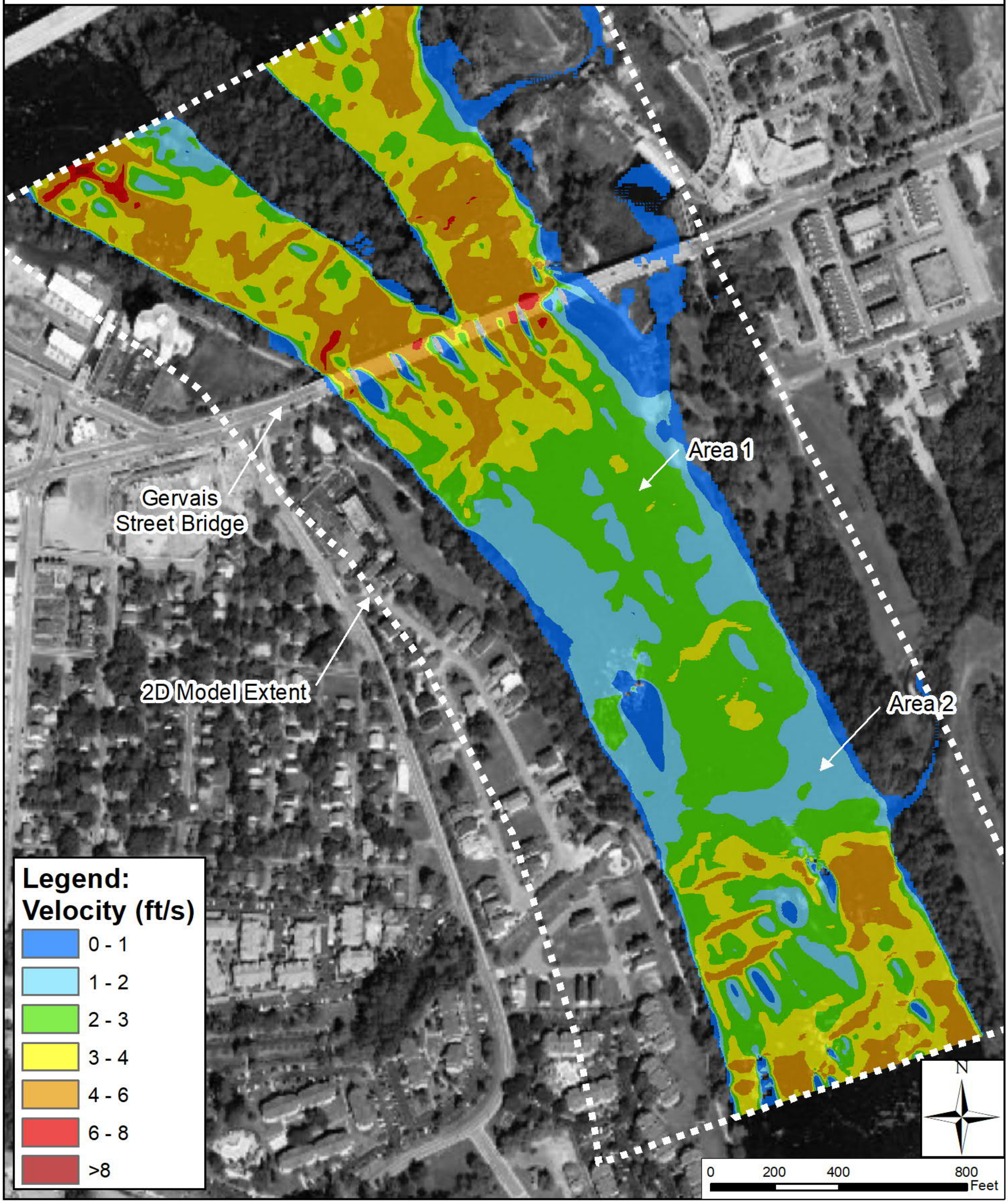
John P. Osterle, P.E.
Project Manager

Tom Edwards
Water Resources Engineer

TE: JPO

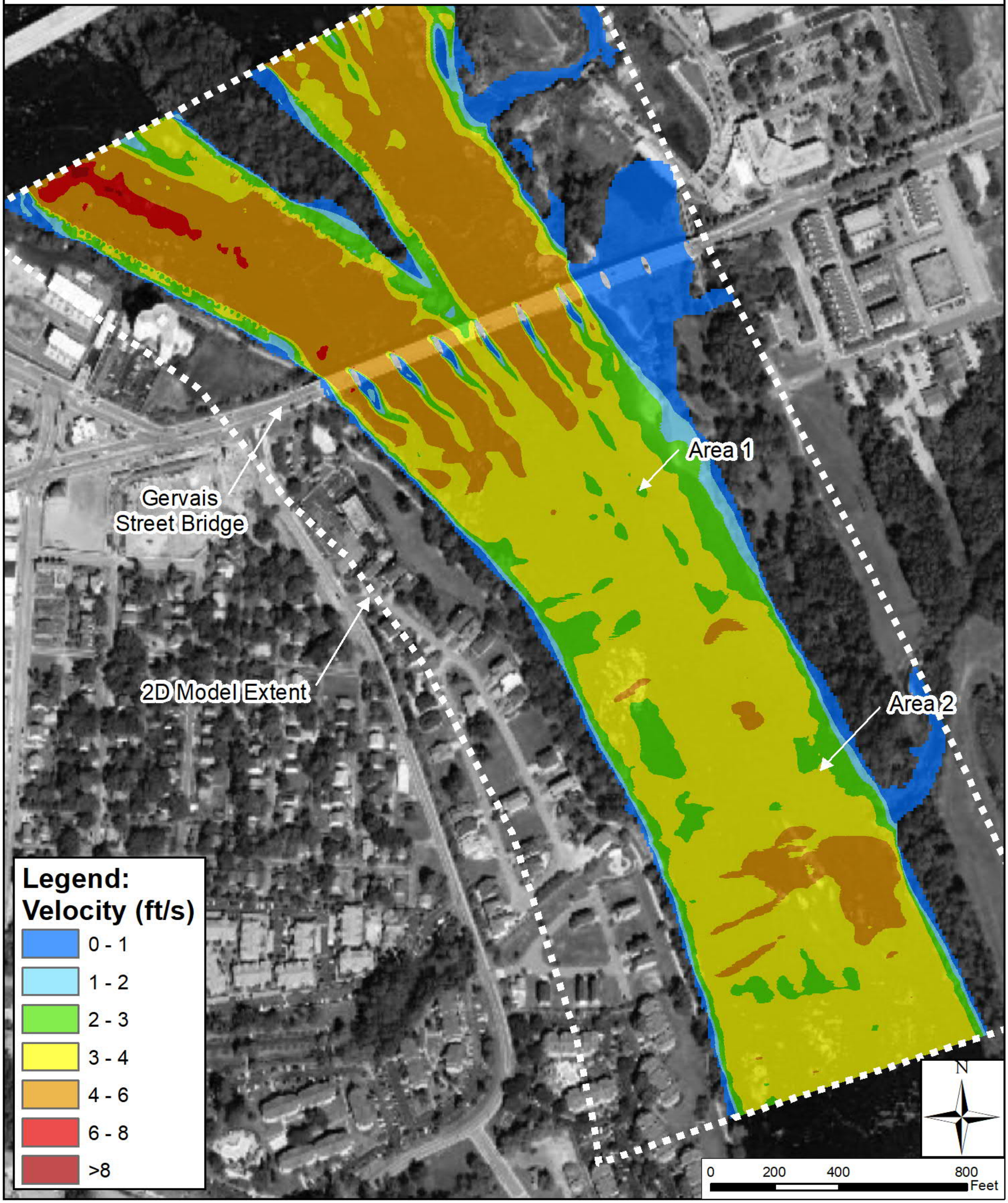
ATTACHMENT A: FIGURES

Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A1: Normal Flow (8,564 cfs)
Existing Scenario: Flow Velocity

