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EVALUATION OF DITCH INLET PROTECTION PRODUCTS FOR SEDIMENT RETENTION

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16. Abstract

Upon starting roadside construction work, construction crews must begin by ripping up a considerable amount of the ground. This process leaves areas such as roadside ditches without vegetation cover, which in turn leaves the soil bare and exposed to the elements such as heavy rains. When the rain hits this bare ditch, soil enters the water runoff and flows into ditch inlets. This soil is detrimental to sewer infrastructure as well as to the environment and must be avoided.

At the Erosion Control Research and Training Center (ECRTC) at the University of Illinois at Urbana-Champaign, various tests were conducted to test the installation and effectiveness of ditch inlet protection products. These tests analyzed the ability of the products to prevent soil from entering ditch inlets via site runoff. The goal of these tests was to compare the various products and determine which could best be implemented in the field at construction sites. Numerous criteria were examined during testing to make the best recommendations to the Illinois Department of Transportation (IDOT).

The products analyzed in testing were: (1) welded-wire inlet protector made of a porous woven monofilament fabric using two installation methods, (2) sediment log with two installation methods, (3) Dandy Pop, (4) Dandy Bag, (5) drop filter bag, (6) silt fence (with a woven slit tape fabric) at a 2 foot spacing from the inlet, and (7) silt fence with a woven monofilament fabric.
Other than the tests done at the ECRTC in the past, there have been only limited studies done of inlet protection products, which makes the tests conducted as part of this project both more difficult and necessary in order to determine what products will work best onsite.

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EXECUTIVE SUMMARY

Upon starting roadside construction work, construction crews must begin by ripping up a considerable amount of the ground. This process leaves areas such as roadside ditches without vegetation cover, which in turn leaves the soil bare and exposed to the elements such as heavy rains. When the rain hits this bare ditch, soil enters the water runoff and flows into ditch inlets. This soil is detrimental to sewer infrastructure as well as to the environment and must be avoided.

At the Erosion Control Research and Training Center (ECRTC) at the University of Illinois at Urbana-Champaign, various tests were conducted to test the installation and effectiveness of ditch inlet protection products. These tests analyzed the ability of the products to prevent soil from entering ditch inlets via site runoff. The goal of these tests was to compare the various products and determine which could best be implemented in the field at construction sites. Numerous criteria were examined during testing to make the best recommendations to the Illinois Department of Transportation (IDOT).

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Other than the tests done at the ECRTC in the past, there have been only limited studies done of inlet protection products, which makes the tests conducted as part of this project both more difficult and necessary in order to determine what products will work best onsite.

CONTENTS

SECTION 1: INTRODUCTION

During road construction, crews often must strip vegetation from roadside ditches in order to carry out their jobs. This loss of vegetation cover leaves the soil vulnerable to erosion and sediment transport. Oftentimes, this sediment finds its way into inlets in roadside ditches that are used to drain water to prevent flooding on the pavement. The sediment is unimpeded in entering the inlet, which results in several concerns. The sediment can wear away at the sewer infrastructure, carry various pathogens and chemicals that will need to be filtered out later, and transport nutrients that can lead to environmental problems.

It is more efficient and less costly to minimize or prevent these problems (using ditch inlet protection products) than to resolve them after the construction project is finished. The products generally reduce the amount of soil that enters an inlet by creating a barrier around the inlet. Such barriers not only blocks soil while allowing water to flow through, they also reduce the velocity of the water as it approaches the inlet. The reduction in water velocity reduces soil erosion and increases the time it takes for water to enter the inlet. Increased time of flow gives sediment more time to settle out in the calm, slow-flowing waters around the inlet that the protection product creates.

Ditch inlet production products, however, can create some undesirable effects as well. Ideally, the products let water flow through while blocking sediment. The products must also be porous enough to prevent ponding but not too porous to let sediment particles pass through it. Some products can achieve this balance better than others. Some are good at trapping sediment but create ponding and vice versa. It is important to evaluate products on these merits as well as to what extent they reduce the amount of soil entering the inlet. If a product stops all sediment from coming through yet creates high levels of ponding, it may not be ideal for use roadways because of the possibility of flooding the road next to the ditch.

Another consideration when evaluating a product is its installation method. A product should be installed in accordance with manufacturer's instructions. Improper installation can lead to flooded roadways and additional maintenance costs. It is also important to determine which installation methods can be improved and which ones lead to product failure upon heavy ponding.

SECTION 2: OBJECTIVES

The purpose of this study was to examine several ditch inlet protection products based on analysis conducted in the laboratory. The products were evaluated on several criteria such as durability, ability to reduce sediment entering the inlet, and ponding effects.

The specific goals of the project were as follows:

- Install each product in accordance with its manufacturer's installation procedures.
- Use the testing protocol developed during the previous set of tests conducted by University of Illinois researchers.
- Conduct tests at the Erosion Control Research and Training Center (ECRTC) on the products and collect samples to examine their effectiveness.
- Examine samples from each test to determine how well the products reduced sediment into the inlet.
- Compare each product and each individual installation method in order to provide recommendations about which products work best and which should be used in a given situation.

SECTION 3: METHODOLOGY

3.1 INLET PROTECTION PRODUCTS

Several products were evaluated during this set of tests. As suggested by the Technical Review Panel (TRP), a few of the products were tested under different installation methods.

3.1.1 Welded-Wire Woven Monofilament Inlet Protector

The welded-wire woven monofilament inlet protector is a manufactured, temporary control barrier made of a wire frame covered by a synthetic fabric. The product slows flow into the inlet to encourage settling of the sediment as well as trapping sediment on the fabric. The synthetic fabric is far more porous than the previously tested welded wire and allows water to flow easier into the inlet, which prevents extreme ponding.

The product was tested using two installation methods: (1) tucking the bottom of the product under the inlet lid so that it directly surrounded the lid and (2) digging a trench 2 feet from the concrete pad of the inlet and burying the extra fabric at the bottom of the inlet in the trench. Some assembly is required; it does not come in a closed circle.

Once the fabric is around the lid tightly or trench 2 feet from the concrete pad, the loose ends must be securely joined. For the first installation method, only one product was needed to completely surround the lid (Figure 3.1). The loose ends were fastened tightly using zip ties with a few inches of overlap. The overlap was positioned away from the direct flow of water.

Figure 3.1 Welded-wire woven monofilament around the lid.

For the second installation method, a trench 6 inches deep was dug 2 feet away from the pad (Figure 3.2). The extra material was placed in the trench facing outward from the inlet. The trench was then backfilled and compacted. Three products were needed to surround the inlet in this test, and an overlap of about 5 inches was used when connecting each product. Again, zip ties were used and the overlaps were positioned away from the direct flow of water.

Figure 3.2 Welded-wire woven monofilament with 2 foot gap.

3.1.2 Sediment Log

Sediment logs are a manufactured, temporary inlet protection device made from biodegradable (aspen wood fiber) materials. This product reduces flow, which promotes settling of the sediment while trapping sediment in the wooden fibers that make up the interior of the log.

This product was tested using two different installation methods. The first installation method involved burying three sediment logs in a 6 inch deep trench dug 2 feet away from the concrete pad of the inlet. Typical sediment log installation protocols were followed. The sediment logs had a 2 foot overlap at each joining of two logs, stakes were staked in at a 45 degree angle against the flow, and stakes were placed at an interval of every 2 feet along the log (Figure 3.3).

Figure 3.3 Sediment log with no erosion control blanket.

The second installation method was the same; however, an erosion control blanket (ECB) was placed in the area between the log and the concrete pad (Figure 3.4). The blanket was an S31 blanket that was buried under the log in the trench. Staples were placed at an interval of every 2 feet in the ditch. In the area between the log and the concrete pad, the staples were placed at an interval of every 2 feet along the log and concrete pad.

Figure 3.4 Sediment log with erosion control blanket.

3.1.3 Dandy Pop

The Dandy Pop is a manufactured, reusable inlet protection device that comes pre-assembled. It is propped up, and the inlet lid is slipped into the product, which is then placed back over the inlet (Figure 3.5). This product is made of a lightweight woven monofilament fabric. It works to reduce flow into the inlet, which promotes settling, and sediment is trapped in the fabric. This product requires no extra work for installation. The opening that the lid is slid through is sealed with Velcro and then placed on the downstream side of the flow.

Figure 3.5 Dandy Pop.

3.1.4 Dandy Bag

The Dandy Bag is a manufactured, reusable inlet protection device that requires very little installation. It is made of a woven monofilament fabric (Figure 3.6). This product reduces flow, which promotes settling, and sediment is trapped in the fabric. The inlet lid is slid into the bag and then placed onto the inlet. The opening is sealed shut with Velcro and placed away from the direct flow of water.

Figure 3.6 Dandy Bag.

3.1.5 Drop Filter Bag

The drop filter bag is a manufactured, temporary inlet protection device that comes pre-assembled and requires very little installation. It collects solids in the fabric and prevents them from entering the inlet. The wire frame is placed inside the inlet, resting on the edge of the inlet. The bag drops inside the inlet and catches sediment that flows in (Figure 3.7).

Figure 3.7 Drop filter bag.

3.1.6 Silt Fence at a 2 Foot Spacing

This product is a manufactured, temporary inlet protection device. It is made of a woven, slit tape fabric. The product reduces the flow of water into the inlet, which promotes settling of the sediment outside of the inlet. For installation, a hexagon trench 6 inches deep was dug 2 feet away from the edge of the concrete pad of the lid. The six stakes were stapled to the fabric, the fabric was placed inside the trench, and the stakes were inserted 1 foot deep into the ground (Figure 3.8). The trench was then backfilled and compacted.

Figure 3.8 Silt fence with 2 foot gap.

3.1.7 Silt Fence with Woven Monofilament Fabric

This product is almost identical to the silt fence described in the previous section, except it is made of a different fabric (Figure 3.9). It follows the same general installation protocol of trenching the bottom of the product 6 inches deep and then stapling it to the stakes, which should be spread out so the product is taut. Cross braces must be placed to ensure stability. The product was set up in a square with the corners 2 feet from the concrete pad. Backfill must be compacted to ensure that little undercutting will occur. This particular setup used a more porous fabric that allows better water flow through it, which should help ensure less ponding and less product failure.

Figure 3.9 Silt fence with woven monofilament fabric.

3.2 FIELD SITE DESCRIPTION

All testing was conducted at the Erosion Control Research and Training Center (ECRTC) at the University of Illinois at Urbana-Champaign's South Farms. The testing was conducted in an L-shaped drainage ditch with a slope of 2%. The channel contained two manhole stormwater inlets, one at the start of the channel and one at the end of the channel. An underground pipe connected the two manholes. A V-notch weir located at the start of the channel was used to measure flow rates. Behind the first manhole, a dam was constructed to shorten the channel (Figure 3.10). The dam was made of three plywood boards buried 13 feet into the ground. The overlaps between the boards were filled with foam plumbing sealant.

(a)

(b)

(c)

Figure 3.10 (a) V-notch weir at the start of channel, (b) inlet manhole, (c) dam behind the inlet.

The retention pond at the ECRTC was used as the water source for each test. Water was pumped from the pond, underground toward the ditch, and then into the ditch behind the V-notch weir. A separate pump was used at the manhole farther down the channel to empty water that collected in the inlet.

