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PERFORMANCE EVALUATION OF SEDIMENT BASIN DESIGNS FOR HIGHWAY CONSTRUCTION SITES IN TENNESSEE

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I am submitting herewith a thesis written by Jeffery Cole Emmett Jr entitled "PERFORMANCE EVALUATION OF SEDIMENT BASIN DESIGNS FOR HIGHWAY CONSTRUCTION SITES IN TENNESSEE." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.

John S. Schwartz, Major Professor

We have read this thesis and recommend its acceptance:

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PERFORMANCE EVALUATION OF SEDIMENT BASIN DESIGNS FOR HIGHWAY CONSTRUCTION SITES IN TENNESSEE

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Jeffery Cole Emmett Jr.
December 2022

ABSTRACT

Performance of three sediment basin designs were tested; they were: 1) the TDEC standard design with a forebay, 2) the TDOT design with an inlet check dam, and 3) the TDOT standard design that does not include an inlet check dam. An 1/17 of an acre scaled physical model sediment basin, was constructed next to an elevated outdoor open flume used to mix known water volumes and sediment mass routed by gravity-flow into the basin. The measurement for performance was simply the percent sediment mass retained in the basin from the total input per experimental run (percent sediment removal). Three experimental replicates per design were completed. Sediment was analyzed by concentrations, loads, and particle size distributions (PSDs). All designs were above the 80% removal regulatory requirement for Tennessee: with TDOT, TDEC, and TDOT with check dam design achieving a total percent sediment removal of 95.4 %, 98.2 %, and 97.9 %, respectively. PSD data from the experiments provided key information for developing a sediment-basin design model to account for differential particle size settling. In addition, these experimental results were compared with sediment basin performance data collected at active highway construction sites, as well as from other published experimental studies.

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CHAPTER 1: INTRODUCTION

Stormwater control measures (SCMs) are best management practices (BMP) used during construction projects to avert or intercept the transportation of sediment from construction sites from entering lakes, streams, and other surface waters. Stormwater runoff from construction sites is enforced by state water quality and storm water regulations. Sediment carries different nutrients and pollutants which have the potential to negatively impact surface water qualities and aquatic wildlife (EPA, 2022). Due to the extremely high potential of erosion on disturbed land, construction sites are potentially a major source of sediment despite though having a relatively small footprint in a watershed (Hangul, 2017).

The TDOT has developed standard drawings and designs for SCMs to meet state water quality standards and storm water regulations from the Tennessee Department of Environment and Conservation (TDEC). From the Tennessee National Pollution Discharge Elimination System (NPDES) General Permit for Discharges of Stormwater Associated with Construction Activities, construction activities must meet an effluent standard requiring 80 percent reduction in total suspended solids (TSS). Discharges covered by the TN NPDES general permit include stormwater point source discharges where soil disturbing activities of one or more acres are located, discharges from support activities associated with a construction activity, and non-stormwater discharges identified in a stormwater pollution prevention plan (SWPPP). Also, the TN NPDES general permit states “the stormwater discharge must not contain total suspended solids, turbidity, or color in such amounts or character that will result in any objectionable appearance compared to the turbidity or color of the receiving water…” (Section 6.3.2.C TDEC 2021). Additionally, regulations require “the stormwater discharge shall not contain pollutants in quantities that will be hazardous or otherwise detrimental to humans, livestock, wildlife, plant life, or fish and aquatic life in the receiving stream" (Section 6.3.2.D TDEC 2021). Thus, it is important to meet these regulatory narratives and standards through construction site SCMs to prevent any negative impact on water or habitat quality.

Two types of SCMs are recognized in the Tennessee Department of Transportation (TDOT) Drainage Manual: vegetative and structural measures (TDOT, 2012). Vegetative SCMs protect the soil from being eroded from rainfall while structural SCMs are physical structures designed to receive and treat stormwater (TDOT, 2012). The most used structural SCMs employed on TDOT project sites are silt fence, silt fence with wire backing, rock check dams, enhanced rock check dams, and sediment tubes (Hangul, 2017). All of which reduce sediment transport by slowing stormwater runoff, creating ponding, and allow for deposition of sediment at the structure. Another SCM used by TDOT is the sediment basin. Sediment basins detain stormwater runoff and reduce sedimentation by promoting gravity settling to occur while discharging from the water surface. Sediment basins, more commonly used in residential site developments, are also used in highway construction sites. Sediment basins are suitably constructed in a drainage area through excavation or embankments to effectively collect and retain sediment. TDOT defines a sediment basin as having an excavated reservoir that includes an embankment, impound area, outlet riser with a principal spillway outlet pipe through the embankment, a surface dewatering device, and an emergency spillway (TDOT, 2012). Design criteria and standard drawings for sediment basins are somewhat similar among agencies, and most design features directly impact the sediment trapping efficiency. Table 1 provides a summary of common design criteria for a sediment basin between TDEC, TDOT, South Carolina Department of Health and Environmental Control (SC DHEC), North Carolina Department of Environmental Quality (NC DEQ), Pennsylvania Department of Transportation (PDOT), and the

Georgia Soil and Water Conservation Commission (GSWCC). Additionally, two outlet risers are commonly used and accepted between these agencies: the Faircloth Skimmer® and a perforated riser (Appendix A).

There are many issues concerning the design of highway construction site SCMs (Smith, 2018). A main issue is the linear site constraints that come with highway construction sites. Only being able to access the right-of-way (ROW) limits the placement and sizing of the sediment basin and purchasing additional land would not be a cost-effective practice. TDEC requires a forebay at the inlet of a sediment basin, which could add to the space constraint issue. The hydrology is also impacted by the linear constraints. Typically, highway corridor drainage areas operate linearly and can have multiple discharge locations. Thus, designing based on the total exposed surface area could lead to inaccuracy and often leads to an oversized sediment basin. Accurate basin delineation is required for the correct design of a basin, which is affected by the topography of the construction site. Run-on water may need to be considered in linear construction sites and could mean that extra water enters the basin or will need to be rerouted away from the basin (Smith, 2018). Additionally, the forebay requirements for a sediment basin require more space, which may not be applicable for highway construction sites.

There is a scarce amount of literature discussing the performance of sediment basins. The sediment basin has the highest removal efficiencies of any other large scale SCMs (McCaleb & McLaughlin, 2008). One study comparing the retention between different sediment traps and basins showed that the sediment basin achieved the highest retention efficiency at 99.6 % while the second closest was the standard trap with silt fence at 45 % retention (McCaleb & McLaughlin, 2008). Most studies compare the effectiveness between a surface skimmer and a perforated riser. Faircloth skimmers have a higher retention efficiency compared to a perforated riser when subjected to the same conditions. A study by J.A. Millen, et. al (1997), showed a skimmer having a retention efficiency of 96.8% while the perforated riser was 94.2%. A similar trend was seen in another study, showing a skimmer with a higher retention efficiency than a perforated riser, 94.2 % and 91.7 % (Rauhofer, et al., 2001). Furthermore, perforated risers are shown to have higher suspended sediment concentrations in the effluent of the basin when compared to a surface skimmer (Millen, et al., 1997). This is probably due that perforated risers do not strictly dewater the basin from the water surface like a skimmer would. Increasing the delay time between the inflow and outflow of the basin led to an increase in retention efficiency; no delay had 96.8%, 12 hours had 97.9% (Bidelspach, et al., 2004). Increasing the delay time allows for more sediment to settle into the permanent pool and for some water to infiltrate into the ground.

One aspect about designing sediment basins that has even less literature on performance is the forebay. No study has directly compared the performance of sediment basins with and without forebays nor quantified the particle size distribution (PSD) of sediment deposited. It is known that forebays capture a large about incoming sediment and could provide an ease of sediment cleanout; a large-scale study of one sediment basin showed that the whole basin captured 76 % of sediment with the forebay contributing 61.5% to that capture percentage (Fang, et al., 2015). However, this study did not compare the sediment capture efficiency to another basin with same geometry and parameters without a forebay. Without this comparison it is difficult to determine the true performance a forebay has when added to the inlet of a sediment basin.

Table 1. Comparison of Sediment Basin Design Criteria

Design Standard	**TDEC**	**TDOT**	**SC DHEC**	**NC DEQ**	**PDOT**	**GSWCC**
Acre Range	5-50	5-50	5-30	5-100	5-100	<150
Minimum L:W	4:1	2:1 (4:1)	2:1	2:1	2:1	2:1
Minimum H:V	2:1	2:1	2:1	2.5:1	2:1	2.5:1
Dewater Time (hours)	Max, 72 Min, none	Max, 168 Min, 72	Max, 120 Min, 48	Max, 120 Min, 48	Max, 168 Min, 48	Max, 72 Min, None
Forebay Requirement	Yes, 25% of wet storage	No	Yes, 20% of sediment storage	No	No	No
Principle Spillway Design Storm	2 or 5-year, 24-hour	2 or 5-year, 24-hour	10-year, 24-hour	2-year, 24-hour	Varies	2-year, 24-hour
Emergency Spillway Design Storm	25-year, 24-hour	25-year, 24-hour	100-year, 24-hour	10-year, 24-hour	2 cfs/acre	25-year, 24-hour

Only a few design tools are available for sediment basins: they include, Haestad Pond Pack™, a FEMA approved software program for hydrologic modeling and detention pond design (CULTEC, Inc., 2012), and an Excel spreadsheet program, SEDspread, created at Auburn University that designs a sediment basin using a design storm event (Auburn University, 2021). However, this program does not consider the site-specific soil composition (or PSD). Site-specific soil composition can provide settling velocities for use in the design of a sediment basin. Improving on sediment basin design, a model is needed to account for soil composition (or PSD). Overall, data and studies on the performance of sediment basins are limited.

The objective of this study is to compare performance through sediment removal efficiencies between three sediment basin designs through a constructed physical model basin with control experiments using known sediment and water inputs. The three design standards will be from TDOT, TDEC, and a modified TDOT with an inlet check dam (TDOT CD). The TDOT design will be a standard sediment basin without a forebay or any inlet protection; the TDEC design will have a forebay including two porous baffles, a rock check dam, and a minimum volume requirement equal to 25 percent of the wet storage (TDEC, 2021); finally, the modified TDOT will include only a rock check dam with no forebay requirements. Initial predictions are that the TDEC design will achieve the highest performance due to the addition of a forebay as an inlet protection, while the TDOT design is expected the perform the lowest due to no form of inlet protection, and the TDOT CD design will perform slightly better than the TDOT but less than the TDEC since the check dam is not as robust as a forebay. An Excel spreadsheet model was created to incorporate soil composition (or PSD) into the design of a sediment basin (Appendix C). Additionally, this study will compare data from pervious field studies on active construction sites from Smith, 2018.

CHAPTER 2: METHODS

The goal of this study was to build a scaled down physical model of a sediment basin to run controlled experiments with each basin modified to reflect the three different designs. Three different designs were chosen to test the sediment removal efficiencies as well as monitor the effluent being discharged. The three basin designs were a TDOT standard, TDEC standard, and a modified TDOT where a check dam is at the inlet of the basin. The designs were based on TDOT's Chapter 10 in the Erosion Prevention and Sediment Control Drainage Manual and TDEC's Erosion and Sediment Control Handbook (4th Edition). Both specify certain requirements for the design of a sediment basin as shown in Table 1 above.

2.1 Sediment Basin Design

For all three designs the main basin remained the same while only the inlet changed between the designs, essentially the TDOT design without an inlet check dam. The main basin design is summarized in Table 2 and visualized in Figure 1. The scaled-down physical model of the basin was not excavated, rather its frame was made using metal T-posts driven into the ground to achieve side slopes of 2:1 and then supported by a wooden support made of 2x4s. The frame was first lined with silt fence to evenly distribute the weight along the frame and then lined with 45 mil EPDM rubber roofing material to ensure the basin was watertight. For the TDEC design requiring a forebay, the existing ground before the basin was elevated roughly 1 foot and a plywood box with a length of 6.25 ft, width of 5.5 ft, and height of 1.5 ft was built. The forebay was also lined with the same rubber roofing material as in the main basin, Class A-1 rip-rap (D_{50} = 9 inches) was added where the main basin and forebay meet, and two porous baffles made of an erosion control blanket were put into the forebay as required by TDEC standards. Finally, to make the check dam, the forebay from the TDEC design was altered. The porous baffles were removed and the was cross section of the forebay was changed from rectangular to trapezoidal to comply with TDOT's design standard for a rock check dam (ET-STR-6). Since the TDOT design did not require a forebay/check dam, the section where the main basin and forebay/check dam meet was temporarily blocked off so only the main basin was being filled.

2.2 Outlet Riser for Dewatering

A 72-hour dewatering time was chosen since TDOT required a minimum dewatering time of 72-hours and TDEC requires a maximum of 72-hours. The "dry storage" is the total volume of water that is to be dewatered down to the permanent pool elevation. Two commoly used types of dewatering devices are the Faircloth Skimmer or a perforated riser. For these experiements, a perforated riser was used as the main form of dewatering as the Faircloth Skimmer® would be harder to size for such a small basin. The final design for the perforated riser came out to be three 3/16 inch orifices spaced 6 inches apart in the vertical with the lowest orifice at the permenant pool height.

2.3 Inlet Mixing Chamber

Since a known amount of water and soil was put into the basin during each experiment, a flume was used as a mixing chamber to allow the sediment to be evenly dispersed during the duration of pumping water into the basin. Afterwards, the sediment laden water was funneled to a 6-inch PVC pipe that discharged into the main basin for the TDOT standard design or the forebay/check dam for the TDEC and modified TDOT design (Figure 2). During the TDOT pumping, a temporary pipe was used to bypass the forebay. For the two types of sediment used in the mixing chamber the soil composition was 33 and 42 % clay, 59 and 50 % silt, and 8 %

sand. Using a soil texture triangle, the two sediments were classified as a silty clay and silty clay loam.

2.4 Sediment and Water Sample Collection

Sediment samples, water samples, and stage data were collected throughout each experiment. The sediment used for each experiment was a mixture of a silty clay and silty clay loam. Two 5-gallon buckets of each soil type (roughly 40-50 pounds) were added for each experiment. Additionally, a centrifugal trash pump (Honda, WT20X, Knoxville, TN) with a 2-inch diameter discharge outlet was used to pump water from a nearby slough of the Tennessee River to mix with the sediment fill the experimental basin. Sediment samples from any settled sediment in the forebay/check dam were taken from each TDEC and TDOT CD experiment and saved to later determine a particle size distribution (PSD). During the initial pumping of the basin (roughly 1 hour), three grab samples of the inlet sediment laden water were collected to determine the suspended sediment concentration (SSC). For the effluent of the basin, an ISCO® 3700 Portable Sampler (ISCO®, Lincoln, NE) collected 24 samples over the 72-hour dewatering period, roughly 1 sample per 3.1 hours) and stored for SSC analysis. Finally, two HOBO™ U20L Series Water Level logger (Onset®, Bourne, MA) stage recording devices were used and collected a pressure measurement every 30 seconds. One was placed in the bottom of the basin main basin to calculate the flow entering the basin, and the other was open to the atmosphere to account for barometric pressure.

