Mitigation Project Name	Muddy Run	County	Duplin	USACE Action ID	2011-02191
DMS ID	95018	Date Project Instituted	7/14/2011	NCDWR Permit No	2012-0817
River Basin	Cape Fear	Date Prepared	5/22/2018		
Cataloging Unit	03030007				

Credit Release Milestone	Stream Credits						Wetland Credits							
	Scheduled Releases (Stream)	Warm	Cool	Cold	Anticipated Release Year (Stream)	Actual Release Date (Stream)	Scheduled Releases (Forested)	Riparian Riverine	Riparian Non-riverine	Non-riparian	Scheduled Releases (Coastal)	Coastal	Anticipated Release Year (Wetland)	Actual Release Date (Wetland)
Potential Credits (Mitigation Plan)		6,797.000												
Potential Credits (As-Built Survey)		6,702.000												
1 (Site Establishment)	N/A				N/A	N/A	N/A				N/A		N/A	N/A
2 (Year 0 / As-Built)	30%	2,010.600			2014	9/24/2014	30%				30%		N/A	N/A
3 (Year 1 Monitoring)	10%	670.200			2015	4/23/2015	10%				10%		N/A	N/A
4 (Year 2 Monitoring)	10%	670.200			2016	4/25/2016	15%				15%		N/A	N/A
5 (Year 3 Monitoring)	10%	670.200			2017	4/3/2017	20%				20%		N/A	N/A
6 (Year 4 Monitoring)	10%	670.200			2018	4/25/2018	10%				10%		N/A	N/A
7 (Year 5 Monitoring)	15%				2019		15%				15%		N/A	N/A
Stream Bankfull Standard	15%	1,005.300			2016	4/25/2016	N/A				N/A			
Total Credits Released to Date		5,696.700												

DEBITS (released credits only)

Ratios	1	1.5	2.5	5	1	3	2	5	1	3	2	5	1	3	2	5
	Stream Restoration	Stream Enhancement I	Stream Enhancement II	Stream Preservation	Riparian Restoration	Riparian Creation	Riparian Enhancement	Riparian Preservation	Nonriparian Restoration	Nonriparian Creation	Nonriparian Enhancement	Nonriparian Preservation	Coastal Marsh Restoration	Coastal Marsh Creation	Coastal Marsh Enhancement	Coastal Marsh Preservation
As-Built Amounts (feet and acres)	6,702.000															
As-Built Amounts (mitigation credits)	6,702.000															
Percentage Released	85%															
Released Amounts (feet / acres)	5,696.700															
Released Amounts (credits)	5,696.700															

NCDWR Permit	USACE Action ID	Project Name															
2013-0987	2008-03258	NCDOT TIP B-4591 - Bridge 4 on SR 1002, New Hanover & Brunswick Counties	32.000														
Remaining Amounts (feet / acres)	5,664.700																
Remaining Amounts (credits)	5,664.700																

Contingencies (if any): None

Signature of Wilmington District Official Approving Credit Release

9/6/18
Date

1 - For DMS, no credits are released during the first milestone
2 - For DMS projects, the second credit release milestone occurs automatically when the as-built report (baseline monitoring report) has been made available to the NCIRT by posting it to the NCEEP Portal, provided the following criteria have been met:
1) Approval of the final Mitigation Plan
2) Recordation of the preservation mechanism, as well as a title opinion acceptable to the USACE covering the property
3) Completion of all physical and biological improvements to the mitigation site pursuant to the mitigation plan
4) Reciept of necessary DA permit authorization or written DA approval for porjects where DA permit issuance is not required

3 - A 15% reserve of credits is to be held back until the bankfull event performance standard has been met

MUDDY RUN STREAM RESTORATION PROJECT
MONITORING REPORT
MONITORING YEAR 5
FINAL

DUPLIN COUNTY, NORTH CAROLINA
PROJECT NO. 95018
SAW-2011-02191
DWR 2012-0817

Prepared for:

Division of Mitigation Services

North Carolina Department of Environment and Natural Resources
1652 Mail Service Center
Raleigh, NC 27699-1652

February 2019

302 Jefferson Street, Suite 110
Raleigh, NC 27605

Corporate Headquarters
5020 Montrose Blvd. Suite 650
Houston, TX 77006
Main: 713.520.5400

February 5, 2019

Lindsay Crocker
NC DEQ Division of Mitigation Services
217 West Jones Street
Raleigh, NC 27604

RE: Muddy Run Stream Restoration Site: MY5 Monitoring Report (NCDMS ID 95018)

Listed below are comments provided by DMS on January 18, 2019 regarding the Muddy Run Stream Restoration Site: Year 5 Monitoring Report and RES' responses.

Add the DWR and IRT number on the cover page (DWR 2012-0817; Corps SAW-2011-02191).
Done.

Table 1. Update the 'existing length (LF)' column to 'Pre-condition length.' Add a column between Pre-condition length that is called 'Mitigation Plan SMUs' and add that information to the table. This will be helpful in IRT conversations to clearly show the changes from MP to AB. Update asterisk below table to reflect 'SMU column does not include channel in easement breaks.' (Is this correct instead of As-built lengths?)
Done. The asterisks have been updated to ensure they are accurate.

Please read whole monitoring report and ensure that it is written for today rather than taken from as-built or mitigation plan. There are sections throughout the document that don't make sense because they are written like they didn't happen yet. (Examples, you mention some structures will be removed after construction…write what happened, not what was planned). Restoration approach, Success criteria, and monitoring plan sections all have sections that need updating.
Done.

Section 3.1.2 - the verbiage on the crest gauges. These monitoring features need to be differentiated because one is called a "crest gauge" (cork and stick), and one is called a "continuous stage recorder." Update this section to clarify and update the CCPV to show crest gauge & continuous stage recorder locations.
This section has been updated to say, "Four sets of continuous stage recorders were installed on the site, one along Reach 1A, one along Reach 1C, one along Reach 2, and one along Reach 3. The continuous stage recorders are made up of manual crest gauges on top of bank and auto logging flow gauges installed within the channel. Auto logging flow gauges record water levels at an hourly interval and manual crest gauges use cork to document the height of bankfull events. The auto logging flow gauges were used to recognize bankfull events that are missed by the manual crest gauge. The flow gauge on Reach 1A was used to document water level in the headwater valley restoration reach to show at least intermittent flow."

Section 5.1.4. Hydrology - update the verbiage to reflect use of crest gauge and continuous stage recorder. Indicate the continuous stage recorder in the stream to document flow and crest gauge on the floodplain to document bankfull events. When you indicate height on crest gauge, is that feet above bankfull?
Done. The height on the crest gauges is above bankfull.

Muddy Run
Duplin County, North Carolina
DMS Project ID 95018

Cape Fear River Basin
HUC 03030007060010

Prepared by:

Resource Environmental Solutions, LLC
302 Jefferson Street, Suite 110
Raleigh, NC 27605
919-209-1061

TABLE OF CONTENTS

1 PROJECT GOALS, BACKGROUND AND ATTRIBUTES

1.1 Location and Setting

The Muddy Run Stream Site ("Site") is located in Duplin County approximately 1.4 miles east of Chinquapin, NC (Figure 1). The project is in the Cape Fear River Basin (8-digit USGS HUC 03030007, 14-digit USGS HUC 03030007060010) (USGS, 1998) and the NCDWQ Cape Fear 03-06-22 sub-basin (NCDWQ, 2002). To access the Site from the town of Chinquapin, travel east on Highway 50, take the first left onto Pickett Bay Road (SR 1819), go 1.1 miles, then turn left onto Kenney Crawley Road. This private road is gravel and will split just past the residential house on the right. Keeping to the left will take you to the downstream portion of Reach 1 and Reaches 2 and 3. Going to the right at the split will take you to the upstream limits of Reach 1 at the Headwater Valley restoration portion.

1.2 Project Goals and Objectives

The Muddy Run stream mitigation project provides numerous ecological and water quality benefits within the Cape Fear River Basin. While many of these benefits are limited to the project area, others, such as pollutant removal and improved aquatic and terrestrial habitat, have more far-reaching effects. Improvements to water quality, hydrology, and habitat are outlined below.

Design Goals and Objectives

Benefits Related to Water Quality	
Nutrient removal	Benefit is achieved through filtering of runoff from adjacent CAFOs through buffer areas, the conversion of active farm fields to forested buffers, improved denitrification and nutrient uptake through buffer zones, and installation of BMPs at the headwaters of selected reaches and ditch outlets.
Sediment removal	Benefit is achieved through the stabilization of eroding stream banks and reduction of sediment loss from field areas due to lack of vegetative cover. Channel velocities have been decreased through a reduction in slope, therefore decreasing erosive forces.
Increase dissolved oxygen concentration	Benefit is achieved through the construction of instream structures to increase turbulence and dissolved oxygen concentrations and riparian canopy restoration to lower water temperature to increase dissolved oxygen capacity.
Runoff filtration	Benefit is achieved through the restoration of buffer areas that receive and filter runoff, thereby reducing nutrients and sediment concentrations reaching water bodies downstream.
Benefits to Flood Attenuation	
Water storage	Benefit is achieved through the restoration of buffer areas which infiltrate more water during precipitation events than under current site conditions.
Improved groundwater recharge	Benefit is achieved through the increased storage of precipitation in buffer areas, ephemeral depressions, and reconnection of existing floodplain. Greater storage of water leads to improved infiltration and groundwater recharge.
Improved/restored hydrologic connections	Benefit is achieved by restoring the stream to a natural meandering pattern with an appropriately sized channel, such that the channel's floodplain is flooded more frequently at flows greater than the bankfull stage.
Benefits Related to Ecological Processes	
Restoration of habitats	Benefit is achieved by restoring riparian buffer habitat to appropriate bottomland hardwood ecosystem.
Improved substrate and instream cover	Benefit is achieved through the construction of instream structures designed to improve bedform diversity and to trap detritus. Stream were designed with the appropriate channel dimension and prevent aggradation and sedimentation within the channel. Substrate has become coarser as a result of the stabilization of stream banks and an overall decrease in the amount fine materials deposited in the stream.

Addition of large woody debris	Benefit is achieved through the addition of wood structures as part of the restoration design. Such structures include log vanes, root wads, and log weirs.
Reduced temperature of water due to shading	Benefit is achieved through the restoration of canopy tree species to the stream buffer areas.
Restoration of terrestrial habitat	Benefit is achieved through the restoration of riparian buffer bottomland hardwood habitats.

1.3 Project Structure

Table 1. Muddy Run Project Components

Reach	Mitigation Type	Pre-Condition Length (LF)	Mitigation Plan SMUs	As-Built Stationing	As-Built Length (LF)	Mitigation Ratio	As-Built SMUs
Reach 1A	Headwater Valley	1,659	1,655	0+66 to 17+87	1,721	1:1	1,691
Reach 1B	P1 Restoration	1,597	1,612	17+87 to 33+98	1,611	1:1	1,581
Reach 1C	P1 Restoration	1,317	1,357	33+98 to 47+73	1,345	1:1	1,330
Reach 2	P1 Restoration	1,448	1,533	2+00 to 17+10	1,510	1:1	1,493
Reach 3	P1 Restoration	464	613	0+94 to 7+01	607	1:1	607
		6,485	**6,770**	**Total**	**6,794**		**6,702**

*As-Built length includes channel in easement breaks.
** SMUs do not include channel in easement breaks.
Note: The decrease between Mitigation Plan and As-Built SMUs can be attributed to the shortening of Reach 2 during landowner negotiations.

1.3.1 Restoration Type and Approach

Reach 1A
Headwater valley restoration was performed along Reach 1A and continued down to Reach 1B. The existing channel adjacent to the hog houses was backfilled to the extent possible such that cut and fill was balanced along the reach. The existing 18-inch corrugated plastic pipe located under the gravel road was removed and replaced with three 12-inch CMPs at a slightly higher elevation. A sediment trapping pool and level spreader BMP immediately downstream of the road crossing was constructed to provide diffuse flow into the valley and collect sediment from the farm access road. The BMP is located outside the conservation easement to allow for maintenance. The reach was not completely filled so as to prevent hydrologic trespass upstream of the road. Grade control structures were placed along portions of the reach that was filled to provide additional vertical stability. During construction, a drain tile was encountered near STA 7+10. The portion of the tile located within the easement was removed, and a subsurface flow structure was installed.

A forested buffer approximately 115 feet wide was planted throughout this reach. Where the channel was redirected towards Reach 2 near STA 11+31, a channel plug was constructed, and flow has been redirected back in a northerly direction. A channel plug and grade control structure has also been installed where an existing ditch enters the buffer from the east. Flow was directed along the reach such that it follows along the natural valley from STA 11+31 down to Reach 1B. An existing 30-inch CMP culvert located at STA 11+12 has been removed and replaced with three 12-inch CMPs to allow the landowner access to all areas of his property, as the restoration will bisect his land. The terminus of the headwater valley at STA 17+25 includes a grade control structure at the transition to a stable channel for Reach 1B.

Reach 1B
Priority Level I restoration was constructed on Reach 1B. For the majority of the reach, the channel has been rerouted to the south of its previous location. Relocating the channel did not impact any forested areas because most of the buffer was clear cut in the fall of 2011. However, there is a small, wooded area along the upstream portion of the reach. The restored channel from STA 17+25 to 20+78 meanders along the existing channel footprint in order to minimize impacts to the established buffer to the south. The elevated road bed along the north side of the existing channel has been removed in order to maintain a continuous connection between the proposed channel and its floodplain. A channel plug and grade control structure was installed where an existing ditch entered the buffer from the north near STA 18+08. An existing 42-inch CMP culvert crossing was removed and replaced with two 36-inch CMPs at STA 20+93 to maintain access to all portions of the landowner's property. The downstream section of Reach 1B has been relocated to avoid impacts to two existing wetland areas adjacent to the channel. There were two ditches within the easement that cross the wetland to the south. These ditches have been plugged to provide diffuse flow through the wetland and into the restored channel. Structures installed along Reach 1B included log grade controls, root wads, and various woody debris structures to enrich habitat and ensure bank stability and channel integrity.

Reach 1C
Priority Level I restoration was performed on Reach 1C. The restoration approach on this reach included relocating the channel to the north of its previous location within the adjacent agricultural field. The relocation also included moving the confluence with Reach 2 to STA 45+27. The channel was plugged and filled to prevent continued flow within the ditch. A 36-inch CMP culvert crossing located at the upstream end of the reach was removed and relocated to STA 33+67. Twin 42-inch culverts were placed in-line with the restored stream to maintain access to all portions of the landowner's property.

By rerouting and raising the channel, the restoration allows the channel frequent access to its floodplain and the creation of small depressional areas within the buffer to enhance habitat for wildlife and aquatic organisms. Structures along this reach include log grade controls, root wads, leaf packs, and various woody debris structures that will improve in-stream habitat and bank stability. The downstream end of Reach 1C terminates at a temporary grade drop structure. The restoration was continued in a subsequent phase of the project, Muddy Run II.

Reach 2
Priority Level I restoration was performed on Reach 2. The bed elevation at the top of the reach is controlled by a 42-inch CMP culvert. This culvert and the associated farm road were moved approximately 100 feet upstream of its current location. The culvert was replaced with a 36-inch CMP to maintain access to the adjacent hog houses and lagoons located just north of the upstream end of the reach. The channel now flows in a northwesterly direction to the confluence with Reach 1C.

The majority of the channel has been relocated north and east of the existing ditch towards the lagoons. The lower end meanders through a large spoil area constructed during installation of the lagoons. This area was graded down to match pre-disturbance elevations, and the cut material was used to fill abandoned ditches throughout the project. The restored stream channel can now access its floodplain regularly. Typical in-stream structures along this reach include log grade controls, root wads, leaf packs, and various woody debris structures that improve habitat and bank stability. All areas within the easement have been planted with native shrub and tree species.

Reach 3
Priority Level I restoration was performed on Reach 3. Its bed elevation was controlled at the top of the reach by a 24-inch CMP culvert. This culvert was removed and replaced with two 42-inch CMPs at a higher elevation to maintain access across the property. The culvert was raised a minimal amount to prevent hydrologic trespass upstream of the project. Restoration began just south of the culvert crossing and involved relocating the channel to the east of the existing ditch into the adjacent spray field. The reach has been reconnected with the primary channel (Reach 1) approximately 146 feet downstream of the confluence with Reach 1C at STA 5+72. A temporary log ramp was installed at the downstream end to tie the restored channel into the existing ditch. This structure was removed when the Muddy Run II Mitigation Project was constructed.

By relocating the channel, the restoration allows the channel regular access to its floodplain and the opportunity for enhanced wetland habitat throughout the buffer. In-stream structures along this reach include log grade controls, root wads, leaf packs, and various woody debris structures that provide bed diversity and subsequently improve habitat and bank stability. All areas within the easement were planted with native shrub and tree species.

Reach 3 was constructed to reflect a drainage area of 391 acres as opposed to the previous area of 85 acres. This significant increase in watershed size incorporates a drainage area that borders Reach 3 to the north and east, which currently directed flows away from the project site. It appears that the drainage features within this additional area were historically diverted north across a natural divide to promote drainage for agricultural production. The Muddy Run II Stream and Wetland Mitigation Project reconnects this drainage to the Muddy Run project site.

1.4 Project History, Contacts and Attribute Data

1.4.1 Project History

The Site was restored by Resource Environmental Solutions, LLC (RES) through a full-delivery contract awarded by NCDMS in 2011. Tables 2, 3, and 4 in **Appendix A** provide a time sequence and information pertaining to the project activities, history, contacts, and baseline information.

1.4.2 Project Watersheds

The easement totals 19.1 acres and is broken into five reaches. Reach 1A has a drainage area of 0.23 square miles (145 acres); it begins at the start of the restoration project (Sta. 0+62) and extends north and west to Sta.17+25. Reach 1B has a drainage area of 0.28 square miles (177 acres); it begins at Sta.17+25 and extends to Sta. 33+67. Reach 1C is the downstream section (Sta. 33+67 to 47+08) of Reach 1 and has a drainage area of 0.37 square miles (238 acres). Reach 2 has a drainage area of 0.1 square miles (60 acres) and flows northwest directly into Reach 1. Reach 3 has a drainage area of 0.13 square miles (85 acres) extending north to south (**Figure 2**). The land use in the project watershed is approximately 49 percent cultivated, 33 percent southern yellow pine, 9 percent bottomland forest/hardwood swamp, 7 percent wooded and shrubland, and 2 percent managed herbaceous cover.

2 Success Criteria

The success criteria for the Site stream restoration was assembled from a combination of the 2003 IRT Stream Mitigation Guidelines and the EEP Monitoring Requirements and Performance Standards Guidance for Stream and-or Wetland Mitigation (11/07/2011). Specific success criteria components are presented below.

2.1 Stream Restoration

2.1.1 Bankfull Events

Two bankfull flow events must be documented within the five-year monitoring period. The two bankfull events must occur in separate years. Otherwise, the stream monitoring will continue until two bankfull events have been documented in separate years. Bankfull events were documented using continuous stage recorders, photographs, and visual assessments for evidence of debris rack lines.

2.1.2 Cross Sections

There should be little change in as-built cross-sections. If changes do take place, they should be evaluated to determine if they represent a movement toward a less stable condition (for example down-cutting or erosion) or are minor changes that represent an increase in stability (for example settling, vegetative changes, deposition along the banks, or decrease in width/depth ratio). Cross-sections are classified using the Rosgen stream classification method, and all monitored cross-sections should fall within the quantitative parameters defined for channels of the design stream type.

2.1.3 Digital Image Stations

Digital images were used to subjectively evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, and effectiveness of erosion control measures. Longitudinal images should not indicate the absence of developing bars within the channel or an excessive increase in channel depth. Lateral images should not indicate excessive erosion or continuing degradation of the banks over time. A series of images over time should indicate successional maturation of riparian vegetation.

2.2 Vegetation

Specific and measurable success criteria for plant density within the riparian buffers on the site follows NCDMS Guidance. Vegetation monitoring plots are 0.02 acres in size and cover greater than two percent of the planted area. Vegetation monitoring occurred annually in the fall of each year. The interim measures of vegetative success for the site are the survival of at least 320 three-year-old trees per acre at the end of Year 3, and the final vegetative success criteria is 260 trees per acre at the end of Year 5. Invasive species on the site will be monitored and treated if necessary throughout the required vegetation monitoring period.

2.3 Scheduling/Reporting

The monitoring program will be implemented to document system development and progress toward achieving the success criteria. The restored stream morphology is assessed to determine the success of the mitigation. The monitoring program will be undertaken for five years or until the final success criteria are achieved, whichever is longer.

Monitoring reports will be prepared in the fall of each year of monitoring and submitted to NCDMS. The monitoring reports will include all information and be in the format required by NCDMS in Version 2.0 of the NCDMS Monitoring Report Template (Oct. 2010).

3 MONITORING PLAN

Annual monitoring data will be reported using the DMS monitoring template. Annual monitoring shall be conducted for stream and vegetation monitoring parameters as noted below.

3.1 Stream Restoration

3.1.1 As-Built Survey

An as-built survey was conducted following construction to document channel size, condition, and location. The survey included a complete profile of thalweg, water surface, bankfull, and top of bank to compare with future geomorphic data. Longitudinal profiles were not required in annual monitoring reports unless requested by NCDMS or USACE.

3.1.2 Bankfull Events

Four sets of continuous stage recorders were installed on the site, one along Reach 1A, one along Reach 1C, one along Reach 2, and one along Reach 3. The continuous stage recorders are made up of manual crest gauges on top of bank and auto logging flow gauges installed within the channel. Auto logging flow gauges use pressure transducers to record water levels at an hourly interval and manual crest gauges use cork to document the height of bankfull events. The auto logging flow gauges were used to recognize bankfull events that are missed by the manual crest gauge. The flow gauge on Reach 1A was used to document water levels in the headwater valley restoration reach to show at least intermittent flow. Manual crest gauges were checked during each site visit to determine if a bankfull event has occurred since the last site visit and readings and debris wrack lines were photographed to document evidence of bankfull events.

3.1.3 Cross Sections

A total of 39 permanent cross sections were installed to monitor channel dimensions and stability. Five cross sections were installed along Reach 1A of the headwater valley restoration section. Ten cross sections (five pools and five shallows) were installed along Reach 1B and four pool and four shallow cross sections were installed along Reach 1C. Reach 2 has a total of 14 cross sections installed throughout its length. Two permanent cross sections were installed along Reach 3. Cross sections were typically located at representative shallow and pool sections along each stream reach. Each cross section was permanently marked with 3/8 rebar pin to establish a monument location at each end. A marker pole was also installed at both ends of each cross section to allow ease locating during monitoring activities. Cross section surveys will be performed once a year during annual monitoring and will include all breaks in slope including top of bank, bottom of bank, streambed, edge of water, and thalweg.

3.1.4 Digital Image Stations

Digital photographs were taken at least once a year to visually document stream and vegetation conditions. This monitoring practice continued for five years following construction and planting. Permanent photo point locations at cross sections and vegetation plots were established so that the same directional view and location may be repeated each monitoring year. Monitoring photographs were also used to document any stream and vegetation problematic areas such as erosion, stream and bank instability, easement encroachment and vegetation damage.

3.1.5 Bank Pin Arrays

Ten bank pin arrays were installed at cross sections located on meander pools. These bank pin arrays were installed along the upstream and downstream third of the meander. Bank pins are a minimum of three feet long and have been installed just above the water surface and every two feet above the lowest pin. Bank pin exposure was recorded at each monitoring event, and the exposed pin were to be driven flush with the bank.

3.1.6 Visual Assessment Monitoring

Visual monitoring of all mitigation areas was conducted a minimum of twice per monitoring year by qualified individuals. The visual assessments included vegetation density, vigor, invasive species, and easement encroachments. Visual assessments of stream stability included a complete stream walk and structure inspection. Digital images were taken at fixed representative locations to record each monitoring event as well as any noted problem areas or areas of concern. Results of visual monitoring was presented in a plan view exhibit with a brief description of problem areas and digital images. Photographs were used to subjectively evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, and effectiveness of erosion control measures. Longitudinal photos should indicate the absence of developing bars within the channel or an excessive increase in channel depth. Lateral photos should not indicate excessive erosion or continuing degradation of the banks over time. A series of photos over time should indicate successional maturation of riparian vegetation.

3.1.7 Surface Flow

Headwater valley restoration areas were monitored to document intermittent or seasonal surface flow. This was accomplished through stage recorders. An auto logging flow gauge and crest gauge was installed within the headwater valley channel and recorded stage conditions at hourly intervals. Stage data was used to determine duration of valley flow. This gauge was downloaded during each site visit to determine if intermittent or seasonal flow conditions are present.

3.2 Vegetation

A total of 20 vegetation plots were randomly established within the planted stream riparian buffer easement. Each vegetation plot measures 22 feet by 40 feet (0.02 acres) and has all four corners marked with PVC posts. Planted woody vegetation was assessed within each plot to establish a baseline dataset. Within each vegetation plot, each planted stem was identified for species, “X” and “Y” origin located, and measured for height. Reference digital photographs were also captured to document baseline conditions. Species composition, density, growth patterns, damaged stems, and survival ratios will be measured and reported on an annual basis. Vegetation plot data was reported for each plot as well as an overall site average.

4 MAINTENANCE AND CONTINGENCY PLAN

All identified problematic areas or areas of concern such as stream bank erosion/instability, aggradation/degradation, lack of targeted vegetation, and invasive/exotic species which prevent the site from meeting performance success criteria will be evaluated on a case by case basis. These areas will be documented, and remedial actions will be discussed amongst NCDMS staff to determine a plan of action. If it is determined remedial action is required, a plan will be provided.

4.1 Stream

No stream problems were identified during the Year 5 monitoring period. The bed and bank erosion noted in Year 4 has stabilized and is no longer a problem.

4.2 Vegetation

No vegetation problem areas were identified during the Year 5 monitoring period. The encroachment area on Reach 1B and the low stem density area near VP9 were addressed in March 2018. RES blocked off the encroachment area with t-posts and signage and there was no indication of continued encroachment in Year 5. Additionally, RES planted container trees in the low stem density area.

5 YEAR 5 MONITORING CONDITIONS (MY5)

The Muddy Run Year 5 Monitoring activities were completed in June, July and September 2018. All Year 5 monitoring data is presented below and in the appendices. The Site met all stream and vegetation interim success criteria and is recommended for close-out.

5.1 Year 5 Monitoring Data Collection

5.1.1 Morphological State of the Channel

All morphological stream data for the Year 5 survey and dimensions were collected during the annual monitoring survey performed during June-July 2018. **Appendix D** includes summary data tables, morphological parameters, and cross section plots.

Profile
The baseline (MY-0) profiles closely match the proposed design profiles. The plotted longitudinal profiles can be found on the As-Built Drawings. Longitudinal profiles will not be performed in annual monitoring reports unless requested by NCDMS or USACE. Morphological summary data tables can be found in **Appendix D**.