3.3 TESTING PROTOCOL

Prior to testing, the channel was prepared to create a suitable testing environment. Two days before testing, weed killer was applied to kill the vegetation in the channel. The next day, the dead weeds were cut and removed. The channel was then tilled, raked, and compacted 24 hours prior to testing to allow satisfactory time for the soil to settle. Tilling was done with a hand tiller perpendicular to the direction of flow. The soil was raked to ensure an even soil distribution along the slopes and for a smooth soil profile. A was is pulled behind a tractor to compact the soil throughout the entire channel. The products were then installed and soil was re-compacted around the inlet with a hand tamper.

Testing cannot proceed until there have been two successive days of dry conditions (i.e., no rain or no flooding from previous testing). The channel was prepared in the same way, prior to each test.

3.3.1 Welded-Wire Woven Monofilament Inlet Protector, Sediment Log, and Silt Fence with Woven Monofilament Fabric

1. Testing began with flooding the area behind the V-notch weir. The test ran for 80 minutes at two different flow rates: 40 minutes at a flow rate of approximately 79 gallons/minute (gpm) or 5 L/s, at which point the flow rate was increased to 158 gallons/minute (gpm) or 10 L/s until the end of the 80 minute test. The timing started as soon as a sample was taken at Location A, which was the point at which the water first came through the V-notch weir.

   Samples were taken every 10 minutes at each point. At Location A, seven samples were taken. Six samples were taken at Location B, just outside the product. Six samples were also taken from Location C, which was just inside the manhole. Samples taken at Location C were gathered by hand because the inlet hole was exposed.

2. The time it took the water to reach the product, breach the product, and enter the manhole was recorded.

3. Observations, particularly the height of water outside the product, were recorded throughout the test.

3.3.2 Dandy Pop, Dandy Bag, and Drop Filter Bag

1. Testing began with flooding the area behind the V-notch weir. The test ran for 80 minutes at two different flow rates: 40 minutes at a flow rate of approximately 79 gallons/minute (gpm) or 5 L/s, at which point the flow rate was increased to 158 gallons/minute (gpm) or 10 L/s until the end of the 80 minute test. The timing started as soon as the sample was taken at Location A, which was the point at which the water first came through the V-notch weir.

   Samples were taken every 10 minutes at each point. At Location A, seven samples were taken. Six samples were taken at Location B, just outside the product. Six samples were also taken from Location C, which was just inside the manhole. For taking samples at Location C, a hand pump was used to pump water up from inside the manhole because these products obstruct access to the hole for taking hand samples.

2. The time it took the water to reach the product, breach the product, and enter the manhole was recorded.

3. Observations, particularly the height of water outside the product, were recorded throughout the test.

SECTION 4: OBSERVATIONS

4.1 WELDED-WIRE WOVEN MONOFILAMENT INLET PROTECTOR

Testing began with the designated flow rate of 79 gpm (5 L/s). The product's porous nature resulted in a fairly quick time of breach. As the test continued, ponding began around the inlet (Figure 4.1). Ponding was kept steady, however, and did not continue to increase though the first flow rate. Due to the porous nature of the material, water flowed through easily and did not begin to fill the entire channel (Figure 4.2). At 40 minutes, the flow rate was increased to 158 gpm (10 L/s), per testing protocols. The product remained fairly stable and did not fail under the increased flow. Undercutting was never observed during the duration of the test. Clearly visible sediment deposits remained on fabric after the test was concluded. Buildup of other biological debris was also observed against the product.

Figure 4.1 Inside of the welded-wire woven monofilament at 79 gpm (5 L/s).

Figure 4.2 Channel ponding during the welded-wire woven monofilament lid test at 79 gpm (5 L/s).

4.2 WELDED-WIRE WOVEN MONOFILAMENT WITH 2 FOOT GAP

Testing began with the designated flow rate of 79 gpm (5 L/s). Like the previous welded-wire installation, this installation also allowed easy flow of water through the product. Due to the large circular area that the product formed, and the ease with which the fabric allowed water through, ponding never became an extreme issue (Figure 4.3). Ponding depths were observed and recorded every 10 minutes outside of the product. Water did not flow around the product's sides until the flow rate was increased at 40 minutes to 158 gpm (10 L/s). At that flow rate, the product remained operational and did not fail. Settled sediment could be observed on the concrete pad during testing. Undercutting was largely a non-factor. At overlap points, some water could be observed flowing through the slight gaps between the ends of the product (Figure 4.4). Clear sediment buildup on the fabric could be observed after the test. Buildup of other biological debris was observed against the product.

Figure 4.3 Welded-wire woven monofilament with 2 foot gap under 79 gpm (5 L/s) flow rate.

Figure 4.4 Welded-wire woven monofilament with 2 foot gap under 79 gpm (5 L/s) flow rate, with overlap failure.

4.3 SEDIMENT LOG WITHOUT EROSION CONTROL BLANKET

Testing began with the designated flow rate of 79 gpm (5 L/s). Due to the large diameter of the circle that the product formed and its porous nature, ponding never became an extreme issue (Figure 4.5). Minor undercutting could be observed early on near the overlaps of the logs. Ponding depth was observed and recorded every 10 minutes outside of the product. Water did not flow around the sides of the product until a flow rate of 158 gpm (10 L/s) was established. At that flow rate, the product remained operational and did not fail. Sediment began settling out on the concrete pad of the inlet, as seen in Figure 4.6. After the test, sediment was observed to have built up in the wooden fibers of the sediment log. Biological debris was also built up on the outside of the product.

Figure 4.5 Sediment log without erosion control blanket, under 79 gpm (5 L/s) flow rate.

Figure 4.6 sediment settling on the concrete pad of the inlet.

4.4 SEDIMENT LOG WITH EROSION CONTROL BLANKET

Testing began with the designated flow rate of 79 gpm (5 L/s). Ponding depth was observed and recorded every 10 minutes outside of the product. Minor undercutting could be observed early on near the overlaps of the logs. Biological debris also built up on the outside of the product. Sediment was observed to begin settling out on the concrete pad of the inlet. Settled-out sediment was also observed on the erosion control blanket laid down in the 2 foot gap (Figure 4.7). Due to the large diameter of the circle that the product formed and its porous nature, ponding never became an extreme issue (Figure 4.8). Water did not flow around the sides of the product until the flow rate was raised to158 gpm (10 L/s). At that flow rate, the product remained operational and did not fail. After the test, sediment was observed to have built up in the wooden fibers of the sediment log and in the straw fibers in the erosion control blanket.

Figure 4.7 Sediment log with erosion control blanket, at 79 gpm (5 L/s) flow rate and showing sediment settling on the blanket.

Figure 4.8 Sediment log with erosion control blanket, at 79 gpm (5 L/s) flow rate, with water not flowing around it.

4.5 DANDY POP

Testing began with the designated flow rate of 79 gpm (5 L/s). Due to the small size of the product, water was able to flow completely around it (Figure 4.9). A minute before sample-taking time, any water trapped in the line was pumped out in order to get a clean sample for that time period (Figure 4.10). When the flow was increased to 158 gpm (10 L/s), the product remained operational and did not fail. Because of pump failure, the last two samples were collected inside of main tent of the product. Those two samples had not flowed through the final bottom section of fabric over the manhole. At the end of testing, sediment had collected on the fabric of the product. Biological debris also built up against the product.

Figure 4.9 Dandy Pop testing at 79 gpm (5 L/s) flow rate.

Figure 4.10 Dandy Pop at 79 gpm (5 L/s) flow rate, inside.

4.6 DANDY BAG

Testing began with the designated flow rate of 79 gpm (5 L/s). The product was fully submerged under water during the testing (Figure 4.11). The ponding became more severe when the flow rate was increased to 158 gpm (10 L/s).

Figure 4.11 Dandy Bag at 79 gpm (5 L/s) flow rate.

4.7 DROP INLET FILTER BAG

Testing began with the designated flow rate of 79 gpm (5 L/s). The water soon overwhelmed the filter bag (Figure 4.13), and it overflowed around 12 minutes after the experiment started (Figure 4.14). During the intervals, a hand pump was used to collect samples from underneath the inlet. At around 60 minutes, when most of the flow had started to go around the product, it became very difficult to acquire samples from under the product. This occurred until the test concluded, which prevented any data from being acquired after that time.

Figure 4.13 Filter bag at 79 gpm (5 L/s) flow rate, inside.

Figure 4.14 Filter bag at 158 gpm (10 L/s) flow rate.

4.8 SILT FENCE, 2 FOOT SPACING

The test began at a fixed flow rate of 79 gpm (5 L/s) (Figure 4.15). A slight rip near the base of the fabric was observed (Figure 4.16); weatherproof tape was used to cover the rip. Water entered the inlet 9 minutes after the experiment started. Undercutting began to occur at the north stake of the product at around 44 minutes. Undercutting occurred at the southeast stake at around 46 minutes, the southeast fabric at around 47 minutes, and the northeast stake at around 48 minutes. With this gradual progression of stake failure, the northernmost stake failed at 50 minutes 30 seconds. Undercutting can be observed in Figures 4.17 and 4.18.

Figure 4.15 Silt fence at 79 gpm (5 L/s) flow rate, inside.

Figure 4.16 Tear in silt fence.

Figure 4.17 Undercutting of silt fence.

Figure 4.18 More undercutting of silt fence.

4.9 SILT FENCE WITH WOVEN MONOFILAMENT FABRIC

The test began at the designated flow rate of 79 gpm (5 L/s). The flow through the fabric was slow to start. The water instead quickly flowed around the sides of the product and infiltrated primarily from the sides and back as ponding occurred (Figure 4.19). This is probably due to a buildup of sediment on the front of the product because the first water to contact it was carrying a high level of sediment. The product held up well and did not create high levels of ponding (Figure 4.20). At 40 minutes into the test, the flow rate was increased to 158 gpm (10 L/s). There was no visible sign of undercutting; ponding increased slightly but remained constant. The product didn't fail throughout the higher flow rate. After testing concluded, debris such as sediment and biological material was built up on the front and sides of the product.

Figure 4.19 Rapid flow around the side of the silt fence (monofilament fabric).

Figure 4.20 Front of the silt fence (monofilament fabric) during testing.

SECTION 5: RESULTS AND DISCUSSION

Sediment concentrations were obtained by weighing the sample jars before they were dried. The jars were then dried for 24 hours at ~98°C and then for another 24 hours at ~103°C. This was done to make sure bubbling did not occur when the jars were full, which would result in a loss of sediment if the jars overflowed. The jars were then cooled and weighed again. They were cleaned and then dried at 103°C for 24 hours, then cooled and weighed again. These weights were used to obtain the sediment concentrations.

Turbidity was measured with a turbidity meter calibrated using standard 0, 10, and 100 nephelometric turbidity unit (NTU) samples. Samples for turbidity were prepared by washing the sample tube out with the water from the sample being tested; the tube was then filled and wiped clean. Turbidity was taken three times for each sample, and the average was used.

The sediment concentration and turbidity results for each product are on the following pages.

5.1 WELDED-WIRE WOVEN MONOFILAMENT INLET PROTECTOR AROUND THE GRATE

Analysis of water samples indicated that sediment concentration (Figure 5.1) and turbidity (Figure 5.2) were lower inside than outside the product. The trend indicates that the product effectively filtered out sediment.

