Study of Compost Use in Bioswales for Compost Market Expansion

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ACKNOWLEDGMENT

ReTAP is a venture of the Clean Washington Center, Washington State's lead agency for the market development of recycled materials, and a Division of the Department of Community Trade and Economic Development. ReTAP is an affiliate of the national Manufacturing Extension Partnership (MEP), a program of the U.S. Commerce Department's National Institute of Standards and Technology. The MEP is a growing nationwide network of extension services to help smaller U.S. Manufacturers improve their performance and become more competitive. ReTAP is also sponsored by the U.S. Environmental Protection Agency and the American Plastics Council.

EXECUTIVE SUMMARY

This report discusses the design, testing procedure, and results from a project that examined the effects of using compost in bioswales for the treatment of storm water runoff. Bioswales are narrow, shallow, grass lined ditches, which are considered appropriate technology for treating contaminated runoff for sediment, hydrocarbon, color, and BOD_5 removal. Design guidelines for bioswales call for a substrate of rich, organic soil suitable for moisture retention and promotion of thick grass growth. Compost, mixed at the appropriate rate to avoid overloading of nutrient and subsequent nutrient rich runoff, is well suited for a bioswale substrate.

The results of testing from several storm events indicated that the use of compost promotes better treatment of the runoff sent through the swale. A test swale 200 feet long was split in half length-wise with a flow divider. One half was built and seeded according to traditional practices, and the other half used compost in the substrate. Identical seeding practices were used on both sides, and equal flow was sent down the two halves.

The compost side showed faster growth, thicker coverage, and higher removal efficiency than the control side (no compost). The compost helped the grass endure poor weather conditions such as dry spells and heavy flow. The thicker growth helped prevent erosion of the soil, and therefore provided more even and slower flow through the swale. Slow flow is needed to ensure that the sediment settles out of the flow, and the control side had erosion problems, in the form of rivulets, where all of the seed and soil was washed out, allowing the water to flow through quickly. The compost side did not erode, and provided the proper flow speed to treat the runoff. In almost every case for all seven of the storms, the compost side outperformed the control side in terms of pollutant contaminant removal.

The report also provides design guidelines for the design of bioswales and the use of compost. Although there are some site specific conditions, bioswales should have a:

- Minimum length of 200 feet.
- Maximum velocity of 1.5 ft/sec.
- Maximum depth of flow of 1 inch (urban).
- Maximum depth of flow of 4 inches (rural).
- Minimum contact time of 2.5 minute.
- Maximum width of 50 feet.
- Maximum grass height of 6 inches of dense growth.

For the compost used in this test, the nutrient needs of the grass were met with a two inch layer tilled in to a depth of six inches. This is approximately what should be used on most swale situations, but the nutrient content of the compost will dictate the exact loading rate, and should be calculated on a site-by-site basis. The calculation methodology is shown in the report.

1. INITIAL SITE ASSESSMENT AND DESCRIPTION

1.1 TREATMENT DESCRIPTION

A biofiltration swale is a vegetated channel which is sloped similarly to a standard storm drain. Stormwater runoff from a given physical area is collected and directed to the swale for water quality treatment. Stormwater enters the swale at one end and exits from the other, with treatment provided as the runoff passes through the channel. Bioswales treat runoff through both physical and microbiological principles.

Bioswale is a term with roots in the words biofiltration and swale. Biofiltration is a general term which refers to physical ability of vegetation to remove pollutants from water. Swales are shallow, wide ditches in which a dense growth of grass is established. Bioswales are broad, shallow ditches specifically designed to direct flow through at a rate and depth which will allow for control of pollution from urban and rural runoff. Bioswales have somewhat recently been recognized as an innovative method of reducing pollutant flow to the surface waters of an area.

Pollutant removal in a bioswale depends on the time the water spends in the swale (residence time) and the contact with the soil and vegetation. As a result, minimum swale lengths along with maximum flow speeds and water depth have been established as part of the design criteria for a bioswale. Residence time depends upon swale length, volume of runoff, and flow velocity. Flow velocity depends upon vegetation, and cross sectional dimension. Performance depends upon proper design of all of these factors.

Treatment is achieved through simultaneous processes of filtration, infiltration, absorption and biological uptake of pollutants in stormwater, which take place as stormwater runs over the vegetated areas of the swale. Vegetation acts as a physical filter which slows flow and causes gravity-settling of particulates; it also acts as a biological sink when direct uptake of dissolved pollutants occur.

Another means of pollutant removal occurs as stormwater comes in contact with the soil surface and infiltrates the underlying soil. Soil filtration acts as an important removal mechanism for both dissolved heavy metals and phosphorus. These contaminants are reduced/removed by undergoing ion exchange with elements in the soil. In addition, biological activity in the soil can metabolize organic contaminants. In cases where porous soils are present, general limits for infiltration must be met, or a liner must be put in place to ensure that the runoff receives treatment along the entire length of the swale.

