CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 16-001
UILU-ENG-2016-2001
ISSN: 0197-9191

EVALUATION OF CURB AND GUTTER INLET PROTECTION PRODUCTS FOR SEDIMENT RETENTION

Prepared By
Rabin Bhattarai
Prasanta Kalita
Anwar Azeem
Ranjeet Jha

University of Illinois at Urbana-Champaign

Research Report No. FHWA-ICT-16-001

A white paper prepared as part of
ICT-R27-102
Installation and Performance Testing of Ditch Checks and Inlet Protection Structures

Illinois Center for Transportation

January 2016

TECHNICAL REPORT DOCUMENTATION PAGE

<table>
<tr><td>1. Report No.
FHWA-ICT-16-001</td><td>2. Government Accession No.</td><td>3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Evaluation of Curb and Gutter Inlet Protection Products for Sediment Retention</td><td>5. Report Date
January 2016</td></tr>
<tr><td>6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
Rabin Bhattarai, Prasanta Kalita, Anwar Azeem, and Ranjeet Jha</td><td>8. Performing Organization Report No.
ICT-16-001
UILU-ENG-2016-2001</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Department of Agricultural and Biological Engineering
University of Illinois at Urbana-Champaign
Urbana, IL 61801</td><td>10. Work Unit No.</td></tr>
<tr><td>11. Contract or Grant No.
R27-102</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Illinois Department of Transportation (SPR)
Bureau of Material and Physical Research
126 East Ash Street
Springfield, IL 62704</td><td>13. Type of Report and Period Covered
White paper; 8/16/2011–1/15/2016</td></tr>
<tr><td>14. Sponsoring Agency Code
FHWA</td></tr>
<tr><td colspan="3">15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.</td></tr>
</table>

16. Abstract

Construction sites are one of the largest sources of sediment and contaminants. When rainfall occurs, sediment is produced as soil particles disintegrate and erode from the bare soil area and are transported to the nearest water conveyance structure, such as an inlet. When soil is disturbed to construct buildings and highways, the rate of erosion increases. Sediment from these areas mixes with water and enters roadside gutters after rainfall or snowmelt events. This can lead to clogging of drainage systems and street flooding. It can also escalate treatment cost for wastewater treatment facilities, due to increased sediment load.

Various tests were performed to analyze the effectiveness of curb and gutter inlet protection products at the Erosion Control Research and Training Center (ECRTC) of the University of Illinois at Urbana-Champaign. The tests analyzed the ability of these products to prevent sediment from entering the inlets. The goal of these tests was to compare the various products and determine which would work best to prevent sediment from entering the inlets at construction sites. Several criteria were used in testing in order to make the best recommendations to the Illinois Department of Transportation (IDOT). The products analyzed in testing were (1) frame and grate, (2) Dandy curb bag, (3) Dandy curb sack (orange fabric), (4) Erosion Eel, (5) GeoHay, (6) SediGuard, and (7) Inlet Pro.

The duration of the test was 15 minutes with a discharge rate of 119 gallons/minute (7.5 L/s). One 5 gallon bucket of clay soil was initially poured into a 300 gallon water tank; half a bucket was later poured at 5 and 10 minutes. This mixture would spill over onto the slab, where samples would be collected before and after the product was installed. Water samples were collected every 3 minutes and were oven-dried to determine sediment concentration. Using this procedure, it was possible to determine how efficient each product was in terms of sediment retention. The SediGuard and Dandy curb sack products performed better than the other products tested. Although several products were able to filter efficiently, they often created excessive ponding. Ponding on an active roadway can potentially create safety concerns. The evaluation was based on two criteria: water should be able to infiltrate the product without creating heavy ponding and the product should retain a large fraction of the sediment.

<table>
<tr><td colspan="2">17. Key Words

Construction, Environment, Materials, Testing</td><td colspan="2">18. Distribution Statement
No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
35 pp.</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

ACKNOWLEDGEMENTS

This publication is based on the results of ICT-R27-102, **Installation and Performance Testing of Ditch Checks and Inlet Protection Structures**. ICT-R27-102 was conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation; and the U.S. Department of Transportation, Federal Highway Administration

Members of the Technical Review Panel (TRP) were the following:

- Joseph Vespa, TRP Chair, Illinois Department of Transportation
- Kathy Cindrich, Illinois Department of Transportation
- Stephanie Dobbs, Illinois Department of Transportation
- Jeff Harpring, Illinois Department of Transportation
- Brian Pfeifer, Federal Highway Administration
- Janis Piland, Federal Highway Administration
- Tom Ripka, Knight E/A, Inc.
- Dan Salsinger, Hanes Geo Components
- Matt Sunderland, Illinois Department of Transportation

EXECUTIVE SUMMARY

Construction sites are one of the largest sources of sediment and associated contaminants. When rainfall occurs, sediment is produced as soil particles disintegrate and erode from the bare soil area and are transported to the nearest water conveyance structure, such as an inlet. When soil is disturbed to construct buildings and highways, the rate of erosion increases. Sediment from these areas mixes with water and enters roadside gutters after rainfall or snowmelt events. This can lead to clogging of drainage systems and street flooding. It can also escalate treatment cost for wastewater treatment facilities, due to increased sediment load.

Various tests were performed to analyze the effectiveness of curb and gutter inlet protection products at the Erosion Control Research and Training Center (ECRTC) of the University of Illinois at Urbana-Champaign. The tests analyzed the ability of these products to prevent sediment from entering the inlets. The goal of these tests was to compare the various products and determine which would work best to prevent sediment from entering the inlets at construction sites. Several criteria were used in testing in order to make the best recommendations to the Illinois Department of Transportation (IDOT). The products analyzed in testing were (1) frame and grate, (2) Dandy curb bag, (3) Dandy curb sack (orange fabric), (4) Erosion Eel, (5) GeoHay, (6) SediGuard, and (7) Inlet Pro.

The duration of the test was 15 minutes with a discharge rate of 119 gallons/minute (7.5 L/s). One 5 gallon bucket of clay soil was initially poured into a 300 gallon water tank; half a bucket was later poured at 5 and 10 minutes. This mixture would spill over onto the slab, where samples would be collected before and after the product was installed. Water samples were collected every 3 minutes and were oven-dried to determine sediment concentration. Using this procedure, it was possible to determine how efficient each product was in terms of sediment retention. The SediGuard and Dandy curb sack products performed better than the other products tested. Although several products were able to filter efficiently, they often created excessive ponding. Ponding on an active roadway can potentially create safety concerns. The evaluation was based on two criteria: water should be able to infiltrate the product without creating heavy ponding and the product should retain a large fraction of the sediment.

CONTENTS

SECTION 1: INTRODUCTION

Water quality deterioration due to sediment is a major environmental problem in the United States. Soil erosion from bare areas leads to the introduction of sediment in water bodies. Sediment from construction sites often finds its way into roadside drainage structures such as inlets and ditches. This leads to water quality degradation caused by increased sediment concentration, and it affects the local aquatic ecosystem. If proper protection measures are not taken, inlets can be clogged due to the accumulated sediment and debris in the sewer system. This in turn can cause flooding of roadways and potentially create hazardous conditions for drivers.

To address such concerns, preventive measures should be implemented to clean sediment entering a water body through inlets. Suspended sediment can be trapped by inlet protection products, reducing wastewater treatment costs. Although coarse sediment particles can't pass through the products, smaller particles such as clay can easily pass through them. Inlet protection products not only act as a barrier to the sediment, but they also help dissipate the flow energy of water. This reduction in velocity increases the amount of time it takes flowing water to enter the inlet, preventing overflow into drains. Implementing these products helps reduce the cost of treating the water and helps prevent flooding of the sewer system.