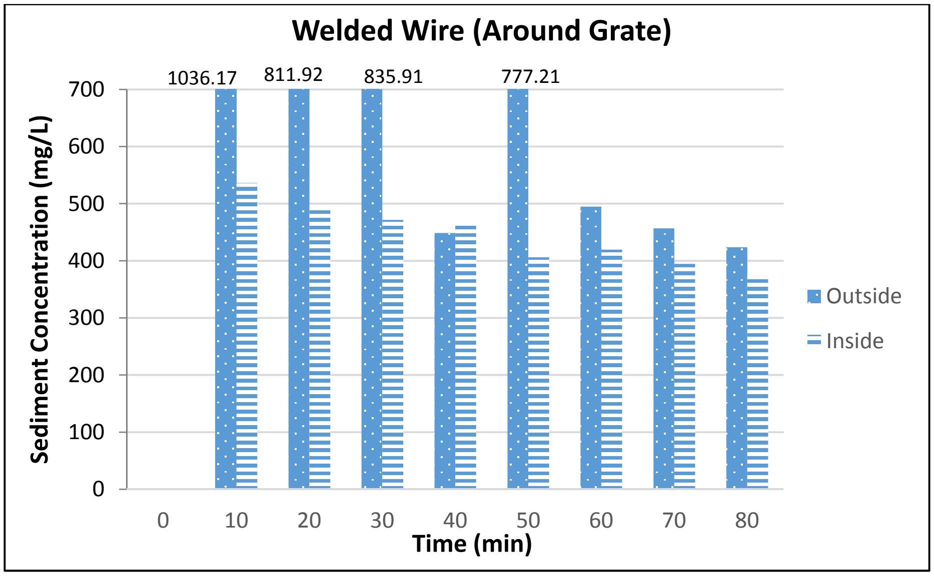

Figure 5.1 Sediment concentrations for welded-wire woven monofilament protector.

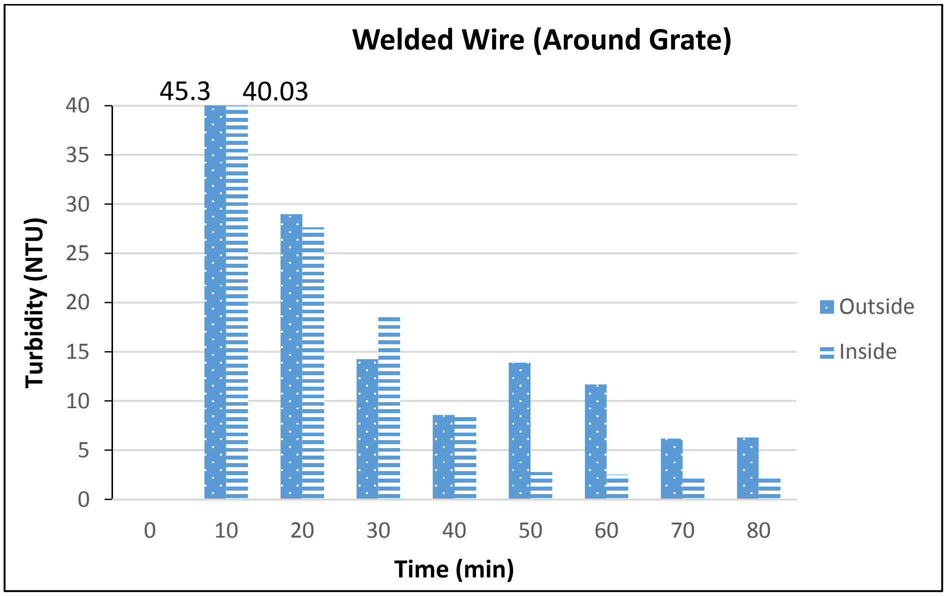

Figure 5.2 Turbidity values for welded-wire woven monofilament protector.

5.2 WELDED-WIRE WOVEN MONOFILAMENT INLET PROTECTOR WITH 2 FOOT GAP

For the majority of the water samples analyzed, sediment concentration (Figure 5.3) and turbidity (Figure 5.4) were lower inside the inlet than outside the product. The trend was more prominent for turbidity compared to sediment concentration. The result indicates that the product effective in filtering out sediment.

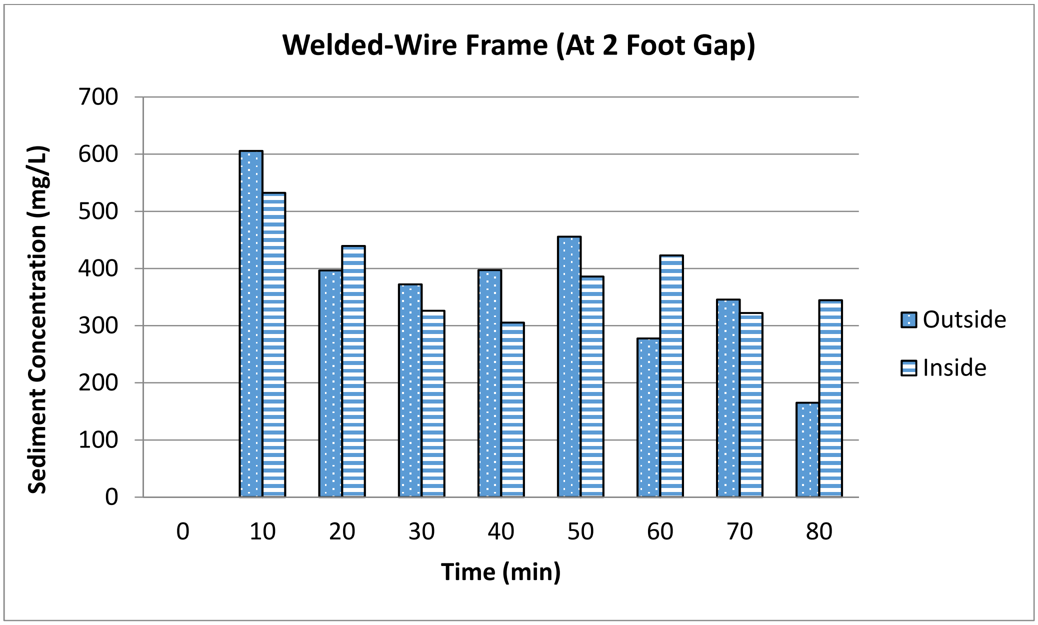

Figure 5.3 Sediment concentrations for welded-wire woven monofilament with 2 foot gap.

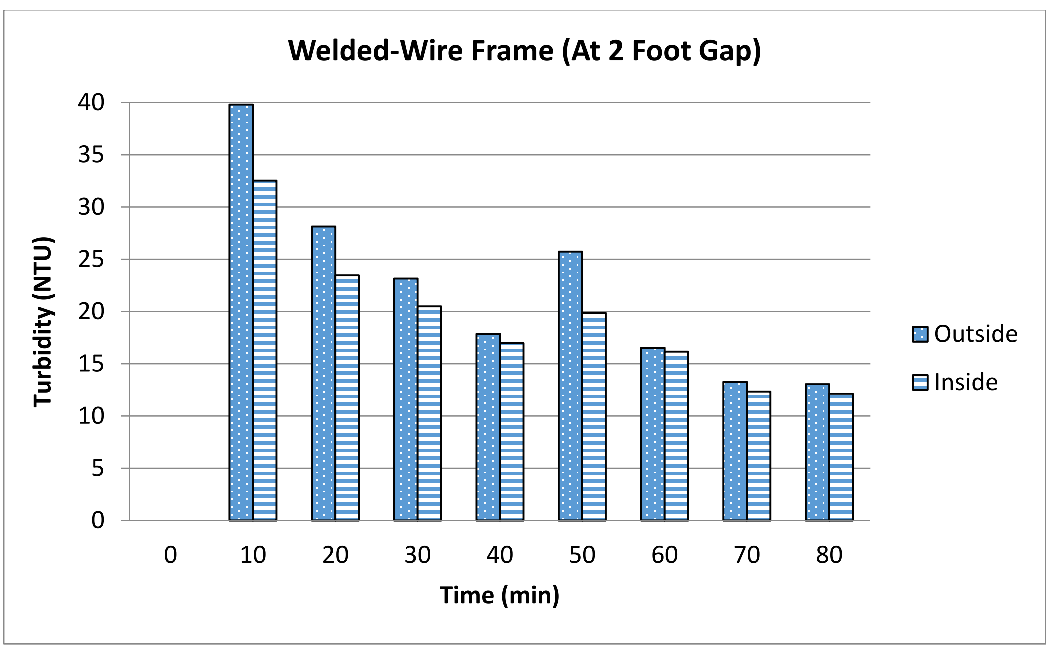

Figure 5.4 Turbidity for welded-wire woven monofilament with 2 foot gap.

5.3 SEDIMENT LOG WITHOUT EROSION CONTROL BLANKET

For the majority of water samples analyzed, sediment concentrations (Figure 5.5) tended to be higher inside the inlet than outside the product. Turbidity had an opposite trend (Figure 5.6). The exposed soil inside the sediment log may have contributed to elevated sediment concentration if the water had not been slowed enough by the product. A small amount undercutting at the overlaps of the product may have also been an issue.

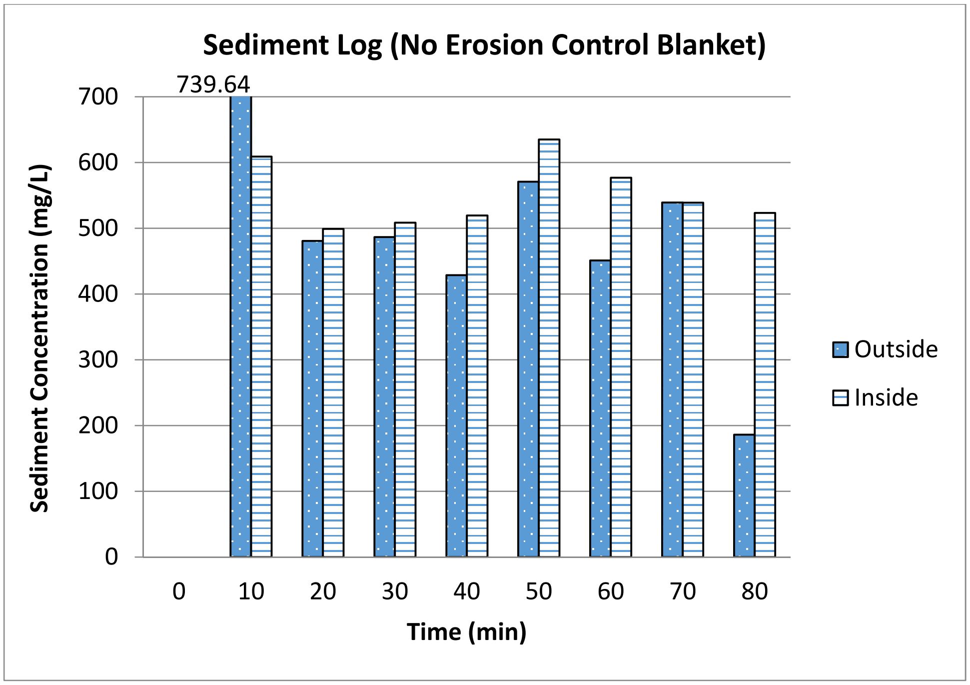

Figure 5.5 Soil concentrations for sediment log without an erosion control blanket.