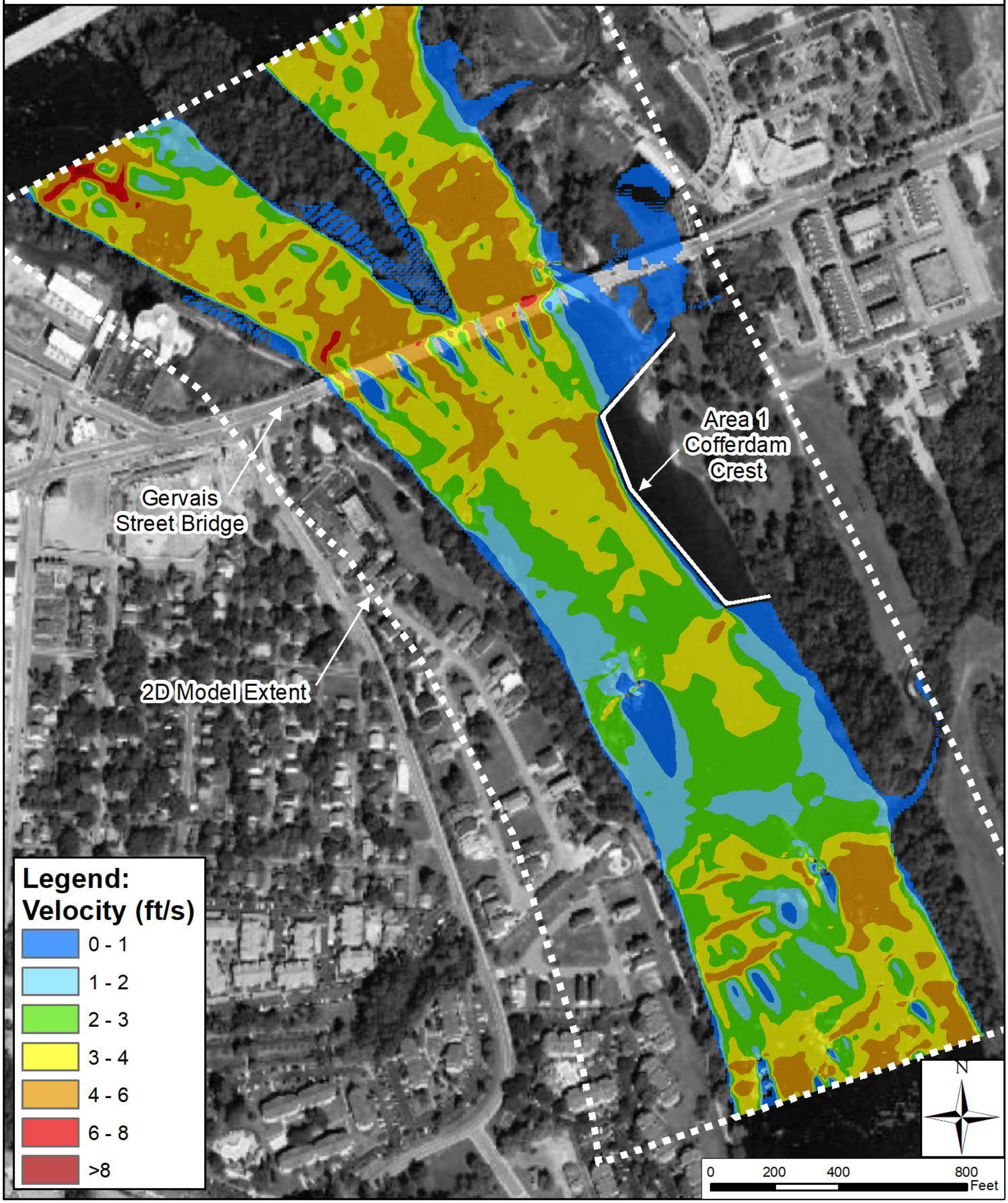


Congaree River Remediation Project
River Bottom Erosion Potential Evaluation

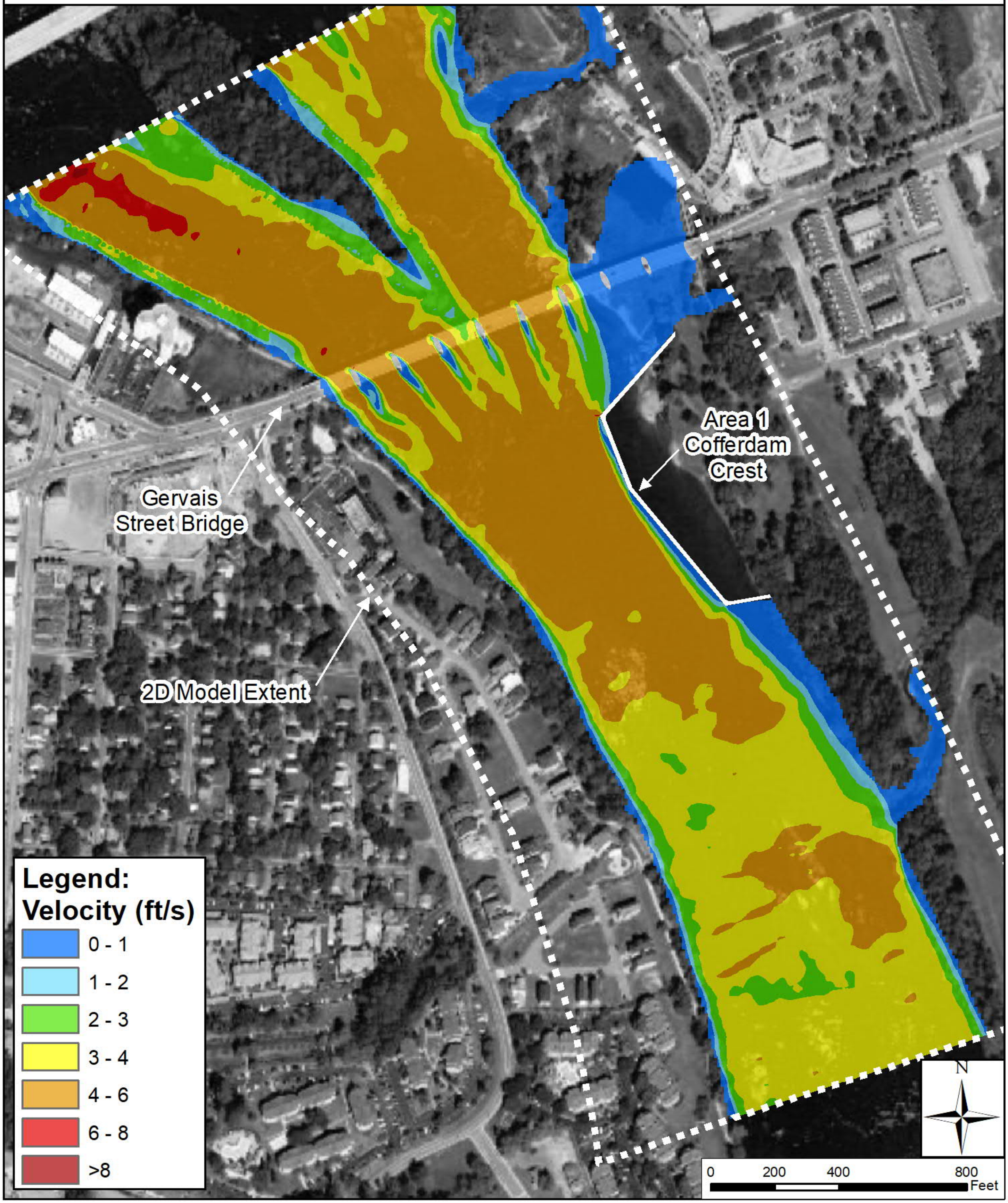
Figure A2: Crest Flow (26,000 cfs)
Existing Scenario: Flow Velocity



Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A3: Normal Flow (8,564 cfs)
Proposed Area-1 Scenario: Flow Velocity

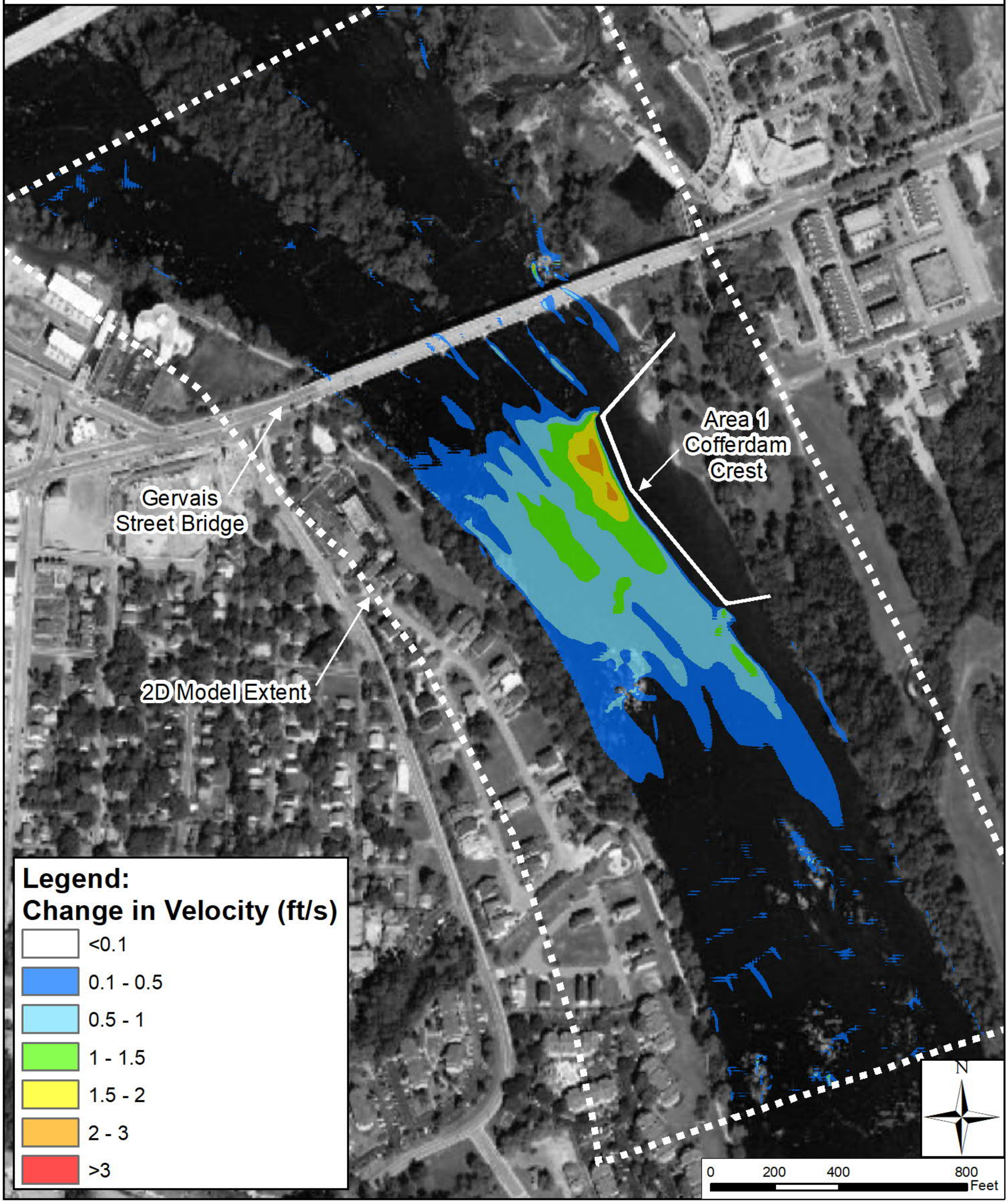


Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A4: Crest Flow (26,000 cfs)
Proposed Area-1 Scenario: Flow Velocity

