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Highway Research Center

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RESEARCH PROJECT TITLE
Evaluation Rock Check Dam Performance using Large-Scale Testing Techniques

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Evaluation of Rock Check Dam Performance using Large-Scale Testing Techniques

Tech Transfer Summary

This projected evaluated the performance of the Iowa DOT standard rock check dam installation and efficient and cost-effective modifications through controlled, large-scale testing at the Auburn University – Research Facility. Modifications to the standard included the removal of an excavation beneath the installation, a smaller rock gradation, and a geotextile overlay with dewatering holes. Performance parameters for erosion prevention included impoundment formation, flow velocity reduction, and dewatering times; sediment-laden testing evaluated sediment deposition and water quality treatment.

Objectives

- Evaluate the existing Iowa DOT rock check dam standard in impoundment formation, impoundment formation, flow velocity reduction, and sediment deposition
- Develop and evaluate efficient and cost-effective rock check dam installation enhancements for implementation by the Iowa DOT

Most Feasible and Effective Installation (MFE-I)

Findings at a Glance

- The Most Feasible and Effective – Installation was determined to be a rock check dam with no excavation, the Iowa DOT erosion stone, a geotextile overlay with dewatering holes, and a reduced width due to outperforming other installations in impoundment formation and reducing the cost of material and installation.
- Adding a geotextile overlay and reducing the size of rock used were found to significantly increase impoundment length and erosion protection compared to the standard installation.

Background

Conveyance channels are commonly used on construction projects, especially highway construction, to collect and guide stormwater runoff to downstream practices or discharge points. However, these channels can be prone to erosion due to high flow velocities and shear stress before stabilization. To protect channels from erosion, ditch checks such as rock check dams are installed in channels to impound runoff and slow flow velocities to non-erosive conditions. Spacing guidance dictates that rock check dams are installed so that the elevation of the toe of the upstream dam is the same as the lowest point of the top of the downstream installation, to ensure that the entire channel is projected; however, if rock check dams do not impound runoff to the top of the installation, areas of the channel are subject to high-velocity erosive flows.

Problem Statement

Erosive flows in unstabilized conveyance channels can be a source of sediment-laden runoff for construction projects, which can overload downstream sediment basins or contribute to sediment-laden discharge off-site. Rock check dams are commonly used on construction projects to slow flow velocities and protect channels from erosion; however, past field monitoring studies have indicated that many standard installations do not properly protect channels from erosion and can be improved. Despite this, very few studies on providing performance enhancements for rock check dam installations have been completed. In this project, large-scale testing techniques were employed at the AU-SRF to evaluate the Iowa DOT standard rock check dam installation and enhanced configurations to improve protection from erosive flows and, as a secondary benefit, capture sediment and treat water quality.

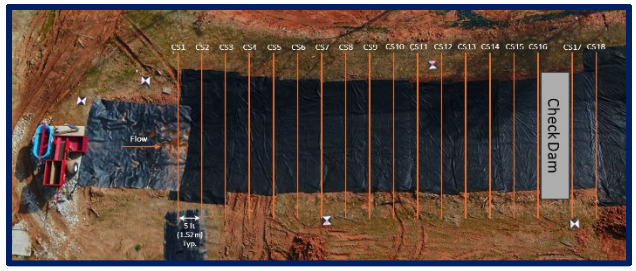
About the AU-SRF

The AU-SRF is a 10-acre outdoor research laboratory aimed to improve and develop stormwater technologies and strategies. The facility is situated adjacent to the National Center for Asphalt Technology Pavement Test Track in Opelika, AL. Since its inception, the AU-SRF has aimed its mission to developing improved erosion and sediment control stormwater technologies and practices; advancing the body of knowledge through research and development, product evaluation, and training.

Materials and Methods

A total of 8 rock check dam installations were evaluated through 3 tests each, each using a low and high flow rate to determine performance under varying conditions representative of those found on Iowa DOT construction projects., for a total of 24 clean-water performance evaluations. After competition of clean water tests, the Iowa DOT standard rock check dam and the highest-performing modified installation were evaluated under sediment-laden conditions to determine the improvements in sediment capture and stormwater treatment, a secondary benefit of rock check dams.

An existing 200 ft long channel, representative of those found on Iowa DOT highway construction projects was used for all tests. 16 upstream and two downstream cross-sections were demarcated with stringlines for testing measurements.



Test Channel

Three water depth and velocity measurements were taken at each cross-section to generate a flow profile for each installation. Additionally, the length of impoundment and dewatering times were monitored for each installation. For sediment-laden testing, water quality samples were taken upstream of the theoretical impoundment length, immediately upstream of the check dam, and the discharge downstream of the installation. Additionally, sediment deposited upstream was removed and measured for total sediment retention.

The results of testing for the Iowa DOT standard installation and subsequent modifications were used to develop additional modifications and work towards the selection of a Most Feasible and Effective Installation (MFE-I).

Modified Rock Check Dams

Standard Installation

The Iowa DOT standard rock check dam installation, consisting of Class D Revetment with a 6 in. excavation and a geotextile underlay, was evaluated. The standard installation impounded approximately 6 feet on average, indicating that only 9% of the channel was protected from erosive flow conditions.

Iowa DOT Standard rock check dam

Removal of Excavation

The first modified component aimed to determine if the excavation beneath the installation played a role in impoundment formation and velocity reduction. No adverse impacts on impoundment length compared to the standard were found after removing the excavation and installing the rock check dam on grade, while also saving cost of material and installation.

Smaller Rock Gradation

In testing of rock check dams constructed of Class D Revetment, large voids were present, leading to high flow-through-rates during testing. An alternative rock gradation used by the Iowa DOT, a smaller erosion stone, was used to construct modified installations. The smaller rock increased impoundment to 33 ft on average, representing over 50% of the channel being protected. Additionally, the smaller rock led to more consistent installation heights that allowed overtopping to occur at the design height of 2 ft, rather than between gaps in larger rocks.

Geotextile Overlay

The addition of a geotextile overlay facilitated addition impoundment as the geotextile became bound with sediment, leading to overtopping. Despite overtopping, the theoretical impoundment was not reached due to flow finding the lowest points to overtop on the installation. An average of 49 ft of impoundment was facilitated, with impoundment increasing for each additional test due to the geotextile losing flow-through capabilities. Geotextile binding with sediment also led to excessive dewatering times, which can be detrimental to the establishment of vegetation in channels and lower storage capacity for subsequent storm events.

Dewatering Holes

To reduce excessive dewatering times facilitated by installations with a geotextile overlay, nine x-shaped, razor blade sized dewatering holes were cut in the geotextile. These dewatering holes did not negatively impact performance in the formation of impoundment while reducing dewatering time from 60 hours to 26 hours on average compared to installations with a geotextile overlay. Despite this improvement, dewatering time increased after each subsequent storm event to a maximum of 60 hours, indicating maintenance is required to ensure dewatering holes remain effective.

Reduced Profile w/ All Modified Components (MFE-I)

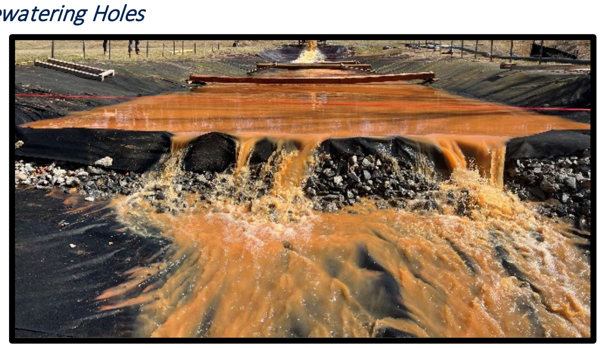
The MFE-I consisted of a combination of modified components (no excavation, smaller rock gradation, and a geotextile overlay with dewatering holes), with a reduced width to further reduce cost of material. This installation had the highest impoundment facilitated, with an average of 58 ft. Additionally, the approximate material cost was reduced by 55% compared to the Iowa DOT standard rock check dam installation. Due to performance improvements in all areas and the reduced cost, this installation was selected as the MFE-I.

Performance of Installation On Grade

Smaller Rock Gradation

Large Rock Overtopping at Low Points

Dewatering Holes

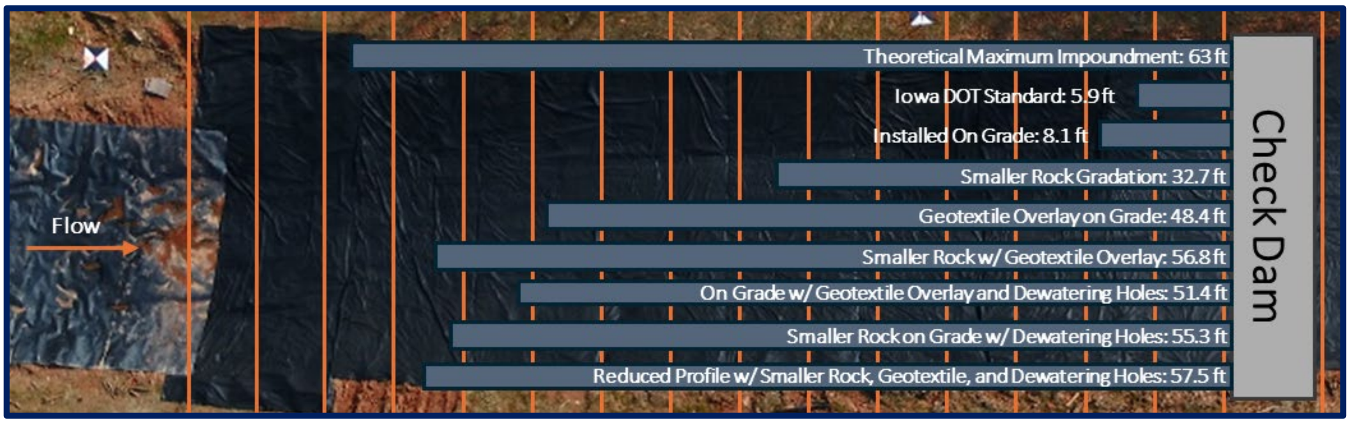


Most Feasible and Effective Installation (MFE-I) overtopping

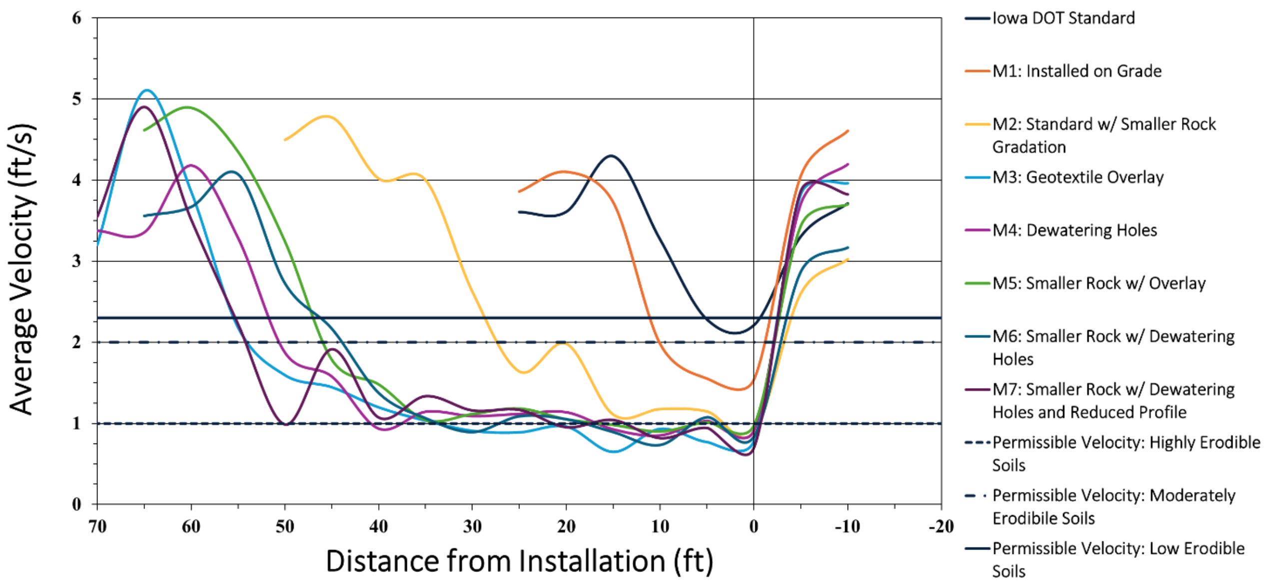
Results

Installations with similar components, such as the geotextile overlay, performed similarly in impoundment formation. Despite the improvements made by modifications, no installation impounded to the theoretical impoundment, indicating that spacing guidance may need to be adjusted or the geotextile underlay may need to be extended. Flow velocities increased immediately downstream of all installations and were still above permissible limits for highly erosive soils in the impoundment formed by highly performing installations.

Sediment-laden performance testing indicated that the additional impoundment facilitated by the MFE-I compared to the standard increased sediment capture from 9.3 to 72.3%. Additionally, the turbidity of the discharge from the MFE-I was significantly lower than that of the standard installation due to the increased impoundment formed and the extended detention time. However, turbidity was not treated effectively by the installations, indicating rock check dams are primarily an erosion control practice.



Performance of Evaluated Rock Check Dam Installations



Velocity Profile for Evaluated Rock Check Dam Installations

Recommendations & Implementation

The following recommendations should be considered based on results:

- Remove the excavation beneath installations and reduce the width to reduce material and installation costs while not losing performance;
- Adopt the smaller Iowa DOT erosion stone due to increased performance without geotextile overlays and more consistent height of installations;
- Employ a geotextile overlay with properly maintained dewatering holes to increase impoundment without excessive dewatering times;
- Use additional erosion control practices in channels with highly erosive soils;
- Extend the geotextile underlay downstream to protect downstream areas from erosive flows after overtopping;
- Employ downstream sediment control practices to ensure sediment is captured and runoff is treated.

Evaluation of Rock Check Dam Performance using Large-Scale Testing Techniques

Final Report
May 2025

AUBURN UNIVERSITY
Highway Research Center

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About the Auburn University Highway Research Center

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16. Abstract

Conveyance channels are commonly used on highway construction projects to manage the flow of water through the project to downstream discharge points or stormwater detention practices. However, these channels can be at risk of erosion before stabilization due to high-velocity flows. A common erosion control practice in channels is a rock check dam, which aims to slow flow by forming impoundment upstream of installations. Based on common spacing guidance, if rock check dams do not impound to their full height, areas of the channel will still be subject to erosive flow conditions. Past research has indicated that a geotextile overlay or smaller choker stone is required to facilitate a full impoundment, particularly in low flow conditions. Despite the widespread use of rock check dams, very few standards include overlays or chokers or have been evaluated for performance. To evaluate the Iowa Department of Transportation (DOT) standard rock check dam installation and develop more efficient and cost-effective modified installations, a standard Iowa DOT channel located at the Auburn University – Stormwater Research Facility was used. Installations were subjected to channelized flow conditions that represent those found on Iowa highway construction projects; measurements taken during testing include water depth, flow velocity, impoundment length, and dewatering time. The Iowa DOT standard installation facilitated 4.2 and 5.9 ft (1.3 and 1.8 m) of impoundment under the low (0.85 ft^3/s [0.024 m^3/s]) and high (1.7 ft^3/s [0.048 m^3/s]), indicating that much of the test channel was subject to high velocity, erosive flows. Installation components such as the removal of the excavation beneath the installation, the use of a smaller rock gradation, the addition of a geotextile overlay, dewatering holes in the geotextile overlay, and reducing the width of the installation, were evaluated to determine the impact on performance and improvements from the standard. Adding a geotextile overlay and switching to a smaller rock gradation significantly increased impoundment length; the addition of dewatering holes in the geotextile overlay resulted in faster dewatering times while not otherwise adversely impacting performance. Additionally, removing the excavation beneath the standard rock check dam installation and reducing the width of the installation were not found to negatively impact performance while reducing the installation and material costs. A most feasible and effective installation (MFE-I) installed on grade with the Iowa DOT erosion stone, a geotextile overlay with dewatering holes, and a reduced width from 6 to 4 ft (1.8 to 1.2 m) increased impoundment lengths to 58.7 and 57.5 ft (17.9 and 17.5 m) under the low and high flow conditions, respectively. The increased impoundment formation also impacted performance under sediment-laden conditions, with the MFE-I capturing 72.4% of introduced sediment, while the Iowa DOT standard installation captured 9.4%. The addition of the geotextile overlay also impacted water quality performance, with the MFE-I having statistically significantly lower discharge turbidity than the standard installation.

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EVALUATION OF ROCK CHECK DAM PERFORMANCE USING LARGE-SCALE TESTING TECHNIQUES

Final Report
May 2025

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NOMENCLATURE

AU-SRF	Auburn University – Stormwater Research Facility
BMP	Best Management Practice
DOT	Department of Transportation
GSWCC	Georgia Soil and Water Conservation Commission
NTU	Nephelometric Turbidity Unit
PAM	Polyacrylamide
SWPPP	Stormwater Pollution Prevention Plan
TSS	Total Suspended Solids

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EXECUTIVE SUMMARY

Conveyance channels are commonly used on highway construction projects to manage the flow of water through the project to downstream discharge points or stormwater detention practices. However, these channels can be at risk of erosion before stabilization due to high-velocity flows. A common erosion control practice in channels is a rock check dam, which aims to slow flow by forming impoundment upstream of installations. Based on common spacing guidance, if rock check dams do not impound to their full height, areas of the channel will still be subject to erosive flow conditions. Past research has indicated that a geotextile overlay or smaller choker stone is required to facilitate a full impoundment, especially under low flow conditions. Despite the widespread use of rock check dams, very few standards include overlays or chokers or have been evaluated for performance. To evaluate the Iowa Department of Transportation (DOT) standard rock check dam installation and develop more efficient and cost-effective modified installations, a standard Iowa DOT channel located at the Auburn University – Stormwater Research Facility was used. Installations were subjected to channelized flow conditions that represent those found on Iowa highway construction projects; measurements taken during testing include water depth, flow velocity, impoundment length, and dewatering time. The Iowa DOT standard installation facilitated 4.2 and 5.9 ft (1.3 and 1.8 m) of impoundment under the low (0.85 ft^3/s [0.024 m^3/s]) and high (1.7 ft^3/s [0.048 m^3/s]), indicating that much of the test channel was subject to high velocity, erosive flows. Installation components such as the removal of the excavation beneath the installation, the use of a smaller rock gradation, the addition of a geotextile overlay, dewatering holes in the geotextile overlay, and reducing the width of the installation, were evaluated to determine the impact on performance and improvements from the standard. Adding a geotextile overlay and switching to a smaller rock gradation significantly increased impoundment length; the addition of dewatering holes in the geotextile overlay resulted in faster dewatering times while not otherwise adversely impacting performance. Additionally, removing the excavation beneath the standard rock check dam installation and reducing the width of the installation were not found to negatively impact performance while reducing the installation and material costs. A most feasible and effective installation (MFE-I) installed on grade with the Iowa DOT erosion stone, a geotextile overlay with dewatering holes, and a reduced width from 6 to 4 ft (1.8 to 1.2 m) increased impoundment lengths to 58.7 and 57.5 ft (17.9 and 17.5 m) under the low and high flow conditions, respectively. The increased impoundment formation also impacted performance under sediment-laden conditions, with the MFE-I capturing 72.4% of introduced sediment, while the Iowa DOT standard installation captured 9.4%. The addition of the geotextile overlay also impacted water quality performance, with the MFE-I having statistically significantly lower discharge turbidity than the standard installation.

1. INTRODUCTION

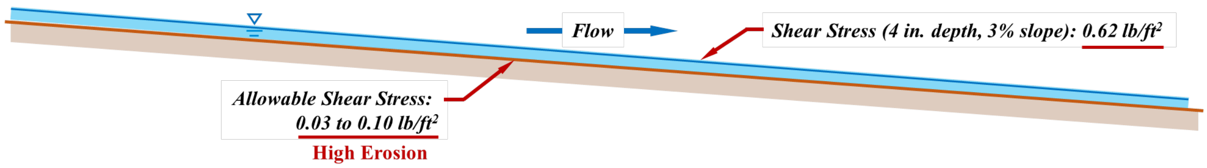
1.1. BACKGROUND

Construction projects, due to their earth-disturbing nature, increase the risk of soil erosion up to 10,000 times compared to undisturbed areas such as forests and grasslands supported by native vegetation *(Haan et al. 1994)*. Uncontrolled runoff from construction can carry pollutants, such as sediment, heavy metals, nutrients, and other detrimental materials, into natural areas or waterways adjacent to construction projects. Of Iowa's assessed waterways, more than 75% of river and stream segments and 67% of lakes and reservoirs are impaired. Due to the presence of pollutants or low water quality, impaired waterways cannot be used for their designated use, including drinking water, recreation, and the support of aquatic life. Sediment-laden runoff is one of the leading causes of impairment in waterways within Iowa, with turbidity and sedimentation being the second and eighth highest causes of impairment in lakes and wetlands, respectively *(Iowa Department of Natural Resources 2015, 2018)*. Sediment entering waterways can negatively impact the environment due to increasing turbidity, sedimentation which can lower the effective capacity of waterways and lead to increased flooding risk, and transporting other harmful pollutants bound to sediment particles *(USEPA 1999)*. Additionally, sediment negatively affects aquatic life, including lowering feeding rates, spawning success, and fish embryo development *(Chapman et al. 2014)*. Non-point source pollution, which includes unmanaged sediment-laden runoff from construction projects, is one of the leading causes of sediment in waterways *(U.S. Environmental Protection Agency 2022)*.

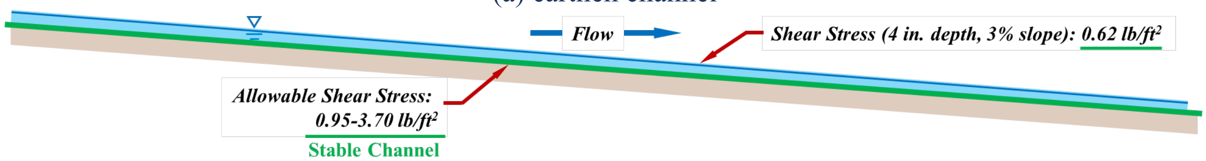
To manage runoff from construction projects and protect adjacent areas, sites that are over 1 acre (0.4 ha) in size are required to develop Stormwater Pollution Prevention Plans (SWPPPs). Some of the requirements for SWPPPs include controlling stormwater volume and velocity to minimize soil erosion on site, controlling discharge to prevent erosion at discharge points, and minimizing sediment discharge from the site *(Iowa Department of Natural Resources 2023)*. Typically, these goals are met with the development of erosion and sediment control plans and the installation of best management practices (BMPs), which are structural, vegetative, or managerial practices used to treat, prevent, or reduce water pollution *(Kaufman 2000)*. The development and implementation of BMPs are required to adequately address the duration, amount, and intensity of local rainfall *(Iowa Department of Natural Resources 2023)*. However, the standards dictating the design and installation of BMPs can vary based on jurisdiction and are often based on rules-of-thumb rather than the results of scientific testing, which can lead to ineffective installations that often spend taxpayer funds without adequately protecting adjacent waterbodies *(Kaufman 2000; Perez et al. 2019)*. The maintenance of BMPs is also specified in SWPPPs, as it is one of the most common causes of BMP failures *(Bhattarai et al. 2016)*.

A common stormwater management practice, especially in highway construction, is the management of flows on a construction project by directing the flow of water into conveyance channels, which are typically not yet stabilized with vegetation for much of the construction process *(Zech et al. 2014)*. These channels are usually triangle or trapezoidal and use gravity to transport runoff to downstream stormwater detention practices, such as sediment basins, or to discharge points *(Schussler et al. 2021; United States Environmental Protection Agency Office of Water 2021)*. Iowa Department of Transportation (DOT) channels are typically trapezoidal with a 10 ft (3.1 m) bottom width, 4 ft (1.2 m) depth, and 6:1 side slopes *(Schussler et al. 2020)*.

The shear stress produced by flow, a function of the unit weight of the fluid, the depth of the flow, and the slope of the hydraulic grade line, is the primary indicator of erosive conditions, with this often being simplified to permissible flow velocities. An un-lined earthen channel has very little allowable shear stress, often between 0.03 and 0.10 lb/ft^2 (1.4 to 4.8 Pa), which can be easily exceeded by flows in conveyance channels on construction projects, as shown in Figure 1.1a; a vegetated channel increases the allowable shear stress to between 0.95 and 3.70 lb/ft^2 (45.5 to 177 Pa), as shown in Figure 1.1b *(Tucker-Kulesza and Zahidul Karim 2017)*. However, immediately after grading and before vegetation is established, conveyance channels are at risk of highly erosive flow conditions.



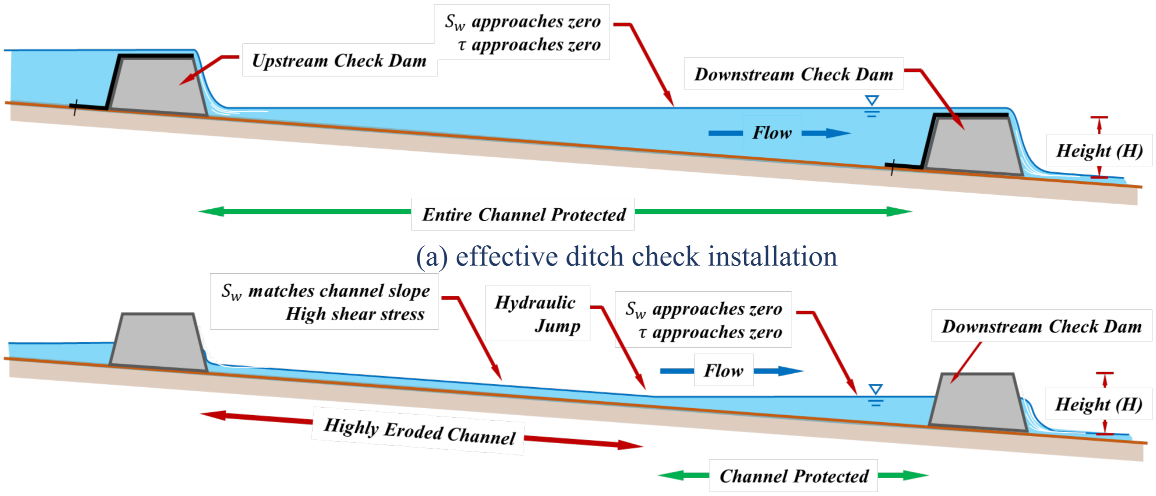
(a) earthen channel



(b) vegetated channel

Figure 1.1: Permissible Shear Stress in Conveyance Channels

To protect unstabilized channels from erosion due to high flow shear stress and velocity, ditch check practices are typically installed. Ditch checks serve primarily as erosion control practices with some sediment control secondary benefits by forming impoundments that reduce flow velocity, protect channels from erosion, and facilitate some sediment deposition as a secondary benefit *(Donald et al. 2013; Wright 2010)*. To adequately protect channels, ditch checks must be able to form a pool of impoundment behind the practice while also withstanding the resulting hydrostatic and uplift force without any structural failures occurring, as shown in Figure 1.2. Rock check dams flatten the slope of the hydraulic grade line (S_w), which is critical in the reduction of erosive shear stress (τ). Typically, ditch checks are installed in channels that are not yet vegetated or when protective lining is not possible; they are most effective when used in series in long channels, with numerous installations protecting segments of the channels *(United States Environmental Protection Agency 2021)*.



(a) effective ditch check installation

(b) ineffective ditch check installation

Figure 1.2: Purpose of Ditch Check Practices

Common ditch check practices include wattles, rock check dams, silt fences, and sandbags. Regardless of the type of ditch check practices installed, the spacing guidance tends to be the same across all jurisdictions: the bottom of the upstream practice should be at or below the elevation of the top of the dewatering weir of the next ditch check practice in series, as shown in Figure 1.3 *(Alabama Soil and Water Conservation Committee 2018)*. The goal of this spacing guidance is to ensure that the impoundment, or length of low-velocity and deeper subcritical flow, protects the entire channel; however, in many cases, ditch check practices are permeable installations that do not form impoundment that reaches the entire height of the installation, leading to a shorter length of impoundment, the presence of high-velocity super critical flows, and unprotected channels. Like all other BMPs, consistent maintenance of ditch check practices is required to prevent failure, which often includes the removal of sediment once reaching half of its capacity and inspecting for structural failures such as bypass or undermining *(McEnroe and Treff 1997; United States Environmental Protection Agency 2021)*.

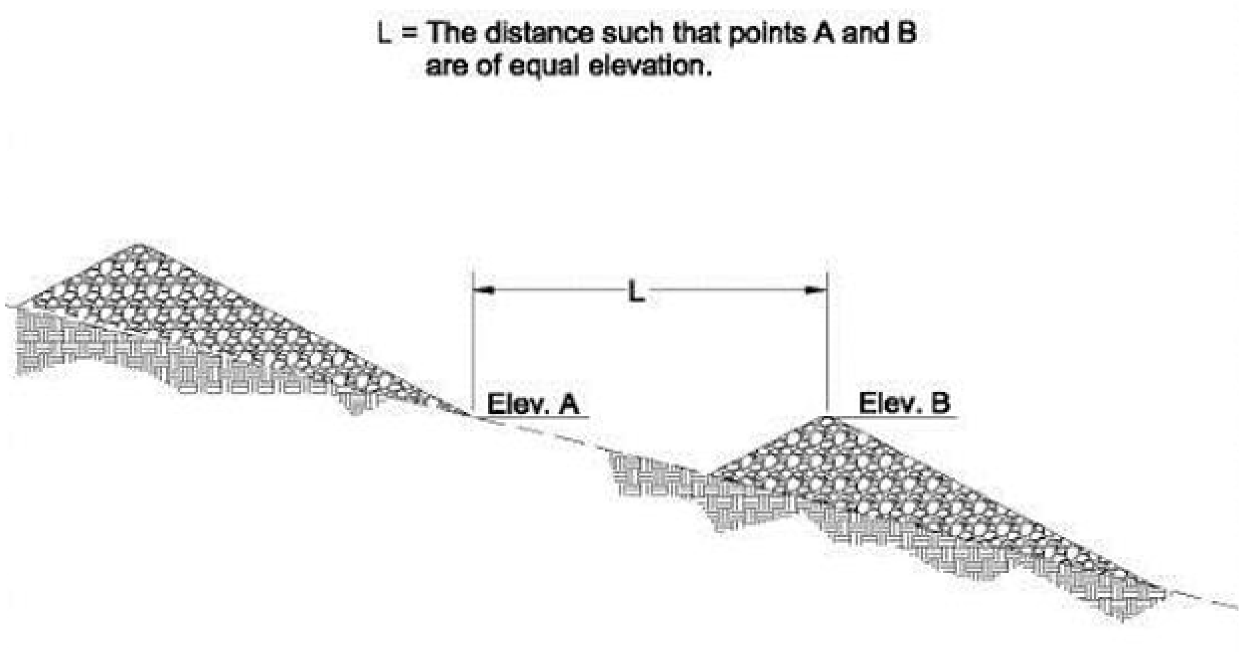
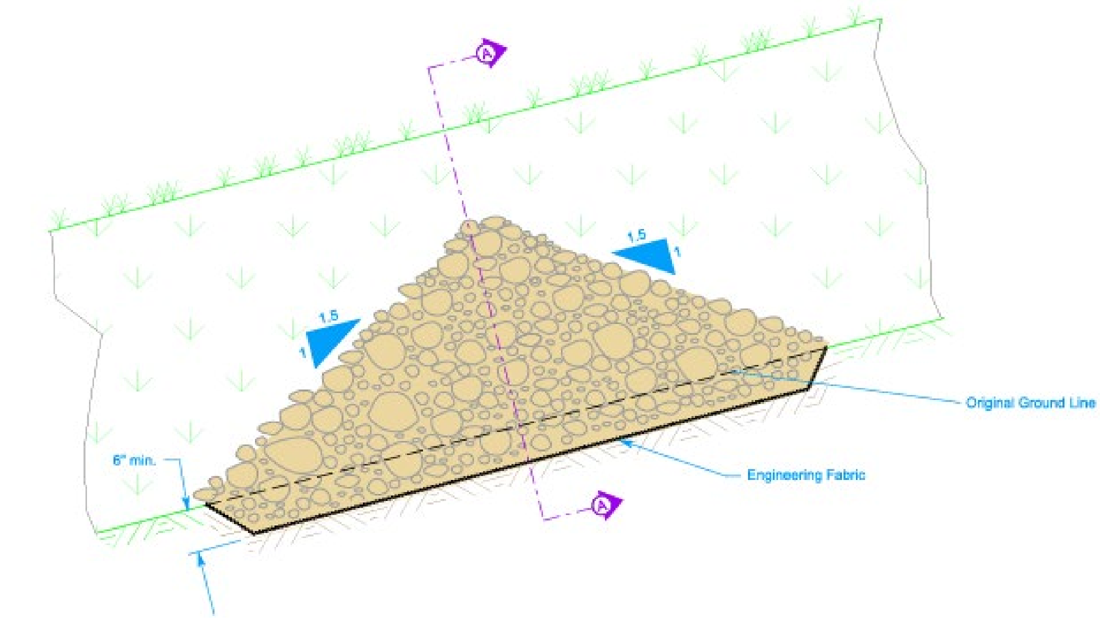


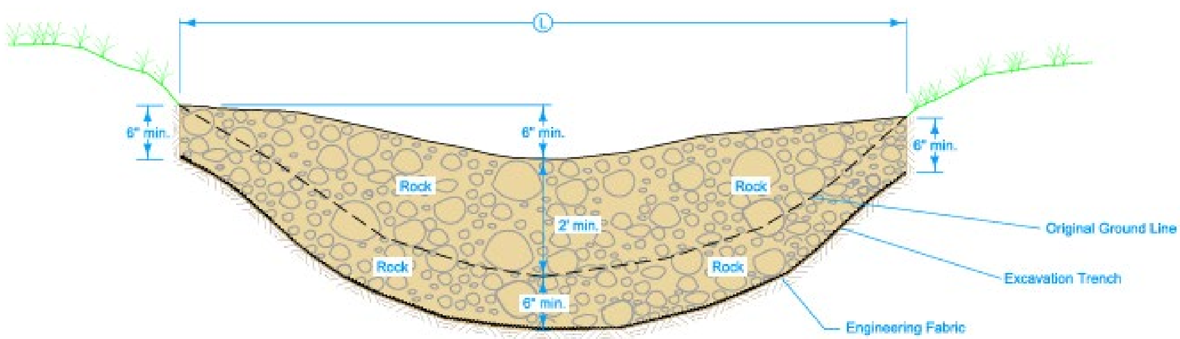
Figure 1.3: Ditch Check Spacing Guidance ***(Zech et al. 2014)***

One of the most common ditch check practices are rock check dams, constructed of various-sized rock across a channel to impound runoff *(United States Environmental Protection Agency, 2021).* A primary advantage of rock check dams is that they can withstand higher-velocity concentrated flows than other ditch check practices without failing or being washed out due to the size and weight of the rock; however, large spaces between rocks in check dam installations with uniformly sized material can lead to a lack of impoundment formation *(Zech et al. 2014)*. Rock check dams are often used instead of other ditch check practices in channels with high discharge, such as in areas with large drainage areas or steep slopes, where other ditch check practices have previously failed (McEnroe & Treff, 1997).