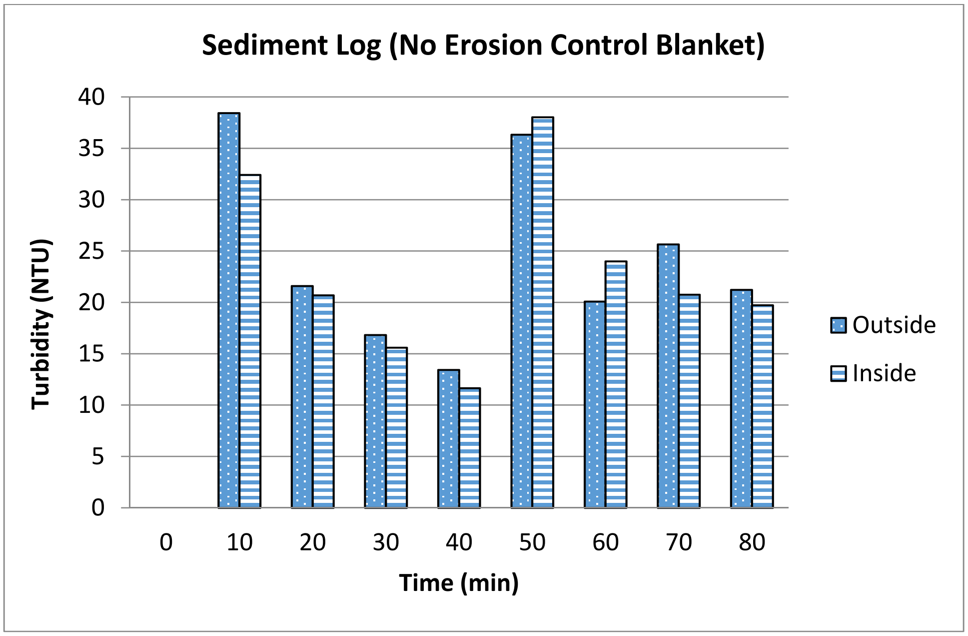

Figure 5.6 Turbidity for sediment log without erosion control blanket.

5.4 SEDIMENT LOG WITH EROSION CONTROL BLANKET

For this test, sediment concentrations typically were lower inside the inlet (Figure 5.7). Turbidity fluctuated greatly throughout the entire test (Figure 5.8). The reduction in sediment concentration was much more consistent and better at the 79 gpm (5 L/s) flow rate than at the 158 gpm (10 L/s) rate.

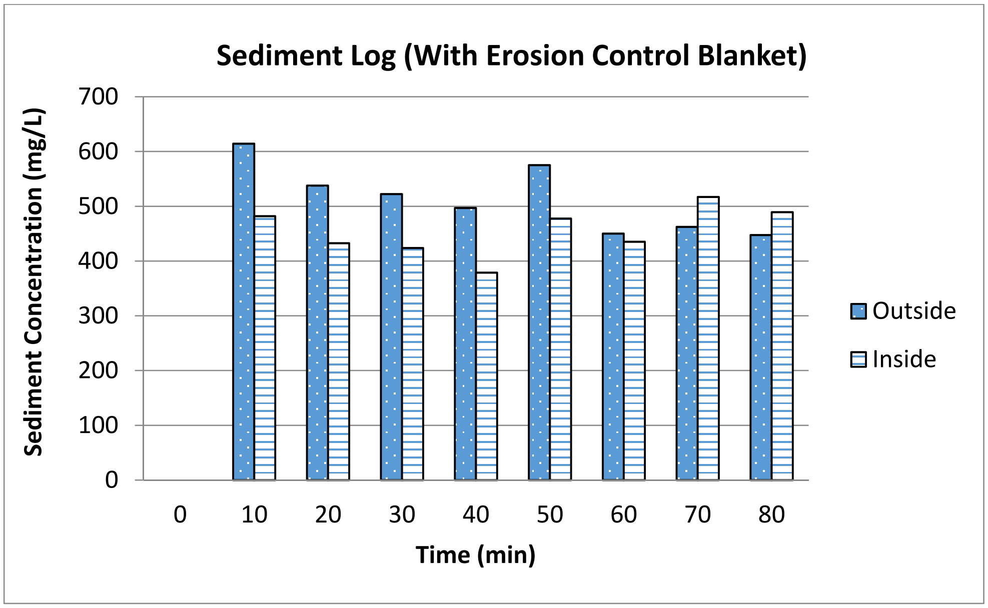

Figure 5.7: Soil concentration for sediment log with erosion control blanket.

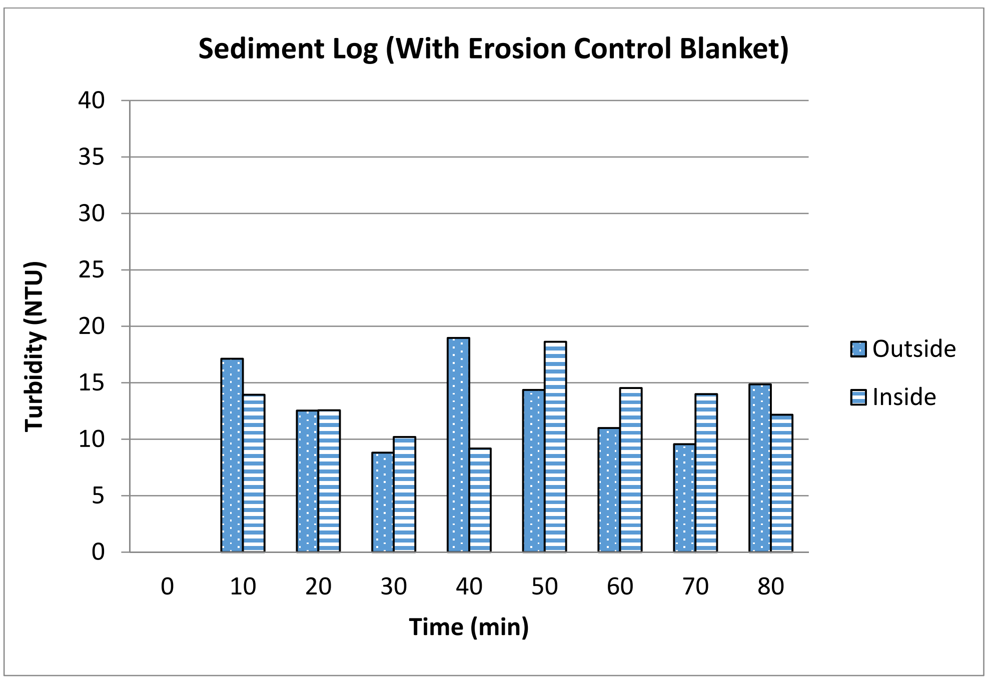

Figure 5.8 Turbidity for sediment log with erosion control blanket.

5.5 DANDY POP

Sediment concentrations fluctuated, but fairly consistent, throughout the testing (Figure 5.9). Problems arose with the hand pump at around 60 minutes; therefore, the last two samples were collected inside of main tent of the product. Those two samples were only partially filtered since they had not passed through the final bottom section of fabric over the manhole**.** Overall, the product seemed to reduce sediment concentration. Turbidity fluctuated throughout the testing, occurring mostly when we increase the flow rate (Figure 5.10).

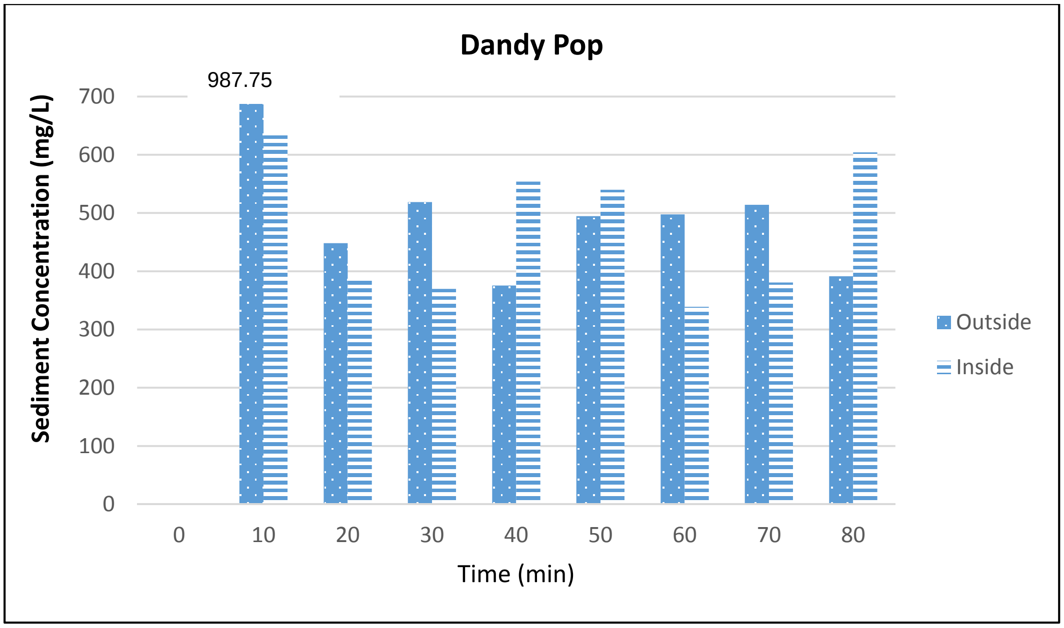

Figure 5.9 Sediment concentrations for Dandy Pop.

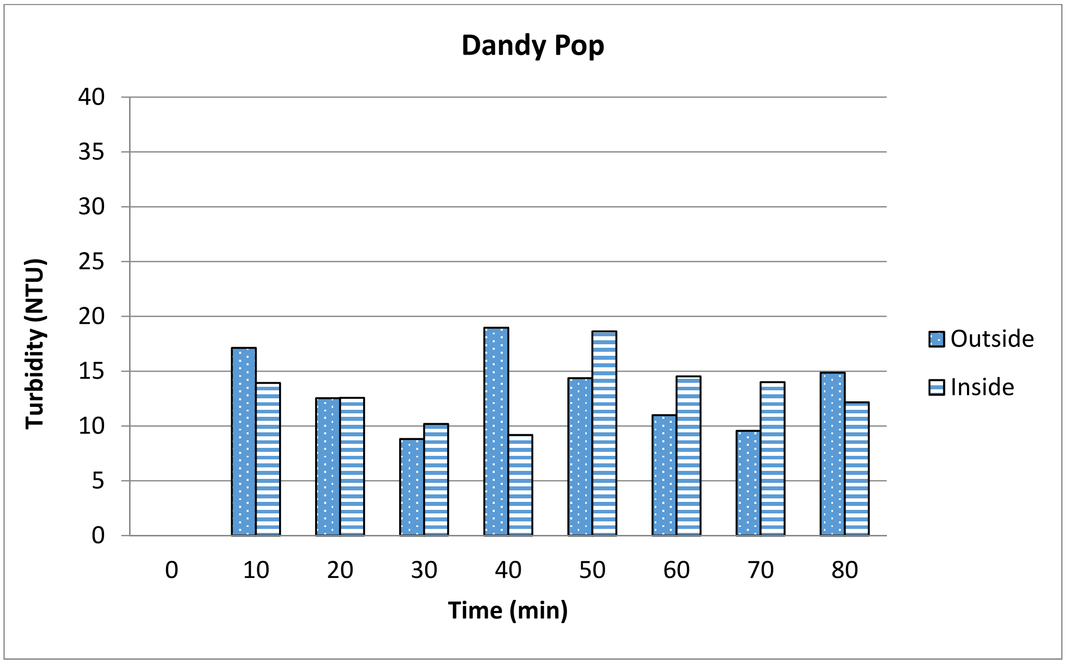

Figure 5.10 Turbidity for Dandy Pop.