Table 2. Main Sediment Basin Design

Design Parameter	**Value**
Bottom Length	23 ft
Bottom Width	1.5 ft
Top Length	28 ft
Top Width	9.5 ft
Side Slopes H:V	2.1:1
Total Height	2 ft
Permanent Pool Height	0.9 ft

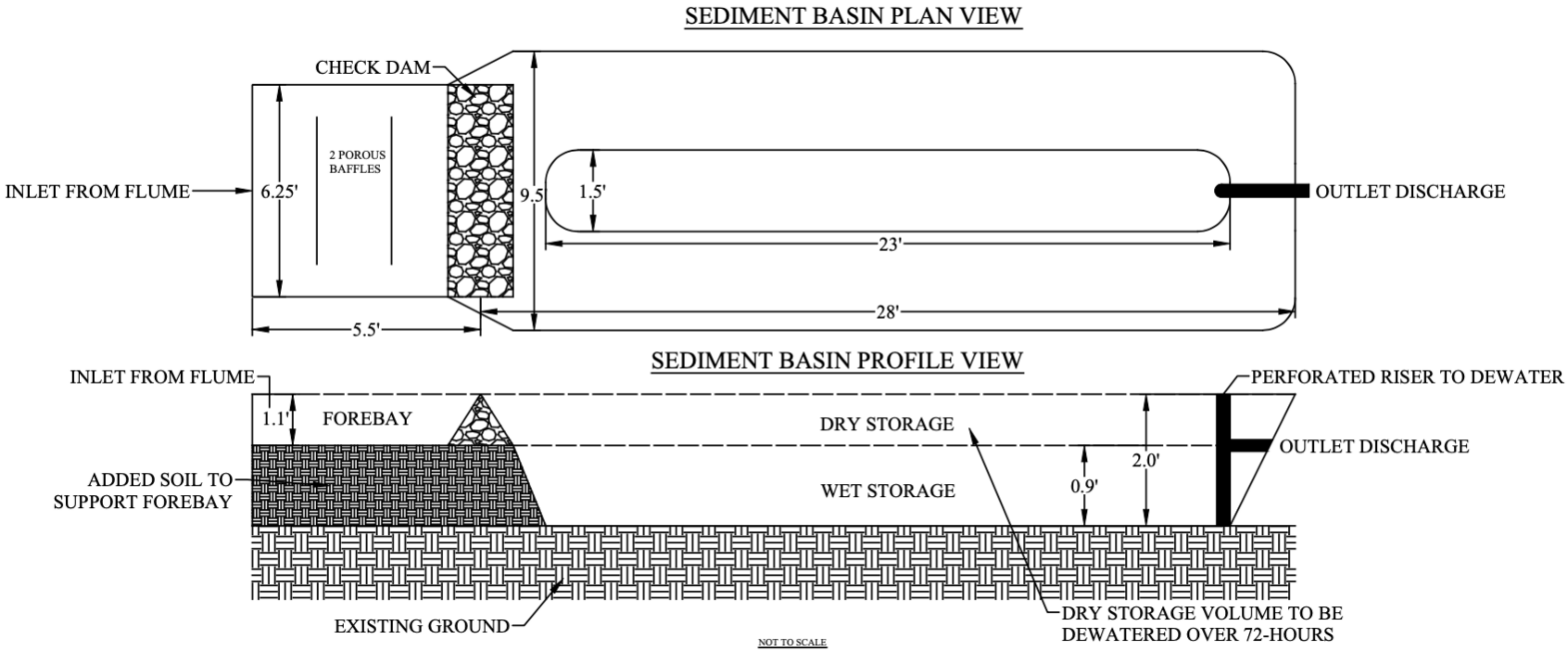

Figure 1. Sediment Basin Design Plan and Profile

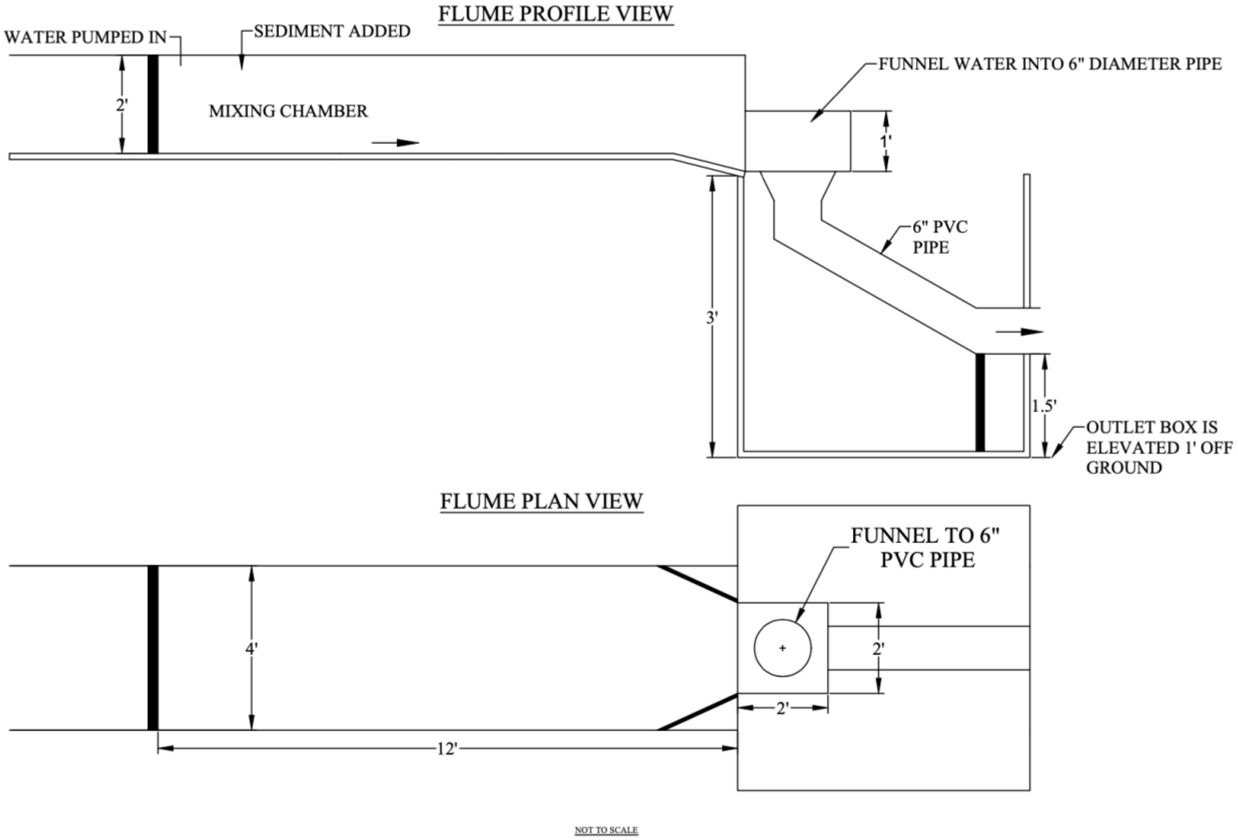

Figure 2. Flume Design for Inlet Mixing Chamber

2.5 Inflow and Outflow

The HOBO™ water level logger in the basin and open to the atmosphere were used to calculate stage in the basin using the difference in pressure between the two devices and a corrected density based on the water temperature at the time of the measurement. To obtain an inflow hydrograph, the stage and known geometry of the basin was used to calculate flow in gallons per minute. Additionally, the outflow of the basin was calculated using the stage from inside the basin and the known heights of the three orifices on the perforated riser to calculate flow. From the stage data, the outflow of the basin was calculated using the equation for orifice flow:

$$Q = C_d A \sqrt{2gH} \qquad \text{(Equation 1)}$$

Where, Cd is the discharge coefficient (dimensionless), A is cross-sectiona area of the orifice (ft^2), g is gravity 32.2 ft/s^2, and H is the static pressure head (ft). Using a coefficient of discharge of 0.6 (TDEC, 2021), the flowrate was calculated using the stage data and converted from cubic feet per second to gallons per minute and plotted against the 72 hours dewater time (Figure 4). It is important to note that the TDOT values for stage and outflow were largest because the total volume is smallest since it does not include a forebay or check dam, thus it needed to be filled to a higher elevation than the other designs to properly be dewatered in 72-hours.

2.6 PSD and SSC

For all sediment samples, a PSD following the standard test method for particle size distribution of fine-grained soils using the hydrometer analysis was completed (ASTM D7928). To calculate SSC from the influent and effluent water samples, the air-drying method was utilized. Each sample was deposited into a drying dish and was air dried over a period of 3 to 5 days. The remaining sediment was weighted to quantify SSC in g/L.

2.7 Statistical Analysis

Each water sample had triplicate values of SSC to calculate mean and standard deviation. An ANOVA Single Factor test for the effluent SSC concentrations between the three design standards was completed to determine any statistically significant difference. Three replicant experiments were conducted per design.

2.8 Performance via Total Percent Sediment Removal

To quantify the performance of each basin, total percent sediment removal was calculated through the following:

$$Total\ Percent\ Sediment\ Removal = \frac{Mass_{in} - Mass_{out}}{Mass_{in}} \quad \text{(Equation 2)}$$

Where $Mass_{out}$ is the total amount of sediment lost through the perforated riser. Using flow and SSC, $Mass_{out}$ can be calculated through:

$$Mass_{out} = \sum Q_i SSC_i \quad \text{(Equation 3)}$$

Where Q_i is the outflow discharge and SSC_i is the suspended sediment concentration, both at specific corresponding sampling time.

CHAPTER 3: RESULTS

A main design criterion for the sediment basin for all designs is that the dewatering time of the dry storage is 72 hours. All nine runs dewatered to the permanent pool elevation in 72 hours. Little variation between the three replicates for each design was observed. The standard deviation at the peak and 72-hour stage for TDOT was 0.048 ft and 0.12 ft; for TDEC, 0.016 ft and 0.11 ft; and for TDOT Check Dam (TDOT CD), 0.034 ft and 0.90 ft. Storm events that occurred during the run of the experiments are responsible for the elevated variation at the 72-hour stage recording. The average stage over the 72-hour dewatering time for each design is shown in Error! Reference source not found..

The outflow hydrograph for each design displayed little variability between the 3 replicates of data, the standard deviation at the peak and 72-hour outflow for TDOT was 0.026 gpm and 0.094 gpm; for TDEC, 0.009 gpm and 0.083 gpm; and for TDOT CD, 0.021 gpm and 0.080 gpm. Again, storm events during the run of the experiments caused the larger variation at the 72-hour outflow. Thus, the outflow was averaged and plotted against the 72-hour dewater time (Appendix B) The TDOT outflow reached a peak of 0.66 gpm and rapidly decreased to only one perforation, the lowest outlet orifice at the surface of the permanent pool, discharging at around hour 20, then slowly reached 0.1 gpm linearly. The TDEC and TDOT CD design reached a smaller peak of 0.61 gpm and, again, rapidly decreased to one perforation around the 15-hour mark until slowly decreasing to 0.1 gpm.