When considering the parameters stated above, it makes intuitive sense that a swale which establishes thick, dense, grass growth is likely to show superior treatment of the runoff directed through it over one with a weaker growth of grass. Therefore, a method of establishing this growth sooner and stronger would be a beneficial addition to a bioswale project. Compost should provide this positive addition, if added at the proper loading rate to ensure that nutrients do no exceed the needs of the grass.

The King County Surface Water Management Division is revising their Surface Water Design Manual, and is proposing new levels of treatment for the protection of sensitive surface water. The four levels of treatment including their target goals are shown in Table 1.

Table 1: Proposed Protection Technologies

Level	Protecting	Target Nutrient Removal	Technology Alternatives
1	Surface waters not tributary to phosphorus sensitive lakes	80% total suspended solids	Bioswale, vegetative strip, sand filter, wet pond
2	Phosphorus sensitive lakes	50% total phosphorus	Larger sand filter, larger wet pond and facility train (i.e. bioswale, sand filter)
3	Salmon bearing streams	50% total zinc	Leaf compost filter and sand filter
4	Sphagnum bog wetlands	50% total phosphate 40% nitrate - nitrate alkalinity < 10 mg/l, pH < 6	3 facility train, i.e. bioswale, leaf compost filter, sand filter or: filter strip, leaf composter, basic sand filter, etc.

1.2 SITE CONDITIONS

The bioswale used for this experiment is located at the Land Recovery, Inc. (LRI) landfill in Puyallup, Pierce County, Washington. The swale is designed to handle and treat runoff from the yard debris receiving and processing area. This area is approximately 1 acre in size and is paved with an impervious surface. Flow from this area consists of leachate from truck loads of yard debris and runoff from rainfall (the site is uncovered). The runoff comes in contact with both unchipped and ground materials, and is directed to a catch basin located at the lowest point of the paved surface. The water flows to a lined holding pond, designed to contain large storm flow and regulate discharge to the bioswale. Level sensors trip pumps at the bottom of the pond, which pump the water approximately 1000' to the bioswale.

1.3 PHOTOGRAPHIC RECORD

A photographic record of site conditions is available in Appendix A. These photos show the site before construction began and during each of the storm sampling events. In addition, there are photos of the pipe discharge (entrance to the bioswale), growth differences, and bioswale discharge. The photos are intended to provide a visual context to the reader.

1.4 BIOSWALE DESIGN BASIS

The bioswale design specifications were derived from two documents. These documents are:

- The King County Surface Water Design Manual, January 1990.
- The Storm Water Management Manual for the Puget Sound Area, DOE, February 1992.

The pertinent chapters of these two documents can be found in Appendix D at the end of this report. In addition to the design guidelines, a sample worksheet for calculating bioswale specifications is included. The design guidelines outline several parameters and list minimums or maximums for each. These include:

• Minimum length	200 feet
• Maximum velocity	1.5 ft/sec
• Maximum depth of flow (urban)	1 inch
• Maximum depth of flow (rural)	4 inches
• Minimum contact time (approximate)	2.5 minutes
• Maximum width	50 feet
• Maximum grass height	6 inches, dense growth

The bioswale designed for the LRI site has been tested for all of the above parameters, and is well within all of the criteria. The swale measured 260 feet long and 10 feet wide, and its hydraulic performance was quite good. The performance comparison for the two sides of the bioswale is addressed in Section 3 of this report.

A flow splitter was designed to split the swale lengthwise and allow for a roughly equal distribution of the flow between the two sides of the swale. The splitter was two feet high and was buried to a depth of one foot, leaving one foot above the ground. It was constructed with wood and had a plastic liner draped over its top. This liner was buried and served as the liner of the swale, as well. Covering the splitter with a liner served to protect the experiment from any danger of cross flow between sides and subsequent skewing of results. The splitter worked well for the duration of the experiment.

2. EXPERIMENTAL PLAN DESIGN

This section defines the compost and seeding application rates used in the experimental design plan for the study of the use of compost in bioswales. Bioswales are used for the treatment of surface runoff from roads, parking lots, and other impervious surfaces. The runoff is polished (cleaned) in a grassy swale through physical and biological removal of contaminants in order to render the water suitable for discharge into the surface water of the surrounding area. The purpose of the study is to determine if the addition of compost to bioswales can increase their effectiveness in treating the runoff for nutrient and contaminant removal.

The experiment used the King County Surface Water Design Manual for the design of the bioswale with modifications in the fertilization recommendations only. The analysis of the compost to be used established what level of nutrients were available in the compost, and therefore what amount of fertilizer could be omitted from the recommendation. The use of compost adds valuable nutrients and organic material for the promotion of target plant survival and growth density. This improvement in soil structure and organic base should, in turn, promote a better polishing effect in a bioswale. There is the possibility that the compost will release nitrogen into the water stream for a period of time. This phenomenon was monitored closely in the bioswale, which was split in two identical halves (side by side), one with compost amendment, and one without.

Supplement Needs (per 1000 square feet, as per King County Surface water Design Manual)

If hydro-seeding -	5 lb. seed mix*
	50 lb. mulch product (native mulch compost, 2 cubic feet)
If broadcast seeding -	5 lb. seed mix*
	70 lb. mulch product (native mulch compost, 2.5 cubic feet)

*Seed mixes are described in detail in Table 5.