The Iowa DOT standard rock check dam has similar characteristics to many other rock check dam standards, requiring a 6 in. (15.2 cm) weir, 2 ft (0.61 m) minimum height, a 6 in. (15.2 cm) trench, and a geotextile underlay. Iowa rock check dams are constructed of Class D Revetment, which has a nominal top size of 250 lb (115 kg) with at least 50% of rock being over 90 lb (40 kg) and 90% of rock being over 5 lb (2 kg). Figure 1.4 shows the Iowa DOT standard rock check dam.



(a) ditch profile



(b) section view

Figure 1.4: Iowa DOT Standard Rock Check Dam *(Iowa DOT 2024)*

Poorly installed, maintained, or designed rock check dams can result in large amounts of erosion within channels, overload downstream practices with sediment, allow sediment-laden flows to discharge to neighboring areas, and increase construction costs due to increased maintenance of downstream practices and mitigation of negative environmental impacts. Additionally, despite the widespread use of rock check dams, many standard practices have not been properly evaluated for performance in preventing erosion and capturing sediment or to determine if performance can be improved through modifications.

1.2. RESEARCH OBJECTIVES AND TASKS

This full-scale testing effort aimed to evaluate and improve the erosion prevention and sediment capture performance of rock check dams under conditions representative of those found on construction projects in the state of Iowa. The following objectives were established to accomplish this goal:

1) Evaluate the existing Iowa DOT rock check dam standard and
2) Develop and evaluate efficient and cost-effective rock check dam installation enhancements.

Six tasks were identified to meet these objectives:

1) Conduct a comprehensive literature review investigating rock check dam standards from other jurisdictions, usage of rock check dams in the state of Iowa, and past performance evaluations of ditch check and rock check dam installations. The literature review will help guide the project in the development of the testing methodology and identify potential modified installations.
2) Develop a large-scale testing methodology for the evaluation of rock check dams, including the determination of performance metrics, data collected, testing order, and flow rates.
3) Conduct large-scale clean-water performance evaluations of rock check dams at the Auburn University – Stormwater Research Facility (AU-SRF) using the previously constructed 200 ft (61 m) Iowa DOT testing channel.
4) Conduct large-scale sediment-laden performance evaluations of the Iowa DOT standard installation and the highest performing modified installation to determine secondary benefits of sediment capture and water quality treatment.
5) Analyze testing data, including flow velocity profiles, impoundment lengths, water quality, and sediment capture for Iowa DOT standard rock check dams and evaluated modifications to develop implementable design recommendations that increase protection from erosion, sediment capture, and reduce material and installation costs.
6) Compile the final report that outlines findings from the literature review, experimental results, data analysis, and design recommendations.

1.3. RESEARCH SIGNIFICANCE

Developing detailed and implementable design guidance and recommendations for Iowa DOT rock check dams from the results of large-scale performance evaluations will allow for the improvement of stormwater management in Iowa by ensuring the commonly used rock check dam practices are effective. Improved rock check dam practices will protect water quality downstream of the practice, reduce the sediment loading on downstream stormwater detention practices, reduce regulatory compliance issues and fines, and improve public perception. Additionally, the results and recommendations from this project can be applied to other jurisdictions to improve the state of practice of rock check dam practices and other ditch checks.

1.4. ORGANIZATION OF THE REPORT

This report is divided into five chapters that describe the steps taken to meet the defined research objectives and the results of the research. Chapter Two is a comprehensive literature review outlining rock check dam standards around the United States, rock check dam usage by the Iowa DOT, and past research evaluations of rock check dams. Chapter Three outlines the testing methodology that was used in the evaluation of rock check dams, including the testing apparatus, testing flow rates, data collection processes, and testing materials. Chapter Four describes the results and data analysis of full-scale testing of rock check dam installations. Chapter Five will summarize major findings, make recommendations on improving the state of practice of rock check dam installations, and describe the impact of the research efforts.

2. LITERATURE REVIEW

2.1. INTRODUCTION

Rock check dams are a common practice on construction projects to protect unstabilized channels from erosion by facilitating impoundment and slowing the flow of water through conveyance channels to levels below the permissible velocities based on the soil type. Despite their widespread use, little research has been conducted on improving rock check dam installations through full-scale testing efforts. To guide research efforts on improving the state of practice for rock check dam installations by developing a testing methodology and identifying potential modifications, a literature review was conducted with three main objectives:

1) Investigate rock check dam standards from around the United States and the rest of the world

2) Determine usage of rock check dams on Iowa DOT construction projects, and

3) Investigate past research efforts on ditch check practices and rock check dams.

2.2. ROCK CHECK DAM STANDARDS

Rock check dam installations, despite their widespread use, are not uniform across different jurisdictions. A review of forty-five U.S. state DOT specifications and erosion control manuals (no specific rock check dam guidance could be found for Arkansas, California, New Mexico, North Dakota, or Washington), as well as the Australasian International Erosion Control Association standards, found that installation specifications vary widely including in height, size and presence of a dewatering weir, spacing, rock gradation, trenching, and use of overlays or underlays. Rock check dam height requirements range from a 1 ft (0.3 m) minimum height to a 3 ft (0.91 m) maximum height. All but one specification had weir requirements; weir size ranged from 4 in. (10.2 cm) to 1 ft (0.3 m) in depth, with the most common specification being 6 in. (15.2 cm). Alaska and Idaho standards are based on the weir depth being half and a quarter of the channel depth, respectively. Only fifteen jurisdictions required a trench or excavation beneath the rock check dam; these ranged from 4 in. (10.2 cm) minimum to as large as 18 in. (45.7 cm). Three trench requirements were only in the center; the rest spanned the entire installation. Seventeen jurisdictions required geotextile underlays to prevent undermining; two required the geotextile to extend downstream an additional length to protect the channel from erosion. Virginia's specification requires rock to extend 10 ft (3 m) downstream of the check dam to protect the channel from erosion downstream of the practice. Spacing requirements tended to be standard, with all recommending the top of the installation being at the same elevation as the bottom of the previous; however, Mississippi and South Dakota had a minimum spacing of 100 and 150 ft (30.5 and 45.7 m), respectively, and West Virginia had a maximum spacing of 300 ft (91.4 m). Rock gradation varied widely from as small as 0.5 to 2 in. (1.3 to 5.1 cm) in diameter to as large as 2 ft (0.61 m) diameter riprap. Two jurisdictions required geotextile overlays weighed down by coarse aggregate to facilitate additional impoundment; eleven use smaller choker stone, typically a coarse aggregate, to slow through the check dam installations and facilitate additional impoundment.

2.3. ROCK CHECK DAM USAGE

A review of Iowa DOT bid tabs found that from 2019 through 2023, $4.1 million was spent on installing, maintaining, and removing rock check dams from construction projects. Over 69,000 linear feet of rock check dams were installed with an average installation cost of $28.79/ft ($94.46/m); the cost per linear foot varied with the amount of rock check dams installed on the projects. Maintaining rock check dams comprised 35.7% of the total costs, with an average maintenance cost of $145.55 per dam. The removal costs comprised 17.3% of the total cost, with an average of $174.07 per removed dam. Numerous projects did not remove all rock check dams installed on the project. According to this estimate, each rock check dam costs $521.12 for installation, maintenance, and removal on average. Due to projects with fewer rock check dams having a higher cost, it would be expected that the cost per rock check dam would be higher. A cost analysis completed as a part of a field monitoring study on an Iowa DOT project in Tama County indicated that the estimated average cost of rock and engineering fabric per rock check dam was $746.08 *(Schussler et al. 2020)*.

2.4. DITCH CHECK PERFORMANCE EVALUATIONS

Numerous studies on the performance of various types of ditch check installations, consisting of either field monitoring or under controlled conditions through small or large-scale laboratory testing, have been completed, primarily focusing on sediment capture/loss, structural performance, or hydraulic performance. Testing efforts conducted through different methods and on different types of ditch check installations, such as wattles or silt fences, provide valuable insight into ditch check performance parameters and how to improve rock check dam performance.

2.4.1. FIELD MONITORING

Field monitoring of ditch check practices can provide insight into installation maintenance requirements and overall structural performance. An early study of rock check dams installed on a construction project in Kanas indicated that rock check dams were effective at preventing blowout and capturing sediment in channels where straw bales ditch checks had previously failed; however, no specific performance indicators were provided *(McEnroe and Treff 1997)*.

McLaughin et al. monitored the turbidity and total suspended solids (TSS) of rock check dams and fiber check dam installations with and without polyacrylamide (PAM) on a construction site in the mountains of North Carolina to compare water quality treatment performance. Rock check dam installations were comprised of large stones with an excavated sediment trap upstream of the dam with no geotextile overlay or choker stone; fiber check dams were coir logs and straw wattles. The rock check dams average discharge turbidity of 3,537 Nephelometric Turbidity Units (NTU), while the fiber check dams with and without PAM performed better with 28 and 164 NTU on average, respectively *(McLaughlin et al. 2009)*.

Erosion and sediment control practices installed on an Iowa DOT construction site were monitored weekly during the fall of 2018 and the summer and fall of 2019. Three ditch check practices (silt fence, wattles, and rock check dams) were monitored. Sediment deposition was measured using stakes at equal intervals and survey equipment to determine accumulation caused by each practice; survey data was used to generate deposition or erosion profiles for each ditch check installation.

Observed structural failures for silt fence ditch check installations included excessive post deflection, overtopping, and flow bypass. The standard Iowa DOT installation especially exhibited undercutting and post deflection. Modifications were tested to improve upon these structural deficiencies, including adding wire fence backing to increase structural effectiveness, a dewatering weir at the center of the installation, and using a V-shape across the channel. Recommendations from monitoring were made to staple geotextile to the ground instead of trenched in to prevent ground disturbance that can lead to undermining and the inclusion of a weir at the center of the installation; it was noted that the price of each installation would increase with modifications, but the installation would have increased longevity than the Iowa DOT standard which could reduce costs in the long run *(Schussler 2019)*.

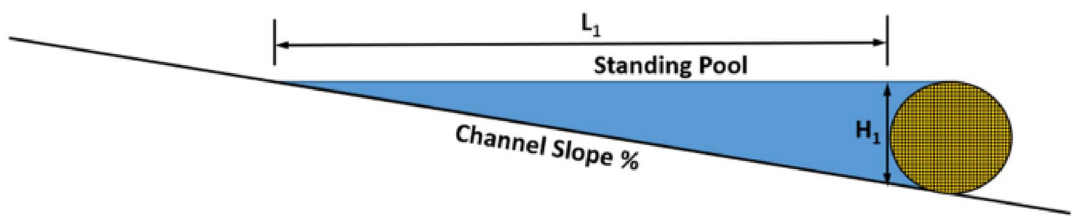
Wattle installations were monitored on the same site: four fill materials (excelsior, straw, wood chips, and switchgrass) were installed using the Iowa DOT standard installation, and three fill materials (straw, excelsior, and wood chips) were installed using a modified installation. The modified wattle installation tested included an underlay, A-frame, nondestructive staking, and sod staples at the front and back of the wattles. The modified wattle installation captured 13.15 times the amount of sediment as the standard installation; all standard installations also experienced undermining. As with the silt fence recommendations from the same study, the modified installations would be more expensive to install; however, the protection from structural failures such as undermining and the increased performance could save money in replacing failed installations and downstream mitigation. The Iowa DOT standard rock check dam installation was also monitored. Previously installed check dams were observed to experience undercutting, as shown in Figure 2.1. Additionally, a clear maintenance requirement was observed as the area immediately upstream of installations became full of sediment without maintenance; lack of proper maintenance can reduce the longevity of rock check dam installations. To improve upon the Iowa DOT standard, the authors recommended including a geotextile overlay to prevent undermining and further aiding in slowing concentrated flow. Unfortunately, due to project constraints, the modified installation could not be installed; however, recommendations were made to test modified rock check dam installations under controlled conditions to improve the standard installation *(Schussler et al. 2020)*.

Figure 2.1: Iowa DOT Rock Check Dam Undermining

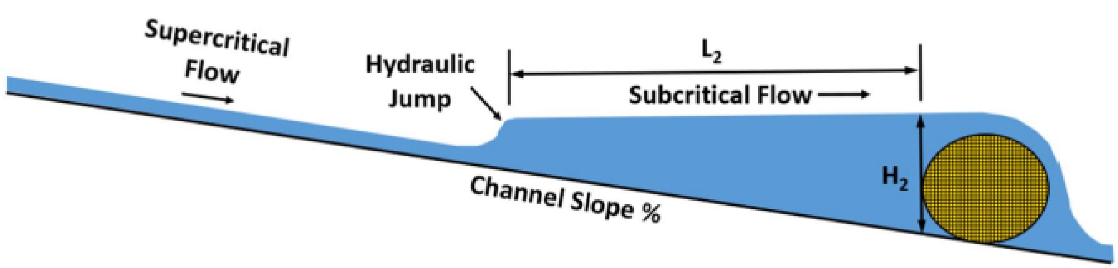
Despite the improvements and observations from field monitoring studies, most monitoring efforts have concluded that more improvements could be made by testing the same practices under controlled conditions. Clear limitations were identified, such as differences in storm events, drainage areas, and other conditions that could influence the results of monitoring ditch check practices and are difficult to standardize (McEnroe & Treff, 1997; J. C. Schussler et al., 2021).

2.4.2. LABORATORY TESTING

Small-scale laboratory testing of ditch check practices has typically been conducted on wattles, including fill material and encasement; however, the results and conclusions from these testing efforts can be applied to rock check dam installations. Multiple flume studies have compared the theoretical impoundment, a level pool with a height of the ditch check that most spacing guidance is based on, to the actual impoundment facilitated; Figure 2.2 shows a diagram of the theoretical and actual impoundment. Whitman et al. calculated depth and length ratios comparing the actual impoundment to the theoretical impoundment as a performance indicator for wattle ditch checks; testing found that all but one wattle tested, an excelsior fiber fill, had depth ratios exceeding 100%, which represents the experimental impoundment depth being greater than the theoretical impoundment depth. Length ratios ranged from 61% to 96%, showing that for every wattle tested, there would be an area of supercritical flow in the channel that can lead to channel erosion, as spacing guidance is based on the theoretical impoundment length *(Whitman et al. 2021)*.



(a) theoretical impoundment



(b) actual impoundment

Figure 2.2: Theoretical and Actual Impoundment Formed by Ditch Checks *(Whitman et al. 2021)*

To improve the state of practice on testing ditch check installations, the ASTM D7208 Standard Test Method for Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion was developed and aims to determine how well a ditch check practice slows or ponds runoff, traps soil particles upstream of the practice, and decreases soil erosion within a channel by comparing the performance of a ditch check installation under those performance criteria to a control test through a bare channel. During a 30-min test period, measurements included water elevation and velocity at multiple cross-sections upstream and downstream of each ditch check installation *(ASTM 2014)*.

Performance evaluations of the Georgia Soil and Water Conservation Commission (GSWCC) standard ditch check BMPs, including rock check dams, straw bales, filter socks, and silt fences, were conducted using the ASTM D7208 test method. Testing found that straw bales and silt fences structurally failed under all flow rates due to increased hydrostatic pressure on the installations. The rock check dam and compost sock were able to hold up under even the highest flow rates tested, 2.0 ft^3/s (0.057 m^3/s), and both reached the performance benchmark of providing an 80% reduction in channel soil loss *(Sprague and Sprague 2012)*. Similar tests using two flow rates, 0.18 and 0.35 ft^3/s (0.005 and 0.01 m^3/s), were run on proprietary ditch check products installed to manufacturer specifications and were evaluated ditch for water quality and structural performance. For most tests, steady state flows, in which impoundment did not increase, were reached approximately 10 min into the test period. In sediment concentration, a "first flush," or period of higher sediment concentration at the start of a stormwater runoff event, was present and concentration declined over the test period. For testing of the higher, 0.35 ft^3/s (0.01 m^3/s), flow rate, only the triangular silt dike showed a decrease in sediment concentration at 1.85%; the permeable plastic product, excelsior log, and straw wattle showed a 2.09, 0.12, and 120.58% increase in sediment concentration between immediately upstream and downstream of the installations. Under the lower 0.18 ft^3/s (0.005 m^3/s) flow rate, the permeable plastic product installation decreased sediment concentration by 3.92%; the other three tested products showed similar performance to the testing results under the higher flow rate. The straw wattle's lack of performance was shown to be due to undercutting. The straw wattle was installed with stakes at a 45-degree angle, a trench under the wattle, and nothing else ensuring ground contact; however, no conclusions were made on whether the installation can be improved to prevent undermining, facilitate additional impoundment, and increase performance *(Bhattarai et al. 2016)*.

Kang et al. evaluated three ditch check configurations with and without PAM flocculant applied, including an excelsior wattle, a rock check dam, and a rock check dam wrapped in an excelsior erosion control blanket for impoundment depth, impoundment length, and sediment deposition. Installations consisted of three practices installed in series and were subjected to three back-to-back simulated stormwater runoff events. The rock check dam installations without PAM or an excelsior blanket had the highest discharge turbidity of the installations tested, averaging around 900 NTUs; the rock check dam with an erosion control blanket had an average discharge turbidity of approximately 400 NTU. Rock check dams without the erosion control blanket wrap also had an over 300% increase in turbidity between the first and the third simulated runoff event, while the dams with the erosion control blanket wrap increased by less than 150%; discharge turbidity for all three installations was not statistically significantly different for the first storm event, only the rock check dam showed a significant jump in turbidity in subsequent storm events, likely due to deposited sediment becoming resuspended. Additionally, the excelsior erosion control blanket tripled sediment capture, with most being captured at the first dam. The impoundment depth, length, and sediment capture of the rock check dam with the erosion control blanket wrap were significantly higher than that of just the rock at the first dam *(Kang et al. 2013)*.

Testing of Alabama DOT standard and modified wattle, rock check dam, sandbag, and silt fence ditch check installations was conducted at the AU-SRF with goals of improving the standard installations and developing improved evaluation tools for ditch check practices. A trapezoidal test channel with a 4 ft (1.2 m) bottom width and 3:1 side slopes was used in the testing of ditch checks under clean and sediment-laden simulated stormwater runoff; key measurements taken during the test period were water depth and velocity measurements taken at multiple cross-sections once steady-state flow was reached, as well as the distance from the ditch check to the hydraulic jump. The data collected during testing was used to develop additional guidance on ditch check performance: a relationship between the ratio between water depth and specific energy (y/E) and Froude number, the dimensional parameter representing the ratio of inertial forces to gravitational forces that provides essential guidance on the state of flow, was graphed and an inflection point found above the y/E ratio of 0.75 was selected as a benchmark for performance *(State of Iowa 2021; Zech et al. 2014)*. The minimum criteria of 0.75 for the depth and energy ratio was chosen due to determining that a depth and energy ratio approaching 1, which additionally leads to a Froude number approach 0, results in lower flow velocity and favorable conditions for protecting channels from erosion. A y/E ratio of 1 represents no flow velocity, and a Froude number under 1 indicates subcritical flow, which has little to no risk of channel erosion *(Donald et al. 2016)*.

In addition to developing an additional performance indicator of ditch checks, testing at the AU-SRF provided the Alabama DOT with guidance to improve the structural performance of wattle, sandbag, and rock check dam ditch check practices. Testing of the standard Alabama DOT wattle installation showed that over time, the impoundment length decreased as flow eroded the soil beneath the wattle and led to undercutting, which can drastically reduce the performance of a wattle ditch check. To facilitate increased ground contact and increase long-term and immediate performance, the addition of sod staples spaced every 10 in. (25.4 cm) on both sides of the wattle, non-destructive A-frame staking, and a geotextile underlay were all tested. The addition of the geotextile underlay, A-frame staking, and sod staples was found to be the most effective installation at forming impoundment, with a 99% increase to 20.5 ft (6.24 m) compared to the Alabama DOT standard that impounded 10.3 ft (3.14 m). Additionally, trenching, despite being recommendation by many jurisdictions and manufacturers to prevent undercutting, was found to reduce contact between the ground and the wattle, decreasing performance; the trenched installation with A-frame staking and a geotextile underlay impounded 8.0 ft (2.4 m), a 22.3% decrease from the installation with no trench *(Zech et al. 2014)*

Evaluations of silt fence ditch checks at the AU-SRF found structural deficiencies such as scour downstream of the practice, leading to the middle t-post losing structural integrity, which can result in complete installation failure. To reduce downstream scour, installations with a hay bale and a no. 4 stone energy dissipation device were tested; neither installation improved downstream erosion, with erosion happening beneath the hay bales and further downstream for the rock, as the flow was able to revert to supercritical flow just downstream of the energy dissipation devices. Another modification, based on the Tennessee DOT standard, was tested, which included an overflow weir at a height of 18 in. (45.7 cm) from the center of the ditch with a downstream riprap energy dissipation device. Including an overflow weir decreased the hydrostatic pressure on the silt fence installations and reduced the amount of silt fence outside the channel if the silt fence is taller than the height of the channel, which is a standard required to prevent flow bypass. Testing of silt fence ditch checks at the AU-SRF concluded that using a weir reduces the effective height of the installation and would prevent the occurrence of installation failure due to excessive impoundment, which can lead to uncontrolled discharge and failure of downstream practices *(Zech et al. 2014)*.

The standard Alabama DOT sandbag installation, only being held in place with gravity and friction, showed a risk of failure from washout under higher flow conditions, starting with a flow rate of 1.12 ft^3/s (0.0317 m^3/s). To increase the impoundment potential and prevent washout, multiple modifications were tested, including changing the orientation of the middle rows of bags, adding additional bags downstream to support the practice, and wrapping the installation in filter fabric. The addition of the geotextile wrap led to the installation not experiencing structural failure under all three flow rates tested (0.56, 1.12, and 1.68 ft^3/s (0.016, 0.0317, 0.0476 m^3/s) and increased the maximum impoundment length, or length of subcritical flow, to 33.5 ft (10.2 m). An impoundment length efficiency, representing the facilitated impoundment compared to the recommended spacing, of 109% was found. *(Zech et al. 2014)*. While the goal of wrapping sandbags in geotextile wrap was to increase structural viability and prevent failure, the additional impoundment generated by the practice could indicate that similar improvements could be facilitated by adding geotextile overlap to rock check dam installations.

The standard Alabama DOT rock check dam installation, 18 in. (45.7 cm) high over a geotextile underlay, was ineffective at forming impoundment due to high flow-through rates during testing. The standard rock check dam installation facilitated a maximum impoundment length of only 14.5 ft (4.42 m); this resulted in an efficiency of only 48.3%, indicating that more than half of the channel was unprotected from erosion due to highly erosive supercritical flows. Two alternative installations were tested to increase impoundment potential: a choker consisting of No. 4 coarse aggregate on the upstream face of the dam and a geotextile wrapped around the front face of the check dam. Figure 2.3 shows the standard and modified rock check dam tested at the AU-SRF. Both modifications increased impoundment, with the choker stone increasing impoundment to 20.5 ft and increasing efficiency to 68% and the geotextile choker doubling impoundment to 29.1 ft (8.9 m) and increasing efficiency to 97.0% *(Zech et al. 2014)*.

(a) Alabama DOT standard rock check dam

(b) rock check dam with aggregate choker

(c) rock check dam with geotextile overlay

Figure 2.3: Rock Check Dams Evaluated by Zech et al. ***(2014)***

2.5. LITERAURE REVIEW CONCLUSIONS

Past ditch check performance evaluations have indicated that the ability to impound runoff behind the practice is pivotal in the ability of the practice to prevent erosion in the channel and deposit sediment to reduce the sediment load of downstream BMPs as a secondary benefit. Common performance indicators of ditch check installations include the length of impoundment or subcritical flow, which can be compared to spacing to determine efficiency. If the impoundment formed does not reach the top of the installation due to having a higher flow-through rate, the subcritical flow will not reach the previous installation, causing portions of the channel to be subjected to erosive supercritical flows.

Despite the widespread use of rock check dams and the ability of installations to withstand higher velocity flows without structural failure, testing of rock check dams has indicated that installations with rock only are unable to facilitate impoundment that reaches the top of installations and fully protect channels from high-velocity erosive flows. However, the addition of an additional installation component on the upstream portion of the rock check dam, such as an erosion control blanket, a layer of coarse aggregate, or a geotextile, can increase the impoundment potential of installations and allow for increased protection of channels from supercritical flows. Most jurisdictions do not require any choker or overlay, which indicates a disconnect between standard practices and the results of scientific research.

The implementation of more effective rock check dam installations, through the use of overlays or chokers, can lower downstream effects of sediment-laden stormwater runoff and provide taxpayer savings by requiring less installations to properly protect channels from erosion without providing excessive additional installation, maintenance, or removal costs.

3. TESTING METHODOLOGY

3.1. INTRODUCTION

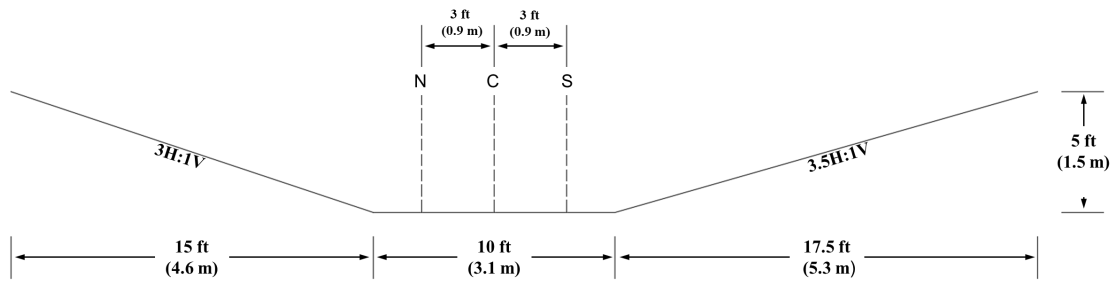
To evaluate rock check dams for performance, a testing methodology was developed that subjected installations to conditions representative of those found on highway construction projects in Iowa and allowed for measurements of flow depth, velocity, and impoundment length to be taken during testing. A modified ASTM D7208 test method was used during testing under varying conditions to determine the effectiveness of rock check dam installations.

3.2. TESTING REGIME

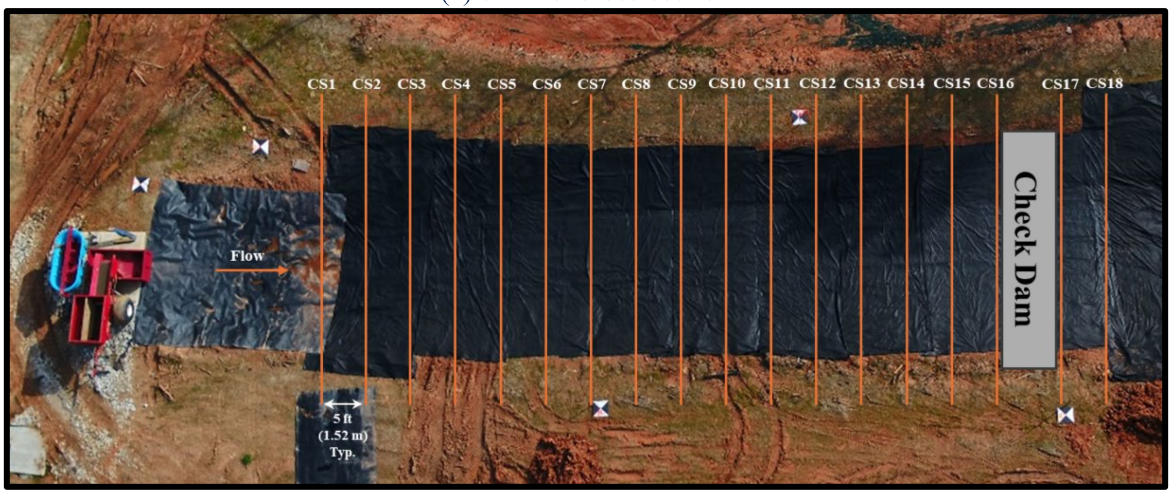
Each tested installation was evaluated for performance during three back-to-back simulated stormwater runoff events to generate data for recommendations and determine how performance changes after multiple runoff events. Testing began with the Iowa DOT standard installation; performance results from tests and past performance evaluations identified through the literature review were used to develop modified installations to improve upon deficiencies within the standard installation and previous modifications. A total of eight installations, including the Iowa DOT standard and seven modified installations, were evaluated, resulting in 24 clean-water tests. After completion of clean-water evaluations, a most feasible and effective installation (MFE-I) was identified as the highest performing installation while also considering potential cost reductions and installation efforts. A total of six sediment-laden tests were conducted on both the Iowa DOT standard installation and the MFE-I to determine how modifications improved sediment capture and water quality improvements, secondary benefits of ditch check practices.

3.3. TEST CHANNEL

An existing channel at the AU-SRF that was previously used for the evaluation of in-channel sediment basins for the Iowa DOT was used for all rock check dam testing efforts and is representative of an Iowa DOT roadside channel with a sediment basin at the downstream end. The test channel has an approximate slope of 3%, side slopes of 3H:1V and 3.5H:1V, a bottom width of 10 ft (3.0 m), and a depth of 5 ft (1.5 m). To allow for consistency and repeated testing, the entire channel was lined with geotextile to prevent erosion from occurring, which would result in increased maintenance between tests and inconsistent flow depths. Figure 3.1a shows a cross-section of the test channel. Along the channel, 18 string lines, spaced 5 ft (1.5 m) apart, were installed across the channel to provide reference points for data collection during testing. Sixteen string lines were installed upstream of the check dam, stretching past the theoretical maximum impoundment length of 63 ft (19.2 m) to ensure a complete flow profile could be created for each installation; two string lines were downstream of the rock check dam installation to evaluate downstream flow conditions. The theoretical maximum impoundment length was determined through a survey of the channel and was the point at which the bottom elevation of the channel was the same as the lowest point of the rock check dam installation. Figure 3.1b shows a layout of the data collection cross-sections.



(a) channel cross-section



(b) channel layout

Figure 3.1: AU-SRF Iowa DOT Test Channel

3.4. FLOW DETERMINATION

Flow was introduced into the channel from a supply pond into a tank with a calibrated weir and a system of valves and tubes that allowed for adjusting and monitoring of introduction flow rates. A plastic energy dissipation pad was immediately downstream of the weir to reduce the energy of flow before it entered the channel.

A two-tiered flow rate was used to properly evaluate rock check dam performance under various conditions. The low rate, 0.85 ft^3/s (0.024 m^3/s), is approximately the peak flow rate produced by the state-wide average 2-yr, 24-hr storm event from a 0.5 ac (0.2 ha) drainage area. A high flow rate of 1.70 ft^3/s (0.048 m^3/s) was used to evaluate the performance of rock check dams under more strenuous conditions representative of a 1 ac (0.4 ha) drainage area in Iowa. At the start of each test period, the flow through the channel was allowed to reach a steady state, with no change in impoundment or water depth occurring

3.5. MEASUREMENTS

During clean water testing at both flow rates, after flow reached these steady-state conditions, water depth and velocity measurements were taken at three locations spaced 3 ft (0.91 m) across at each cross-section: north, center, and south. For cross-sections where flow did not stretch across the entire bottom width of the channel, typically at the far upstream end of the channel and downstream of the rock check dam installation where super critical flow was occurring, measurements were taken at approximately the center of flow and a quarter of the width from each side to develop a flow profile across each cross-section. Flow depth was measured with a ruler and was measured to the nearest hundredths of a foot; the maximum flow depth facilitated by each installation was compared with the height of the installation, 2 ft (0.6 m) for all installations, to determine a depth efficiency, as shown in Eq. 3.1. Flow velocity was determined with a stagnation tube, which allows for measuring velocity head with a ruler, which can then be converted to flow velocity. Due to its importance in calculating the Froude number of flow, which is a vital metric for identifying where erosive supercritical flows occur, the top width of flow was measured at each cross-section. Measurements were taken at a minimum of three supercritical cross-sections upstream of the hydraulic jump to generate a complete flow profile.

$$Depth\ Efficiency\ (\%) = \frac{Maximum\ Measured\ Depth}{Height\ of\ Installation} \qquad \textbf{Eq. 3.1}$$

For each flow rate, the location in the channel where the hydraulic jump, where flow converts from erosive supercritical flows to lower velocity subcritical flows was identified, and the distance from the front face of the rock check dam to the hydraulic jump was measured. The distance to the hydraulic jump, also referred to as the length of the impoundment, can be compared to the theoretical maximum impoundment length, determined by finding the elevation of the lowest point on the top of the rock check and finding the point at which the channel has the same elevation. The comparison between the actual and theoretical impoundment lengths is referred to as the impoundment length efficiency and represents the portion of the channel protected from erosive supercritical flows. Eq. 3.2 shows the length efficiency calculation:

$$Length\ Efficiency\ (\%) = \frac{Impoundment\ Facilitated}{Theoretical\ Maximum\ Impoundment} \qquad \textbf{Eq. 3.2}$$

Another key performance parameter for rock check dam installations that was monitored is dewatering time; excess dewatering times can lead to the inability of a channel to be stabilized and can reduce performance for subsequent storm events. For installations where long dewatering times were anticipated, such as those with a geotextile overlay, a Solinist Levellogger was installed immediately upstream of rock check dam installations to determine dewatering times. The Levellogger took water pressure measurements at 15-second intervals to calculate water depth upstream of the dam, allowing for the time for the rock check dam to completely drain after the conclusion of flow introduction to be recorded.

3.6. SEDIMENT-LADEN EVALUATIONS

To determine the performance of the Iowa DOT rock check dam in sediment capture and water quality and to determine potential improvements in these secondary benefits made through modifications, a total of six sediment-laden performance evaluations were performed. The flow and sediment introduction rates were identical to those used in the testing of in-channel sediment basins under Iowa DOT conditions to allow for the comparison of sediment capture by rock check dams to practices tested in that previous testing effort, such as a forebay for a sediment basin. A constant flow rate of 1.70 ft^3/s (0.48 m^3/s) was introduced over a 30-minute test period. Sediment introduction was completed by hand into a mixing trough; a total of 1,962 lb (890 kg) was introduced during the 30-minute test period at a rate of 65.4 lb/min (29.7 kg/min) *(Schussler et al. 2022)*. The sediment used in testing was native soil to AU-SRF stored in a stockpile on-site and is classified as a sandy loam. To remove debris and large clumps, the soil was run through a mechanical shaker. Soil was then measured into 90 buckets with 21.8 lb (9.9 kg) per bucket; during testing, each bucket was dumped at a consistent rate over a 20-second period.