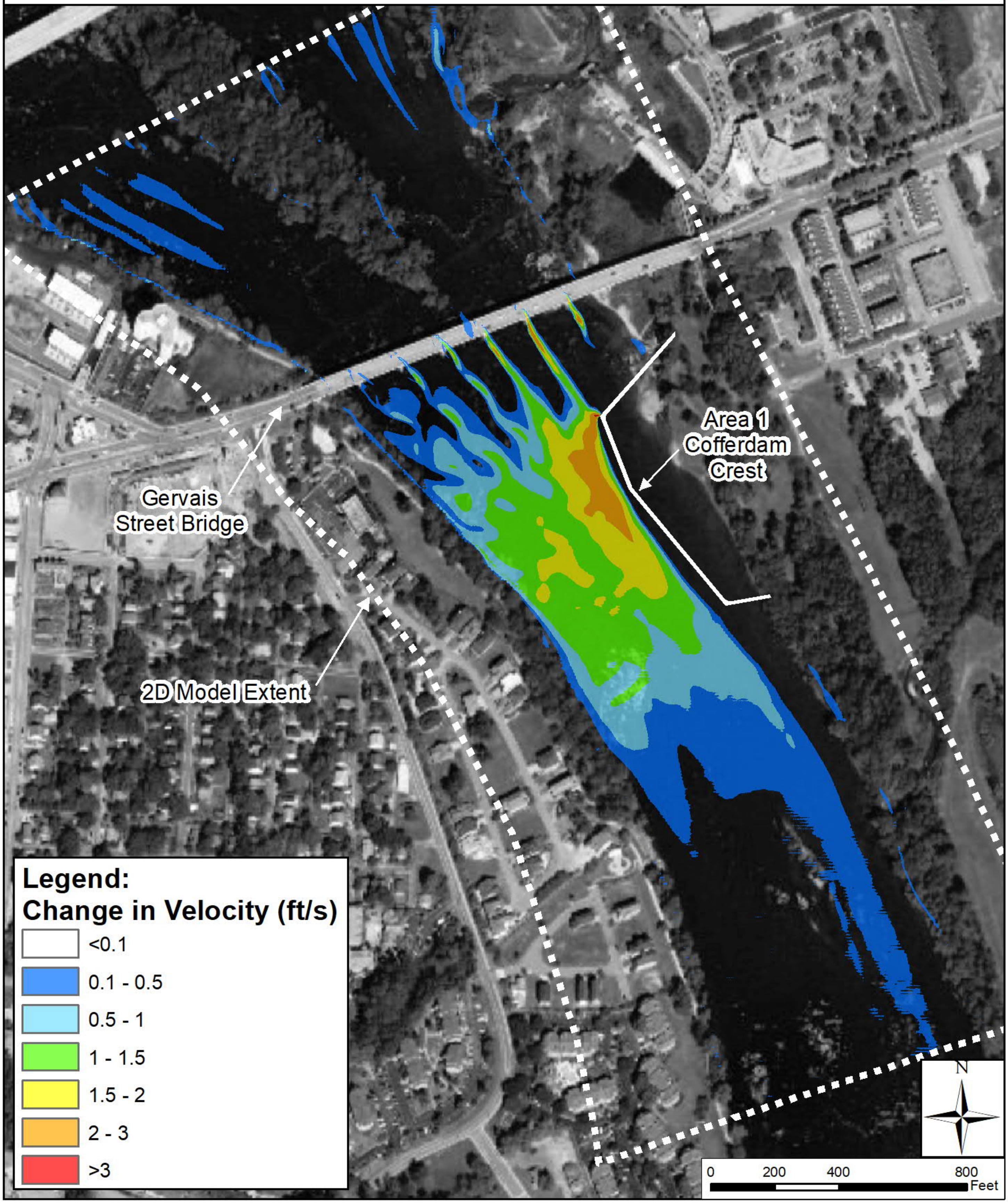


Congaree River Remediation Project
River Bottom Erosion Potential Evaluation

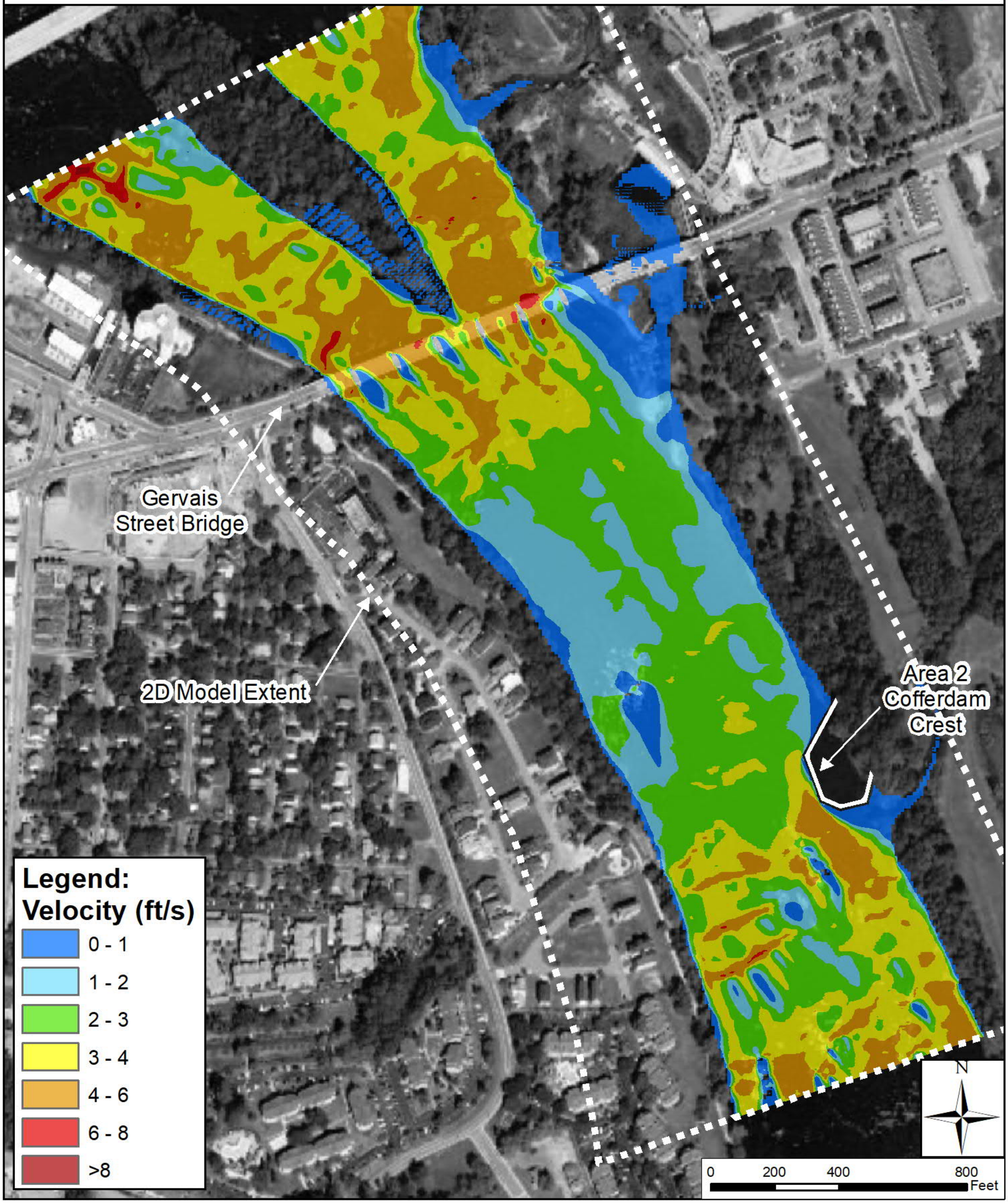
Figure A5: Normal Flow (8,564 cfs)
Proposed Area-1 Scenario: Change in Flow Velocity



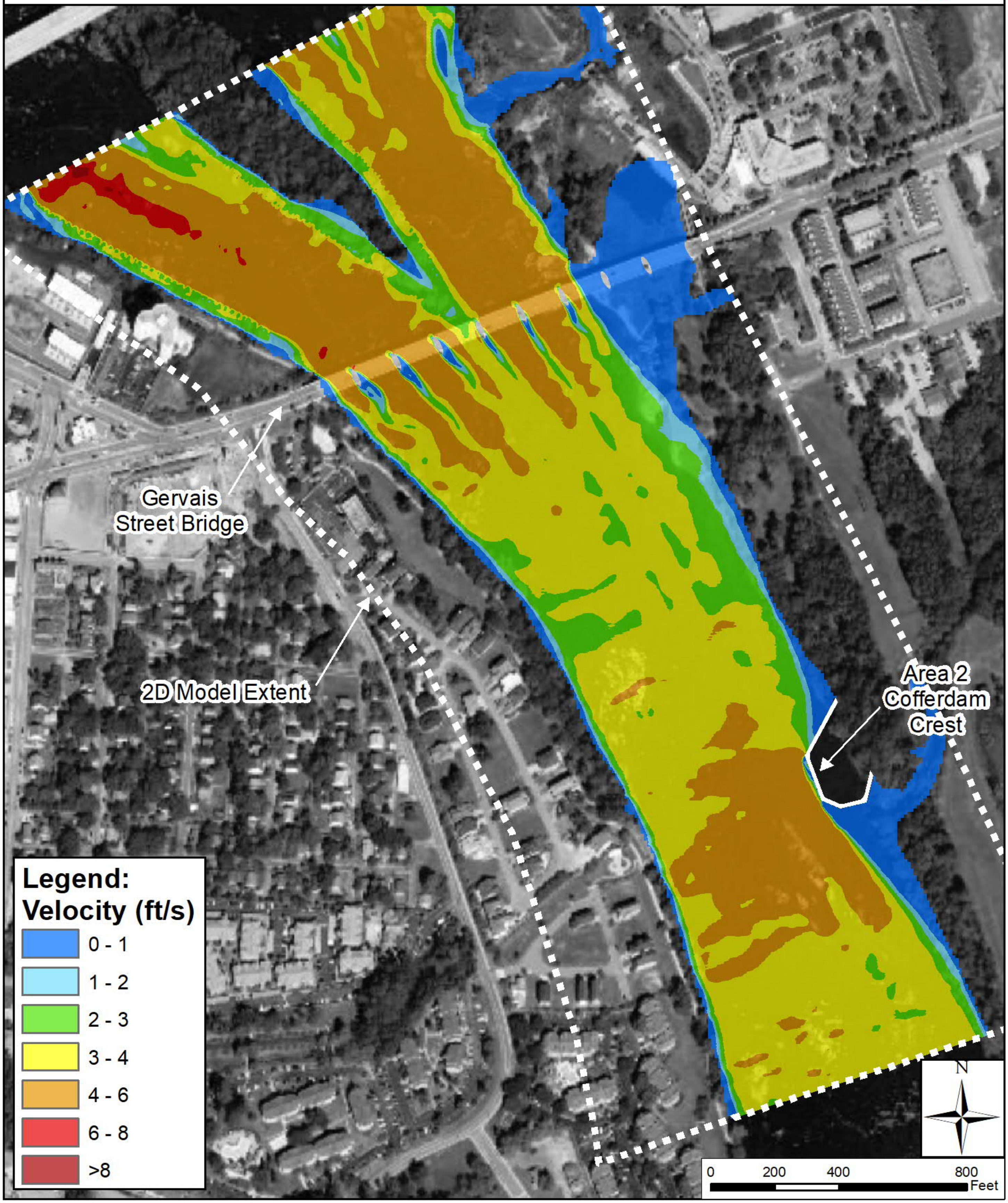
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A6: Crest Flow (26,000 cfs)
Proposed Area-1 Scenario: Change in Flow Velocity