Nutrient needs for the grass seed mix were modified from the King County Surface Water Design Manual to take into consideration the nutrients already present in the compost and the organic nature of the material. The nutrient needs described in Table 2 are based upon actual data from uptake studies on the listed grasses.

Table 2: Nutrient Needs of Several Grass Types

	Nutrient Uptake (pounds per acre)		
Grass type	**Nitrogen (N)**	**Phosphorus (P)**	**Potassium (K)**
Bluegrass	200	29	149
Tall Fescue	135	24	149
Brome Grass	166	29	211
Average	167	27	170
Average lb/1000 ft^2	3.8	0.6	3.9

The bioswale designed at the LRI landfill at 10' wide and 260' long, had a total surface area of 2600 square feet. Half of the bioswale area, or 1300 square feet, was treated with compost, while the other half was treated as described in the King County Surface Water Design Manual.

Pounds of Nutrients Required

As stated, the area of the bioswale which was amended with compost was approximately 1300 square feet. The nutrient needs in lb/1000 ft^2 can be converted to lb/1300 ft^2 by multiplying by 1.3. The nutrients available in the compost can be expressed in dry lbs./cy. From this, an application rate can be calculated in cubic yards/1300 ft^2 with the following equation:

$$\text{cubic yards of compost/1300 ft}^2 = \frac{\text{lb nutrients/1300 ft}^2}{\text{lb available nutrients/cy}}$$

The compost will be applied in a quantity to satisfy the lower of the two demands for nitrogen and phosphorus, in an effort not to over apply either. In this case, the compost is applied to supply all of the nitrogen needs of the grasses. Table 3 shows the characteristics of the compost used to amend the bioswale.

Table 3: Compost Characteristics

Parameter		
Nitrogen	1.30%	
Phosphorus	0.17%	
Potassium	1.75%	
Salinity	8.5	mmhos/cm
pH	5.9	
Solids content	60%	
Bulk density	800	lb/cy
Dry weight of compost	480	dry lb/cy
Mineralization rate	10%	

Table 4 details the calculation process for determining the compost application rate for the bioswale. As can be seen in Table 4, there is sufficient nitrogen in the 7.9 cubic yards of compost designed to meet the plant needs. Nitrogen and phosphorus were chosen as limiting factors since they both pose a threat to the area surface waters.

Table 4: - Nutrient Needs and Loading for Bioswale

Nutrients Needed for Experimental Section	**Nitrogen**	**Phosphorus**	**Potassium**
Nutrient uptake			
Avg. lb/1000 ft^2	3.8	0.6	3.9
Avg. lb/1300 ft^2	4.94	0.78	5.07
Nutrients available			
Total- lb/cy	6.24	0.82	8.40
Mineralization rate	10%	10%	100%
Available-lb/cy	0.624	0.0816	8.4
Cubic yards needed	7.9	9.6	0.6
Assuming nitrogen and phosphorus are limiting factors			
Design volume	7.9	cubic yards	
Additional phosphorus	1.3	lbs.	

Seeding Needs

The seeding needs for the bioswale are presented in Table 5. The seeding needs shown represent the quantity of each variety of seed required for one half of the bioswale. This recipe was repeated for each side of the experiment. The swale was planted using the rural seed mix, which includes Kentucky Bluegrass, Tall Fescue, Perennial Rye, and Chewings Fescue.

Table 5: - Seeding Needs For Bioswale Design

Lbs. seed/1000 ft^2	5 lb.
Lbs. seed/1300 ft^2	6.5 lb.

Urban Application	**Percent of Mix**	**Lb. of Seed**
Kentucky Bluegrass	30%	2.0
Creeping Red Fescue	40%	2.6
Perennial Rye	30%	2.0
Rural Application		
Kentucky Bluegrass	15%	1.0
Tall Fescue	40%	2.6
Perennial Rye	30%	2.0
Chewings Fescue	15%	1.0
Wetlands Mixture*		
Creeping Red Fescue	40%	2.6
Red Top	30%	2.0
Birdsfoot Trefoil	30%	2.0

*Wetland mix should also include several varieties of tubers. Information is available in Appendix B, King County Surface Water Manual, Chapter 6.3.

List of Analyses Initially Tested

A bioswale is designed to remove a wide variety of constituents from the runoff which is directed through its course. In order to determine exactly what was present in the flow at the LRI site, the project outlined several contaminants to test for in an initial sampling period. The results from these analyses were then used to determine which parameters would be tested for during the performance phase of the project. Those parameters which were negligible in the initial sample were eliminated from the performance phase testing. Table 6 shows the results of the initial testing analyses.