5.6 DANDY BAG

Sediment concentrations (Figure 5.11) and turbidity (Figure 5.12) were consistently lower inside the inlet than outside the product for at both flow rates. This product worked quite well.

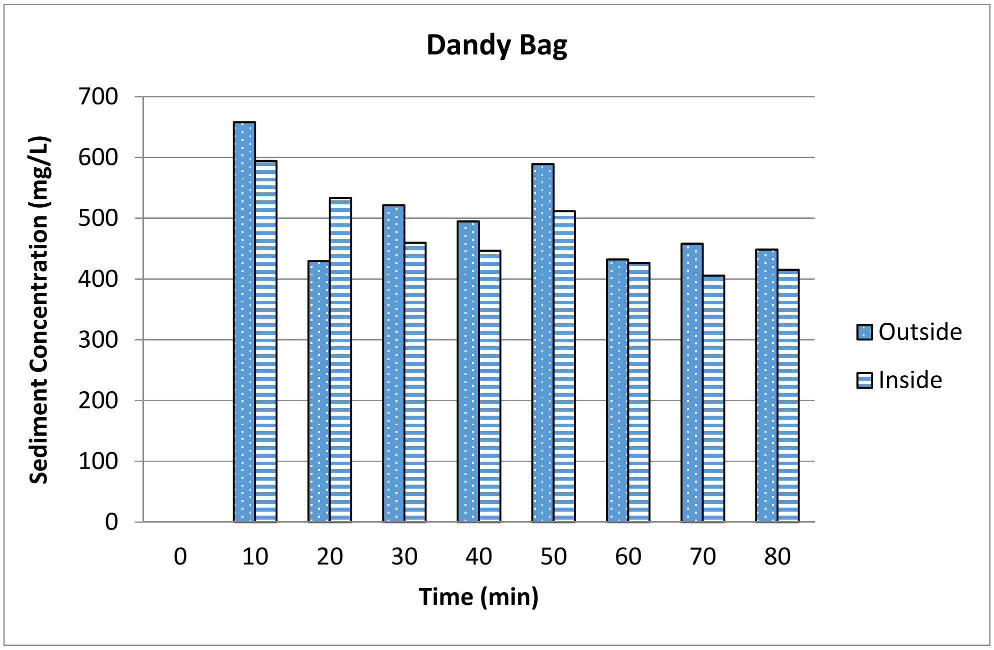

Figure 5.11 Sediment concentration for Dandy Bag.

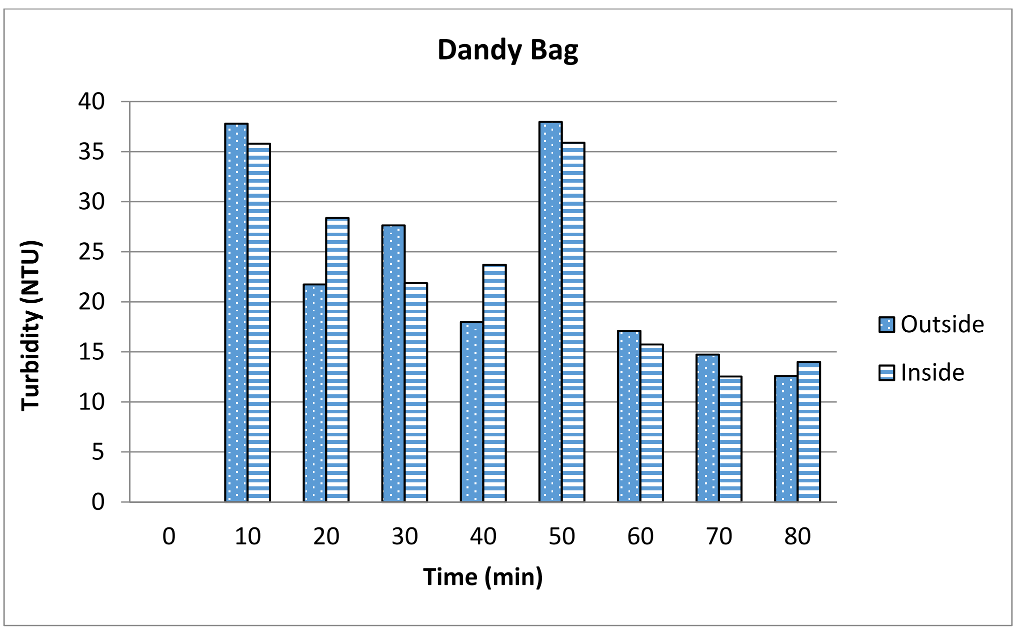

Figure 5.12 Turbidity for the Dandy Bag.

5.7 DROP FILTER BAG

For lower flow rates, sediment concentrations (Figure 5.13) and turbidity (Figure 5.14) remained slightly lower inside the inlet compared to outside the product. As time went on, ponding grew severe and made it difficult for the product to continue filtering out sediment; likewise, taking samples became difficult. Around 60 minutes, it was noted that most of the flow had bypassed the product. Consequently, water samples could not be collected through the hand pump.

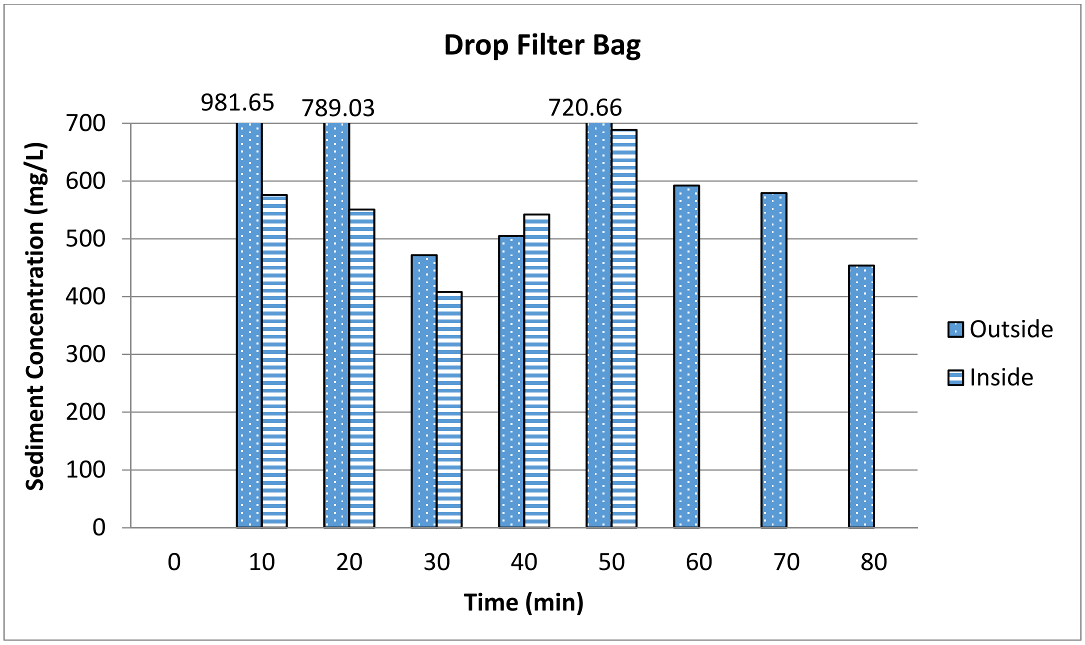

Figure 5.13 Sediment concentrations for drop filter bag.

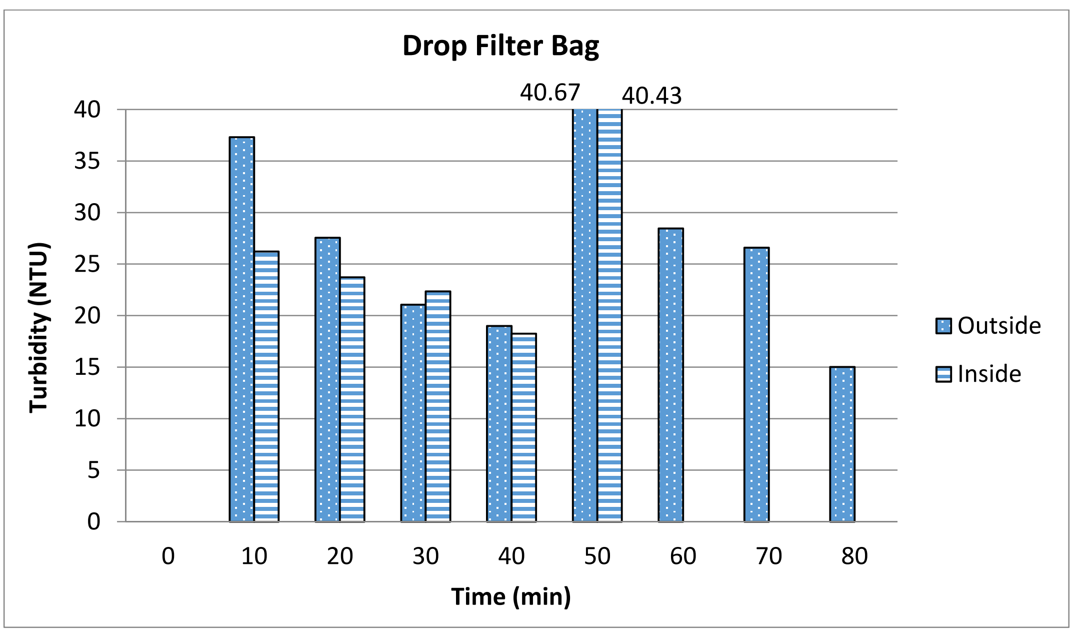

Figure 5.14 Turbidity for drop filter bag.

5.9 SILT FENCE WITH 2 FOOT GAP

There was a high sediment concentration throughout the test (Figure 5.15). This was due to severe undercutting of the product. This can be seen in the results, where a huge spike in concentration and turbidity is seen around 50 minutes when the north stake failed due to undercutting (Figure 5.16).