Water quality grab samples were taken at four locations to evaluate the impact of rock check dams on turbidity and TSS. Sampling locations were at the theoretical impoundment length approximately 63 ft (19.2 m) from the front face of the check dam to represent the upstream conditions, the top and bottom of the impoundment formed immediately upstream of the installation to determine water quality treatment within the impoundment, and immediately downstream of the rock check dam to determine overall treatment. Samples were taken every 3 minutes during the flow introduction period; after the conclusion of flow introduction, samples were taken at 3-minute intervals for 15 minutes immediately following flow introduction, at 5-minute intervals for 15 minutes, at 45 minutes after flow concludes, and at 60 minutes after flow concludes to evaluate how water quality changes during dewatering. Additionally, water samples were taken from flow during testing before sediment was introduced to serve as a baseline level. After testing, samples were evaluated for turbidity and TSS according to ASTM standards *(ASTM 2018a; b)*.

3.7. TESTING MATERIALS

Materials that fit the Iowa DOT's standards were used to construct rock check dams for evaluation, including two gradations of rock. The Iowa DOT standard rock check dam and some modifications were constructed of Iowa DOT Class D Revetment with a nominal top size of 250 lbs (113 kg), at least 50% of stones weighing over 90 lbs (41 kg), at least 90% of stones weighing more than 5 lbs (2.3 kg), and no rock sized at 3 in. (7.62 cm) or less. For other modifications, rock fitting the Iowa DOT erosion stone guidelines and gradation were used, with a nominal 6 in. (15.2 cm) size, 100% passing a 9 in. (23 cm) screen, and 100% being retained on a 3 in. (7.6 cm) screen. Additionally, both rock gradations met quality requirements published by the Iowa DOT *(Iowa Department of Transportation 2023)*. Geotextiles used for both underlays and overlays were nonwoven and fit the Iowa DOT specifications for embankment erosion control. 6 in. (15.2 cm) sod staples were used to secure geotextiles.

4. TESTING RESULTS

4.1. INTRODUCTION

Three installations of the Iowa DOT standard rock check dam were evaluated, along with seven modified installations. Modifications altered installation components, such as removing the excavation beneath the installation, reducing the rock's size, adding a geotextile overlay, and dewatering holes added to the geotextile overlay. Modifications all aimed to improve performance by increasing impoundment length and depth, preventing long dewatering times, and reducing the cost of installation and material. At the conclusion of clean-water testing of all installations, the highest performing installation was selected as the MFE-I. The standard and modified installations are described below:

- Standard Iowa DOT Installation (STD): standard used on Iowa highway construction projects, constructed of Class D Revetment, 2.5 ft (0.76 m) in height, with a 6 in. (15.2 cm) weir at the center, 1.5H:1V side slopes, a bottom width of 6 ft (1.82 m) and a 6 in. (15.2 cm) excavation beneath the installation, and a geotextile underlay.

- Modification 1 (M1): identical to the standard installation with no excavation beneath the installation.

- Modification 2 (M2): identical to the standard installation using a smaller gradation rock, equivalent to the Iowa DOT erosion stone (nominal 6 in. (15.2 cm) and between 3 and 9 in. (7.6 and 22.9 cm)).

- Modification 3 (M3): identical to M1 with the addition of a geotextile overlay over the front upstream of the installation secured two feet upstream of the installation with 6 in. (15.2 cm) sod staples and at the top of the rock check dam installation with rock.

- Modification 4 (M4): identical to M3 with the addition of nine dewatering holes in the fabric to allow for steady dewatering after the conclusion of flow introduction. Holes were spaced every 1 ft (0.3 m) vertically in three columns, one in the center of the channel and the other on the north and south ends of the bottom width of the channel. Holes were x-shaped and were approximately 0.625 in. (1.59 cm) in width, the width of a standard razor blade.

- Modification 5 (M5): identical to M3 with the smaller Iowa DOT erosion stone.

- Modification 6 (M6): identical to M5 with the addition of the nine dewatering holes used in M4.

- Modification 7 (M7): smaller Iowa DOT erosion stone, a geotextile overlay with nine dewatering holes, and with the bottom width of the installation reduced to approximately 4 ft (1.2 m) and steeper side slopes at 1H:1V.

4.2. CLEAN-WATER TESTING RESULTS

The standard Iowa DOT installation, under both the low and high flow rates, only slowed flow immediately upstream of the installation. An impoundment length of 4.2 ft (1.3 m) and 5.9 ft (1.8 m) was facilitated for the 0.85 and 1.70 ft^3/s (0.024 and 0.048 m^3/s) flow rates, respectively, indicating that only 7% and 9% of the channel was protected from erosive flows. Additionally, a maximum impoundment depth of 0.62 ft (0.19 m) was facilitated immediately upstream of the rock check dam, indicating much of the material in the installation was not playing a role in slowing flow. Only one cross-section upstream of the installation had subcritical flows during testing of both flow rates, further indicating much of the channel was subject to erosive flows. The performance of the Iowa DOT standard installation under clean-water conditions can be shown in Figure 4.1.

Figure 4.1: Upstream Impoundment of Iowa DOT Standard Installation

M1 was developed to determine if the excavation beneath the standard installation impacted the installation's performance. Average impoundment lengths of 5.3 ft (1.6 m) and 8.1 ft (2.5 m) were facilitated for the low and high flow rate tests, respectively, as shown in Figure 4.2. A maximum impoundment depth of 0.68 ft (0.21 m) was formed upstream of the installation. When compared to the Iowa DOT standard installation, a statistically significant difference was not found at a 99% confidence level between impoundment lengths and depths across each set of testing and flow rates, indicating that a loss or gain of performance was not shown through installing the rock check dam on grade rather than in the 6 in. (15.2 cm) excavation. Removal of this excavation would save installation and material costs for Iowa DOT rock check dams.

Figure 4.2: Upstream Impoundment of M1

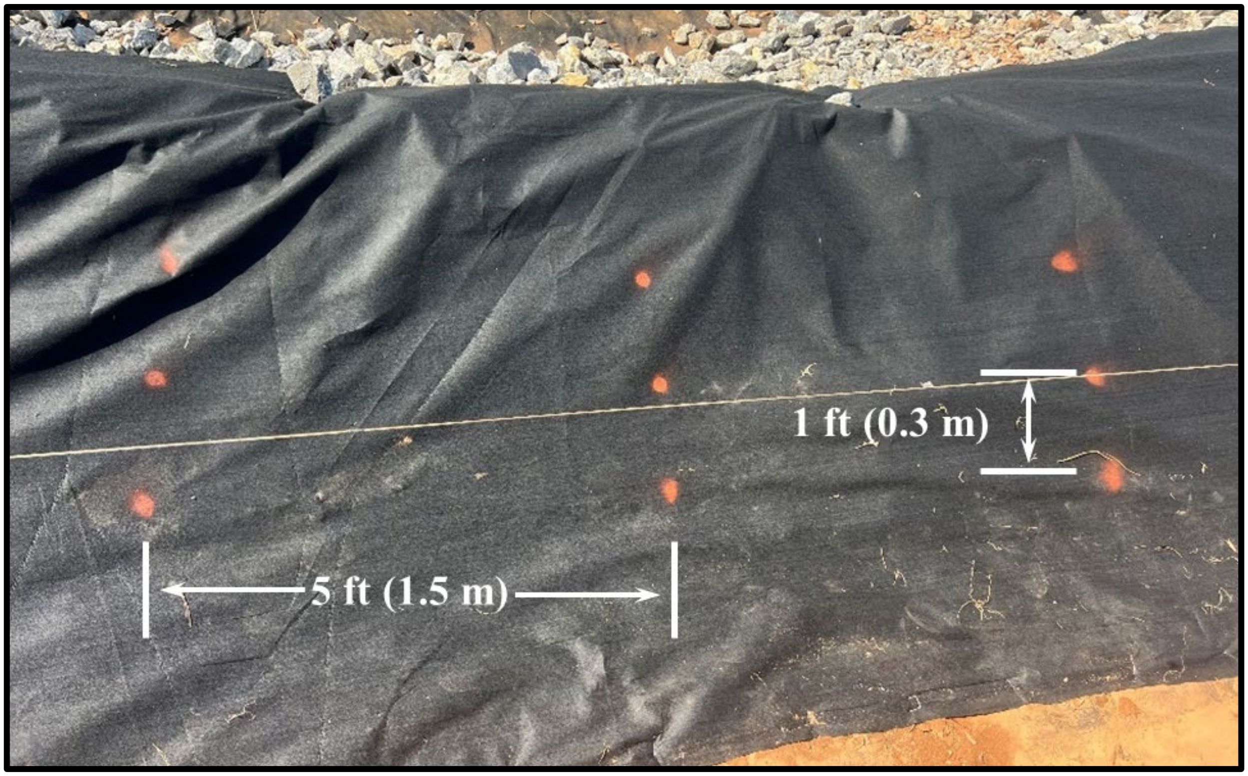
The results of testing for both the standard installation and M1 indicated little flow velocity reduction capabilities due to large voids between rocks. To improve performance, a smaller rock gradation, also used by the Iowa DOT in other applications, was used for M2; this rock gradation, referred to as erosion stone, had a nominal size of 6 in. (15.2 cm) and was between 3 and 9 in. (7.6 and 22.9 cm). This smaller rock gradation, installed in an identical configuration to the Iowa DOT standard, facilitated increased impoundment length and depth compared to both installations that used the larger Class D revetment. As shown in Figure 4.3, impoundment lengths of 21.6 ft (6.58 m) and 32.7 ft (9.97 m) were facilitated for the low and high flow rates, respectively. Additionally, the average flow velocity for the smaller rock gradation installation was significantly lower than the average downstream velocity from the installations using the same rock as the Iowa DOT standard at a 95% confidence level; however, the average downstream velocities of 2.4 and 2.8 ft/sec (0.73 and 0.85 m/sec) for the low and high flow rate testing still exceed the permissible velocities for most soil types *(Massachusetts Department of Environmental Protection 2003)*.

Figure 4.3: Upstream Impoundment of M2

The smaller rock gradation and decreased pore size improved performance compared to the standard installation with the larger rock gradation; however, highly erosive flow velocities were still present for more than half of the channel indicating that additional performance improvements needed to be made to fully protect channels from erosion. Past performance evaluations of rock check dams have shown that adding a geotextile overlay improves performance through the formation of additional impoundment. M3 was developed using the Iowa DOT standard rock gradation with a non-woven geotextile secured with 6 in. (15.2 cm) sod staples 2 ft (0.6 m) upstream of the dam, draped over the front face of the installed and secured on the back side of the installation with loose rock. M3, due to the addition of the geotextile, increased impoundment length to 49.3 ft (15 m) and 48.4 ft (14.8 m) on average for the low and high flow rates, respectively. For the low flow testing, impoundment length increased during each subsequent test as the geotextile became clogged with the low amounts of sediment from the supply pond; the third simulated storm event had an impoundment length of 62.5 ft (19.1 m). A similar pattern was shown for impoundment depth, with the first simulated storm event having the lowest depth and increasing for each subsequent test for the low flow rate. Additionally, for all but the first simulated storm event, the higher testing flow rate had a lower impoundment length than the low flow rates, with all tests having between 47.5 and 49.1 ft (14.5 and 15 m). The improved performance of M3 is shown in Figure 4.4.

Figure 4.4: Upstream Impoundment of M3

During testing of M3, high dewatering times, exceeding 72 hours, were experienced as the geotextile became clogged with sediment. For testing of all subsequent installations, dewatering times were monitored using a Solinist™ levelogger. To reduce dewatering times, M4 was developed, which included three sets of dewatering holes spaced 1 ft (0.3 m) vertically up the front face of the installation at the center of the channel and at the toes of the side slopes, 5 ft (1.5 m) apart. The dewatering holes are shown in Figure 4.5.



(a) dewatering hole locations


(b) dewatering hole

Figure 4.5: Dewatering Holes

During testing, M4 experienced similar impoundment lengths to M3, averaging 46.7 ft (14.2 m) and 51.4 ft (15.7 m) for the low and high flows, respectively. The pattern of impoundment depth increasing with each subsequent test was also present. The addition of the dewatering holes did not limit performance in impoundment length; no statistically significant difference was found in impoundment length between M3 and M4, as shown in Table 4-1.

Table 4-1: Statistical Analysis of Impoundment Lengths for Dewatering Holes

Flow Rate	n Geotextile	Geotextile Impoundment Length (ft [m])	n Dewatering Holes	Dewatering Holes Impoundment Length (ft [m])	df	T-calc	p-value
Low Flow	3	49.3 [15.0]	3	46.7 [14.2]	2	0.26	0.411
High Flow	3	48.4 [14.8]	3	51.4 [15.7]	2	-1.26	0.168

Despite the improvements made to rock check dam installations through the addition of a geotextile overlay, impoundment heights failed to reach the 2 ft (0.6 m) height stipulated in the specifications. Flow was able to overtop at the lowest point, which was often a gap between rocks, as shown in Figure 4.6; additionally, the geotextile would form around the large, often jagged rocks, increasing the risk of tearing. To combat this, M5 was developed, which was an identical installation to M3 (no excavation and with a geotextile overlay) but with the Iowa DOT erosion stone rather than the Class D Revetment. The smaller gradation rock had the goal of more consistent and reliable installation height, while also providing increased performance compared to the larger rock in the event of the geotextile failing.

Figure 4.6: Flow Overtopping at Lowest Point Between Large Rocks of M3

M5 showed similar results to both installations with geotextile overlay that employed the larger rock gradation with average impoundment lengths of 52.5 ft (16 m) and 56.8 ft (17.3 m) for the low and high flow rate testing, respectively, while also overtopping at a more consistent water depth as shown in Figure 4.7. An additional installation, M6, was evaluated that used the geotextile overlay and dewatering holes over an installation with smaller rock; M6 facilitated average impoundments of 49.9 ft (15.2 m) and 55.3 ft (16.9 m) for the low and high flow rates, respectively. The impoundment facilitated by M5 and M6 did not have a statistically significant difference. The installations using the smaller rock with the geotextile overlays (M5 and M6) had a statistically significantly greater impoundment length than the two evaluated installations with the larger Class D Revetment (M3 and M4) under testing of the higher flow rate due to the more consistent height and reduced low points at the center of the installation.

Figure 4.7: M5 overtopping

M5, due to the geotextile overlay clogging with sediment, experienced long dewatering times, with an average of 60 hours to fully drain between tests. Dewatering time increased during each subsequent simulated stormwater runoff event, reaching a maximum of over 100 hours for the third and final test period. Adding the dewatering holes to M6 reduced dewatering time on average to 26 hours, with a maximum of 60 hours for the final test periods; the first and second tests had dewatering times of 5 and 12 hours, respectively. The increase in dewatering times with the dewatering holes indicates a potential need for maintenance of dewatering holes to ensure steady dewatering. A comparison of the maximum dewatering times experienced by two installations in the final test periods is shown in Figure 4.8. Both installations had a steady dewatering, with the weep holes leading to a considerably faster dewatering period.

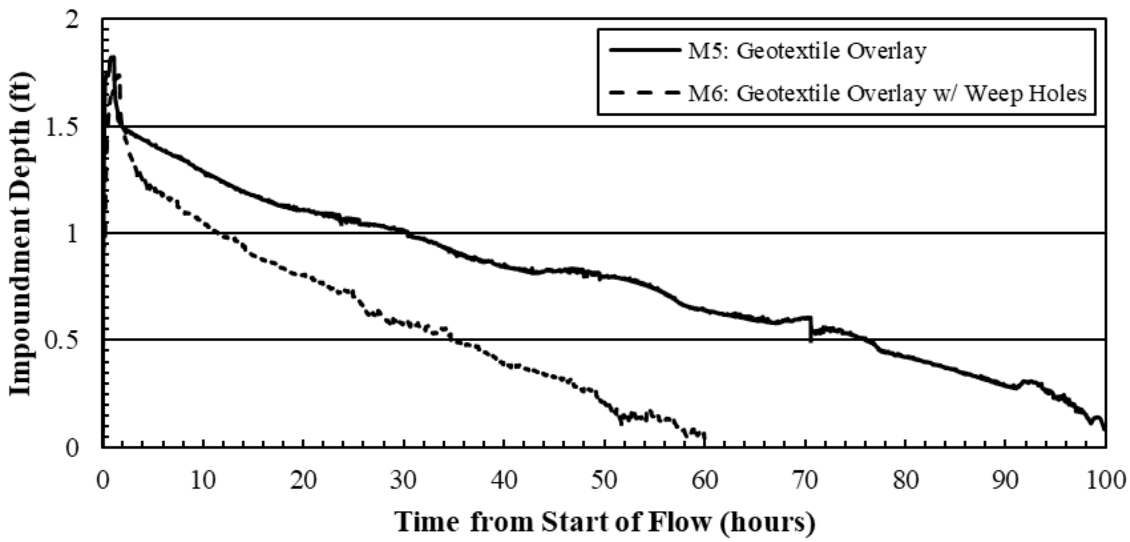


Figure 4.8: Dewatering times of M5 and M6

To further reduce the cost of material and installation, M7 was developed, which was identical to M6 but with steeper side slopes to reduce the bottom width of the installation from 6 ft (1.8 m) to 4 ft (1.2 m), considerably reducing material used per installation; a cross-section view of M7 and the standard configuration used by all other evaluated rock check dams is shown in Figure 4.9. Impoundment levels facilitated by the reduced profile installation were similar to those by other installations with geotextile overlays, with an average of 58.7 ft and 57.5 ft (17.9 and 17.5 m) facilitated for the low and high flow rates, respectively. Additionally, little visible washout was experienced by the installation through the three simulated stormwater runoff events.

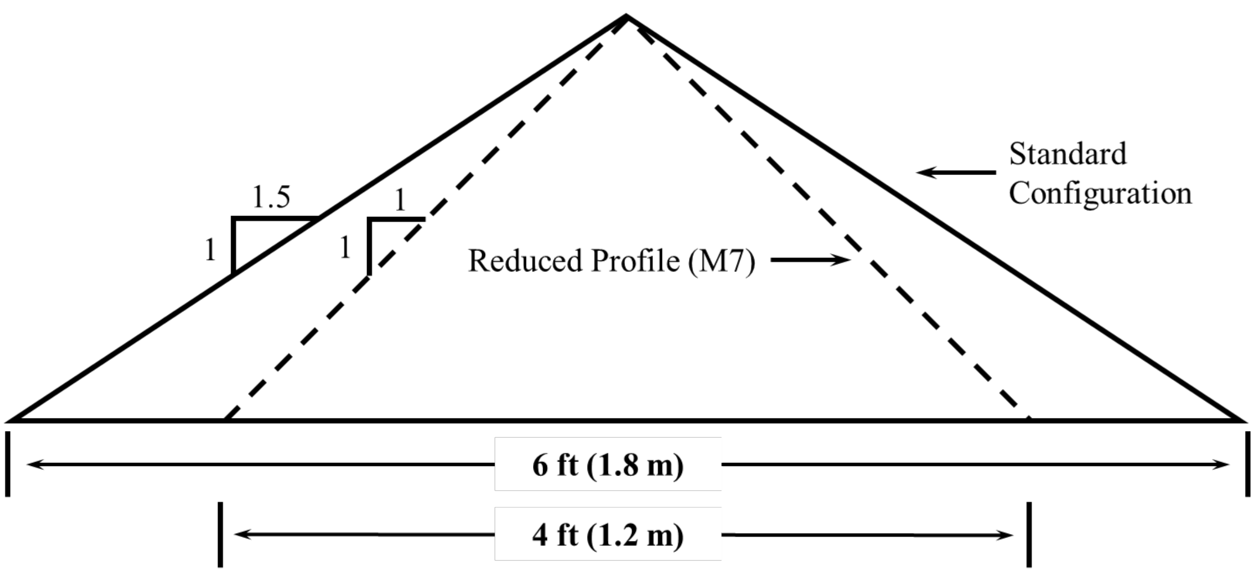


Figure 4.9: Cross-section of M7 and standard configuration

All installations, despite overtopping occurring, had impoundment that did not reach the theoretical impoundment length of 63 ft (19.2 m). On average, the impoundment length decreased for overtopped installations when subjected to higher flow rates. These results match small-scale research of ditch check practices that indicated that the location of the hydraulic jump, indicating the transition from erosive supercritical flows to slower subcritical flows, may not be at the theoretical impoundment length. To ensure proper protection of channels from erosion, spacing guidance may need to be adjusted, or other practices may need to be used in tandem with rock check dams.

4.2.1. INSTALLATION COMPARISON

Figure 4.10 shows a performance comparison of impoundment facilitated by the various installations during high-flow testing. Results indicate that installations with similar components, such as a geotextile overlay performed similarly overall. Installations without the geotextile overlay failed to impound water and facilitate less erosive subcritical flows for much of the channel. However, even the highest-performing installations failed to reach the theoretical maximum impoundment length determined using the height of the installation and the slope of the channel.

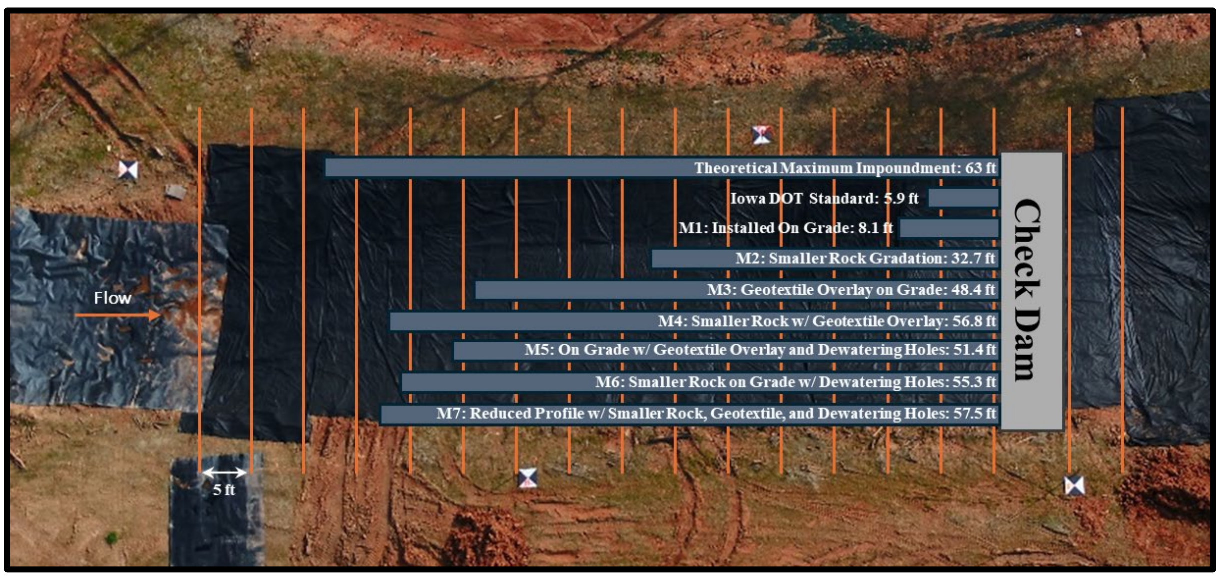


Figure 4.10: Impoundment Comparison

A material cost analysis was conducted to provide more detailed and implementable recommendations for the Iowa DOT based on the approximate amount of rock used in the installation, the cost of rock at quarries in Iowa, and the geotextiles used in the installation. Table 4.2 shows both the approximate material costs of each installation and the overall performance under both testing flow rates. The removal of the excavation reduced the material cost by requiring less than the Iowa DOT standard installation; additionally, the installation cost will be lessened due to labor not being required to dig out the excavation. The addition of the geotextile overlay increased material cost; however, the additional protection from erosion provided by the overlay provides performance benefits and the removal of the excavation results in more effective and affordable installations.

Table 4-2: Cost and Performance Comparisons

		0.85 ft³/s (0.024 m³/s)					
Installation	**Description**	**Est. Material Cost**	**Avg. Impoundment Length (ft [m])**	**Length Efficiency (%)**	**Max. Depth (ft [m])**	**Depth Efficiency (%)**	**No. of Cross-Sections with Subcritical Flow**
Standard	-	$673	4.2 [1.3]	7	0.39 [0.12]	20	1
M1	Installed on Grade	$425	5.3 [1.6]	8	0.39 [0.12]	20	1
M2	Standard w/ Smaller Rock Gradation	$539	21.6 [6.6]	34	0.66 [0.20]	33	4
M3	Geotextile Overlay	$516	49.3 [15.0]	78	1.66 [0.51]	83	13
M4	Dewatering Holes	$516	46.7 [14.2]	74	1.64 [0.50]	82	11
M5	Smaller Rock w/ Overlay	$433	52.5 [16.0]	83	1.75 [0.53]	88	10
M6	Smaller Rock w/ Dewatering Holes	$433	49.9 [15.2]	79	1.69 [0.52]	85	12
M7	M6 w/ Reduced Profile	$304	58.7 [17.9]	93	1.75 [0.53]	88	12
		1.70 ft³/s (0.048 m³/s)					
Installation	**Description**	**Est. Material Cost**	**Avg. Impoundment Length (ft [m])**	**Length Efficiency (%)**	**Max. Depth (ft [m])**	**Depth Efficiency (%)**	**No. of Cross-Sections with Subcritical Flow**
Standard	-	$673	5.9 [1.8]	9	0.60 [0.18]	30	1
M1	Installed on Grade	$425	8.1 [2.5]	13	0.64 [0.20]	32	3
M2	Standard w/ Smaller Rock Gradation	$539	32.7 [10.0]	52	1.05 [0.32]	53	6
M3	Geotextile Overlay	$516	48.4 [14.8]	77	1.99 [0.61]	100	12
M4	Dewatering Holes	$516	51.4 [15.7]	82	2.09 [0.64]	105	11
M5	Smaller Rock w/ Overlay	$433	56.8 [17.3]	90	1.85 [0.57]	93	11
M6	Smaller Rock w/ Dewatering Holes	$433	55.3 [16.9]	88	1.83 [0.56]	92	11
M7	M6 w/ Reduced Profile	$304	57.5 [17.5]	91	1.85 [0.57]	93	12

To determine the statistical relevance of the installation components that were modified, a multiple linear regression model was developed. Independent variables used in the analysis were the installation components: rock gradation, excavation, geotextile overlay, dewatering holes, and the reduced profile. A value of 0 was selected for each installation component that matched the Iowa DOT Standard, while 1 was selected for the modified component. The dependent variable directly affected by each independent variable was impoundment length efficiency, representing the portion of the channel protected from erosion, under high-flow conditions. A base condition of no impoundment formed was used. The results of the analysis are shown in Table 4.3.

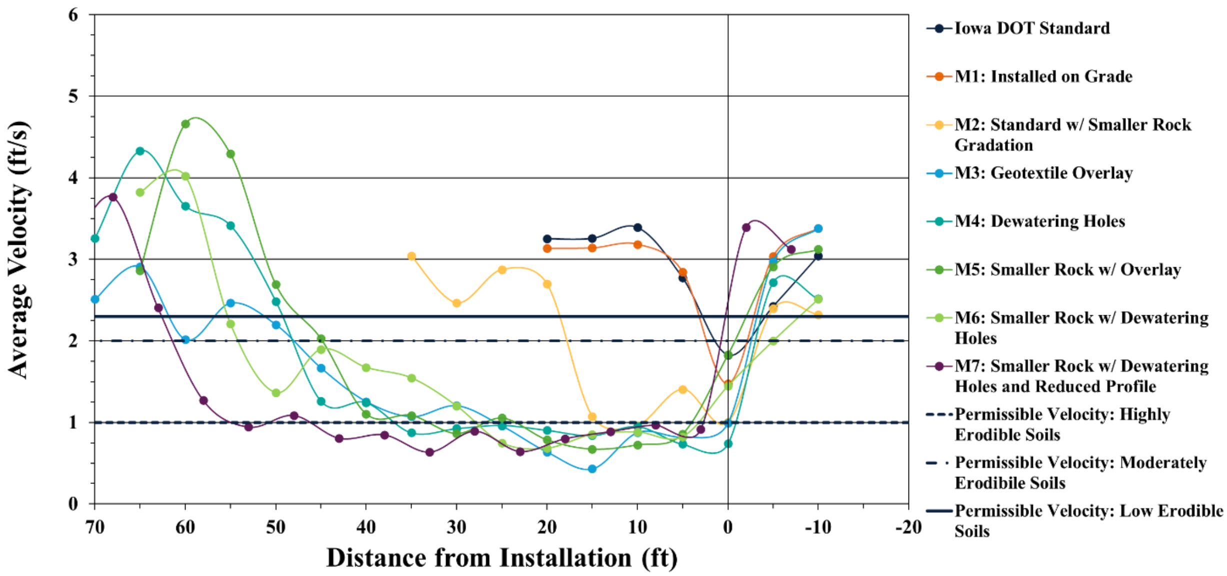
Table 4.3: Statistical Relationship of Rock Check Dam Components

	Statistical Significance	
Installation Component	Coefficients	p-Value
Base	0	n/a
Rock Gradation	30.75	0.097
Excavation	13	0.527
Geotextile Overlay	55.125	0.098
Dewatering Holes	1.5	0.940
Reduced Profile	-9.375	0.714

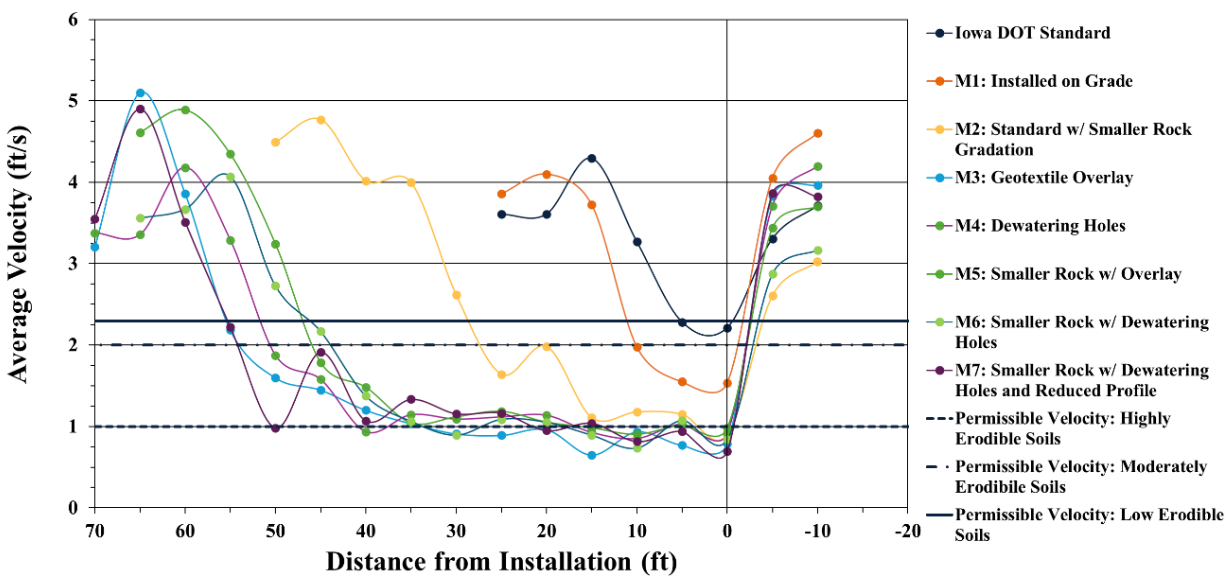
At a 90% confidence level, the analysis results indicate that only two installation components statistically significantly impacted impoundment length efficiency: the smaller rock gradation and geotextile overlay. During testing of rock check dams, the removal of the excavation, the addition of dewatering holes, and the reduced width of the installation were not found to adversely affect the impoundment performance of the installation while providing benefits in other areas, such as reduced material costs and shorter dewatering periods.

4.2.2. FLOW VELOCITY REDUCTION

The formation of impoundment by rock check dams results in reduced flow velocity, protecting channels from erosion; areas where the flow velocity is below permissible values are protected from erosion. Figure 4.9 shows the average velocity for both the low and high flow rates. Practices that performed similarly in impoundment formation also had similar flow velocity patterns. The two installations, the Iowa DOT standard and M1 without the excavation that used the standard rock gradation without the addition of a geotextile overlay only slowed flow velocities to non-erosive levels immediately upstream of the rock check dam installation, indicating that much of the channel was not protected from erosion. M2, using the same configuration of the standard installation with a smaller rock gradation, had a distance upstream of approximately 25 ft (7.6 m) with non-erosive flows for most soil types; however, this still resulted in erosive flows for much of the channel. The five installations with geotextile overlays showed similar results in flow velocity, with larger portions of the channel having flow velocities that would lead to non-erosive conditions.



(a) low flow testing



(b) high flow testing

Figure 4.11: Average Flow Velocity for Rock Check Dam Installations

Downstream of all rock check dam installations, flow velocities increased to erosive levels, indicating downstream protection is required to ensure erosion does not occur, as shown in Figure 4.10. Additionally, for high-flow testing, the average velocity for rock check dam installation in areas where impoundment was formed was still above permissible velocities for highly erodible soils, indicating additional protection is required for channels with erosive soils where high flows are expected.

Figure 4.12: High Flow Velocities Downstream of Overtopped Installation

4.2.3. CLEAN-WATER TESTING CONCLUSIONS

Overall, clean water testing on eight rock check dams with various installation components resulted in the following conclusions: (1) the excavation beneath the installation provides no benefit while increasing material and construction costs, (2) the smaller Iowa DOT erosion stone outperforms the standard Class D Revetment used in the standard installation, (3) the addition of a geotextile overlay is vital in ensuring installations protect channels from erosion by increasing impoundment length, (4) dewatering holes in a geotextile overlay reduce dewatering times without adversely impacting performance, (5) an installation with reduced width can further reduce material cost without impacting overall performance, (6) additional erosion control practices may be necessary if the soil in the channel is especially erosive, and (7) the highest performing rock check dam installations did not protect the entire channel from erosive flows. Based on these conclusions of clean water testing on rock check dams, M7 was recommended as the MFE-I due to outperforming other modifications in impoundment formation, velocity reduction, and dewatering while reducing costs considerably compared to the standard installation.

4.3. SEDIMENT-LADEN TESTING RESULTS

After the conclusion of clean-water testing, both the Iowa DOT standard installation and the MFE-I were evaluated under three additional simulated stormwater runoff events that had sediment introduced to determine performance in the secondary benefits of sediment capture and water quality treatment and any improvements made by the increased clean water performance of the MFE-I.

4.3.1. IOWA DOT STANDARD INSTALLATION

Due to the low impoundment levels formed by the Iowa DOT standard installation, little sediment deposition occurred. The sediment deposited was immediately upstream of the rock check dam, with little to no sediment able to fall out of suspension anywhere else in the channel due to high flow velocities, as shown in Figure 4.12. Deposited sediment was removed, weighed, and evaluated for moisture content to compare the dry weight of deposited sediment to the dry weight of introduced sediment to determine overall sediment capture. After three sediment-laden stormwater runoff events, only 9.4% of introduced sediment was deposited upstream of the rock check.