Dimension
The Year 5 (MY-5) cross sectional dimensions closely matches the baseline cross section parameters. Minimal changes were noticed for most Year 5 cross section surveys resulting from stable bed and bank conditions. Starting in Year 5, Bank Height Ratio (BHR) was calculated on riffles using the baseline bankfull cross sectional area. With a fixed cross-sectional area (based on the baseline data), minor changes in channel dimension corresponds with slight changes in bankfull stage. Therefore, the new bankfull stage is used to more accurately calculate current BHRs and entrenchment ratios (ER). None of the riffle cross sections exceeded a 1.2 BHR. All cross-section plots and data tables can be found in **Appendix D**.

Sediment Transport
The Year 5 conditions show that shear stress and velocities have been reduced for all three restoration reaches. Pre-construction conditions documented all three reaches as sand bed channels and remain classified as sand bed channels post-construction. Visual assessments (**Appendix B**) show the channels are transporting sediment as designed.

Bank Pin Arrays
Ten bank pin arrays were observed and measured for bank erosion located on the outside meander bends. If bank pin exposure was noticeable, it was measured, recorded, photographed, and then driven flush with the bank at each monitoring location. No bank pin arrays recorded any exposure during the Year 5 monitoring season. Bank pin array data tables can be found in **Table 12, Appendix D**.

5.1.2 Vegetation

The Year 5 monitoring (MY5) vegetation survey was completed in late September 2018 and resulted in an average of 623 planted stems per acre, well above the interim survival density of 260 stems per acre at the end of Year 5 monitoring. The average stems per vegetation plot was 12 planted stems. The minimum planted stem per plot was 9 stems and the maximum was 20 stems per plot. Multiple volunteer tree species were noted during MY5 activities. The average stem height is 8.8 feet. Vegetation summary data tables and plot photos can be found in **Appendix C**.

5.1.3 Photo Documentation

Permanent photo point locations have been established at cross sections, and vegetation plots by RES staff. Any additional problem areas or areas of concern have been documented with a digital photograph during monitoring activities. Stream digital photographs can be found in **Appendix B** and **Appendix C** for vegetation photos.

5.1.4 Stream Hydrology

Four sets of continuous stage recorders were installed on the site, one along Reach 1A, one along Reach 1C, one along Reach 2, and one along Reach 3. The continuous stage recorders are made up of manual crest gauges on top of bank and auto logging flow gauges installed within the channel. Four stage recorders documented bankfull events during the Year 5 monitoring period. Stage Recorder 2, which is located on Reach 1C, documented 17 bankfull events during MY5 with the highest reading of 1.4 feet. Stage recorder 3 (Reach 2) logged 22 bankfull events during Year 5 with a reading with the highest reading of 2.48 feet. Stage Recorder 4's (Reach 3) pressure transducer could not be accessed due to high water therefore number of bankfull events could not be recorded. However, the highest manual crest gauge reading was 3.5 feet. Stage Recorder 1 is installed on Reach 1A where headwater valley restoration was performed and documented 55 days of consecutive flow. This stream reach flowed for a total of 179 days during the Year 5 monitoring period. Stage recorder summary data and photo documentation of the bankfull events can be found in **Appendix E**.

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Appendix A

Project Background Data and Maps

Appendix A. **General Tables and Figures**
Table 1 Project Components and Mitigation Credits
Monitoring Report Year 5

Table 1. Project Components and Mitigation Credits
Muddy Run Stream Restoration/NCDMS Project # 95018

Mitigation Credits

	Stream		Riparian Wetland		Non-riparian Wetland		Buffer	Nitrogen Nutrient Offset	Phosphorous Nutrient Offset
Type	R	RE	R	RE	R	RE			
Totals	6,702		N/A	N/A	N/A	N/A	N/A	N/A	N/A

Project Components

Project Component -or- Reach ID	As-Built Stationing/Location (LF)	Pre-Construction Footage/Acreage	Approach (PI, PII etc.)	Restoration -or- Restoration Equivalent	Restoration Footage or Acreage	Mitigation Ratio
Reach 1A	0+66 to 17+87	1,659	HWV	Restoration	1,691	1 : 1
Reach 1B	17+87 to 33+98	1,597	P1	Restoration	1,581	1 : 1
Reach 1C	33+98 to 47+73	1,317	P1	Restoration	1,330	1 : 1
Reach 2	2+00 to 17+10	1,448	P1	Restoration	1,493	1 : 1
Reach 3	0+94 to 7+01	464	P1	Restoration	607	1 : 1

Component Summation

Restoration Level	Stream (linear feet)	Riparian Wetland (acres)		Non-riparian Wetland	Buffer (square feet)	Upland (acres)
		Riverine	Non-Riverine			
Restoration	5,011					
Headwater Valley	1,691					
Enhancement						
Enhancement I						
Enhancement II						
Creation						
Preservation						
High Quality Preservation						

BMP Elements

Element	Location	Purpose/Function	Notes
---	---	---	---
---	---	---	---
---	---	---	---

BMP Elements
BR = Bioretention Cell; SF = Sand Filter; SW = Stormwater Wetland; WDP = Wet Detention Pond; DDP = Dry Detention Pond; FS = Filter Strip; S = Grassed Swale; LS = Level Spreader; NI = Natural Infiltration Area; FB = Forested Buffer

Note: The decrease between Mitigation Plan and As-Built SMUs can be attributed to the shortening of Reach 2 due to landowner negotiations.

Table 2. Project Activity and Reporting History

Project Activity and Reporting History Muddy Run Stream Restoration / NCDMS Project #95018		
Activity or Report	**Data Collection Complete**	**Completion or Delivery**
Mitigation Plan	NA	November 2012
Final Design – Construction Plans	NA	August 2013
Construction Completed	NA	April 2014
Site Planting Completed	NA	April 2014
Baseline Monitoring Document (Year 0 Monitoring – baseline)	July 2014	September 2014
Year 1 Monitoring	November 2014	December 2014
Year 2 Monitoring	December 2015	February 2016
Year 3 Monitoring	November 2016	December 2016
Year 3 Invasive Species Management		October 2016
Year 4 Monitoring	Stream: July 2017 Veg: October 2017	February 2018
Year 5 Invasive Species Management		June 2018
Year 5 Monitoring	Stream: July 2018 Veg: September 2018	February 2019

Table 3. Project Contacts

Project Contacts Table Muddy Run Stream Restoration /NCDMS Project # 95018	
Designer	WK Dickson and Co., Inc. 720 Corporate Center Drive Raleigh, NC 27607 (919) 782-0495 Frasier Mullen, PE
Construction Contractor	GP Jenkins 6566 HWY 55 W Kinston, NC 28504 (252) 569-1222 Gary Jenkins
Planting Contractor	H&J Forestry Matt Hitch
Seeding Contractor	Rain Services, Inc. Lupe Cruz
Seed Mix Sources	Green Resource
Nursery Stock Suppliers	Arbogen
Full Delivery Provider Project Manager:	Resource Environmental Solutions, LLC 302 Jefferson Street. Suite 110 Raleigh, NC 27605 (919) 829-9909 David Godley
Monitoring Performers Project Manager:	Resource Environmental Solutions, LLC 302 Jefferson Street. Suite 110 Raleigh, NC 27605 (919) 741-6268 Ryan Medric

Table 4. Project Information and Attributes

Project Information					
Project Name			Muddy Run Stream Restoration		
County			Duplin		
Project Area (acres)			19.1		
Project Coordinates (latitude and longitude)			34.830843^0 N , -77.792838 ^{0} W		
Project Watershed Summary Information					
Physiographic Province			Coastal Plain		
River Basin			Cape Fear		
USGS Hydrologic Unit 8-digit	03030007		USGS Hydrologic Unit 14-digit	0303007060010	
DWQ Sub-basin			03-06-22		
Project Drainage Area (acres)			391		
Project Drainage Area Percentage of Impervious Area			<1%		
CGIA Land Use Classification					

Reach Summary Information

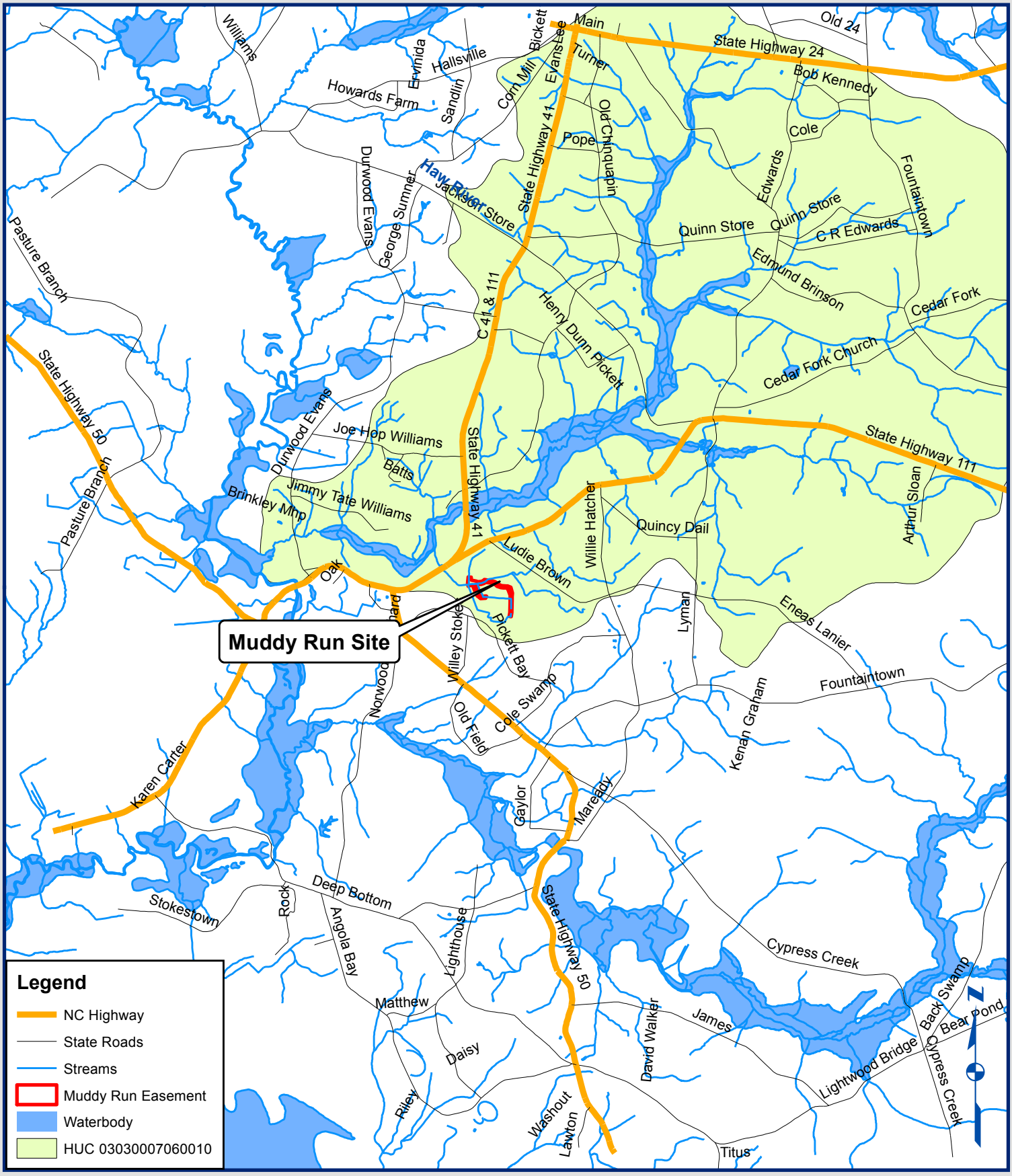
Parameters	Reach 1A	Reach 1B	Reach 1C	Reach 2	Reach 3
Length of Reach (linear feet)	1,691	1,581	1,330	1,510	607
Valley Classification					
Drainage Area (acres)	145	177	238	60	391
NCDWQ Stream Identification Score	24	29	33	26.5	24.5
NCDWQ Water Quality Classification	NA	NA	NA	NA	NA
Morphological Description (stream type)					
Evolutionary Trend					
Underlying Mapped Soils	Foreston / Rains	Goldsboro / Rains	Goldsboro / Rains	Rains	Rains
Drainage Class	---	---	---	---	---
Soil Hydric Status	Hydric	Hydric	Hydric	Hydric	Hydric
Slope	0.0016	0.0022	0.0019	0.0023	0.0010
FEMA Classification	Zone X	Zone X	Zone X	Zone X	Zone X
Native Vegetation Community	Coastal Plain Small Stream Swamp				
Percent Composition of Exotic Invasive Vegetation	0%	0%	0%	0%	0%

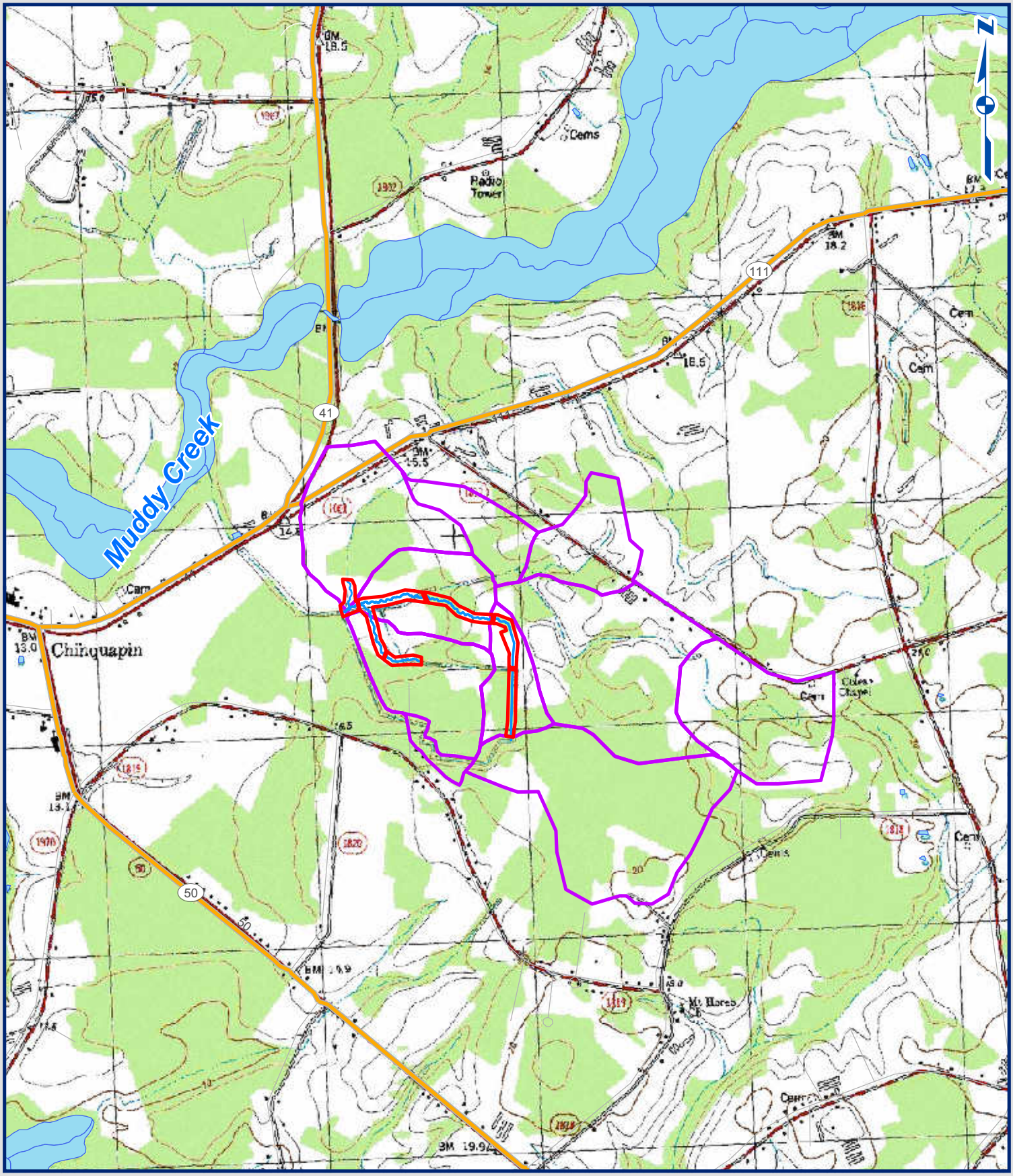
Wetland Summary Information

Parameters	Wetland 1	Wetland 2	Wetland 3
Size of Wetland (acres)			
Wetland Type (non-riparian, riparian riverine or riparian non-riverine)			
Mapped Soil Series			
Drainage class			
Soil Hydric Status			
Source of Hydrology			
Hydrologic Impairment			
Native vegetation community			
Percent composition of exotic invasive vegetation			

Regulatory Considerations

Regulation	Applicable?	Resolved?	Supporting Documentation
Waters of the United States – Section 404	X	X	USACE NWP 27
Waters of the United States – Section 401	X	X	401 Water Quality Cert.
Endangered Species Act	X	X	USFWS (Corr. Letter)
Historic Preservation Act	X	X	SHPO (Corr. Letter)
Coastal Zone Management Act (CZMA)/ Coastal Area Management Act (CAMA)	N/A	N/A	N/A
FEMA Floodplain Compliance			
Essential Fisheries Habitat	N/A	N/A	N/A


Muddy Run Site
Legend
NC Highway
State Roads
Streams
Muddy Run Easement
Waterbody
HUC 03030007060010
Williams
Ervinida
Hallsville
Howards Farm
Sandlin
Corn Mill
Bickett
Evanstee
Main
Turner
Old 24
State Highway 24
Bob Kennedy
State Highway 41
Pope
Old Chinquapin
Cole
Edwards
Fountaintown
Haw River
Jackson Store
Durwood Evans
George Sumner
Pasture Branch
Quinn Store
C R Edwards
Edmund Brinson
Cedar Fork
C 41 & 111
Henry Dunn Pickett
Cedar Fork Church
State Highway 50
Joe Hop Williams
Batts
Jimmy Tate Williams
Brinkley Mnp
State Highway 111
Arthur Sloan
Willie Hatcher
Quincy Dail
Ludie Brown
Oak
Willey Stokes
Pickett Bay
Lyman
Eneas Lanier
Norwood
Cole Swamp
Old Field
Kenan Graham
Karen Carter
Gaylor
Maready
Deep Bottom
Stokestown
Rock
Angola Bay
Lighthouse
State Highway 50
Cypress Creek
Matthew
James
David Walker
Back Swamp
Bear Pond
Lightwood Bridge
Daisy
Riley
Washout
Lawton
Titus
N
Figure 1.
Project Vicinity Map
Muddy Run Site
0
0.75
1.5
3
Miles
1 inch = 1.5 miles
DUPLIN COUNTY
Scale: NTS



res

Figure 2.
USGS/Watershed Map
Muddy Run Site

0 1,000 2,000 4,000 Feet

1 inch = 2,000 feet

Legend

- Muddy Run Streams
- Drainage Areas
- Muddy Run Easement
- Waterbodies

Appendix B

Visual Assessment Data

Reach	Mitigation Type	As-Built Length	Mitigation Ratio	SMUs
Reach 1A	Headwater Valley	1,691	1:1	1,691
Reach 1B	P1 Restoration	1,581	1:1	1,581
Reach 1C	P1 Restoration	1,345	1:1	1,330
Reach 2	P1 Restoration	1,510	1:1	1,493
Reach 3	P1 Restoration	607	1:1	607
		6,734		**6,702**

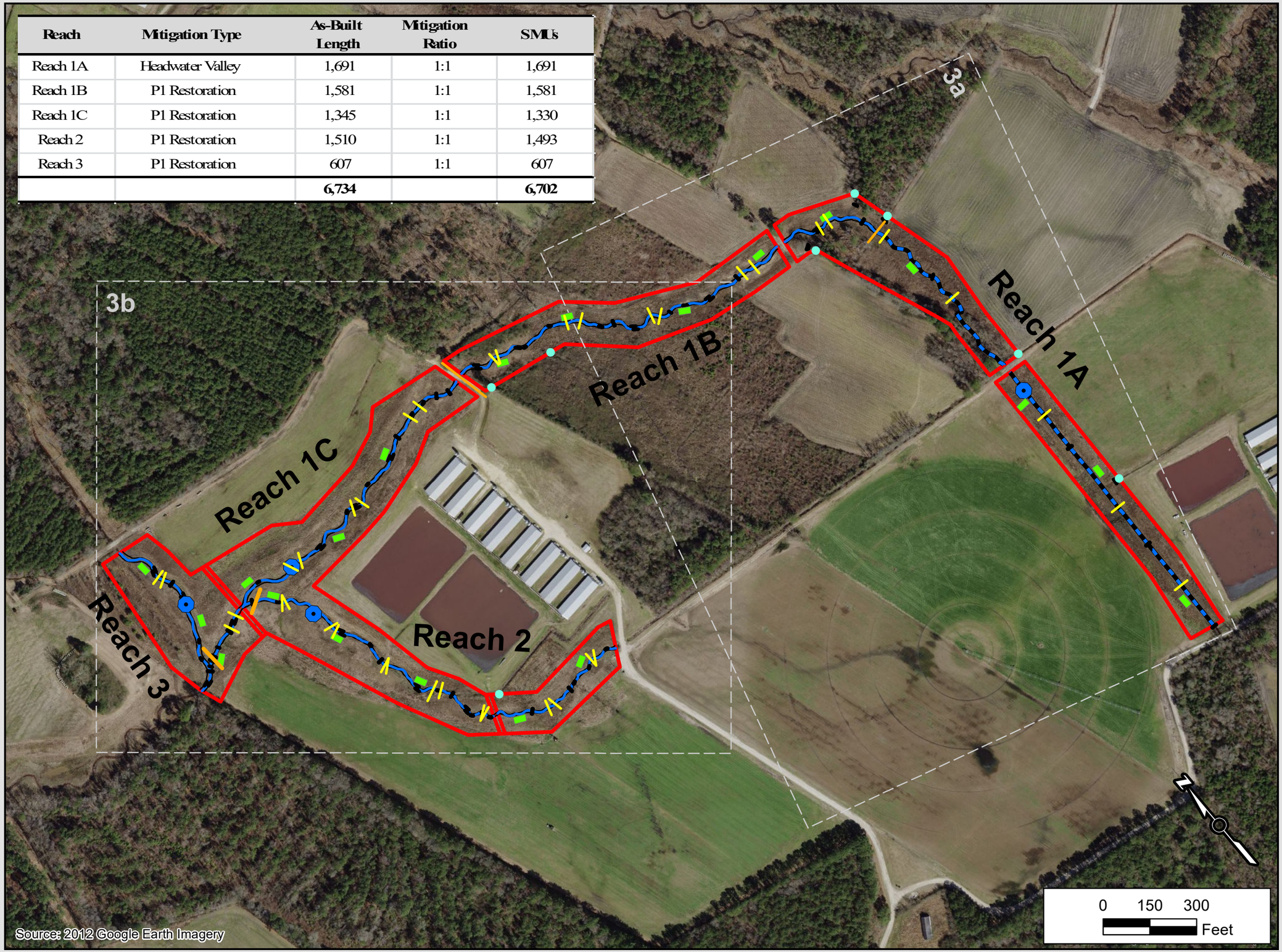


Figure 3a.
Muddy Run Mitigation Site
Current Conditions
Overview Map
MY5 2018

Duplin County, NC

res

Legend

- Easement Boundary
- Restoration
- Reach Breaks

Vegetation Plot

- >260 stems/acre
- Stream Structures
- HWV Restoration
- Restoration
- Cross Sections
- Agricultural BMP
- Stage Recorder

Figure 3b.
Muddy Run Mitigation Site
Current Conditions Map
Duplin County, NC
MY5 2018

Reach 1A

Reach 1B

VP 1
VP 2
VP 3
VP 4
VP 5
VP 6
VP 7
VP 8

Reach	Mitigation Type	As-Built Length	Mitigation Ratio	SMUs
Reach 1A	Headwater Valley	1,691	1:1	1,691
Reach 1B	P1 Restoration	1,581	1:1	1,581
Reach 1C	P1 Restoration	1,345	1:1	1,330
Reach 2	P1 Restoration	1,510	1:1	1,493
Reach 3	P1 Restoration	607	1:1	607
		6,734		**6,702**

0 150 300
Feet

Legend

- Easement Boundary
- HWV
- Restoration
- Cross Sections
- Stream Structures
- Reach Breaks
- Rain Gauge
- Agricultural BMP
- Stage Recorder

Vegetation Plot

- >260 stems/acre

Reach	Mitigation Type	As-Built Length	Mitigation Ratio	SMUs
Reach 1A	Headwater Valley	1,691	1:1	1,691
Reach 1B	P1 Restoration	1,581	1:1	1,581
Reach 1C	P1 Restoration	1,345	1:1	1,330
Reach 2	P1 Restoration	1,510	1:1	1,493
Reach 3	P1 Restoration	607	1:1	607
		6,734		**6,702**