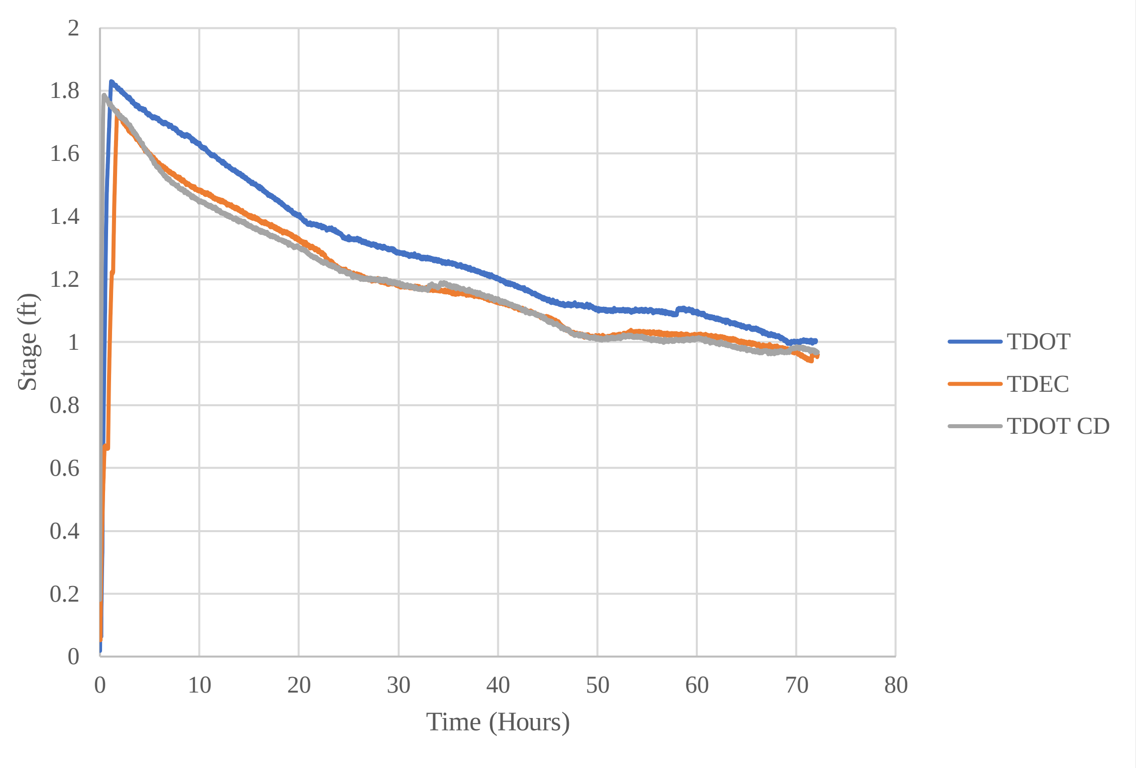

Figure 3. Basin Stage vs 72-hour Dewater Time for TDOT, TDEC, and TDOT CD

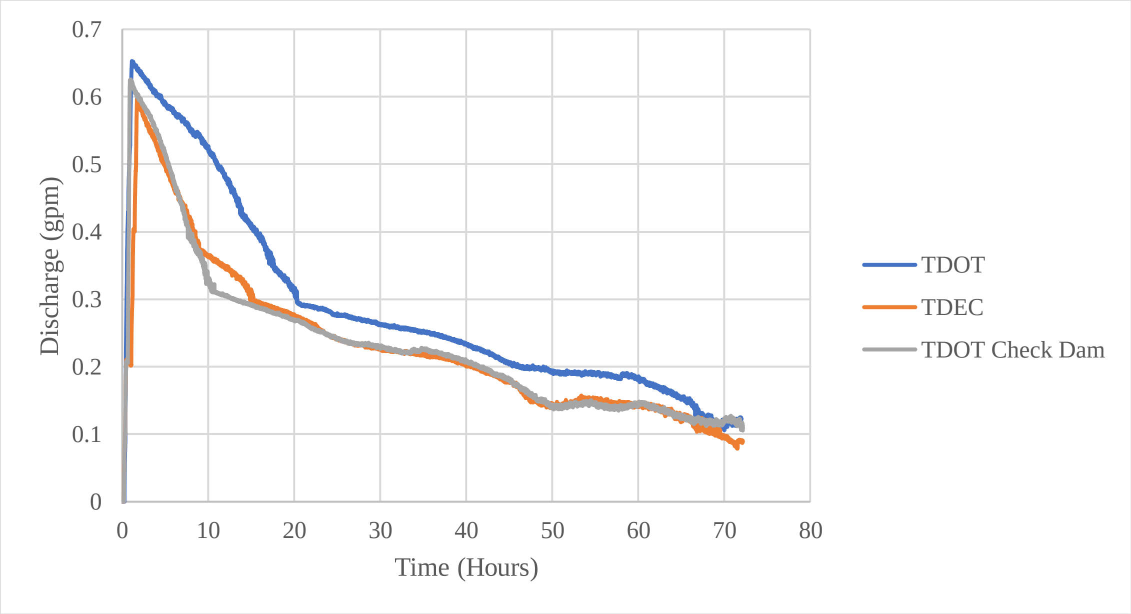

Figure 4. Outflow Discharge vs 72-hour Dewater Time for TDOT, TDEC, and TDOT CD

Since a known amount of sediment was added for each experiment and the sediment settled in the forebay and check dam were measured, the percent of soil settled before or in the basin was determined. Due to the standard TDOT design having no inlet protection, 100 percent of the sediment entered the main basin. As for the TDEC and TDOT CD, the percent are shown in Table 3. Additionally, the soil composition was determined from the soil samples gathered from the check dam, forebay, and the two used in the mixing chamber. The forebay and check dam were identical in soil composition and classified as a silty clay loam with 36 % clay, 56 % silt, and 8 % sand. Similarly, the averaged inlet soil composition was classified as a silty clay loam with 37.5 % clay, 54.5 % silt, and 8 % sand (Figure 6).

The effluent water samples SSC was averaged for the TDOT, TDEC, and TDOT CD design experiments and plotted against the dewatering time (Figure 6). Peak SSC values for TDOT, TDEC, and TDOT CD were 1.33 g/L, 0.62 g/L, and 1.09 g/L, respectively. After the first two samples, around hour 6 into the dewatering, the concentrations have little variation between the three different designs. An ANOVA Single Factor (α= 0.05) test between each of the designs at a specified sample time was completed to help show any statistical difference between the data. Only the first sample point, at hour 0 into the dewatering time, displayed any significant difference between the three designs (p = 0.016), with the range of p-values for the other sampling times being 0.163-0.997. To best represent this data, a box and whisker plot of specific groupings of sample times was created (Figure 7).

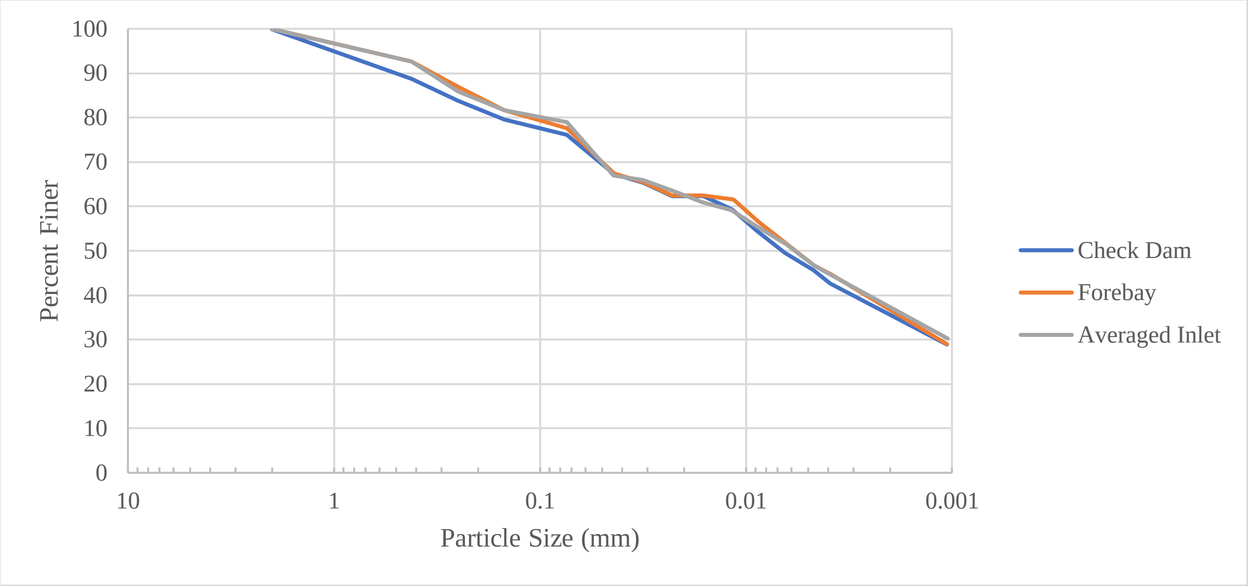

Figure 5. Particle Size Distribution of Collected Forebay, Check Dam, and Averaged Inlet

Table 3. Summary of Sediment Settled

	TDEC			**TDOT Check Dam**		
	Run 1	**Run 2**	**Run 3**	**Run 1**	**Run 2**	**Run 3**
Total Sediment Added (lbs)	94.7	100.1	79.4	82.8	89.8	83.6
Percent of Sediment Settled Prior to Main Basin (%)	68.1	74.3	79.1	63.5	74.5	67.4
Percent of Sediment Entering Main Basin (%)	31.9	25.7	20.9	32.3	25.5	32.6

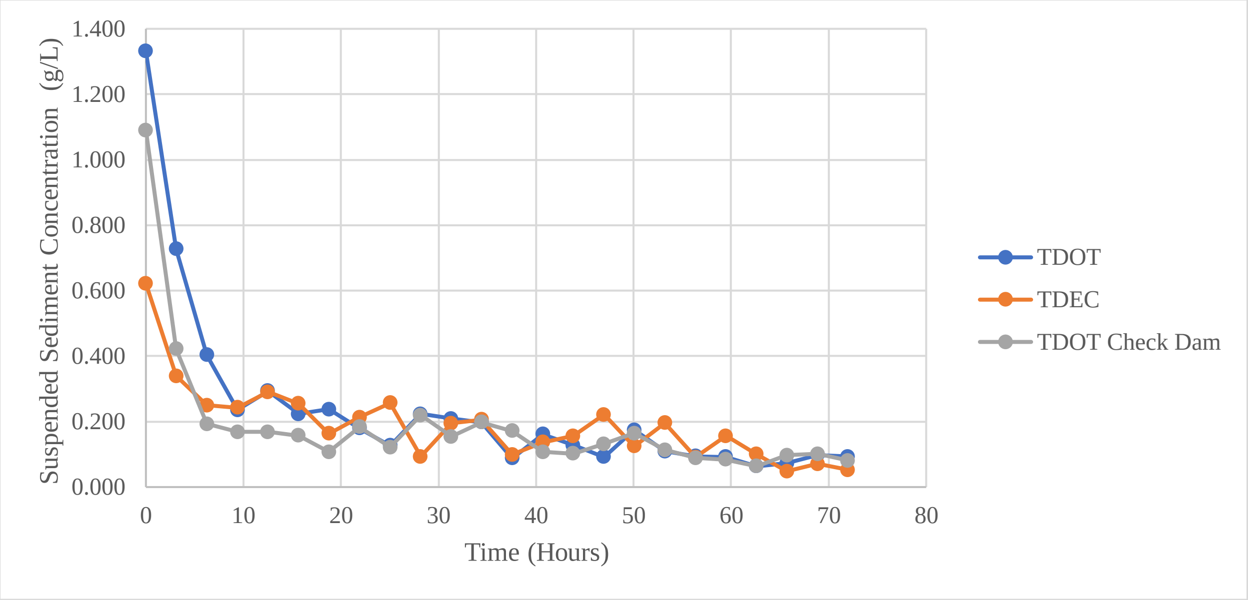

Figure 6. SSC vs 72-hour Dewater Time for TDOT, TDEC, and TDOT CD

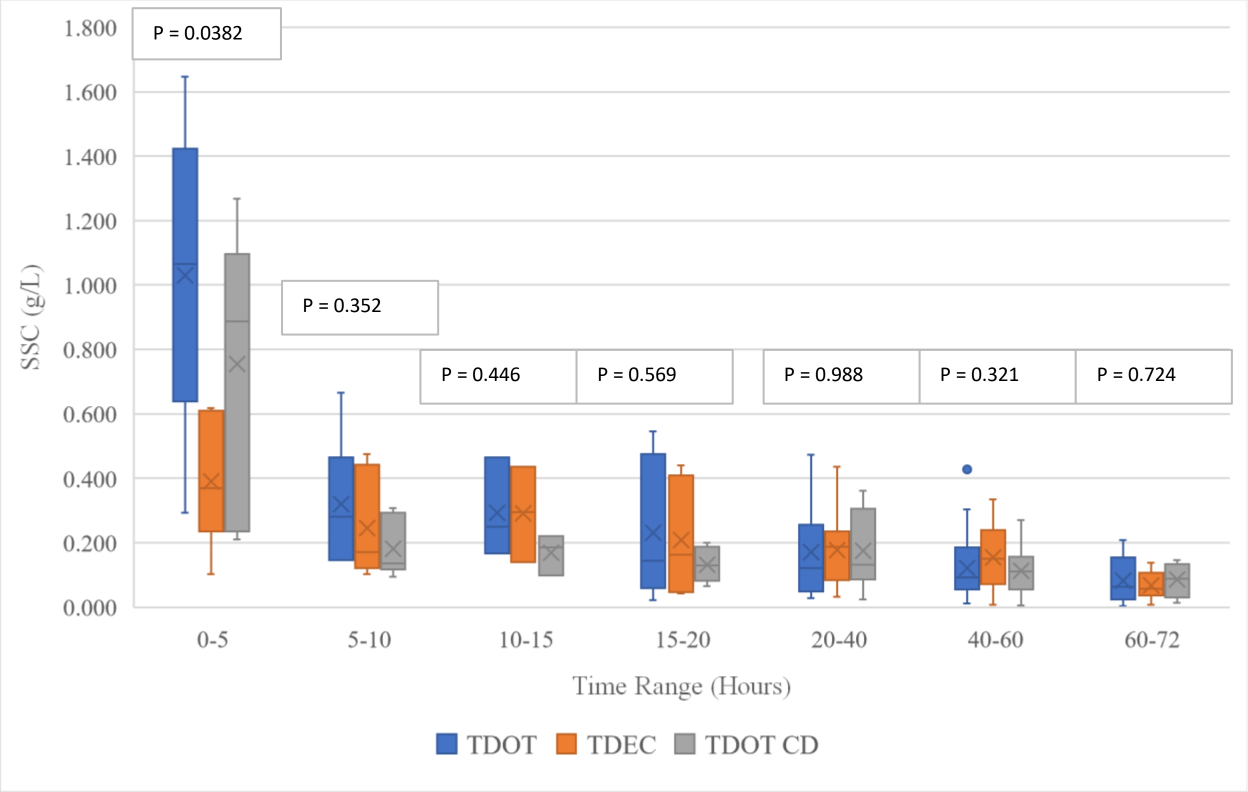

Figure 7. Box and Whisker Plots for SSC Over Experimental Time Intervals

Finally, to determine the total sediment basin performance, as percent sediment removal, a mass balance was utilized. The mass balance included the total mass added (M_{in}), cumulative sediment discharged (M_{out}), and the mass of the sediment that settled in the forebay/check dam ($M_{retained}$). A summary of the sediment removals for each experiment is in Table 4. The average total percent sediment removal for the TDOT, TDEC, and TDOT with check dam design is 95.4 %, 98.2 %, and 97.9 %, respectively. While the partial sediment removal of the forebay/check dam for TDEC and TDOT CD averaged to be 73.2 % and 68.5 %, respectively.

Table 4. Total Percent Sediment Removal Summary

Experiment	M_{in} (lbs)	$M_{retained}$ (lbs)	$M_{retained}$ (%)	M_{out} (lbs)	Total Percent Removal (%)
TDOT 1	98.0	0	0	3.80	96.1
TDOT 2	98.9	0	0	5.75	94.2
TDOT 3	97.0	0	0	3.85	96.0
TDEC 1	97.4	64.5	66.2	1.21	98.1
TDEC 2	100.1	74.3	74.2	2.98	98.0
TDEC 3	79.4	62.8	79.1	1.49	98.3
TDOT CD 1	82.8	52.6	63.5	1.57	98.1
TDOT CD 2	89.8	66.9	74.5	1.91	97.9
TDOT CD 3	83.6	56.3	67.4	2.02	97.6

CHAPTER 4: DISCUSSION

Minimizing the overall footprint while maintaining effective sediment removal is important at highway construction sites due to the linearity of the site. Out of the three designs tested, TDOT CD design is most valuable for these highway construction sites since it requires less area than the TDEC design and has the potential to reach similar removal efficiencies. However, the limited number of other studies further supports the need to expand this research topic.