Figure 4.13: Sediment Deposition Upstream of Iowa DOT Standard Installation

Water quality samples taken through the test periods at the theoretical impoundment length, immediately upstream and downstream of the rock check dam, also indicated little treatment in turbidity. The samples taken upstream, at the location of the theoretical impoundment depth, had an average turbidity of 985 NTU. Immediately upstream of the rock check dam had an average of 1,199 NTU, while downstream had an average of 1,173 NTU. No pattern of turbidity over time was shown at any of the sampling locations. Paired t-tests were conducted on the water quality data to determine if water quality treatment occurred as sediment-laden flow passed through the rock check dam installation. Despite the average turbidity downstream being lower than immediately upstream, no statistically significant difference was found between grab samples taken simultaneously at the two locations, indicating the Iowa DOT rock check dam is ineffective at treating sediment-laden runoff for turbidity. Additionally, statistically significant differences were found between the grab samples taken at the theoretical impoundment length and both immediately upstream and downstream of the installation, showing a degradation in water quality as flow passed through the installation. This increased turbidity is likely due to the resuspension of the little sediment deposited immediately upstream of the installation.

Based on the lack of sediment deposition upstream and the lack of water quality treatment, sediment-laden testing results for Iowa DOT standard installation indicate that there are little to no secondary sediment control benefits due to the low levels of impoundment facilitated by the installation.

4.3.2. MFE-I

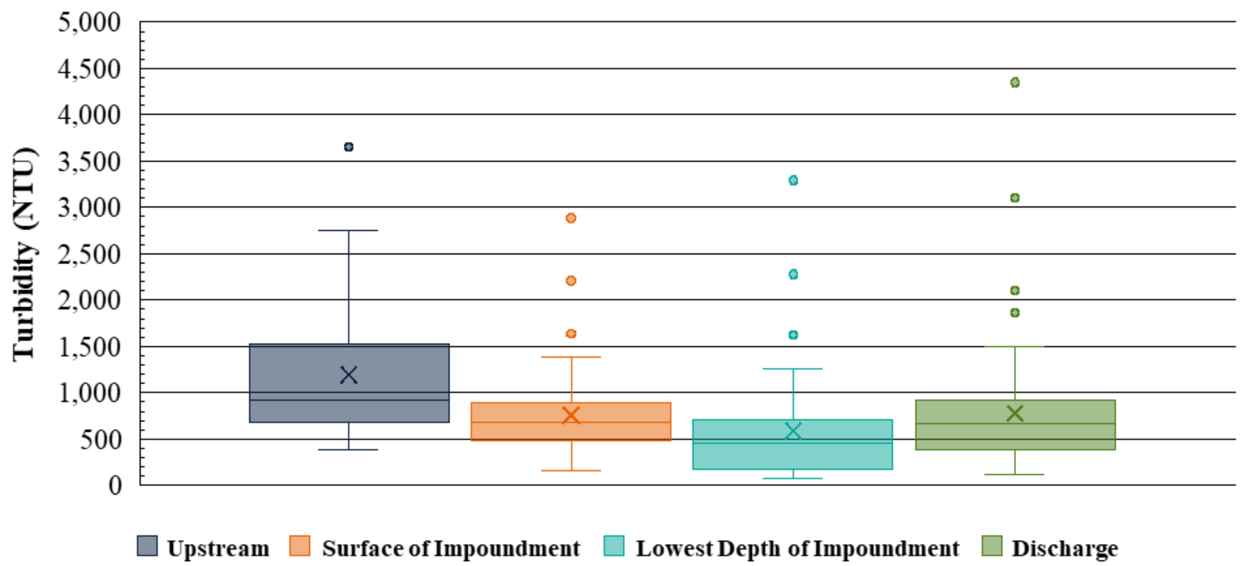
Due to the additional impoundment formed by the MFE-I during sediment-laden evaluations, increased sediment was deposited in the impoundment formed by the installation. 72.4% of the introduced sediment was captured upstream of the installation. A large portion of this sediment was captured immediately after the hydraulic jump, as shown in Figure 4.13a; the sediment that was deposited further upstream was visibly coarser than the sediment captured immediately upstream of the rock check dam installation, as shown in Figure 4.13b.

(a) upstream sediment deposition

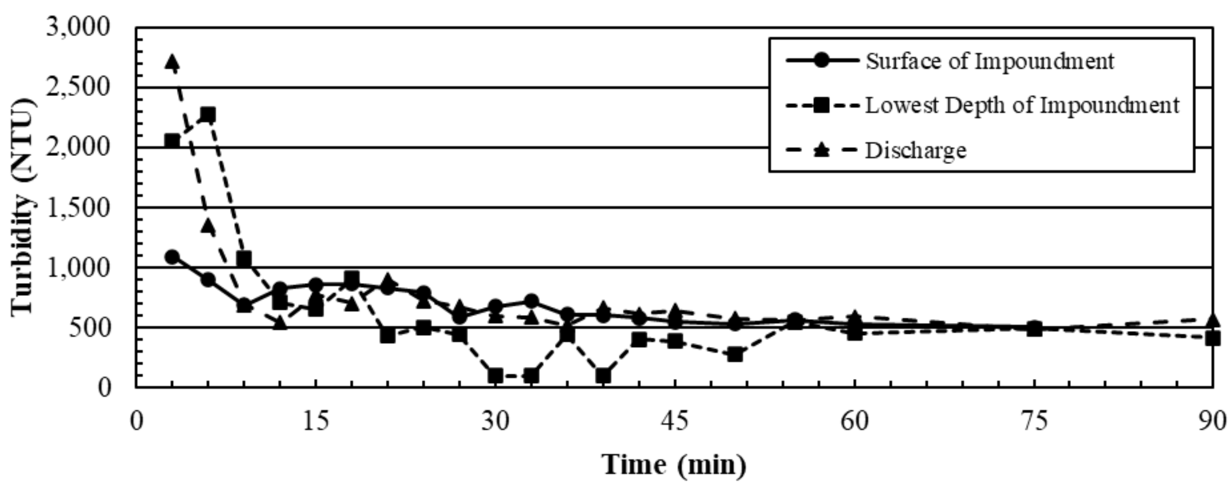
(b) coarse material deposited

Figure 4.14: MFE-I Sediment Deposition.

Due to the increased impoundment depth facilitated by the MFE-I rock check dam installation, water quality grab samples could be taken at both the surface and the lowest depth of the impoundment upstream of the installation. The average turbidity at the surface of the impoundment was 756 NTU; the lowest depth of the impoundment averaged 641 NTU. The discharge immediately downstream of the installation averaged 777 NTU. Figure 4.14a shows a distribution of the turbidity of water grab samples at the water's surface of the impoundment, the lowest depth of the impoundment, and discharge; the surface of impoundment and discharge had similar ranges and averages due to the installation overtopping. Figure 4.14b, showing average turbidity over time, indicates a "first-flush" effect occurred as the first runoff resuspended deposited sediment and increased turbidity immediately at the beginning of each test period, with turbidity then stabilizing to approximately 650 NTU for the water's surface of the impoundment and discharge.



(a) turbidity distribution



(b) turbidity over time

Figure 4.15: MFE-I Turbidity

In other practices, such as sediment barriers, the surface of the impoundment typically has significantly higher water quality and lower turbidity due to sediment deposition within the impoundment (Roche et al. 2024). However, no statistically significant difference in water quality was present during evaluations of the MFE-I rock check dam installation. This lack of a difference is likely due to the short-circuiting effect caused by the installation overtopping during testing; before the installation overtopped, average turbidity was higher at the lowest depth of the impoundment than at the water's surface. Additionally, the overtopping of the installation led to there not being a statistically significant difference between the turbidity of grab samples taken at the water's surface of the impoundment and the discharge, indicating little treatment of turbidity.

Despite the sediment deposition facilitated by the MFE-I, little to no treatment of turbidity was shown by the installation. These results indicate that, while sediment deposition can occur upstream of a well-performing rock check dam installation, this deposition is likely only the coarse portion of the sediment present in runoff, with the colloidal silts and clays remaining in runoff, resulting in turbid runoff. Additional downstream practices, such as a sediment basin, would be necessary to ensure that runoff from a conveyance channel can be discharged off-site. The lack of turbidity treatment also confirms that even well-performing check dam installations are primarily erosion control practices, with any sedimentation being a secondary benefit.

4.3.3. COMPARISONS

An overview of sediment-laden test results is shown in Table 4.4. The MFE-I outperformed the Iowa DOT standard installation in sediment capture and water quality. The MFE-I captured 63% more sediment upstream of the practice than the standard installation due to the increased impoundment facilitated. The increased impoundment also reduced discharge turbidity compared to the standard installation by slowing flow, allowing more sediment to fall out of suspension. The sediment capture results of the MFE-I are similar to the results of evaluations of Iowa DOT sediment basins under identical testing flow and sediment introduction rates; a forebay composed of a rock check dam with a geotextile overlay captured between 77 and 79% of introduced sediment after six simulated stormwater runoff events. However, additional capture of less coarse material required a downstream sediment basin practice *(Schussler et al. 2022)*.

Table 4.4: Sediment-laden Testing Comparison

Installation	Sediment Capture (%)	Avg. Discharge Turbidity (NTU)	Avg. Time to Overtop (min)	Max. Impoundment Depth (ft [m])	Max. Impoundment Length (ft [m])
Iowa DOT Standard	9.4	1,173	N/A	0.45 [0.14]	8 [2.4]
MFE-I	72.4	777	4.80	1.88 [0.57]	59 [18.0]

Water quality grab samples taken downstream of both installations were compared using two statistical methods to determine if the decreased average downstream turbidity was due to the increased dewatering time compared to the standard, allowing for more time for treatment, or due to the additional impoundment formed upstream. The results of both analyses are shown in Table 4.5. An unpaired t-test was conducted between all discharge water quality grab samples for the Iowa DOT standard installation and the MFE-I to determine if the improved installation's discharge turbidity was significantly lower. Results indicated that, due to the very low p-value, discharge turbidity was significantly less for the MFE-I compared to the Iowa DOT Standard Installation. To determine if this water quality improvement was due to the extended dewatering period or due to the increased impoundment during the flow introduction period, a paired t-test was conducted that only compared water quality grab samples taken at the same time during testing, resulting in only 11 analyzed samples for each test due to the short dewatering period of the Iowa DOT standard installation. Analysis results indicate that, at a 90% confidence level, turbidity was lower for the MFE-I than the standard installation when samples were taken simultaneously during testing. The results of analyses indicate that both the increased impoundment depth and dewatering time impacted the reduced turbidity of the MFE-I compared to the standard installation.

Table 4.5: Statistical Analysis of Discharge Turbidity

Test	n	Standard Mean Turbidity (NTU)	MFE-I Mean Turbidity (NTU)	df	T-calc	p-value
Unpaired	33/60[a]	1,174	777	88	3.88	0.0001
Paired	33	1,174	936	32	1.40	0.0852

[a] 33 grab samples for Standard; 60 grab samples for MFE-I

The discharge water quality would be improved with the addition of a geotextile overlay to rock check dam installations due to both the increased impoundment potential during a stormwater runoff event and the longer dewatering period, allowing for more sedimentation to occur in the impoundment formed; however, results also indicate that excessive dewatering times are not required for additional turbidity treatment, due to minimal turbidity reduction shortly after the dewatering period begins.

Due to past sediment basin testing using the same introduction conditions, water quality results can be compared to other testing efforts. The discharge turbidity of the MFE-I rock check dam was lower on average during dewatering than a previously evaluated unlined Iowa DOT sediment basin. However, the turbidity was higher on average than the results of improved sediment basins, indicating that rock check dams were primarily serving as an erosion control practice and additional downstream practices are necessary to properly treat sediment-laden stormwater runoff *(Schussler et al. 2022)*.

4.4. RESULTS SUMMARY

Clean water tests of the Iowa DOT standard rock check dam installation indicated that the installations protected only a small portion of the upstream channel from erosive flows. The addition of a geotextile and the use of a smaller rock gradation were found to improve the impoundment formation potential upstream, resulting in more effective rock check dam installations; however, even the best-performing installations did not fully impound to the theoretical maximum based on the height of the check dam and the slope of the channel. The addition of dewatering holes in the geotextile overlay was shown to reduce excessive dewatering times that occurred due to the clogging of the geotextile with sediment while also not reducing performance. Additionally, removing the excavation beneath the installation and reducing the width from 6 ft (1.8 m) to 4 ft (1.2 m) were not found to adversely impact performance while also reducing the cost of installation and material. Due to these results, M7, with a geotextile overlay with dewatering holes, a smaller rock gradation, and reduced width, was selected as the MFE-I.

Both the Iowa DOT standard installation and the MFE-I were subjected to sediment-laden performance evaluations to determine performance improvements in the secondary benefits of capturing sediment and treating water quality. The MFE-I, due to the additional impoundment formed, was found to capture 63% more sediment upstream of the installation and had significantly lower discharge turbidity. However, sediment-laden results indicate that rock check dams are primarily an erosion control practice and additional downstream treatment, such as a sediment basin, is needed to ensure sediment capture and treatment of sediment-laden stormwater runoff.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. INTRODUCTION

Rock check dams are commonly used to protect unstabilized channels from high-velocity erosive flows during construction on Iowa highway construction projects and throughout the U.S. Despite their widespread use, little research has been conducted on their effectiveness in impoundment formation, velocity reduction, and sediment capture and how to improve installations in both erosion prevention and the secondary sediment capture benefits. This research aimed to determine the performance of Iowa DOT rock check dams and develop more efficient and cost-effective installation configurations through full-scale testing. A six-step research plan was completed to reach these objectives:

1) Conduct a comprehensive literature review investigating rock check dam standards from other jurisdictions, usage of rock check dams in the state of Iowa, and past performance evaluations of ditch check and rock check dam installations. The literature review will help guide the project in the development of the testing methodology and identify potential modified installations.

2) Develop a large-scale testing methodology for the evaluation of rock check dams, including the determination of performance metrics, data collected, testing order, and flow rates.

3) Conduct large-scale clean-water performance evaluations of rock check dams at the Auburn University – Stormwater Research Facility (AU-SRF) using the previously constructed 200 ft (61 m) Iowa DOT testing channel.

4) Conduct large-scale sediment-laden performance evaluations of the Iowa DOT standard installation and the highest performing modified installation to determine secondary benefits of sediment capture and water quality treatment.

5) Analyze testing data, including flow velocity profiles, impoundment lengths, water quality, and sediment capture for Iowa DOT standard rock check dams and evaluated modifications to develop implementable design recommendations that increase protection from erosion, sediment capture, and reduce material and installation costs.

6) Compile the final report that outlines findings from the literature review, experimental results, data analysis, and design recommendations.

By meeting these objectives through the accomplishment of the six tasks, this research provides valuable insight into the erosion control capabilities of rock check dams with various installation components, while also providing guidance to the Iowa DOT on improving the state of practice of rock check dams through more efficient and cost-effective installations.

5.2. TESTING RESULTS

A total of 24 clean-water performance evaluations were conducted on the Iowa DOT standard installation and seven modified installations, with each installation being evaluated under three tests, each using two flow rates. Key performance parameters were impoundment length and depth, flow velocity reduction, and dewatering time, which were identified in the literature review and through testing as pertinent to the performance of ditch check installations in protecting channels from erosion. The results of testing from the standard installation and modifications were used to develop additional modifications to further improve performance and reduce the cost of installation and material. Modification components included the removal of the excavation beneath the installation, switching to a smaller rock gradation, the addition of a geotextile overlay, the addition of dewatering holes to the geotextile overlay, and a reduction in width.

Overall, clean-water testing and the following statistical analysis of testing data resulted in the following conclusions:

1) The excavation beneath the installation provides no benefit while increasing material and construction costs.

2) The smaller DOT erosion stone outperforms the standard Class D Revetment used in the standard installation due to smaller voids and more consistent installation heights.

3) The addition of a geotextile overlay is vital in ensuring installations protect channels from erosion.

4) Dewatering holes in a geotextile overlay reduce dewatering times without adversely impacting performance.

5) An installation with reduced width can further reduce material costs without impacting performance.

6) Additional erosion control practices may be necessary if the soil of the channel is especially prone to erosion.

7) Flow velocities increased to erosive levels downstream of all installations.

8) Even the highest-performing rock check dam installations did not protect the entire channel from erosive flows.

Based on the results of clean-water testing, a modified installation installed on-grade with the Iowa DOT erosion stone, a geotextile overlay with nine dewatering holes, and a reduced width from 6 ft (1.8 m) to 4 ft (1.2 m) was selected as the MFE-I. The MFE-I increased impoundment length from under 6 ft (1.8 m) to 57.5 ft (17.5 m) compared to the standard installation, resulting in 82% more of the channel being protected from erosive flows. The addition of dewatering holes in the geotextile overlay prevented impoundment from remaining behind the installation for extensive periods of time; however, dewatering time increased for this installation after each subsequent test period, indicating that maintenance is required to ensure dewatering holes remain unclogged and effective. Additionally, the MFE-I reduced the approximate cost of material from the standard installation by 55% while removing the need for an excavation beneath the installation, reducing installation costs.

Sediment-laden performance evaluations of both the Iowa DOT standard installation and the MFE-I indicated that the improved impoundment performance of the MFE-I increased sediment capture from 9.4% to 72.4% compared to the standard installation. Additionally, the discharge turbidity was statistically significantly lower for the MFE-I than the standard installation due to the increased impoundment formed upstream and the dewatering period allowing for additional treatment. However, when compared to other practices, it is evident that rock check dams are primarily an erosion control practice, with little water quality treatment occurring.

5.3. RECOMMENDATIONS FOR IMPLEMENTATION AND EXPECTED BENEFITS

Based on the results of both clean-water and sediment-laden testing, it is recommended that the Iowa DOT adopts a rock check dam installation using the smaller erosion stone gradation and with geotextile overlay with dewatering holes to improve performance and protect unstabilized channels from erosion. Additionally, extending the geotextile underlay downstream would prevent erosion from installations overtopping. As cost-saving measures, it is recommended that installations be installed on grade with no excavation beneath and that the width of installation be reduced to reduce both material and installation costs. Maintenance recommendations for improved rock check dam installations include the regular removal of deposited sediment to ensure that suspension of material does not impact downstream practices or areas and ensuring that dewatering holes remain unclogged to ensure that impoundment does not remain behind the installation for excessive periods of time which can decrease the establishment of vegetation.

Adopting these recommendations would increase the erosion prevention capabilities of rock check dams on Iowa highway construction projects. Decreasing the volume of eroded soil in conveyance channels prevents the overloading of downstream practices, such as sediment basins, leading to decreased maintenance and saving taxpayer funds, while also ensuring regulatory compliance on construction projects.

5.4. RECOMMENDATIONS FOR FUTURE RESEARCH

Despite the improvements made to rock check dams in erosion prevention and sediment capture compared to the standard, results indicated that the improved installation only functioned as a sediment capturing device for coarse-sized sediment, due to the lack of turbidity treatment compared to other practices. Installations could be improved in sediment capture and water quality treatment through the use of flocculants or other enhanced treatment methods. Additionally, the testing methodology outlined in this report could be replicated to evaluate other ditch check practices such as wattles, slash mulch berms, and silt fences, including practices that may pose less safety hazards to motorists.

5.5. CONCLUSIONS

This research aimed to contribute to the body of knowledge on the performance of rock check dams in preventing erosion and improving the effectiveness of the practices. Modified components, including removing the excavation beneath the installation, using a smaller rock gradation, adding a geotextile overlay with dewatering holes, and reducing the width of the installation, greatly improved performance in reducing erosive flow velocities, capturing sediment, and treating water quality while ensuring recommendations were implementable by considerably reducing material and installation costs. The methodology used and outlined in Chapter 2 can be used for other ditch check practices to improve their performance through evaluation and modification. The results of testing under both clear-water and sediment-laden conditions provide implementable guidance to the Iowa DOT and other jurisdictions that will improve erosion control in conveyance channels on highway construction projects.

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APPENDIX A: TEST DATA

Date: 4/22/2024
Installation: Standard – T1
Techs and Workers:

Start Time: 3:16 PM
End Time:

Installation Descr.: Iowa DOT Standard Installation

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.16	0.15	0.13	0.22	0.31	0.24	0.15
Center			0.09	0.06	0.13	0.16	0.40	0.18	0.06
South			0.28	0.11	0.11	0.28	0.35	0.12	0.19
Top Width (in.)			61	68	77	90	123	68	108
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.47	0.33	0.40	0.33	0.35	0.37	0.45
Center			0.12	0.15	0.25	0.22	0.46	0.25	0.29
South			0.30	0.29	0.29	0.31	0.40	0.21	0.32

Length of pool upstream of ditch check (ft): 6.25

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
***H**water(ft.)*	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
***H**water(ft.)*	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.18	0.23	0.21	0.24	0.46	0.36	0.07	0.26
Center		0.25	0.19	0.09	0.32	0.54	0.62	0.22	0.23
South		0.08	0.12	0.19	0.31	0.46	0.62	0.15	0.17
Top Width (in.)		98	80	98	128	129	152	100	106
***H**velocity(ft.)*	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
***H**velocity(ft.)*	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.29	0.27	0.51	0.26	0.51	0.40	0.46	0.65
Center		0.49	0.49	0.50	0.55	0.64	0.95	0.27	0.48
South		0.33	0.37	0.39	0.43	0.51	0.71	0.29	0.25

Length of pool upstream of ditch check (ft): 6.7

Dewatering Time:

Comments/Observations During Test:
Could not evaluate dewatering time due to impoundment of basin reaching end of dam during the photos stage of testing

Date: 4/23/2024 **Start Time:** 10:50 AM

Installation: STD T2 **End Time:**

Techs and Workers:

Installation Descr.: Iowa Dot Standard

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.17	0.18	0.13	0.16	0.32	0.06	0.23
Center			0.10	0.04	0.12	0.26	0.35	0.21	0.18
South			0.11	0.11	0.11	0.21	0.38	0.13	0.11
Top Width (in.)			64	76	74	88	114	83	86
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.38	0.42	0.36	0.37	0.37	0.19	0.38
Center			0.31	0.21	0.24	0.38	0.38	0.24	0.32
South			0.31	0.27	0.33	0.32	0.46	0.23	0.14

Length of pool upstream of ditch check (ft): 2.9

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.21	0.16	0.17	0.25	0.36	0.31	0.06	0.28
Center		0.22	0.15	0.16	0.24	0.41	0.58	0.24	0.23
South		0.06	0.11	0.11	0.28	0.46	0.61	0.13	0.17
Top Width (in.)		86	82	94	120	126	146	106	106
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.42	0.32	0.45	0.52	0.42	0.37	0.34	0.57
Center		0.42	0.42	0.42	0.50	0.62	0.65	0.34	0.48
South		0.24	0.25	0.42	0.45	0.57	0.66	0.32	0.24

Length of pool upstream of ditch check (ft): 5.8

Dewatering Time (min): 2

Comments/Observations During Test:

Date: 4/23/2024 **Start Time:** 11:00 AM

Installation: Standard - T3 **End Time:**

Techs and Workers: Corinne

Installation Descr.:

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.18	0.13	0.11	0.11	0.22	0.05	0.15
Center			0.11	0.06	0.09	0.23	0.38	0.15	0.17
South			0.09	0.11	0.20	0.12	0.40	0.08	0.16
Top Width (in.)			68	78	80	86	121	88	92
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.43	0.35	0.36	0.26	0.24	0.21	0.42
Center			0.33	0.19	0.24	0.42	0.51	0.21	0.33
South			0.29	0.25	0.31	0.28	0.44	0.17	0.19

Length of pool upstream of ditch check (ft): 3.4

Comments/Observations During Test:

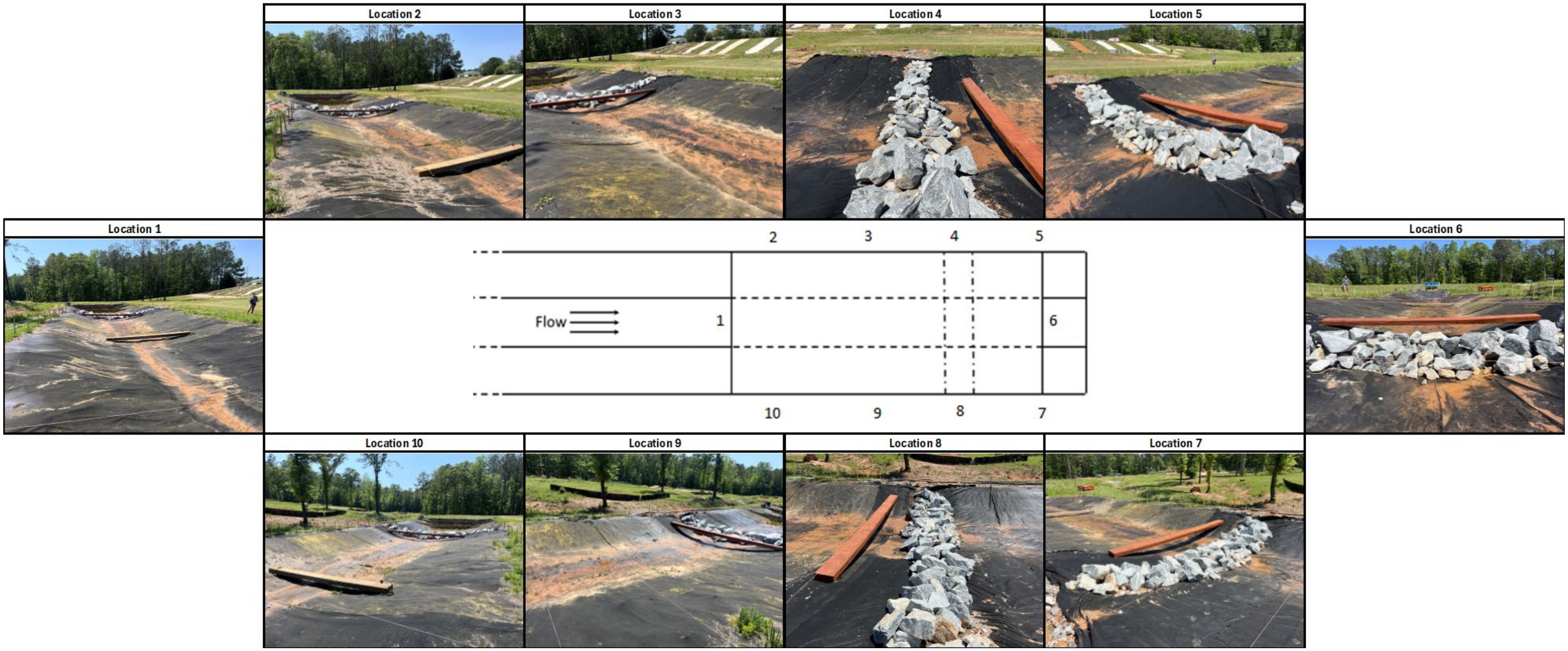
Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.22	0.24	0.19	0.21	0.35	0.27	0.09	0.25
Center		0.21	0.15	0.14	0.24	0.42	0.57	0.22	0.18
South		0.05	0.12	0.12	0.29	0.41	0.56	0.15	0.18
Top Width (in.)		102	74	98	118	134	154	106	98
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.37	0.42	0.48	0.42	0.38	0.31	0.44	0.65
Center		0.51	0.50	0.45	0.49	0.62	0.66	0.26	0.47
South		0.26	0.36	0.36	0.38	0.43	0.59	0.32	0.26

Length of pool upstream of ditch check (ft): 5.3

Dewatering Time:

Comments/Observations During Test:

Pre-Test


Location 2
Location 3
Location 4
Location 5
Location 1
Location 6
Location 10
Location 9
Location 8
Location 7
Flow
1
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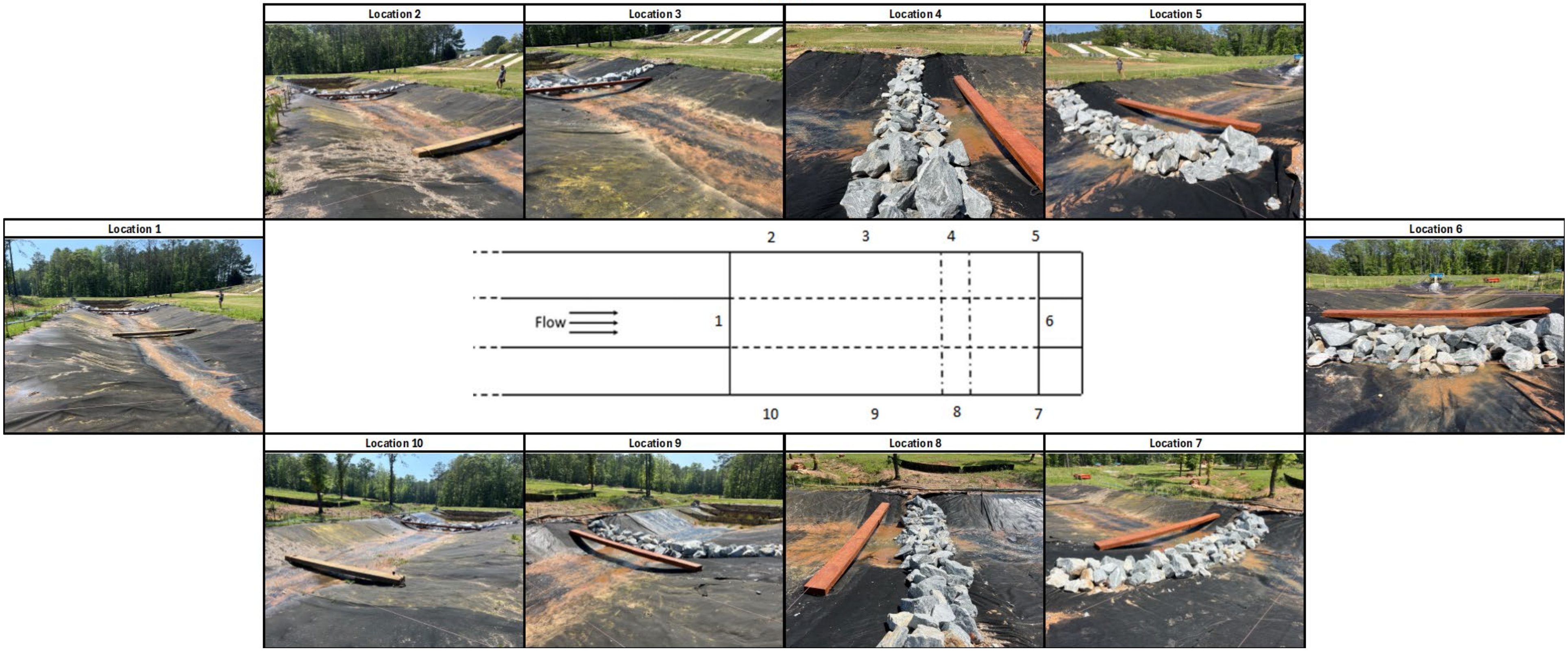
10

0.85 cfs


Location 2
Location 3
Location 4
Location 5
Location 1
Location 6
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Flow
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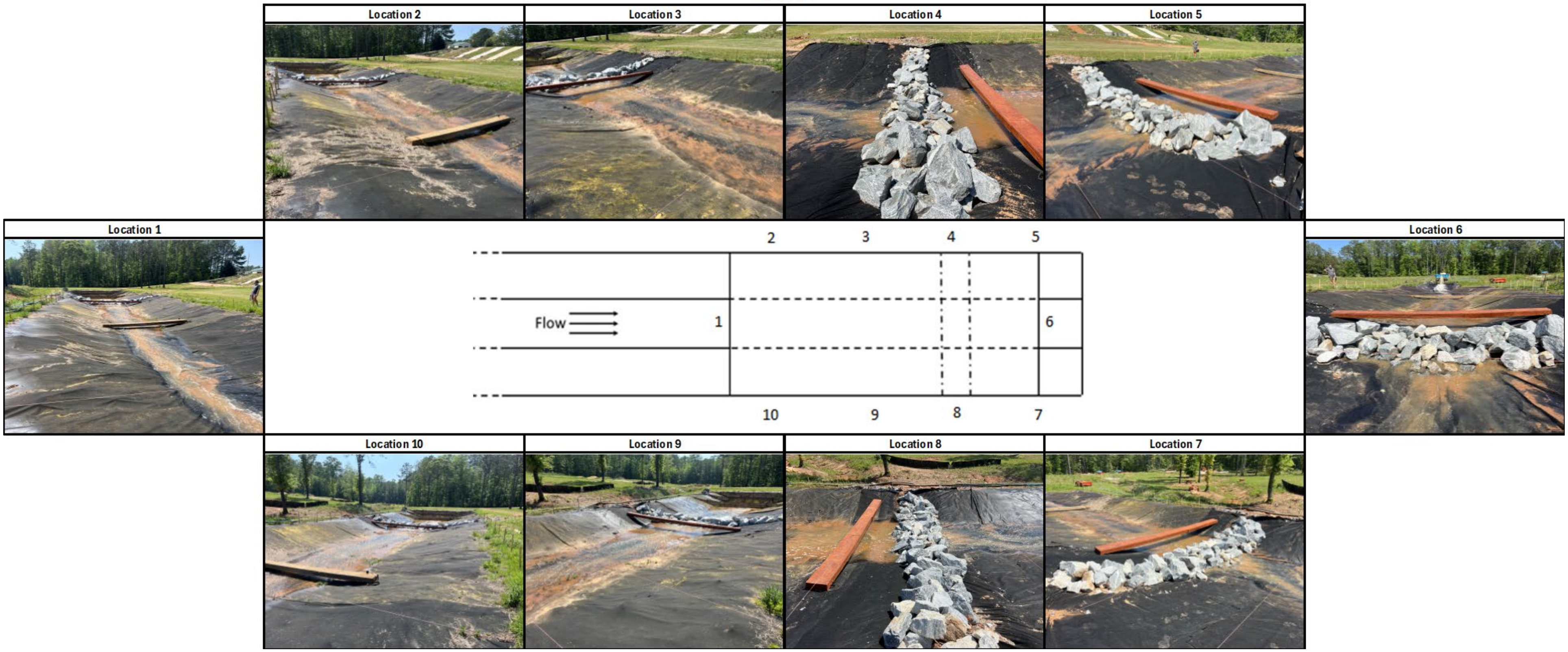
Location 10
Location 9
Location 8
Location 7

1.70 cfs


Location 2
Location 3
Location 4
Location 5
Location 1
Location 6
2
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Flow
1
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Location 10
Location 9
Location 8
Location 7

Date: 6/7/2024 **Start Time:** 9:25 AM

Installation: Standard Excavation-less - T1 **End Time:**

Techs and Workers:

Installation Descr.: Iowa DOT Standard Installation Installed on Grade

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North			0.20	0.10	0.17	0.21	0.21	0.14	0.18
Center			0.11	0.08	0.13	0.31	0.36	0.12	0.04
South			0.13	0.10	0.11	0.33	0.38	0.19	0.15
Top Width (in.)			62	72	70	96	124	80	88
$H_{velocity}$(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North									
Center									
South									
$H_{velocity}$(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North			0.34	0.33	0.35	0.29	0.23	0.27	0.31
Center			0.30	0.15	0.22	0.46	0.39	0.38	0.12
South			0.19	0.23	0.32	0.42	0.47	0.34	0.45