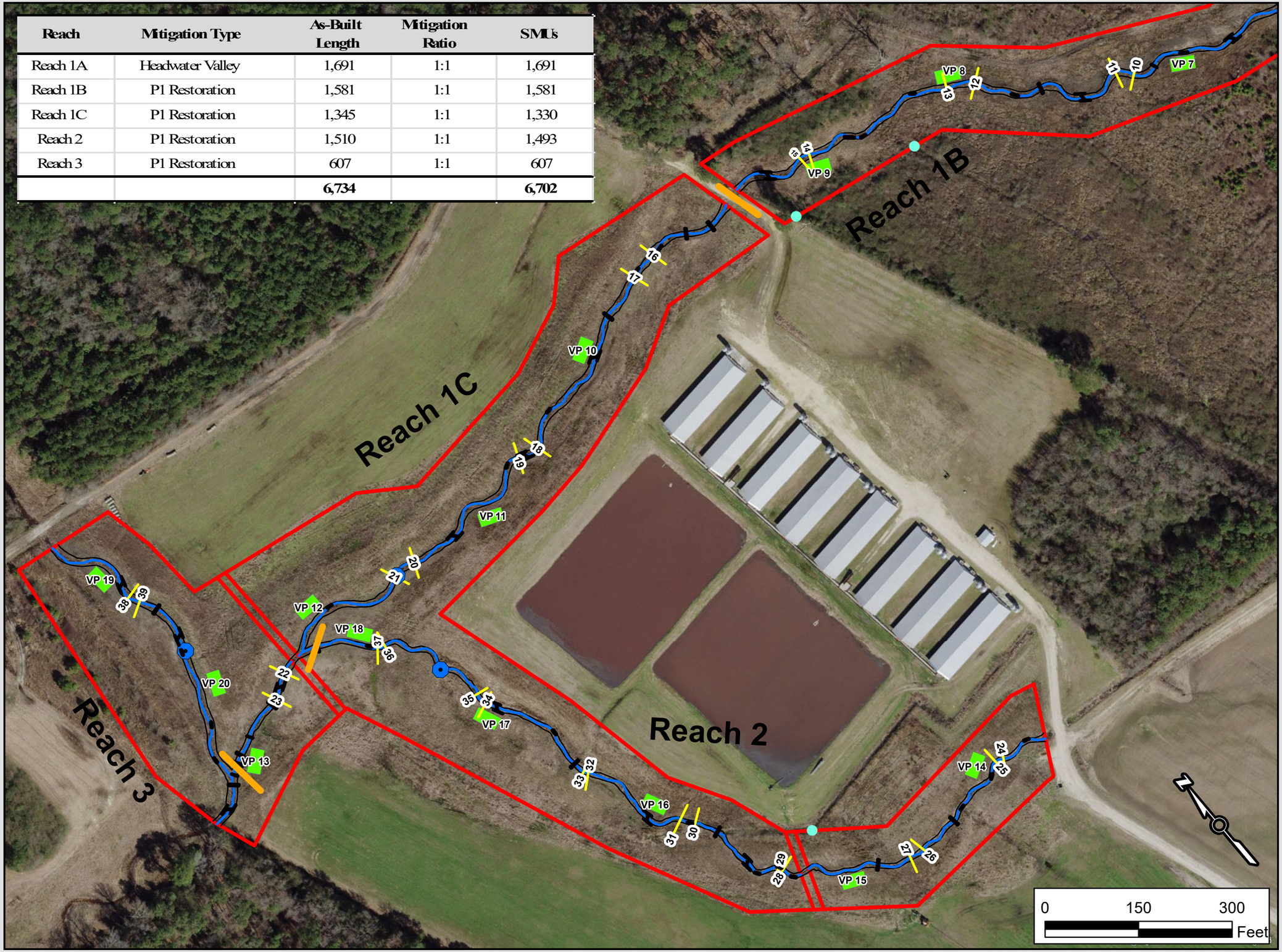


Figure 3c.
Muddy Run Mitigation Site
Current Conditions Map
Duplin County, NC
MY5 2018

res

Legend

- Easement Boundary
- HWV Restoration
- Restoration
- Cross Sections
- Reach Breaks
- Stream Structures
- Stage Recorder
- Agricultural BMP

Vegetation Plot

- >260 stems/acre

Table 5a **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 1A**
Assessed Length **1691**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	*NA	*NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth ≥ 1.6)	*NA	*NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	*NA	*NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	*NA	*NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	*NA	*NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	0	0	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	4	4			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	4	4			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	4	4			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence does not exceed 15%. (See guidance for this table in EEP monitoring guidance document)	**NA	**NA			*NA			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	2	2			100%			

* NA - Headwater Valley Restoration does not have a riffle/pool sequence.
** NA - No bank protection structures were used in this section.
[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 5b **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 1B**
Assessed Length **1581**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	NA	NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth≥ 1.6)	NA	NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	NA	NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	NA	NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	NA	NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	0	0	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	16	16			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	7	7			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	16	16			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence doesnot exceed 15%. (See guidance for this table in EEP monitoring guidance document)	5	5			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	4	4			100%			

[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 5c **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 1C**
Assessed Length **1330**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	NA	NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth≥ 1.6)	NA	NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	NA	NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	NA	NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	NA	NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	2	10	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	2	10	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	17	17			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	8	8			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	17	17			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence doesnot exceed 15%. (See guidance for this table in EEP monitoring guidance document)	5	5			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	4	4			100%			

[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 5d **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 2**
Assessed Length **1493**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	NA	NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth≥ 1.6)	NA	NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	NA	NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	NA	NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	NA	NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	0	0	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	17	17			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	5	5			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	17	17			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence doesnot exceed 15%. (See guidance for this table in EEP monitoring guidance document)	9	9			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	3	3			100%			

[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 5e **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 3**
Assessed Length **607**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	NA	NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth≥ 1.6)	NA	NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	NA	NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	NA	NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	NA	NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	0	0	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	8	8			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	2	2			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	8	8			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence doesnot exceed 15%. (See guidance for this table in EEP monitoring guidance document)	3	3			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	3	3			100%			

[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 6 Vegetation Condition Assessment

Planted Acreage[1] **17.5**

Vegetation Category	Definitions	Mapping Threshold	CCPV Depiction	Number of Polygons	Combined Acreage	% of Planted Acreage
1. Bare Areas	Very limited cover of both woody and herbaceous material.	0.1 acres	Vertical Red Lines	0	0.00	0.0%
2. Low Stem Density Areas	Woody stem densities clearly below target levels based on MY3, 4, or 5 stem count criteria.	0.1 acres	Vertical Yellow Lines	0	0.00	0.0%
			Total	0	0.00	0.0%
3. Areas of Poor Growth Rates or Vigor	Areas with woody stems of a size class that are obviously small given the monitoring year.	0.25 acres	Vertical Yellow Lines	0	0.00	0.0%
			Cumulative Total	0	0.00	0.0%

Easement Acreage[2] **19.1**

Vegetation Category	Definitions	Mapping Threshold	CCPV Depiction	Number of Polygons	Combined Acreage	% of Easement Acreage
4. Invasive Areas of Concern[4]	Areas or points (if too small to render as polygons at map scale).	1000 SF	Horizontal Lines	0	0.00	0.0%
5. Easement Encroachment Areas[3]	Areas or points (if too small to render as polygons at map scale).	none	Vertical Red Lines	0	0.00	0.0%

1 = Enter the planted acreage within the easement. This number is calculated as the easement acreage minus any existing mature tree stands that were not subject to supplemental planting of the understory, the channel acreage, crossings or any other elements not directly planted as part of the project effort.

2 = The acreage within the easement boundaries.

3 = Encroachment may occur within or outside of planted areas and will therefore be calculated against the overall easement acreage. In the event a polygon is cataloged into items 1, 2 or 3 in the table and is the result of encroachment, the associated acreage should be tallied in the relevant item (i.e., item 1,2 or 3) as well as a parallel tally in item 5.

4 = Invasives may occur in or out of planted areas, but still within the easement and will therefore be calculated against the overall easement acreage. Invasives of concern/interest are listed below. The list of high concern spcies are those with the potential to directly outcompete native, young, woody stems in the short-term (e.g. monitoring period or shortly thereafter) or affect the community structure for existing, more established tree/shrub stands over timeframes that are slightly longer (e.g. 1-2 decades). The low/moderate concern group are those species that generally do not have this capacity over the timeframes discussed and therefore are not expected to be mapped with regularity, but can be mapped, if in the judgement of the observer their coverage, density or distribution is suppressing the viability, density, or growth of planted woody stems. Decisions as to whether remediation will be needed are based on the integration of risk factors by EEP such as species present, their coverage, distribution relative to native biomass, and the practicality of treatment. For example, even modest amounts of Kudzu or Japanese Knotweed early in the projects history will warrant control, but potentially large coverages of Microstegium in the herb layer will not likley trigger control because of the limited capacities to impact tree/shrub layers within the timeframes discussed and the potential impacts of treating extensive amounts of ground cover. Those species with the "watch list" designator in gray shade are of interest as well, but have yet to be observed across the state with any frequency. Those in *red italics* are of particular interest given their extreme risk/threat level for mapping as points where isolated specimens are found, particularly ealry in a projects monitoring history. However, areas of discreet, dense patches will of course be mapped as polygons. The symbology scheme below was one that was found to be helpful for symbolzing invasives polygons, particulalry for situations where the conditon for an area is somewhere between isolated specimens and dense, discreet patches. In any case, the point or polygon/area feature can be symbolized to describe things like high or low concern and species can be listed as a map inset, in legend items if the number of species are limited or in the narrative section of the executive summary.

Table 7. Stream Problem Areas Muddy Run Stream Restoration Project - Project # 95018			
Feature Issue	**Station # / Range**	**Suspected Cause**	**Photo Number**
N/A	N/A	N/A	N/A

Table 8. Vegetation Problem Areas Muddy Run Stream Restoration Project - Project # 95018			
Feature Category	**Station Numbers**	**Suspected Cause**	**Photo Number**
N/A	N/A	N/A	N/A

Figure 4. MY5 – 2018 Vegetation Plot Photos

Muddy Run - Vegetation Monitoring Plot 1
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 2
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 3
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 4
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 5
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 6
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 7
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 8
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 9
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 10
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 11
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 12
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 13
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 14
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 15
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 16
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 17
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 18
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 19
September 25, 2018

Muddy Run - Vegetation Monitoring Plot 20
September 25, 2018

Appendix B - Stream and Vegetation Problem Area Photos

No stream or vegetation problem areas in Year 5.

Appendix C

Vegetation Plot Data

Table 9. Planted Stem Total Counts (Species by Plot)
Table 9b. Monitoring Year 4 Stem County Summary (Annual Means)
Table 9c. Planted Species Totals
Table 9d. 2015 Supplemental Planting Species Totals

Table 9a. Vegetation Plot Criteria Attainment			
Muddy Run / Project No. 95018			
Vegetation Plot ID	Planted Stems/Acre	Vegetation Survival Threshold Met?	Tract Mean
1	700	Yes	100%
2	450	Yes	
3	800	Yes	
4	500	Yes	
5	600	Yes	
6	450	Yes	
7	550	Yes	
8	550	Yes	
9	550	Yes	
10	600	Yes	
11	750	Yes	
12	650	Yes	
13	600	Yes	
14	650	Yes	
15	1000	Yes	
16	600	Yes	
17	650	Yes	
18	550	Yes	
19	750	Yes	
20	500	Yes	

Table 9a. Planted Total Stem Counts (Species by Plot)
Muddy Run Stream Restoration Site

		Current Plot Data (MY5 2018)																			
Species	**Common Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Taxodium distichum	Bald Cypress	5		6		2	1	1	1	1	5	4	5	5	5		5	3		6	
Fraxinus pennsylvanica	Green Ash	3	1	3	1		1		5	2		2			1	3				1	4
Quercus sp.	Unknown Oak sp.																				
Quercus lyrata	Overcup Oak				2	2			1	1	1	1				1	2	2	1		2
Betula nigra	River birch	4	2	2							1		2			1	3	1		2	1
Quercus michauxii	Swamp Chestnut Oak	1		2	4	1	1	7	1		1	1	5	1		11			5	1	
Nyssa biflora	Swamp Tupelo		1		1	4	1	3	1			1	1	3	2	3		7		4	
Plantanus occidentalis	American Sycamore		5	2	2	1	1			6	2	4		3	3				4		1
Quercus laurifolia	Laurel Oak	1		1		2	4		2	1	2	2			2	1	2		1	1	2
Species Count		**5**	**4**	**6**	**5**	**6**	**6**	**3**	**6**	**5**	**6**	**7**	**4**	**4**	**5**	**6**	**4**	**4**	**4**	**6**	**5**
Stem Count		**14**	**9**	**16**	**10**	**12**	**9**	**11**	**11**	**11**	**12**	**15**	**13**	**12**	**13**	**20**	**12**	**13**	**11**	**15**	**10**
Stems per Acre		**700**	**450**	**800**	**500**	**600**	**450**	**550**	**550**	**550**	**600**	**750**	**650**	**600**	**650**	**1000**	**600**	**650**	**550**	**750**	**500**

[1]No livestakes or volunteers included in tally

Table 9b. Monitoring Year 5 Stem Count Summary (Annual Means)
Muddy Run Stream Restoration Site

	Baseline		Year 1		Year 2				Year 3				Year 4				Year 5				
Vegetation Plot	**Stems Planted**	**Stems/Acre Baseline**	**Planted Living Stems**	**Stems/Acre Year 1**	**Planted Living Stems**	**Stems/Acre Year 2**	**Total Living Stems***	**Total Stems/Acre Year 2***	**Planted Living Stems**	**Stems/Acre Year 3**	**Total Living Stems***	**Total Stems/Acre Year 3***	**Planted Living Stems**	**Stems/Acre Year 4**	**Total Living Stems***	**Total Stems/Acre Year 4***	**Planted Living Stems**	**Stems/Acre Year 5**	**Total Living Stems***	**Total Stems/Acre Year 5***	**Average Stem Height (ft)**
1	16	800	15	750	15	750	15	750	15	750	15	750	15	750	21	1050	14	700	14	700	14.1
2	15	750	9	450	9	450	9	450	9	450	9	450	9	450	11	550	9	450	9	450	11.8
3	17	850	16	800	16	800	18	900	16	800	16	800	16	800	32	1600	16	800	16	800	11.9
4	14	700	14	700	13	650	13	650	11	550	18	900	12	600	43	2150	10	500	15	750	8.0
5	14	700	13	650	11	550	11	550	11	550	11	550	12	600	30	1500	12	600	15	750	4.7
6	15	750	15	750	15	750	22	1100	10	500	10	500	10	500	40	2000	9	450	20	1000	5.9
7	17	850	16	800	17	850	17	850	11	550	11	550	11	550	34	1700	11	550	21	1050	3.6
8	16	800	15	750	11	550	11	550	11	550	11	550	11	550	14	700	11	550	11	550	7.1
9	13	650	12	600	12	600	18	900	12	600	12	600	12	600	42	2100	11	550	23	1150	4.4
10	16	800	14	700	13	650	13	650	13	650	13	650	13	650	13	650	12	600	12	600	11.9
11	17	850	17	850	16	800	16	800	16	800	16	800	15	750	18	900	15	750	15	750	11.0
12	14	700	14	700	12	600	12	600	12	600	12	600	13	650	13	650	13	650	13	650	8.6
13	16	800	15	750	13	650	13	650	13	650	13	650	13	650	14	700	12	600	12	600	6.2
14	17	850	17	850	16	800	16	800	15	750	15	750	14	700	15	750	13	650	15	750	12.1
15	18	900	17	850	22	1100	22	1100	19	950	19	950	20	1000	23	1150	20	1000	20	1000	10.2
16	16	800	14	700	14	700	14	700	13	650	13	650	12	600	12	600	12	600	12	600	13.4
17	18	900	18	900	15	750	15	750	14	700	14	700	13	650	15	750	13	650	17	850	6.9
18	16	800	16	800	14	700	14	700	13	650	13	650	13	650	14	700	11	550	17	850	4.5
19	14	700	14	700	14	700	14	700	15	750	15	750	15	750	16	800	15	750	37	1850	3.2
20	15	750	15	750	12	600	12	600	11	550	11	550	12	600	15	750	10	500	11	550	12.0
Min	**13**	**650**	**9**	**450**	**9**	**450**	**9**	**450**	**9**	**450**	**9**	**450**	**9**	**450**	**11**	**550**	**9**	**450**	**9**	**450**	**3.2**
Max	**18**	**900**	**18**	**900**	**22**	**1100**	**22**	**1100**	**19**	**950**	**19**	**950**	**20**	**1000**	**43**	**2150**	**20**	**1000**	**37**	**1850**	**14.1**
Average	**15.7**	**785**	**14.8**	**740**	**14**	**700**	**15**	**738**	**13**	**650**	**13**	**668**	**13**	**653**	**22**	**1088**	**12**	**623**	**16**	**813**	**9**

* Calculations include volunteer species.
Plot Size = 40 X 22 feet = 0.020 Acres
Number Trees/Acres = # of Trees * 50

Table 9c. Planted Species Totals

Species	Common Name	Total Planted
Trees - Bare Root		
Taxodium distichum	Bald Cypress	2,000
Fraxinus pennsylvanica	Green Ash	1,900
Quercus lyrata	Overcup Oak	1,600
Betula nigra	River birch	1,600
Quercus michauxii	Swamp Chestnut Oak	2,000
Nyssa biflora	Swamp Tupelo	1,800
Plantanus occidentalis	American Sycamore	2,000
Quercus laurifolia	Laurel Oak	1,600
	Total	**14,500**
Live Stakes		
Salix nigra	Black Willow	3,000
	Total	**3,000**

Table 9d. 2015 Supplemental Planting Species Totals

Species	Common Name	Total Planted
Trees - Bare Root		
Quercus lyrata	Overcup Oak	900
Betula nigra	River birch	300
Quercus michauxii	Swamp Chestnut Oak	800
Plantanus occidentalis	American Sycamore	500
	Total	**2,500**

Appendix D

Stream Geomorphology Data

Appendix D. Table 10 - Morphological Parameters Summary Data
Project Name/Number: Muddy Run Mitigation Project/95018

	Reference Reach			Existing[1]					Design								As-Built/Baseline							
				MR1A	MR1B	MR1C	MR2	MR3	MR1B		MR1C		MR2		MR3		MR1B		MR1C		MR2		MR3	
Feature	Pool	Run	Shallow	Run	Run	Run	Run	Run	Shallow		Shallow		Shallow		Shallow		Shallow		Shallow		Shallow		Shallow	
Drainage Area (ac)	286	286	286	145	177	238	60	85	177		238		60		391		177		238		60		391	
NC Regional Curve Discharge (cfs)			9.3	6	7	8	3	4	7		8		3		12		7		8		3		12	
Design/Calculated Discharge (cfs)	---	---	13	---	---	---	---	---	9		13		4		19		12.1		13.8		5.4		13.5	
Dimension																								
BF Width (ft)	10.9	8.9	7.0	6.6	7.3	9.7	6.9	7.2	8.2		9.5		5.6		11.4		11.6		11.5		9.9		11.9	
Floodprone Width (ft)	100	100	100	9.9	10.3	15.3	10.3	10.7	> 50		> 50		> 50		> 50		> 50		> 50		> 50		> 50	
BF Cross Sectional Area (ft^2)	11.4	8.4	5	5	4.4	5.6	3.6	3.3	6.6		8.9		3.1		13.1		7.4		8.3		4.8		9.3	
BF Mean Depth (ft)	1.0	0.9	0.8	0.8	0.6	0.6	0.5	0.5	0.8		0.9		0.6		1.1		0.6		0.7		0.5		0.8	
BF Max Depth (ft)	2.1	1.7	1.3	1.1	0.9	1.3	1.0	0.8	1.3		1.5		0.9		1.7		1.4		1.5		1		1.6	
Width/Depth Ratio	10.4	9.5	8.8	8.7	12.2	17.1	13.2	15.8	10		10		10		10		18.6		15.7		21.2		15.1	
Entrenchment Ratio	9.2	11.2	15.1	1.5	1.4	1.5	1.5	10.5	> 2.2		> 2.2		> 2.2		> 2.2		> 2.2		> 2.2		> 2.2		> 2.2	
Wetted Perimeter (ft)	12.8	9.7	7.4	6.9	7.7	10.3	7.2	7.4	8.7		10.1		5.9		12.1		12.2		11.9		10.3		12.4	
Hydraulic Radius (ft)	0.9	0.9	0.7	0.7	0.6	0.5	0.5	0.4	0.8		0.9		0.5		1.1		0.6		0.7		0.5		0.8	
Substrate																								
	Fine Sand			Fine Sand					Fine Sand		Fine Sand		Fine Sand		Fine Sand		Fine Sand		Fine Sand		Fine Sand		Fine Sand	
Pattern																								
	Min	**Max**	**Med**	---	---	---	---	---	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Channel Beltwidth (ft)	13.6	31.8	23.1	---	---	---	---	---	13.3	40.0	18.0	37.2	10.2	26.8	20.6	40.3	17.9	45.3	14.9	40.3	12.1	27.5	17.3	45.8
Radius of Curvature (ft)	11.0	27.6	17.6	---	---	---	---	---	11.4	40.4	14.8	40.8	8.9	21.7	22.8	46.5	14.5	48.7	16.8	54.9	11.1	29.4	33.8	74.9
Radius of Curvature Ratio	1.5	3.7	2.3						1.4	4.9	1.6	3.5	1.6	3.4	2.0	4.1	1.3	4.2	1.5	4.8	1.1	3.0	2.8	6.3
Meander Wavelength (ft)	34.9	68.3	54.5	---	---	---	---	---	23.2	89.9	33.2	71.2	16.2	48.6	56.5	144	44.9	99.2	37.3	94.9	20.6	44.0	41.88	88.7
Meander Width Ratio	1.8	4.2	3.1	---	---	---	---	---	1.6	4.9	1.9	3.9	1.8	4.8	1.8	3.5	1.5	3.9	1.3	3.5	1.2	2.8	1.5	3.8
Profile																								
Shallow Length (ft)	3.1	30.7	12.6	---	---	---	---	---	5	72	10	72	4	62	25.9	39.9	8	27	18	35	7.1	24.3	6.0	27.0
Run Length (ft)	2.2	33.2	11.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pool Length (ft)	4.2	9.5	5.8	---	---	---	---	---	17	36	20	34	9	20	18.2	49.0	12	28	14	30	11.6	20.2	9.0	28.0
Pool -to-Pool Spacing (ft)	17.5	59.8	36.3	---	---	---	---	---	23	95	25	97	16	78	37.0	90.0	20	82	25	69	22	75	16.0	90.0
Additional Reach Parameters																								
Valley Length (ft)	274			---	---	---	---	---	1485		1194		1560		554		1485		1194		1560		554	
Channel Length (ft)	309			1638	1590	1324	1448	464	1652		1386		1533		613		1584		1344		1510		607	
Sinuosity	1.1			1.0	1.0	1.0	1.0	1.0	1.1		1.2		1.0		1.1		1.1		1.1		1.0		1.1	
Water Surface Slope (ft/ft)	0.004			---	---	---	---	---	---		---		---		---		---		---		---		---	
Channel Slope (ft/ft)	0.003			0.0016	0.0033	0.0035	0.0032	0.0055	0.0022		0.0019		0.0023		0.0008		0.0036		0.0031		0.0024		0.0022	
Rosgen Classification	E5			G5c	F5	F5	F5	F5	E5		E5		E5		E5		E5		E5		E5		E5	
*Habitat Index																								

[1] Bankfull stage was estimated using NC Regional Curve equations and existing conditions data

Appendix D. Table 11 - Monitoring Data - Dimensional Morphology Summary (Dimensional Parameters – Cross Sections)

Project Name/Number: Muddy Run Mitigation Project/95018

	Cross Section 1 (HWV)							Cross Section 2 (HWV)							Cross Section 3 (HWV)							Cross Section 4 (HWV)							Cross Section 5 (HWV)						
MY5 based on fixed baseline bankfull cross sectional area*	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.							(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.							(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.							(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.							(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.						
Bankfull Width (ft)																																				
Floodprone Width (ft)																																				
Bankfull Mean Depth (ft)																																				
Bankfull Max Depth (ft)																																				
Bankfull Cross Sectional Area (ft^2)																																				
Bankfull Width/Depth Ratio																																				
Bankfull Entrenchment Ratio																																				
Bankfull Bank Height Ratio																																				
	Cross Section 6 (Pool)							**Cross Section 7 (Shallow)**							**Cross Section 8 (Shallow)**							**Cross Section 9 (Pool)**							**Cross Section 10 (Shallow)**						
MY5 based on fixed baseline bankfull cross sectional area*	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	49.5	49.5	49.5	49.5	49.5	49.50		49.5	49.5	49.5	49.5	49.5	49.58		48.5	48.5	48.5	48.5	48.5	48.62		48.3	48.3	48.3	48.3	48.3	48.3		46.5	46.5	46.5	46.5	46.5	46.55	
Bankfull Width (ft)	9.0	8.4	9.4	9.2	9.6	10.0		10.7	10.7	11.6	11.5	10.8	11.5		9.6	8.9	9.6	8.9	9.3	10.6		8.8	8.1	8.8	7.8	7.3	8.6		14.3	14.4	15.7	13.5	16.2	16.2	
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	45.0		50.0	50.0	50.0	50.0	50.0	45.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0	
Bankfull Mean Depth (ft)	1.1	1.0	1.0	1.0	1.0	0.9		0.7	0.7	0.7	0.7	0.7	0.7		0.7	0.6	0.6	0.5	0.6	0.6		0.9	0.8	0.7	0.9	1.0	0.9		0.5	0.4	0.4	0.5	0.4	0.4	
Bankfull Max Depth (ft)	2.2	2.1	2.0	1.8	1.9	1.9		1.7	1.7	1.7	1.6	1.6	1.6		1.4	1.4	1.2	1.1	1.2	1.3		1.7	1.5	1.5	1.5	1.6	1.7		1.3	1.1	1.2	1.2	1.1	1.2	
Bankfull Cross Sectional Area (ft^2)	9.4	8.5	9.1	8.9	9.5	9.4		8.0	8.0	8.1	7.8	7.5	8.0		6.4	5.7	5.8	4.7	5.4	6.4		7.5	6.7	6.5	6.9	7.0	7.5		6.8	6.1	6.2	6.4	6.4	6.8	
Bankfull Width/Depth Ratio	8.5	8.3	9.8	9.5	9.8	10.5		14.4	14.4	16.6	17.1	15.5	16.5		14.4	14.0	15.9	16.8	16.0	17.4		10.3	9.8	11.7	8.9	7.6	9.9		29.9	34.2	39.9	28.5	41.2	38.2	
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>3.9		>2.2	>2.2	>2.2	>2.2	>2.2	>4.2		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>3.1	
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	1.1	1.1		1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	0.9	1.0	
	Cross Section 11 (Pool)							**Cross Section 12 (Shallow)**							**Cross Section 13 (Pool)**							**Cross Section 14 (Shallow)**							**Cross Section 15 (Pool)**						
MY5 based on fixed baseline bankfull cross sectional area*	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	46.4	46.4	46.4	46.4	46.4	46.52		45.6	45.6	45.6	45.6	45.6	45.67		45.5	45.5	45.5	45.5	45.5	45.58		45.0	45.0	45.0	45.0	45.0	45.01		44.4	44.4	44.4	44.4	44.4	44.49	
Bankfull Width (ft)	14.7	14.4	15.4	16.1	16.4	17.6		11.4	11.4	11.2	7.7	10.4	14.2		13.2	12.3	14.0	12.7	14.7	15.3		12.0	12.3	11.4	11.1	13.0	15.0		10.0	9.9	11.5	10.9	10.6	11.7	
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	45.0		50.0	50.0	50.0	50.0	50.0	45.0		50.0	50.0	50.0	50.0	50.0	45.0	
Bankfull Mean Depth (ft)	0.6	0.6	0.5	0.5	0.5	0.5		0.6	0.6	0.5	0.6	0.4	0.5		0.6	0.6	0.5	0.5	0.5	0.5		0.7	0.7	0.7	0.7	0.6	0.6		0.9	0.9	0.8	0.8	0.8	0.8	
Bankfull Max Depth (ft)	1.8	1.5	1.4	1.5	1.4	1.5		1.2	1.2	1.2	1.1	1.1	1.2		1.4	1.3	1.2	1.1	1.1	1.2		1.4	1.5	1.4	1.3	1.4	1.5		1.9	1.8	1.7	1.7	1.6	1.7	
Bankfull Cross Sectional Area (ft^2)	9.1	7.9	7.7	8.2	8.3	9.1		7.1	6.3	5.9	4.3	4.5	7.1		8.4	7.2	7.6	6.8	7.6	8.4		8.7	8.4	7.9	7.4	8.0	8.7		9.1	8.8	9.1	8.2	8.3	9.1	
Bankfull Width/Depth Ratio	23.9	26.1	30.8	31.7	32.6	34.1		18.2	20.7	21.3	13.8	24.1	28.3		20.7	21.1	25.8	23.5	28.6	28.0		16.4	17.8	16.5	16.7	21.3	25.7		11.1	11.1	14.6	14.5	13.5	15.0	
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>3.5		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>3.0		>2.2	>2.2	>2.2	>2.2	N/A	N/A	
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	0.9	1.0		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	1.0	0.9		1.0	1.0	1.0	1.0	N/A	N/A	
	Cross Section 16 (Shallow)							**Cross Section 17 (Pool)**							**Cross Section 18 (Pool)**							**Cross Section 19 (Shallow)**							**Cross Section 20 (Shallow)**						
MY5 based on fixed baseline bankfull cross sectional area*	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	44.0	44.0	44.0	44.0	44.0	44.08		43.7	43.7	43.7	43.7	43.7	43.93		42.8	42.8	42.8	42.8	42.8	42.94		43.0	43.0	43.0	43.0	43.0	43.06		42.6	42.6	42.6	42.6	42.6	42.74	
Bankfull Width (ft)	13.3	14.0	14.8	14.5	15.0	19.5		13.0	12.3	12.8	13.0	13.0	23.1		8.9	8.7	8.4	8.4	9.1	10.3		11.9	11.6	11.4	9.5	9.6	12.4		10.8	10.8	15.7	10.2	13.7	11.9	
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0	
Bankfull Mean Depth (ft)	0.8	0.7	0.7	0.6	0.6	0.5		0.9	0.8	0.8	0.7	0.7	0.5		1.1	1.1	1.0	1.0	1.0	1.0		0.7	0.7	0.7	0.6	0.6	0.7		0.7	0.7	0.5	0.7	0.5	0.7	
Bankfull Max Depth (ft)	1.4	1.4	1.3	1.1	1.4	1.6		1.5	1.7	1.7	1.5	1.3	1.8		2.0	1.9	1.8	1.6	1.7	1.8		1.5	1.5	1.4	1.2	1.3	1.5		1.6	1.5	1.2	1.4	1.4	1.5	
Bankfull Cross Sectional Area (ft^2)	10.0	9.8	10.1	8.2	8.3	10.0		11.3	10.4	10.2	9.3	8.8	11.3		10.2	9.4	8.8	8.6	9.1	10.2		8.1	7.8	7.8	5.4	6.1	8.1		8.0	7.3	8.0	7.0	7.0	8.0	
Bankfull Width/Depth Ratio	17.6	20.1	21.7	25.8	26.9	38.4		15.0	14.5	15.9	18.2	19.3	47.3		7.7	8.1	8.1	8.3	9.1	10.5		17.4	17.1	16.7	16.7	15.2	18.9		14.5	16.1	30.6	14.9	26.8	17.7	
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	>2.2	>2.6		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>4.0		>2.2	>2.2	>2.2	>2.2	>2.2	>4.2	
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	1.0	0.9		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0	1.0	1.0	

* Annual measurements for monitoring year MY5 are based on fixed baseline cross sectional area. Prior years' annual measurements were based on fixed baseline bankfull elevations.