These products should be able to retain sediment while creating minimum or no ponding. Products must be porous enough to prevent flooding—but not so porous that sediment particles can flow through it without restriction. It is important to evaluate products on these merits, along with the extent to which they reduce the amount of soil entering the inlet. If a product stops all sediment from coming through, high levels of ponding will occur. This scenario is not ideal for roadways and may make them unusable.

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 due to insufficient filtration and/or excessive ponding.

SECTION 2: OBJECTIVES

The purpose of this study was to examine several products for sediment retention in curb and gutter inlets and provide recommendations based on the results of performance tests and analysis. The analysis was based on the following criteria: the extent of ponding, sediment trapping efficiency, and product durability.

The specific goals of the project were as follows:

- Conduct a field experiment and collect samples to test product effectiveness in sediment retention.
- Examine the extent of flooding created by each product.
- Provide recommendations about which products worked best under the test conditions.

SECTION 3: METHODOLOGY

3.1 CURB AND GUTTER INLET PROTECTION PRODUCTS

Seven products were tested at the Erosion Control Research and Training Center (ECRTC) at the recommendation of the Illinois Department of Transportation (IDOT).

3.1.1 Frame and Grate

The frame and grate (Figure 3.1) is made of durable galvanized framing with geotextile filter bags set deep underneath the grate. This product is reusable with proper cleaning. It can handle a large flow because it has a feature that allows flow to overtop the bag underneath the grate (FleXstorm 2014). The bag is able to hold a large amount of debris inside the sack, preventing debris from settling on the grate and blocking the flow entering the inlet. The product requires routine maintenance to remove debris from the bag after each rainfall event. The frame is adjustable and can fit on any size of grate (Figure 3.2). Product installation is fairly easy, requiring only one or two personnel.

Figure 3.1 Outside view of installed frame and grate product.

Figure 3.2 Inside view of installed frame and grate product.

Installation method (FleXstorm 2014):

1. Remove the grate from the casting or concrete drainage structure.
2. Clean ledge (lip) of the casting frame/drainage structure; ensure it’s free of dirt.

3. Drop in the inlet filter through the clear opening; be sure suspension hangers rest firmly on the inside ledge (lip) of the casting.
4. Reinsert the grate and confirm that it is elevated no more than 1/8 inch (steel hanger thickness).
5. Attach the stainless steel mounting brackets using the concrete fasteners provided.

3.1.2 Dandy Curb Sack (Orange Fabric)

The Dandy curb sack (orange fabric) (Figure 3.3) is a sediment control product to prevent sediment-laden runoff from urban areas, along with providing inlet protection. The product is made up of high-visibility monofilament geotextile, consisting of a large sack that rests underneath the grate. The product also has a curb filter, allowing all water to be filtered efficiently. Water enters through the grate, where sediment and other debris collect in the sack. For optimal performance, it is advised to clean the sack when it becomes more than one third full of sediment (Dandy Curb Sack 2009). To clean the unit, simply remove the grate and lift the unit from the grate using the lifting straps (Figure 3.4).

Figure 3.3 Outside view of installed Dandy curb sack product.

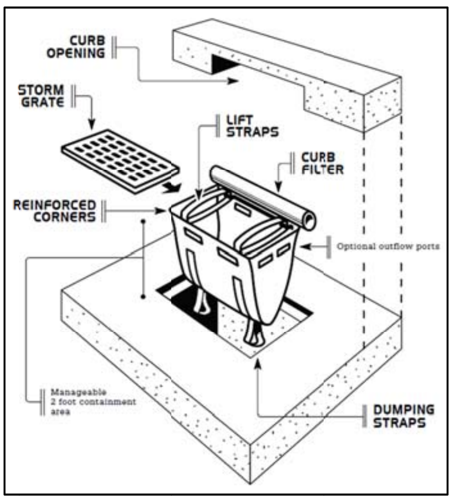

Figure 3.4 Details of Dandy curb sack product (dandyproducts.com).

Installation method:

1. Remove the grate.
2. Wrap grate around the lower and top lift straps.
3. Insert Dandy curb sack into framing and place grate on top; ensure straps are on top of the grate.
4. Wedge curb filter against the curb to prevent curbside leaking.

3.1.3 Dandy Curb Bag

The Dandy curb bag (Figure 3.5) is a sediment control product made of a woven monofilament geotextile fabric that allows sediment and other contaminants to filter efficiently. Water flows through the top of the grate, reducing flow to allow sediment to be trapped within the fabric (Figure 3.6). The grate is slid into the bag, which is then inserted into the framing. The opening is sealed shut with Velcro and placed away from the direct flow of water (Dandy Curb Bag 2009).

Figure 3.5 Outside view of Dandy curb bag product (thedrainagesource.com).

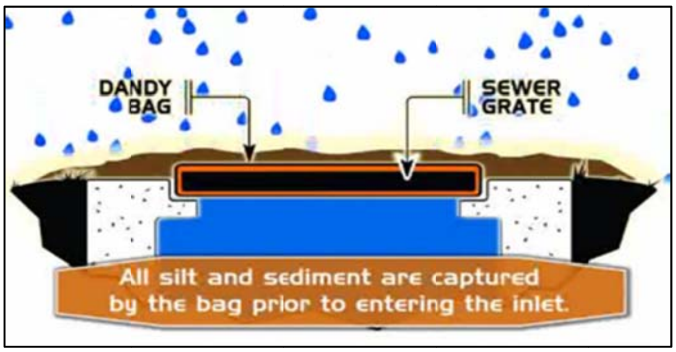

Figure 3.6 Details of Dandy curb bag product (dandyproducts.com).

Installation method:

1. Open Dandy curb bag pouch, slide grate into bag and seal shut with Velcro.
2. Using lifting straps, insert product into grate framing.

3.1.4 GeoHay

The GeoHay (Figure 3.7) is a sediment control product made of recycled synthetic carpet fibers and is used in both paved and unpaved areas. Sandbags are commonly used to secure the product for paved areas, whereas stakes are used primarily for unpaved areas. This product only allows flow through the curbside opening, requiring the grate to be covered for curb and gutter applications. GeoHay has a capacity to filter out 2 acres of drainage area (GeoHay 2011). If the product has sediment that has accumulated to one half of its original height, it should be removed and replaced.

Figure 3.7 GeoHay.

Installation method:

1. If a grate is present, cover the grate with an impermeable material.
2. Place GeoHay alongside curb.
    a. If the surface is paved, place sandbags (or bricks) on top of product.
    b. If the surface is unpaved, stake product into the ground.

3.1.5 Erosion Eel

The Erosion Eel (Figure 3.8) is a sediment control product consisting of a weighted sediment tube filled with recycled tires, made up of woven polypropylene geotextile (Erosion Eel 2009). It should be kept free from collected sediment and debris for long-term use.

Figure 3.8 Erosion Eel.

Installation method:

1. Place the product around the inlet of gutter.
2. Ensure surface is uniform for good ground contact.
3. Ensure Erosion Eel is kept around the grate, compressed against the curb.

3.1.6 SediGuard

The SediGuard (Figure 3.9) is a low-profile sediment control product that can be driven over without damage. Water flows through the top and sides, trapping sediment within the material. The product is placed over the grate and secured by zip ties. This product can be easily cleaned by sweeping the surface.

Figure 3.9 SediGuard.

Installation method:

1. Place SediGuard over the grate.
2. Ensure SediGuard overlaps/aligns with the grate gridding on all sides to prevent seepage.
3. Lift grate; loop zip tie through grate and SediGuard.
    a. Make small holes in the product; the holes should be aligned with the grate and have equal spacing.
    b. Loop zip tie through SediGuard, wrapping it around grate gridding.