Length of pool upstream of ditch check (ft): 6.25

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.23	0.24	0.22	0.28	0.35	0.25	0.11	0.12
Center		0.14	0.17	0.11	0.35	0.47	0.58	0.19	0.08
South		0.09	0.08	0.21	0.30	0.46	0.59	0.22	0.18
Top Width (in.)		98	66	88	122	134	152	88	92
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.36	0.48	0.52	0.29	0.38	0.27	0.24	0.48
Center		0.53	0.52	0.37	0.55	0.56	0.65	0.31	0.42
South		0.22	0.26	0.28	0.31	0.47	0.61	0.57	0.47

Length of pool upstream of ditch check (ft): 8.5

Dewatering Time:

Comments/Observations During Test:
Immediate dewatering

Date: 6/11/2024 **Start Time:**
Installation: STD Excavation less-T2 **End Time:**
Techs and Workers:

Installation Descr.: Iowa DOT Standard Installation Installed on Grade

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}*(ft.)*	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}*(ft.)*	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.17	0.11	0.13	0.11	0.25	0.11	0.11
Center			0.09	0.07	0.08	0.16	0.32	0.09	0.03
South			0.11	0.10	0.11	0.28	0.36	0.16	0.14
Top Width (in.)			60	66	72	102	118	78	88
$H_{velocity}$*(ft.)*	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$*(ft.)*	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.34	0.32	0.31	0.30	0.28	0.24	0.25
Center			0.29	0.23	0.25	0.31	0.35	0.23	0.22
South			0.19	0.25	0.22	0.31	0.38	0.33	0.34

Length of pool upstream of ditch check (ft): 6.25 Time (mins):

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.21	0.23	0.23	0.22	0.33	0.38	0.10	0.12
Center		0.13	0.17	0.11	0.32	0.41	0.62	0.09	0.07
South		0.09	0.10	0.22	0.29	0.46	0.66	0.21	0.14
Top Width (in.)		90.00	66.00	81.00	122.00	136.00	154.00	102.00	92.00
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.34	0.45	0.49	0.25	0.35	0.41	0.45	0.49
Center		0.60	0.55	0.48	0.52	0.59	0.65	0.37	0.37
South		0.24	0.25	0.34	0.30	0.47	0.68	0.51	0.48

Length of pool upstream of ditch check (ft): 9

Dewatering Time:

Comments/Observations During Test:
Immediate Dewatering

Date: 6/23/2024

Installation: Standard Excavation-less -T3

Techs and Workers:

Start Time:

End Time:

Installation Descr.: Iowa DOT Standard Installation Installed on Grade

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H$_{water}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H$_{water}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.15	0.11	0.16	0.18	0.21	0.04	0.15
Center			0.10	0.07	0.13	0.18	0.35	0.16	0.10
South			0.10	0.13	0.13	0.19	0.44	0.18	0.18
Top Width (in.)			66.00	69.00	72.00	102.00	128.00	78.00	88.00
H$_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
H$_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North			0.34	0.28	0.30	0.34	0.22	0.16	0.33
Center			0.30	0.19	0.29	0.37	0.43	0.24	0.22
South			0.29	0.30	0.33	0.34	0.47	0.32	0.51

Length of pool upstream of ditch check (ft): 3.25

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
Top Width (in.)									
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.21	0.24	0.26	0.28	0.40	0.40	0.13	0.16
Center		0.17	0.18	0.14	0.24	0.52	0.62	0.11	0.11
South		0.08	0.11	0.21	0.34	0.50	0.68	0.24	0.14
Top Width (in.)		96.00	72.00	90.00	120.00	139.00	158.00	96.00	94.00
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North		0.32	0.48	0.48	0.31	0.41	0.42	0.39	0.49
Center		0.57	0.53	0.51	0.53	0.61	0.69	0.43	0.35
South		0.42	0.40	0.31	0.36	0.51	0.76	0.49	0.55

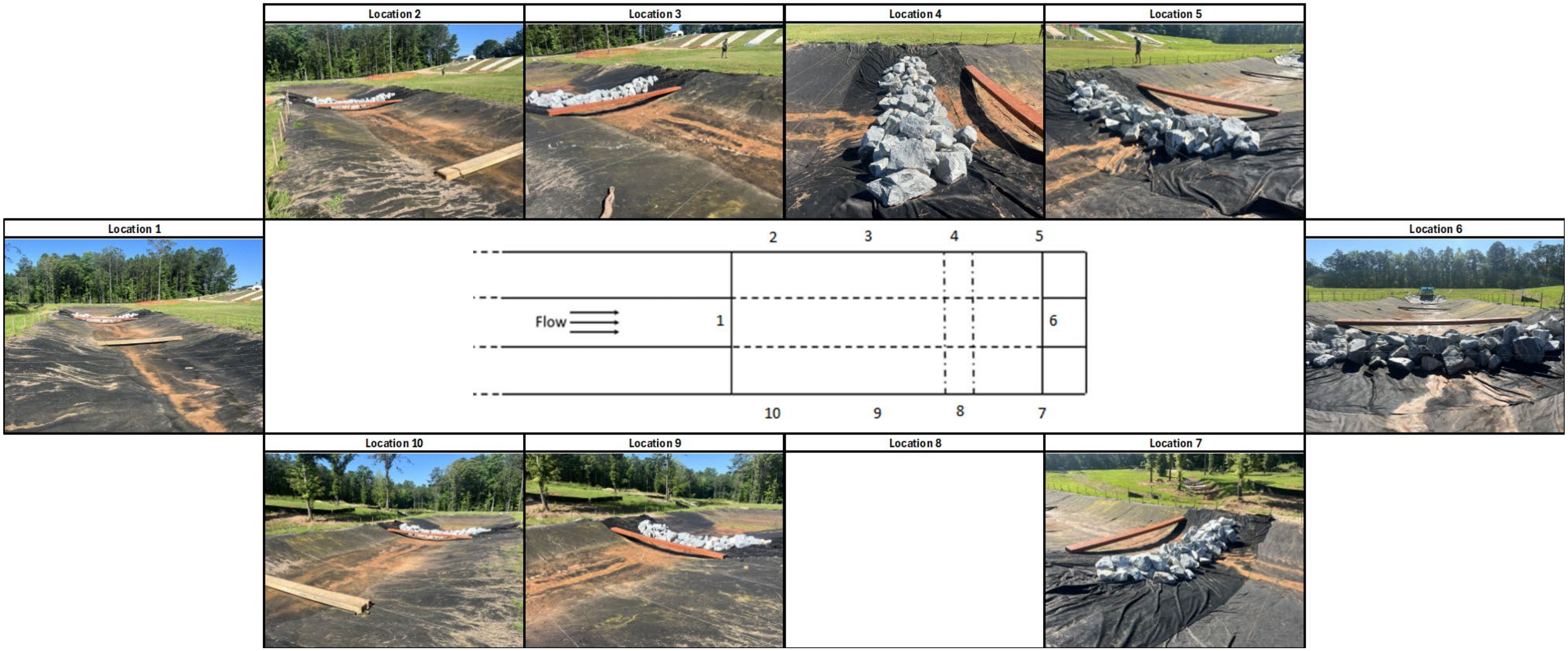
Length of pool upstream of ditch check (ft): 6.9

Time (mins):

Dewatering Time:

Comments/Observations During Test:
Immediate Dewatering

Pre-Test


Location 2
Location 3
Location 4
Location 5
Location 1
Location 6
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Flow
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10
9
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7
Location 10
Location 9
Location 8
Location 7

0.85 cfs

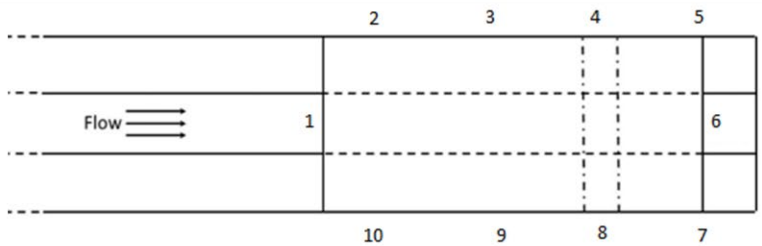
Location 2

Location 3

Location 4

Location 5

Location 1



Location 6

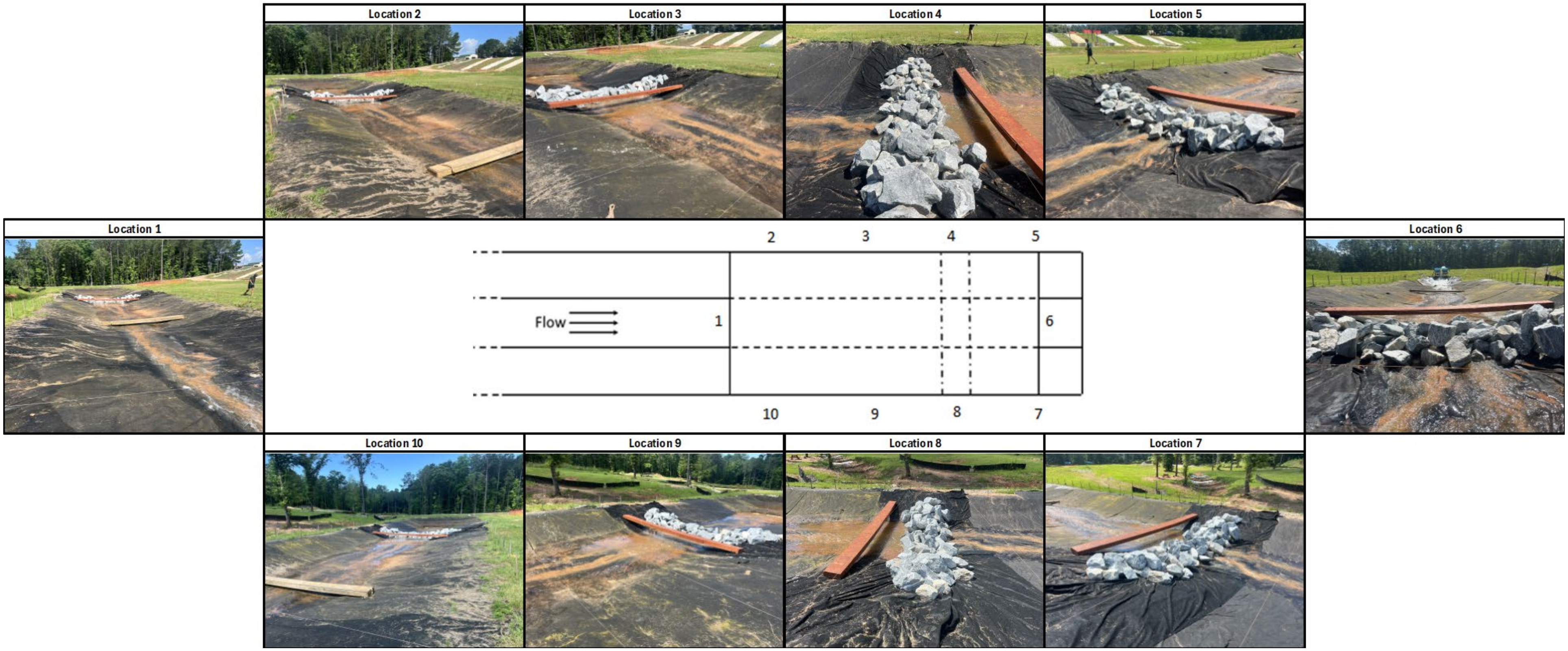
Location 10

Location 9

Location 8

Location 7

1.70 cfs


Location 2
Location 3
Location 4
Location 5
Location 1
Location 6
Location 10
Location 9
Location 8
Location 7
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Flow
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8
7

Date: 3/21/2024

Installation: Smaller Rock - T1

Techs and Workers: Roche and Donald

Start Time:

End Time:

Installation Descr.: Iowa DOT Standard with Iowa DOT Erosion Stone

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North									
Center									
South									
H_{water}(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North	0.20	0.11	0.18	0.20	0.24	0.31	0.39	0.13	0.16
Center	0.20	0.18	0.10	0.21	0.36	0.51	0.61	0.09	0.10
South	0.06	0.13	0.16	0.21	0.36	0.52	0.64	0.01	0.05
$H_{velocity}$(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North									
Center									
South									
$H_{velocity}$(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North	0.23	0.22	0.32	0.24	0.24	0.35	0.42	0.19	0.35
Center	0.28	0.30	0.20	0.24	0.39	0.57	0.61	0.14	0.25
South	0.25	0.28	0.26	0.26	0.36	0.55	0.64	0.24	0.18

Length of pool upstream of ditch check (ft): 20.8

Comments/Observations During Test:
Instant Flow through

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North							0.09	0.11	0.14
Center							0.18	0.21	0.10
South							0.18	0.09	0.10
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.15	0.20	0.29	0.45	0.60	0.64	0.76	0.12	0.17
Center	0.20	0.35	0.42	0.60	0.71	0.81	0.95	0.18	0.18
South	0.09	0.21	0.40	0.58	0.70	0.84	0.99	0.15	0.24
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North							0.35	0.29	0.28
Center							0.75	0.55	0.50
South							0.40	0.35	0.25
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.24	0.21	0.30	0.46	0.61	0.65	0.78	0.18	0.40
Center	0.45	0.54	0.60	0.63	0.75	0.84	0.97	0.24	0.30
South	0.27	0.22	0.42	0.59	0.72	0.85	1.01	0.30	0.34

Length of pool upstream of ditch check (ft): 34

Dewatering Time:

Comments/Observations During Test:

Date: 3/25/2024

Installation: Smaller Rock - T2

Techs and Workers: Roche and Donald

Start Time:

End Time:

Installation Descr.: Iowa DOT Standard Installation with Iowa DOT erosion stone

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H**water(ft.)**	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									0.06
Center									0.08
South									0.09
H**water(ft.)**	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.16	0.11	0.17	0.08	0.32	0.32	0.34	0.12	0.23
Center	0.17	0.16	0.10	0.25	0.39	0.52	0.64	0.15	0.11
South	0.08	0.14	0.12	0.18	0.38	0.53	0.69	0.13	0.14
H**velocity(ft.)**	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									0.24
Center									0.37
South									0.28
H**velocity(ft.)**	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.22	0.23	0.28	0.08	0.33	0.35	0.41	0.24	0.33
Center	0.25	0.32	0.18	0.32	0.45	0.55	0.67	0.19	0.14
South	0.22	0.22	0.30	0.18	0.39	0.54	0.71	0.27	0.16

Length of pool upstream of ditch check (ft): 23.4

Comments/Observations During Test:
Immediate flow through

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North						0.14	0.07	0.08	0.16
Center						0.12	0.15	0.17	0.06
South						0.17	0.13	0.08	0.17
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.14	0.25	0.31	0.36	0.59	0.67	0.70	0.23	0.24
Center	0.31	0.42	0.53	0.52	0.70	0.83	0.98	0.14	0.17
South	0.13	0.33	0.48	0.52	0.72	0.93	1.07	0.11	0.22
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North						0.57	0.24	0.28	0.27
Center						0.72	0.65	0.48	0.26
South						0.43	0.59	0.42	0.56
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.16	0.27	0.32	0.36	0.59	0.68	0.72	0.36	0.47
Center	0.33	0.43	0.56	0.59	0.71	0.86	0.99	0.22	0.22
South	0.31	0.41	0.67	0.54	0.75	0.95	1.09	0.27	0.34

Length of pool upstream of ditch check (ft): 33

Dewatering Time: 5.75

Comments/Observations During Test:

Date: 3/25/2024 **Start Time:**

Installation: Smaller Rock – T3 **End Time:**

Techs and Workers: Roche and Donald

Installation Descr.: Iowa DOT Standard Installation with Iowa DOT erosion stone

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H**$_{water}$**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
H**$_{water}$**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.16	0.11	0.16	0.14	0.25	0.31	0.39	0.08	0.18
Center	0.16	0.14	0.12	0.23	0.39	0.49	0.63	0.14	0.12
South	0.04	0.13	0.11	0.21	0.36	0.50	0.66	0.10	0.23
H**$_{velocity}$**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North									
Center									
South									
H**$_{velocity}$**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.21	0.24	0.32	0.14	0.26	0.34	0.42	0.21	0.27
Center	0.31	0.36	0.21	0.29	0.46	0.53	0.64	0.17	0.15
South	0.17	0.22	0.19	0.22	0.37	0.52	0.67	0.18	0.33

Length of pool upstream of ditch check (ft): 20.5

Comments/Observations During Test:

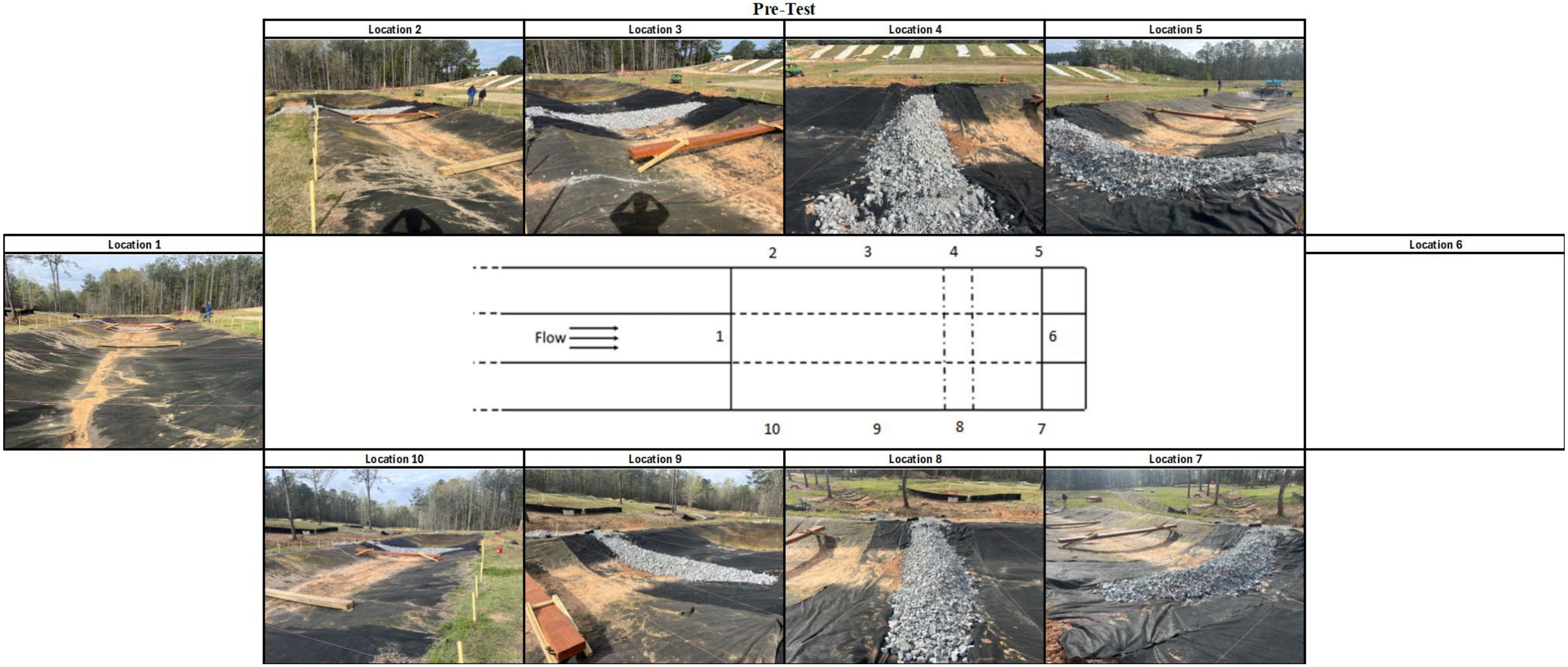
Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North							0.07	0.13	0.11
Center							0.18	0.16	0.13
South							0.12	0.09	0.16
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.14	0.20	0.31	0.48	0.58	0.74	0.72	0.13	0.23
Center	0.29	0.41	0.55	0.62	0.64	0.86	0.99	0.19	0.14
South	0.14	0.41	0.32	0.58	0.73	0.74	1.09	0.16	0.13
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North							0.26	0.28	0.28
Center							0.72	0.33	0.52
South							0.54	0.45	0.58
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.22	0.21	0.33	0.49	0.59	0.75	0.73	0.22	0.43
Center	0.32	0.42	0.57	0.64	0.69	0.87	0.99	0.28	0.24
South	0.44	0.64	0.64	0.63	0.81	0.83	1.10	0.32	0.32

Length of pool upstream of ditch check (ft): 31

Dewatering
Time (min): 5.12

Comments/Observations During Test:

Pre-Test



Location 2
Location 3
Location 4
Location 5
Location 1
Location 6
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4
5
Flow
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6
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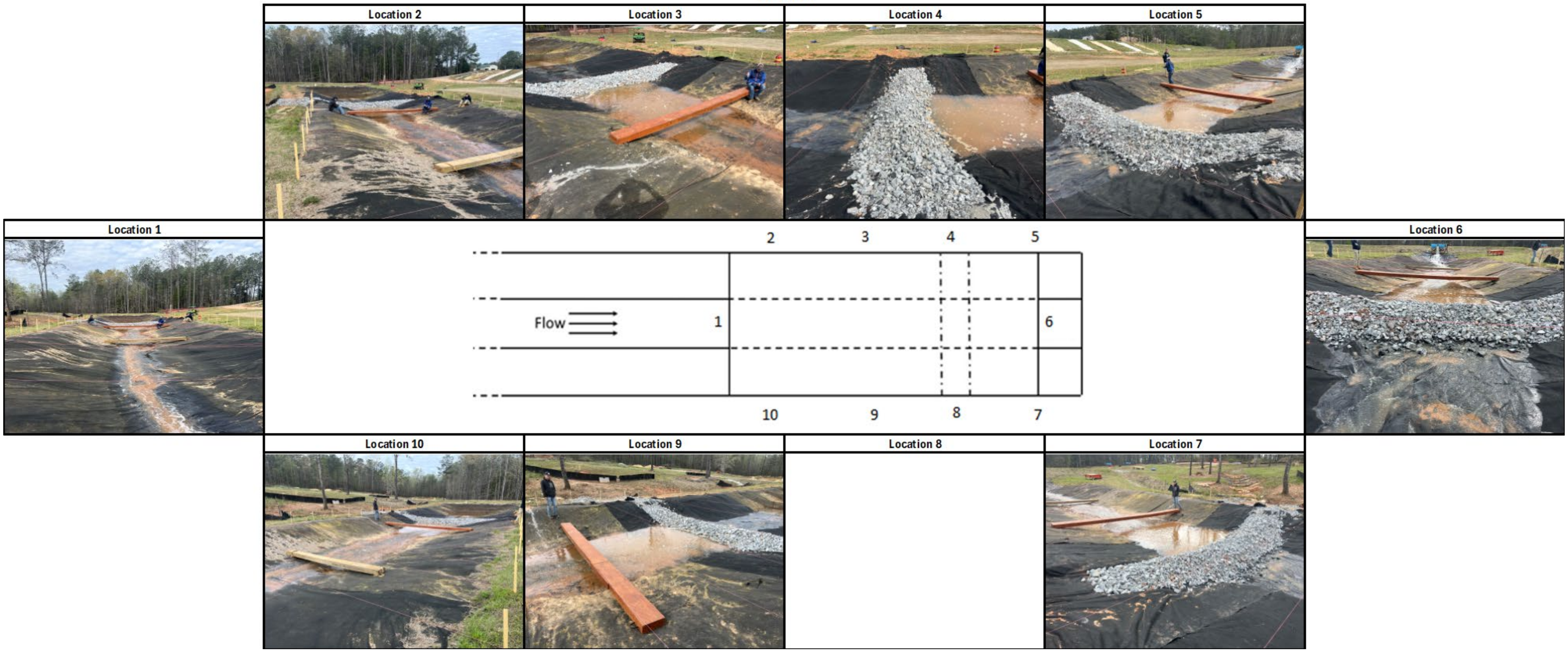
Location 10
Location 9
Location 8
Location 7

0.85 cfs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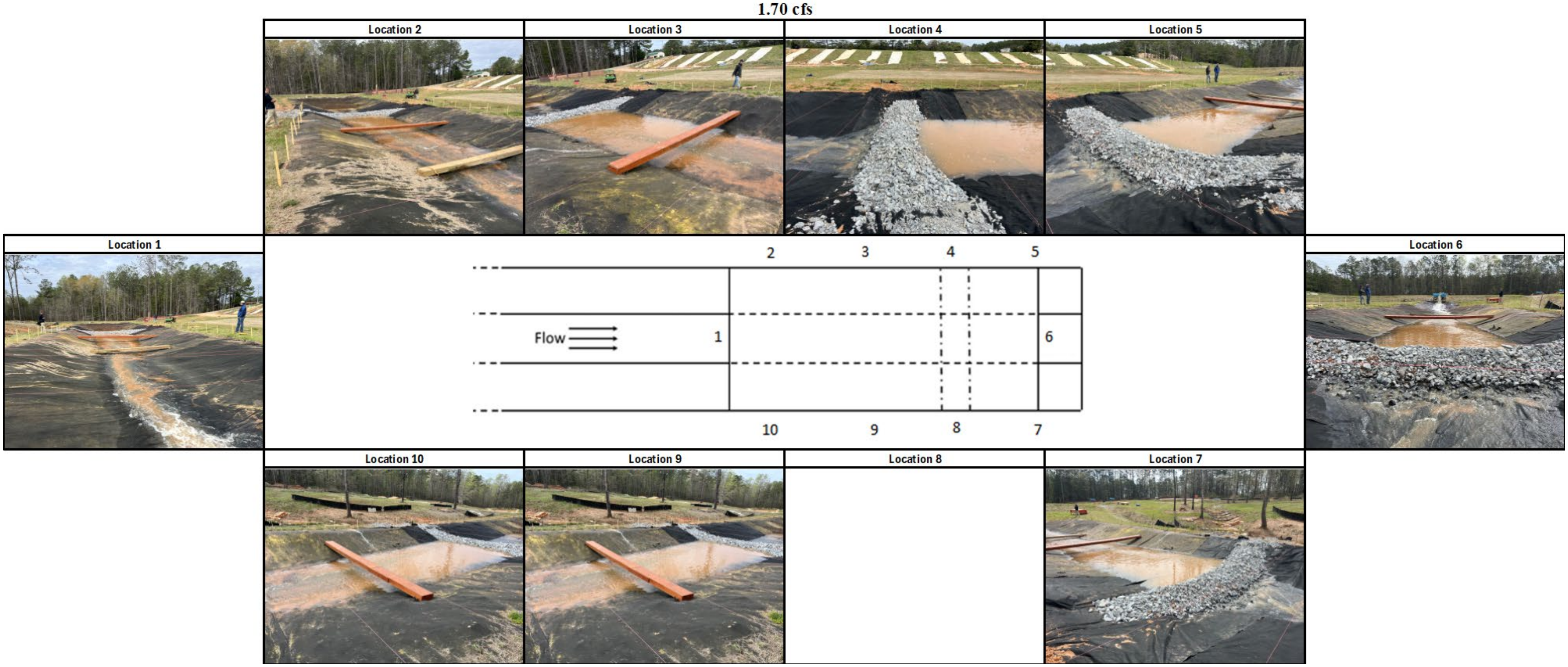
Location 7

1.70 cfs


Location 2
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Location 8
Location 7

Date: 6/18/2024 **Start Time:**

Installation: Geotextile Overlay - T1 **End Time:**

Techs and Workers:

Installation Descr.: Geotextile Overlay over Standard Installation on grade

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North					0.06	0.11	0.08	0.18	0.35
Center					0.11	0.11	0.18	0.20	0.36
South					0.13	0.14	0.13	0.27	0.28
Top Width (in.)					68	74	88	126	158
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.44	0.52	0.55	0.74	0.79	0.94	0.86	0.06	0.16
Center	0.55	0.68	0.78	0.85	1.00	1.09	1.16	0.12	0.12
South	0.44	0.49	0.56	0.72	0.94	1.15	1.25	0.18	0.14
Top Width (in.)	172	186	190	202	209	212	219	76	86
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North					0.23	0.32	0.23	0.19	0.35
Center					0.41	0.27	0.24	0.22	0.37
South					0.48	0.46	0.42	0.33	0.41
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.46	0.52	0.55	0.75	0.81	0.95	0.88	0.20	0.46
Center	0.55	0.68	0.80	0.85	1.01	1.09	1.17	0.34	0.23
South	0.52	0.52	0.59	0.74	0.98	1.16	1.26	0.34	0.36

Length of pool upstream of ditch check (ft): 31.1

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.06	0.12	0.25	0.34	0.44	0.65	0.85
Center			0.21	0.21	0.42	0.52	0.61	0.66	0.85
South			0.22	0.24	0.47	0.52	0.62	0.62	0.58
Top Width (in.)			64	88	136	153	169	199	206
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.96	0.98	1.00	1.19	1.86	1.40	1.36	0.20	0.18
Center	1.10	1.18	1.31	1.35	1.31	1.54	1.65	0.08	0.15
South	0.87	0.96	1.06	1.09	1.40	1.54	1.71	0.21	0.17
Top Width (in.)	212	223	229	246	254	248	254	98	90
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.33	0.16	0.27	0.34	0.45	0.65	0.86
Center			0.66	0.52	0.44	0.55	0.62	0.67	0.85
South			0.72	0.64	0.63	0.73	0.73	0.72	0.66
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.96	0.99	1.01	1.21	1.88	1.41	1.37	0.36	0.46
Center	1.11	1.19	1.32	1.35	1.33	1.54	1.66	0.39	0.26
South	0.94	1.00	1.08	1.12	1.42	1.56	1.72	0.49	0.54

Length of pool upstream of ditch check (ft): 47.5

Dewatering Time: Over 6 hours

Comments/Observations During Test:
Impounded to CS3 when pumps were turned off (~60 ft)

Date: 6/25/2024 **Start Time:**

Installation: Geotextile Overlay - T2 **End Time:**

Techs and Workers:

Installation Descr.: Geotextile Overlay over Standard Installation On Grade

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.21	0.18	0.20	0.25	0.38	0.61	0.71	0.91
Center		0.26	0.18	0.25	0.50	0.55	0.51	0.71	0.92
South		0.23	0.14	0.19	0.52	0.54	0.63	0.45	0.92
Top Width (in.)		33	34	86	148	163	188	205	214
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.96	1.07	1.16	1.40	1.41	1.54	1.46	0.08	0.11
Center	1.19	1.26	1.41	1.51	1.62	1.75	1.78	0.18	0.13
South	1.11	1.14	1.34	1.46	1.61	1.72	1.85	0.19	0.12
Top Width (in.)	222	229	243	256	262	260	263	88	92
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.70	0.52	0.24	0.27	0.40	0.62	0.72	0.91
Center		0.61	0.65	0.43	0.56	0.57	0.51	0.72	0.93
South		0.26	0.44	0.47	0.62	0.61	0.72	0.50	0.96
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.11	1.10	1.17	1.40	1.42	1.56	1.46	0.18	0.33
Center	1.20	1.29	1.41	1.52	1.63	1.77	1.80	0.22	0.22
South	1.12	1.16	1.35	1.48	1.61	1.73	1.91	0.36	0.37

Length of pool upstream of ditch check (ft): 54.25

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.28	0.22	0.25	0.30	0.45	0.57	0.80	1.07
Center		0.27	0.29	0.32	0.51	0.58	0.49	0.79	0.99
South		0.25	0.21	0.24	0.45	0.64	0.66	0.52	0.68
Top Width (in.)		40	46	112	156	184	196	218	224
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.10	1.21	1.31	1.47	1.51	1.75	1.70	0.14	0.15
Center	1.30	1.41	1.50	1.65	1.71	1.84	2.01	0.22	0.19
South	1.15	1.18	1.21	1.45	1.64	1.93	2.05	0.25	0.15
Top Width (in.)	234	240	252	264	274	274	272	99	100
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.83	0.53	0.28	0.33	0.48	0.58	0.80	1.08
Center		0.85	0.80	0.51	0.59	0.60	0.51	0.81	1.01
South		0.34	0.53	0.71	0.75	0.79	0.72	0.64	0.75
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.12	1.21	1.32	1.48	1.52	1.76	1.70	0.25	0.42
Center	1.31	1.42	1.52	1.65	1.73	1.86	2.03	0.31	0.25
South	1.17	1.22	1.26	1.48	1.66	1.95	2.06	0.62	0.52

Length of pool upstream of ditch check (ft): 49.125

Dewatering Time:

Comments/Observations During Test:
Impounded to 63 ft when pumps were turned off

Date: 6/26/2024 **Start Time:**

Installation: Geotextile Overlay - T3 **End Time:**

Techs and Workers:

Installation Descr.: Geotextile Overlay Standard Rock Trenchless

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.21	0.18	0.21	0.35	0.47	0.51	0.64	0.96
Center		0.21	0.20	0.34	0.41	0.49	0.65	0.80	0.93
South		0.28	0.15	0.40	0.33	0.38	0.52	0.32	0.92
Top Width (in.)		38	36	114	156	176	190	208	218
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.06	1.10	1.20	1.41	1.51	1.63	1.63	0.14	0.16
Center	1.22	1.31	1.45	1.49	1.69	1.75	1.92	0.16	0.10
South	1.15	1.28	1.40	1.45	1.65	1.84	1.98	0.25	0.08
Top Width (in.)	233	237	248	258	265	266	270	88	94
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.61	0.41	0.23	0.35	0.48	0.52	0.65	0.97
Center		0.48	0.51	0.37	0.47	0.52	0.65	0.81	0.95
South		0.32	0.32	0.52	0.40	0.43	0.56	0.41	0.96
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.07	1.12	1.20	1.41	1.52	1.64	1.65	0.32	0.37
Center	1.24	1.32	1.46	1.49	1.70	1.77	1.93	0.24	0.15
South	1.16	1.31	1.41	1.45	1.67	1.85	2.00	0.46	0.32

Length of pool upstream of ditch check (ft): 62.5

Comments/Observations During Test:
Still water present from previous test 22 hours previous. No flow through for first 10 minutes. 100% efficiency point was at 62.5 ft