Appendix D. Table 11 - Monitoring Data - Dimensional Morphology Summary (Dimensional Parameters – Cross Sections)

Project Name/Number: Muddy Run Mitigation Project/95018

	Cross Section 21 (Pool)							Cross Section 22 (Shallow)							Cross Section 23 (Pool)							Cross Section 24 (Shallow)							Cross Section 25 (Pool)						
MY5 based on fixed baseline bankfull cross sectional area*	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	42.3	42.3	42.3	42.3	42.3	42.42		41.8	41.8	41.8	41.8	41.8	41.89		41.5	41.5	41.5	41.5	41.5	41.53		45.2	45.2	45.2	45.2	45.2	45.34		45.2	45.2	45.2	45.2	45.2	45.33	
Bankfull Width (ft)	10.6	10.5	12.3	13.1	10.5	11.6		9.8	11.4	10.0	9.4	9.7	12.9		10.6	11.7	11.5	10.9	11.2	11.5		9.1	9.9	8.9	8.4	8.3	11.0		8.6	8.2	8.5	8.4	7.6	10.8	
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	36.4		50.0	50.0	50.0	50.0	50.0	50.0	
Bankfull Mean Depth (ft)	1.1	1.1	0.9	0.9	0.9	1.0		0.7	0.6	0.6	0.7	0.7	0.6		0.7	0.6	0.6	0.6	0.5	0.6		0.5	0.5	0.4	0.4	0.4	0.4		0.6	0.6	0.6	0.5	0.5	0.5	
Bankfull Max Depth (ft)	2.2	2.2	2.1	1.9	1.7	2.1		1.4	1.5	1.4	1.3	1.4	1.5		1.2	1.3	1.1	1.3	1.2	1.3		1.0	0.9	0.7	0.7	0.7	0.8		1.3	1.2	1.1	0.9	1.0	1.1	
Bankfull Cross Sectional Area (ft^2)	11.5	11.5	11.7	11.7	10.0	11.5		7.2	7.1	6.3	6.3	6.4	7.2		7.0	7.3	6.8	6.7	6.1	7.0		4.6	4.5	3.2	3.3	3.2	4.6		5.3	4.9	4.8	3.9	4.0	5.3	
Bankfull Width/Depth Ratio	9.8	9.6	13.0	14.6	11.1	11.7		13.3	18.2	15.9	14.1	14.9	23.3		16.3	18.7	19.5	17.9	20.3	18.8		18.2	21.5	24.4	21.6	21.8	26.4		13.9	13.8	15.0	18.0	14.4	22.2	
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>3.9		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>3.3		>2.2	>2.2	>2.2	>2.2	N/A	N/A	
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	1.1	0.9		1.0	1.0	1.0	1.0	N/A	N/A	
	Cross Section 26 (Shallow)							**Cross Section 27 (Pool)**							**Cross Section 28 (Shallow)**							**Cross Section 29 (Pool)**							**Cross Section 30 (Pool)**						
MY5 based on fixed baseline bankfull cross sectional area*	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	44.6	44.6	44.6	44.6	44.6	44.70		44.5	44.5	44.5	44.5	44.5	44.60		44.0	44.0	44.0	44.0	44.0	44.13		43.6	43.6	43.6	43.6	43.6	43.81		42.7	42.7	42.7	42.7	42.7	42.84	
Bankfull Width (ft)	7.3	9.1	8.5	7.6	7.7	10.1		7.0	7.6	7.3	7.2	7.7	8.7		19.6	20.1	20.3	15.9	14.7	19.1		9.7	10.1	9.4	9.0	9.8	14.0		7.4	7.3	8.5	8.6	6.2	8.1	
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0	
Bankfull Mean Depth (ft)	0.6	0.5	0.4	0.5	0.5	0.4		0.7	0.6	0.7	0.6	0.6	0.6		0.4	0.4	0.4	0.4	0.4	0.4		0.7	0.6	0.5	0.5	0.5	0.5		0.5	0.5	0.5	0.4	0.4	0.5	
Bankfull Max Depth (ft)	1.1	1.1	1.0	1.0	0.9	1.1		1.4	1.4	1.3	1.2	1.2	1.3		1.2	1.3	1.1	1.1	1.1	1.2		1.5	1.3	1.2	1.2	1.3	1.5		1.1	0.9	1.0	0.9	0.7	1.0	
Bankfull Cross Sectional Area (ft^2)	4.3	4.1	3.4	3.6	3.5	4.3		5.1	5.1	4.8	4.4	4.4	5.1		8.2	8.7	7.6	6.7	6.6	8.4		6.4	6.2	4.5	4.5	4.6	6.4		4.0	3.6	3.9	3.6	2.5	4.0	
Bankfull Width/Depth Ratio	12.2	20.1	21.2	16.3	17.2	23.3		9.5	11.2	10.9	11.9	13.5	15.0		47.1	46.3	54.0	38.0	32.6	43.3		14.7	16.5	19.4	18.2	21.1	30.4		13.6	15.0	18.2	20.1	15.4	16.1	
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	>2.2	>5.0		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>2.6		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	N/A	N/A	
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	1.0	0.9		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	N/A	N/A	
	Cross Section 31 (Shallow)							**Cross Section 32 (Shallow)**							**Cross Section 33 (Pool)**							**Cross Section 34 (Shallow)**							**Cross Section 35 (Pool)**						
MY5 based on fixed baseline bankfull cross sectional area*	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	42.9	42.9	42.9	42.9	42.9	43.03		42.6	42.6	42.6	42.6	42.6	42.79		42.4	42.4	42.4	42.4	42.4	42.54		42.2	42.2	42.2	42.2	42.2	42.3		42.1	42.1	42.1	42.1	42.1	42.28	
Bankfull Width (ft)	11.3	12.3	13.5	11.3	12.1	16.3		6.8	7.2	6.9	6.3	7.4	10.8		7.1	7.4	7.8	7.1	7.1	8.6		8.4	7.8	6.8	7.1	7.4	9.7		7.7	7.8	8.0	7.3	6.7	7.1	
Floodprone Width (ft)	70.0	70.0	70.0	70.0	70.0	70.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	47.9		50.0	50.0	50.0	50.0	50.0	44.6		50.0	50.0	50.0	50.0	50.0	45.0	
Bankfull Mean Depth (ft)	0.4	0.4	0.3	0.4	0.4	0.3		0.5	0.5	0.5	0.5	0.4	0.3		0.6	0.6	0.4	0.5	0.5	0.5		0.5	0.5	0.5	0.4	0.4	0.4		0.7	0.7	0.6	0.7	0.7	0.8	
Bankfull Max Depth (ft)	0.9	0.9	1.0	1.0	1.0	0.9		1.0	1.0	1.0	1.0	1.0	1.1		1.1	1.0	0.8	0.8	0.8	1.0		0.9	0.9	0.9	0.8	0.9	1.0		1.4	1.4	1.1	1.2	1.2	1.3	
Bankfull Cross Sectional Area (ft^2)	4.6	4.5	4.6	4.0	4.3	4.6		3.7	3.8	3.5	3.2	3.2	3.7		4.3	4.3	3.2	3.5	3.3	4.3		3.9	3.6	3.2	3.1	2.8	3.9		5.6	5.3	4.7	5.0	4.9	5.6	
Bankfull Width/Depth Ratio	28.3	33.7	39.3	31.7	33.9	57.2		12.4	13.4	13.6	12.5	17.4	31.8		11.5	12.9	19.4	14.5	15.4	17.2		18.1	16.5	14.7	16.3	19.7	24.1		10.5	11.3	13.8	10.6	9.1	8.9	
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	>2.2	>4.3		>2.2	>2.2	>2.2	>2.2	>2.2	>4.6		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>4.6		>2.2	>2.2	>2.2	>2.2	N/A	N/A	
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	0.9	0.9		1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	0.9	1.0		1.0	1.0	1.0	1.0	N/A	N/A	
	Cross Section 36 (Shallow)							**Cross Section 37 (Pool)**							**Cross Section 38 (Pool)**							**Cross Section 39 (Shallow)**													
MY5 based on fixed baseline bankfull cross sectional area*	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	41.8	41.8	41.8	41.8	41.8	41.73		41.8	41.8	41.8	41.8	41.8	41.83		41.1	41.1	41.1	41.1	41.1	41.15		41.1	41.1	41.1	41.1	41.1	41.18								
Bankfull Width (ft)	7.4	7.8	9.8	7.8	9.1	8.6		9.6	10.0	9.2	9.7	9.4	14.5		15.6	15.5	16.7	16.1	16.3	18.0		11.9	11.6	12.1	11.9	12.3	14.2								
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0		50.0	50.0	50.0	50.0	50.0	50.0								
Bankfull Mean Depth (ft)	0.6	0.6	0.5	0.6	0.4	0.5		0.5	0.4	0.5	0.5	0.5	0.4		1.2	1.1	1.0	1.0	1.0	1.0		0.8	0.7	0.7	0.7	0.6	0.7								
Bankfull Max Depth (ft)	1.0	1.0	1.0	1.0	0.8	1.0		1.3	1.1	1.1	1.1	1.0	1.2		2.5	2.2	2.3	2.0	2.0	2.2		1.6	1.5	1.5	1.5	1.4	1.7								
Bankfull Cross Sectional Area (ft^2)	4.4	4.3	4.5	4.7	3.7	4.4		5.1	4.4	4.2	5.1	4.6	5.1		18.6	17.3	17.3	16.4	16.7	18.2		9.3	8.1	8.0	8.1	7.9	9.3								
Bankfull Width/Depth Ratio	12.2	14.2	21.0	13.0	22.5	16.7		18.2	22.9	19.8	18.3	19.1	40.9		13.0	14.0	16.1	15.7	15.8	17.9		15.1	16.6	18.4	17.5	19.0	21.9								
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	>2.2	>5.8		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	N/A	N/A		>2.2	>2.2	>2.2	>2.2	>2.2	>3.5								
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	N/A	N/A		1.0	1.0	1.0	1.0	0.9	0.9								

* All annual measurements for monitoring year MY5 are based on fixed baseline cross sectional area. Prior years' annual measurements were based on fixed baseline bankfull elevations.

Table 12.Muddy Run Bank Pin Array Summary

Cross Section	Location	Position	Year 1 Reading (ft)	Year 2 Reading (ft)	Year 3 Reading (ft)	Year 4 Reading (ft)	Year 5 Reading (ft)
XS 6 @ Sta. 19+70 Reach 1	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 11 @ Sta. 26+70 Reach 1	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 15 @ Sta. 32+75 Reach 1	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 18 @ Sta. 39+70 Reach 1	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 23 @ Sta. 46+30 Reach 1	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.1	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 25 @ Sta. 2+90 Reach 2	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 29 @ Sta. 7+60 Reach 2	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 33 @ Sta. 11+45 Reach 2	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 37 @ Sta. 15+80 Reach 2	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
XS 38 @ Sta. 2+55 Reach 3	US	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0	0.0

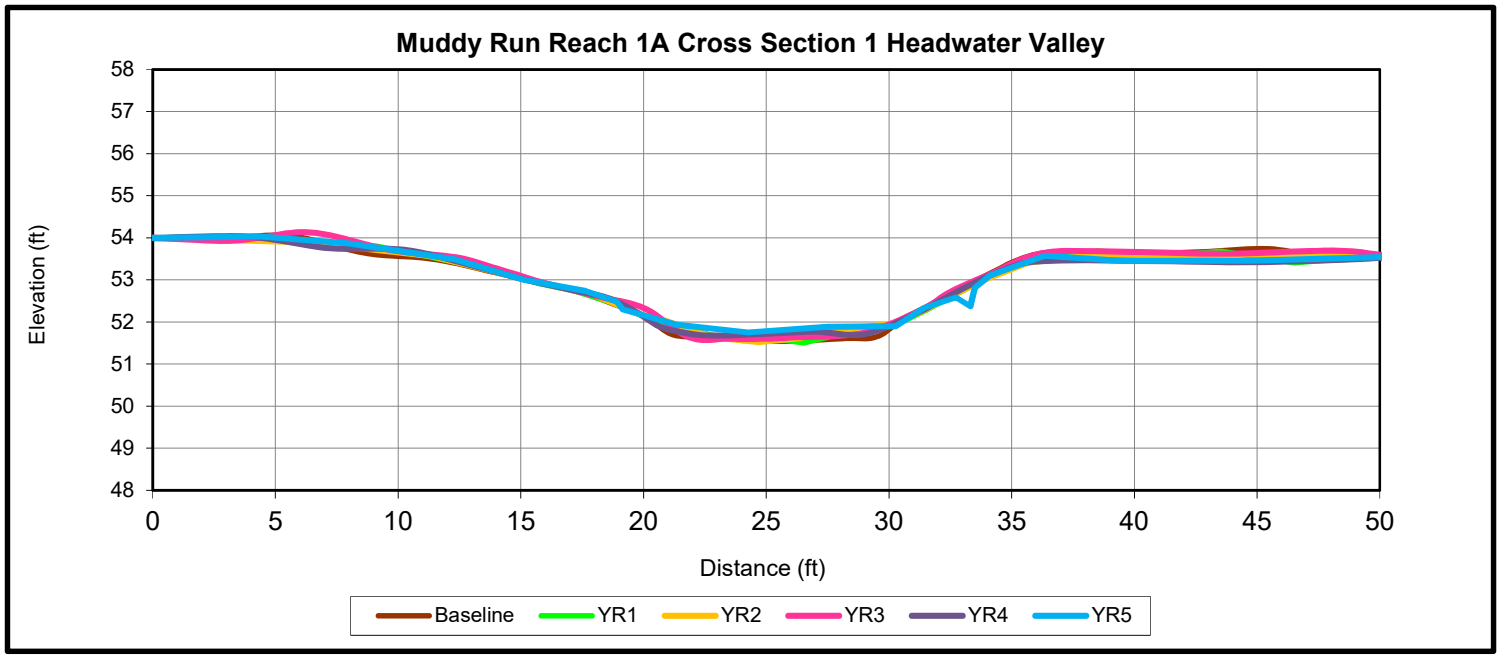
Notes:

US - Upstream from cross section

DS - Downstream from cross section

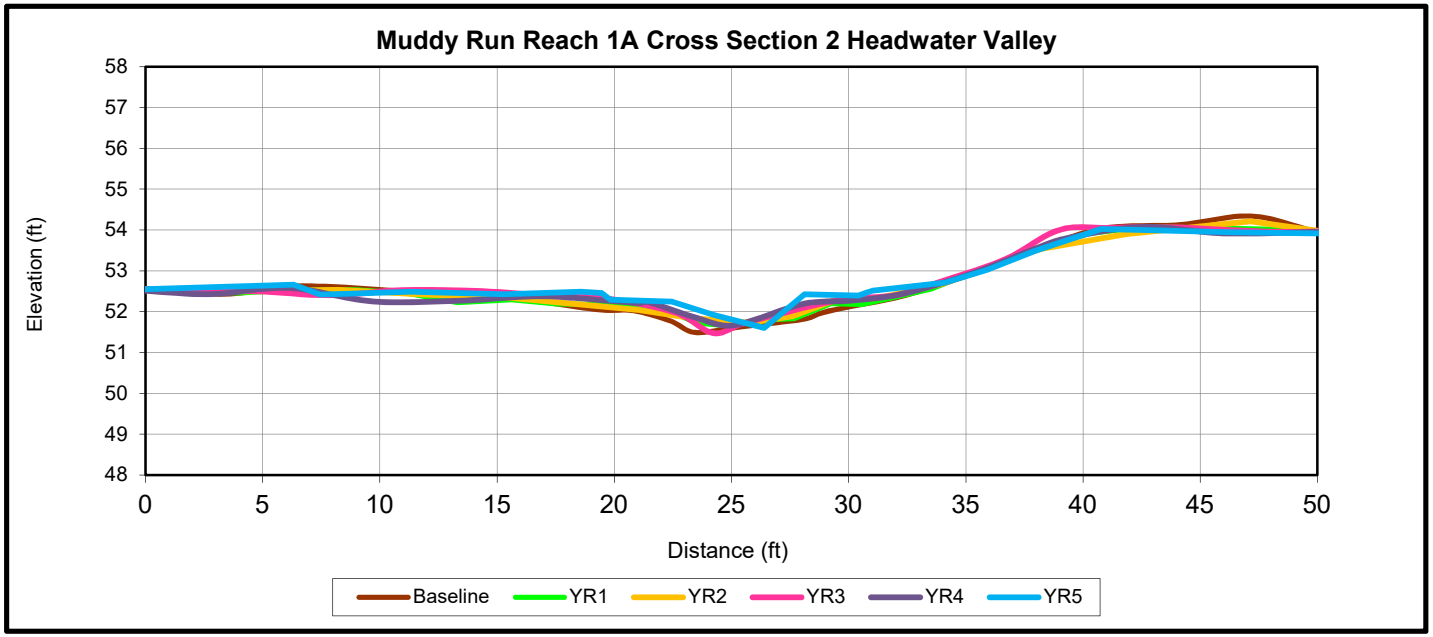
Upstream

Downstream



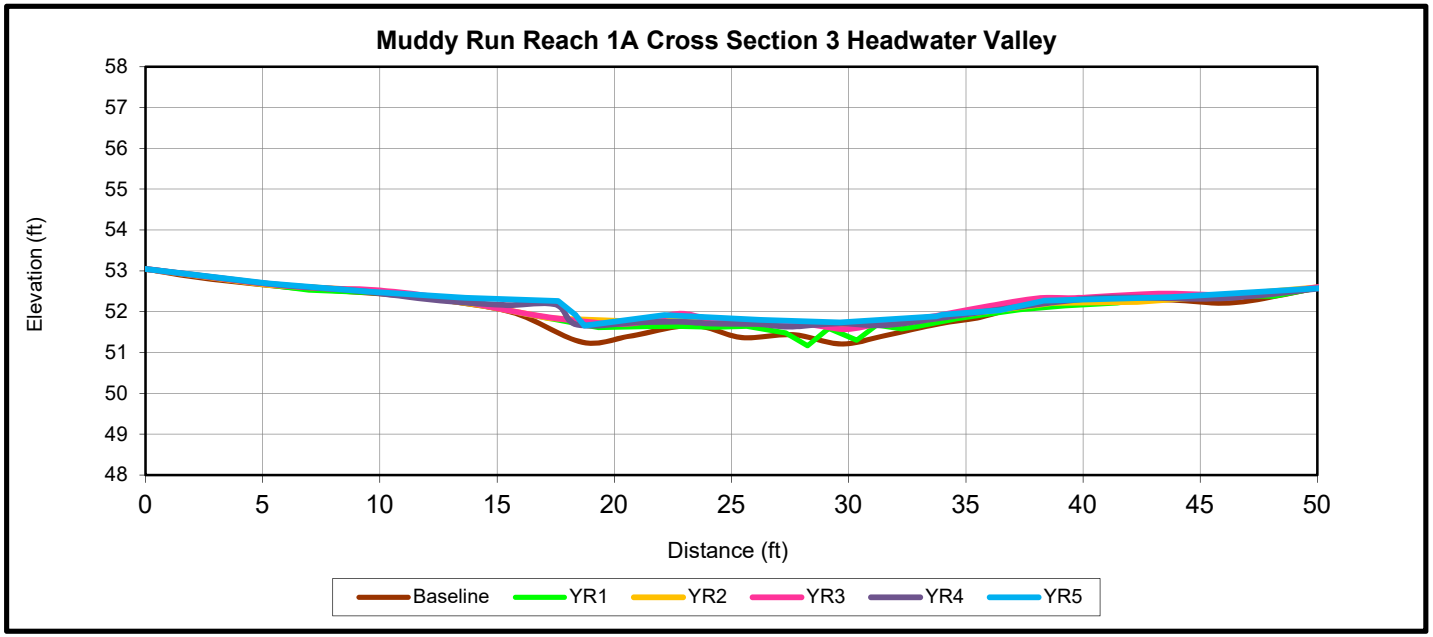
Upstream

Downstream



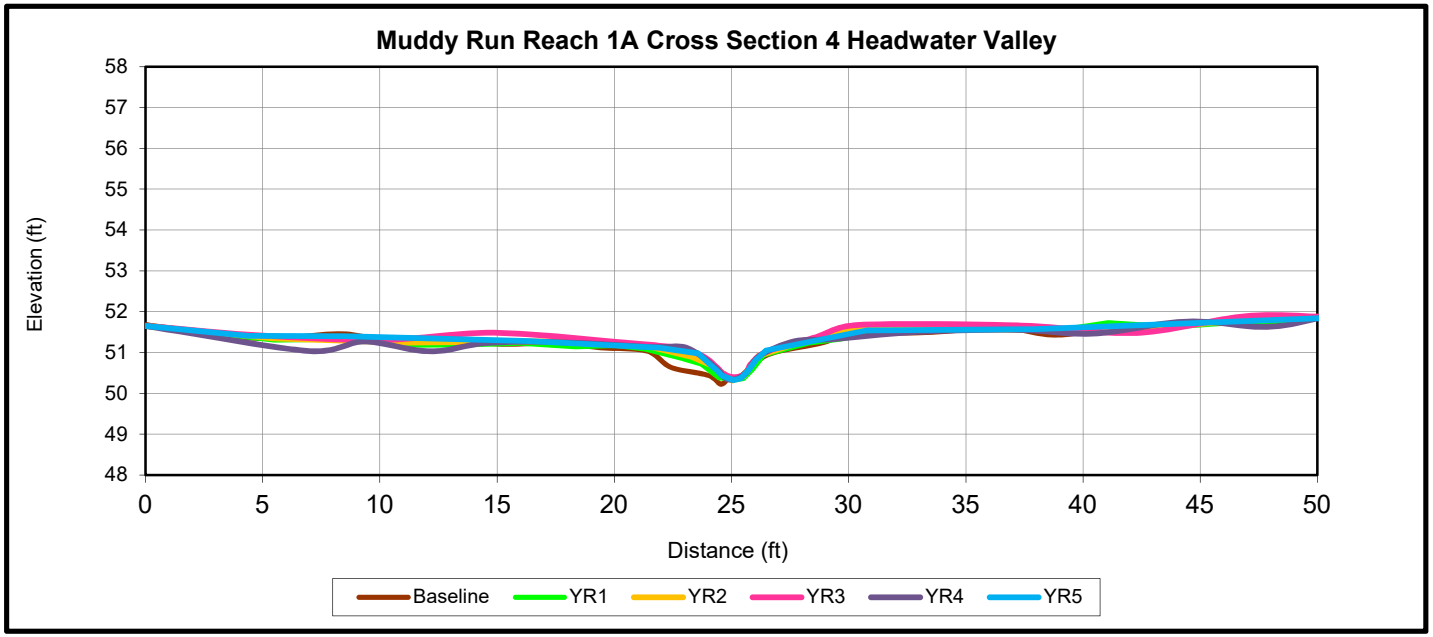
Upstream

Downstream



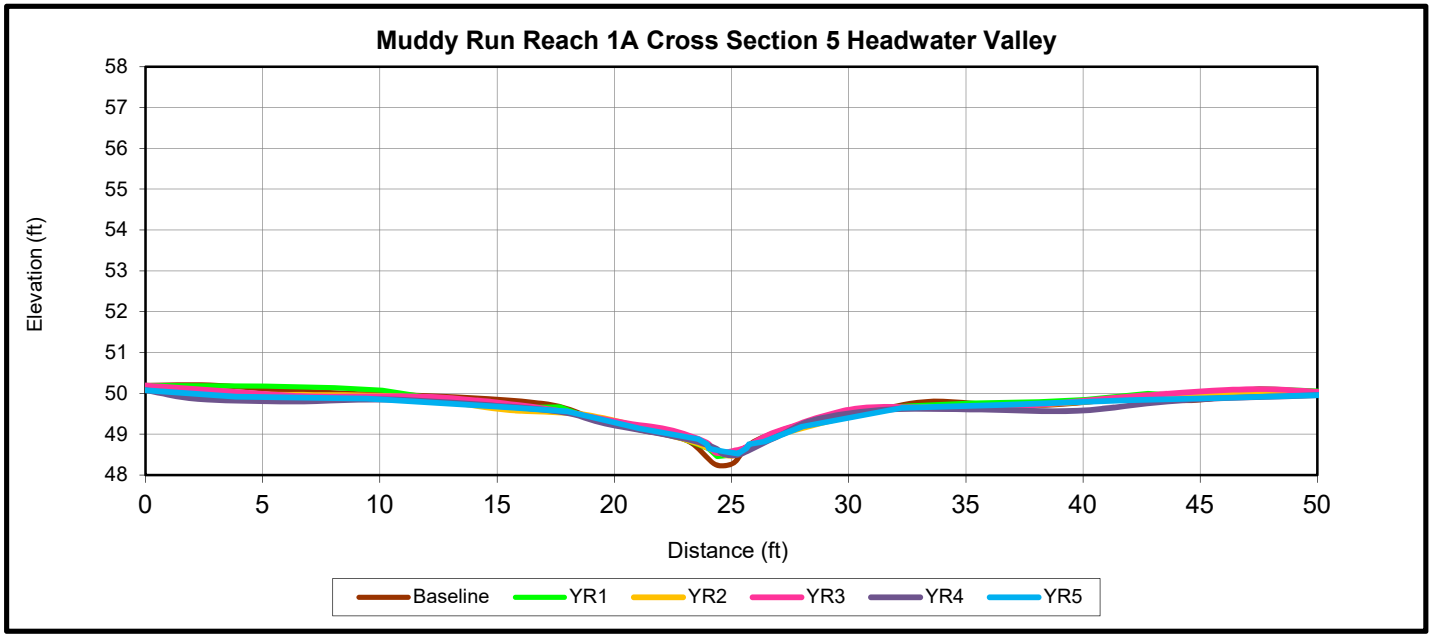
Upstream

Downstream



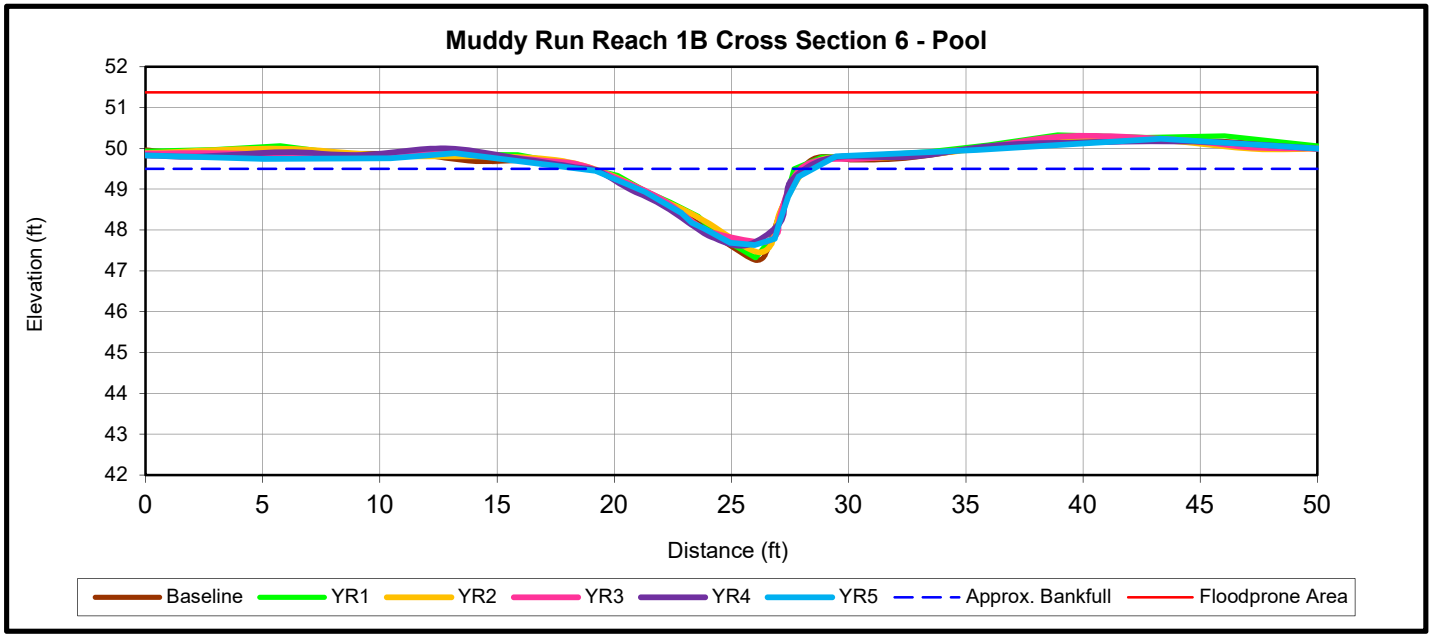
Upstream

Downstream



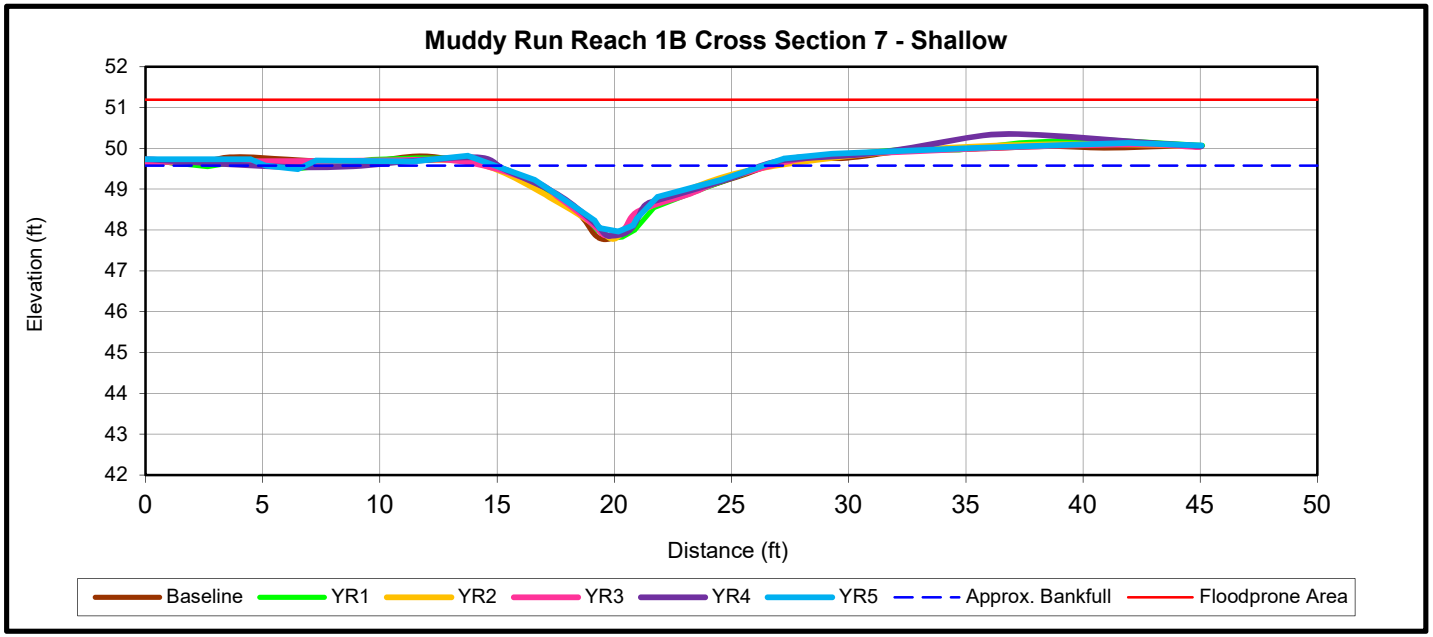
Upstream

Downstream



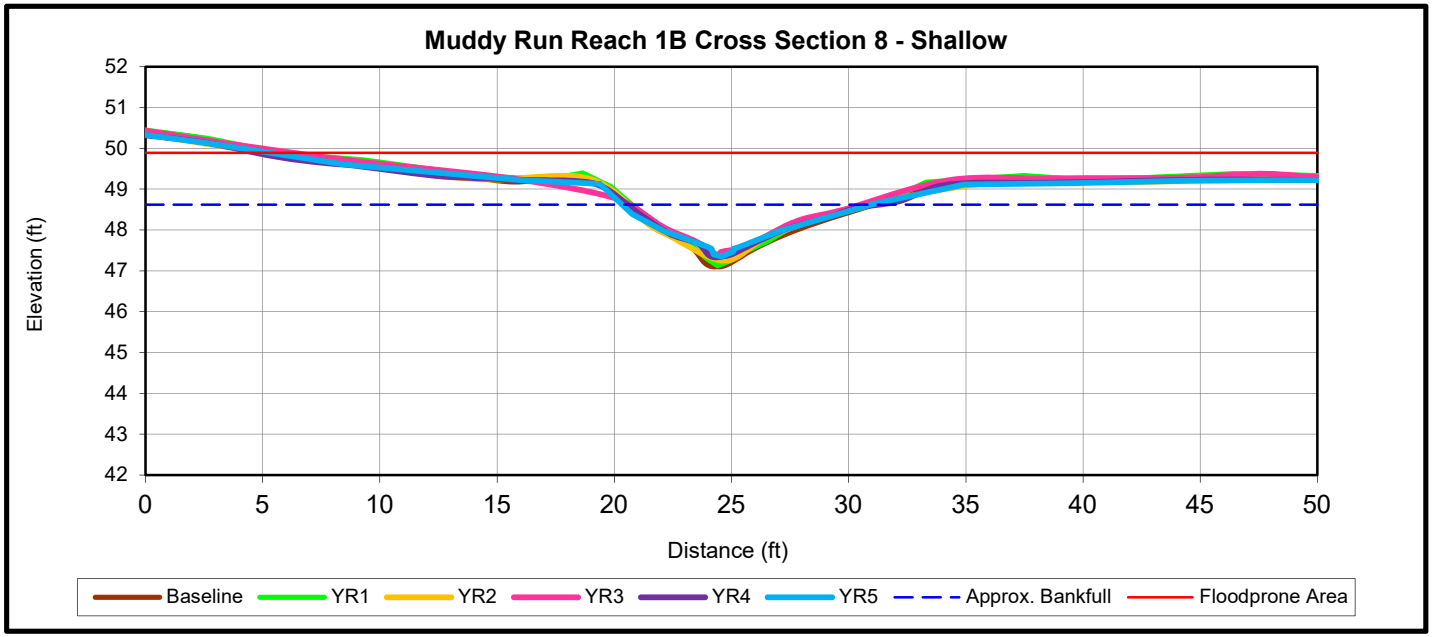
Upstream

Downstream



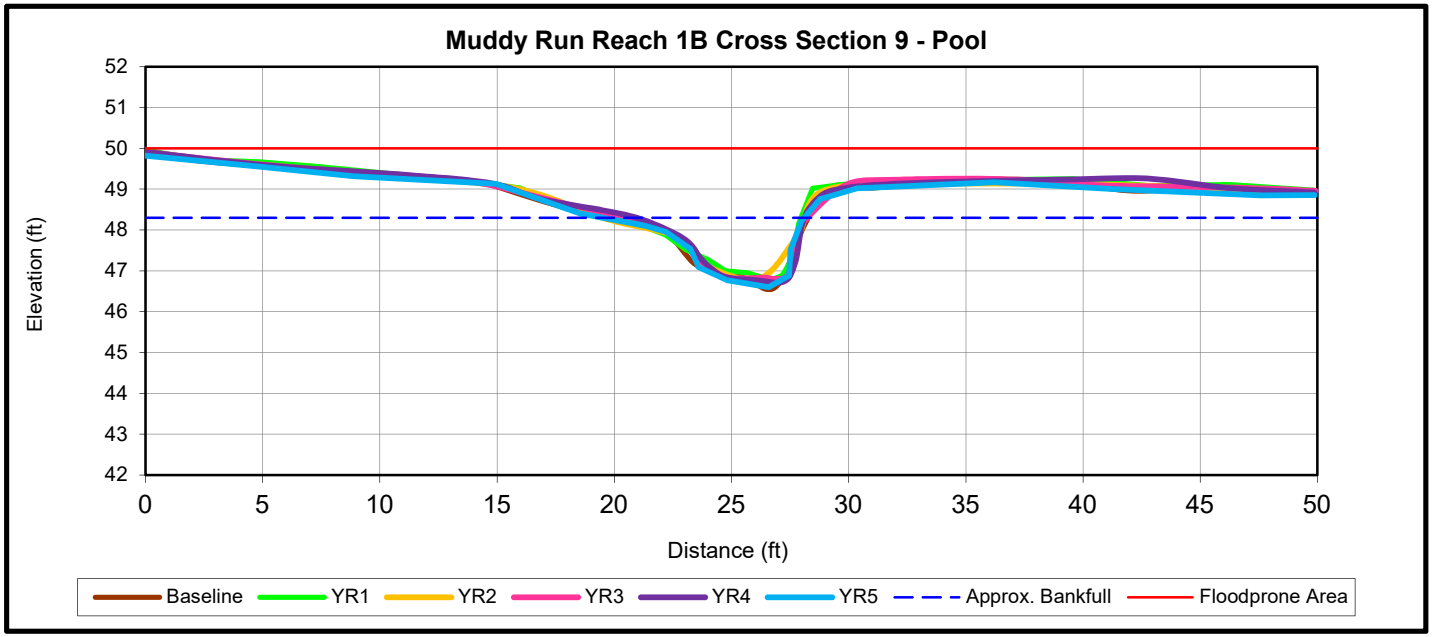
Upstream

Downstream



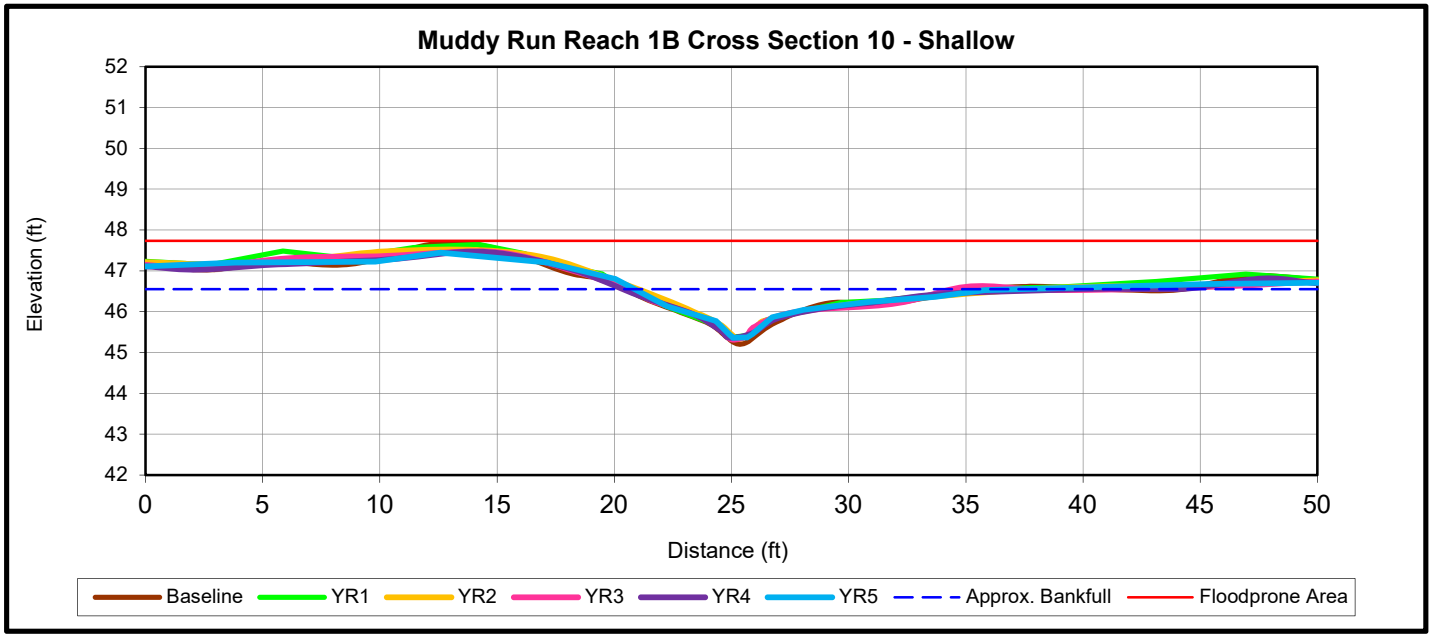
Upstream

Downstream



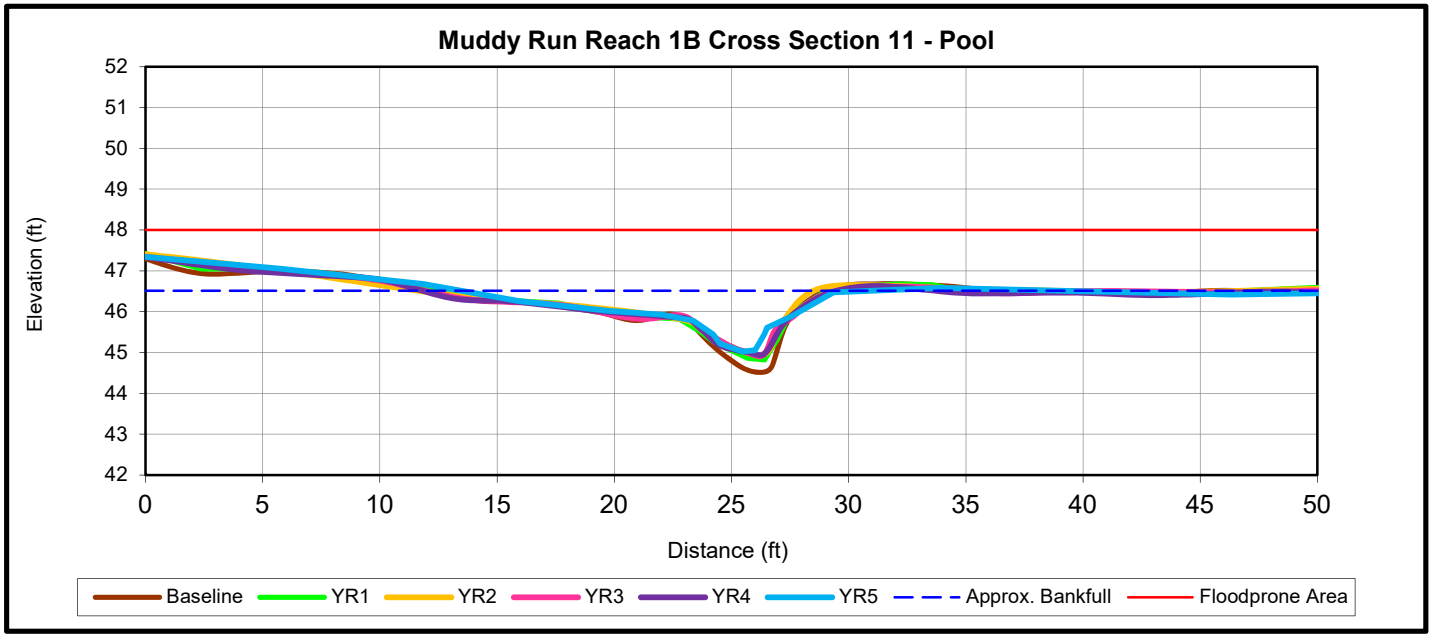
Upstream

Downstream



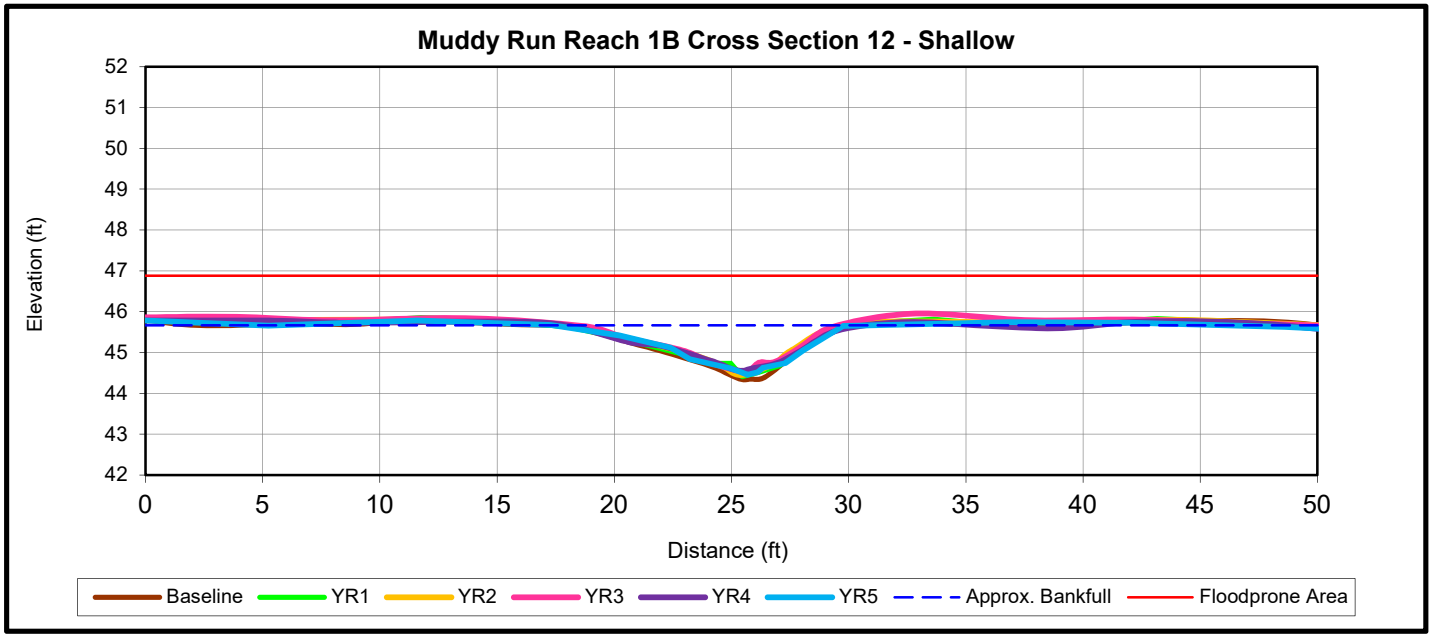
Upstream

Downstream



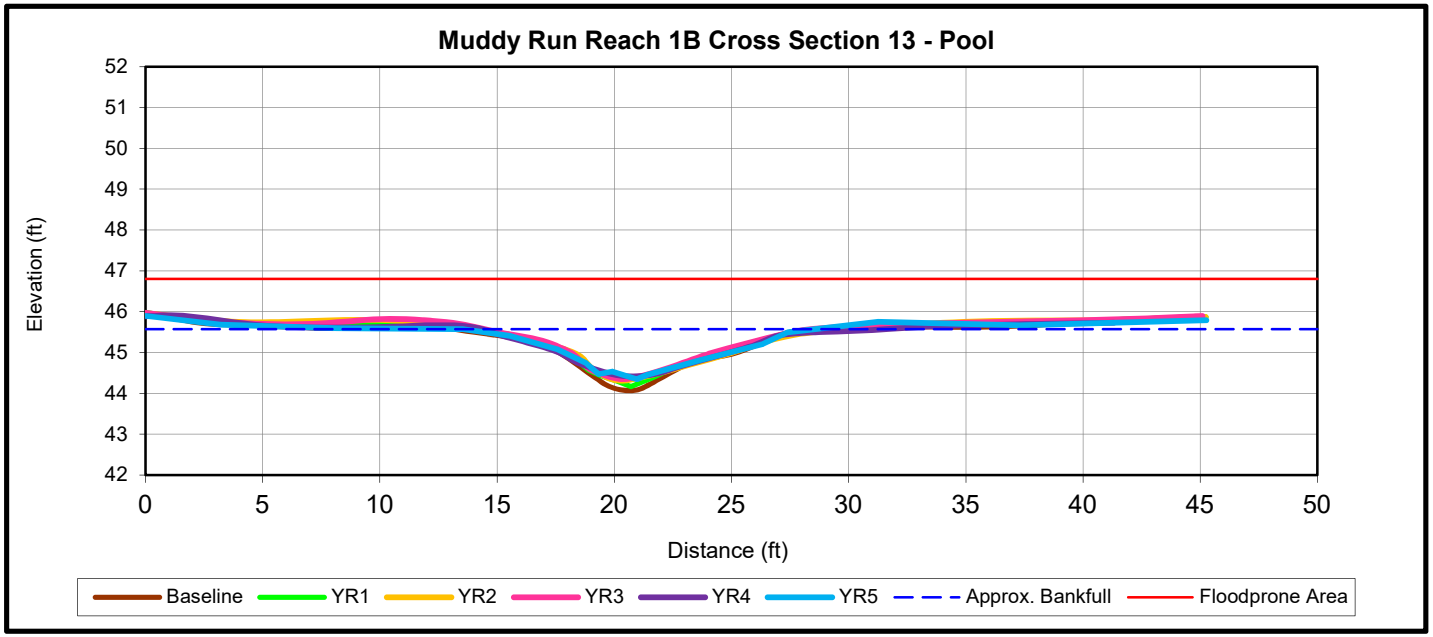