Table 6: Initial Testing Analyses

Parameter	Initial Sample Results	Comments
Total suspended solids (ppm)	6	Test during perf. phase
Total petroleum hydrocarbons		
Diesel and oil (ppb)	310	Test during perf. phase
Priority metals (ppb)		
Antimony	ND	Discontinue testing
Arsenic	ND	Discontinue testing
Beryllium	ND	Discontinue testing
Cadmium	ND	Discontinue testing
Chromium	ND	Discontinue testing
copper	ND	Discontinue testing
Lead	ND	Discontinue testing
Mercury	ND	Discontinue testing
Nickel	ND	Discontinue testing
Selenium	ND	Discontinue testing
silver	ND	Discontinue testing
Thallium	ND	Discontinue testing
Zinc	26	Fresh surf. water limit 110
Color	30	Test during perf. phase
BOD_5	ND	Continue to test despite ND
Nutrients (ppm)		
Total kjeldahl nitrogen	1.8	Test during perf. phase
Ammonium nitrogen	0.7	Test during perf. phase
Nitrate+nitrite nitrogen	0.3	Test during perf. phase
Phosphorus	0.17	Test during perf. phase

3. PERFORMANCE MONITORING

Performance monitoring occurred over a period of one month after grass began to establish itself in both halves of the bioswale. The spring of 1996 was rather wet, and in order to establish growth, LRI staff tented the bioswale with plastic to trap heat. This method worked quite well, and monitoring began in early May. Three storms were tested during the month of May. Through an extension of the original project contract, four more storm events were tested during the following winter (December through March). These events were tested to determine the bioswale's performance after a full season of summer growth. For the first three storms, samples were collected at the pipe outlet (bioswale entrance), the 100 foot mark (both compost and control side), and the bioswale outlet (both compost and control side). During the last four storms, the bioswale was tested at the pipe outlet and at the bioswale outlet (both compost and control side). Each sample (five total for each storm event) was tested for:

- Total suspended solids (ppm)
- Total petroleum hydrocarbons (diesel and oil)
- Color
- BOD_5
- Total kjeldahl nitrogen
- Ammonium nitrogen
- Nitrate+nitrite nitrogen
- Phosphorus

In addition, on the date of each storm event, measurements of average grass height and density of coverage (control and compost sides) were recorded for comparison. This data helped determine whether the use of compost established grass growth faster. If grass is established faster, flow can be directed through the swale sooner and treatment of runoff can begin. Finally, the flow speed in feet per second was recorded for each storm to ensure that the design maximum of 1.5 feet per second was not exceeded. Slower flow will produce better treatment due to contact time with the soil and improved settling of solids. Thicker growth slows down the flow which provides better treatment, and allows more contact time with the organisms in the soil. The results of these parameters are presented later in this section.

Table 7 shows the data from the pipe outlet and the end of each bioswale section. The following sections show descriptions of the removal efficiency for each of the storm events.

Table 7 - Testing Results for Each Storm Event

Parameters	Storm 1			Storm 2			Storm 3			Storm 4		
	Pipe	Compost	Control	Pipe	Compost	Control	Pipe	Compost	Control	Pipe	Compost	Control
BOD_5 (mg/l)	430	350	420	240	121	186	450	410	370	40	34	40
Total Solids (mg/l)	107	74	69	75	88	112	86	118	0	40	38	43
Color (color units)	400	600	500	1000	1200	1000	600	700	0	200	200	200
Nutrients (mg/l)												
Ammonia-N	29	29	29	20	12	16	26	21	0	1	0	1
TKN	53	48	55	37	28	33	55	43	0	7	5	7
Nitrate+Nitrite -N	ND	ND	ND	ND	ND	ND	1	1	0	0	1	4
Total Phosphorus	107	74	69	5	3	4	7	7	0	2	1	2
TPH												
Diesel (*u*g/L)	6,030	8190	8490	0	0	0	5170	1230	0	2820	2230	2370
Oil (*u*g/l)	1,120	1970	1830	1100	1020	1030	2050	ND	0	3340	3220	3830

Parameters	Storm 5			Storm 6			Storm 7		
	Pipe	Compost	Control	Pipe	Compost	Control	Pipe	Compost	Control
BOD_5 (mg/l)	15	12	13	5	7	9	0	6	7
Total solids (mg/l)	228	184	200	156	120	208	40	33	45
Color (color units)	900	800	900	30	20	25	40	30	40
Nutrients (mg/l)									
Ammonia-N	2	1	1	1	1	1	0.25	0.13	0.00
TKN	12	4	6	2	3	4	1.50	2.90	4.30
Nitrate+Nitrite-N	1	1	1	1	1	1	0.30	0.30	0.40
Total phosphorus	1	1	1	1	1	1	0.33	0.42	0.31
TPH									
Diesel (*u*g/L)	610	1200	740	650	390	490	676	700	950
Oil (*u*g/l)	860	870	2120	108	920	850	1080	1080	1090

As was expected with the wet spring conditions, grass establishment increased throughout the testing period, and subsequently, performance of the bioswale improved over time. The graphs in this section show treatment as a percent difference from the pipe outlet. A negative percent increase indicates pollutant removal, while a positive percent increase indicates an increase in pollutant. Each graph compares the treatment levels achieved by both the compost and control sides for each parameter. The spreadsheet containing the lab analysis data is contained in Appendix B. The removal efficiency by percent is somewhat deceptive, as a low initial content and a small change (i.e,. 4 ppm at pipe outlet, 1 ppm at swale discharge) will show on the graph as a substantial reduction (75% removal). These graphs are intended to show trends, and when looking at specific removal efficiencies, it is wise to refer back to the corresponding table of data for each graph.