3.1.7 Inlet Pro

The Inlet Pro is nearly identical to the Dandy curb sack but is made of a different fabric. The product has flaps that sit outside of the grate, weighed down by rebars to ensure the product is secured (Figure 3.10). As water flows into the grate, debris and sediment collect in the sack underneath. This product requires routine cleanup after each rainfall event.

Figure 3.10 Inlet Pro.

Installation method:

1. Remove the grate.
2. Insert the product into framing and place grate on top.
3. Ensure flaps are on the slab; place rebars inside the exterior flap holes.
4. Place two bricks on curbside rebar to ensure top flap stays secured (if necessary).

3.2 TESTING PROTOCOL

3.2.1 Field Setup

To test the sediment filtration by curb and gutter inlet protection products, certain procedures were followed. Before each test, the test area (concrete slab) was thoroughly cleaned of any debris (Figure 3.11).

Figure 3.11 Preparation of field for testing.

3.2.2 Flow Calibration

To calibrate flow, a volume time measurement was done using a 26.5 gallon (100 L) graduated water bucket (Figure 3.12). The time duration to fill the bucket entirely to 26.5 gallon (100 L) was noted with a stopwatch, and the flow rate was calculated by dividing the total volume by time. The average time to fill 26.5 gallon (100 L) was calculated to be around 13.3 seconds, providing a flow rate of 119 gallons/minute (gpm) or 7.5 L/s.

Figure 3.12 Graduated water bucket, 100 L *(*Yankee Containers®)*.*

3.3 TEST SETUP

The total duration of the test was 15 minutes. Water from the pump was discharged at a rate of 119 gallons/minute (7.5 L/s) and was poured into a 300 gallon tank. At the beginning of the test, one 5 gallon bucket of clay soil was added to the tank and stirred continuously throughout the experiment (Figure 3.13). A half bucket (2.5 gallon) of clay soil was added to the tank 5 and 10 minutes after the initial addition (Figure 3.14). Continuous mixing prevented any soil from settling to the bottom.

Figure 3.13 Sediment mixing.

Figure 3.14 Adding clay soil.

3.4 SAMPLE COLLECTION

The samples were collected in glass jars from the outlet of the soil mixture tank (Figure 3.15) and beneath the grate (Figure 3.16). Samples were collected every 3 minutes until the 15 minute mark, along with a sample taken when the test initially started. The soil mixture tank was stirred continuously to ensure that the samples would have a consistent homogenous soil concentration.

Figure 3.15 Sample from mixture tank.

Figure 3.16 Sample from beneath grate.

3.5 LABORATORY ANALYSIS

Collected samples were taken to a lab to measure sediment concentrations. If possible, turbidity readings were taken for the samples in nephelometric turbidity units (NTUs).

As samples were acquired during the experiment, they were organized based on time duration from initial to final (Figure 3.17). These samples were collected in cylindrical glass jars and taken to the lab where they were initially weighed (W1) (Figure 3.18). Jars were then placed in an oven at ~105°C for ~48 to 72 hours to evaporate the water (Figure 3.19). Once the water evaporated, the bottles containing soil residue were weighed again (W2) (Figure 3.20). As a final step, the bottles were washed and weighed (W3). The weight of the soil residue was obtained by subtracting W3 from W2 (W4 = W2 – W3).

Figure 3.17 Sample collection.

Figure 3.18 Soil sample weighing (W1).

Figure 3.19 Heating the samples.

Figure 3.20 Soil residue weighing (W2).

SECTION 4: OBSERVATIONS

4.1 FRAME AND GRATE

At the experimental flow rate of 119 gallons/minute (7.5 L/s), the frame and grate (Figure 4.1) appeared to convey the flow efficiently. Water started to collect around the curb, and it drained through the sides of the product (Figure 4.2). Water collected inside the bag, but it never rose above the level of the grate due to the overflow protection feature (Figure 4.3). Upon completion of the experiment, the slab was entirely drained within 2-1/2 minutes. The quick drainage likely prevented a heavy amount of sediment from being captured upon overflowing. This product didn't create much ponding, but sediment retention efficiency was small compared to other products tested. Routine cleaning is suggested because the product could become heavily restricted if clogged by debris in the sack.

Figure 4.1 Frame installed under a grate.

Figure 4.2 Frame and grate curbside flow.

Figure 4.3 Frame and grate overflow protection.

4.2 DANDY CURB SACK (ORANGE FABRIC)

Within several minutes, water collected around the Dandy curb sack (orange fabric) (Figure 4.4) with restricted flow into the grate. Heavy ponding occurred around the slab (Figure 4.5), with sediment collecting around the product as intended. Upon completion of the experiment, we found several pieces of debris were found beneath the grate. Results suggest that this debris may have restricted the total flow passing through the grate. Observations suggest that this sack could potentially become full from debris over an extended period. This product worked well for sediment retention, but it created significant ponding compared to other products tested.

Figure 4.4 Dandy curb sack (installed).

Figure 4.5 Dandy curb sack at 119 gpm (7.5 L/s) flow rate.

4.3 DANDY CURB BAG

Within several minutes, the Dandy curb bag (Figure 4.6) experienced ponding with restricted flow into the grate (Figure 4.7). By 9 minutes, severe ponding caused water to come off the slab. By 11 minutes, ponding drastically increased (Figure 4.8), which caused the water to overtop the curb (Figure 4.9). Once the test was finished, it took around 11-1/2 minutes for slab to be entirely drained. Once fully drained, the slab had a high density of soil surrounding the grate. Because water overtopped the curb, this was classified as a product failure. The product worked well for sediment retention, but it created significant ponding compared to other products tested.

Figure 4.6 Dandy curb bag (installed).

Figure 4.7 Dandy curb bag at 119 gpm (7.5 L/s) flow rate.

Figure 4.8 Dandy curb bag at 119 gpm (7.5 L/s) flow rate, concrete slab.

Figure 4.9 Water overtopping curb, product failure (Dandy curb bag).

4.4 GEOHAY

Within several seconds, ponding immediately occurred around the GeoHay (Figure 4.10). Within 2 minutes, water overtopped the curb (Figure 4.11). At that point, the test was ended and the product was classified as a failure. It took around 8 to10 minutes to entirely drain the slab.

Figure 4.10 GeoHay at 119 gpm (7.5 L/s).

Figure 4.11 Water overtopping curb (GeoHay).

4.5 EROSION EEL

The Erosion Eel drained effectively, with ponding around the grate (Figure 4.12). Sediment-laden water appeared to pass through small gaps alongside the curb unfiltered and enter the grate (Figure 4.13). Once the test ended, it took around 11-1/2 minutes to entirely drain the slab. There appeared to be no reduction in sediment concentration once water passed through the product. This product created moderate ponding compared to other products tested.

Figure 4.12 Erosion Eel at 119 gpm (7.5 L/s).

Figure 4.13 Erosion Eel draining.

4.6 SEDIGUARD

The SediGuard (Figure 4.14) proved to drain sediment-laden water efficiently under the experimental flow rate of 119 gallons/minute (7.5 L/s) (Figure 4.15). Throughout the experiment, there was a reasonable amount of ponding on the slab (Figure 4.16). Upon completion of the experiment, the slab was completely drained in 2-1/2 minutes. A good amount of soil was surrounding the grate (Figure 4.17). This product appeared to be very efficient in terms of sediment retention without creating much ponding compared to other products tested.

Figure 4.14 SediGuard (installed).

Figure 4.15 Flow through the SediGuard during testing.