Upstream

Downstream



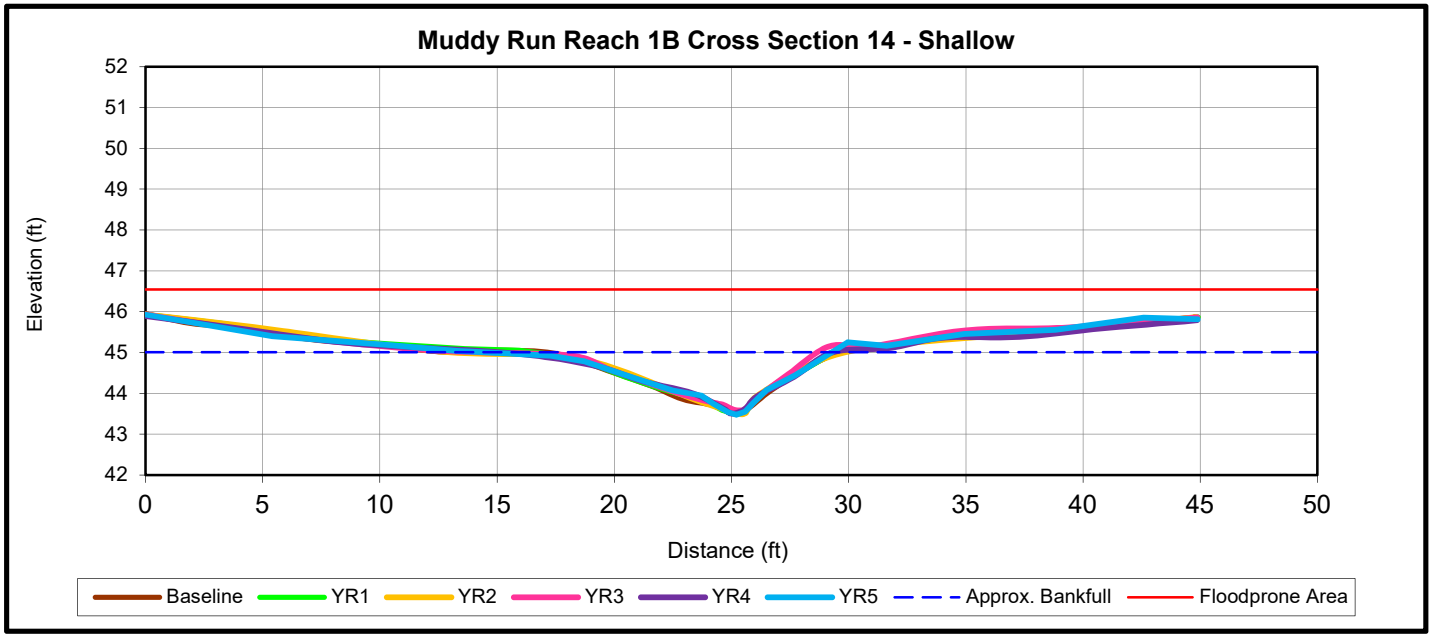
Upstream

Downstream



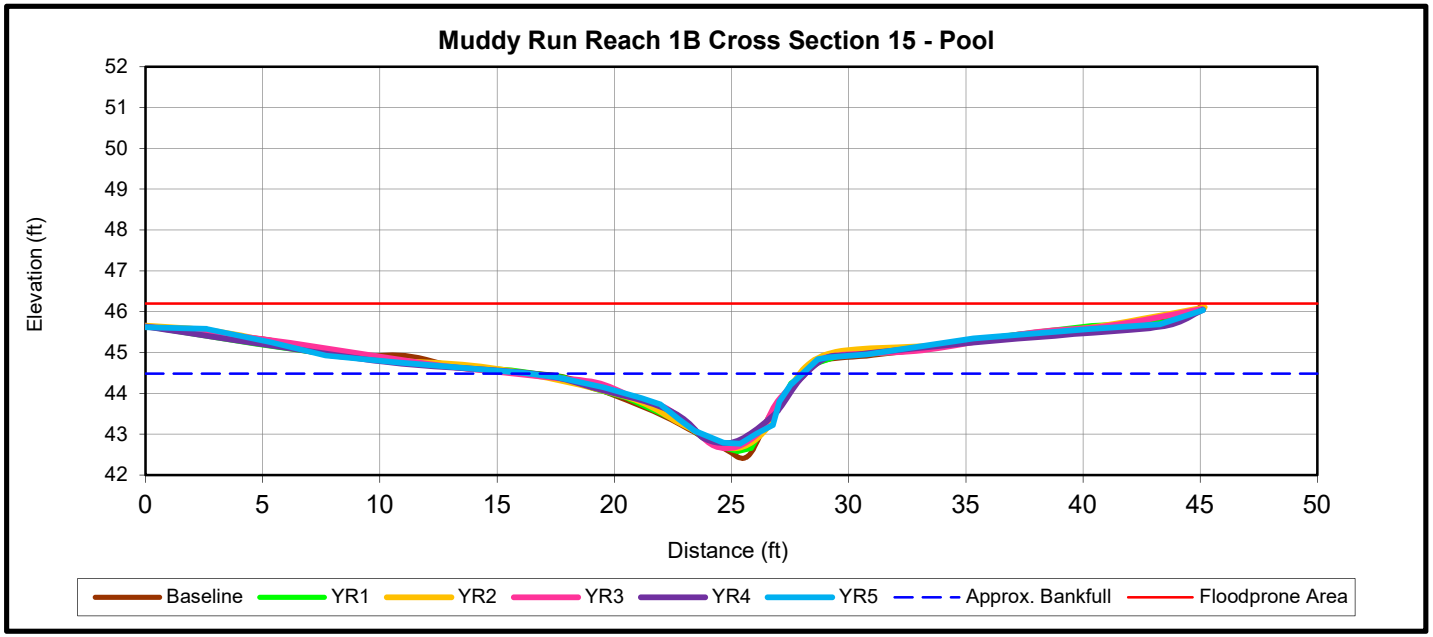
Upstream

Downstream



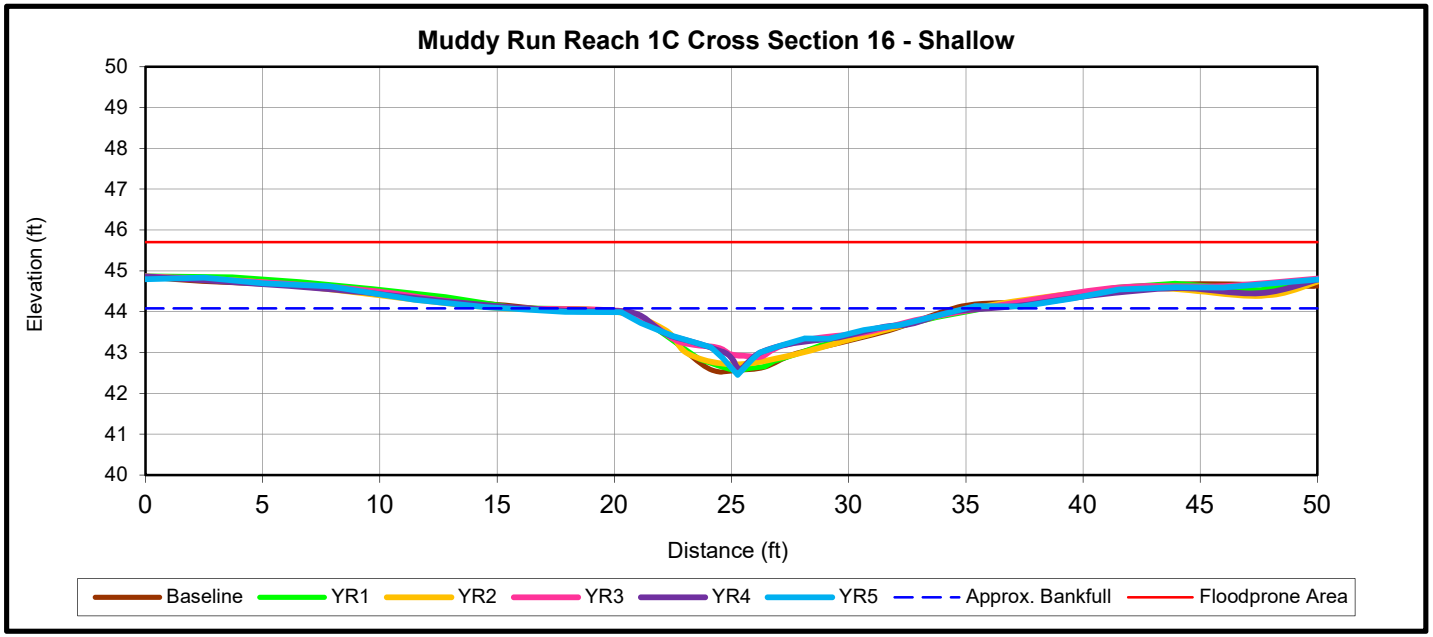
Upstream

Downstream



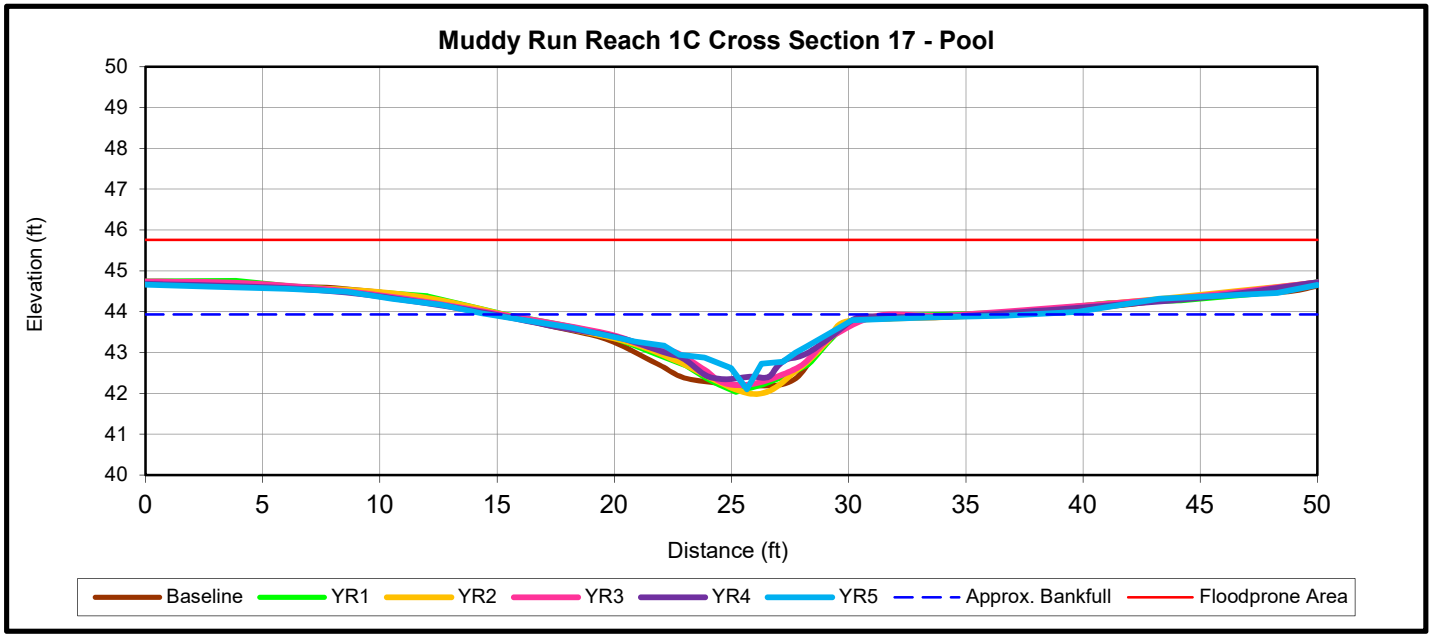
Upstream

Downstream



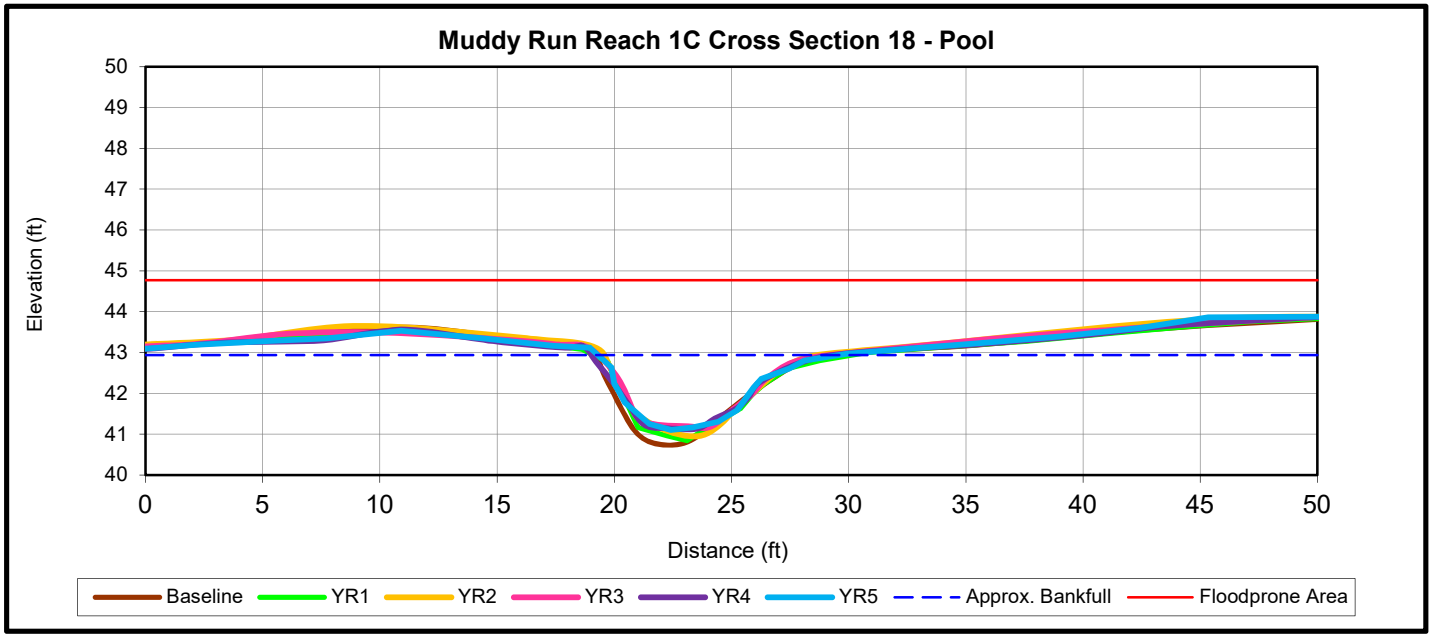
Upstream

Downstream



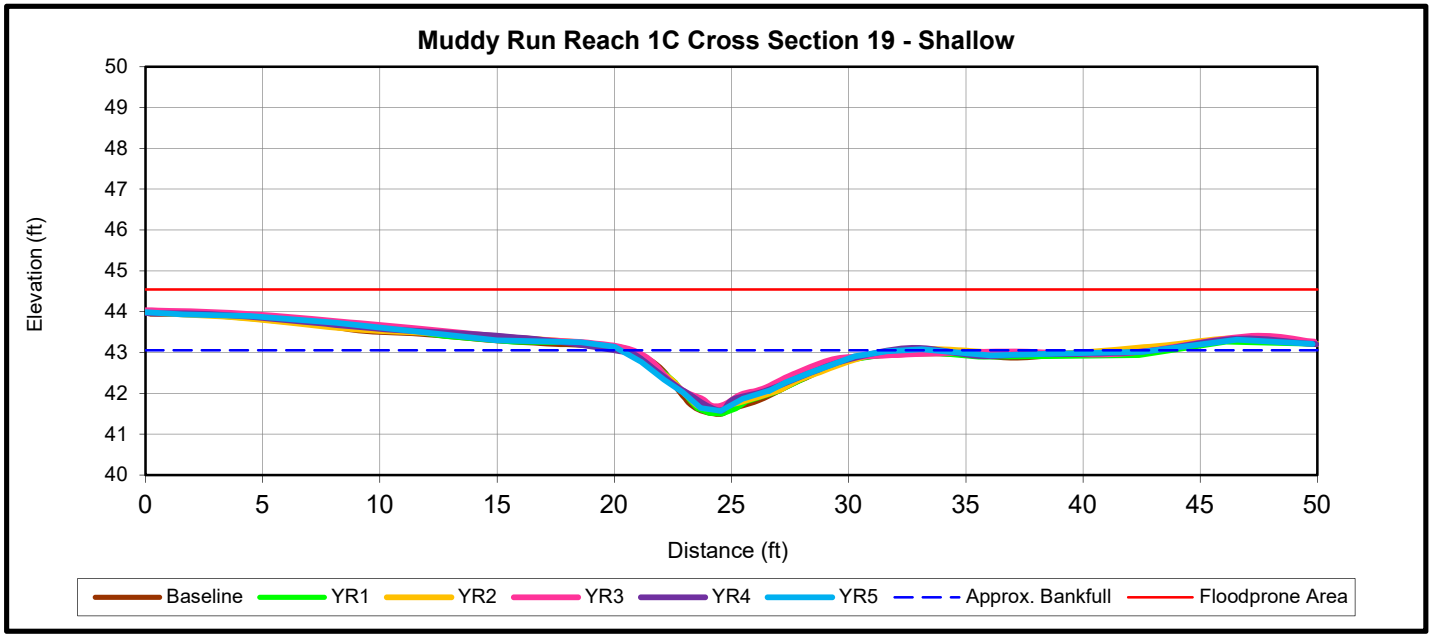
Upstream

Downstream



Upstream

Downstream



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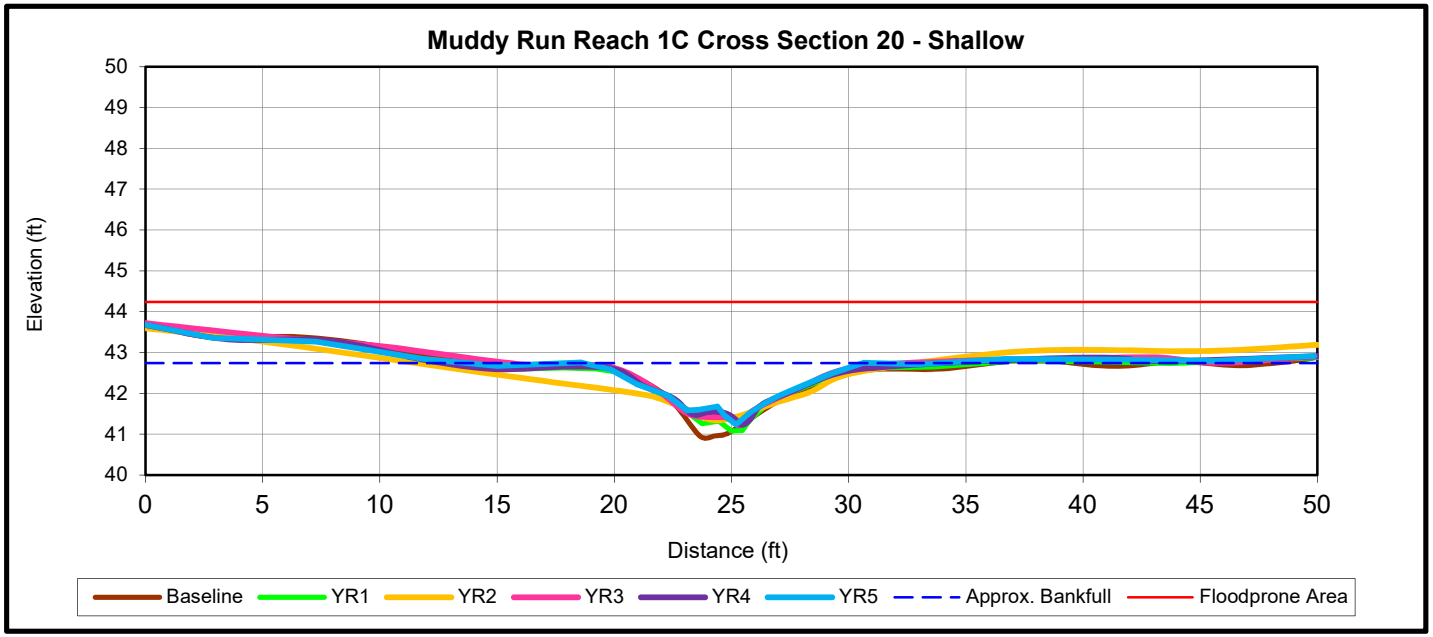
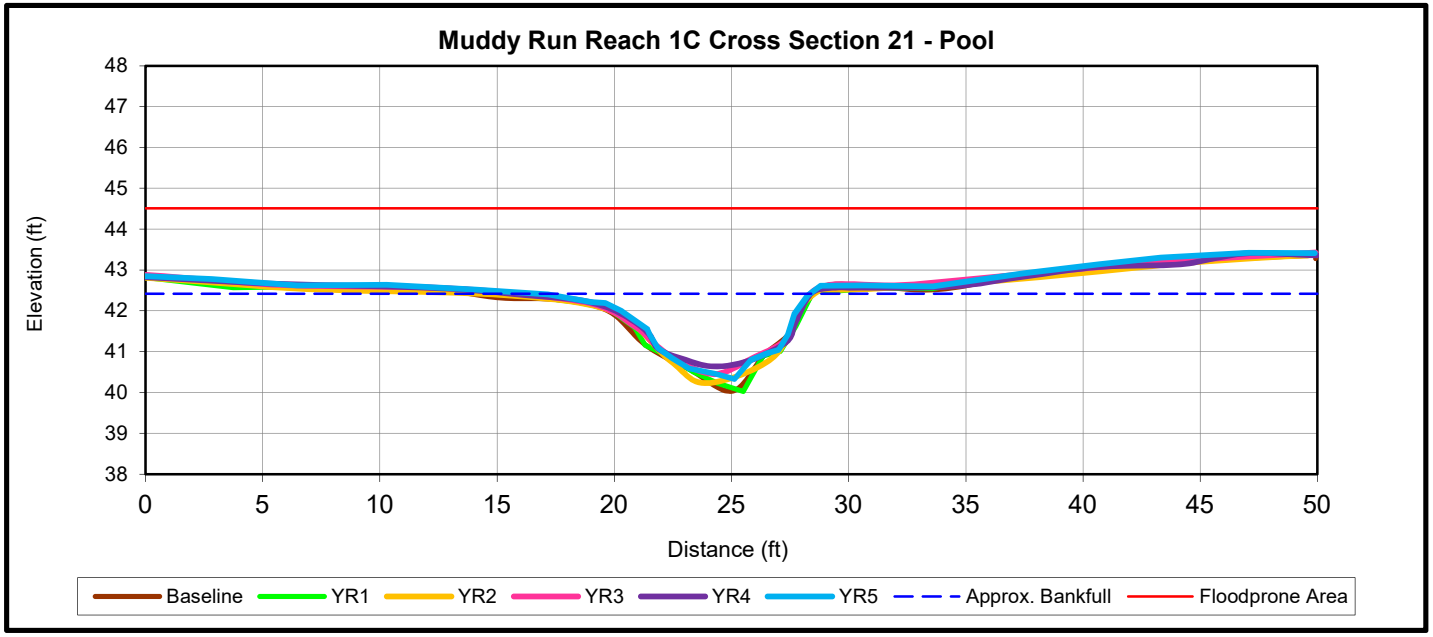


Upstream

Downstream



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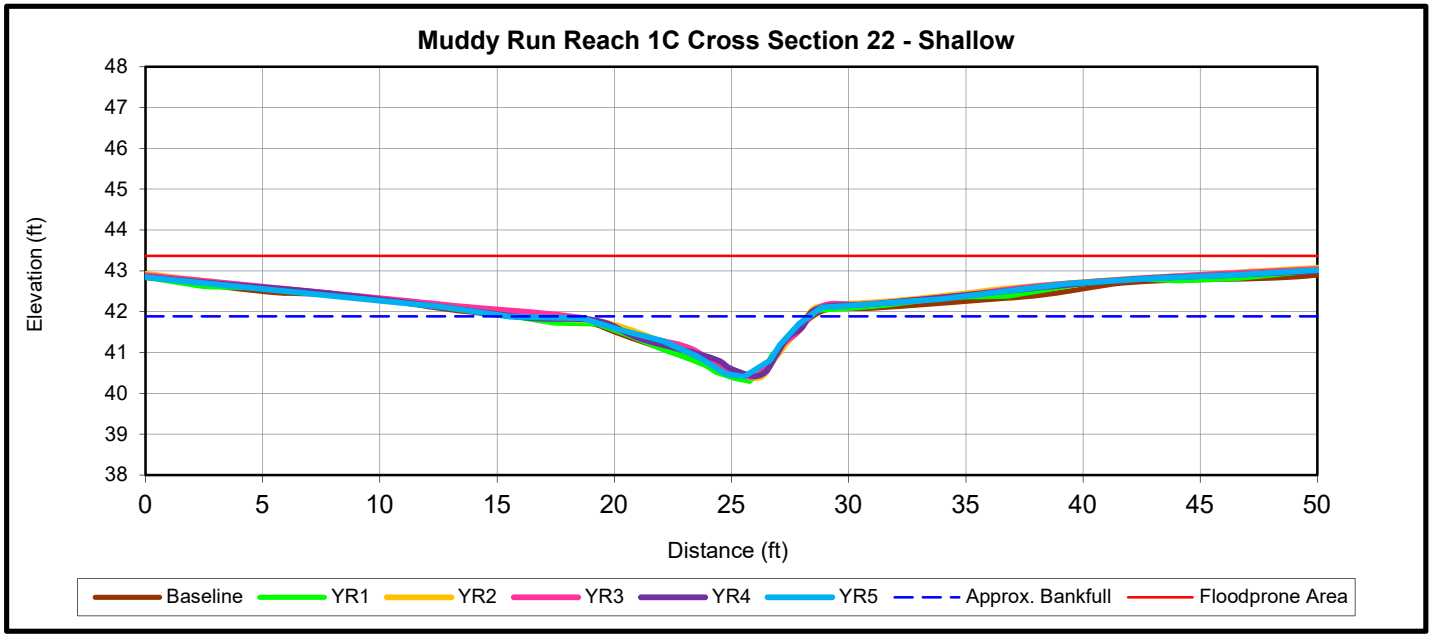

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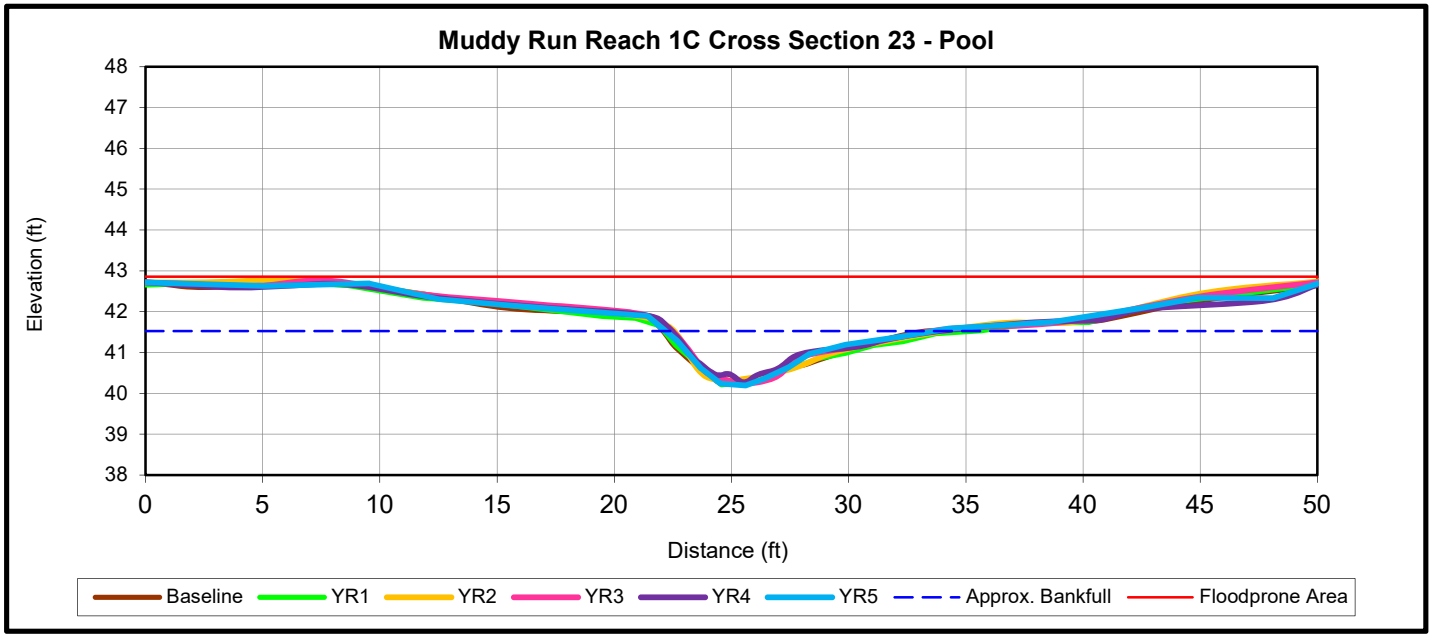