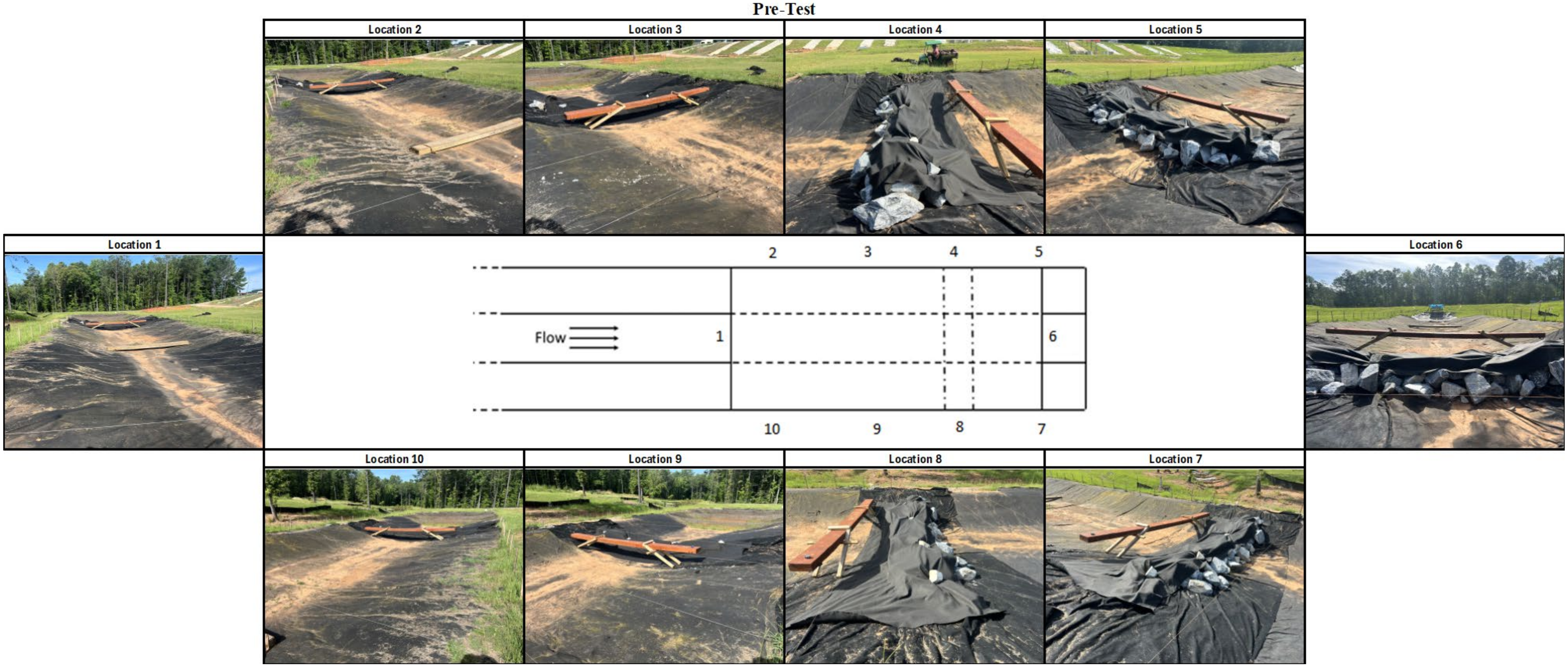
Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.31	0.25	0.30	0.25	0.28	0.31	0.73	0.70
Center		0.31	0.31	0.38	0.21	0.32	0.51	0.80	1.00
South		0.25	0.22	0.44	0.42	0.48	0.72	0.67	1.08
Top Width (in.)		42	72	124	164	184	202	218	220
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.10	1.19	1.30	1.52	1.53	1.75	1.70	0.15	0.21
Center	1.30	1.42	1.52	1.62	1.78	1.91	2.01	0.19	0.16
South	1.10	1.19	1.26	1.39	1.65	1.78	2.04	0.21	0.11
Top Width (in.)	238	242	256	270	278	276	273	98	104
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.84	0.72	0.31	0.27	0.28	0.33	0.74	0.73
Center		0.75	0.85	0.41	0.24	0.34	0.55	0.82	1.01
South		0.41	0.54	0.68	0.50	0.58	0.79	0.71	1.08
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.11	1.20	1.31	1.52	1.54	1.75	1.71	0.48	0.56
Center	1.3	1.42	1.52	1.62	1.78	1.92	2.03	0.32	0.24
South	1.13	1.23	1.29	1.41	1.67	1.80	2.05	0.61	0.64

Length of pool upstream of ditch check (ft): 48.5

Dewatering Time:

Comments/Observations During Test:

Pre-Test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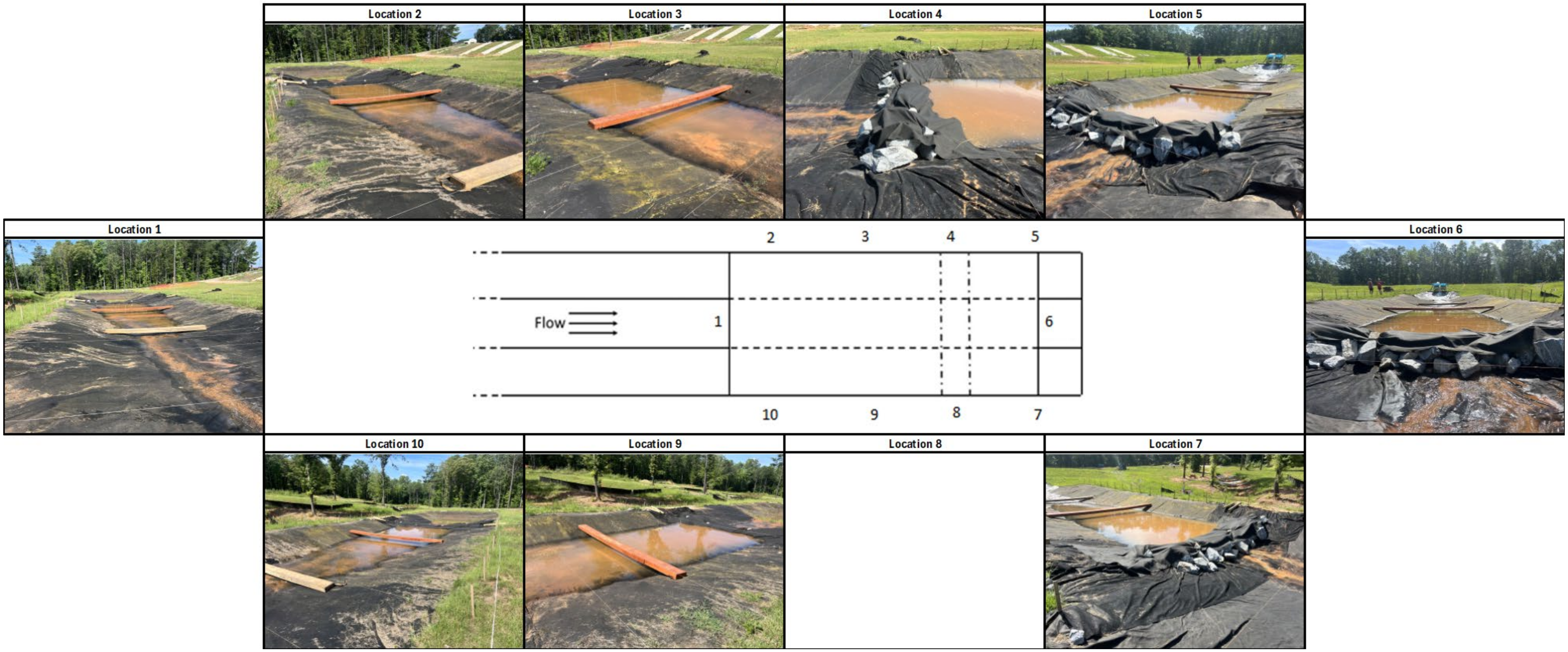
Location 8
Location 7

0.85 cfs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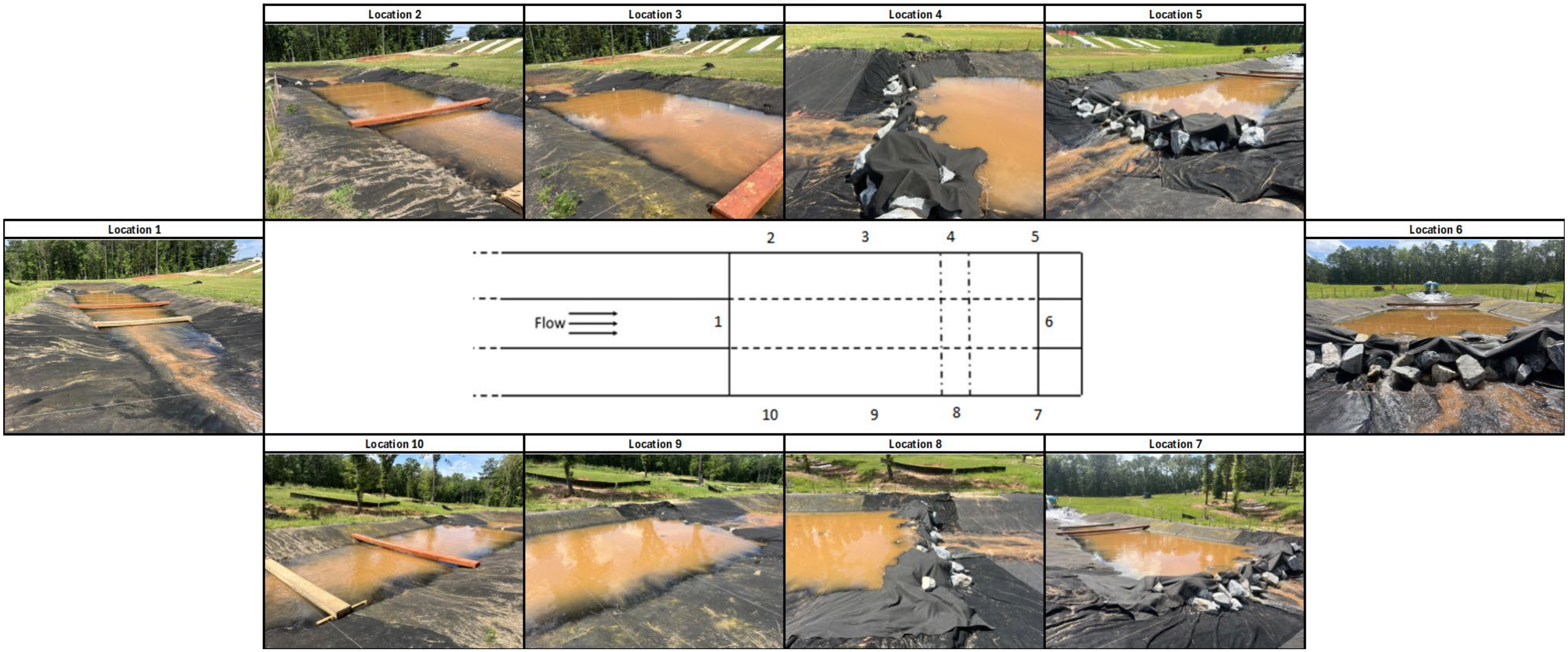
Location 7

1.70 cfs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Location 10
Location 9
Location 8
Location 7

Date: 9/17/2024
Installation: Dewatering Holes - T1
Techs and Workers:

Start Time:
End Time:

Installation Descr.: Standard rock on grade w/ geotextile overlay and dewatering holes

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H**$_{water}$**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North				0.11	0.11	0.18	0.25	0.35	0.51
Center				0.18	0.16	0.14	0.35	0.41	0.53
South				0.06	0.06	0.12	0.30	0.44	0.55
Top Width (in.)				54	58	94	130	158	183
H**$_{water}$**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.63	0.66	0.65	0.97	1.04	1.20	1.15	0.14	0.22
Center	0.75	0.88	0.94	1.09	1.21	1.31	1.39	0.14	0.11
South	0.72	0.80	0.96	1.04	1.19	1.31	1.48	0.24	0.11
Top Width (in.)	184	204	222	222	225	230	234	82	98
H**$_{velocity}$**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North				0.22	0.28	0.29	0.27	0.36	0.52
Center				0.60	0.45	0.31	0.49	0.51	0.58
South				0.45	0.18	0.27	0.31	0.47	0.55
H**$_{velocity}$**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.68	0.70	0.68	0.99	1.06	1.21	1.15	0.33	0.34
Center	0.78	0.89	0.94	1.10	1.22	1.31	1.42	0.26	0.32
South	0.73	0.81	0.97	1.05	1.20	1.32	1.51	0.37	0.15

Length of pool upstream of ditch check (ft): 45.2

Comments/Observations During Test:
Immediate flow through

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North				0.05	0.16	0.30	0.45	0.86	0.94
Center				0.10	0.16	0.41	0.73	0.92	0.96
South				0.15	0.25	0.54	0.64	0.52	0.78
Top Width (in.)				98	138	168	192	218	224
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.19	1.15	1.32	1.48	1.70	1.94	1.75	0.12	0.18
Center	1.31	1.32	1.54	1.69	1.80	1.84	2.01	0.08	0.11
South	1.19	1.33	1.48	1.65	1.75	1.68	2.09	0.25	0.21
Top Width (in.)	240	240	257	258	270	274	286	92	100
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North				0.38	0.18	0.32	0.47	0.86	0.94
Center				0.42	0.44	0.45	0.74	0.94	0.97
South				0.55	0.54	0.73	0.76	0.54	0.84
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.2	1.16	1.33	1.50	1.71		1.76	0.21	0.42
Center		1.34	1.56	1.69	1.81	1.85	2.02	0.35	0.34
South	1.21	1.35	1.49	1.66	1.75		2.10	0.47	0.51

Length of pool upstream of ditch check (ft): 50

Dewatering Time:

Comments/Observations During Test:

Date: 10/1/2024 **Start Time:** 1:56 PM

Installation: Dewatering Holes - T2 **End Time:** 3:15 PM

Techs and Workers:

Installation Descr.: Standard rock on grade w/ geotextile overlay and dewatering holes

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North				0.11	0.21	0.31	0.38	0.51	0.71
Center				0.18	0.23	0.26	0.44	0.54	0.79
South				0.11	0.19	0.24	0.45	0.31	0.70
Top Width (in.)				48	104	134	138	168	190
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.80	0.86	0.94	1.15	1.21	1.31	1.30	0.11	0.12
Center	0.94	1.05	1.15	1.25	1.41	1.46	1.59	0.11	0.07
South	0.85	0.95	1.11	1.20	1.36	1.48	1.65	0.18	0.15
Top Width (in.)	198.00	216	222	232	242	240	244	82	92
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North				0.35	0.48	0.44	0.38	0.53	0.72
Center				0.38	0.57	0.45	0.54	0.59	0.81
South				0.45	0.36	0.36	0.53	0.33	0.73
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.81	0.88	0.98	1.16	1.22	1.33	1.30	0.17	0.32
Center	0.96	1.07	1.16	1.26	1.42	1.47	1.61	0.22	0.12
South	0.89	0.96	1.12	1.21	1.38	1.48	1.66	0.36	0.31

Length of pool upstream of ditch check (ft): 42

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.24	0.18	0.25	0.19	0.18	0.48	0.79	1.04
Center		0.31	0.30	0.14	0.22	0.22	0.52	0.70	1.00
South		0.28	0.24	0.19	0.24	0.25	0.46	0.45	0.79
Top Width (in.)		38	48	88	162	164	166	176	197
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.11	1.19	1.23	1.48	1.56	1.72	1.68	0.15	0.22
Center	1.25	1.38	1.48	1.64	1.74	1.86	2.00	0.15	0.09
South	1.11	1.19	1.25	1.58	1.70	1.88	2.10	0.25	0.17
Top Width (in.)	229	239	252	265	273	270	276	99	104
H_{velocity}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.85	0.51	0.32	0.21	0.21	0.50	0.81	1.05
Center		0.73	0.74	0.57	0.36	0.28	0.59	0.72	1.04
South		0.51	0.61	0.57	0.35	0.41	0.52	0.49	0.82
H_{velocity}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.13	1.22	1.26	1.49	1.57	1.73	1.69	0.35	0.44
Center	1.26	1.41	1.50	1.66	1.75	1.87	2.01	0.32	0.31
South	1.14	1.23	1.37	1.59	1.73	1.90	2.12	0.61	0.46

Length of pool upstream of ditch check (ft): 48.2

Dewatering Time:

Comments/Observations During Test:
Impounded to 63 feet when pumps were shut off

Date: 10/3/2024 **Start Time:** 1:15 PM
Installation: Dewatering Holes – T3 **End Time:**
Techs and Workers:

Installation Descr.: Standard rock on grade w/ geotextile overlay and dewatering holes

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H**_{water}**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.26	0.11	0.23	0.36	0.42	0.55	0.70	0.86
Center		0.28	0.19	0.31	0.32	0.48	0.66	0.66	0.92
South		0.16	0.17	0.15	0.15	0.52	0.64	0.71	0.80
Top Width (in.)		28	88	81	108	128	163	194	205
H**_{water}**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.97	1.02	1.14	1.35	1.44	1.49	1.49	0.11	0.16
Center	1.04	1.25	1.38	1.44	1.63	1.65	1.75	0.06	0.08
South		1.16	1.31	1.41	1.54	1.65	1.80	0.16	0.09
Top Width (in.)	212	227	236.00	248	260	256	258	75	90
H**_{velocity}**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.63	0.47	0.29	0.44	0.44	0.55	0.70	0.87
Center		0.35	0.45	0.35	0.47	0.51	0.67	0.67	0.92
South		0.28	0.43	0.43	0.27	0.56	0.65	0.75	0.82
H**_{velocity}**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.97	1.03	1.15	1.35	1.46	1.51	1.49	0.14	0.20
Center	1.05	1.26	1.40	1.45	1.64	1.67	1.76	0.17	0.12
South		1.17	1.32	1.45	1.56	1.66	1.82	0.32	0.21

Length of pool upstream of ditch check (ft): 53

Comments/Observations During Test:

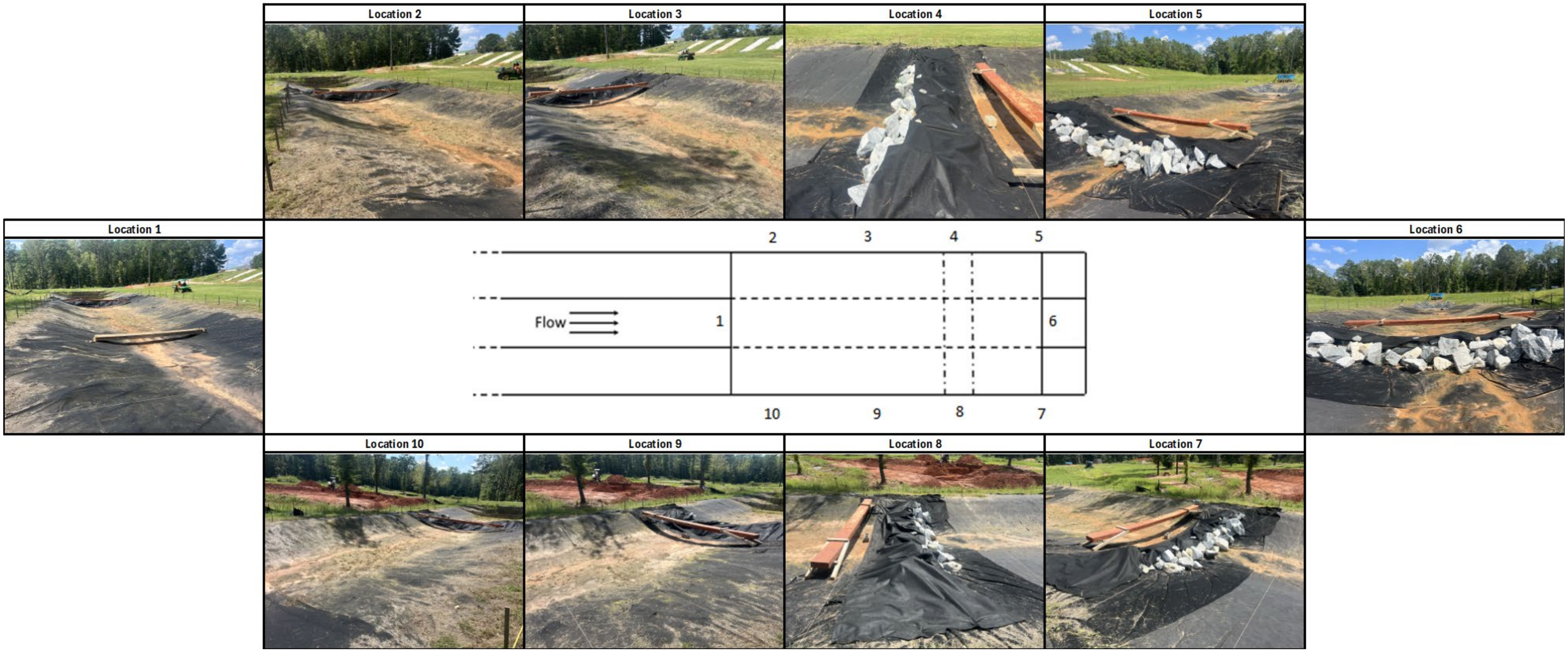
Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.25	0.21	0.29	0.22	0.60	0.36	0.81	1.05
Center		0.33	0.31	0.45	0.32	0.57	0.47	0.76	1.01
South		0.24	0.24	0.21	0.26	0.29	0.58	0.75	0.77
Top Width (in.)		40	44	116	166	128	156	167	190
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.09	1.17	1.24	1.50	1.51	1.75	1.65	0.16	0.21
Center	1.22	1.41	1.50	1.63	1.74	1.88	2.00	0.11	0.13
South	1.05	1.27	1.45	1.58	1.73	1.86	2.08	0.25	0.15
Top Width (in.)	231.00	240	249	252	260	274	277	92	99
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.85	0.72	0.34	0.37	0.62	0.37	0.81	1.07
Center		0.72	0.85	0.81	0.62	0.59	0.48	0.78	1.06
South		0.47	0.46	0.52	0.38	0.34	0.69	0.77	0.78
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.12	1.22	1.27	1.52	1.53	1.79	1.67	0.31	0.51
Center	1.25	1.41	1.51	1.65	1.76	1.91	2.01	0.33	0.45
South	1.06	1.28	1.45	1.61	1.74	1.88	2.10	0.56	0.51

Length of pool upstream of ditch check (ft): 56

Dewatering Time:

Comments/Observations During Test:
Impounded to 63 feet with pump shut off

Pre-Test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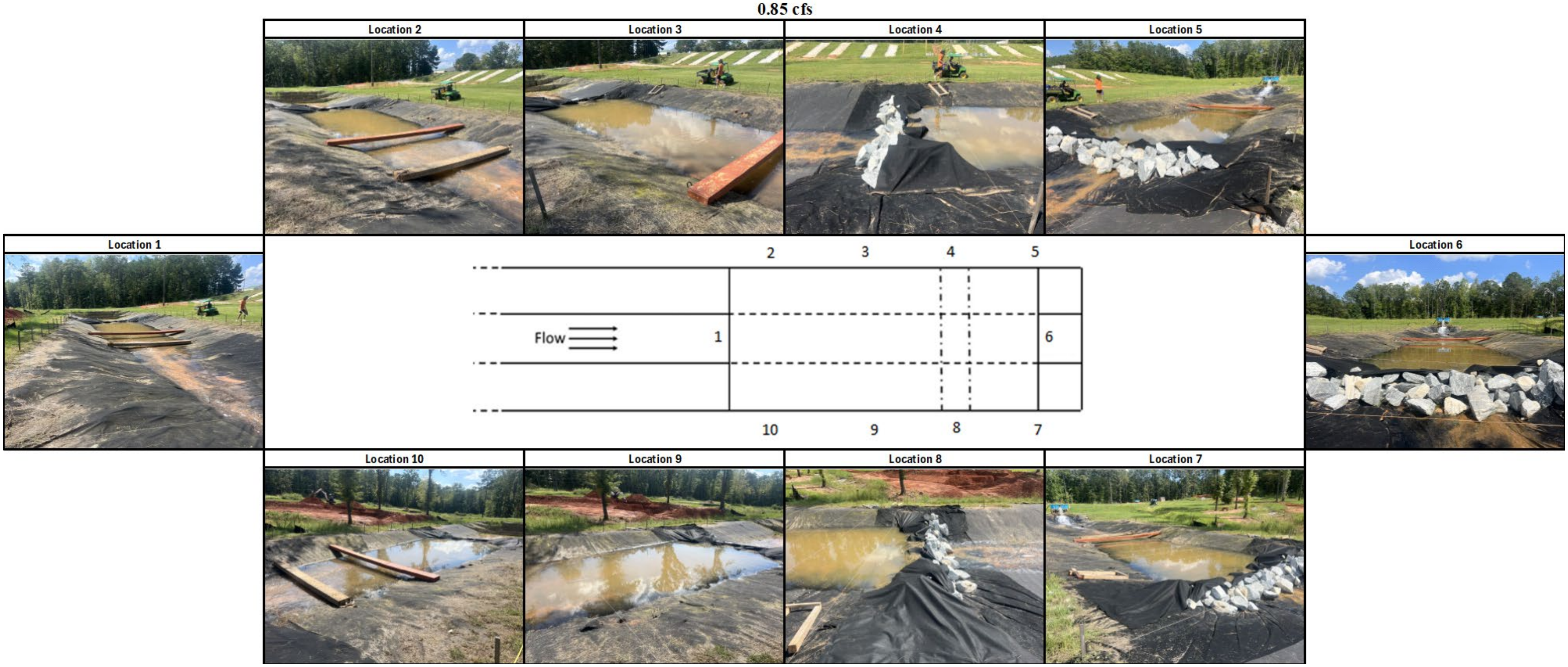
0.85 cfs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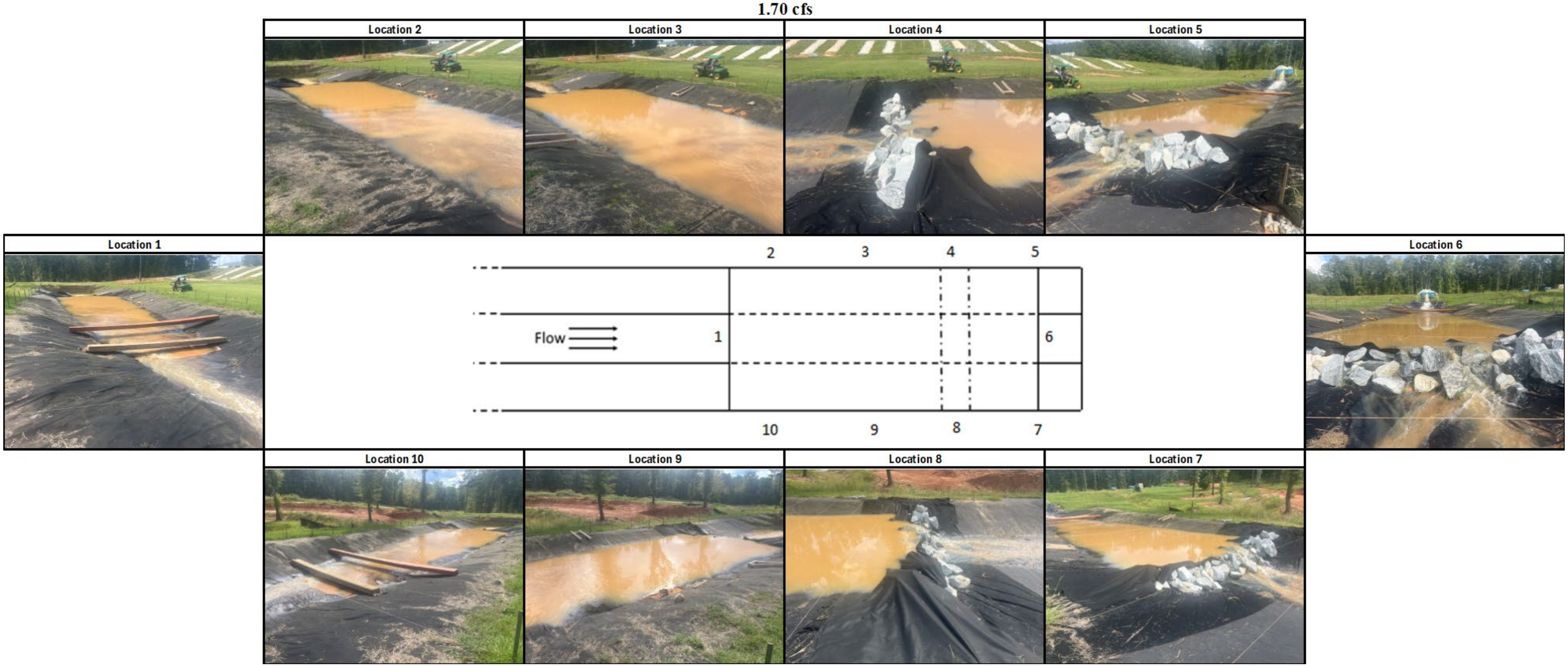
1.70 cfs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Date: 10/15/24

Installation: Small Rock Geotextile – T1

Techs and Workers:

Start Time: 2:43

End Time:

Installation Descr.: Smaller rock gradation on grade w/ geotextile overlay

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North				0.08	0.11	0.12	0.12	0.22	0.43
Center				0.12	0.12	0.15	0.11	0.21	0.37
South				0.17	0.08	0.11	0.06	0.25	0.35
Top Width (in.)				42	52	61	94	139	158
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.46	0.55	0.64	0.84	0.88	0.99	0.98	0.11	0.08
Center	0.64	0.74	0.82	0.94	1.10	1.17	1.30	0.07	0.07
South	0.54	0.66	0.80	0.89	1.05	1.20	1.39	0.19	0.09
Top Width (in.)	181	191	199	209	213	220	226	82	88
H_{velocity}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North				0.27	0.37	0.25	0.27	0.26	0.48
Center				0.39	0.45	0.31	0.21	0.31	0.42
South				0.43	0.25	0.23	0.19	0.26	0.36
H_{velocity}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.48	0.57	0.64	0.85	0.89	1.00	1.01	0.27	0.22
Center	0.67	0.78	0.83	0.94	1.10	1.17	1.31	0.14	0.13
South	0.55	0.67	0.81	0.90	1.06	1.22	1.39	0.31	0.23

Length of pool upstream of ditch check (ft): 42.5

Comments/Observations During Test:
Immediate flow through

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.21	0.08	0.08	0.18	0.45	0.52	0.77
Center			0.31	0.16	0.18	0.25	0.47	0.61	0.81
South			0.24	0.16	0.16	0.25	0.36	0.48	0.72
Top Width (in.)			46	71	74	110	134	172	192
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.84	0.95	1.03	1.26	1.30	1.54	1.49	0.21	0.18
Center	0.98	1.15	1.25	1.40	1.52	1.64	1.79	0.14	0.15
South	0.83	0.92	1.06	1.34	1.35	1.55	1.81	0.23	0.18
Top Width (in.)	202	222	229	242	256	254	258	83	98
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.56	0.53	0.50	0.23	0.47	0.52	0.78
Center			0.68	0.74	0.58	0.52	0.59	0.66	0.82
South			0.54	0.67	0.61	0.48	0.46	0.52	0.75
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.86	0.96	1.04	1.27	1.30	1.56	1.51	0.31	0.43
Center	0.99	1.16	1.26	1.40	1.53	1.65	1.79	0.24	0.27
South	0.85	0.94	1.08	1.36	1.38	1.56	1.82	0.58	0.51

Length of pool upstream of ditch check (ft): 48.5

Dewatering Time:

Comments/Observations During Test:
Overtopped, 49 with pumps off

Date: 10/17/2024
Installation: Smaller Rock Gradation - T2
Techs and Workers:

Start Time: 1:10 PM
End Time:

Installation Descr.: Smaller rock gradation on grade w/ geotextile overlay

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North			0.25	0.10	0.22	0.21	0.45	0.54	0.76
Center			0.25	0.21	0.25	0.42	0.50	0.60	0.85
South			0.05	0.31	0.32	0.39	0.49	0.62	0.73
Top Width (in.)			56	67	120	132	159	155	188
H_{water}(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North	0.80	0.95	0.99	1.08	0.93	1.37	1.52	0.16	0.20
Center	0.99	1.13	1.19	1.35	1.45	1.59	1.73	0.14	0.12
South	0.81	0.95	1.01	1.02	1.25	1.60	1.73	0.25	0.14
Top Width (in.)	196.00	218	228	246	244	250	260	87	94
$H_{velocity}$(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North			0.47	0.14	0.25	0.22	0.46	0.56	0.77
Center			0.49	0.35	0.31	0.51	0.51	0.63	0.87
South			0.15	0.44	0.55	0.55	0.53	0.65	0.76
$H_{velocity}$(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North	0.82	0.97	1.03	1.12	0.95	1.37	1.53	0.22	0.31
Center	1.01	1.17	1.20	1.41	1.47	1.60	1.74	0.20	0.16
South	0.86	0.99	1.05	1.06	1.28	1.61	1.75	0.42	0.30

Length of pool upstream of ditch check (ft): 62

Comments/Observations During Test:
Overtopped at low flow, filled in 10-15 minutes

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.06	0.11	0.16	0.22	0.53	0.61	0.84
Center			0.25	0.25	0.25	0.32	0.56	0.63	0.93
South			0.27	0.30	0.29	0.35	0.55	0.58	0.82
Top Width (in.)			65.00	72.00	131.00	138.00	155.00	180.00	193.00
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.91	1.02	1.00	1.20	1.18	1.28	1.43	0.22	0.22
Center	1.05	1.16	1.25	1.39	1.52	1.70	1.84	0.11	0.20
South	0.99	0.90	1.12	1.14	1.33	1.44	1.61	0.25	0.25
T Top Width (in.)	205.00	222.00	236.00	246.00	248.00	257.00	263.00	89.00	99.00
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.20	0.17	0.22	0.27	0.55	0.64	0.86
Center			0.56	0.63	0.36	0.38	0.61	0.68	0.95
South			0.60	0.65	0.55	0.62	0.65	0.69	0.86
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.93	1.03	1.02	1.23	1.21	1.32	1.47	0.42	0.45
Center	1.08	1.19	1.27	1.42	1.54	1.73	1.87	0.25	0.29
South	1.02	1.01	1.14	1.16	1.35	1.46	1.63	0.45	0.51

Length of pool upstream of ditch check (ft): 66

Dewatering Time:

Comments/Observations During Test:

Date: 10/22/24 **Start Time:** 1:15 PM
Installation: Smaller Rock Geotextile - T3 **End Time:**
Techs and Workers:

Installation Descr.: Smaller rock gradation on grade w/ geotextile overlay

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H**$_{water}$**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.12	0.15	0.20	0.21	0.41	0.51	0.78
Center			0.21	0.19	0.24	0.17	0.49	0.50	0.78
South			0.20	0.15	0.12	0.25	0.46	0.57	0.66
Top Width (in.)			30	68	106	144	155	186	186
H**$_{water}$**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.84	0.92	0.99	1.20	1.26	1.35	1.45	0.10	0.11
Center	0.99	1.11	1.22	1.33	1.44	1.58	1.75	0.09	0.06
South	0.72	0.88	1.05	1.16	1.35	1.59	1.68	0.17	0.08
Top Width (in.)	202	221	226	240	250	248	256	72	84
H**$_{velocity}$**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.47	0.32	0.28	0.22	0.41	0.51	0.78
Center			0.41	0.55	0.48	0.23	0.51	0.50	0.79
South			0.38	0.52	0.35	0.37	0.53	0.61	0.70
H**$_{velocity}$**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.84	0.93	1.00	1.22	1.27	1.36	1.46	0.22	0.22
Center	0.99	1.12	1.23	1.33	1.45	1.60	1.75	0.14	0.15
South	0.75	0.92	1.07	1.19	1.37	1.61	1.69	0.38	0.29