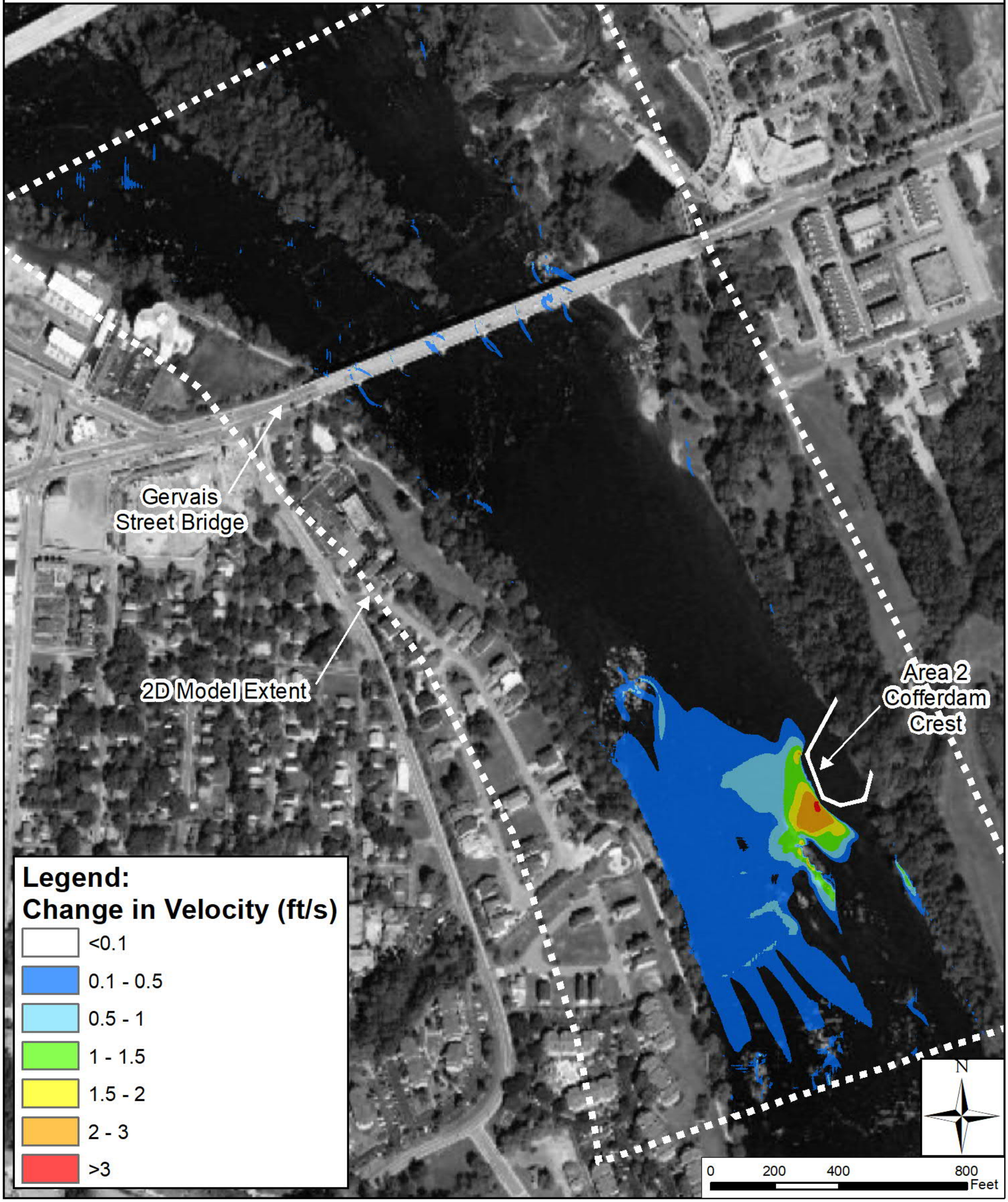
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A7: Normal Flow (8,564 cfs)
Proposed Area-2 Scenario: Flow Velocity



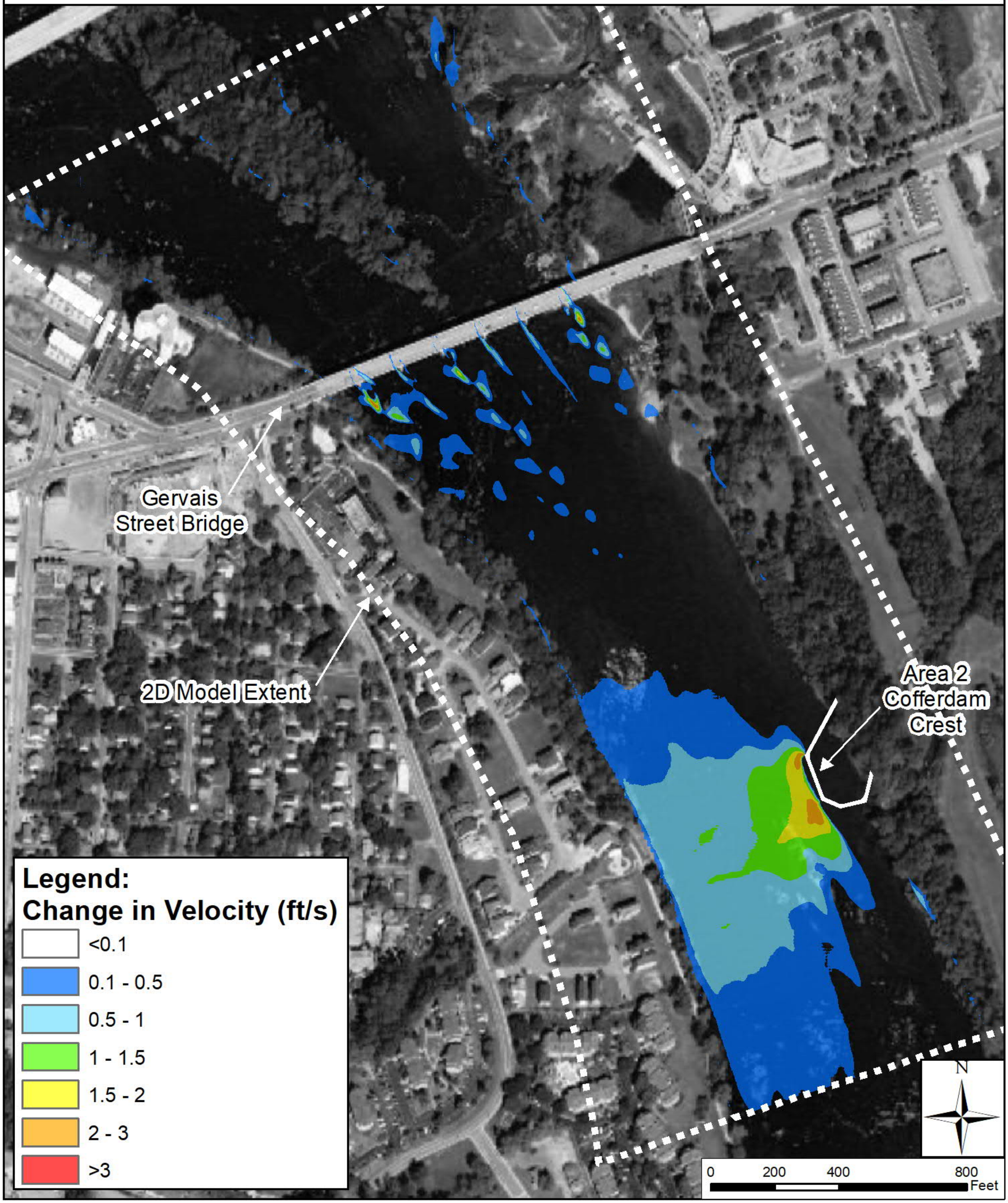
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A8: Crest Flow (26,000 cfs)
Proposed Area-2 Scenario: Flow Velocity



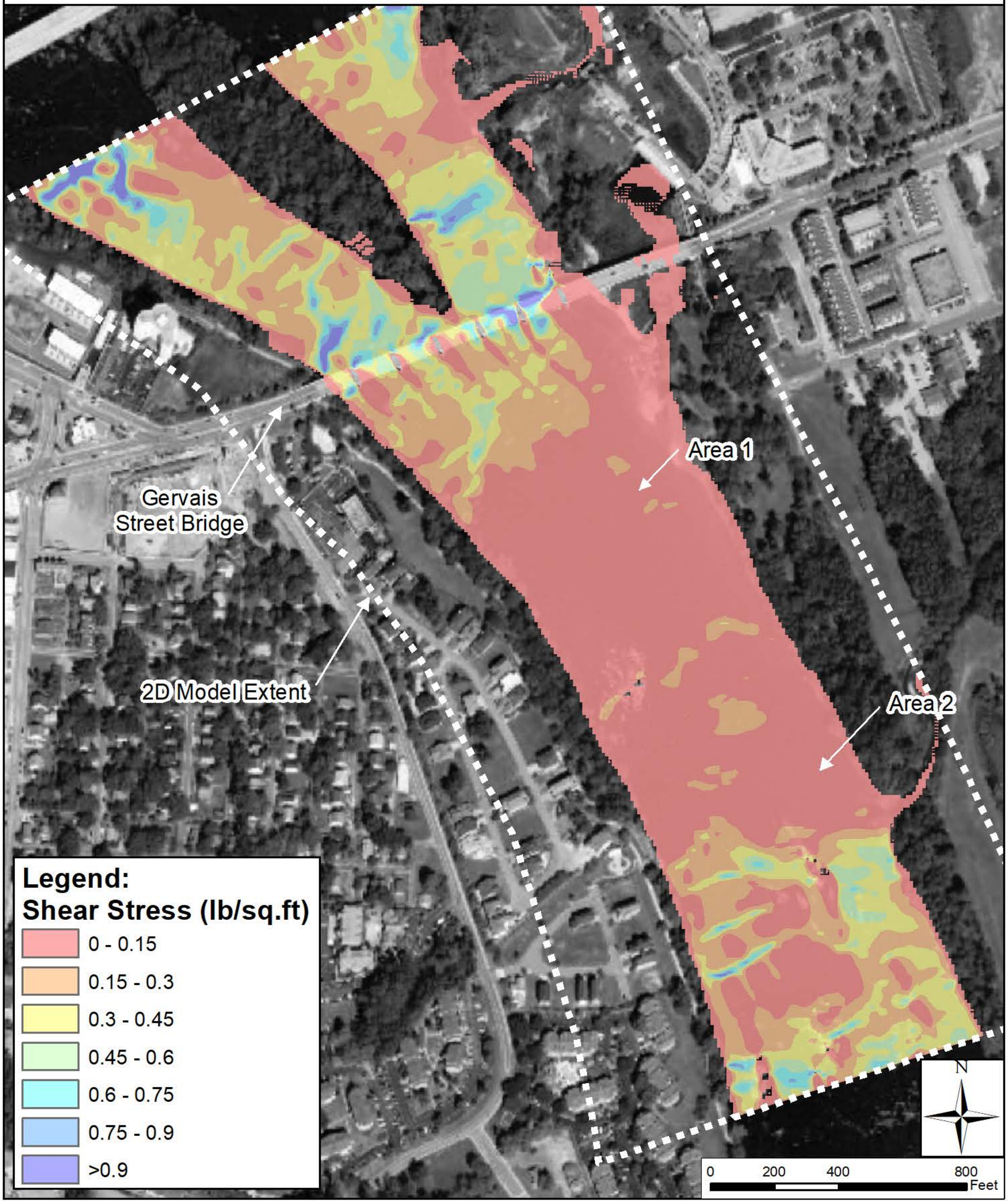
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A9: Normal Flow (8,564 cfs)
Proposed Area-2 Scenario: Change in Flow Velocity