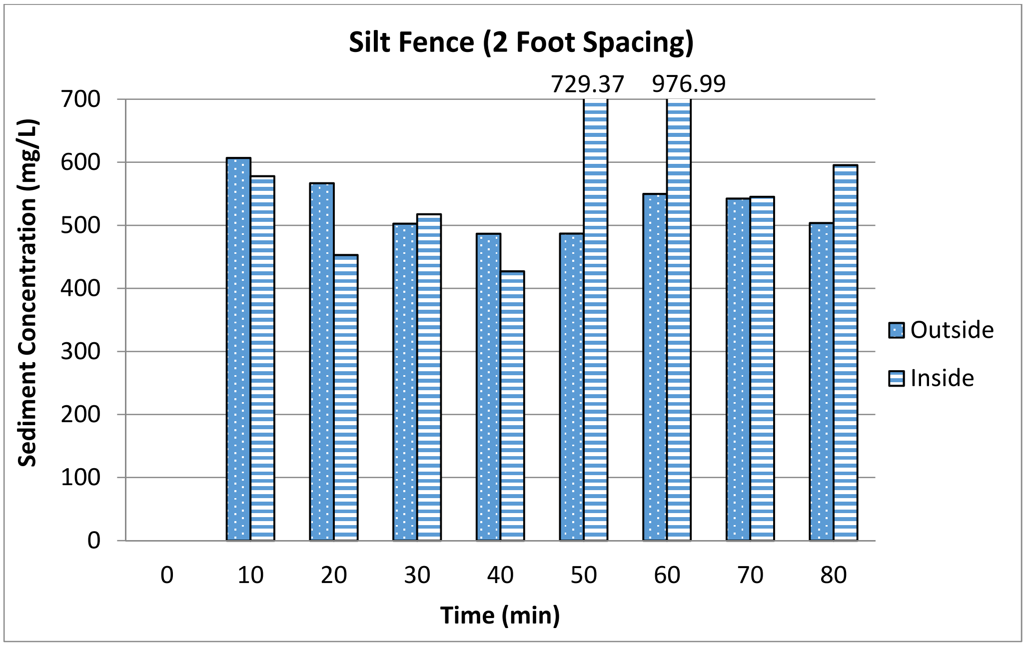

Figure 5.15 Sediment concentrations for silt fence with 2 foot gap.

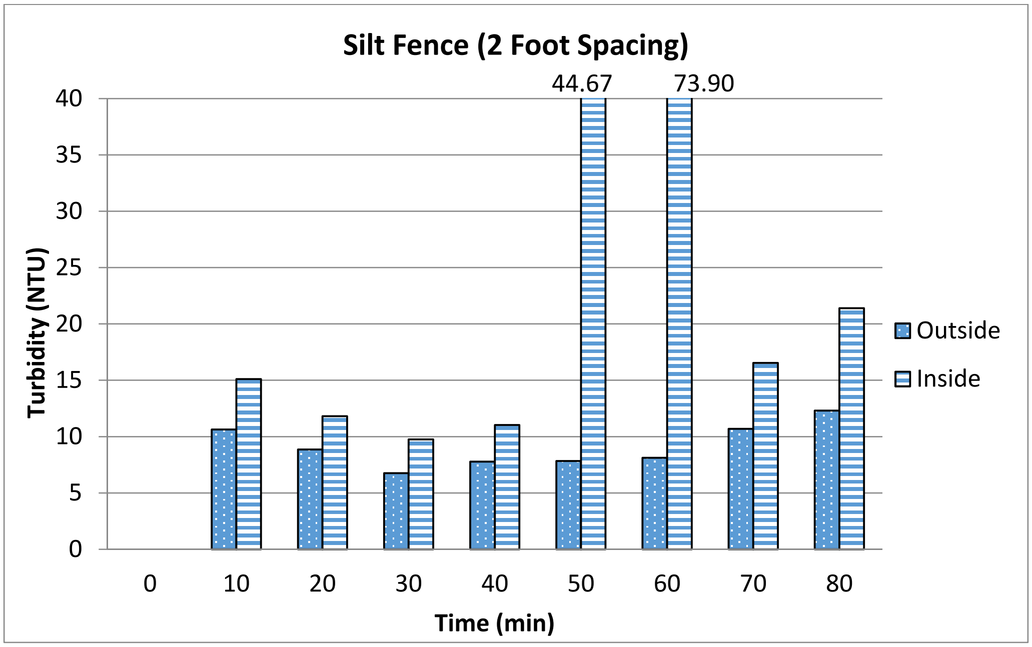

Figure 5.16 Turbidity for silt fence with 2 foot gap.

5.10 SILT FENCE WITH WOVEN MONOFILAMENT FABRIC

Sediment concentrations (Figure 5.17) were lower inside the fabric compared to outside for most of the water samples analyzed. It was also noted that the sediment concentration were similar inside the fabric for both high and low flow rates. Turbidity was fairly consistent throughout the experiment (Figure 5.18).

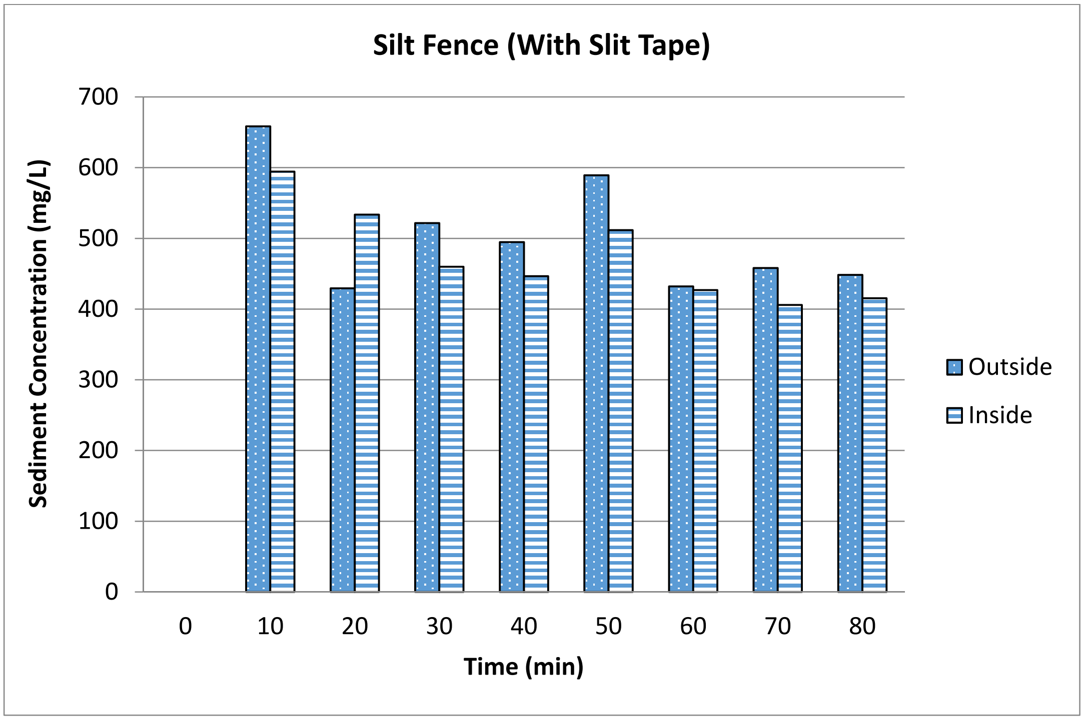

Figure 5.17 Sediment concentrations for silt fence with woven monofilament fabric.

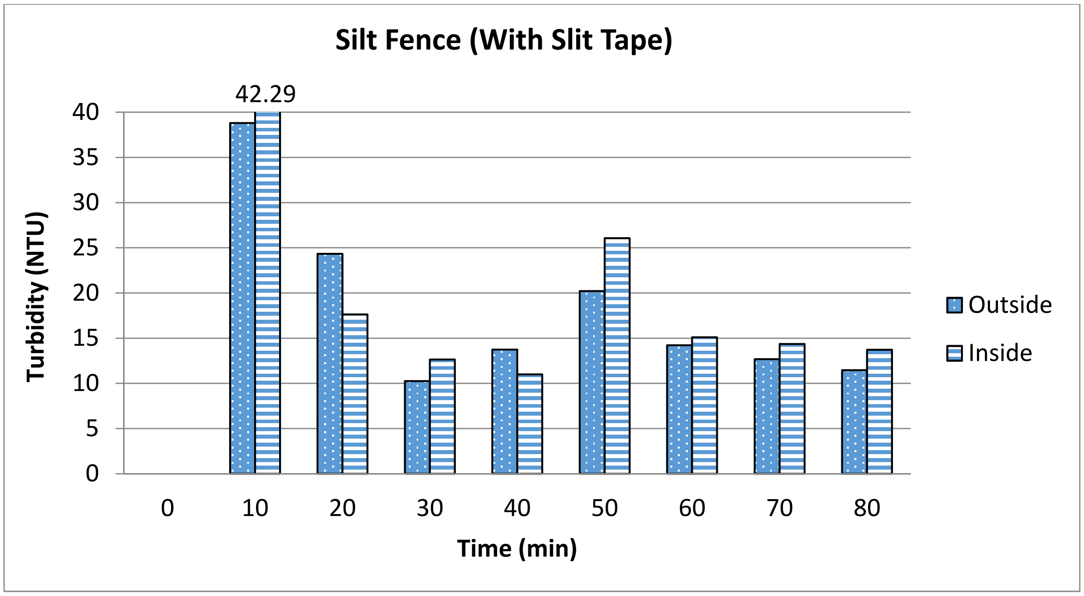

Figure 5.18 Turbidity for silt fence with woven monofilament fabric.

SECTION 6: RECOMMENDATIONS

6.1 PRODUCT COMPARISON

Figure 6.1 and the accompanying discussion provide a comprehensive performance overview of each product under 79 gpm (5 L/S) flow. The product recommendations are based on observations and results, along with ease of installation. For 79 gpm (5 L/S) flow, the percent sediment concentration reduction is as follows:

- Welded wire (around grate): 37.21%
- Welded wire (at 2 foot gap): 9.51%
- Sediment log (no ECB): –0.01%
- Sediment log (with ECB): 20.9%
- Dandy Pop: 16.54%
- Dandy Bag: 3.31%
- Drop filter bag: 24.41%
- Silt fence (with a woven slit tape fabric at 2 foot spacing): 8.66%
- Silt fence (with monofilament fabric): 13.60%