4.1 Dewatering Time

TDOT sets the 72-hour minimum to adequately provide proper settling while allowing for multiple storms to happen within quick succession, however, some agencies have lower minimum dewatering times of 48 hours (Table 1). Additionally, most controlled studies determining the performance of a sediment basin dewatered the basin in only 24 hours. With such a wide range of dewatering times used in other studies and as required from different agencies, it spotlights highly variable definitions of an effective dewatering time. Scarce amount of literature is even present to backup any set minimum dewatering time. One can speculate the reason is, so the sediment basin discharge does not significantly impact a receiving streams flow capacity.

4.2 Outflow

The perforated riser is more commonly used than the Faircloth skimmer, but both are recognized by TDOT and TDEC as a viable option to adequately dewater the basin (Zech, et al., 2012). Perforated risers typically have higher peak discharges compared to a skimmer® and rapidly decrease until only one perforation is discharging (Millen, et al., 1997). For all three design's outflows, this trend can be seen in Error! Reference source not found..

Even though this study used a lined basin, it is important to note how infiltration can potentially impact the outflow of an unlined sediment basin. Soil composition is a huge factor for determining the infiltration rates and can be highly variable depending on site conditions. Bidelspach, et. al (2004) observed infiltration rates ranging from 0.4 mm/hr (0.016 in/hr) to 22.0 mm/hr (0.87 in/hr) from various sediment basins in Pennsylvania and found that a typical Pennsylvania sediment basin can be dewatered in 7 days or less when the infiltration rate exceeds 3 mm/hr (0.12 in/hr). If a basin is fully dewatered strictly through infiltration 100 % of sediment will be removed. Thus, there is potential for site specific infiltration rates to be implemented into the dewatering device design of the basin.

4.3 Suspended Sediment Concentration

As expected, the TDOT design had the highest starting SSC values due to a lack of any inlet protection such as a forebay or check dam (Figure 6). The TDEC design achieved the lowest starting SSC values and could be a result of the two porous baffles required in the forebay causing the sediment to aggregate and settle quicker (Thaxton & McLaughlin, 2005). Following the peaks, the SSC for all designs declined exponentially until the last sample at 72-hours. The same exponential decline was observed by Millen, et al. (1997) using a perforated riser, with a peak SSC just above 1.8 g/L and final value of just under 0.1 g/L over 16-hours. However, it is important to note that perforated risers tend to have significantly higher peak SSC when compared to a Faircloth Skimmer® (Millen, et al., 1997).

From Figure 7 only the first two SSC samples (hours 0-5) were statistically different between all designs ($p = 0.382$), demonstrating that each design influenced the beginning SSC. However, all designs effectively reduced SSC to statistically similar values after hour 5. Another important observation is how little SSC changed from 20–40-hour until the 60–72-hour grouping, starting around 0.2 g/L and decreasing to roughly 0.1 g/L between all designs. Since there is such a small change in SSC over that period, it might suggest a lower minimum dewatering time requirement.

4.4 Percent Sediment Removal

It was hypothesized that the TDEC design would achieve the highest percent removal due to the addition of the forebay, while the TDOT design would achieve the lowest removal since there is no inlet protection. The addition of the check dam was thought to increase removal and the results reveal it is very similar to TDEC's design. This suggests that what plays an important role in increasing the total percent sediment removal is the use of an inlet protection prior to the main basin. Because this study used a rubber liner as the material for the basin the percent sediment removals for each design might be slightly elevated; according to Fennessey & Jarrett (1997), which concluded that there is a significant difference between lined (97.2 %) and unlined basins (94.9%) for percent sediment removal. However, this elevation might be offset because percent sediment removals for basins with perforated risers (94.2 %) tend to be slightly lower than ones with a Faircloth Skimmer ® (96.8 %) (Millen, et al., 1997). One sediment basin with a Skimmer ® even achieved 99.6 % sediment removal (McCaleb & McLaughlin, 2008).

It is assumed that most of the sediment lost is clay and potentially some silt. This assumption is simply based on the settling velocity of particle classifications: for a fine silt (0.01 mm) particle, the settling velocity is 1.2 hours per foot (at 50 ^{o}F); for a med-coarse clay (0.002 mm), the settling velocity is 31 hours per foot (at 50 ^{o}F). 100 percent silt removal can be achievable through altering a basins design, by increasing the surface area to inflow ratio, but clay removal relies heavily on flocculation (Tennessee Department of Environment and Conservation, 2021). A common flocculant recognized by TDOT and TDEC to be used in increasing the removal of colloidal clays is polyacrylamide (PAM). However, site specific characteristics need to be accounted for since different formulations of PAM are designed to bind to different soil types (Tennessee Department of Environment and Conservation, 2021).

From Smith (2018), many qualitative observations should be noted from the monitoring and evaluation of two TDOT sediment basins: Study 1 with an inlet mass of 1,930 kg and sediment removal of 76.8 %, and Study 2 with an inlet mass of 0.0016 kg and sediment removal of 97.4 %. One observation is that clean water and groundwater could become a potential issue and need to be routed to bypass the basin such that the basin does not exceed design flows. Another, site layouts may constrict the sediment basin to have smaller L:W ratios than what is required by TDOT, thus causing short circuiting and sediment loss. Finally, a large accumulation of sediment at the inlet structure will require regular maintenance necessary for performance. All these observations further demonstrate how variable each site can be and any design assumptions need to be based on true field site characteristics, and that proper maintenance is required to control sediment at the inlet.

4.5 Sediment Basin Spreadsheet Model

An Excel spreadsheet sediment basin design model was created to include PSD (or % Sand, Silt, Clay) as a main design factor to correctly size a sediment basin. The model still uses current design standards as required by TDOT: drainage area, design discharge, dry and wet storage volumes, basin geometry specifications, and dewatering time. An outlined step-by-step user manual detailing the computations and design process can be found in Appendix C.

4.6 Conclusions

Through a physical model, the performance of three sediment basin designs were evaluated by the total percent sediment removal. TDEC achieved the highest percent sediment removal (98.2 %), TDOT CD had very similar results to TDEC (97.9 %), and TDOT the lowest (95.4 %). A check dam in front of a TDOT standard sediment basin proves to be nearly as efficient as the TDEC requirement to include a forebay and two porous baffles and suggests the importance of a form of inlet protection prior to the main basin. The smaller footprint of the TDOT CD could help minimize space constraints at linear highway construction sites while still providing effective sediment removal. However, proper maintenance of the inlet protection and main basin are necessary for high performance, and site-specific characteristics should be the basis of design. Additionally, the small decrease in effluent SSC from hours 20-72 could suggest a change in minimum basin dewatering time.

Future steps for an improved study could include comparing different dewatering times to be able to suggest a most time-removal effective requirement. The inconsistent dewatering times between multiple regulatory agencies and other research studies proves that it is an unknown. Additionally, varying the inflow hydrographs and total amount of sediment added could help show if these results hold true for different storm events and with alternative sediment loads. Sediment basins designs are becoming more dependent on site specific characteristics and what leads to higher performance on one site may not be true on another.

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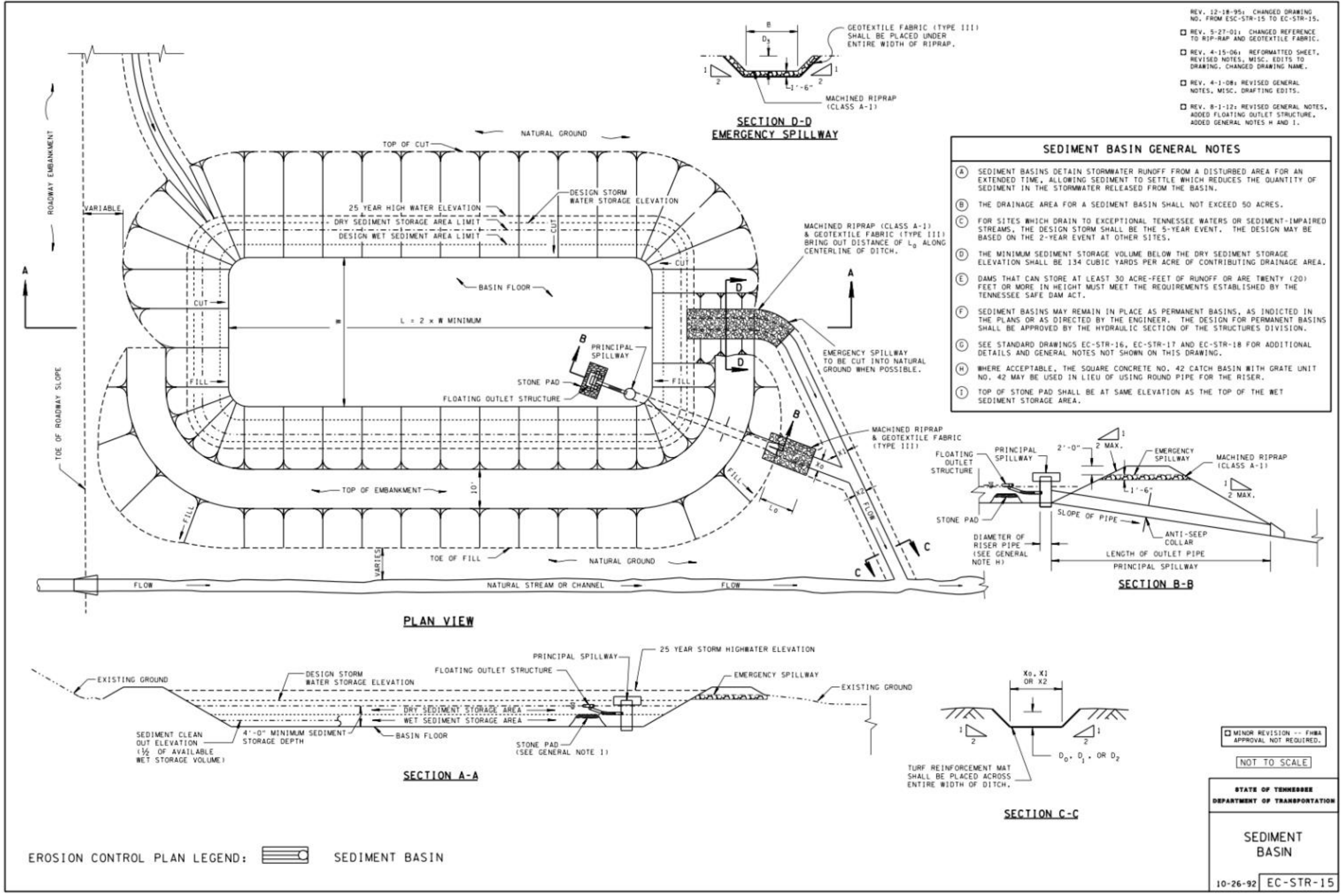
APPENDICIES

APPENDIX A: TDOT Standard Drawings



REV. 12-18-95: CHANGED DRAWING NO. FROM ESC-STR-15 TO EC-STR-15.

☐ REV. 5-27-01: CHANGED REFERENCE TO RIP-RAP AND GEOTEXTILE FABRIC.

☐ REV. 4-15-06: REFORMATTED SHEET. REVISED NOTES. MISC. EDITS TO DRAWING. CHANGED DRAWING NAME.

☐ REV. 4-1-08: REVISED GENERAL NOTES. MISC. DRAFTING EDITS.

☐ REV. 8-1-12: REVISED GENERAL NOTES. ADDED FLOATING OUTLET STRUCTURE. ADDED GENERAL NOTES H AND I.

SEDIMENT BASIN GENERAL NOTES

Ⓐ SEDIMENT BASINS DETAIN STORMWATER RUNOFF FROM A DISTURBED AREA FOR AN EXTENDED TIME, ALLOWING SEDIMENT TO SETTLE WHICH REDUCES THE QUANTITY OF SEDIMENT IN THE STORMWATER RELEASED FROM THE BASIN.

Ⓑ THE DRAINAGE AREA FOR A SEDIMENT BASIN SHALL NOT EXCEED 50 ACRES.

Ⓒ FOR SITES WHICH DRAIN TO EXCEPTIONAL TENNESSEE WATERS OR SEDIMENT-IMPAIRED STREAMS, THE DESIGN STORM SHALL BE THE 5-YEAR EVENT. THE DESIGN MAY BE BASED ON THE 2-YEAR EVENT AT OTHER SITES.

Ⓓ THE MINIMUM SEDIMENT STORAGE VOLUME BELOW THE DRY SEDIMENT STORAGE ELEVATION SHALL BE 134 CUBIC YARDS PER ACRE OF CONTRIBUTING DRAINAGE AREA.

Ⓔ DAMS THAT CAN STORE AT LEAST 30 ACRE-FEET OF RUNOFF OR ARE TWENTY (20) FEET OR MORE IN HEIGHT MUST MEET THE REQUIREMENTS ESTABLISHED BY THE TENNESSEE SAFE DAM ACT.

Ⓕ SEDIMENT BASINS MAY REMAIN IN PLACE AS PERMANENT BASINS, AS INDICTED IN THE PLANS OR AS DIRECTED BY THE ENGINEER. THE DESIGN FOR PERMANENT BASINS SHALL BE APPROVED BY THE HYDRAULIC SECTION OF THE STRUCTURES DIVISION.

Ⓖ SEE STANDARD DRAWINGS EC-STR-16, EC-STR-17 AND EC-STR-18 FOR ADDITIONAL DETAILS AND GENERAL NOTES NOT SHOWN ON THIS DRAWING.

Ⓗ WHERE ACCEPTABLE, THE SQUARE CONCRETE NO. 42 CATCH BASIN WITH GRATE UNIT NO. 42 MAY BE USED IN LIEU OF USING ROUND PIPE FOR THE RISER.

Ⓘ TOP OF STONE PAD SHALL BE AT SAME ELEVATION AS THE TOP OF THE WET SEDIMENT STORAGE AREA.

GEOTEXTILE FABRIC (TYPE III) SHALL BE PLACED UNDER ENTIRE WIDTH OF RIPRAP.