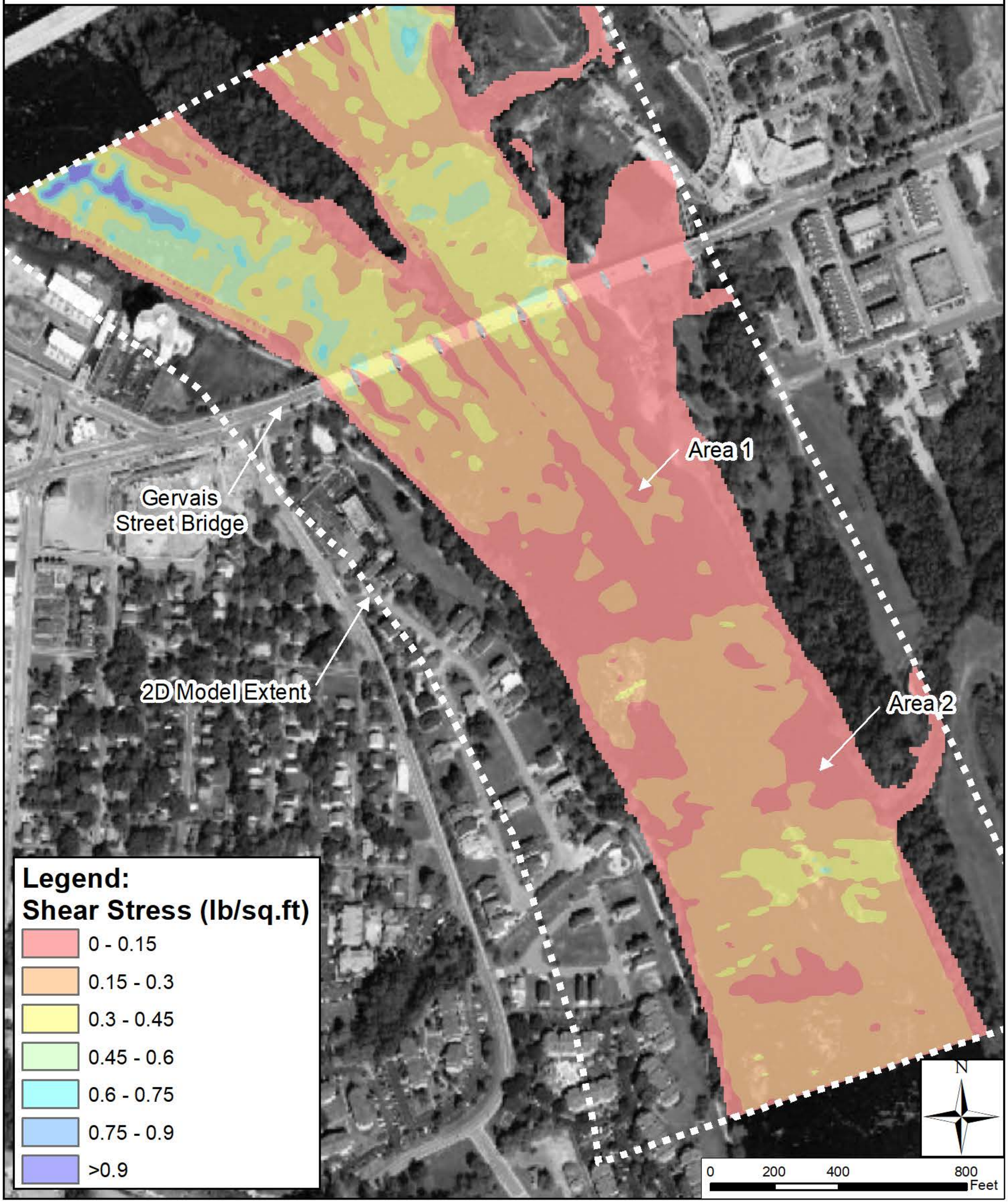
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A10: Crest Flow (26,000 cfs)
Proposed Area-2 Scenario: Change in Flow Velocity



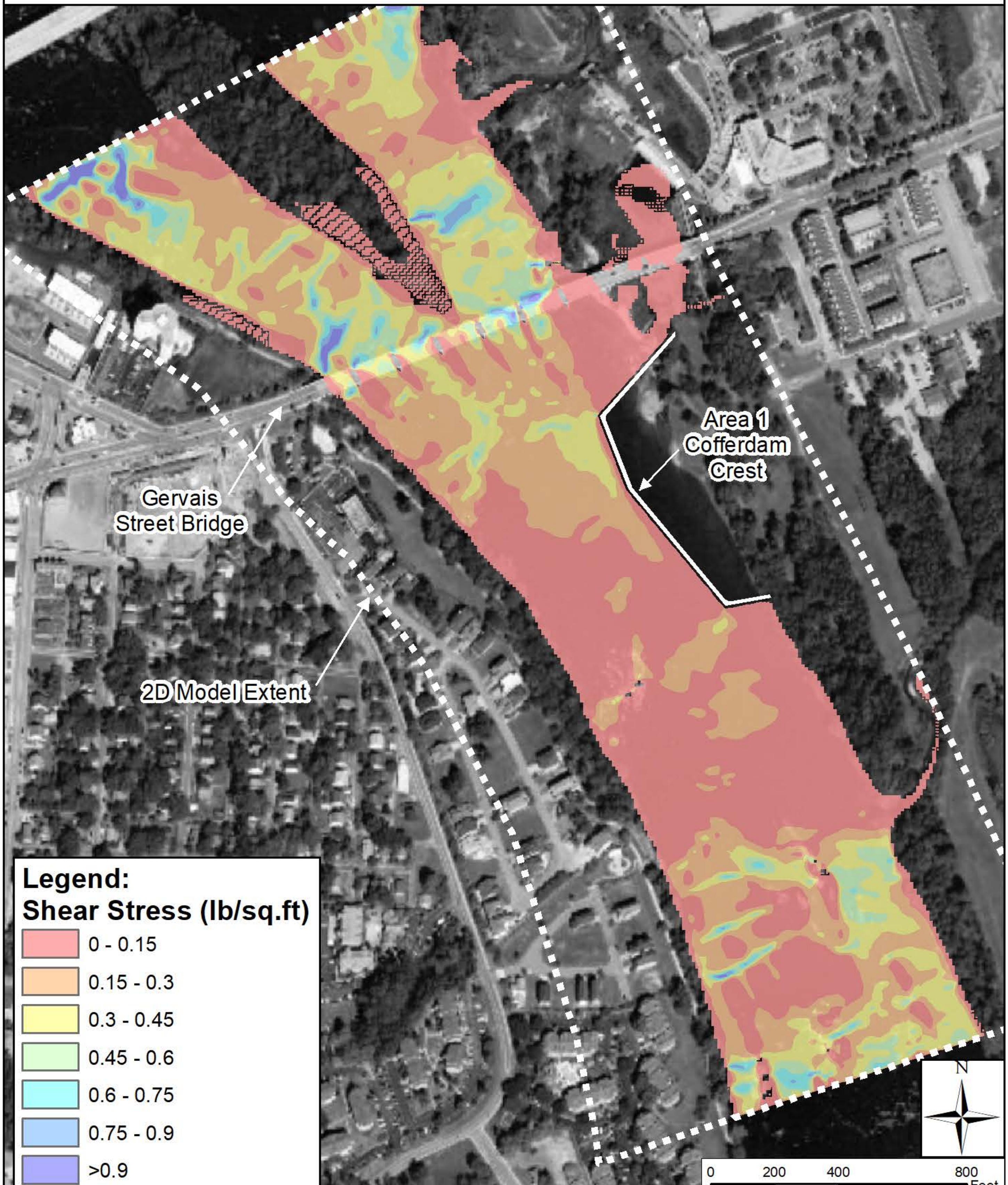
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A11: Normal Flow (8,564 cfs)
Existing Scenario: Shear Stress