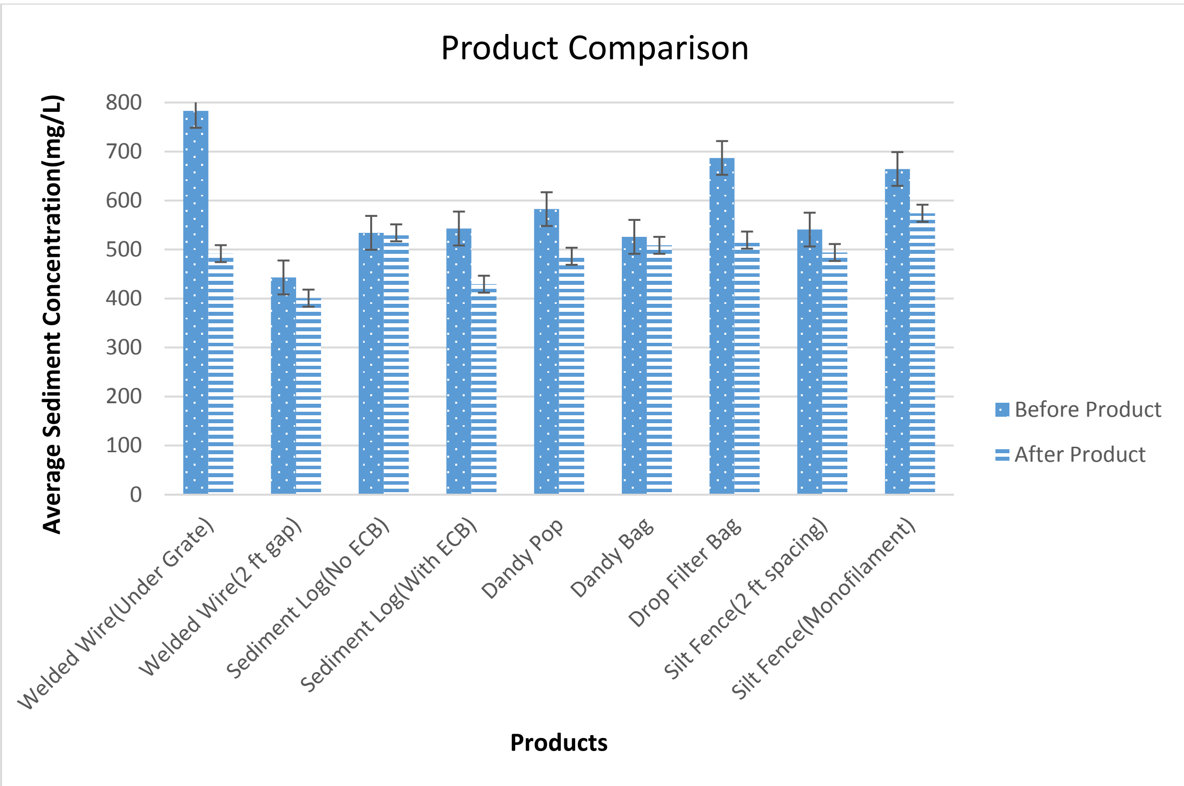

Figure 6.1 Product comparison under 79 gpm flow

Based on observations and data analysis for products under 79 gpm (5 L/S), the welded wire (around grate) trapped the highest level of sediment compared to the other products tested, proving to have optimal filtration with minimal ponding (Figure 6.1). The Dandy Pop performed very well, among the better products tested. The product was simple to install, and can be used multiple times with proper maintenance. Proper installation is suggested, as water can easily leak through gaps in Velcro.

The drop filter bag performed very well, but experienced significant ponding. For best use, routine maintenance must be practiced to prevent debris from clogging the sack. The sediment log (with ECB), welded wire (2 foot gap), silt fence (with monofilament fabric), silt fence (at 2 foot spacing) were found to perform well when compared to other products for reducing sediment concentration. The welded wire was observed to have water that flowed through the gaps, which likely effected our results.

Dandy Bag performed below average when compared to other products tested, based on the percent reduction in sediment concentration before and after the products. This product experienced average to above average levels of ponding, while being able to filter an average level of sediment. Despite the Dandy Bag being entirely submerged during testing, it was still able to filter some sediment.

Figure 6.2 and the accompanying discussion provide a comprehensive performance overview of each product under 158 gpm (10 L/S) flow. The product recommendations are based on observations and results, along with ease of installation. For 158 gpm (10 L/S), the percent sediment concentration reduction is as follows:

- Welded wire (around Grate): 25.90%
- Welded wire (at 2 foot gap): -18.61%
- Sediment log (no ECB): –30.15%
- Sediment log (with ECB): 0.82%
- Dandy Pop: 1.81%
- Dandy Bag: 8.75%
- Drop filter bag: -17.45%
- Silt fence (with a woven slit tape fabric at 2 foot spacing): -36.7%
- Silt fence (with monofilament fabric): -8.35%

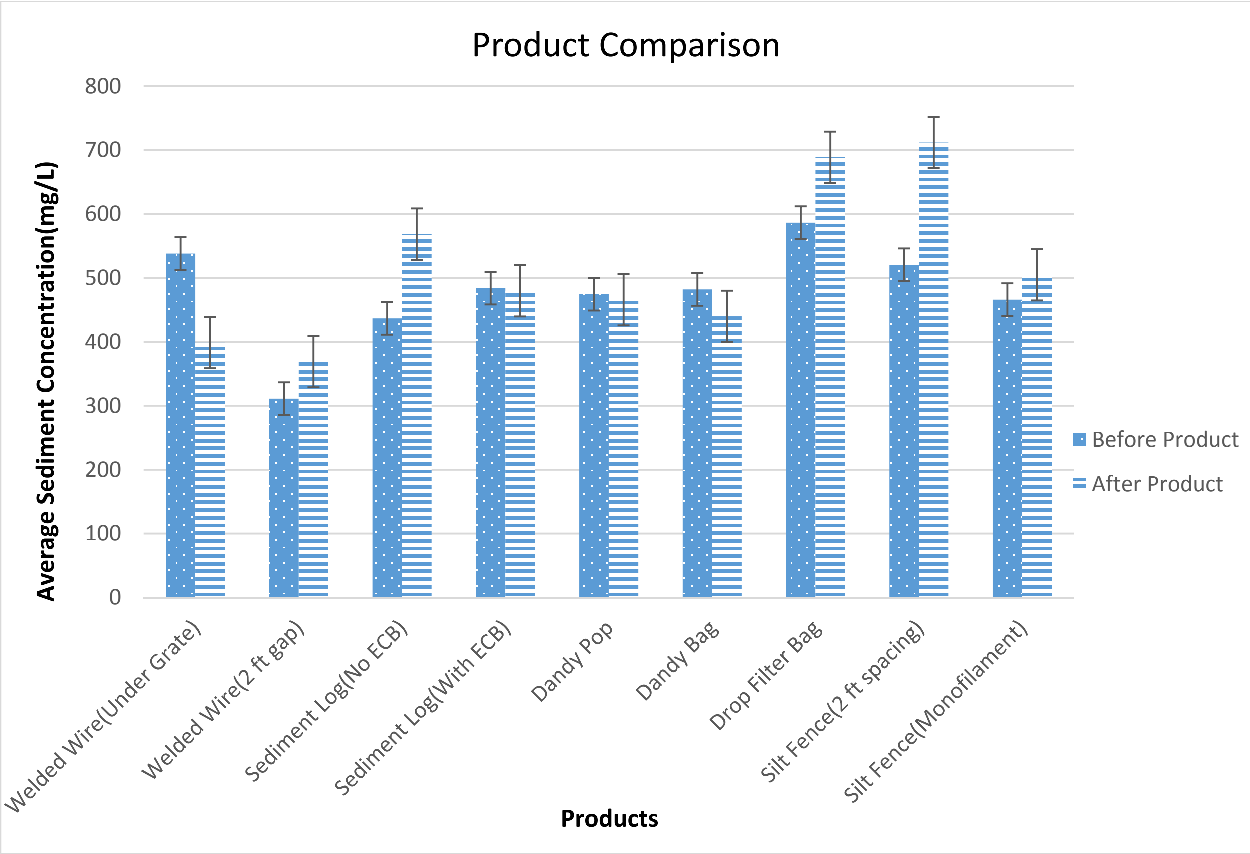

Figure 6.2 Product Comparison under 158 gpm flow

Based on observations and data analysis for products under 158 gpm (10 L/S), the welded wire (around grate) trapped the highest level of sediment compared to the other products tested, proving to have optimal filtration with minimal ponding (Figure 6.2). The sediment log (with ECB), Dandy Pop and Dandy Bag performed above average when compared to other products tested. The Dandy Pop was able to filter sediment, and experienced average levels of ponding. Despite the Dandy Bag being entirely submerged during testing, it was still able to filter the most amount of sediment.

Although the silt fence (with monofilament fabric) had small increase of sediment concentration, it was able to handle high loads when compared to other products tested. The welded wire (2 foot gap), sediment log (no ECB), drop filter bag, and silt fence (at 2 foot spacing) are not recommended, as they experienced an increase in sediment concentration. Overlaps in the welded wire allowed water to seep through the product easily. This was the weak point for the product for the sediment discharge. In case of sediment log, water could seep through the gaps if the overlapping of logs was not placed well. Trenching and proper compaction must be practiced, as undercutting is a potential problem with both products. Proper maintenance for the drop filter bag is suggested, as debris could heavily prevent proper filtration. Debris likely filled the drop filter bag, which led to the product filtering minimal amounts.

6.2 PRODUCT ANALYSIS

6.2.1 Welded Wire, Around the Grate

Sediment removal: Results from sediment concentration and turbidity analysis indicated that this product was very effective at filtering out sediment. It was one of the most consistent products in both turbidity reduction and concentration reduction across all samples in respect to both flow rates.

- **Ease of installation:** This product's ease of installation was a significant advantage. Use of zip ties to secure the overlap and ease in sliding the product under the lid made it easy to install quickly and correctly.
- **Ponding:** The porous nature of this material makes it ideal for areas that cannot sustain high levels of ponding. Water levels outside of the product tended to increase until a certain level of equilibrium was reached. After that, water levels tended to stay constant until the flow rate was increased.
- **Product failure:** The area of concern was the overlap where the material was brought together. If the product is not secured well, water could seep through a gap in the material. It held up to both flow rates without any issues and could easily be used in the field.

6.2.2 Welded Wire with 2 Foot Gap

- **Sediment removal:** Results from sediment concentration and turbidity analysis indicated that this installation method was less effective than its counterpart (i.e., under the lid). Results from sediment concentration and turbidity analysis indicated that this product was only effective at filtering out sediment at flow rates around 79 gpm.
- **Ease of installation:** This product was difficult to install. It required considerable time, multiple products, and very specific trenching instructions. Because proper installation is necessary to ensure the product does not fail, it could create issues when used in the field. If the backfill soil is not properly compacted, the overlaps are not secured properly, or the trench is too shallow, failure could occur. Space can be an issue due to the gap. The product should be used only in areas that can clearly accommodate it. Use of the product would not be feasible in ditches with steep side slopes where it would be acting as ditch check. Likewise, if grading activities are being performed on the ditch, the area occupied by the inlet protection devices may be too large and could affect the maneuverability of equipment in the area.
- **Ponding:** As with the previous installation method for this product, ponding was not a major issue. The product, however, required considerable space to be installed, which makes it less than ideal for use in smaller channels.
- **Product failure:** Overlaps can allow water to seep through the product easily if they are not secured well. Furthermore, if the backfill is not compacted well, then undercutting can be an issue. Otherwise, this product performed well at both flow rates.

6.2.3 Sediment Log Without Erosion Control Blanket

- **Sediment removal:** Results from sediment concentration and turbidity analysis indicated that this product and installation method was less effective than its counterpart (i.e., with ECB. This could be due to installation error. However, our results indicate that the product might be marginally effective at low flow rates.