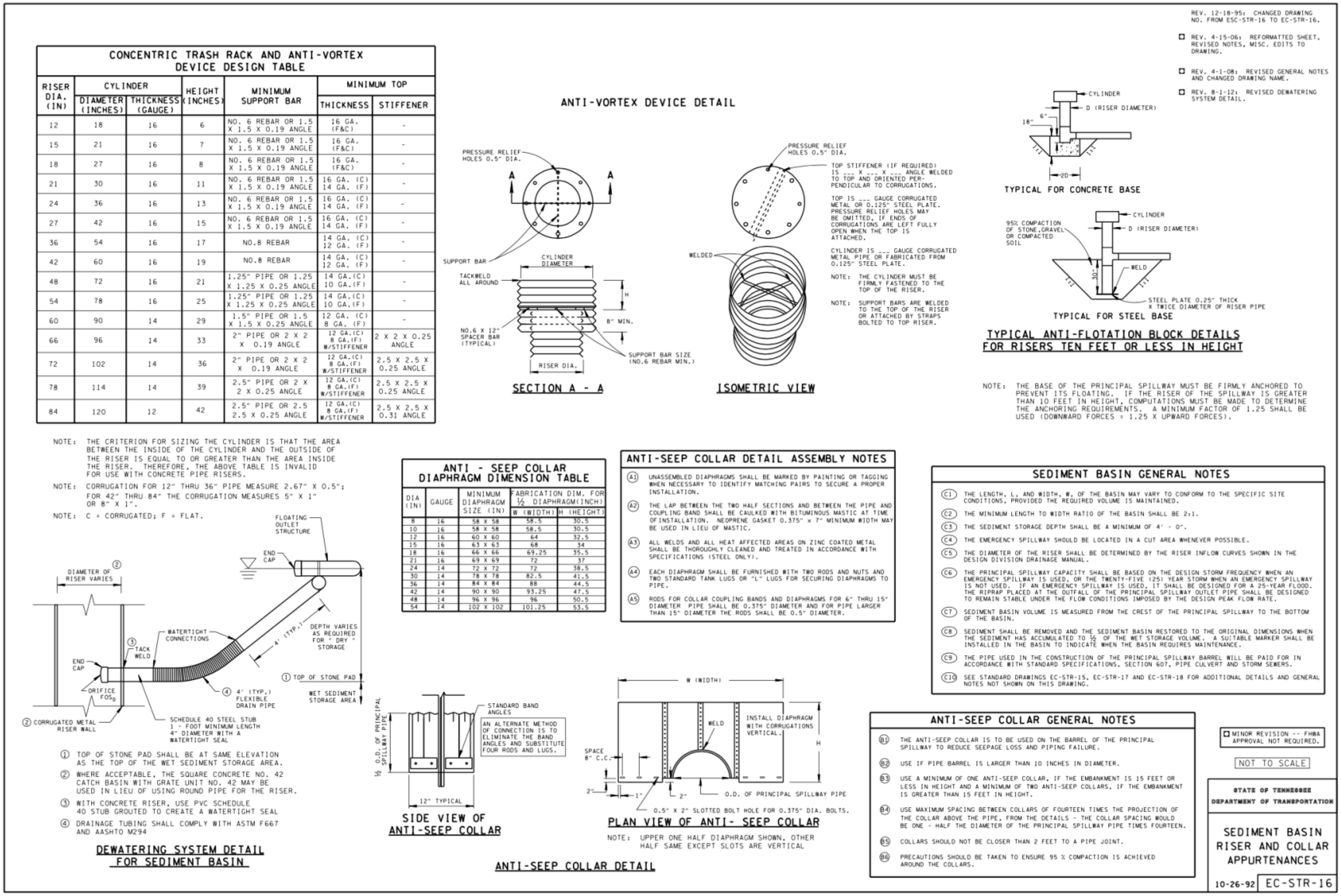
MACHINED RIPRAP (CLASS A-1) & GEOTEXTILE FABRIC (TYPE III) BRING OUT DISTANCE OF L_a ALONG CENTERLINE OF DITCH.

EMERGENCY SPILLWAY TO BE CUT INTO NATURAL GROUND WHEN POSSIBLE.

TURF REINFORCEMENT MAT SHALL BE PLACED ACROSS ENTIRE WIDTH OF DITCH.

☐ MINOR REVISION -- FHWA APPROVAL NOT REQUIRED.

Figure A-1. Standard TDOT design drawing for a sediment basin (TDOT 2017)



REV. 12-18-95: CHANGED DRAWING NO. FROM ESC-STR-16 TO EC-STR-16.

☐ REV. 4-15-06: REFORMATTED SHEET, REVISED NOTES, MISC. EDITS TO DRAWING.

☐ REV. 4-1-08: REVISED GENERAL NOTES AND CHANGED DRAWING NAME.

☐ REV. 8-1-12: REVISED DEWATERING SYSTEM DETAIL.

CONCENTRIC TRASH RACK AND ANTI-VORTEX DEVICE DESIGN TABLE

RISER DIA. (IN)	CYLINDER		HEIGHT (INCHES)	MINIMUM SUPPORT BAR	MINIMUM TOP	
	DIAMETER (INCHES)	THICKNESS (GAUGE)			THICKNESS	STIFFENER
12	18	16	6	NO. 6 REBAR OR 1.5 X 1.5 X 0.19 ANGLE	16 GA. (F&C)	-
15	21	16	7	NO. 6 REBAR OR 1.5 X 1.5 X 0.19 ANGLE	16 GA. (F&C)	-
18	27	16	8	NO. 6 REBAR OR 1.5 X 1.5 X 0.19 ANGLE	16 GA. (F&C)	-
21	30	16	11	NO. 6 REBAR OR 1.5 X 1.5 X 0.19 ANGLE	16 GA. (C) 14 GA. (F)	-
24	36	16	13	NO. 6 REBAR OR 1.5 X 1.5 X 0.19 ANGLE	16 GA. (C) 14 GA. (F)	-
27	42	16	15	NO. 6 REBAR OR 1.5 X 1.5 X 0.19 ANGLE	16 GA. (C) 14 GA. (F)	-
36	54	16	17	NO.8 REBAR	14 GA. (C) 12 GA. (F)	-
42	60	16	19	NO.8 REBAR	14 GA. (C) 12 GA. (F)	-
48	72	16	21	1.25" PIPE OR 1.25 X 1.25 X 0.25 ANGLE	14 GA.(C) 10 GA.(F)	-
54	78	16	25	1.25" PIPE OR 1.25 X 1.25 X 0.25 ANGLE	14 GA.(C) 10 GA.(F)	-
60	90	14	29	1.5" PIPE OR 1.5 X 1.5 X 0.25 ANGLE	12 GA. (C) 8 GA. (F)	-
66	96	14	33	2" PIPE OR 2 X 2 X 0.19 ANGLE	12 GA.(C) 8 GA.(F) W/STIFFENER	2 X 2 X 0.25 ANGLE
72	102	14	36	2" PIPE OR 2 X 2 X 0.19 ANGLE	12 GA.(C) 8 GA.(F) W/STIFFENER	2.5 X 2.5 X 0.25 ANGLE
78	114	14	39	2.5" PIPE OR 2 X 2 X 0.25 ANGLE	12 GA.(C) 8 GA.(F) W/STIFFENER	2.5 X 2.5 X 0.25 ANGLE
84	120	12	42	2.5" PIPE OR 2.5 2.5 X 0.25 ANGLE	12 GA.(C) 8 GA.(F) W/STIFFENER	2.5 X 2.5 X 0.31 ANGLE

NOTE: THE CRITERION FOR SIZING THE CYLINDER IS THAT THE AREA BETWEEN THE INSIDE OF THE CYLINDER AND THE OUTSIDE OF THE RISER IS EQUAL TO OR GREATER THAN THE AREA INSIDE THE RISER. THEREFORE, THE ABOVE TABLE IS INVALID FOR USE WITH CONCRETE PIPE RISERS.

NOTE: CORRUGATION FOR 12" THRU 36" PIPE MEASURE 2.67" X 0.5"; FOR 42" THRU 84" THE CORRUGATION MEASURES 5" X 1" OR 8" X 1".

NOTE: C = CORRUGATED; F = FLAT.

ANTI-VORTEX DEVICE DETAIL

TOP STIFFENER (IF REQUIRED) IS ___ X ___ X ___ ANGLE WELDED TO TOP AND ORIENTED PERPENDICULAR TO CORRUGATIONS.

TOP IS ___ GAUGE CORRUGATED METAL OR 0.125" STEEL PLATE. PRESSURE RELIEF HOLES MAY BE OMITTED, IF ENDS OF CORRUGATIONS ARE LEFT FULLY OPEN WHEN THE TOP IS ATTACHED.

CYLINDER IS ___ GAUGE CORRUGATED METAL PIPE OR FABRICATED FROM 0.125" STEEL PLATE.

NOTE: THE CYLINDER MUST BE FIRMLY FASTENED TO THE TOP OF THE RISER.

NOTE: SUPPORT BARS ARE WELDED TO THE TOP OF THE RISER OR ATTACHED BY STRAPS BOLTED TO TOP RISER.

SECTION A - A

ISOMETRIC VIEW

TYPICAL FOR CONCRETE BASE

TYPICAL FOR STEEL BASE

TYPICAL ANTI-FLOTATION BLOCK DETAILS FOR RISERS TEN FEET OR LESS IN HEIGHT

NOTE: THE BASE OF THE PRINCIPAL SPILLWAY MUST BE FIRMLY ANCHORED TO PREVENT ITS FLOATING. IF THE RISER OF THE SPILLWAY IS GREATER THAN 10 FEET IN HEIGHT, COMPUTATIONS MUST BE MADE TO DETERMINE THE ANCHORING REQUIREMENTS. A MINIMUM FACTOR OF 1.25 SHALL BE USED (DOWNWARD FORCES = 1.25 X UPWARD FORCES).

① TOP OF STONE PAD SHALL BE AT SAME ELEVATION AS THE TOP OF THE WET SEDIMENT STORAGE AREA.

② WHERE ACCEPTABLE, THE SQUARE CONCRETE NO. 42 CATCH BASIN WITH GRATE UNIT NO. 42 MAY BE USED IN LIEU OF USING ROUND PIPE FOR THE RISER.

③ WITH CONCRETE RISER, USE PVC SCHEDULE 40 STUB GROUTED TO CREATE A WATERTIGHT SEAL

④ DRAINAGE TUBING SHALL COMPLY WITH ASTM F667 AND AASHTO M294

DEWATERING SYSTEM DETAIL FOR SEDIMENT BASIN

ANTI - SEEP COLLAR DIAPHRAGM DIMENSION TABLE

DIA (IN)	GAUGE	MINIMUM DIAPHRAGM SIZE (IN)	FABRICATION DIM. FOR ½ DIAPHRAGM(INCH)	
			W (WIDTH)	H (HEIGHT)
8	16	58 X 58	58.5	30.5
10	16	58 X 58	58.5	30.5
12	16	60 X 60	64	32.5
15	16	63 X 63	68	34
18	16	66 X 66	69.25	35.5
21	16	69 X 69	72	37
24	14	72 X 72	72	38.5
30	14	78 X 78	82.5	41.5
36	14	84 X 84	88	44.5
42	14	90 X 90	93.25	47.5
48	14	96 X 96	96	50.5
54	14	102 X 102	101.25	53.5

ANTI-SEEP COLLAR DETAIL ASSEMBLY NOTES

(A1) UNASSEMBLED DIAPHRAGMS SHALL BE MARKED BY PAINTING OR TAGGING WHEN NECESSARY TO IDENTIFY MATCHING PAIRS TO SECURE A PROPER INSTALLATION.

(A2) THE LAP BETWEEN THE TWO HALF SECTIONS AND BETWEEN THE PIPE AND COUPLING BAND SHALL BE CAULKED WITH BITUMINOUS MASTIC AT TIME OF INSTALLATION. NEOPRENE GASKET 0.375" x 7" MINIMUM WIDTH MAY BE USED IN LIEU OF MASTIC.

(A3) ALL WELDS AND ALL HEAT AFFECTED AREAS ON ZINC COATED METAL SHALL BE THOROUGHLY CLEANED AND TREATED IN ACCORDANCE WITH SPECIFICATIONS (STEEL ONLY).

(A4) EACH DIAPHRAGM SHALL BE FURNISHED WITH TWO RODS AND NUTS AND TWO STANDARD TANK LUGS OR "L" LUGS FOR SECURING DIAPHRAGMS TO PIPE.

(A5) RODS FOR COLLAR COUPLING BANDS AND DIAPHRAGMS FOR 6" THRU 15" DIAMETER PIPE SHALL BE 0.375" DIAMETER AND FOR PIPE LARGER THAN 15" DIAMETER THE RODS SHALL BE 0.5" DIAMETER.

SEDIMENT BASIN GENERAL NOTES

(C1) THE LENGTH, L, AND WIDTH, W, OF THE BASIN MAY VARY TO CONFORM TO THE SPECIFIC SITE CONDITIONS, PROVIDED THE REQUIRED VOLUME IS MAINTAINED.

(C2) THE MINIMUM LENGTH TO WIDTH RATIO OF THE BASIN SHALL BE 2:1.

(C3) THE SEDIMENT STORAGE DEPTH SHALL BE A MINIMUM OF 4' - 0".

(C4) THE EMERGENCY SPILLWAY SHOULD BE LOCATED IN A CUT AREA WHENEVER POSSIBLE.

(C5) THE DIAMETER OF THE RISER SHALL BE DETERMINED BY THE RISER INFLOW CURVES SHOWN IN THE DESIGN DIVISION DRAINAGE MANUAL.

(C6) THE PRINCIPAL SPILLWAY CAPACITY SHALL BE BASED ON THE DESIGN STORM FREQUENCY WHEN AN EMERGENCY SPILLWAY IS USED, OR THE TWENTY-FIVE (25) YEAR STORM WHEN AN EMERGENCY SPILLWAY IS NOT USED. IF AN EMERGENCY SPILLWAY IS USED, IT SHALL BE DESIGNED FOR A 25-YEAR FLOOD. THE RIPRAP PLACED AT THE OUTFALL OF THE PRINCIPAL SPILLWAY OUTLET PIPE SHALL BE DESIGNED TO REMAIN STABLE UNDER THE FLOW CONDITIONS IMPOSED BY THE DESIGN PEAK FLOW RATE.

(C7) SEDIMENT BASIN VOLUME IS MEASURED FROM THE CREST OF THE PRINCIPAL SPILLWAY TO THE BOTTOM OF THE BASIN.

(C8) SEDIMENT SHALL BE REMOVED AND THE SEDIMENT BASIN RESTORED TO THE ORIGINAL DIMENSIONS WHEN THE SEDIMENT HAS ACCUMULATED TO ½ OF THE WET STORAGE VOLUME. A SUITABLE MARKER SHALL BE INSTALLED IN THE BASIN TO INDICATE WHEN THE BASIN REQUIRES MAINTENANCE.

(C9) THE PIPE USED IN THE CONSTRUCTION OF THE PRINCIPAL SPILLWAY BARREL WILL BE PAID FOR IN ACCORDANCE WITH STANDARD SPECIFICATIONS, SECTION 607, PIPE CULVERT AND STORM SEWERS.