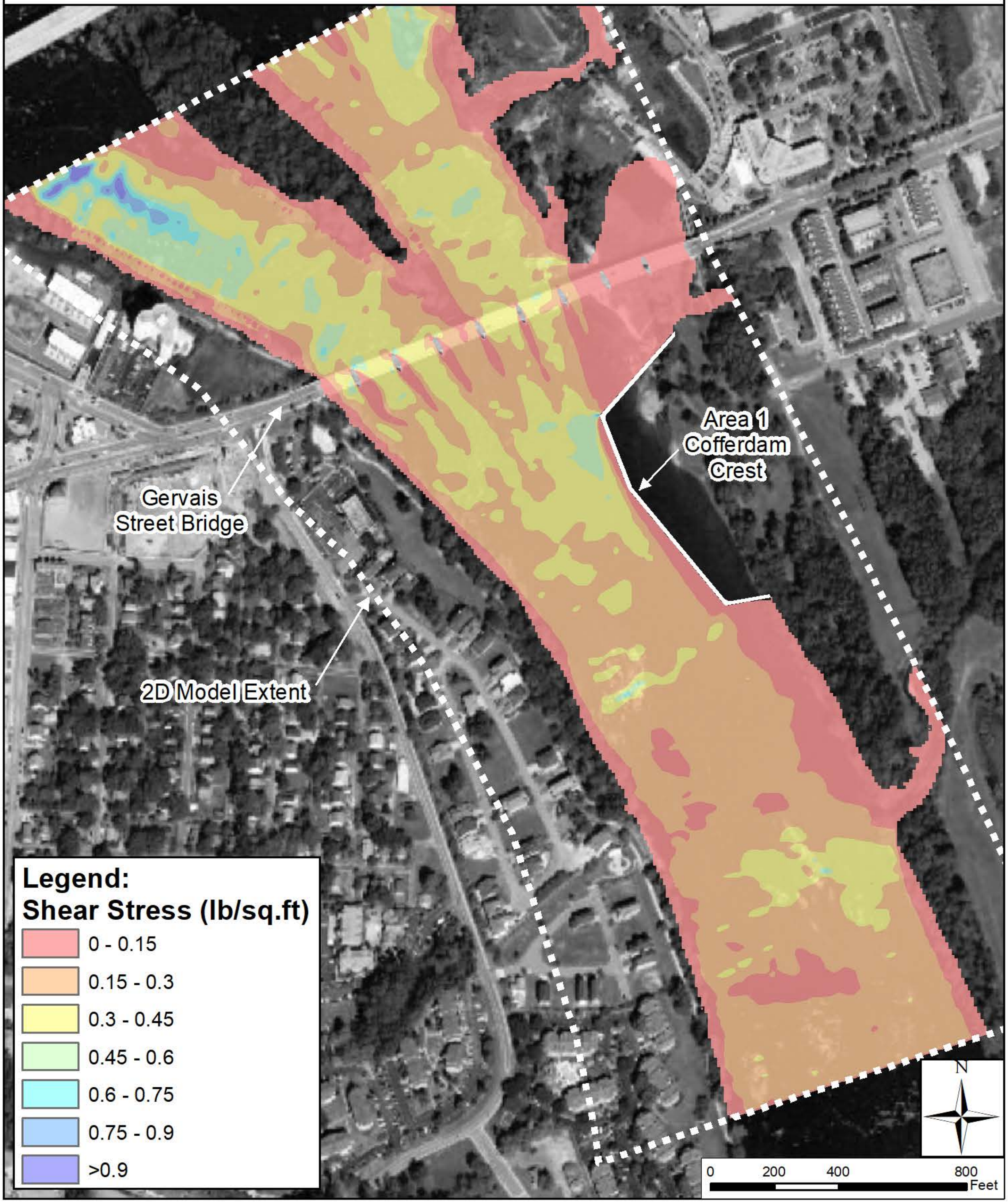
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A12: Crest Flow (26,000 cfs)
Existing Scenario: Shear Stress



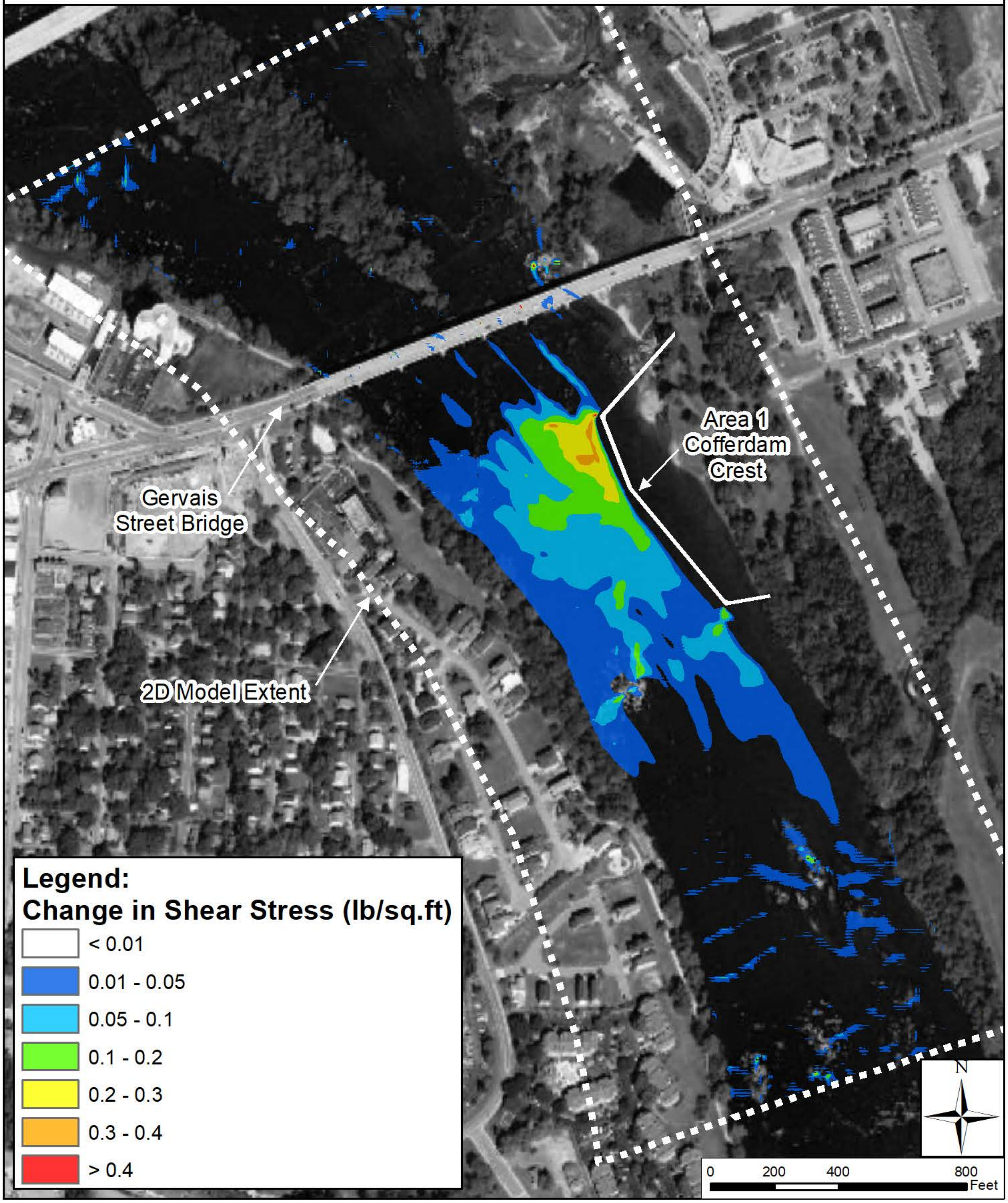
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A13: Normal Flow (8,564 cfs)
Proposed Area-1 Scenario: Shear Stress



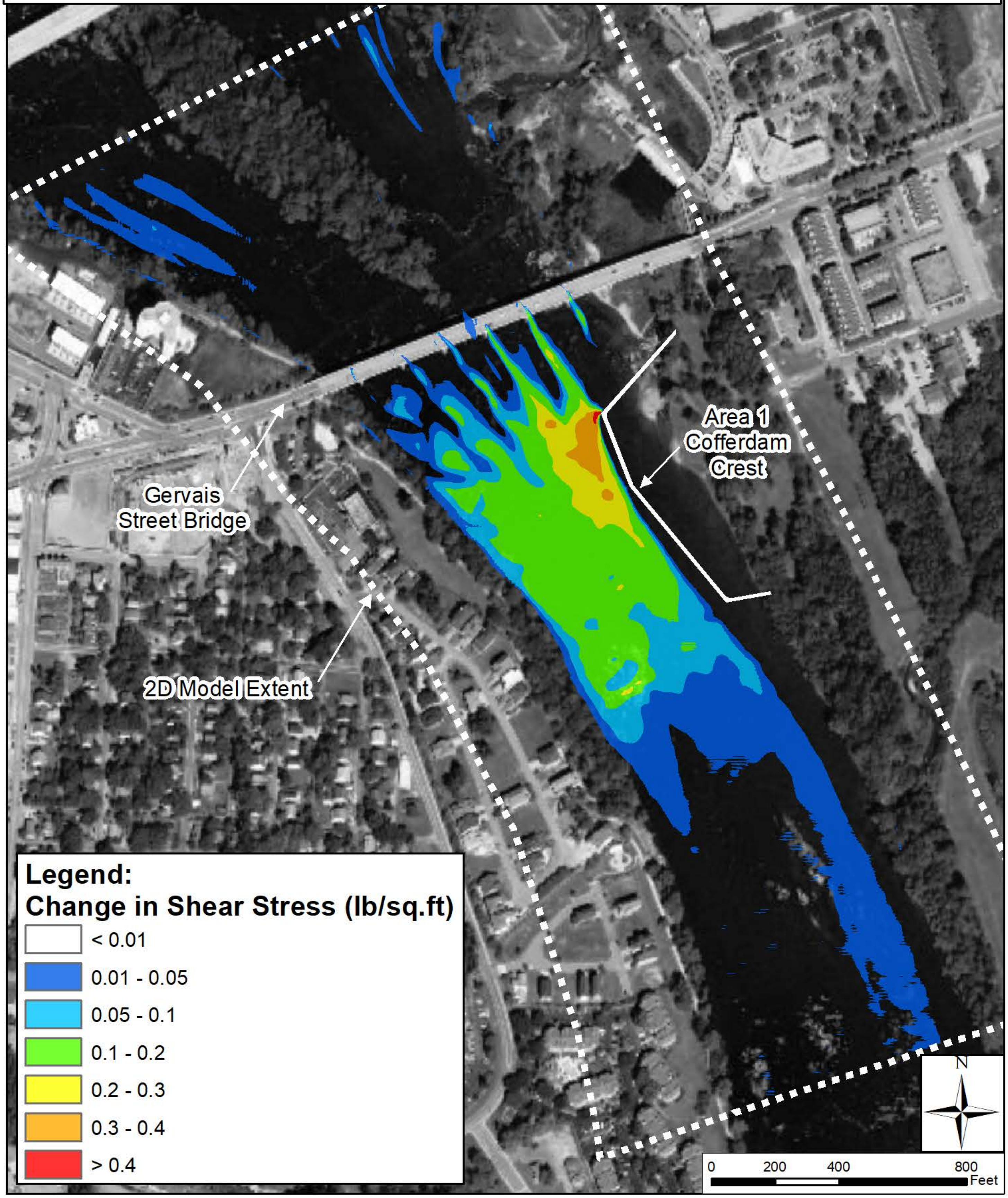
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A14: Crest Flow (26,000 cfs)
Proposed Area-1 Scenario: Shear Stress