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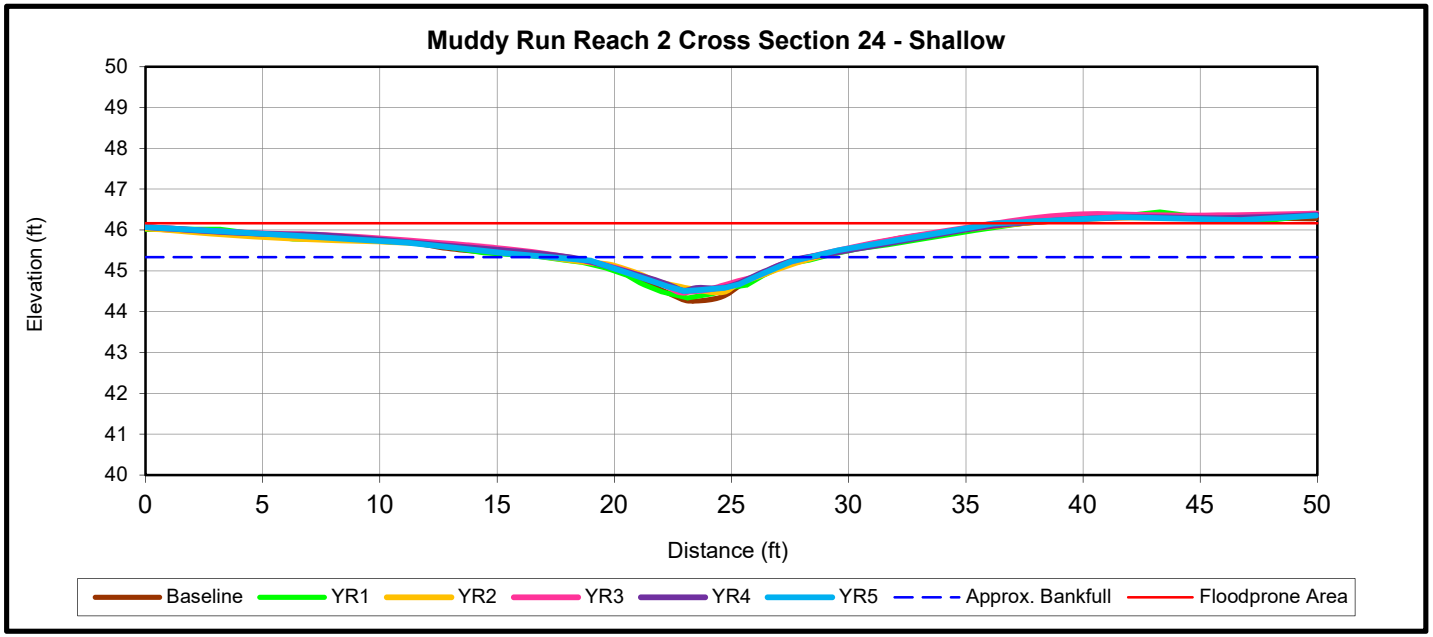
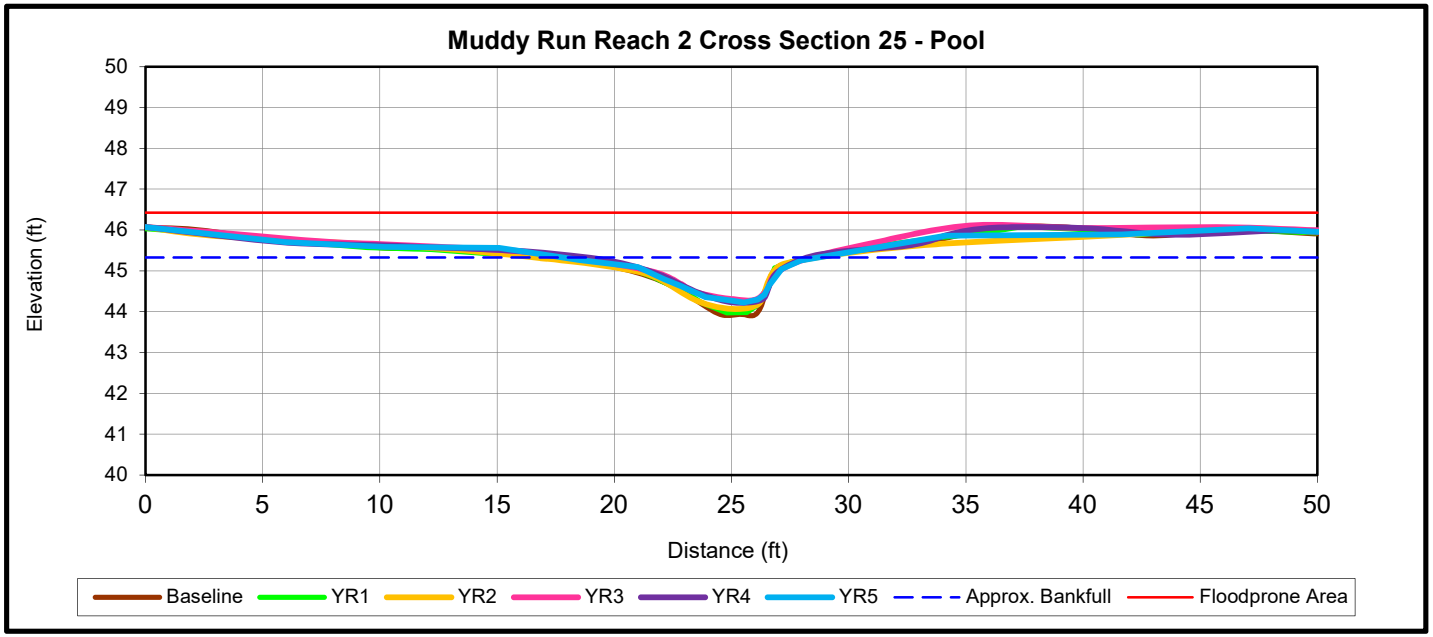


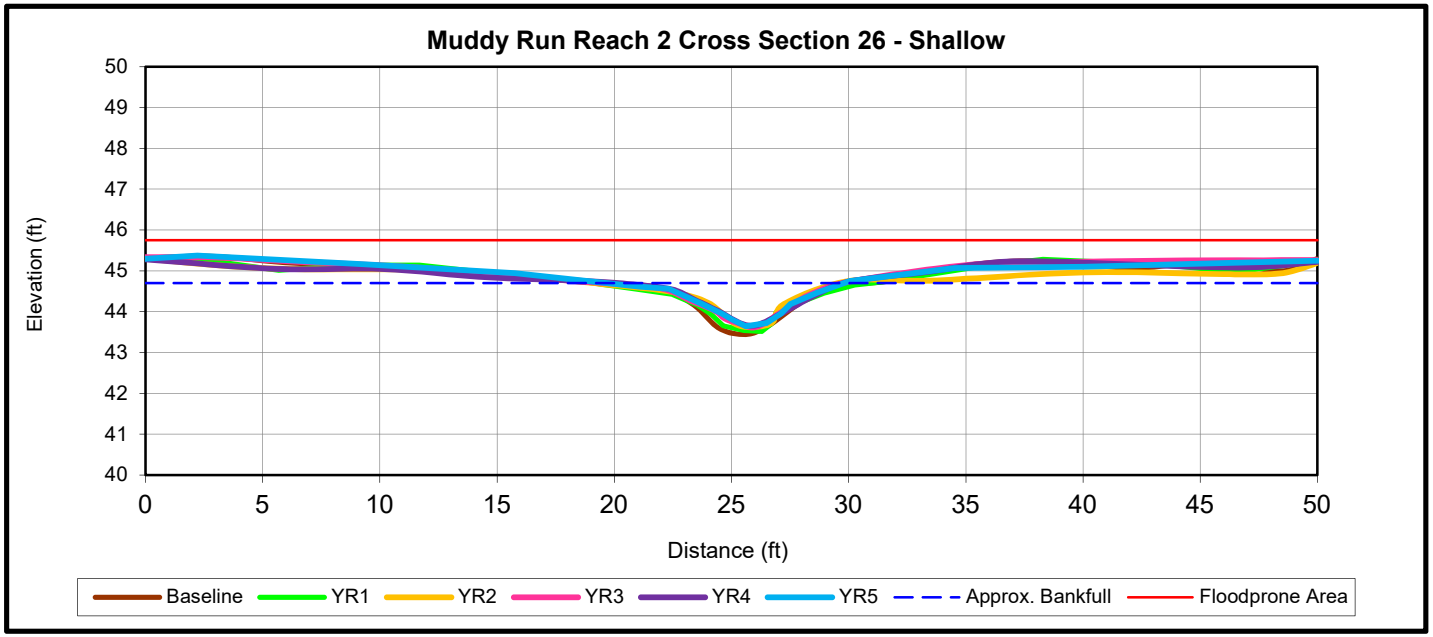
Upstream

Downstream



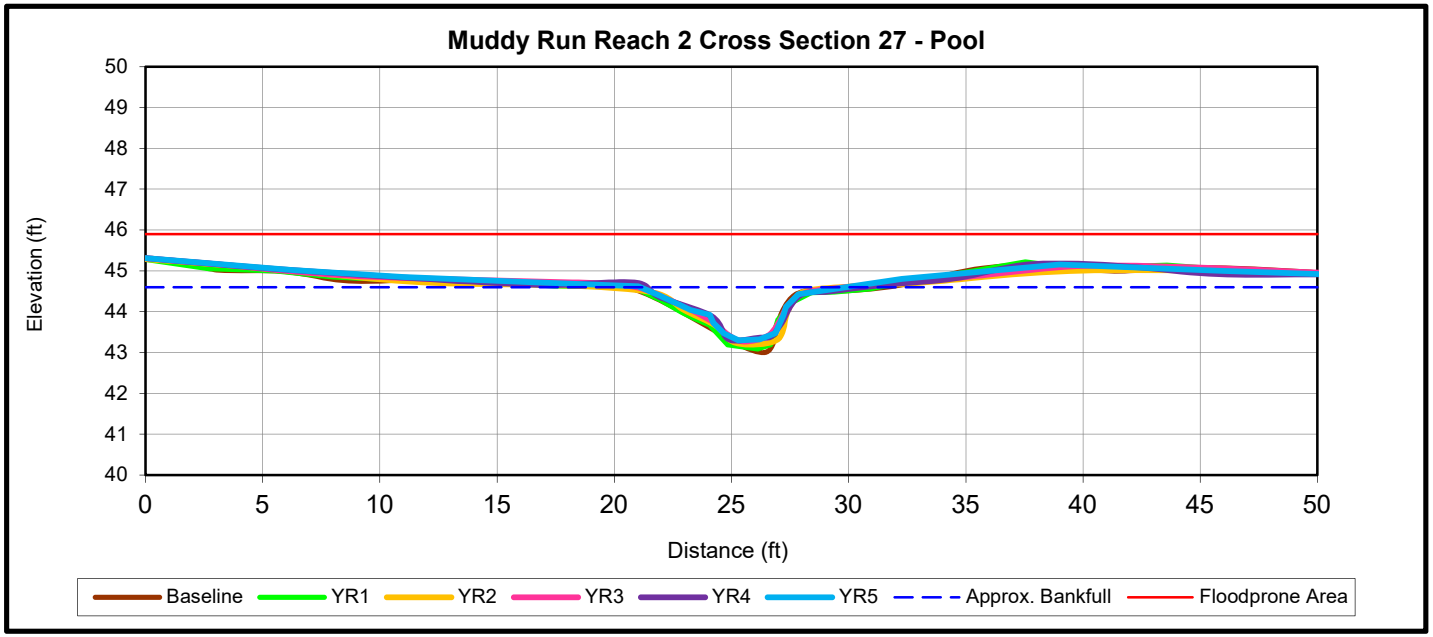
Upstream

Downstream



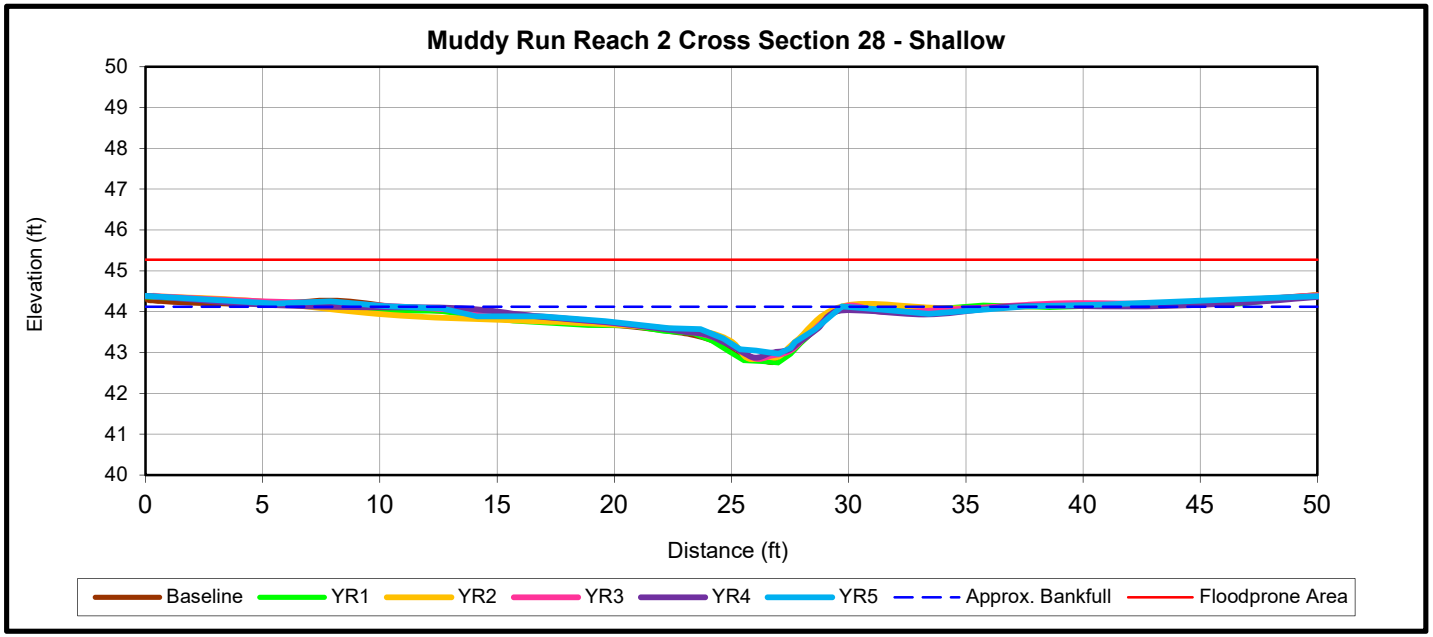
Upstream

Downstream



Upstream

Downstream



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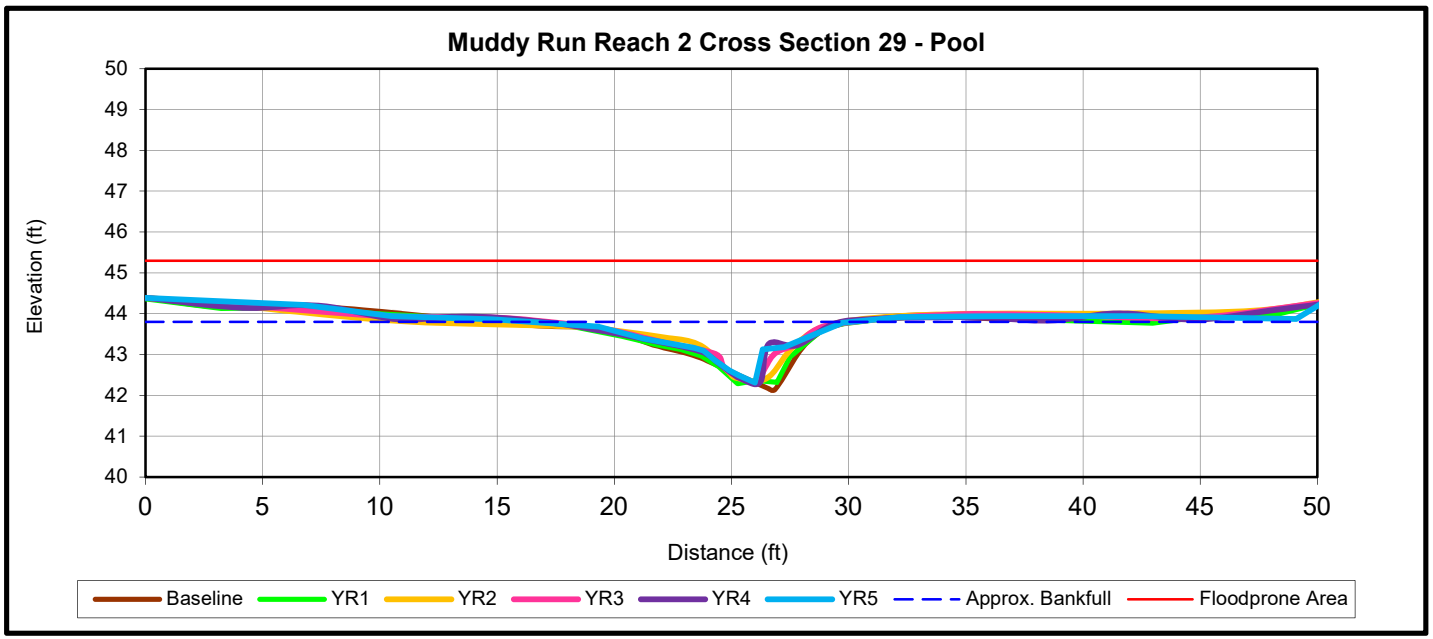
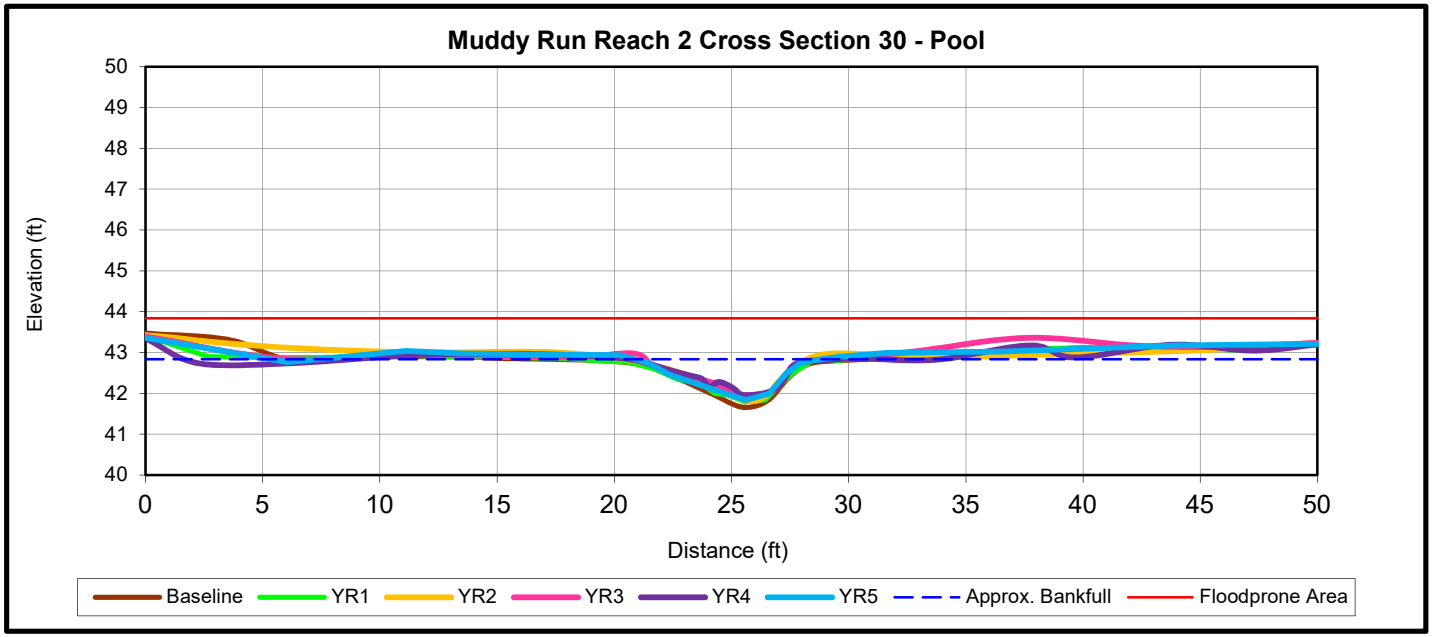