Figure 4.16 Ponding around the SediGuard.

Figure 4.17 Sediment residue around SediGuard after slab was drained.

4.7 INLET PRO

At 2-1/2 minutes, ponding occurred around the product (Figure 4.18). By 7-1/2 minutes, a whirlpool formation occurred on top of the grate (Figure 4.19). By 10 minutes, the ponding increased and soon formed a small pool around the grate (Figure 4.20). By 11 minutes, severe ponding occurred, and continued to increase until the experiment ended. Within 2 minutes after the experiment ended, water was in the initial stage of overtopping the curb (Figure 4.21). Around 10 minutes after the experiment ended, water had mostly drained off the slab and was surrounded by a thick layer of sediment (Figure 4.22). Once it was fully drained, several pieces of debris were captured on top (Figure 4.23), along with residue within the sack (Figure 4.24). Because severe ponding occurred only toward the end of the experiment, a thick layer of sediment was still captured despite ponding. Proper maintenance likely must be conducted to prevent accumulated debris from collecting inside the sack and leading to flow restriction. This product worked well for sediment retention, but it created significant ponding compared to other products tested.

Figure 4.18 Inlet Pro at 119 gpm (7.5 L/s) flow rate.

Figure 4.19 Inlet Pro whirlpool formation.

Figure 4.20 Inlet Pro accumulated ponding.

Figure 4.21 Product nearly overtopping after experiment ended (Inlet Pro).

Figure 4.22 Sediment residue after draining slab (Inlet Pro).

Figure 4.23 Exterior debris after draining slab (Inlet Pro).

Figure 4.24 Accumulated sack residue after draining slab (Inlet Pro).

SECTION 5: RESULTS AND DISCUSSION

5.1 FRAME AND GRATE

Throughout the frame and grate experiment, it was observed that sediment concentration decreased with increasing time (Figure 5.1). It was observed that the sediment concentration after the product jumped up around 9 minutes. It was suspected that this spike in values was likely due to the product being filled with sediment and debris, with water overtopping the sack. As observed in Figure 5.1, the difference in sediment concentration before and after the product was installed was small throughout the experiment.

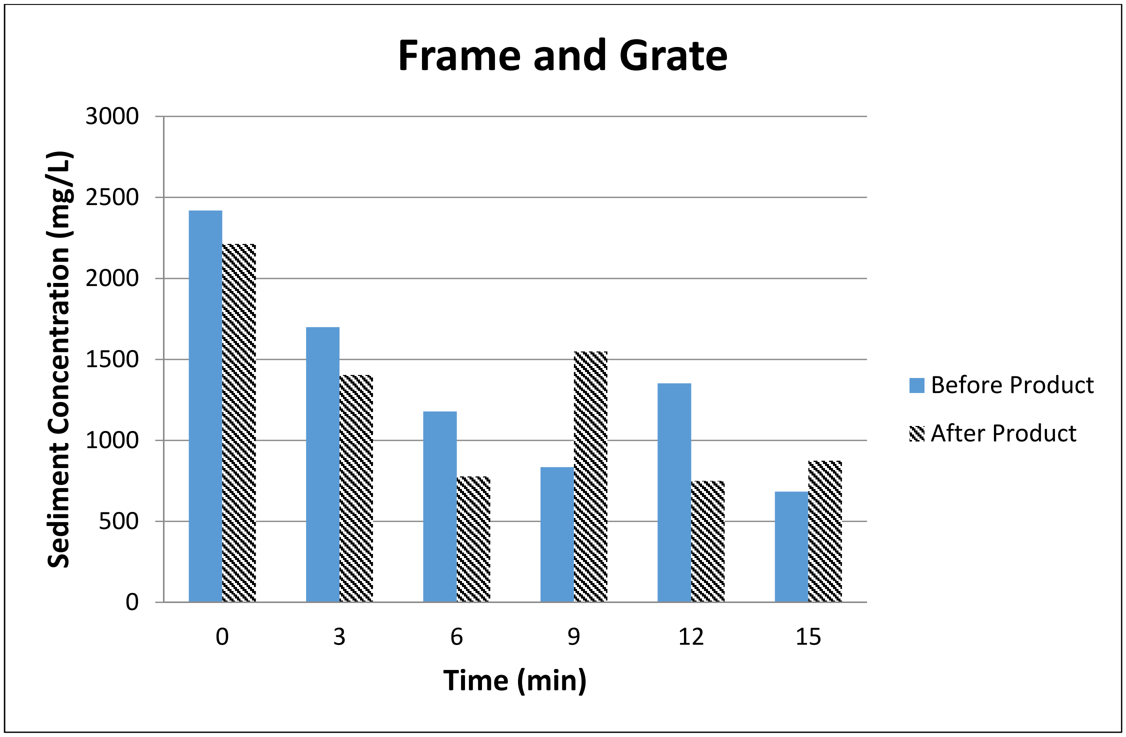

Figure 5.1 Sediment concentrations for frame and grate.

5.2 DANDY CURB SACK

Throughout the experiment, it was observed that sediment concentration decreased with increasing time (Figure 5.2). Because there was significant ponding, any added soil would merely swirl in the pool formed in front of the product. Despite the ponding, results show that the product is very effective in retaining sediment.

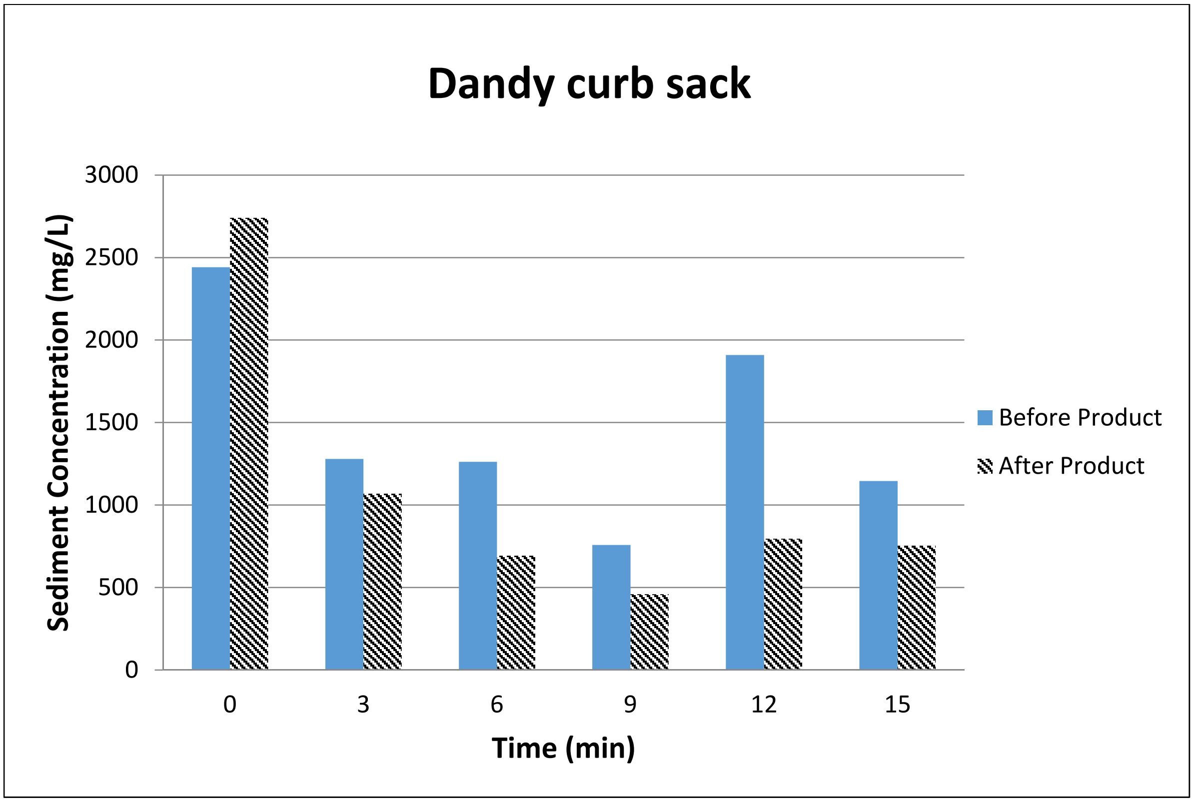

Figure 5.2 Sediment concentrations for Dandy curb sack.