3.1 STORM 1 DATA

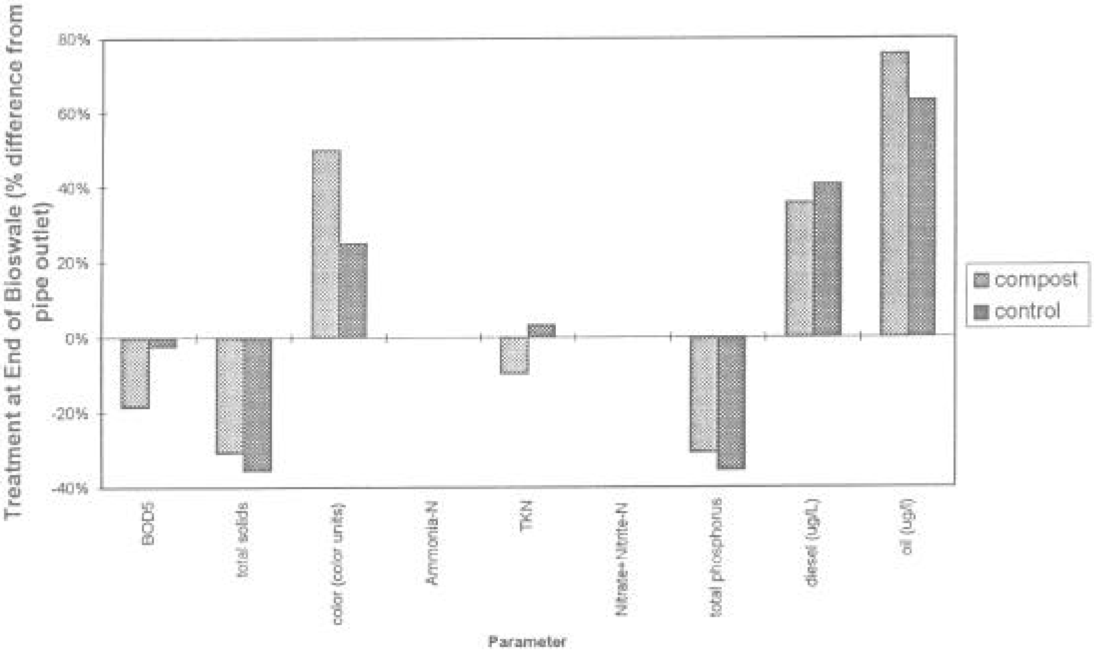
The data for Storm 1 shows pollutant removal for BOD_5, total solids, TKN, and total phosphorus. Levels increased for color, diesel, and oil. This data is shown in Figure 1. This increase could be due to a number of factors, including lack of grass establishment, sampling error, or silt transport. At this point, grass was not fully established in either side of the swale. Figures 8 and 9 are graphical representations of grass height and grass coverage, respectively, for each side of the swale and for each storm event. As can be seen from these figures, grass height and coverage was less than optimal for the removal of pollutants during Storm 1. Table 8 shows the data for the analysis of Storm 1 discharge from the pipe and the end of the swale.

Table 8 - Testing Results for Storm 1

Parameters	Pipe	Compost	Control
BOD$_5$ (mg/l)	430	350	420
Total Solids (mg/l)	107	74	69
Color (color units)	400	600	500
Nutrients (mg/l)			
Ammonia-N	29	29	29
TKN	53	48	55
Nitrate+Nitrite-N	ND	ND	ND
Total Phosphorus	107	74	69
TPH			
Diesel (*u*g/L)	6,030	8190	8490
Oil (*u*g/l)	1,120	1970	1830