- **Ease of installation:** The installation for this product requires several specifications to be met, which could create issues in the field. If stakes are not properly placed and spaced and overlaps are not securely fastened, undercutting could be a significant problem. If the trenching is done correctly with proper depth and compaction, the risk of undercutting will be reduced. Space can be an issue due to the gap. It should be used in areas that can accommodate it. This configuration would not be feasible for use in ditches with steep side slopes where the product would be acting as ditch check. Likewise, if grading activities are being performed on the ditch, the area occupied by the inlet protection devices may be too large and could affect the maneuverability of equipment in the area.
- **Ponding:** Ponding was not an issue during testing, which suggests the product would be good for use in areas where ponding cannot occur. However, this product took up the most space, so it must be used only in areas where it can fit.
- **Product failure:** The largest potential for product failure will occur at overlaps of the logs. If the overlaps are not set up well, there will be several failures as water seeps through. Furthermore, trenching must be done correctly to prevent major undercutting.

6.2.4 Sediment Log with Erosion Control Blanket

- **Sediment removal:** Results from sediment concentration and turbidity analysis indicated that this installation method was much more effective than its counterpart (i.e., without ECB). This is probably because the erosion control blanket helped the soil settle out and also covered the soil in the 2 foot gap, which prevented soil from eroding. This setup is recommended over the setup without the blanket, even though it was difficult to install and took up a lot of space. It was one of the most consistent products in both turbidity reduction and concentration reduction across all samples in respect to both flow rates.
- **Ease of installation:** This was the most difficult installation out of all the products tested. This product required a lot of time, precision, and resources, which will create problems in the field if crews do not install the product correctly. All of the same installation problems as the previous set up were present, along with the additional problems of installing an erosion control blanket. If stakes for the blanket are not spaced correctly, the blanket will be ineffective. Space can be an issue due to the gap. It should be used in areas that can accommodate it. This configuration would not be feasible for use in ditches with steep side slopes where the product would be acting as ditch check. Likewise, if grading activities are being performed on the ditch, the area occupied by the inlet protection devices may be too large and could affect the maneuverability of equipment in the area.
- **Ponding:** This product created low levels of ponding. It is porous enough to allow material through, so ponding is not a concern. It did, however, take up a lot of space and spread the ponding out toward the side of the ditch.
- **Product failure:** This product can have issues at overlaps between two logs. Water could potentially seep through these overlaps if they are not set up correctly. Due to trenching, undercutting can also be an issue, so proper installation is very important.

6.2.5 Dandy Pop

- **Sediment removal:** Results from sediment concentration and turbidity analysis indicated that this product was primarily effective at filtering out sediment at flow rates around 79 gpm.
- **Ease of installation:** This product was one of the easiest to install. Because it came pre-assembled, it took little effort to put it in the field. It is also theoretically reusable if

maintained after use. The only concern would be if the Velcro that seals the product is not properly fastened or facing the flow.

- **Ponding:** The product took up very little space and did not cause a lot of ponding. There should be no problems using this product in the field.
- **Product failure:** This product stood up well to both flow rates. Because of the high quality of manufacturing, there is very little risk of failure due. However, there could be issues if the Velcro fails and water seeps through unrestricted.

6.2.6 Dandy Bag

- **Sediment removal:** Results from sediment concentration and turbidity analysis indicated that this product was very effective at filtering out sediment. It was one of the most consistent products in both turbidity reduction and concentration reduction across all samples in respect to both flow rates.
- **Ease of installation:** This product was very easy to install—just slide the lid into it and place it over the manhole. The product could also be reused, in theory, if proper maintenance is performed after use.
- **Ponding:** Ponding was a little more severe with this product. As sediment settled on top of the bag, it impeded the flow of water, creating more ponding, especially at higher flow rates.
- **Product failure:** This product stood up well to all flow rates and has very low risk of failure. Its high quality of manufacturing seems to allow it to withstand large loads.

6.2.7 Drop Filter Bag

- **Sediment removal:** Results indicated that this product was only effective with flow rate of 79 gpm. However, as flow rates increased, ponding became severe, and the product seemed unable to withstand the flow. When failure began, the product performed poorly.
- **Ease of installation:** Although this product was easy to install, it required the manhole to be dimensionally perfect as the product sizing gave little tolerance. It can become wedged inside, which makes it slightly difficult to remove. It requires no additional installation steps because it is pre-manufactured. Because of its low space requirement, this product is very good for areas where larger products cannot be used. It is usually installed in roadways and ditches where traffic conditions and the possibility of flooding make the installation of other inlet protection devices unfeasible or not recommended due to safety reasons, which makes the product unique compared to the others tested.
- **Ponding:** Ponding was quite severe with this product because sediment settled inside the bag and impeded flow. It is not recommended for use in areas where high flow rates will occur or where flooding will be a major problem. Ponding is primarily issue at high flow rates.
- **Product failure:** The product struggled to keep up with the load at high flow rates over 79 gpm. This resulted in poor filtration and extreme ponding.

6.2.8 Silt Fence with 2 Foot Gap

- **Sediment removal:** Results from sediment concentration and turbidity analysis indicated that this product only filtered sediment at flow rates of 79 gpm. As the flow rate increased, the product's performance decreased. Once failure occurred, the product struggled to perform.
- **Ease of installation:** This product was difficult to install because it required proper trenching, staking, and tightness between the stakes. If not installed correctly, it will fail severely. Even with careful installation, undercutting can occur easily, and failure is possible if the product rips. Space can be an issue due to the gap. It should be used in areas that can accommodate it. This configuration would not be feasible for use in ditches with steep side slopes where the product would be acting as ditch check. Likewise, if grading activities are being performed on the ditch, the area occupied by the inlet protection devices may be too large and could affect the maneuverability of equipment in the area.
- **Ponding:** Ponding was very prominent with this product at high flow rate (158 gpm). It should not be used in areas with high flow or where ponding must be avoided. It is relatively inexpensive, however, which is an advantage.
- **Product failure:** Undercutting was a significant problem with this product. Furthermore, the extreme ponding put considerable stress on the product as the water level rose, leading to increased chances of product failure at high flow rate (158 gpm).

6.2.9 Silt Fence with Woven Monofilament Fabric

- **Sediment removal:** Results from sediment concentration and turbidity analysis indicated that this product filtered sediment at flow rates under 79 gpm. As the flow rate increased, the product's performance slightly decreased. As the product did not fail, due to fabric permeability, the product struggled to perform optimally at high flow rate (158 gpm).
- **Ease of installation:** Like any silt fence, it was fairly simple to install but the work must be done carefully or the product will likely fail. Overall, ease of installation was average when compared to other products. It should be used in areas that can accommodate it. This configuration would not be feasible for use in ditches with steep side slopes where the product would be acting as ditch check. Likewise, if grading activities are being performed on the ditch, the area occupied by the inlet protection devices may be too large and could affect the maneuverability of equipment in the area.
- **Ponding:** Compared to a regular silt fence, this product was much better at preventing ponding. It allowed much more water to flow through it than a typical non-porous silt fence. It had limited flow through the front of the product where the water flow hit first, but overall ponding was low and the product took up only a moderate amount of space.
- **Product failure:** This product held up well at both flow rates, but filtered most efficiently at flow rate of 79 gpm. There was no undercutting, unlike with a typical silt fence, due to permeability of the fabric

6.3 SUMMARY OF PRODUCT COMPARISON

Product/Criteria	**Sediment Removal**	**Ease of Installation**	**Ponding**	**Product Failure**
Welded wire (around grate)	Good	Good	Good	No
Welded wire (at 2 foot gap)	Bad	Decent	Decent	No
Sediment log (no ECB)	Bad	Decent	Decent	No
Sediment log (with ECB)	Good	Bad	Decent	No
Dandy Pop	Decent	Good	Good	No
Dandy Bag	Good	Good	Bad	No
Drop filter bag	Bad	Good	Bad	Yes
Silt fence (at 2 foot gap)	Bad	Decent	Bad	Yes
Silt fence (woven monofilament)	Good	Decent	Good	No

Note: Good: 8–10, Decent: 5–7, Bad: 0–4

APPENDIX: SUPPLEMENTARY PHOTOGRAPHS FROM FIELD TESTING

Additional photographs from the field testing are included to provide details about various product installation methods and evaluation procedures.

Figure A.1 Welded-wire woven monofilament fabric, pre-testing.

Figure A.2 Welded-wire woven monofilament fabric after testing started.

Figure A.3 Welded-wire woven monofilament fabric entering manhole.

Figure A.4 Measuring depth in front of welded-wire woven monofilament fabric.

Figure A.5 Sediment log, pre-testing.

Figure A.6 Sediment log installation.

Figure A.7 Sediment log during testing.

Figure A.8 Sediment log water accumulation.

Figure A.9 Dandy Pop during testing.

Figure A.10 Hand pump for sample collection with Dandy Pop.

Figure A.11 Dandy Bag, pre-testing.

Figure A.12 Dandy Bag during testing.

Figure A.13 Dandy Bag submerged.

Figure A.14 Drop filter bag, pre-testing.

Figure A.15 Drop filter bag, with water overflowing product.

Figure A.16 Drop filter bag overflowing manhole.

Figure A.17 Silt fence (2 foot gap), pre-testing.

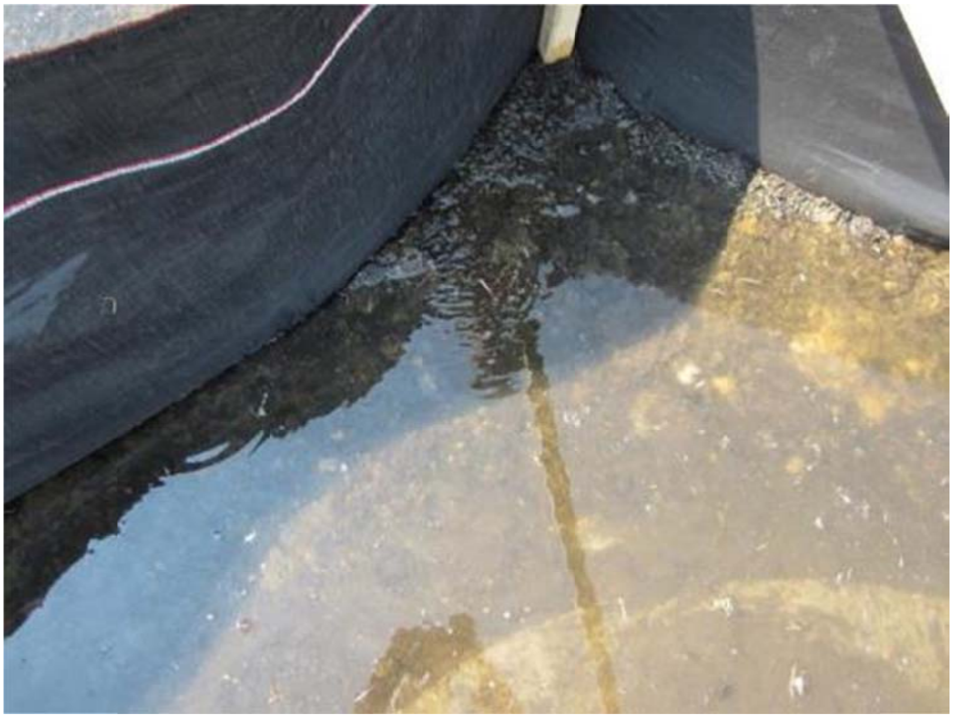

Figure A.18 Silt fence (2 foot gap) undercutting.

Figure A.19 Silt fence (2 foot gap) product failure.

Figure A.20 Water catchment system solid works assembly.

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