5.3 DANDY CURB BAG

For 9 minutes after the experiment started, it was observed that sediment concentrations were lower once water passed through the product (Figure 5.3). Once ponding became severe, around 10 minutes, sediment concentrations before the product was installed were almost same or lower than sediment control after the product was installed. At 12 minutes, sediment concentrations (after the product was installed) increased, likely due to ponding.

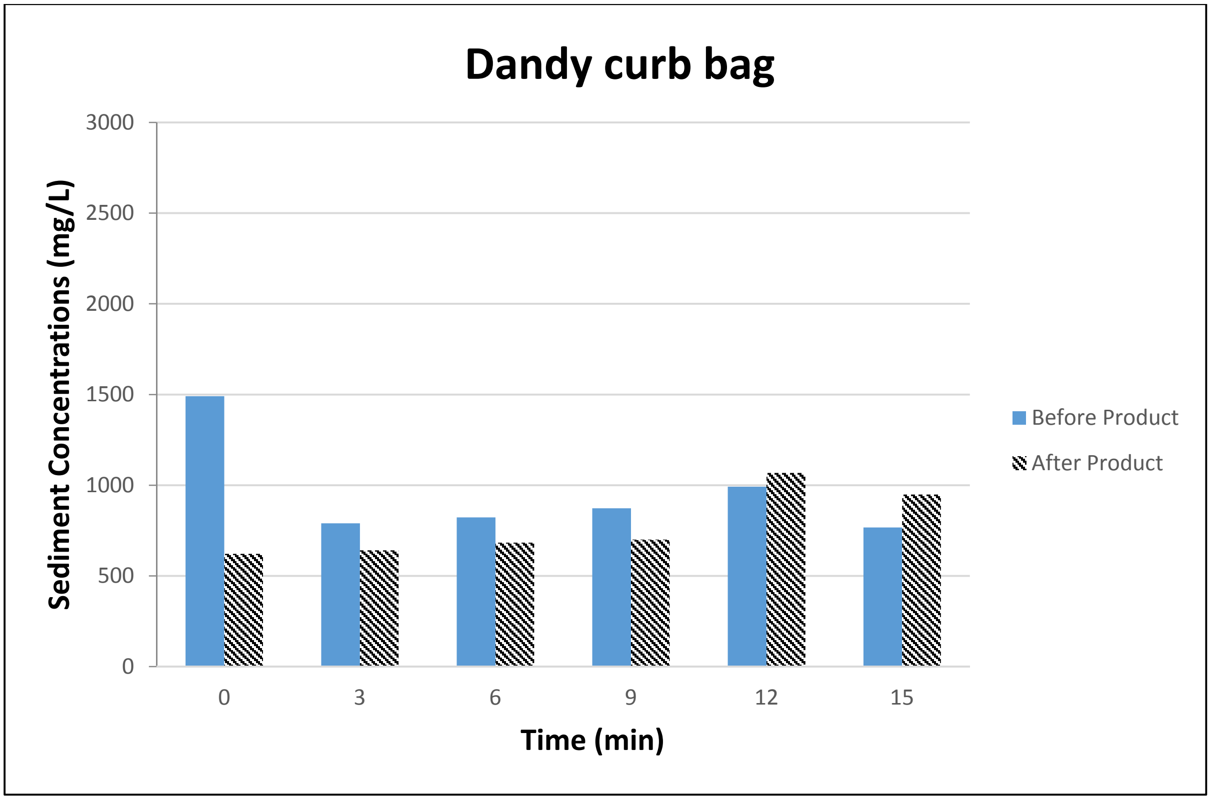

Figure 5.3 Sediment concentrations for Dandy curb bag.

5.4 GEOHAY

The GeoHay proved to be ineffective because it ponded within 2 or 3 minutes. Minimal flow entered the product, and it quickly ponded the concrete slab. The experiment was concluded at that point, and the GeoHay product was classified as a product.

5.5 EROSION EEL

Based on the sample analysis results, it can be observed from the graph that sediment concentration before and after the product were the same (Figure 5.4). One reason could be the gaps alongside the curb, which were unable to be covered due to the product being very rigid. This allowed high levels of sediment to freely pass through the product unfiltered with minimal restriction. Since the results indicated that the product was not able to retain any sediment, the Erosion Eel was found to be inadequate for curb and gutter protection measure.

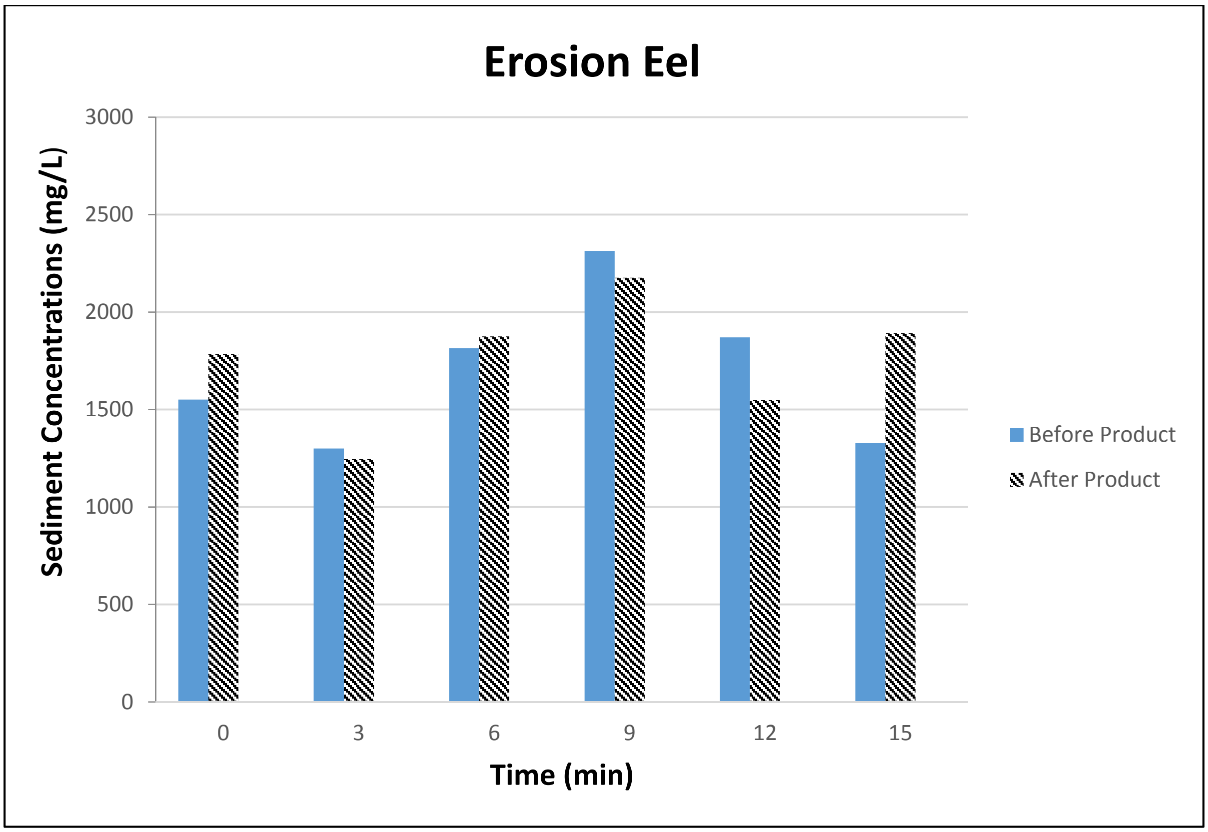

Figure 5.4 Sediment concentrations for Erosion Eel.