Figure 1

Storm 1 Treatment Comparison for Compost Amended Bioswale and Control



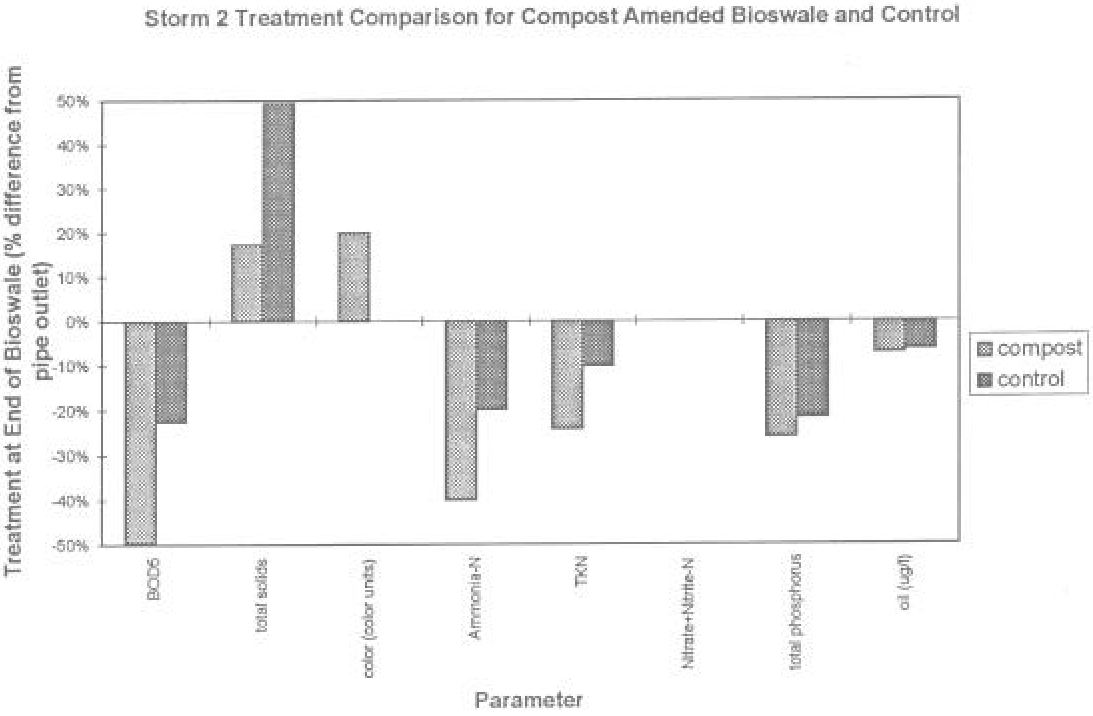
2 STORM 2 DATA

Storm 2 occurred a week and a half after Storm 1. Between these two events, another large storm occurred requiring the pond to be pumped at a high rate of flow. Two pumps were turned on to handle the flow, and a large amount of sediment was deposited in the first thirty feet of both sides of the swale. When sampling for Storm 2 occurred, grass was starting to re-establish in these sections, but much sediment was still exposed. This may explain why the swale shows increases in total solids and color, while showing significant decreases in BOD_5, nutrients, and oil. In all cases where reductions were observed, the compost side out-performed the control side. Again, Figures 8 and 9 are graphical representations of coverage estimates and average grass heights in the compost-amended side and the control side. Storm 2 data is shown in Figure 2 and Table 9.

Table 9 - Testing Results for Storm 2

Parameters	**Pipe**	**Compost**	**Control**
BOD_5 (mg/l)	240	121	186
Total Solids (mg/l)	75	88	112
Color (color units)	1000	1200	1000
Nutrients (mg/l)			
Ammonia-N	20	12	16
TKN	37	28	33
Nitrate+Nitrite-N	ND	ND	ND
Total Phosphorus	5	3	4
TPH			
Diesel (*u*g/L)	0	0	0
Oil (*u*g/l)	1100	1020	1030