Length of pool upstream of ditch check (ft): 53

Comments/Observations During Test:
Low flow through

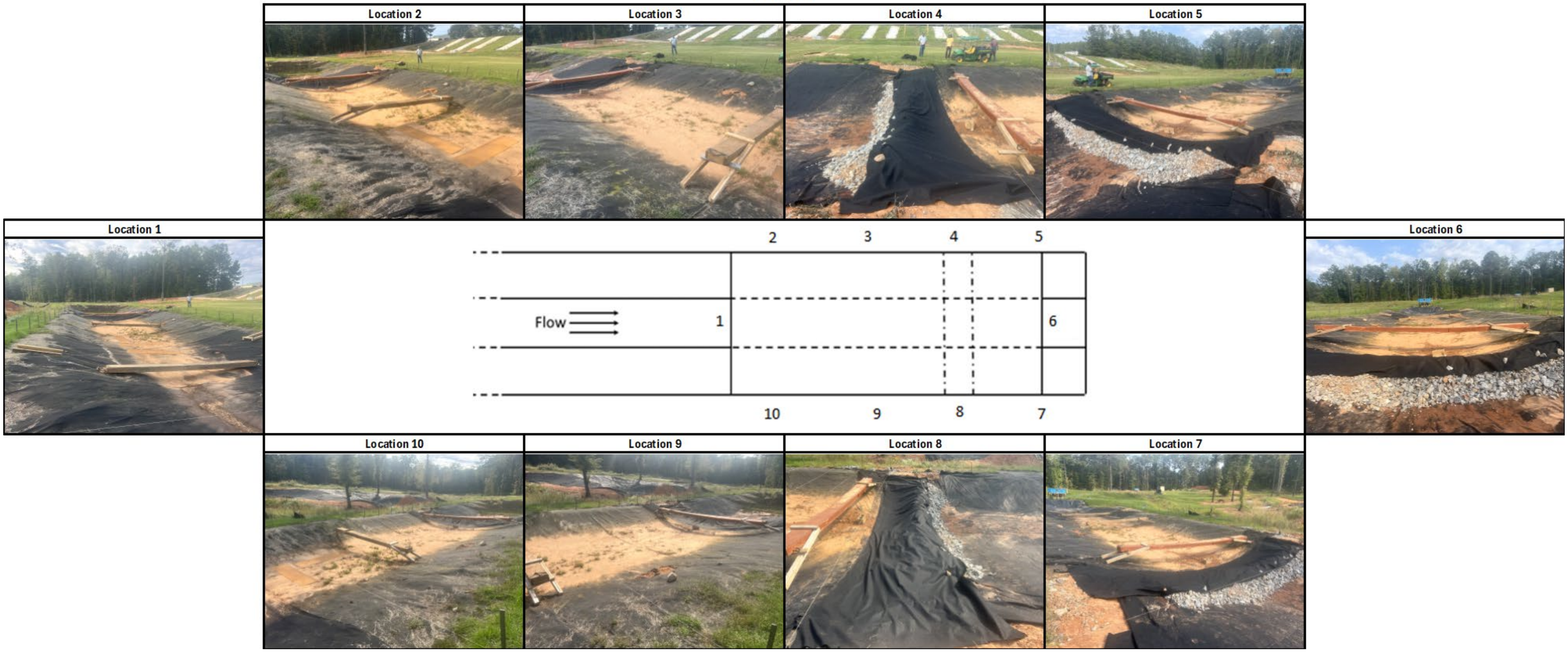
Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.17	0.08	0.12	0.18	0.50	0.62	0.85
Center			0.31	0.16	0.25	0.25	0.55	0.55	0.80
South			0.26	0.23	0.15	0.22	0.48	0.26	0.76
Top Width (in.)			52	70	120	137	158	142	184
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.89	0.99	1.07	1.28	1.34	1.51	1.53	0.19	0.17
Center	1.05	1.19	1.29	1.39	1.55	1.66	1.75	0.12	0.09
South	0.88	1.11	1.19	1.32	1.51	1.65	1.85	0.18	0.16
Top Width (in.)	201	223	233	244	246	251	259	76	94
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.60	0.43	0.34	0.37	0.50	0.62	0.85
Center			0.72	0.51	0.65	0.48	0.59	0.62	0.82
South			0.65	0.72	0.36	0.48	0.58	0.32	0.79
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.9	1.01	1.10	1.29	1.34	1.51	1.54	0.35	0.47
Center	1.07	1.20	1.30	1.42	1.57	1.68	1.77	0.27	0.18
South	0.9	1.13	1.21	1.33	1.53	1.67	1.86	0.51	0.51

Length of pool upstream of ditch check (ft): 56

Dewatering Time:

Comments/Observations During Test:

Pre-Test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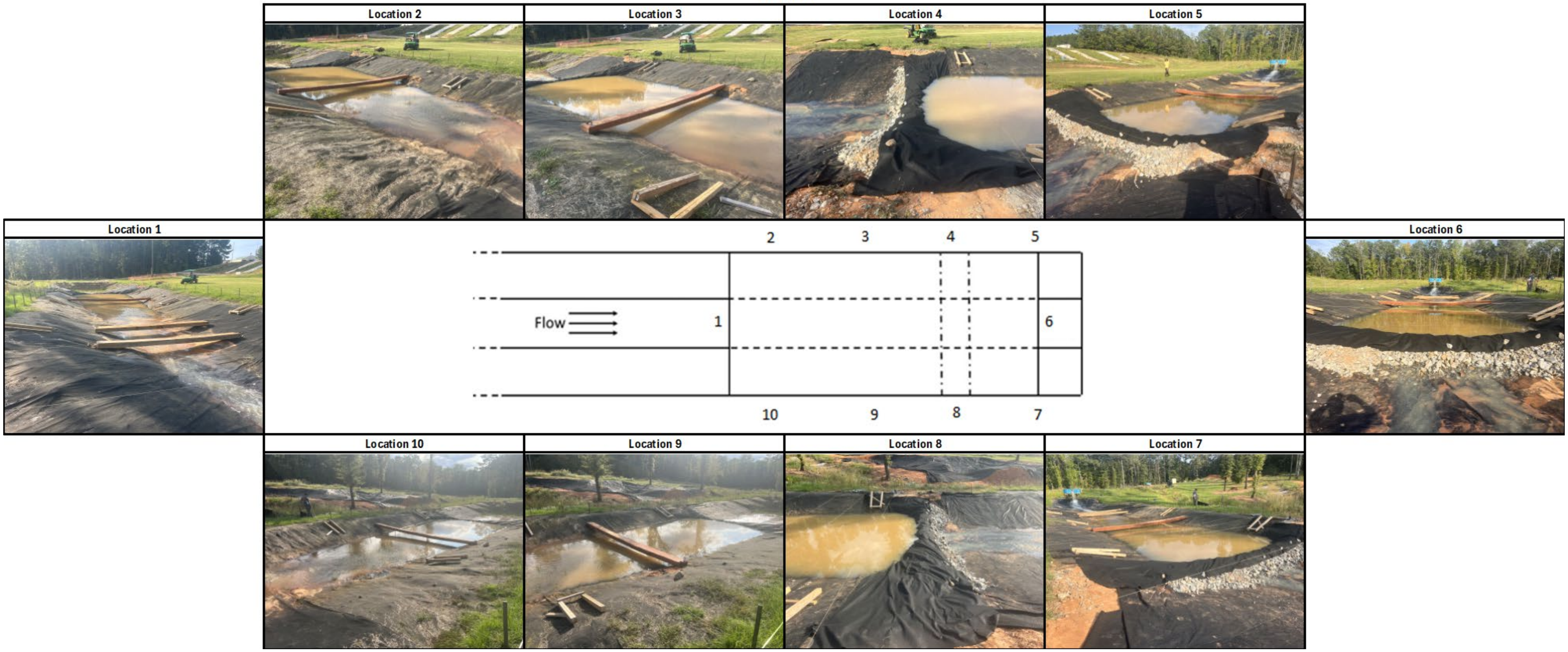
0.85 cfs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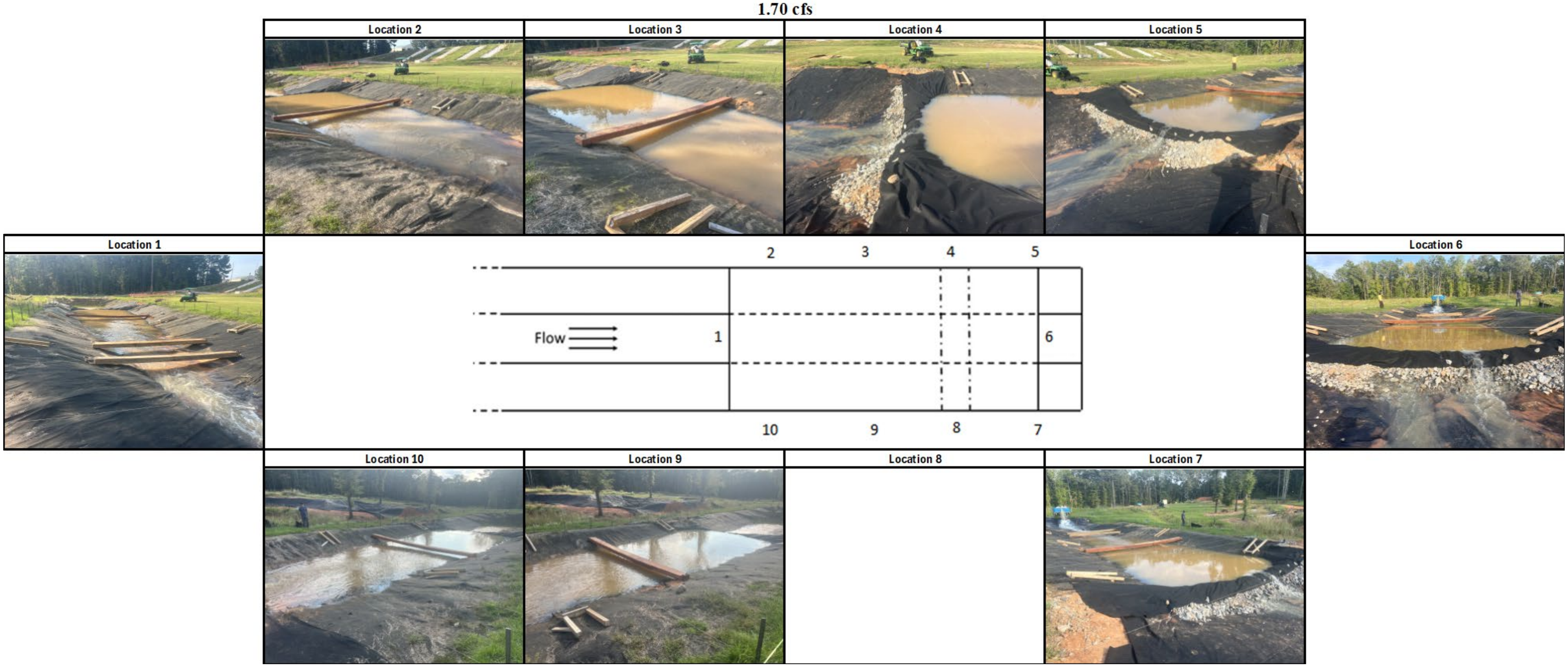
1.70 cfs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Location 9
Location 8
Location 7

Date: 11/22/2024
Installation: Smaller Rock Dewatering Holes – T1
Techs and Workers:

Start Time: 10:22 AM
End Time: 11:45 AM

Installation Descr.: Smaller rock on grade w/ geotextile overlay and dewatering holes

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North							0.08	0.07	0.17
Center							0.08	0.14	0.12
South							0.10	0.08	0.11
Top Width (in.)							96	116	128
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.20	0.35	0.31	0.56	0.58	0.70	0.64	0.15	0.12
Center	0.34	0.45	0.55	0.63	0.77	0.83	0.98	0.10	0.06
South	0.28	0.32	0.47	0.50	0.72	0.82	1.04	0.21	0.12
Top Width (in.)	149	154	165	180	184	189	200	78	96
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North							0.15	0.14	0.23
Center							0.23	0.24	0.16
South							0.28	0.22	0.19
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.21	0.35	0.31	0.58	0.61	0.71	0.65	0.12	0.31
Center	0.37	0.47	0.56	0.63	0.78	0.84	0.99	0.16	0.09
South	0.43	0.36	0.52	0.54	0.75	0.84	1.06	0.32	0.28

Length of pool upstream of ditch check (ft): 34.3

Comments/Observations During Test:
Immediate flow through

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North					0.18	0.17	0.31	0.41	0.71
Center					0.19	0.21	0.29	0.36	0.62
South					0.11	0.07	0.27	0.42	0.65
Top Width (in.)					76	68	126	128	194
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.73	0.85	0.92	1.17	1.29	1.43	1.42	0.22	0.18
Center	0.92	1.04	1.20	1.30	1.45	1.55	1.71	0.15	0.11
South	0.81	0.95	1.11	1.21	1.41	1.55	1.80	0.21	0.14
Top Width (in.)	200	218	226	243	247	251	250	95	100
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North					0.45	0.56	0.33	0.43	0.73
Center					0.62	0.62	0.57	0.56	0.69
South					0.67	0.41	0.35	0.44	0.66
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.76	0.88	0.94	1.19	1.30	1.45	1.43	0.44	0.47
Center	0.94	1.09	1.22	1.30	1.46	1.57	1.72	0.23	0.16
South	0.83	0.96	1.12	1.24	1.42	1.59	1.81	0.39	0.36

Length of pool upstream of ditch check (ft): 52

Dewatering Time:

Comments/Observations During Test:
Impounded to 53 feet with pump off

Date: 11/26/2024 **Start Time:** 9:25 AM
Installation: Smaller Rock Dewatering Holes - T2 **End Time:** 11:10 AM
Techs and Workers:

Installation Descr.: Smaller rock on grade w/ geotextile overlay and dewatering holes

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North			0.12	0.05	0.11	0.30	0.35	0.52	0.71
Center			0.23	0.07	0.18	0.35	0.46	0.51	0.66
South			0.21	0.21	0.24	0.35	0.35	0.36	0.56
Top Width (in.)			34	66	102	106	154	184	194
H_{water}(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North	0.76	0.86	0.99	1.15	1.24	1.35	1.38	0.16	0.12
Center	0.93	1.09	1.16	1.29	1.43	1.51	1.68	0.10	0.09
South	0.92	0.86	1.11	1.16	1.40	1.53	1.69	0.18	0.13
Top Width (in.)	204.00	214	228	239	250	244	249	77	91
$H_{velocity}$(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North			0.47	0.26	0.18	0.32	0.37	0.53	0.72
Center			0.41	0.27	0.22	0.36	0.52	0.51	0.68
South			0.37	0.55	0.44	0.42	0.36	0.61	0.68
$H_{velocity}$(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North	0.77	0.86	0.99	1.16	1.25	1.36	1.41	0.21	0.25
Center	0.95	1.09	1.16	1.29	1.44	1.51	1.70	0.23	0.14
South	0.95	0.91	1.12	1.17	1.42	1.55	1.70	0.25	0.21

Length of pool upstream of ditch check (ft): 57

Comments/Observations During Test:
Effective height of erosion stone is much more consistent than the large class stone

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.22	0.08	0.12	0.25	0.52	0.60	0.76
Center			0.29	0.11	0.18	0.36	0.57	0.51	0.79
South			0.16	0.17	0.16	0.41	0.42	0.46	0.72
Top Width (in.)			42	72	110	120	122	132	178
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.85	0.95	1.08	1.25	1.29	1.48	1.48	0.22	0.21
Center	1.00	1.15	1.25	1.35	1.51	1.62	1.75	0.14	0.24
South	0.98	1.06	1.20	1.31	1.48	1.60	1.82	0.23	0.14
Top Width (in.)	208	219	227	244	248	256	262	76	98
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.66	0.45	0.24	0.27	0.54	0.61	0.77
Center			0.85	0.61	0.47	0.38	0.66	0.56	0.81
South			0.68	0.78	0.49	0.48	0.51	0.53	0.75
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.85	0.97	1.09	1.25	1.31	1.49	1.49	0.36	0.42
Center	1.01	1.17	1.27	1.37	1.52	1.64	1.76	0.27	0.33
South	1.01	1.07	1.23	1.32	1.48	1.61	1.83	0.42	0.34

Length of pool upstream of ditch check (ft): 56

Dewatering Time:

Comments/Observations During Test:

Date: 12/12/24 **Start Time:** 8:39 AM

Installation: Smaller Rock Dewatering Holes - T3 **End Time:**

Techs and Workers:

Installation Descr.: Smaller rock on grade w/ geotextile overlay and dewatering holes

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North			0.16	0.04	0.20	0.11	0.39	0.50	0.69
Center			0.21	0.11	0.26	0.31	0.44	0.51	0.66
South			0.13	0.12	0.32	0.37	0.41	0.46	0.57
Top Width (in.)			42	68	98	126	158	172	188
H_{water}(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North	0.79	0.93	0.92	1.18	1.18	1.28	1.60	0.12	0.14
Center	0.84	1.02	1.11	1.18	1.36	1.44	1.59	0.11	0.11
South	0.73	0.83	0.96	1.00	1.31	1.50	1.32	0.15	0.12
Top Width (in.)	192	208	226	234	236	242	250	88	93
$H_{velocity}$(ft.)	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9
North			0.41	0.26	0.22	0.11	0.41	0.50	0.72
Center			0.48	0.26	0.31	0.33	0.46	0.52	0.66
South			0.31	0.56	0.46	0.51	0.49	0.51	0.63
$H_{velocity}$(ft.)	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17 (DS)	CS18 (DS)
North	0.80	0.94	0.94	1.19	1.19	1.29	1.62	0.25	0.27
Center	0.84	1.02	1.12	1.20	1.36	1.45	1.61	0.13	0.18
South	0.76	0.86	0.97	1.03	1.32	1.52	1.66	0.25	0.22

Length of pool upstream of ditch check (ft): 58.5

Comments/Observations During Test:

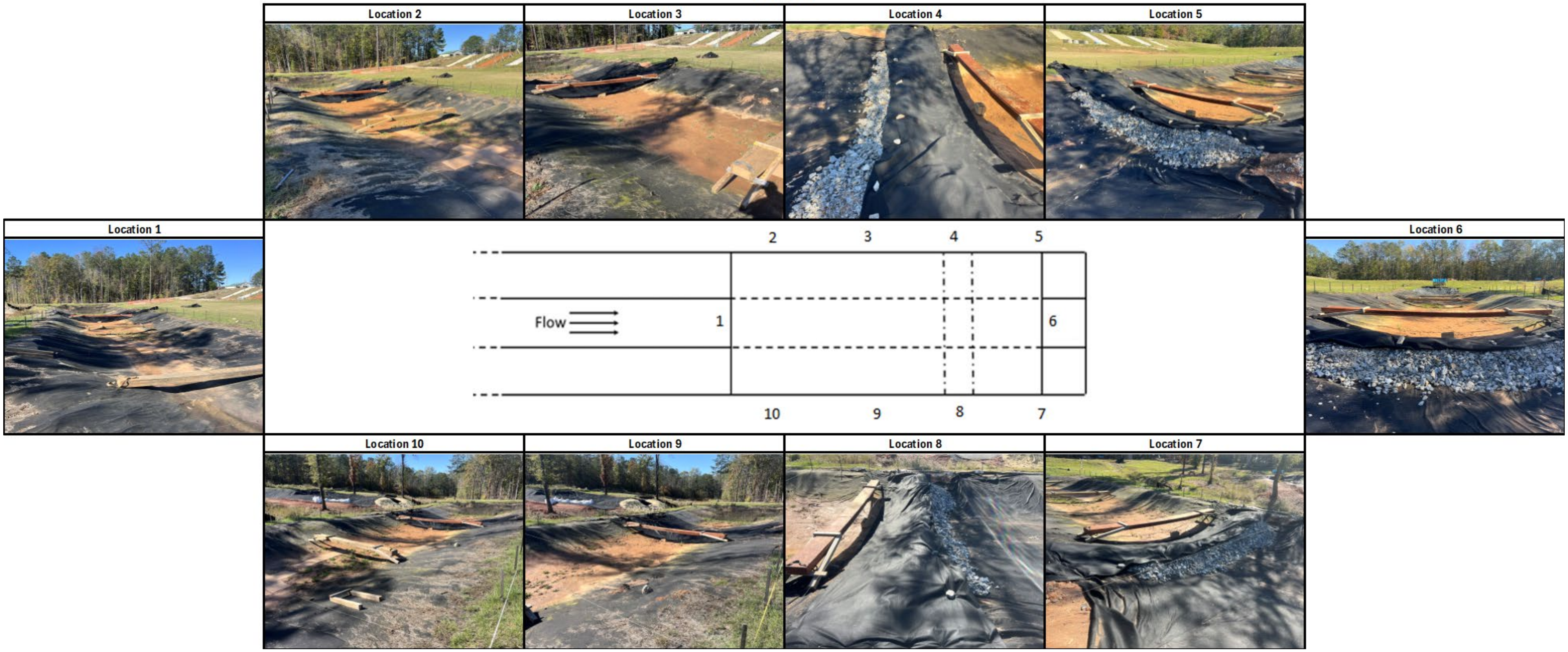
Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.18	0.11	0.26	0.39	0.45	0.58	0.76
Center			0.31	0.18	0.32	0.42	0.55	0.49	0.80
South			0.21	0.17	0.18	0.42	0.34	0.56	0.73
Top Width (in.)			42	72	116	148	170	184	188
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.85	0.96	1.06	1.21	1.23	1.43	1.48	0.21	0.18
Center	0.99	1.14	1.22	1.35	1.48	1.58	1.76	0.15	0.15
South	0.81	0.96	0.96	1.13	1.34	1.65	1.83	0.22	0.13
Top Width (in.)	202	224	230	236	242	254	256	82	104
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North			0.66	0.48	0.34	0.42	0.46	0.58	0.76
Center			0.66	0.61	0.36	0.45	0.60	0.49	0.81
South			0.54	0.74	0.67	0.52	0.51	0.61	0.76
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.85	0.97	1.08	1.24	1.25	1.44	1.49	0.29	0.38
Center	1	1.15	1.23	1.36	1.48	1.60	1.77	0.21	0.21
South	0.84	0.98	0.98	1.16	1.36	1.67	1.85	0.34	0.31

Length of pool upstream of ditch check (ft): 58

Dewatering Time:

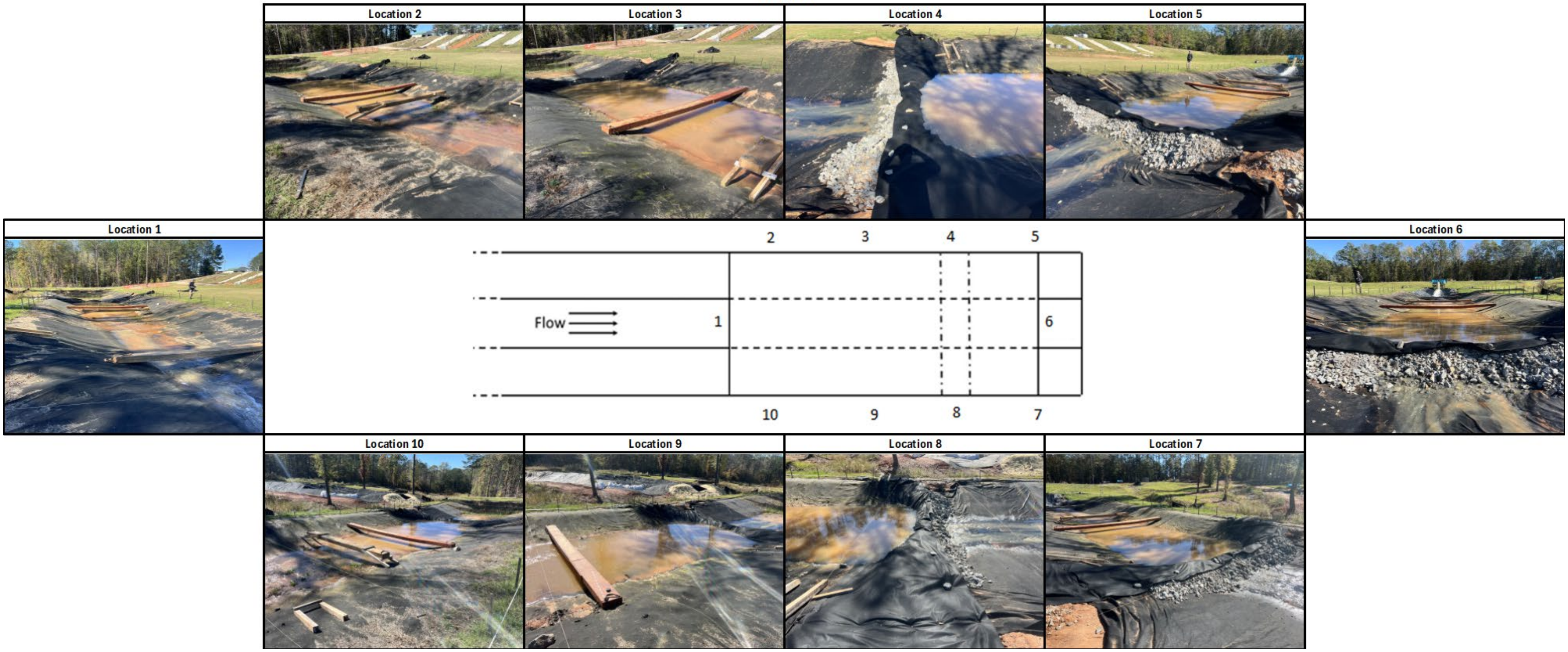
Comments/Observations During Test:

Pre-Test



Location 2
Location 3
Location 4
Location 5
Location 1
Location 6
Location 10
Location 9
Location 8
Location 7
Flow
1
2
3
4
5
6
7
8
9
10

0.85 cfs


Location 2
Location 3
Location 4
Location 5
Location 1
Location 6
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Flow
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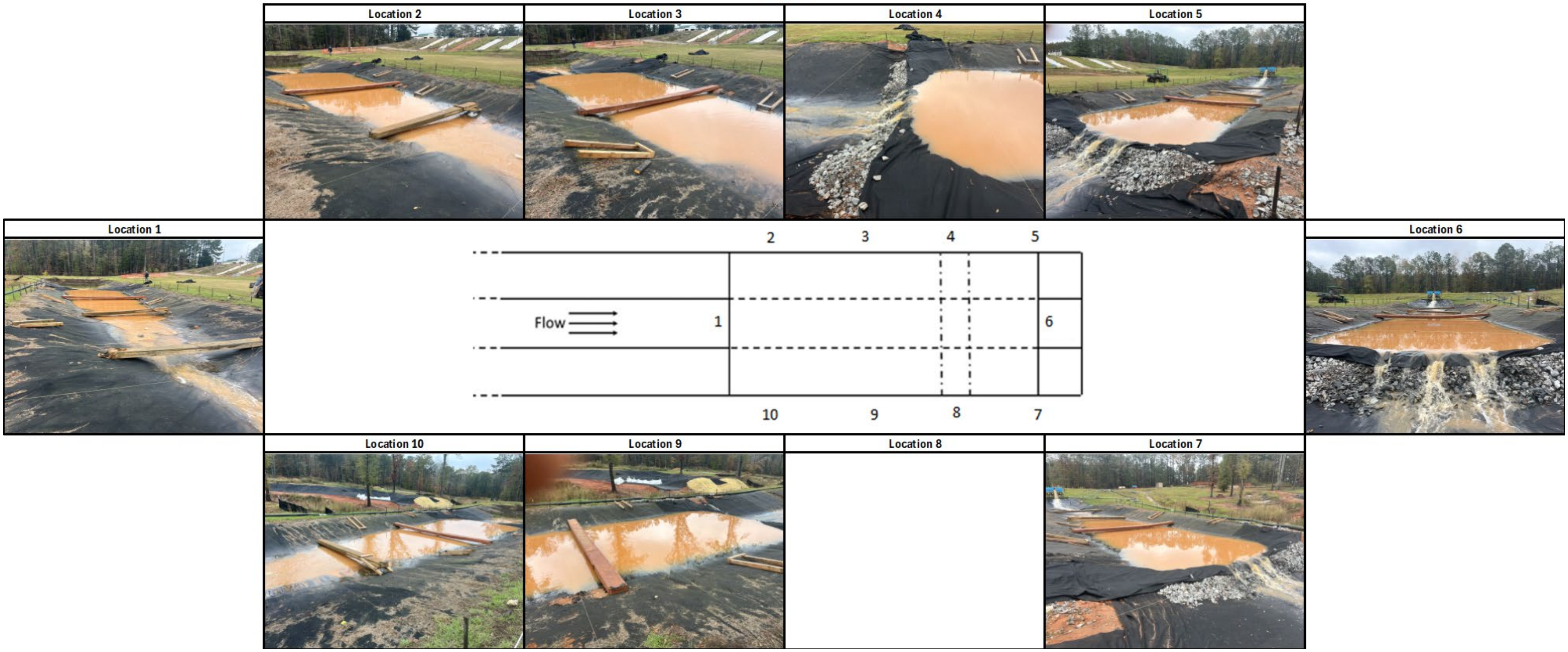
Location 10
Location 9
Location 8
Location 7

1.70 cfs


Location 2
Location 3
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Flow
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Location 6
Location 10
Location 9
Location 8
Location 7

Date: 2/11/2025
Installation: Reduced Profile - T1
Techs and Workers:

Start Time: 10:10 AM
End Time: 12:37 PM

Installation Descr.: Smaller rock, on grade, geotextile overlay w/ dewatering holes and reduced width to 4 ft

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H$_{water}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.29	0.15	0.13	0.25	0.35	0.52	0.55	0.76
Center		0.32	0.23	0.11	0.41	0.44	0.64	0.65	0.81
South		0.31	0.18	0.23	0.37	0.45	0.50	0.66	0.70
Top Width (in.)		36	43	89	146	154	178	190	200
H$_{water}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.85	0.95	0.98	1.19	1.20	1.41	1.43	0.11	0.14
Center	1.00	1.14	1.21	1.28	1.43	1.50	1.58	0.06	0.11
South	0.79	0.91	0.98	1.12	1.36	1.50	1.62	0.04	0.08
Top Width (in.)	204	220	228	236	248	246	255	114	106
H$_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.42	0.38	0.16	0.25	0.35	0.53	0.55	0.76
Center		0.45	0.51	0.22	0.45	0.45	0.64	0.66	0.81
South		0.38	0.52	0.53	0.42	0.51	0.53	0.68	0.72
H$_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.85	0.95	0.98	1.20	1.21	1.42	1.44	0.29	0.35
Center	1.01	1.16	1.23	1.29	1.43	1.51	1.61	0.21	0.28
South	0.82	0.94	1.00	1.12	1.37	1.51	1.63	0.26	0.22

Length of pool upstream of ditch check (ft): 59

Comments/Observations During Test:
Cross sections are now 3 feet further up (i.e., 5 feet is now 8 feet)

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.40	0.21	0.22	0.35	0.48	0.35	0.75	0.98
Center		0.42	0.25	0.27	0.47	0.55	0.75	0.80	0.99
South		0.30	0.26	0.19	0.47	0.57	0.63	0.80	0.94
Top Width (in.)		46	46	90	154	158	182	194	212
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.09	1.08	1.17	1.43	1.41	1.58	1.48	0.15	0.23
Center	1.22	1.35	1.46	1.54	1.71	1.88	1.91	0.12	0.11
South	1.15	1.15	1.30	1.29	1.63	1.61	1.72	0.11	0.09
Top Width (in.)	224	234	240	260	264	268	274	118	118
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.65	0.65	0.34	0.36	0.48	0.66	0.76	1.00
Center		0.65	0.72	0.53	0.54	0.57	0.77	0.81	1.01
South		0.44	0.61	0.61	0.63	0.65	0.72	0.84	1.02
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1.1	1.09	1.19	1.44	1.42	1.59	1.48	0.43	0.56
Center	1.25	1.36	1.46	1.56	1.72	1.91	1.92	0.33	0.31
South	1.17	1.22	1.32	1.33	1.66	1.62	1.73	0.38	0.39

Length of pool upstream of ditch check (ft): 58

Dewatering Time:

Comments/Observations During Test:
64 feet with pump off

Date: 2/14/2025 **Start Time:** 10:23 AM
Installation: Reduced Profile - T2 **End Time:**
Techs and Workers:

Installation Descr.: Smaller rock, on grade, geotextile overlay w/ dewatering holes and reduced width to 4 ft

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.19	0.12	0.14	0.28	0.39	0.56	0.63	0.86
Center		0.28	0.20	0.17	0.42	0.47	0.63	0.74	0.89
South		0.26	0.19	0.21	0.40	0.42	0.55	0.68	0.76
Top Width (in.)		41	40	94	144	150	178	206	208
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.94	1.03	1.11	1.31	1.45	1.49	1.56	0.10	0.11
Center	1.11	1.25	1.32	1.42	1.59	1.69	1.78	0.05	0.14
South	0.95	0.99	1.18	1.06	1.36	1.41	1.50	0.11	0.07
Top Width (in.)	218	228	239	254	259	254	256	130	106
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.59	0.32	0.16	0.29	0.40	0.57	0.63	0.87
Center		0.39	0.46	0.25	0.45	0.48	0.66	0.75	0.92
South		0.36	0.34	0.44	0.48	0.45	0.59	0.73	0.81
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.94	1.03	1.11	1.31	1.46	1.52	1.56	0.30	0.33
Center	1.12	1.26	1.33	1.46	1.60	1.72	1.81	0.17	0.28
South	0.97	1.02	1.19	1.10	1.41	1.42	1.52	0.31	0.13

Length of pool upstream of ditch check (ft): 57

Comments/Observations During Test:

Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.35	0.13	0.20	0.33	0.47	0.64	0.70	0.93
Center		0.45	0.22	0.20	0.43	0.55	0.71	0.71	0.95
South		0.39	0.23	0.32	0.41	0.52	0.59	0.69	0.91
Top Width (in.)		35	47	114	150	166	184	199	214
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.91	1.11	1.10	1.22	1.22	1.51	1.49	0.13	0.18
Center	1.16	1.31	1.42	1.51	1.67	1.88	1.94	0.16	0.12
South	1.05	1.11	1.18	1.37	1.54	1.66	1.76	0.12	0.17
Top Width (in.)	228	233	248	260	262	267	274	122	124
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.70	0.51	0.22	0.33	0.47	0.65	0.71	0.95
Center		0.52	0.60	0.26	0.66	0.56	0.73	0.72	0.96
South		0.49	0.55	0.65	0.56	0.59	0.69	0.73	0.96
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.95	1.12	1.11	1.24	1.22	1.52	1.49	0.36	0.48
Center	1.17	1.32	1.44	1.53	1.68	1.89	1.95	0.34	0.36
South	1.07	1.13	1.22	1.38	1.56	1.67	1.78	0.35	0.32

Length of pool upstream of ditch check (ft): 56.5

Dewatering Time:

Comments/Observations During Test:

Date: 2/18/2025 **Start Time:** 8:34 AM
Installation: Reduced Profile - T3 **End Time:** 10:10 AM
Techs and Workers:

Installation Descr.: Smaller rock, on grade, geotextile overlay w/ dewatering holes and reduced width to 4 ft

Water Depth | Velocity Measurements

Flow Rate: 0.85 cfs (0-15 mins.)