5.6 SEDIGUARD

During the experiment, it was observed that sediment concentration after the product was smaller than before the product (Figure 5.5). A predominantly uniform trend of proper filtration was observed throughout the experiment.

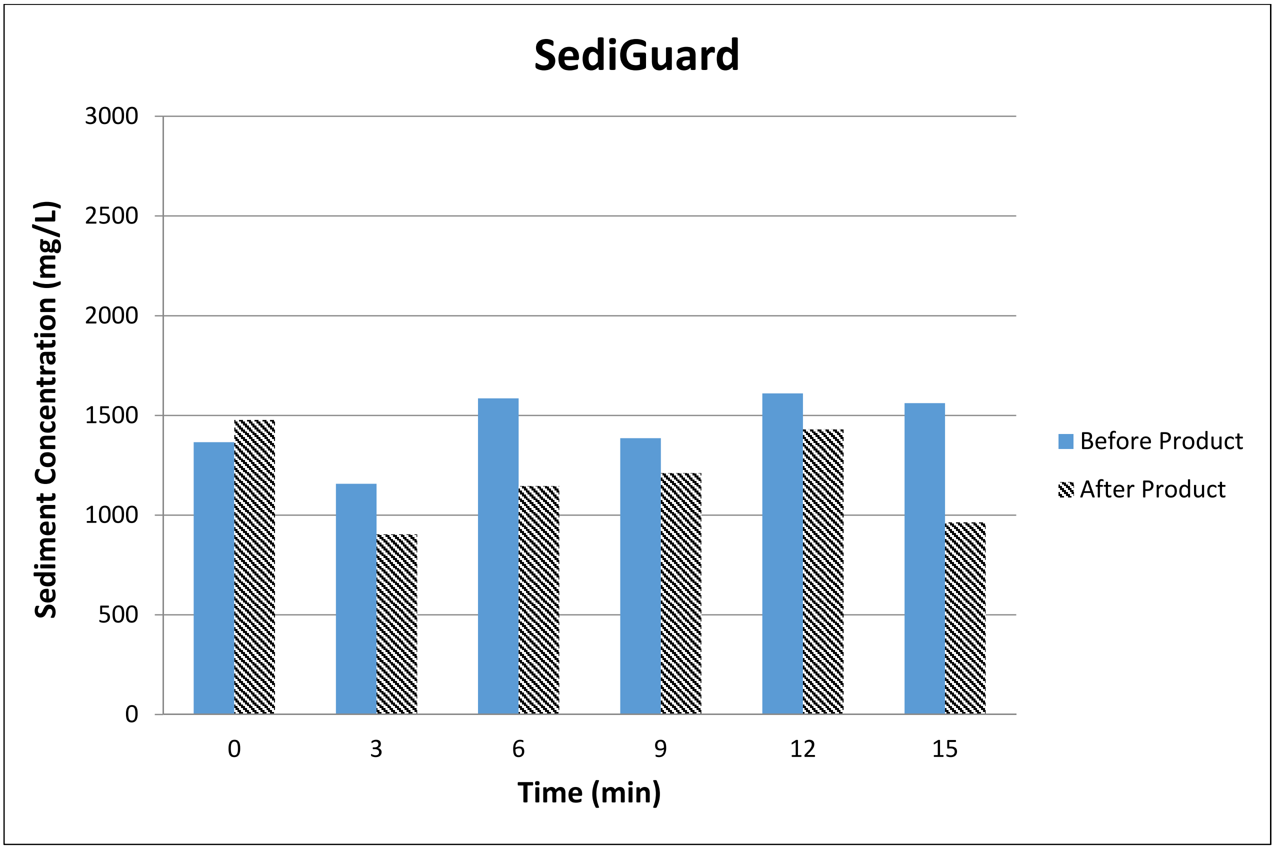

Figure 5.5 Sediment concentrations for SediGuard.

5.7 INLET PRO

Based on sample analysis results, it was observed that throughout the experiment, sediment concentration after the product was smaller than before the product (Figure 5.6). This product proved to perform very well, consistently filtering sediment during the entire experiment. Sediment concentrations after the product slightly fluctuated, likely by ponding that caused soil to circulate around it. Because added sediment would increase before product concentration, it would merely swirl and have a negligible effect with water entering the product.

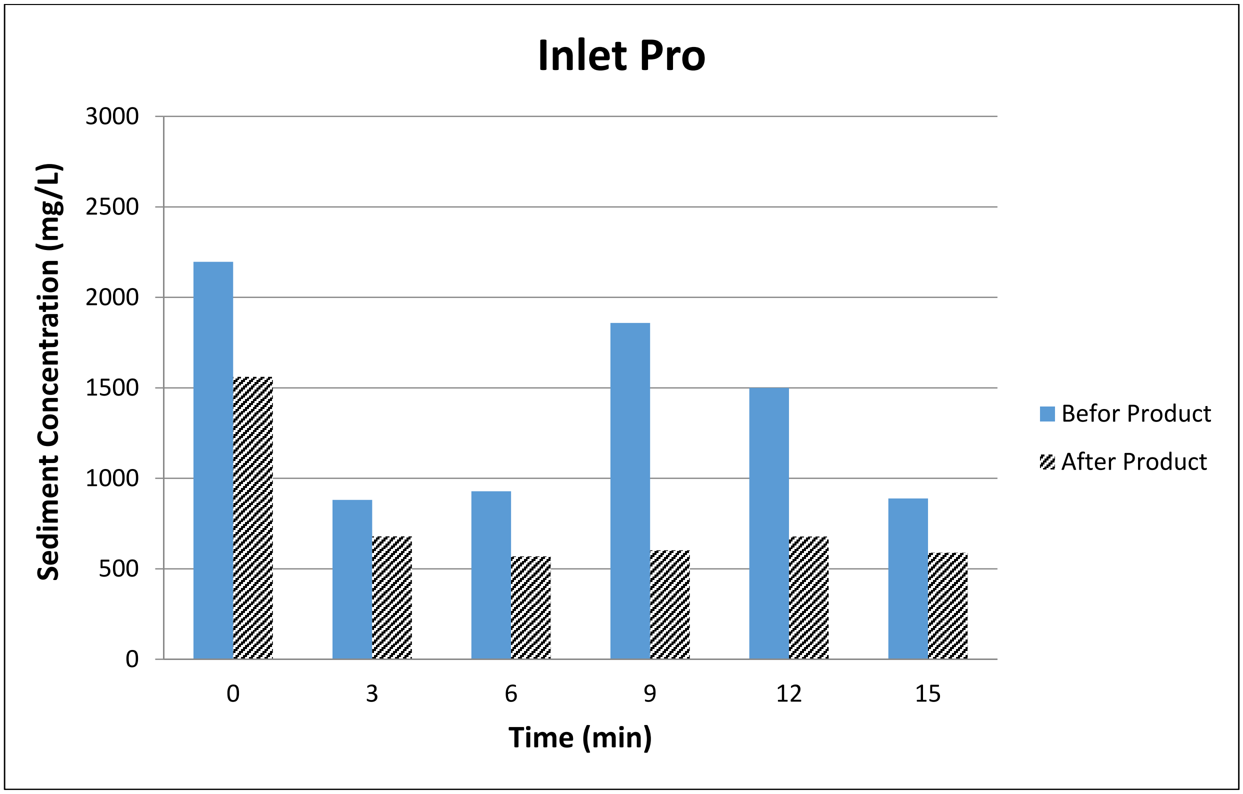

Figure 5.6 Sediment concentrations for Inlet Pro.