Figure 2



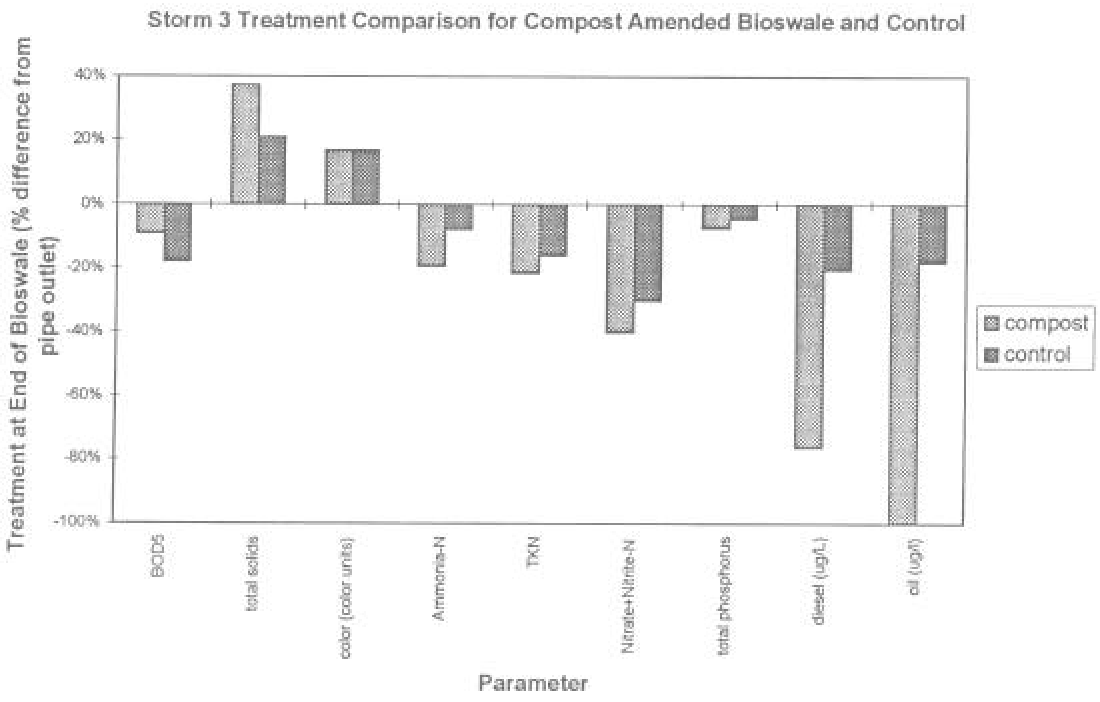
3.3 STORM 3 DATA

Storm 3 data shows much the same trends observed during Storm 2. The data (Figure 3) shows an increase in both total solids and color, and decreases in BOD_5, all nutrients, and diesel and oil. Again, in all cases where reductions were observed (with the exception of BOD_5), the compost out-performed the control plots. As can be seen in Figures 8 and 9, the grass coverage and height had improved at this point as compared to Storm 1 and Storm 2, and as a result, a greater degree of removal was seen. Table 10 shows the raw data from the lab analyses.

Table 10 - Testing Results for Storm 3

Parameters	**Pipe**	**Compost**	**Control**
BOD_5 (mg/l)	450	410	370
Total Solids (mg/l)	86	118	0
Color (color units)	600	700	0
Nutrients (mg/l)			
Ammonia-N	26	21	0
TKN	55	43	0
Nitrate+Nitrite-N	1	1	0
Total Phosphorus	7	7	0
TPH			
Diesel (*u*g/L)	5170	1230	0
Oil (*u*g/l)	2050	ND	0

Figure 3


Storm 3 Treatment Comparison for Compost Amended Bioswale and Control

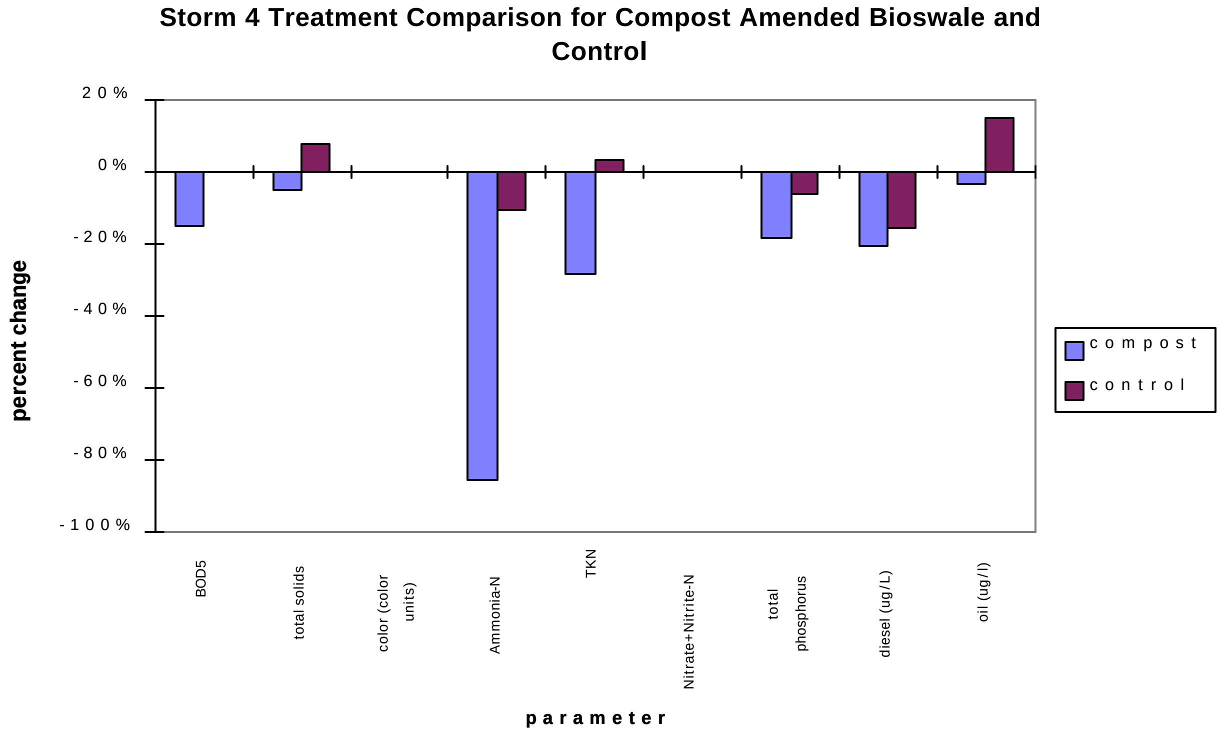
3.4 STORM 4 DATA

As can be seen in Table 7, the strength of the runoff is significantly less strong for the samples taken at the pipe discharge for the event Storm 4 and beyond. This is due to an operational change at the site during the fall of 1996. The grinding operation was moved indoors, and therefore, the rain which falls on the impervious surfaces around the collection pond no longer runs through raw and freshly ground yard debris, picking up solids, color, BOD_5, etc. Storm 4 data shows many of the same trends observed during Storm 3, with the exception of an equal or greater removal efficiency for the compost side as compared to the control side for all parameters. The data (Figure 4) shows no increases in detection of any parameters for the compost side. As can be seen in Figures 8 and 9, the grass coverage and height had improved at this point as compared to earlier storm events, and as a result, a greater degree of removal was seen. Table 11 shows the data for Storm 4.