(C10) SEE STANDARD DRAWINGS EC-STR-15, EC-STR-17 AND EC-STR-18 FOR ADDITIONAL DETAILS AND GENERAL NOTES NOT SHOWN ON THIS DRAWING.

AN ALTERNATE METHOD OF CONNECTION IS TO ELIMINATE THE BAND ANGLES AND SUBSTITUTE FOUR RODS AND LUGS.

SIDE VIEW OF ANTI-SEEP COLLAR

PLAN VIEW OF ANTI- SEEP COLLAR

NOTE: UPPER ONE HALF DIAPHRAGM SHOWN, OTHER HALF SAME EXCEPT SLOTS ARE VERTICAL

ANTI-SEEP COLLAR DETAIL

ANTI-SEEP COLLAR GENERAL NOTES

(B1) THE ANTI-SEEP COLLAR IS TO BE USED ON THE BARREL OF THE PRINCIPAL SPILLWAY TO REDUCE SEEPAGE LOSS AND PIPING FAILURE.

(B2) USE IF PIPE BARREL IS LARGER THAN 10 INCHES IN DIAMETER.

(B3) USE A MINIMUM OF ONE ANTI-SEEP COLLAR, IF THE EMBANKMENT IS 15 FEET OR LESS IN HEIGHT AND A MINIMUM OF TWO ANTI-SEEP COLLARS, IF THE EMBANKMENT IS GREATER THAN 15 FEET IN HEIGHT.

(B4) USE MAXIMUM SPACING BETWEEN COLLARS OF FOURTEEN TIMES THE PROJECTION OF THE COLLAR ABOVE THE PIPE, FROM THE DETAILS - THE COLLAR SPACING WOULD BE ONE - HALF THE DIAMETER OF THE PRINCIPAL SPILLWAY PIPE TIMES FOURTEEN.

(B5) COLLARS SHOULD NOT BE CLOSER THAN 2 FEET TO A PIPE JOINT.

(B6) PRECAUTIONS SHOULD BE TAKEN TO ENSURE 95 % COMPACTION IS ACHIEVED AROUND THE COLLARS.

☐ MINOR REVISION -- FHWA APPROVAL NOT REQUIRED.

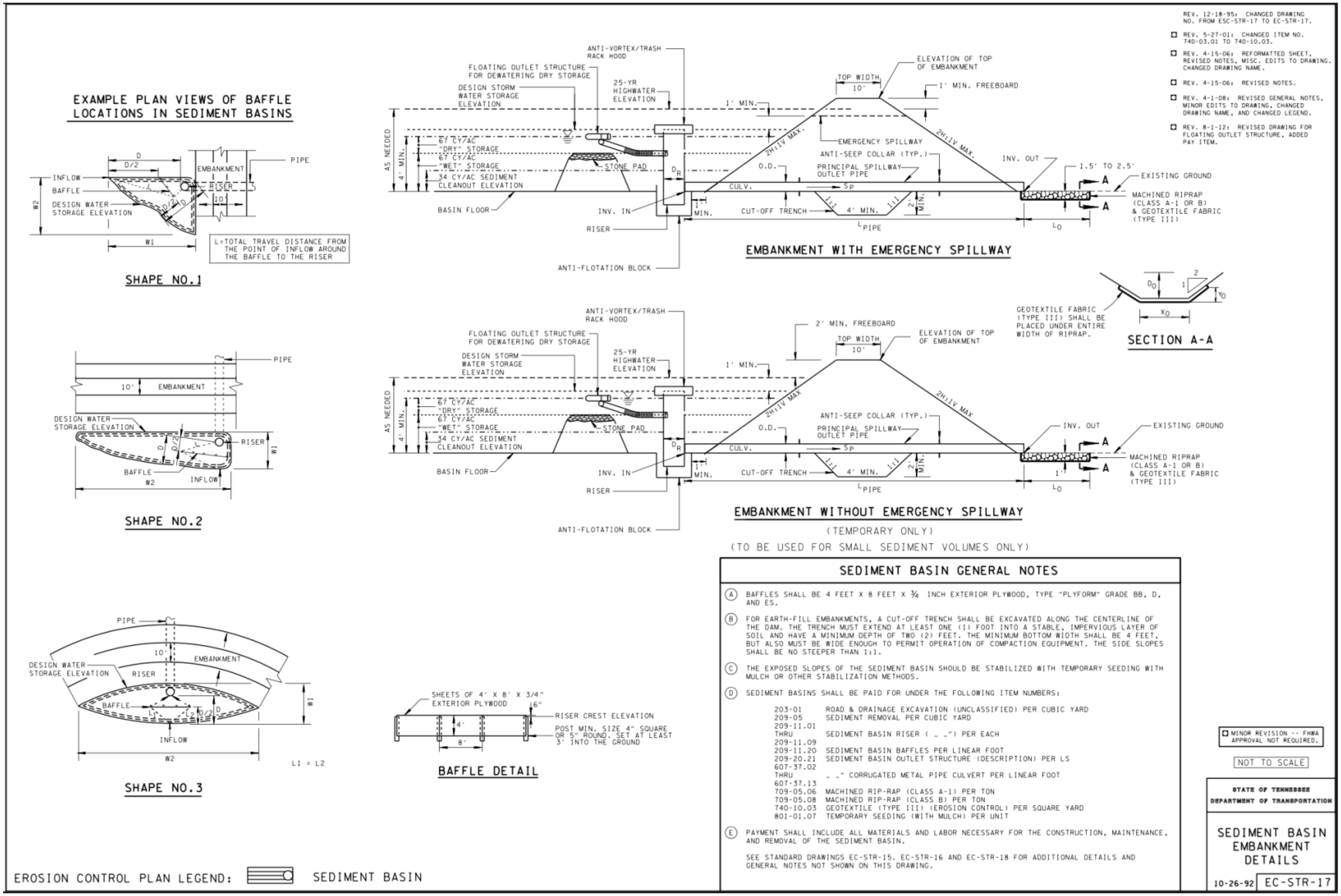
NOT TO SCALE

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

SEDIMENT BASIN
RISER AND COLLAR
APPURTENANCES

10-26-92 EC-STR-16

Figure A-2. Standard TDOT design drawing for a sediment basin (TDOT 2017)



REV. 12-18-95: CHANGED DRAWING NO. FROM ESC-STR-17 TO EC-STR-17.

☐ REV. 5-27-01: CHANGED ITEM NO. 740-03.01 TO 740-10.03.

☐ REV. 4-15-06: REFORMATTED SHEET, REVISED NOTES, MISC. EDITS TO DRAWING. CHANGED DRAWING NAME.

☐ REV. 4-15-06: REVISED NOTES.

☐ REV. 4-1-08: REVISED GENERAL NOTES, MINOR EDITS TO DRAWING, CHANGED DRAWING NAME, AND CHANGED LEGEND.

☐ REV. 8-1-12: REVISED DRAWING FOR FLOATING OUTLET STRUCTURE, ADDED PAY ITEM.

SEDIMENT BASIN GENERAL NOTES

Ⓐ BAFFLES SHALL BE 4 FEET X 8 FEET X ¾ INCH EXTERIOR PLYWOOD, TYPE "PLYFORM" GRADE BB, D, AND ES.

Ⓑ FOR EARTH-FILL EMBANKMENTS, A CUT-OFF TRENCH SHALL BE EXCAVATED ALONG THE CENTERLINE OF THE DAM. THE TRENCH MUST EXTEND AT LEAST ONE (1) FOOT INTO A STABLE, IMPERVIOUS LAYER OF SOIL AND HAVE A MINIMUM DEPTH OF TWO (2) FEET. THE MINIMUM BOTTOM WIDTH SHALL BE 4 FEET, BUT ALSO MUST BE WIDE ENOUGH TO PERMIT OPERATION OF COMPACTION EQUIPMENT. THE SIDE SLOPES SHALL BE NO STEEPER THAN 1:1.

Ⓒ THE EXPOSED SLOPES OF THE SEDIMENT BASIN SHOULD BE STABILIZED WITH TEMPORARY SEEDING WITH MULCH OR OTHER STABILIZATION METHODS.

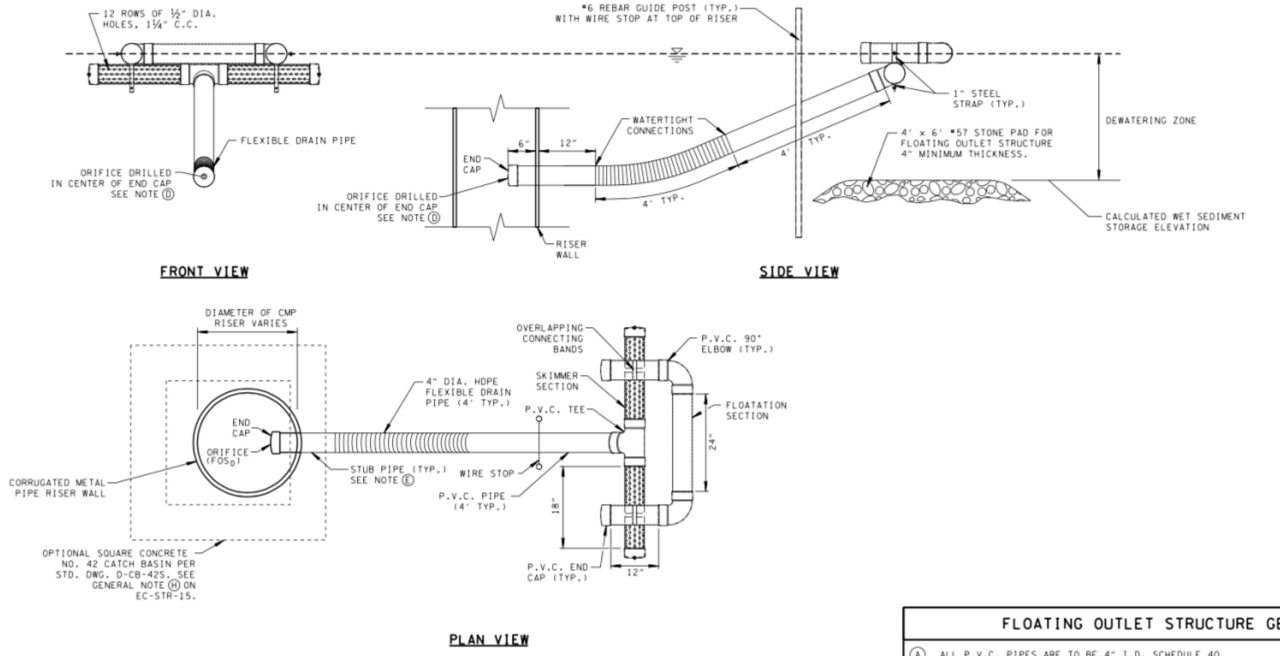
Ⓓ SEDIMENT BASINS SHALL BE PAID FOR UNDER THE FOLLOWING ITEM NUMBERS:

203-01	ROAD & DRAINAGE EXCAVATION (UNCLASSIFIED) PER CUBIC YARD
209-05	SEDIMENT REMOVAL PER CUBIC YARD
209-11.01 THRU 209-11.09	SEDIMENT BASIN RISER (_ _") PER EACH
209-11.20	SEDIMENT BASIN BAFFLES PER LINEAR FOOT
209-20.21	SEDIMENT BASIN OUTLET STRUCTURE (DESCRIPTION) PER LS
607-37.02 THRU 607-37.13	_ _" CORRUGATED METAL PIPE CULVERT PER LINEAR FOOT
709-05.06	MACHINED RIP-RAP (CLASS A-1) PER TON
709-05.08	MACHINED RIP-RAP (CLASS B) PER TON
740-10.03	GEOTEXTILE (TYPE III) (EROSION CONTROL) PER SQUARE YARD
801-01.07	TEMPORARY SEEDING (WITH MULCH) PER UNIT

Ⓔ PAYMENT SHALL INCLUDE ALL MATERIALS AND LABOR NECESSARY FOR THE CONSTRUCTION, MAINTENANCE, AND REMOVAL OF THE SEDIMENT BASIN.

SEE STANDARD DRAWINGS EC-STR-15, EC-STR-16 AND EC-STR-18 FOR ADDITIONAL DETAILS AND GENERAL NOTES NOT SHOWN ON THIS DRAWING.

Figure A-3. Standard TDOT design drawing for a sediment basin (TDOT 2017)



FLOATING OUTLET STRUCTURE

ORIFICE SIZE, FOS_D (IN.)	DISCHARGE, Q (FT^3/SEC)	EQUATIONS FOR MINIMUM AND MAXIMUM ORIFICE SIZE
1"	0.019	$Q_{MAX} = \frac{\text{DEWATERING ZONE VOLUME } (FT^3)}{259200}$
1.5"	0.041	
2"	0.074	
2.5"	0.116	
3"	0.167	$Q_{MIN} = \frac{\text{DEWATERING ZONE VOLUME } (FT^3)}{604800}$
3.5"	0.227	
4"	0.297	

PROCEDURE FOR ORIFICE SELECTION

① KNOWING THE SIZE AND SHAPE OF THE DEWATERING ZONE, CALCULATE THE VOLUME OF WATER (CUBIC FEET) FROM THE BOTTOM OF THE DEWATERING ZONE TO THE TOP OF THE DEWATERING ZONE.

② SOLVE FOR Q_{MAX} AND Q_{MIN} BASED ON THE VOLUME OF THE DEWATERING ZONE.

③ SELECT AN ORIFICE SIZE (FOS_D) THAT HAS A CORRESPONDING DISCHARGE BETWEEN Q_{MAX} AND Q_{MIN}.

FLOATING OUTLET STRUCTURE GENERAL NOTES

Ⓐ ALL P.V.C. PIPES ARE TO BE 4" I.D. SCHEDULE 40.

Ⓑ ALL JOINTS OF THE FLOATATION SECTION SHALL BE SOLVENT WELDED TO ENSURE AN AIRTIGHT ASSEMBLY. CONTRACTOR TO CONDUCT A TEST TO CHECK FOR LEAKS PRIOR TO INSTALLATION. JOINTS OF THE SKIMMER SECTION NEED NOT BE WATER-TIGHT.

Ⓒ 4" HDPE FLEXIBLE DRAIN PIPE IS TO BE ATTACHED TO THE BASIN OUTLET STRUCTURE WITH WATER-TIGHT CONNECTIONS.

Ⓓ ORIFICE IS TO BE SIZED ACCORDINGLY TO STORAGE VOLUME AND TO SLOWLY RELEASE RUNOFF. THE BASIN DEWATERING TIME SHOULD BE NO LESS THAN 3 DAYS.