SECTION 6: RECOMMENDATIONS

6.1 PRODUCT COMPARISON

Figure 6.1 and the accompanying discussion provide a comprehensive performance overview of each product. The product recommendations are based on observations and results, along with ease of installation. The GeoHay product is not included in the comparison because the product created significant ponding and overtopped the curb within 2 minutes into testing.

The percent change in sediment concentration before and after each product is as follows:

- Dandy curb bag: 18.70%
- Dandy curb sack: 25.95%
- Erosion Eel: –3.40%
- Frame and Grate: 7.36%
- SediGuard: 17.72%
- Inlet Pro: 43.25%

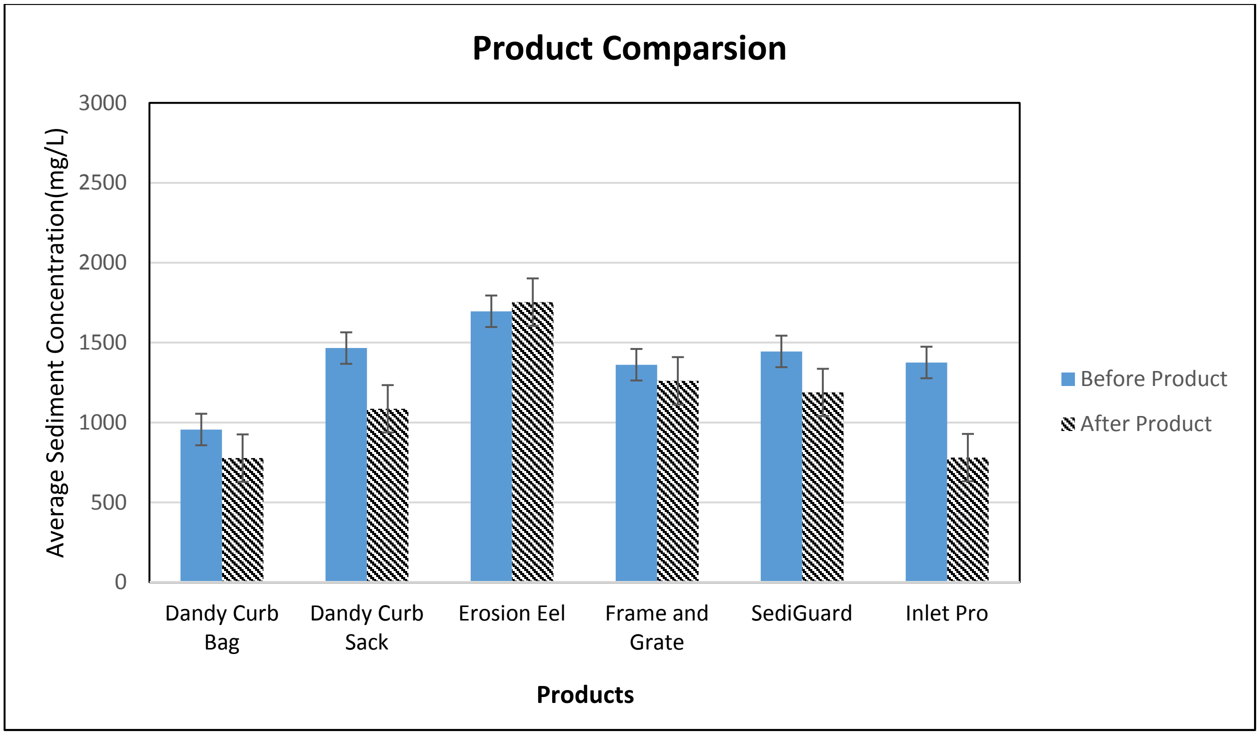

Figure 6.1 Comparison of average sediment concentration for curb and gutter inlet protection products tested.

Based on observations and data analysis, the SediGuard, Dandy curb sack, and Inlet Pro were found to perform better than the other products for reducing sediment concentration. The Inlet Pro performed the best out of the products tested, achieving the highest percent reduction in sediment concentration.

Based on the percent reduction in sediment concentration before and after the products, both Dandy curb sack and Inlet Pro trapped more sediment than the SediGuard, but they experienced more ponding. Both products allowed large debris and other contaminants to collect in the sack, which initially caused unrestricted flow without ponding. As sediment collected in the sack, it allowed water to slowly seep through and filtered the contaminants. This design provided a good compromise, allowing for filtration and free flow into the grate without immediate clogging. Once the sack filled with water, however, any additional water would back up and create ponding. The Inlet Pro performed better than Dandy curb sack, primarily due to its fabric permittivity. Despite the Inlet Pro having a higher level of ponding, it still achieved the highest percent reduction in sediment concentration compared to others. Therefore, both Dandy curb sack and Inlet Pro fabrics may work better with a flow rate of higher than 119 gallons/minute (7.5 L/s).

Despite being less effective in trapping sediment, SediGuard required less maintenance and ponded much less when compared to Dandy curb sack and Inlet Pro. The SediGuard provided a balance between sediment retention and ponding with minimal cleanup/maintenance, making it the best product overall compared to others. Hence, the SediGuard may work well with flow rates of less or more than 119 gallons/minute (7.5 L/s). The one worry we have this product would be during winter and snow plows.

The Dandy curb bag initially performed well, but ponding conditions became severe as testing time increased. After several minutes, the accumulated ponding led to product failure (water overtopping the curb). Also, a low overall total sediment concentration (compared to the other products) was observed both before and after the product. This was possibly due to improper mixing of the soil in the tank. Because of ponding severity, this product may work better with a flow rate of higher than 119 gallons/minute (7.5 L/s).

The overflow protection feature of the frame and grate allowed any additional water to simply spill over without being filtered if the sack was full. Even though the overflow protection prevents street flooding, it will reduce the effectiveness of the product to filter the sediment. For optimal performance, this product may work better with a flow rate of less than 119 gallons/minute (7.5 L/s). It is possible that performance of the frame and grate would improve if the currently used fabric is replaced by more a porous one.

The Erosion Eel is not recommended. It had the lowest percent reduction in sediment concentration. Due to the rigidity of the Erosion Eel, water could bypass (underneath and around) the product. Despite proper installation, water leaked through the points where the product was unable to make proper contact with the slab.

The GeoHay is not recommended either. The product immediately failed when water entered the grate. There was immediate ponding after 2 minutes, and the entire slab was flooded. Because the grate was entirely covered, water was forced to enter through the curbside drain only. The curbside drain does not have enough surface area to drain a high volume of water, which led to immediate ponding.