Head Height									
H_{water}(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.26	0.14	0.10	0.31	0.36	0.55	0.64	0.88
Center		0.28	0.24	0.21	0.43	0.44	0.63	0.71	0.85
South		0.18	0.17	0.29	0.42	0.55	0.56	0.68	0.82
Top Width (in.)		34	54	88	148	150	178	202	206
H_{water}(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.96	1.00	1.17	1.28	1.39	1.56	1.69	0.09	0.12
Center	1.08	1.22	1.32	1.41	1.53	1.73	1.84	0.07	0.06
South	1.01	1.01	1.14	1.18	1.44	1.39	1.52	0.06	0.09
Top Width (in.)	216	231	238	246	250	255	260	114	86
$H_{velocity}$(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.51	0.38	0.12	0.32	0.37	0.56	0.65	0.88
Center		0.37	0.39	0.30	0.46	0.45	0.66	0.72	0.87
South		0.31	0.34	0.38	0.45	0.57	0.60	0.70	0.85
$H_{velocity}$(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.97	1.02	1.17	1.29	1.40	1.57	1.71	0.23	0.35
Center	1.09	1.23	1.33	1.42	1.54	1.74	1.85	0.33	0.17
South	1.01	1.04	1.16	1.19	1.47	1.41	1.53	0.22	0.22

Length of pool upstream of ditch check (ft): 60

Comments/Observations During Test:

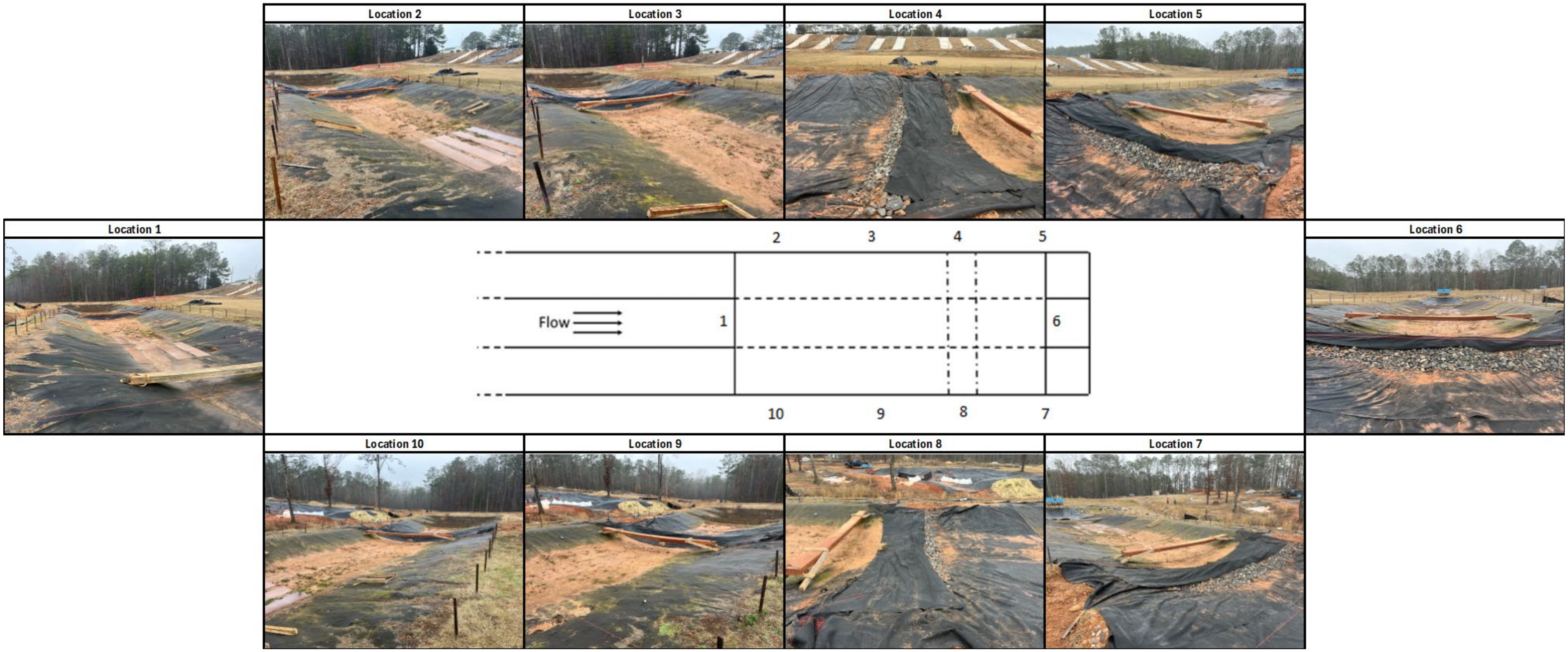
Flow Rate: 1.7 cfs (15-30 mins.)									
Head Height									
H**water**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.32	0.12	0.19	0.31	0.41	0.63	0.71	0.91
Center		0.38	0.22	0.16	0.46	0.55	0.73	0.75	0.93
South		0.33	0.26	0.21	0.42	0.52	0.55	0.72	0.91
Top Width (in.)		39	58	98	152	163	184	192	212
H**water**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	0.99	1.09	1.11	1.35	1.38	1.51	1.52	0.09	0.25
Center	1.15	1.32	1.43	1.51	1.67	1.79	1.92	0.08	0.21
South	1.04	1.11	1.30	1.25	1.51	1.50	1.72	0.12	0.19
Top Width (in.)	218	228	230	256	258	262	265	124	110
H**velocity**(ft.)	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**CS7**	**CS8**	**CS9**
North		0.72	0.50	0.21	0.32	0.41	0.64	0.72	0.92
Center		0.62	0.57	0.65	0.59	0.57	0.76	0.76	0.95
South		0.44	0.56	0.61	0.58	0.55	0.65	0.76	0.96
H**velocity**(ft.)	**CS10**	**CS11**	**CS12**	**CS13**	**CS14**	**CS15**	**CS16**	**CS17 (DS)**	**CS18 (DS)**
North	1	1.13	1.12	1.37	1.39	1.53	1.53	0.35	0.56
Center	1.19	1.36	1.45	1.52	1.68	1.81	1.93	0.25	0.35
South	1.06	1.12	1.31	1.26	1.52	1.51	1.74	0.39	0.32

Length of pool upstream of ditch check (ft): 58

Dewatering Time:

Comments/Observations During Test:
63 feet with pump off

Pre-Test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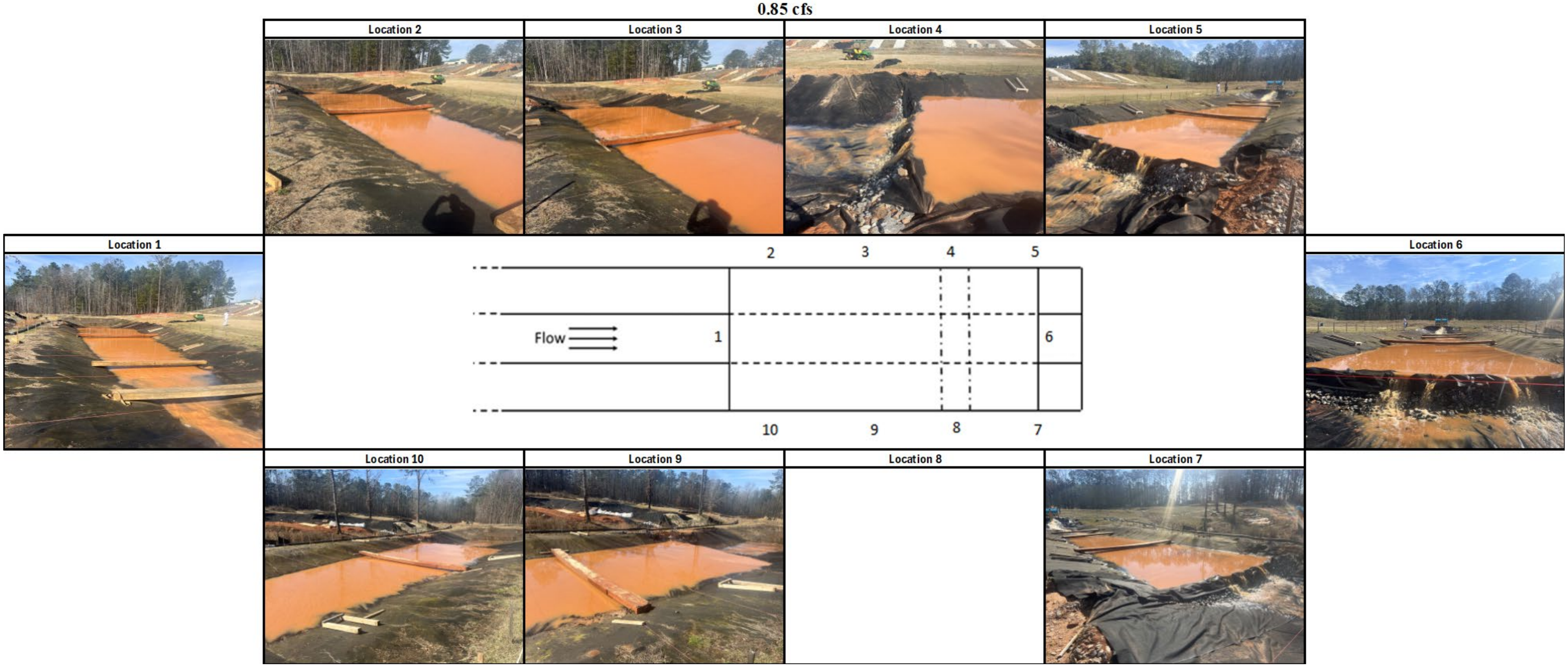
Location 8
Location 7

0.85 cfs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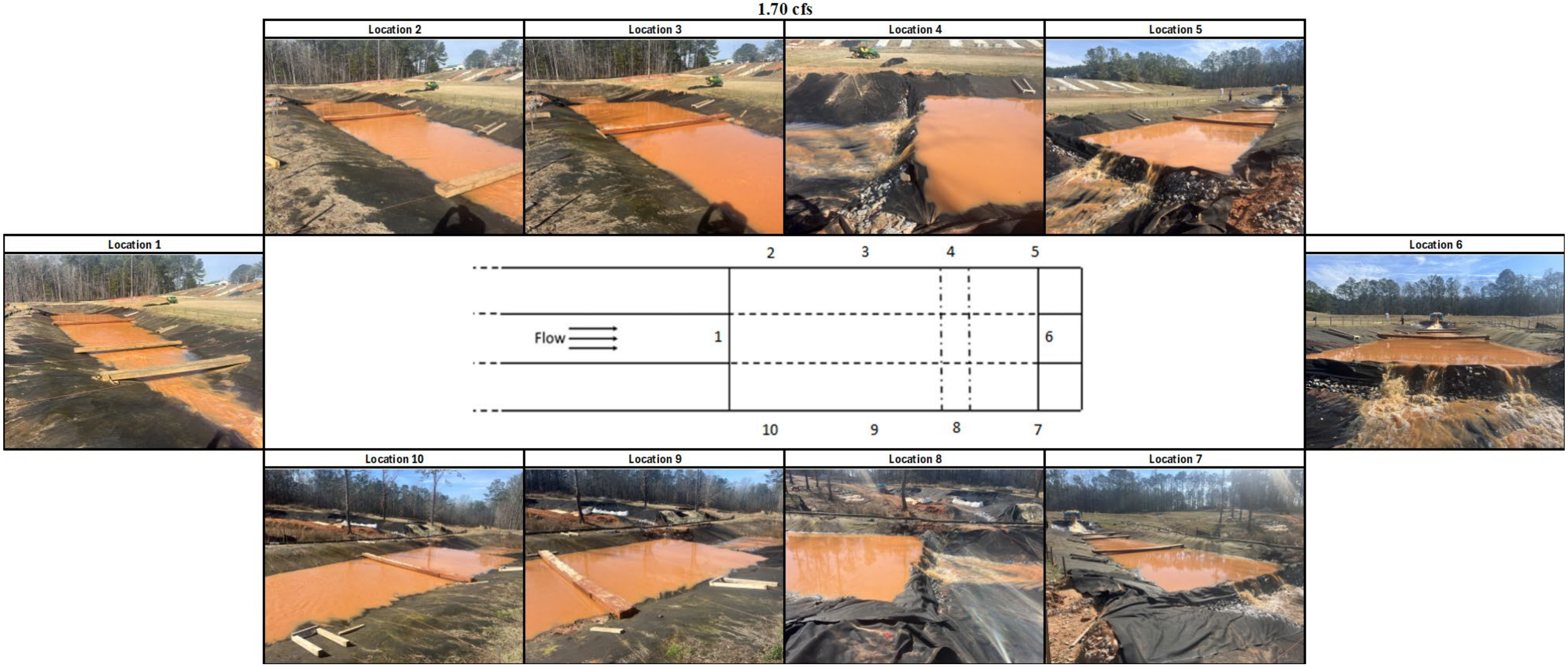
1.70 cfs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Iowa DOT Rock Check Dam Sediment- Laden Testing Data Sheet

Date: 4/28/2025 **Start Time:** 2:30 PM
Installation: Standard Sediment - T1 **End Time:** 3:00 PM
Techs and Workers:

Installation Descr.: Iowa DOT Standard Installation

Max Depth (ft): 0.33
Impoundment Length (ft): 7
Time of Overtop (min): N/A

Date: 4/29/2025 **Start Time:** 2:01 PM
Installation: Standard Sediment - T2 **End Time:** 2:31 PM
Techs and Workers:

Installation Descr.: Iowa DOT Standard Installation

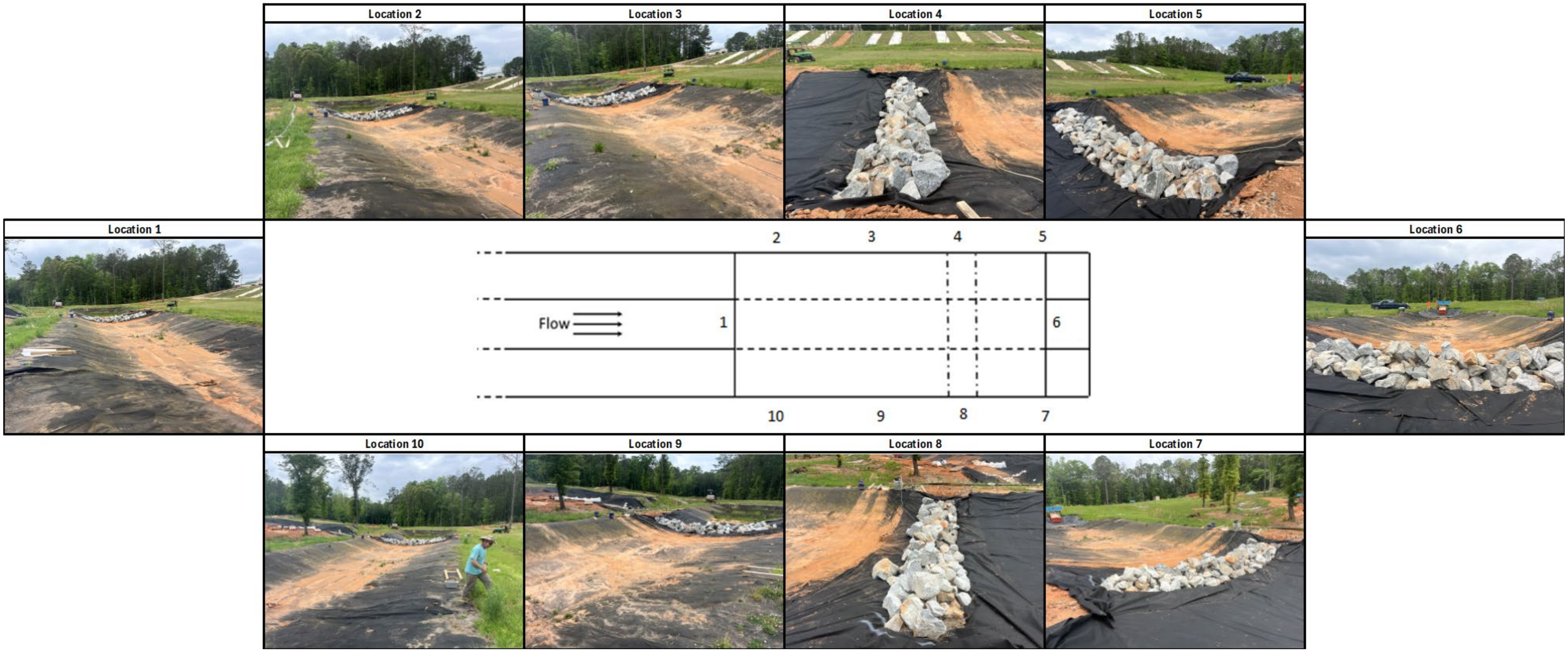
Max Depth (ft): 0.45
Impoundment Length (ft): 8
Time of Overtop (min): N/A

Date: 5/1/2025 **Start Time:** 10:51 AM
Installation: Standard Sediment - T3 **End Time:** 11:21 AM
Techs and Workers:

Installation Descr.: Iowa DOT Standard Installation

Max Depth (ft): 0.34
Impoundment Length (ft): 7.5
Time of Overtop (min): N/A

Pre-Test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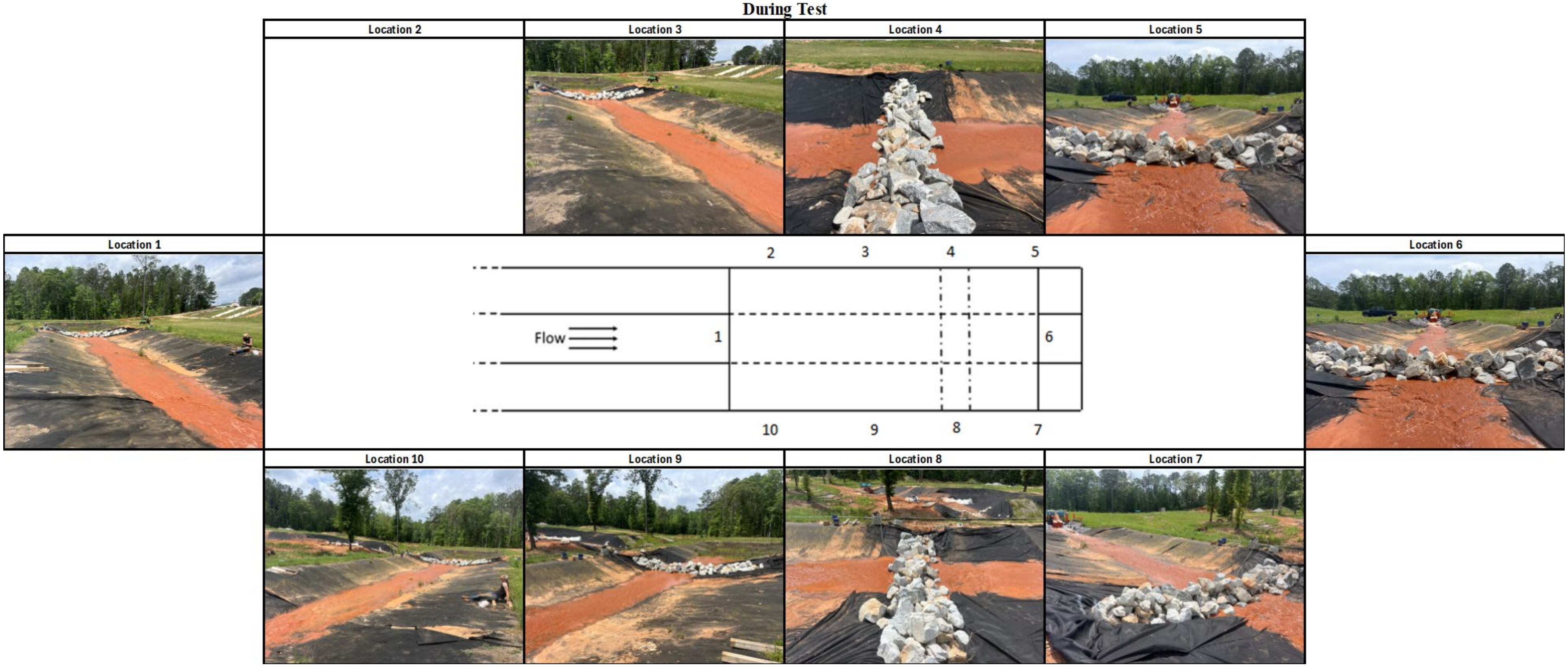
During Test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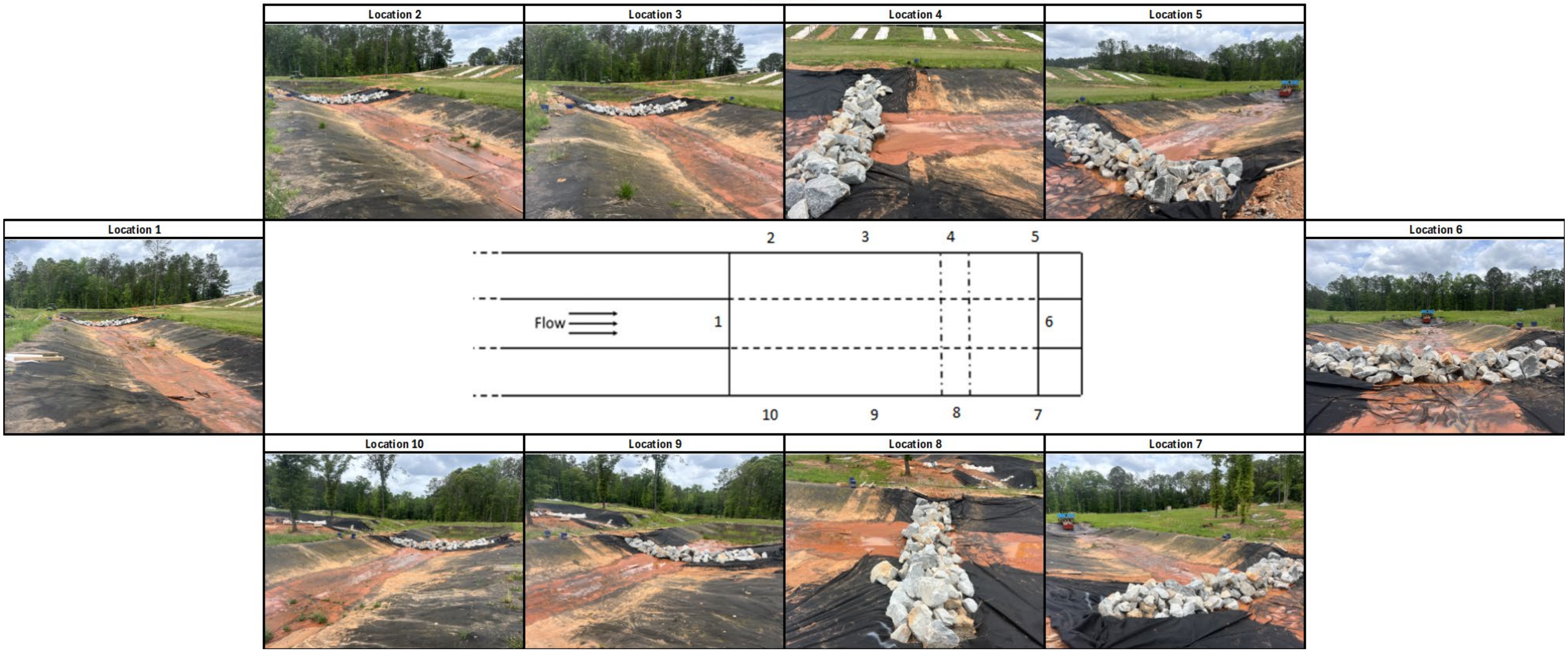
Post-Test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Iowa DOT Rock Check Dam Sediment- Laden Testing Data Sheet

Date: 3/3/2025 **Start Time:** 3:54 PM
Installation: MFE-I Sediment - T1 **End Time:** 4:24 PM
Techs and Workers:

Installation Descr.: Smaller rock, on grade, geotextile overlay w/ dewatering holes and reduced width to 4 ft

Max Depth (ft): 1.88
Impoundment Length (ft): 59
Time of Overtop (min): 9.5

Date: 3/4/2025 **Start Time:** 10:44 AM
Installation: MFE-I Sediment - T2 **End Time:** 11:14 AM
Techs and Workers:

Installation Descr.: Smaller rock, on grade, geotextile overlay w/ dewatering holes and reduced width to 4 ft

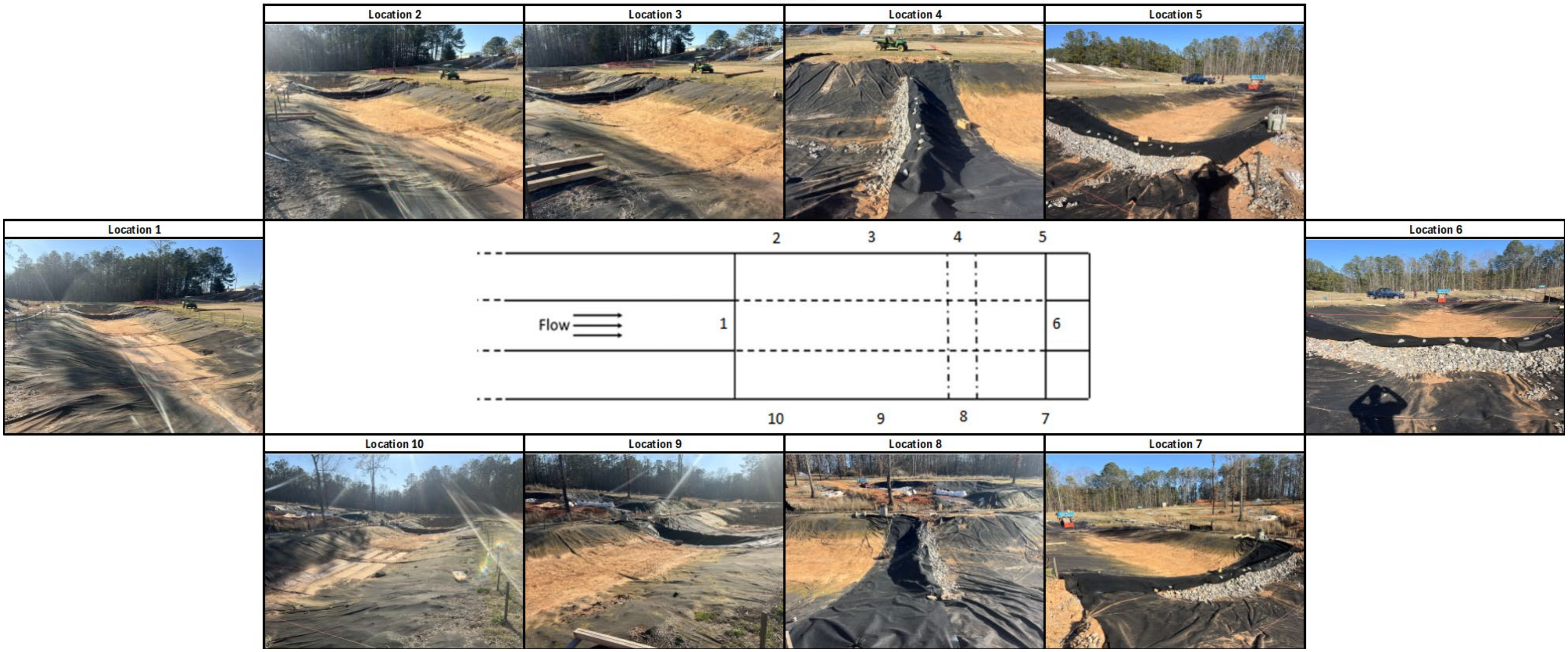
Max Depth (ft): 1.88
Impoundment Length (ft): 59
Time of Overtop (min): 5

Date: 3/21/2025 **Start Time:** 1:34 PM
Installation: MFE-I Sediment - T3 **End Time:** 2:04 PM
Techs and Workers:

Installation Descr.: Smaller rock, on grade, geotextile overlay w/ dewatering holes and reduced width to 4 ft

Max Depth (ft): 1.91
Impoundment Length (ft): 57
Time of Overtop (min): 4.8

Pre-Test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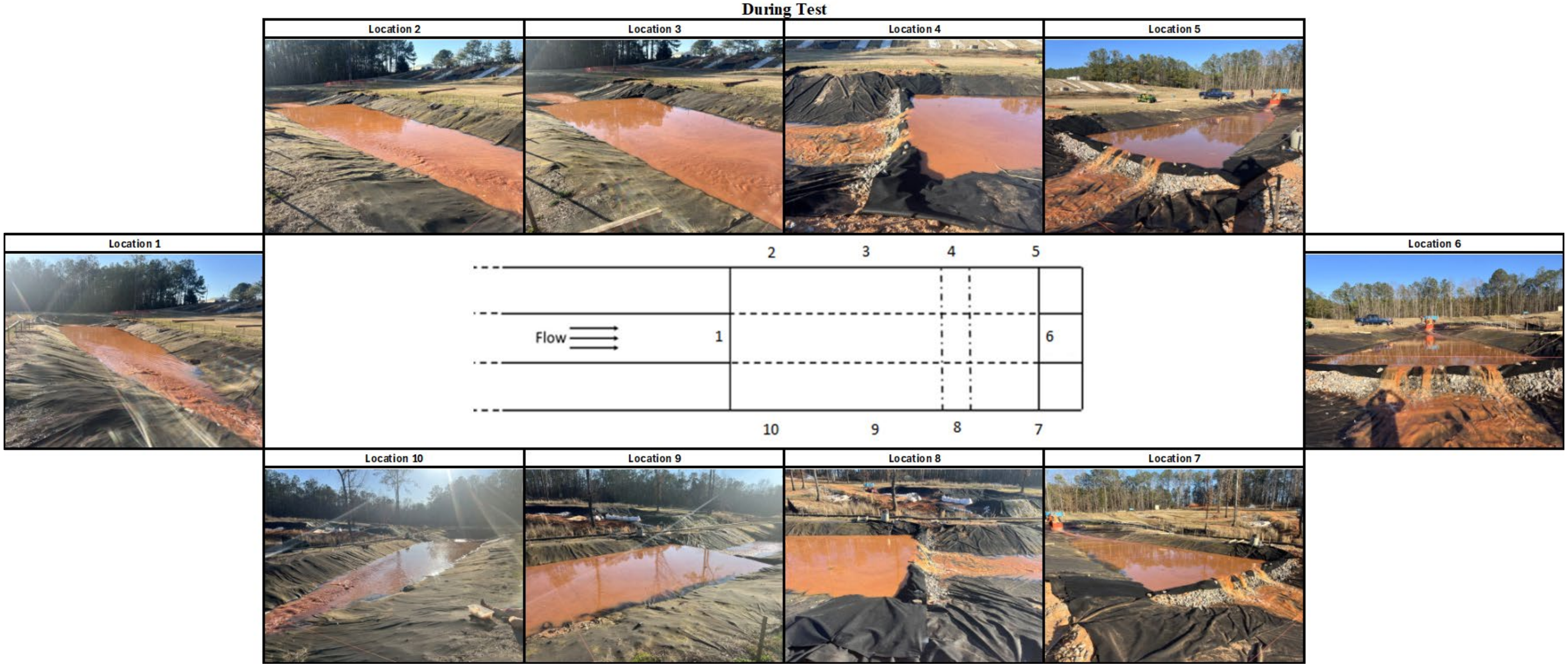
During Test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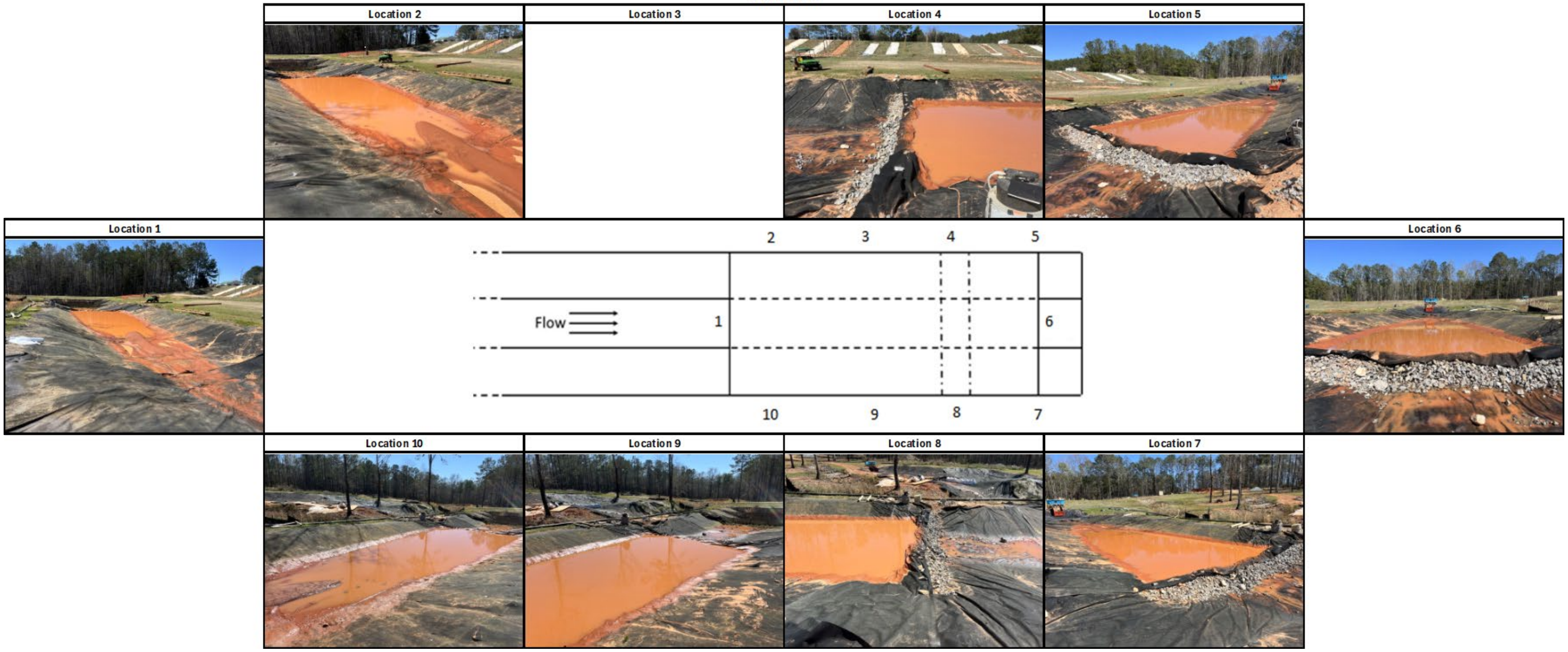
Post-Test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