Ⓔ FOR CORRUGATED METAL RISER, STUB PIPE SHALL BE SCHEDULE 40 STEEL PIPE TACK WELDED TO CREATE A WATERTIGHT SEAL. FOR CONCRETE RISER, STUB PIPE SHALL BE SCHEDULE 40 P.V.C. PIPE GROUTED TO CREATE A WATERTIGHT SEAL.

Ⓕ MATERIALS:

SOLID PIPE - 4" SCHEDULE 40 P.V.C.
PERFORATED PIPE - 4" SCHEDULE 40 P.V.C.
90° TEE (1 EA.) - 4" SCHEDULE 40 P.V.C.
90° ELBOW (2 EA.) 4" SCHEDULE 40 P.V.C.
CAP (4 EA.) - 4" SCHEDULE 40 P.V.C., SOLID
FLEXIBLE PIPE - 4" CORRUGATED HDPE (NON-PERFORATED)
MINERAL AGGREGRATE - SIZE *57

Ⓖ FLOATING OUTLET STRUCTURE SHALL BE PAID FOR UNDER THE FOLLOWING ITEM NUMBERS:

209-20.21 SEDIMENT BASIN OUTLET STRUCTURE (DESCRIPTION) L.S.

PAYMENT SHALL INCLUDE ALL MATERIALS AND LABOR NECESSARY FOR THE CONSTRUCTION, MAINTENANCE, AND REMOVAL OF THE FLOATING OUTLET STRUCTURE, INCLUDING REPLACMENT OF THE STONE PAD AS NECESSARY.

Ⓗ SEE THE QPL FOR APPROVED ALTERNATE FLOATING OUTLET STRUCTURES. THE ORIFICE SIZING PROCEDURE ON THIS SHEET IS NOT VALID FOR ALTERNATE FLOATING OUTLET STRUCTURES. ALTERNATE FLOATING OUTLET STRUCTURES SHALL BE DESIGNED TO ACHIEVE A SIMILAR DEWATERING TIME.

Ⓘ SEE STANDARD DRAWINGS EC-STR-15, EC-STR-16 AND EC-STR-17 FOR ADDITIONAL DETAILS AND GENERAL NOTES NOT SHOWN ON THIS DRAWING.

NOT TO SCALE

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

SEDIMENT BASIN
FLOATING OUTLET
STRUCTURE

8-01-12 EC-STR-18

Figure A-4. Standard TDOT design drawing for a sediment basin (TDOT 2017)

APPENDIX B: Other Data and Photos

Figure B-1. Photos from experimental run

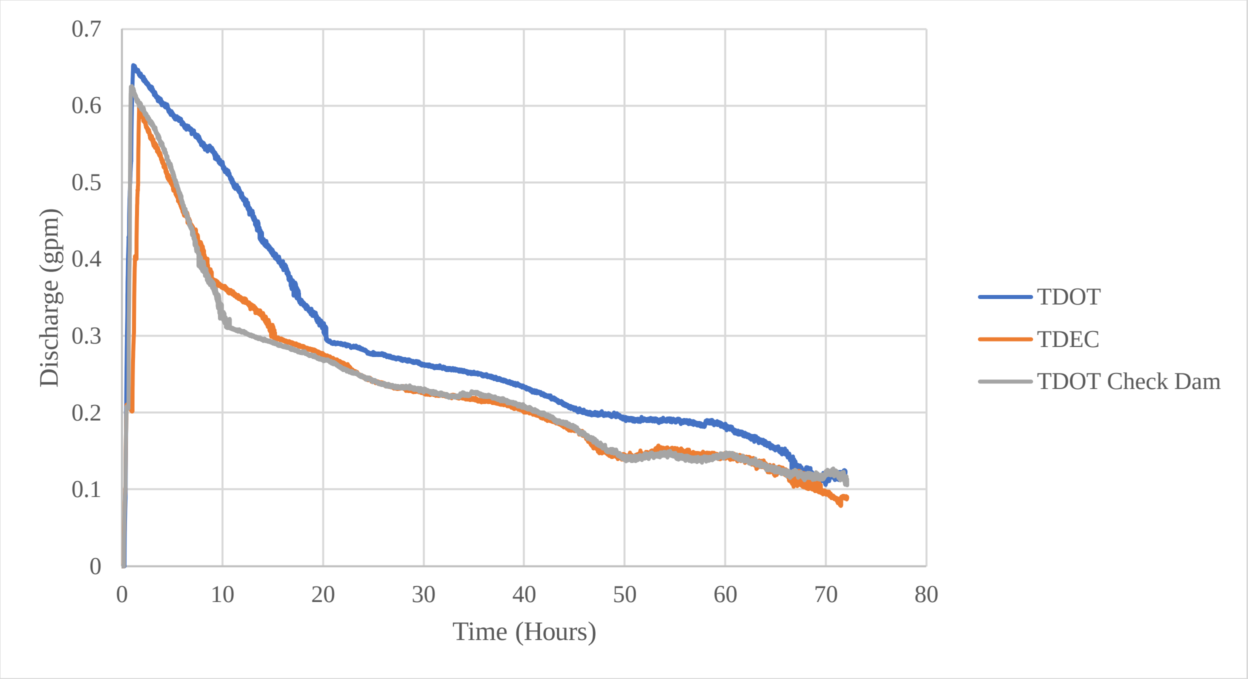
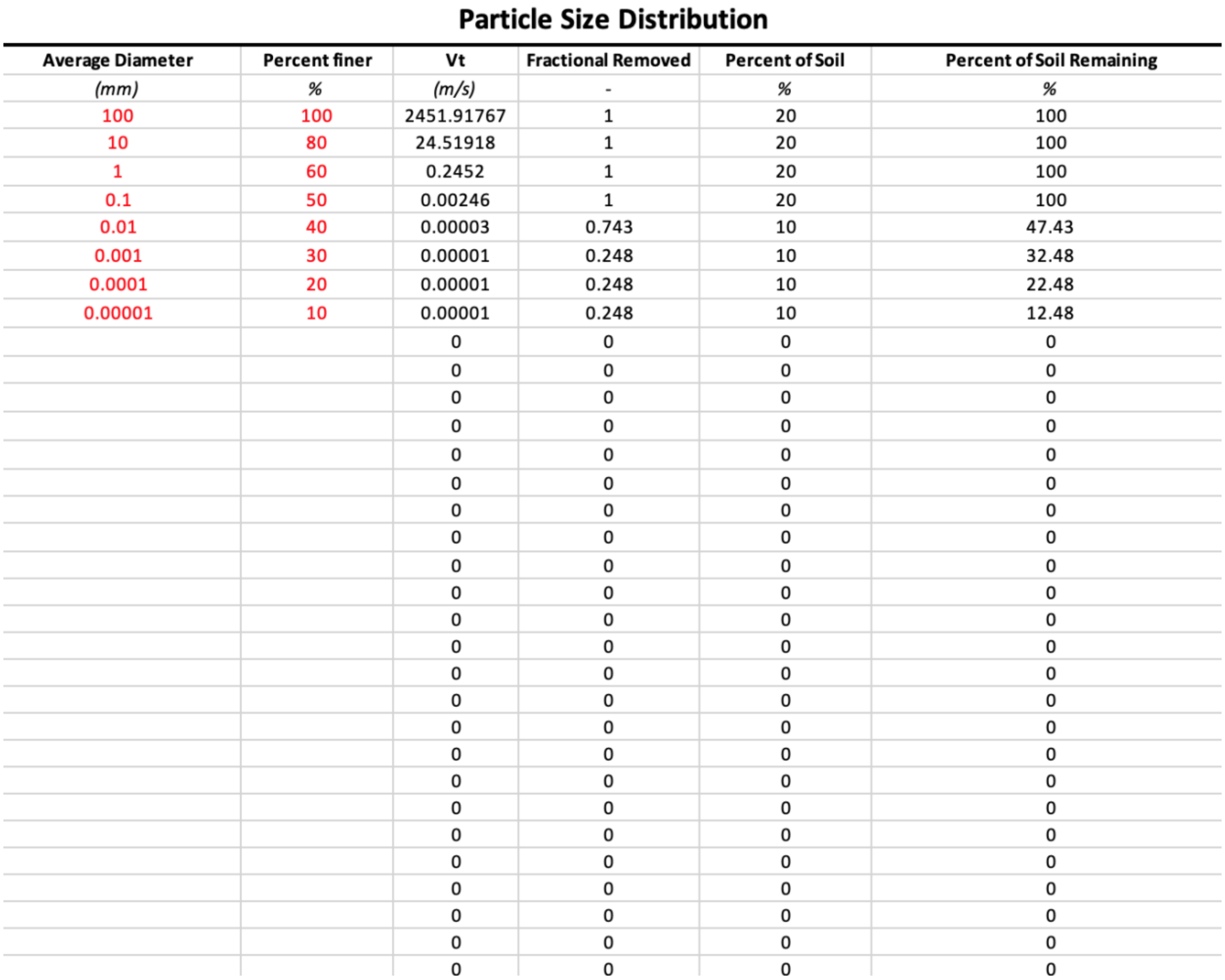


Figure B-2. Average outflow (gpm) for TDOT, TDEC, and TDOT CD designs over 72-hour dewatering period

APPENDIX C: Sediment Basin Design Spreadsheet Model

Steps for User:

1) Input either Particle Size Distribution (PSD) (average diameter (mm) and percent finer) or Sand, Silt, and Clay Percentages. Select "PSD" or "% Sand, Silt, Clay" in Cell M16.



Particle Size Distribution

Average Diameter	Percent finer	Vt	Fractional Removed	Percent of Soil	Percent of Soil Remaining
(mm)	*%*	*(m/s)*	-	*%*	*%*
100	100	2451.91767	1	20	100
10	80	24.51918	1	20	100
1	60	0.2452	1	20	100
0.1	50	0.00246	1	20	100
0.01	40	0.00003	0.743	10	47.43
0.001	30	0.00001	0.248	10	32.48
0.0001	20	0.00001	0.248	10	22.48
0.00001	10	0.00001	0.248	10	12.48
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
		0	0	0	0
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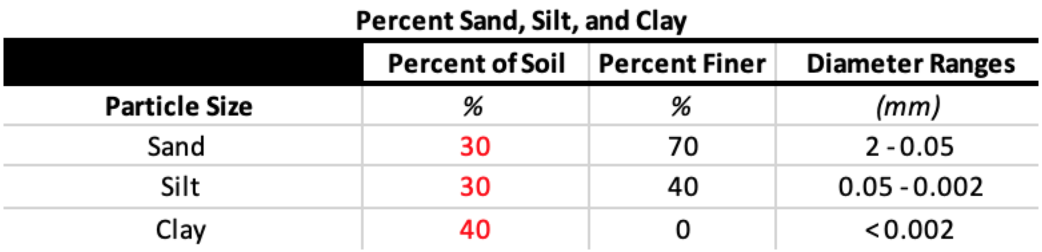
		0	0	0	0
		0	0	0	0
		0	0	0	0



Percent Sand, Silt, and Clay

	Percent of Soil	Percent Finer	Diameter Ranges
Particle Size	*%*	*%*	*(mm)*
Sand	30	70	2 - 0.05
Silt	30	40	0.05 - 0.002
Clay	40	0	<0.002

2) Input average water density, average particle density, and dynamic viscosity for use in fractional removal and settling velocities.

Water Density	1000	*kg/m3*
Particle Density	1400	*kg/m3*
Dynamic Viscosity	0.0008891	*Pa-s*

3) If using:
    a. **PSD** – Choose smallest particle size (mm) to be 100 % removed and enter in Cell E11.
    b. **Sand, Silt, and Clay** – Choose the percent of Sand, Silt, or Clay to be removed in Cells G69 and H69.
4) Input:
    a. **Drainage Area** (acres) – Cell M9
    b. **Stream Parameters** – Available or Unavailable in Cell M13
    c. **Design Discharge** (cfs) – 2 Yr. 24 hr (available) or 5 Yr. 24 hr. (unavailable) in Cell M10
    d. **Emergency Spillway Present** – Yes or No in Cell M15
    e. **Emergency Spillway Discharge** (cfs) – 25 Yr. 24 hr. discharge in Cell 14 (**Enter regardless of spillway present or not)**
5) Choose dewatering device: Faircloth Skimmer ® or perforated riser in Cell Z20.
6) Enter a bottom width (ft) for the emergency spillway design (trapezoidal) in Cell AA24.
7) Press "RUN"

Percent Removal Calculations:

1) Settling velocity (v_t) calculated through the following:

$$v_t = \frac{(\rho_p - \rho_f)d^2}{18\mu} g$$

$\rho_p = \text{particle density} \left({}^{kg}/_{m^3}\right)$
$\rho_f = \text{fluid density} \left({}^{kg}/_{m^3}\right)$
$d = \text{particle diameter (mm)}$
$\mu = \text{dynamic viscosity (Pa} - \text{s)}$
$g = \text{gravity} \left({}^{m}/_{s^2}\right)$

2) Fractional removal is then calculated using:

$$\text{Fractional Removal} = \frac{v_t}{v_o}$$

$v_o = \text{overflow velocity} \left({}^{m}/_{s}\right)$

*Overflow velocity is assumed to be at the dry storage height

How Basin is Designed:

1) **Overflow Velocity** (ft/s) – Goal seeks to find v_o such that:

$$\frac{v_t}{v_o} = 1$$

For either 100 % removal diameter (Cell G11) or diameter associated with % Sand, Silt, Clay removal (Cell H69).

2) **Dry Storage**
    a. Surface area (SA, ft^2) calculated at dry storage height using (Cell W23):

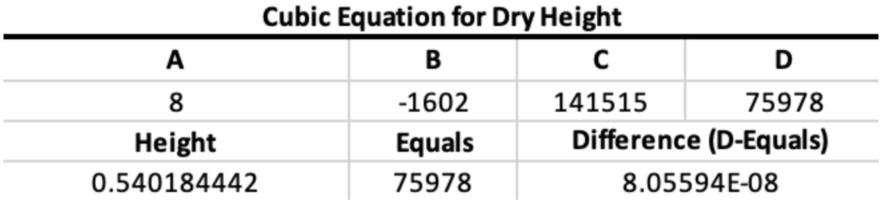
    $$\frac{Q}{v_o} = SA$$

    For discharge (Q, cfs) of either 2, 5, or 25 Yr. 24 hr.

    b. Width (w, ft) calculation based on TDOT length-to-width (L:W) standard of 2:1 such that (Cell W20):

    $$w = \sqrt{\frac{SA}{2}}$$

    c. Dry storage height (ft) is solved through a cubic equation relating height to volume in the basin (Cell W22). Goal seeks to minimize error between actual (Cell Y56) and calculated (Cell W58) dry storage volume. Actual dry storage volume is assumed to be the TDOT standard minimum dry storage volume equal to 1809 cubic feet per acre.