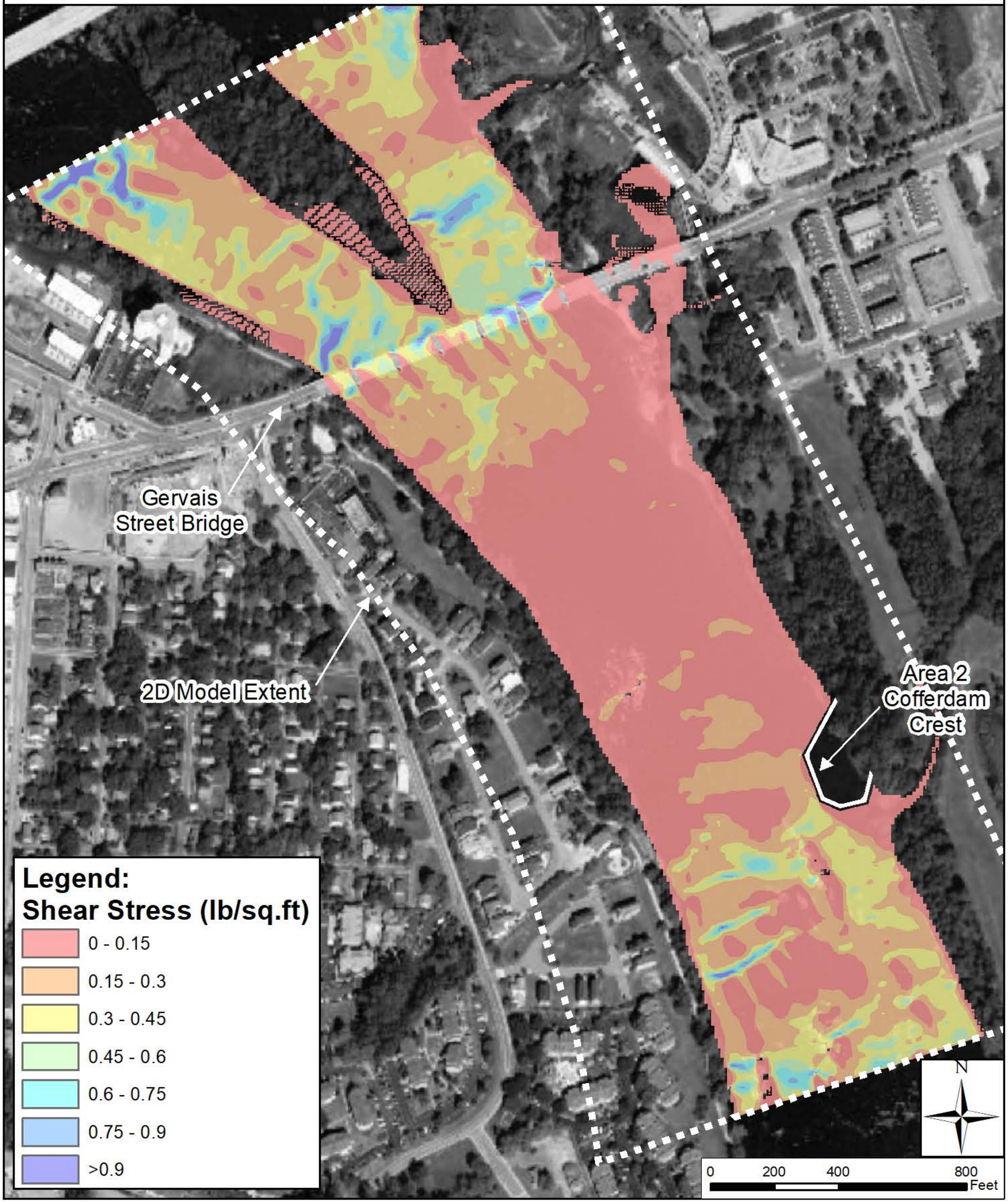
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A15: Normal Flow (8,564 cfs)
Proposed Area-1 Scenario: Change in Shear Stress



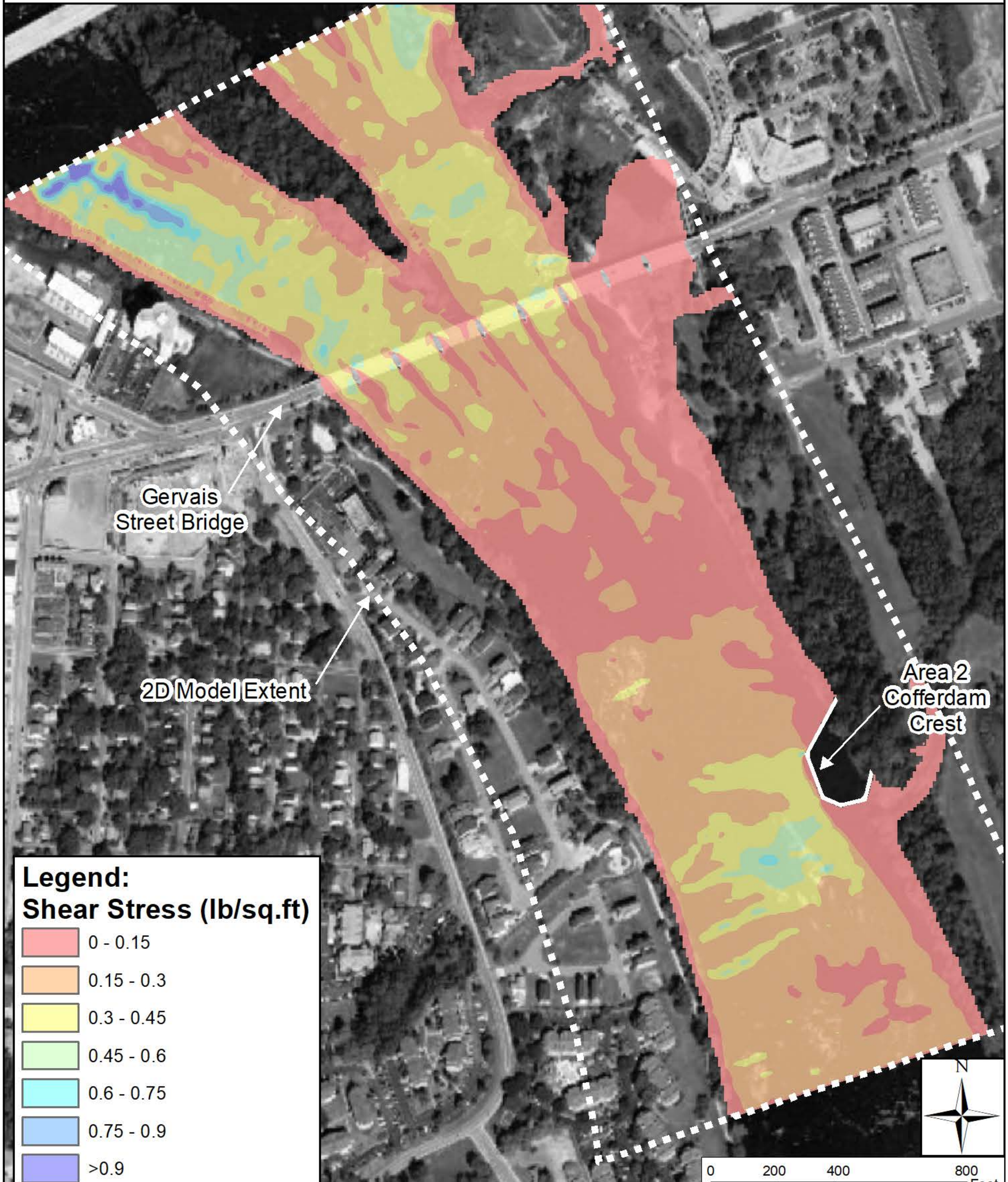
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A16: Crest Flow (26,000 cfs)
Proposed Area-1 Scenario: Change in Shear Stress



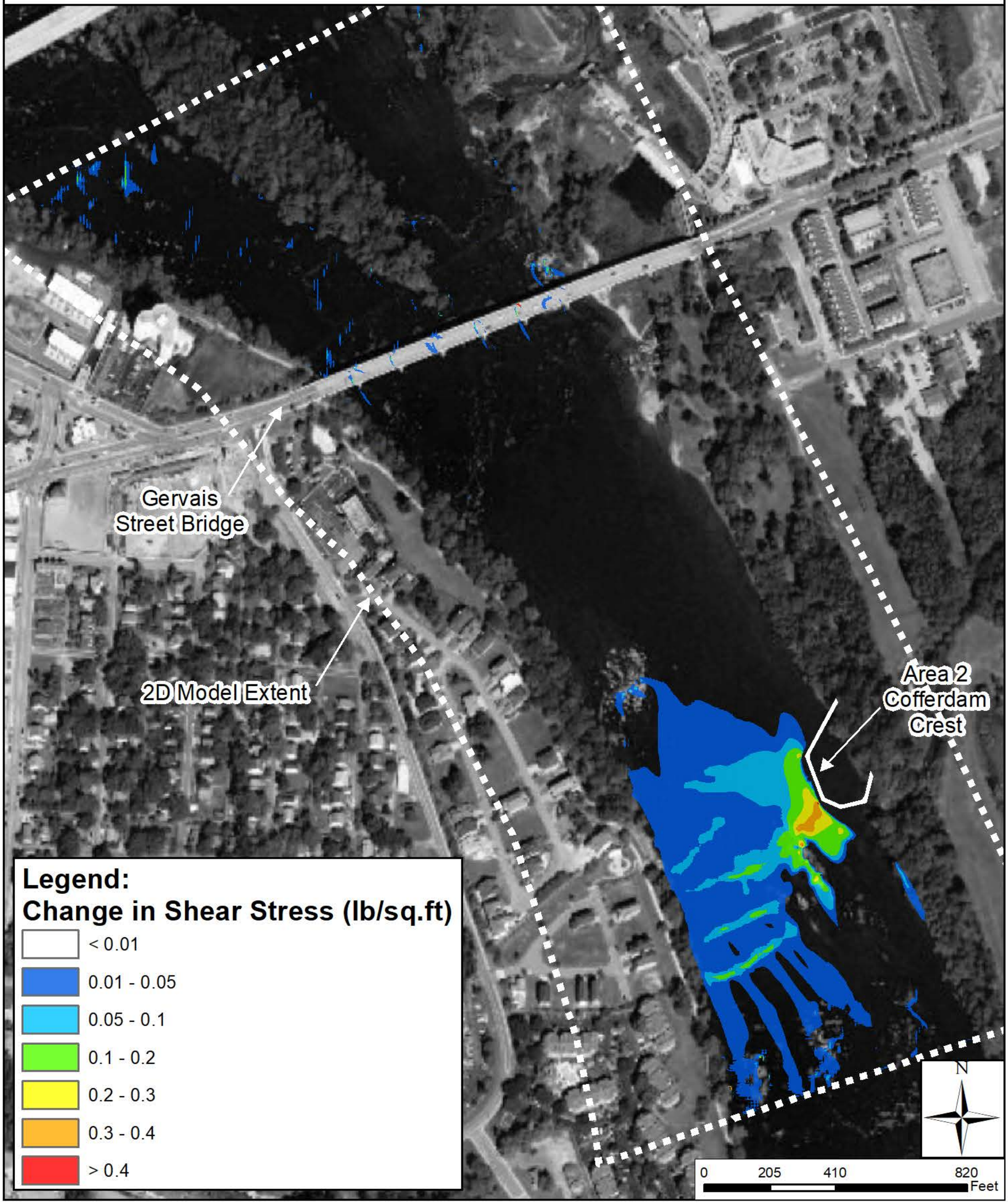
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A17: Normal Flow (8,564 cfs)
Proposed Area-2 Scenario: Shear Stress