6.2 PRODUCT ANALYSIS

6.2.1 Frame and Grate

- **Sediment removal:** This product was not very effective; it filtered far less sediment compared to other products tested. For the flow rate (119 gallons/minute) used in this testing, filtration was inefficient. For optimal use, this product may work better with a flow rate of less than 119 gallons/minute.
- **Ease of installation:** This product was fairly easy to install, mainly because it could be adjusted to fit over various-sized grates. Once the product was wedged underneath the grate, it was somewhat difficult to remove for cleaning. Because this low-profile product sits underneath the grate, it is best suited for use in areas with heavy traffic.
- **Ponding:** Because of its overflow protection mechanism, this product experienced minimal amounts of ponding. If the sack is filled with debris or sediment, however, water will overtop the sack unfiltered.
- **Product failure:** Because the product had overflow protection and sat underneath the grate, it was considered very durable and able to withstand heavy traffic. This product requires cleaning after each rainfall event because water will overtop the sack unfiltered if the sack is filled with debris or sediment.

6.2.2 Dandy Curb Sack

- **Sediment removal:** This product was very effective but unable to handle the experimental flow rate (119 gallons/minute), as evidenced by the heavy ponding that nearly flooded the slab. Despite heavy ponding, it was able to filter a significant amount of sediment compared to the other products. Observations suggest that this product may work better for a flow rate of less than 119 gallons/minute (7.5 L/s).
- **Ease of installation:** This product was fairly easy to install; it fit perfectly underneath the grate. Once wedged inside, it required no additional installation work and can be kept in use for long durations. Because it sits beneath the grate, this product is most applicable for use in heavy traffic areas.
- **Ponding:** Ponding was quite severe with this product; sediment and debris tended to settle inside and restrict flow. Once the bag became filled with water, any additional water backed up and created ponding. The product might not be a good choice where flooding is a major problem. Because this product filtered very well, it needs to be cleaned routinely after each rainfall event.
- **Product failure:** For the given experimental flow rate of 119 gallons/minute (7.5 L/s), the product was not found to be porous enough to convey the sediment-laden water efficiently. Because of this, the product created extreme ponding, which can be a safety concern for heavy traffic areas.

6.2.3 Dandy Curb Bag

- **Sediment removal:** Results indicated that this product filtered a fair amount of sediment. This product was consistent in filtering sediment throughout the experiment, but it produced heavy amounts of ponding. Once extreme ponding occurred, the product was unable to filter, and water overtopped the curb. This product may work better with a flow rate of less than 119 gallons/minute (7.5 L/s).

- **Ease of installation:** This product was very easy to install. The grate is wrapped around the product, and the opening is secured with Velcro. This product was easy to clean and required minimal maintenance once installed.
- **Ponding:** Ponding was quite severe, which nearly flooded the entire concrete slab during testing.
- **Product failure:** This product was unable to handle the experimental flow rate (119 gallons/minute or 7.5 L/s). The flow eventually overtopped the curb, which can be classified as a product failure due to excessive ponding.

6.2.4 GeoHay

- **Sediment removal:** This product was unable to filter any sediment; it immediately ponded after testing started.
- **Ease of installation:** This product was very easy install; it required the grate to be covered and the product placed on top.
- **Ponding:** This product performed very poorly; it immediately ponded after testing started. Because the product is designed to cover only curbside opening and the grate was covered with plastic, it significantly reduced the surface area that water could drain into the inlet.
- **Product failure:** This product immediately ponded, and within 2 minutes it nearly overtopped the curb. Based on the immense ponding and overtopping, this product was classified as a failure.

6.2.5 Erosion Eel

- **Sediment removal:** This product was the least efficient, showing an increased sediment concentration after water passed through the product. Due to the rigidity of this product, water passed through the gaps unrestricted. This was directly reflected in the sediment concentrations—only a minimal amount of sediment was filtered.
- **Ease of installation:** This product was very easy to install, but it required several people to position it properly due to its weight. Once installed, it does not need to be maintained or cleaned.
- **Ponding:** This product experienced average levels of ponding, primarily due to water leaking through the gaps along the curb and sides.
- **Product failure:** The product was too rigid and therefore could not create a good ground contact, which resulted in gaps. Because water passed through the gaps, this product was unable to filter any sediment.

6.2.6 SediGuard

- **Sediment removal:** This was among the best products tested. It was able to handle the experimental flow rate (119 gallons/minute or 7.5 L/s) and filter sediment. After the testing ended, a thick layer of sediment surrounded the product. Observations suggested that this product may work well with flow rates of less or more than 119 gallons/minute (7.5 L/s).
- **Ease of installation:** This product was fairly easy to install; it fit perfectly on top of the grate. Secured by zip ties, this product requires minimal maintenance—just a sweeping after each rainfall event. Because it is a low-profile product, it is best suited for use in areas with heavy traffic.

- **Ponding:** Ponding was quite minimal but average compared to other products. Water flowed primarily though the top edges—specifically, through the corners alongside the curb.
- **Product failure:** This product was able to work efficiently for sediment retention under the experimental flow rate of 119 gallons/minute (7.5 L/s).

6.2.7 Inlet Pro

- **Sediment removal:** This product was the most effective compared to others, but it was unable to handle the experiment flow rate (119 gallons/minute or 7.5 L/s). Despite heavy ponding, it still filtered a significant amount of sediment. This product may work better with a flow rate less than 119 gallons/minute (7.5 L/s).
- **Ease of installation:** This product was fairly easy to install; it fit perfectly underneath the grate. Once wedged inside, it required no additional installation and can be kept in use for long durations. Because the product sat beneath the grate, it is most applicable for use in heavy traffic areas.
- **Ponding:** Ponding was quite severe with this product. Sediment and debris tended to settle inside and restrict flow. Once the bag filled with water, however, any additional water backed up and created ponding. Water nearly overtopped the curb at the conclusion of the test, which may lead to possible product failure. Because this product filtered very well, it needs to be cleaned routinely after each rainfall event.
- **Product failure:** For the given experimental flow rate of 119 gallons/minute (7.5 L/s), the product was not found to be porous enough to convey the sediment-laden water efficiently. This resulted in restriction in flow, which led to extreme ponding and possible product failure.

6.3 SUMMARY OF PRODUCT COMPARISON

Table 6.1 is an overview of the results discussed in this section and is provided for easy reference.

Table 6.1 Comparison Table

Product/Criteria	Sediment Removal	Ease of Installation	Ponding	Product Failure
Frame and grate	Decent	Decent	Good	No
Dandy Curb Sack	Good	Good	Decent	No
Dandy Curb Bag	Good	Good	Bad	Yes
GeoHay	Bad	Good	Bad	Yes
Erosion Eel	Bad	Good	Good	No
SediGuard	Good	Decent	Good	No
Inlet Pro	Great	Good	Decent	No

Note: Great: 9–10, Good: 7–8, Decent: 4–6, Bad: 0–3

REFERENCES

Dandy Curb Bag, *Expert Filtration for Sediment-Laden Storm Water,* Dandy Products Inc., 2009. Web. 21 June 2015 (http://www.dandyproducts.com/Products/DandyBag.aspx).

Dandy Curb Sack, *Storm Grate Filtration—Maximum Inlet Protection, Specially Designed to Hang Underneath a Storm Grate,* Dandy Products Inc., 2009. Web. 21 June 2015 (http://www.dandyproducts.com/Products/DandySack.aspx).

Erosion Eel, *Special Specification—Erosion Eels™.* Friendly Environment, 2009. Web. June 2015 (http://www.erosioneel.com/2010%20Specifications.pdf).

FleXstorm, FleXstorm Operation and Maintenance Plan. FLeXstorm Inlet Filters, 2014. Web. June 2015 (http://www.inletfilters.com/sites/default/files/resource-files/opn-maint-plan-10.pdf).

GeoHay. *GeoHay Bale General Notes.* GeoHay Products, 2011. Web. June 2015 (http://www.geohay.com/Grate%20Inlet%20Filter%20Drawing.pdf).