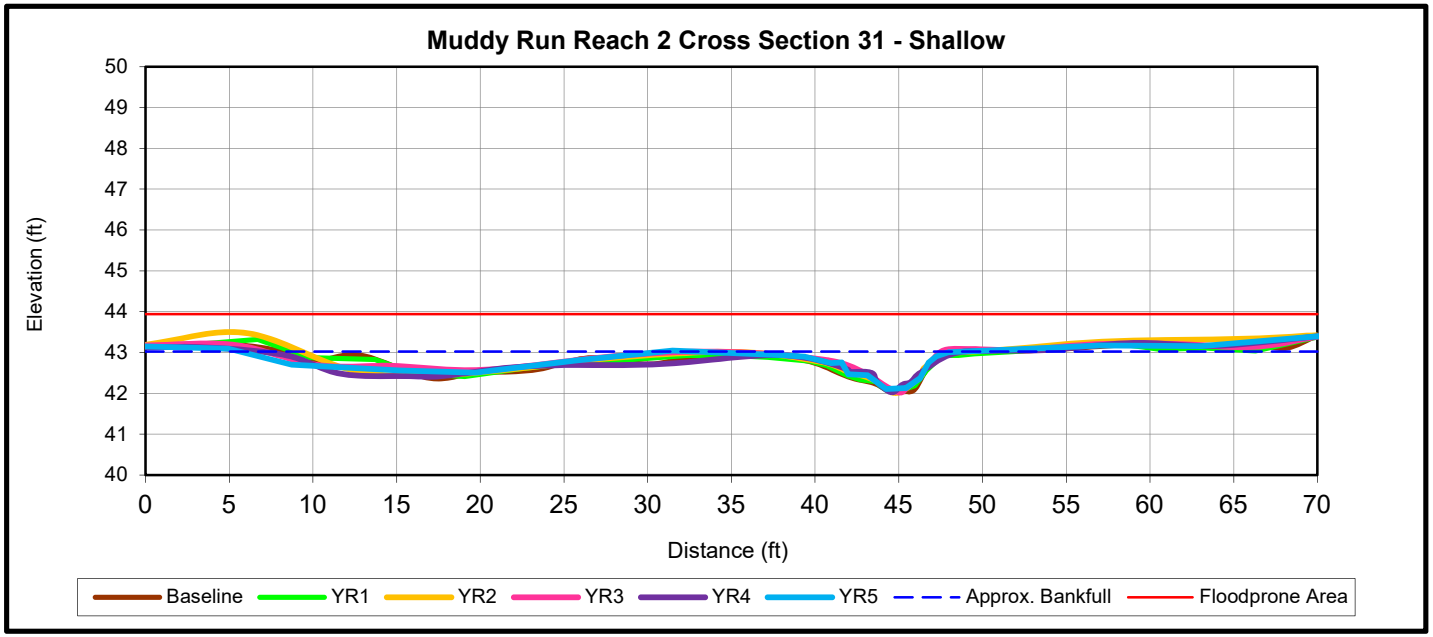
Upstream

Downstream



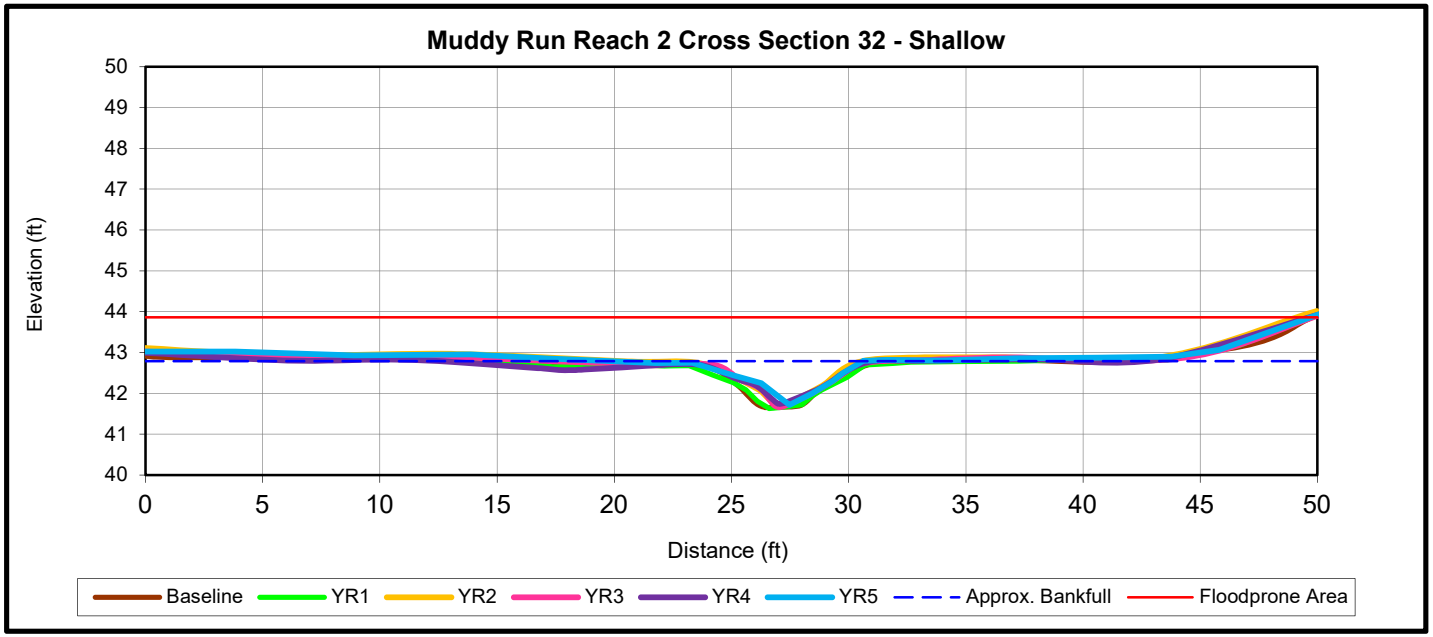
Upstream

Downstream



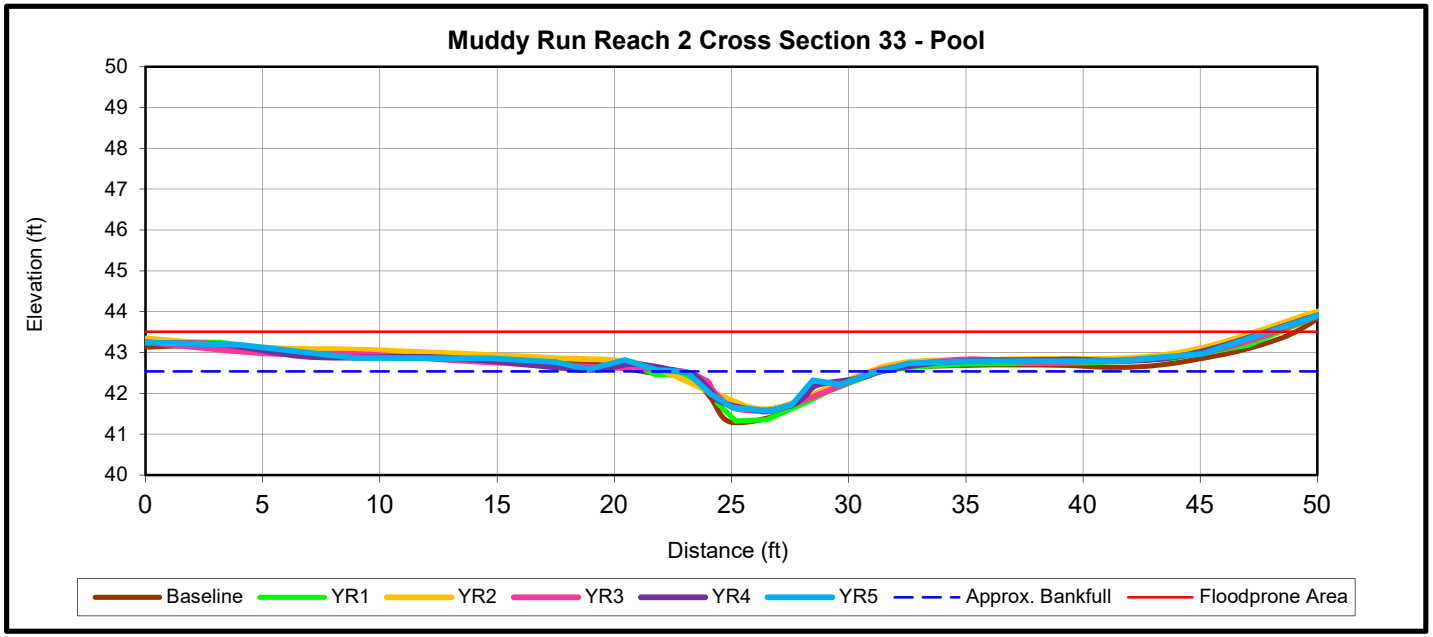
Upstream

Downstream



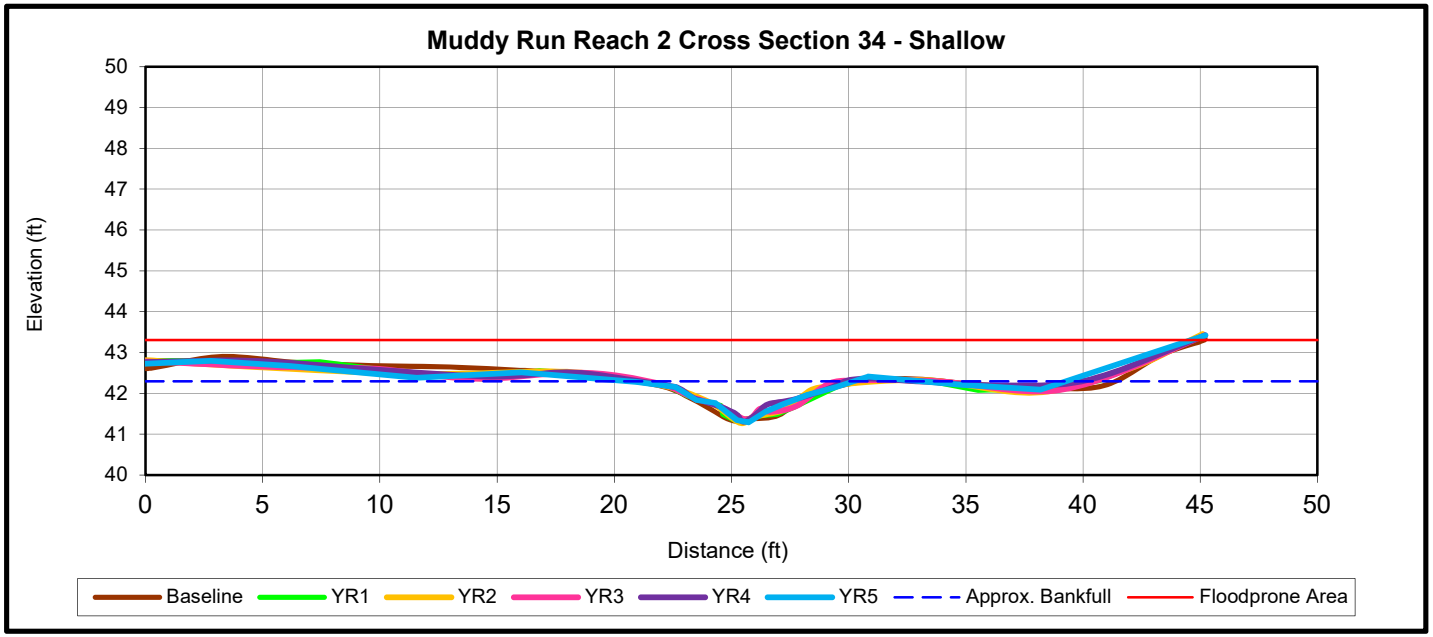
Upstream

Downstream



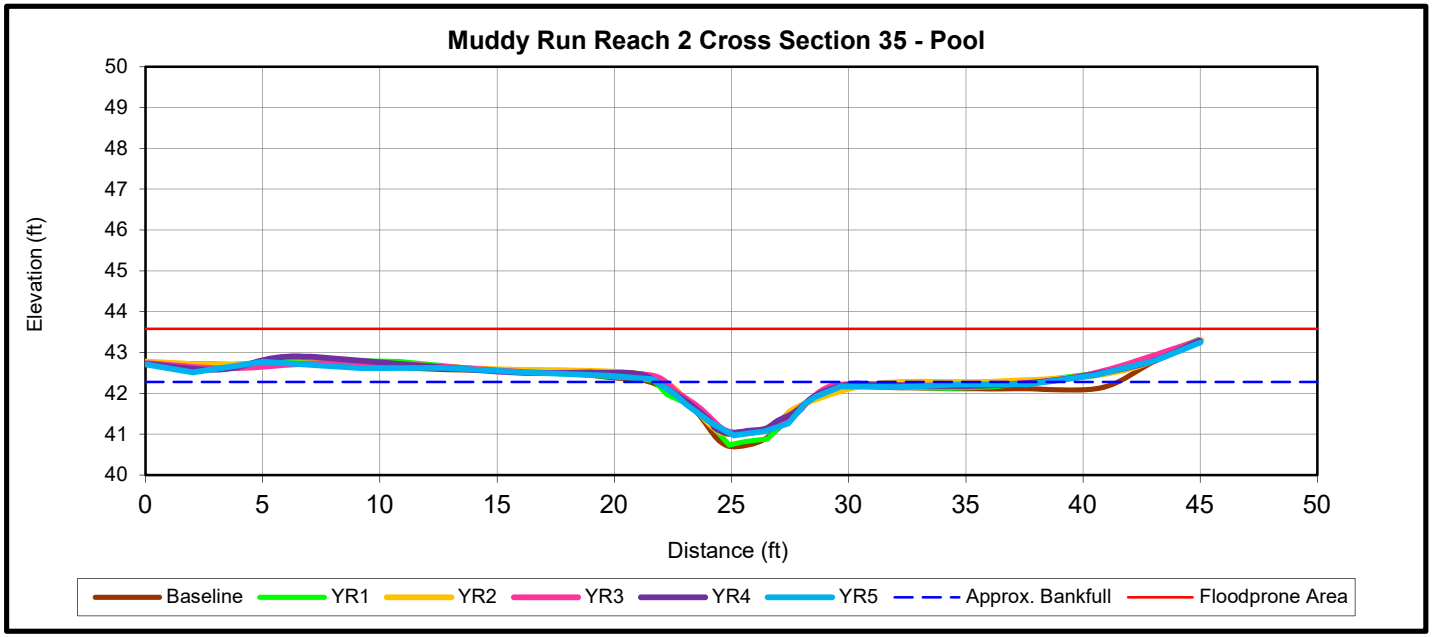
Upstream

Downstream



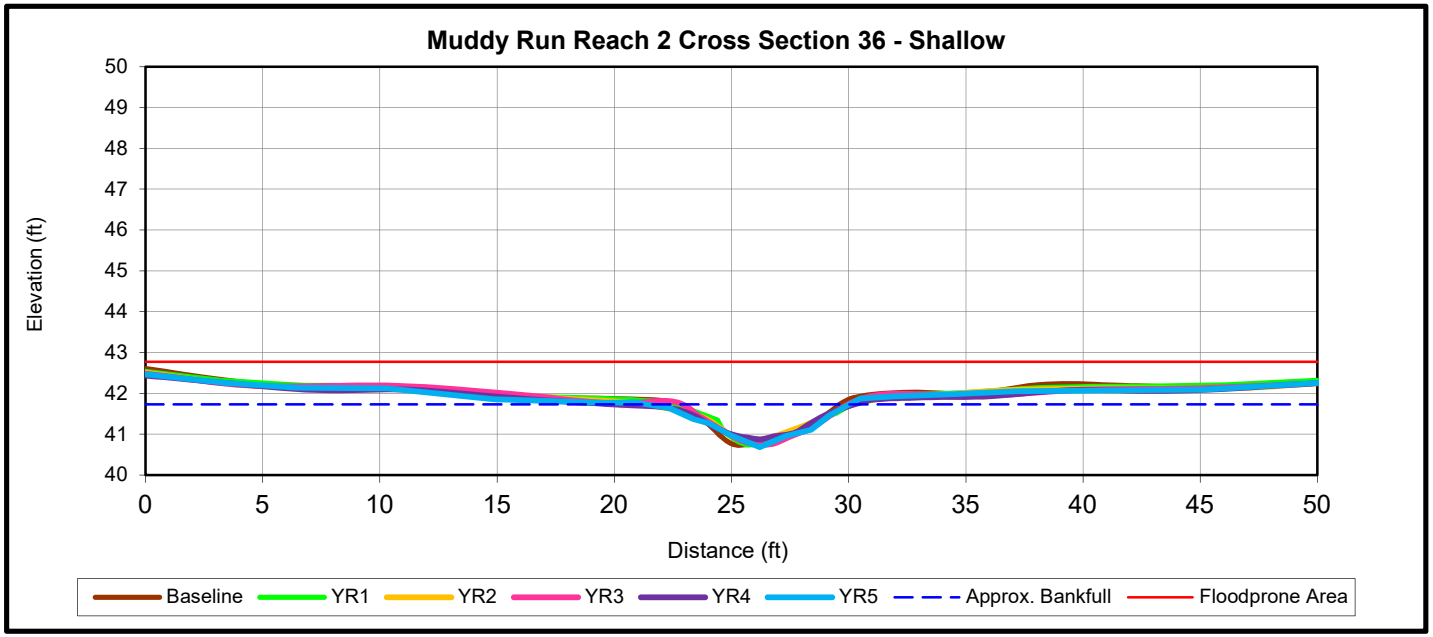
Upstream

Downstream



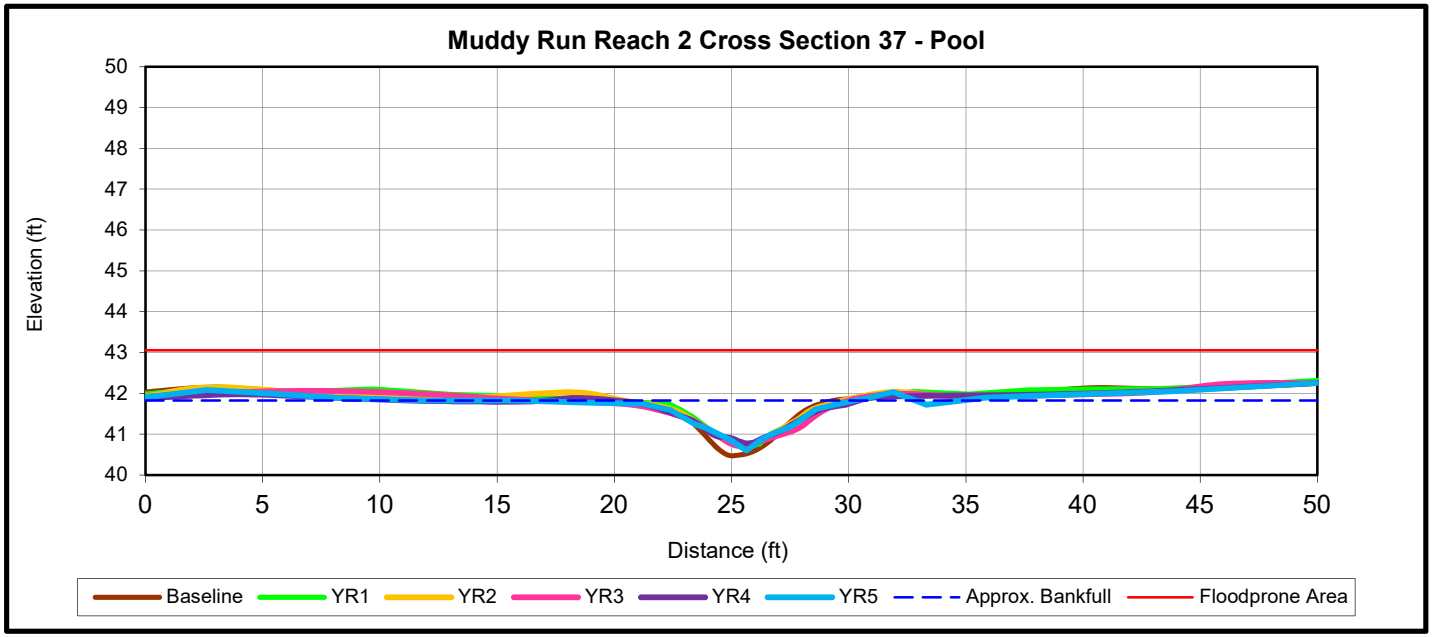
Upstream

Downstream



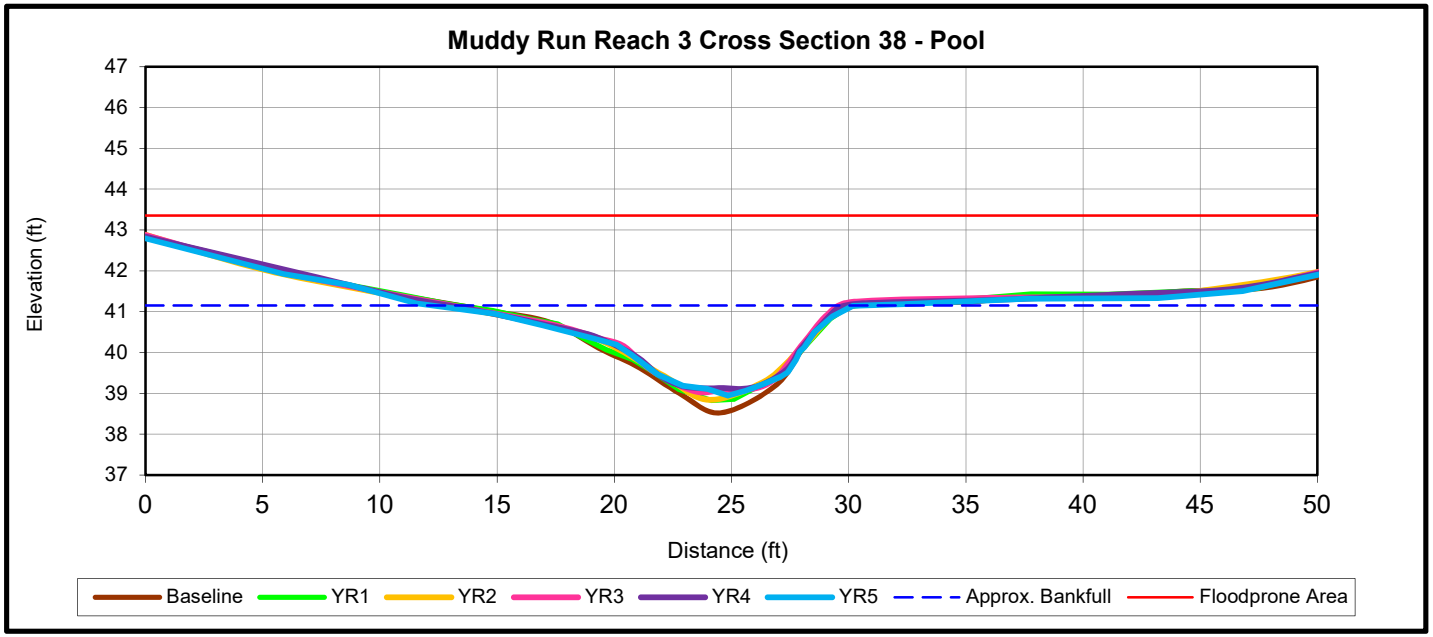
Upstream

Downstream



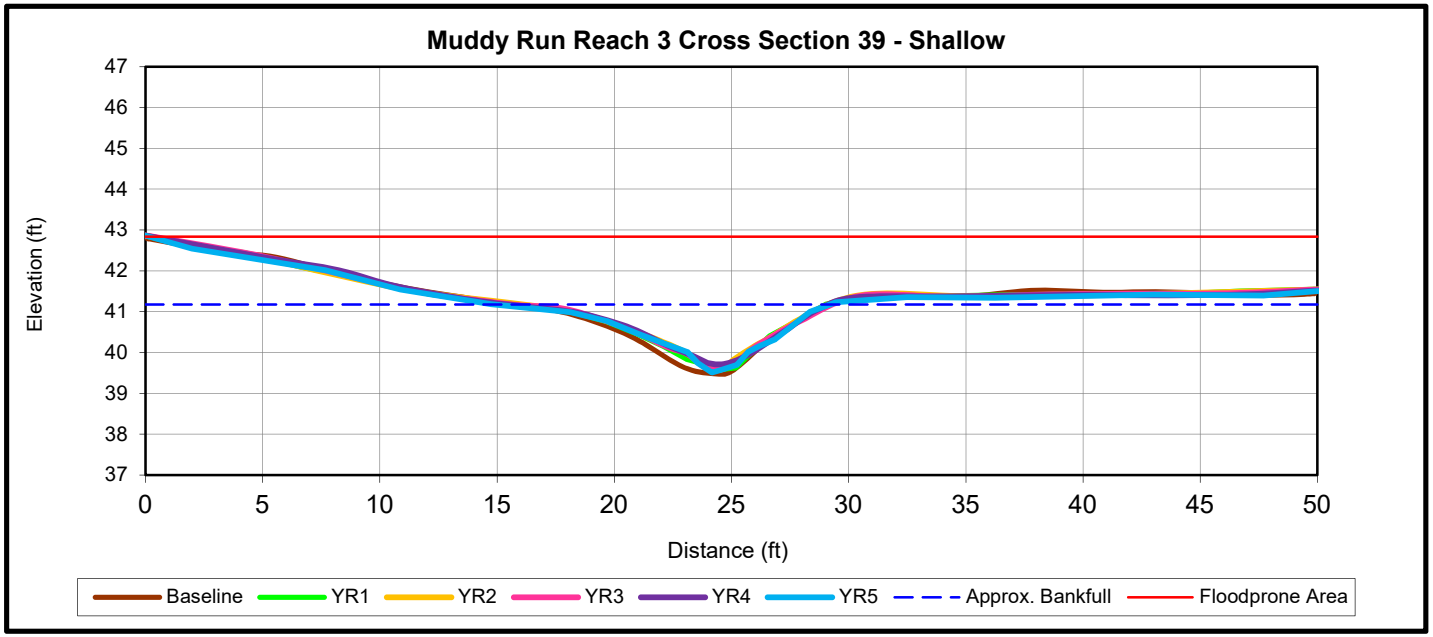
Upstream

Downstream



Upstream

Downstream



Appendix E

Hydrology Data

Table 13. Documentation of Geomorphologically Significant Flow Events
Table 14. Rainfall Summary
MY5 2018 Muddy Run ACG1 Flow Chart
Figure 7. Crest Gauge Verification Photos

Table 13. Documentation of Geomorphologically Significant Events

Stage Recorder	Headwater Valley Flow Events	Maximum Consecutive Flow Days	Cumulative Flow Days
Stage Recorder 1 (HWV Reach 1A)			
MY1	16	8	37
MY2	34	96	162
MY3	41	76	168
MY4	34	53	197
MY5	17	55	179
Stage Recorder	**Number of Bankfull Events**	**Maximum Bankfull Height (ft.)**	
Stage Recorder 1 (HWV Reach 1A)			
MY1	N/A	1.1	
MY2	N/A	0.95	
MY3	N/A	2.3	
MY4	N/A	1.5	
MY5	N/A	2.82	
Stage Recorder 2 (Reach 1C)			
MY1	9	0.85	
MY2	16	1.3	
MY3	13	2.3	
MY4	18	1.3	
MY5	17	1.4	
Stage Recorder 3 (Reach 2)			
MY1	10	0.9	
MY2	12	1.1	
MY3	14	1.7	
MY4	14	1.27	
MY5	22	2.48	
Stage Recorder 4 (Reach 3)			
MY1	4	1.05	
MY2	9	1.8	
MY3	11	2.7	
MY4	12	2.05	
MY5	≥1	3.65	

Table 14. Rainfall Summary

Month	Average	Normal Limits		Wallace Station	On-Site Auto Rain Gauage
		30 Percent	70 Percent		
January	4.33	3.32	5.03	5.78	---
February	3.23	2.14	3.87	1.24	---
March	4.50	3.23	5.32	3.57	---
April	3.16	1.70	3.85	5.22	---
May	3.68	2.69	4.34	10.56	---
June	4.49	3.11	5.34	5.76	---
July	6.06	4.16	7.22	6.14	10.18
August	5.40	3.12	6.56	1.52	8.16
September	5.00	2.04	6.07	18.88	27.37
October	3.21	1.62	3.92	0.88	0.48
November	2.89	1.83	3.49	---	---
December	3.24	2.14	3.88	---	---
Total	49.19	31.10	58.89	59.55	46.19

MY5 2018 Muddy Run Reach 1A (HWV) Flow Chart

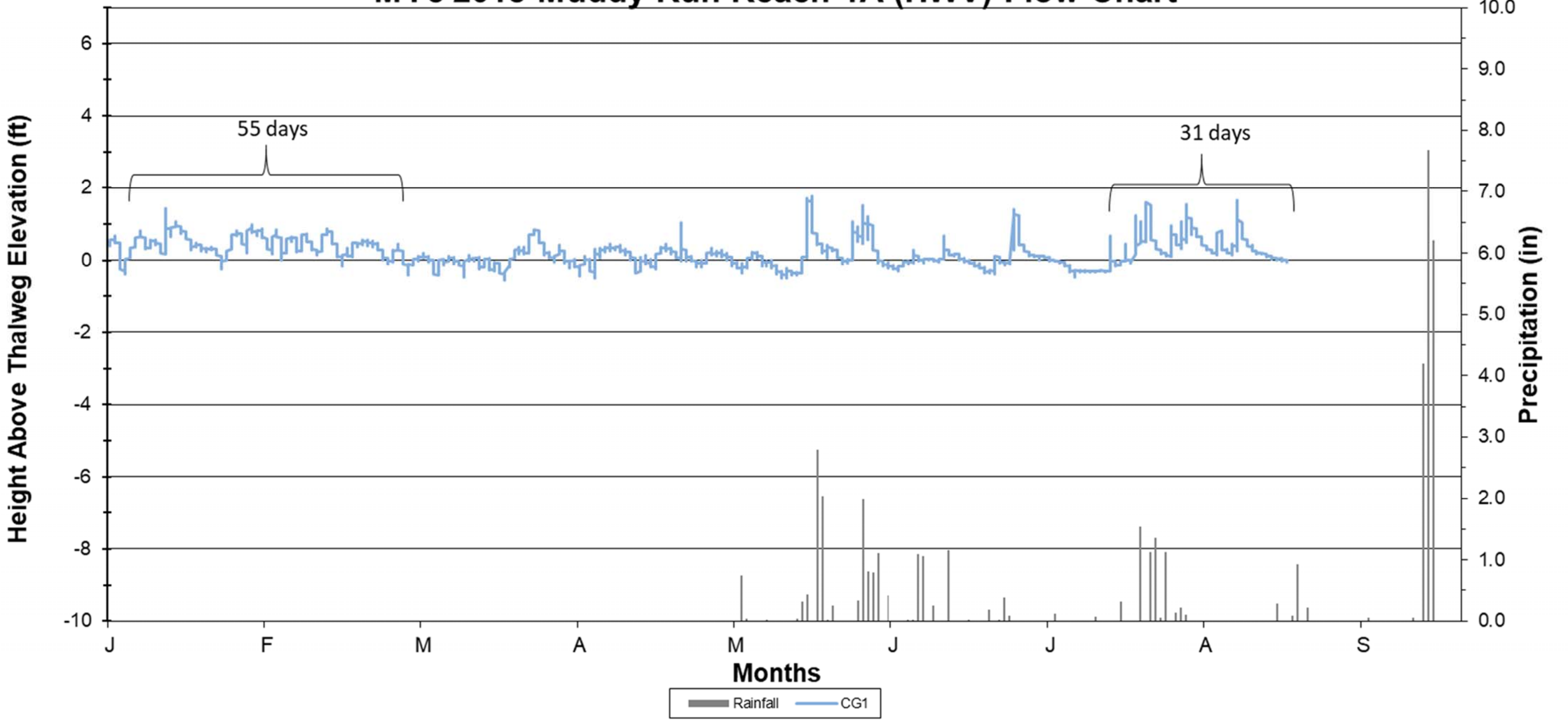


Figure 7 – Crest Gauge Verification Photos

Crest Gauge 1 Reading: 2.82 feet

Crest Gauge 2 Reading: 1.4 feet

Crest Gauge 3 Reading: 2.48 feet

Crest Gauge 4 Reading: 3.65 feet