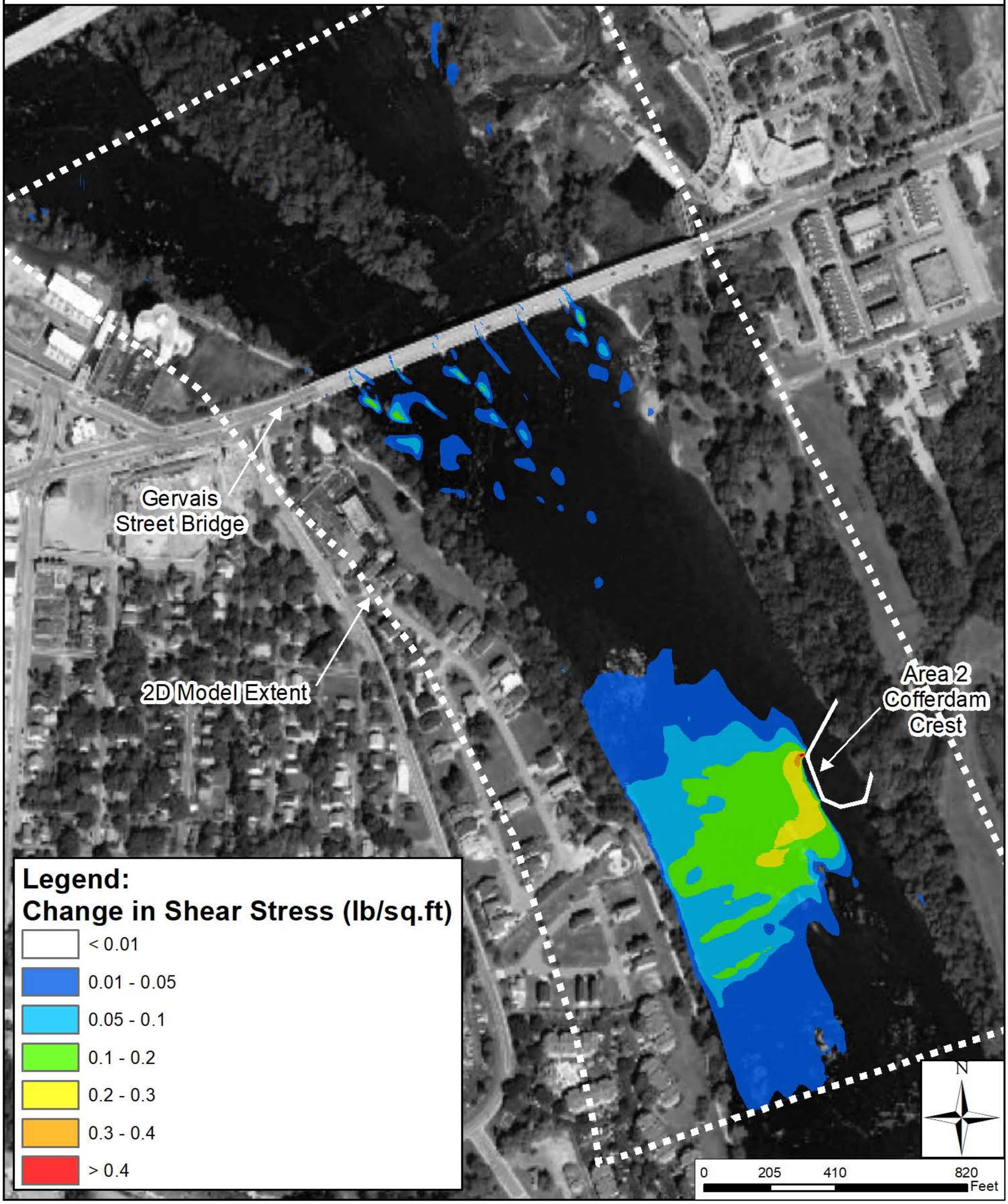
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A18: Crest Flow (26,000 cfs)
Proposed Area-2 Scenario: Shear Stress



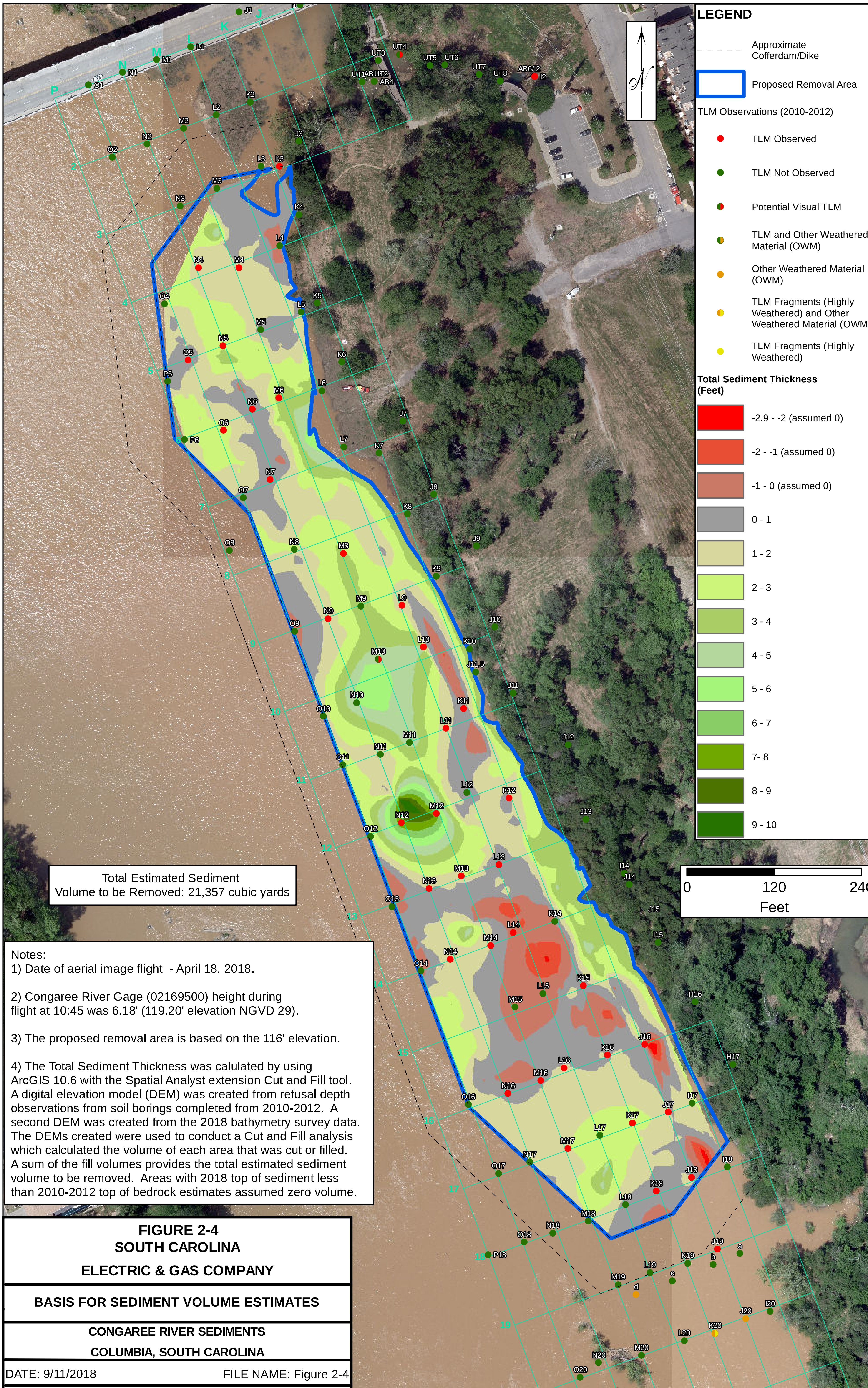
Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A19: Normal Flow (8,564 cfs)
Proposed Area-2 Scenario: Change in Shear Stress



Congaree River Remediation Project
River Bottom Erosion Potential Evaluation
Figure A20: Crest Flow (26,000 cfs)
Proposed Area-2 Scenario: Change in Shear Stress



ATTACHMENT B: RIVER BOTTOM SEDIMENT DEPTHS



Notes:
1) Date of aerial image flight - April 18, 2018.

2) Congaree River Gage (02169500) height during flight at 10:45 was 6.18' (119.20' elevation NGVD 29).

3) The proposed removal area is based on the 116' elevation.

4) The Total Sediment Thickness was calulated by using ArcGIS 10.6 with the Spatial Analyst extension Cut and Fill tool. A digital elevation model (DEM) was created from refusal depth observations from soil borings completed from 2010-2012. A second DEM was created from the 2018 bathymetry survey data. The DEMs created were used to conduct a Cut and Fill analysis which calculated the volume of each area that was cut or filled. A sum of the fill volumes provides the total estimated sediment volume to be removed. Areas with 2018 top of sediment less than 2010-2012 top of bedrock estimates assumed zero volume.

FIGURE 2-4
SOUTH CAROLINA ELECTRIC & GAS COMPANY

BASIS FOR SEDIMENT VOLUME ESTIMATES

CONGAREE RIVER SEDIMENTS
COLUMBIA, SOUTH CAROLINA

DATE: 9/11/2018 FILE NAME: Figure 2-4

APEX COMPANIES, LLC