Cubic Equation for Dry Height

A	B	C	D
8	-1602	141515	75978
Height	**Equals**	**Difference (D-Equals)**	
0.540184442	75978	8.05594E-08	

    *Minimum height of 4 ft is required by TDOT, largest value is chosen.

    d. Design volume is calculated (cubic feet) in Cell W24

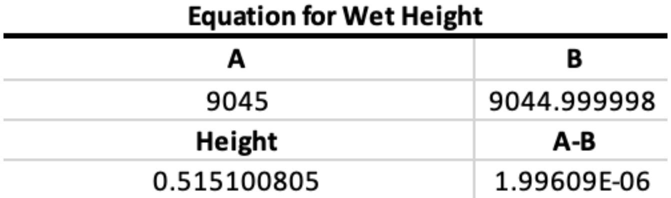
3) **Bottom of Basin Geometry**
    a. Bottom width (ft) calculated using minimum TDOT standard side slopes ratio (H:V) of 2:1 where (Cell W10):

    $$(\text{dry width}) - (\text{H:V})(2)(\text{dry height}) = \text{Bottom width}$$

    b. Bottom length (Cell W11):

    $$(\text{dry length}) - (\text{H:V})(2)(\text{dry length}) = \text{Bottom length}$$

4) **Wet Storage**
    a. Wet storage height (ft) is calculated using goal seek to minimize the difference between TDOT minimum volume requirement for wet storage (Cell Z56) and calculated wet storage volume as a function of height (Cell AA56). TDOT requirement for wet storage is 1809 cubic feet per acre. Height is shown in Cell W15.



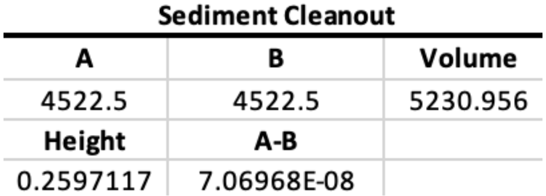
Equation for Wet Height

A	B
9045	9044.999998
Height	**A-B**
0.515100805	1.99609E-06

b. Wet storage width (ft) calculated by using minimum TDOT standard side slopes ratio (H:V) of 2:1 where (Cell W13):
$$(\text{bottom width}) - (\text{H:V})(2)(\text{wet storage height}) = \text{Wet storage width}$$
c. Wet storage length (Cell W14):
$$(\text{bottom length}) - (\text{H:V})(2)(\text{wet storage height}) = \text{Wet storage length}$$
d. Surface area (square feet) calculated and shown in Cell W16.
e. Design volume (cubic feet) shown in Cell W17.

5) **Sediment Cleanout**

a. Height for sediment cleanout is calculated using goal seek to minimize the difference between TDOT minimum requirement for sediment cleanout (Cell AB56) and calculated sediment cleanout as a function of height (Cell AC56). TDOT requirement for sediment cleanout volume is 905 cubic feet per acre. Height for sediment cleanout is shown in Cell W33.

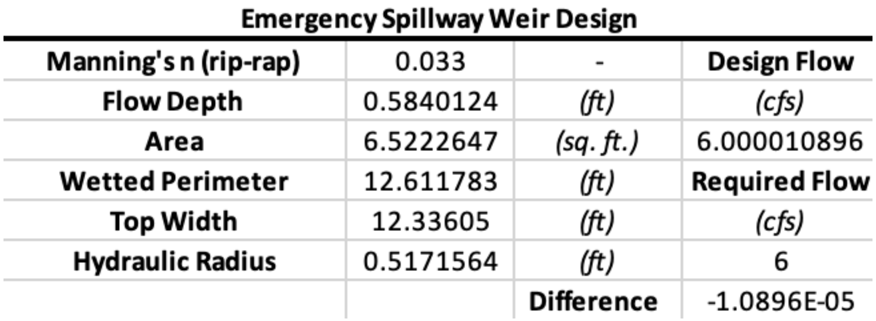


Sediment Cleanout

A	B	Volume
4522.5	4522.5	5230.956
Height	**A-B**	
0.2597117	7.06968E-08	

6) **Emergency Spillway Design**

a. Height of emergency spillway is required to be 1 foot higher than the dry storage height, as required by TDOT (Cell W27).
b. Freeboard (Cell W28) as required by TDOT:
   i. If emergency spillway is present, freeboard is 1 foot.
   ii. If emergency spillway is not present, freeboard is 2 feet.
c. Weir design (trapezoidal) for emergency spillway calculates flow depth such that:
$$Q_{\text{design}} = Q_{\text{required}}$$
Where Q_{required} is the 25 Yr. 24 hr. discharge (Cell M14) and Q_{design} is calculated by:
$$Q = \frac{1.49}{n} A {R_h}^{2/3} \sqrt{S_o}$$
$A = \text{area (ft}^2)$
$R_h = \text{Hydraulic radius (ft)}$
$n = 0.033\ (\text{rip} - \text{rap})$
$S_o = \text{slope} \left({}^{\text{ft}}/_{\text{ft}}\right)$



Emergency Spillway Weir Design

Manning's n (rip-rap)	0.033	-	**Design Flow**
Flow Depth	0.5840124	*(ft)*	*(cfs)*
Area	6.5222647	*(sq. ft.)*	6.000010896
Wetted Perimeter	12.611783	*(ft)*	**Required Flow**
Top Width	12.33605	*(ft)*	*(cfs)*
Hydraulic Radius	0.5171564	*(ft)*	6
		Difference	-1.0896E-05

A goal seek minimizes the difference between the required flow and design flow as a function of flow depth. Final flow depth is shown in Cell AA25. Top width of the emergency spillway is calculated and shown in Cell AA27. Additionally, rip-rap thickness is required by TDOT to be 1.5 feet thick (Cell AA26).

7) **Embankment**
   a. Embankment height (ft), if no emergency spillway is present, is calculated by (Cell W30):

$$\text{Embankment height} = \text{emergency spillway height} + \text{freeboard}$$

And if an emergency spillway is present:

$$\text{Embankment height} = \text{emergency spillway height} + \text{freeboard} + \text{flow depth of weir} + 1.5'$$

   b. Top width of embankment is required by TDOT to be 10ft.

8) **Dewatering Device**
   a. Faircloth Skimmer ®
      i. Known discharge for specific diameter skimmer ®.
      ii. Q_{max} and Q_{min} calculated by:

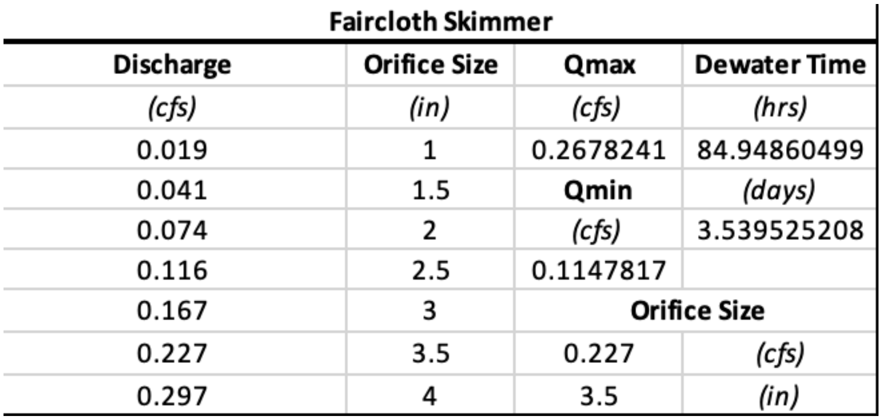
$$Q_{max} = \frac{Dewater\ volume}{259200}\ (cfs)$$

$$Q_{min} = \frac{Dewater\ volume}{604800}\ (cfs)$$

Largest Q that fit's between Q_{max} and Q_{min} and the corresponding diameter is chosen (Cell AA21).

      iii. Dewatering time (hrs) calculated by (Cell AA22):

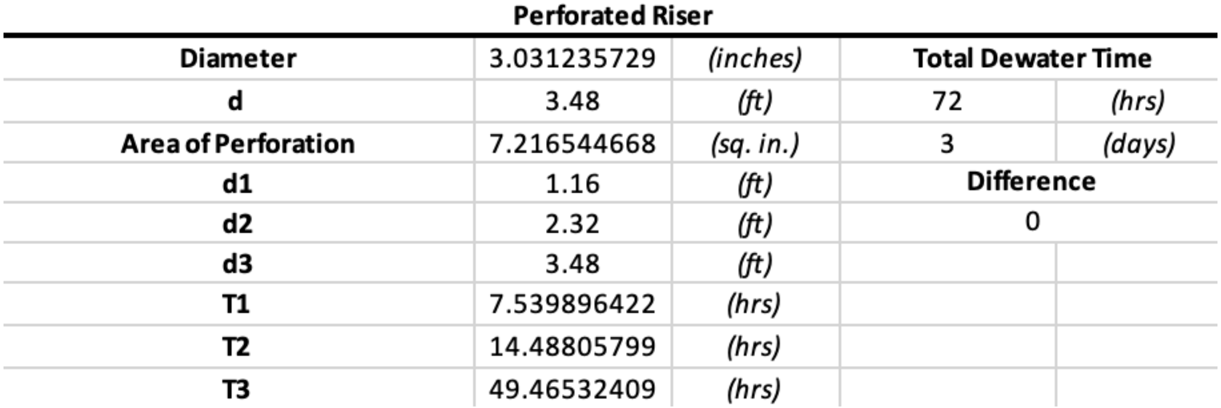
$$Dewatering\ time = {\frac{Dewater\ volume}{Q}}\Big/_{3600}$$



Faircloth Skimmer

Discharge	Orifice Size	Qmax	Dewater Time
(cfs)	*(in)*	*(cfs)*	*(hrs)*
0.019	1	0.2678241	84.94860499
0.041	1.5	**Qmin**	*(days)*
0.074	2	*(cfs)*	3.539525208
0.116	2.5	0.1147817	
0.167	3	**Orifice Size**	
0.227	3.5	0.227	*(cfs)*
0.297	4	3.5	*(in)*

b. Perforated Riser
   i. 3 perforations equally spaced over dry storage height
      1. T1, T2, and T3 are the corresponding dewatering time between each perforation

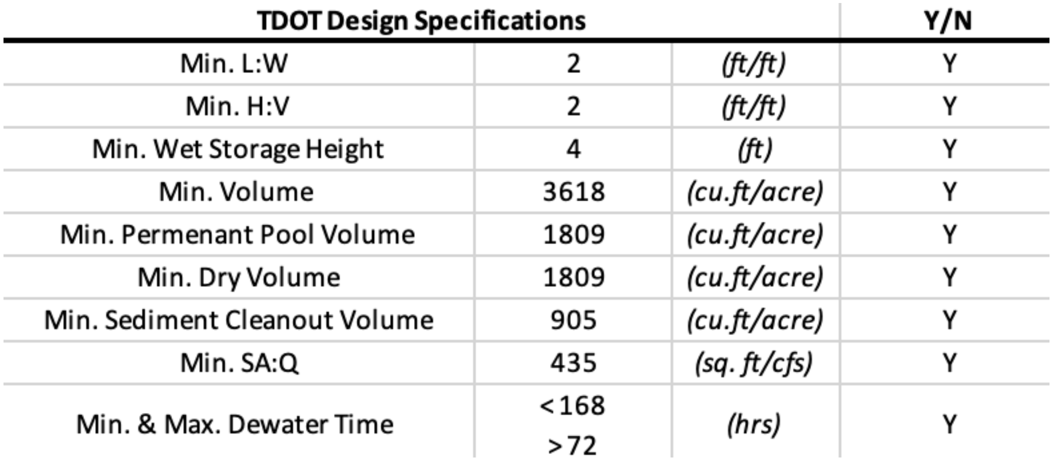


Perforated Riser

Diameter	3.031235729	*(inches)*	**Total Dewater Time**	
d	3.48	*(ft)*	72	*(hrs)*
Area of Perforation	7.216544668	*(sq. in.)*	3	*(days)*
d1	1.16	*(ft)*	**Difference**	
d2	2.32	*(ft)*	0	
d3	3.48	*(ft)*		
T1	7.539896422	*(hrs)*		
T2	14.48805799	*(hrs)*		
T3	49.46532409	*(hrs)*		

   ii. Goal seeks such that the perforation diameter (Cell AA21) results in a total dewatering time of 72 hours.

9) **Design Specification Check**
   a. TDOT regulations checked with current basin desing
      i. Minimum L:W ratio
      ii. Minimum H:V ratio
      iii. Minimum wet storage volume
      iv. Minimum total volume of basin
      v. Minimum permanent pool volume
      vi. Minimum dry storage volume
      vii. Minimum sediment cleanout
      viii. Minimum surface area to flow ratio (SA:Q)
      ix. Minimum and maximum dewatering time



TDOT Design Specifications			Y/N
Min. L:W	2	*(ft/ft)*	Y
Min. H:V	2	*(ft/ft)*	Y
Min. Wet Storage Height	4	*(ft)*	Y
Min. Volume	3618	*(cu.ft/acre)*	Y
Min. Permenant Pool Volume	1809	*(cu.ft/acre)*	Y
Min. Dry Volume	1809	*(cu.ft/acre)*	Y
Min. Sediment Cleanout Volume	905	*(cu.ft/acre)*	Y
Min. SA:Q	435	*(sq. ft/cfs)*	Y
Min. & Max. Dewater Time	<168 >72	*(hrs)*	Y

10) **Other**

   a. An error can occur when the user chooses too large of a particle size to remove or too small of a percent removal for the chosen soil type. Essentially, the designed basin will need to be smaller than TDOT requirements and will give negative values for some design features. Thus, the user will need to choose a smaller particle size or larger removal of the selected soil type.

Vita

Jeffery Cole Emmett Jr. grew up in Ooltewah, Tennessee. After high school he attended the University of Tennessee, Knoxville and received a Bachelor of Science degree in Civil Engineering with a minor in Watershed. Then, he chose to continue his education at the University of Tennessee, Knoxville to pursue a Master of Science degree in Environmental Engineering. After graduation, he will begin his new position as an Engineering Associate at a local engineering firm.