Table 11 - Testing Results for Storm 4

Parameters	**Pipe**	**Compost**	**Control**
BOD_5 (mg/l)	40	34	40
Total Solids (mg/l)	40	38	43
Color (color units)	200	200	200
Nutrients (mg/l)			
Ammonia-N	1	0	1
TKN	7	5	7
Nitrate+Nitrite-N	0	1	4
Total Phosphorus	2	1	2
TPH			
Diesel (*u*g/L)	2820	2230	2370
Oil (*u*g/l)	3340	3220	3830

Figure 4



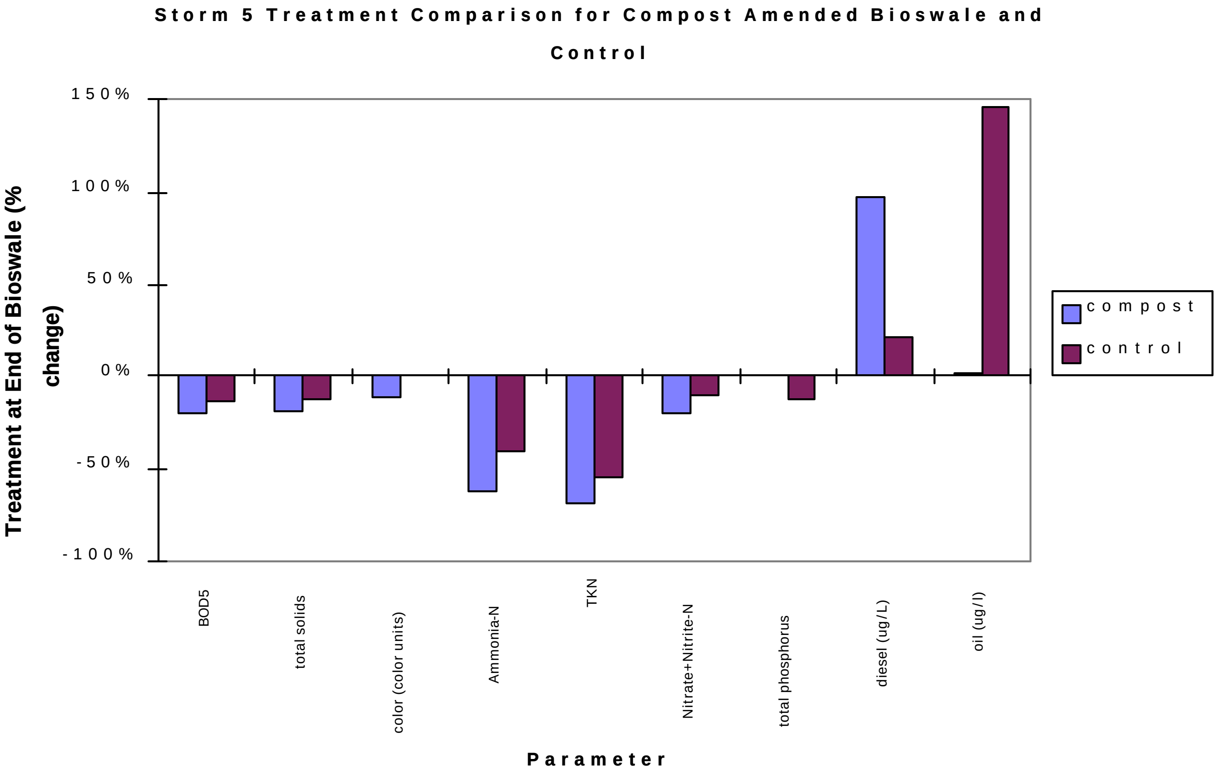
3.5 *STORM 5 DATA*

An event occurred at the site between Storm 4 sampling and Storm 5 sampling which accounts for the elevated levels of TPH at the end of the swale. An oily residue formed on the pond and was pumped into the bioswale. Because the residue caught in the grass, the samples at the end of the swale showed higher TPH results than the outlet of the pipe during the sampling for storm 5, which was otherwise a normal storm event. All other parameters show decreases at the end of the swale. Figure 5 and Table 12 represent the data obtained for Storm 5.

Table 12 - Testing Results for Storm 5

Parameters	Pipe	Compost	Control
BOD_5 (mg/l)	15	12	13
Total Solids (mg/l)	228	184	200
Color (color units)	900	800	900
Nutrients (mg/l)			
Ammonia-N	2	1	1
TKN	12	4	6
Nitrate+Nitrite-N	1	1	1
Total Phosphorus	1	1	1
TPH			
Diesel (*u*g/L)	610	1200	740
Oil (*u*g/l)	860	870	2120

Figure 5



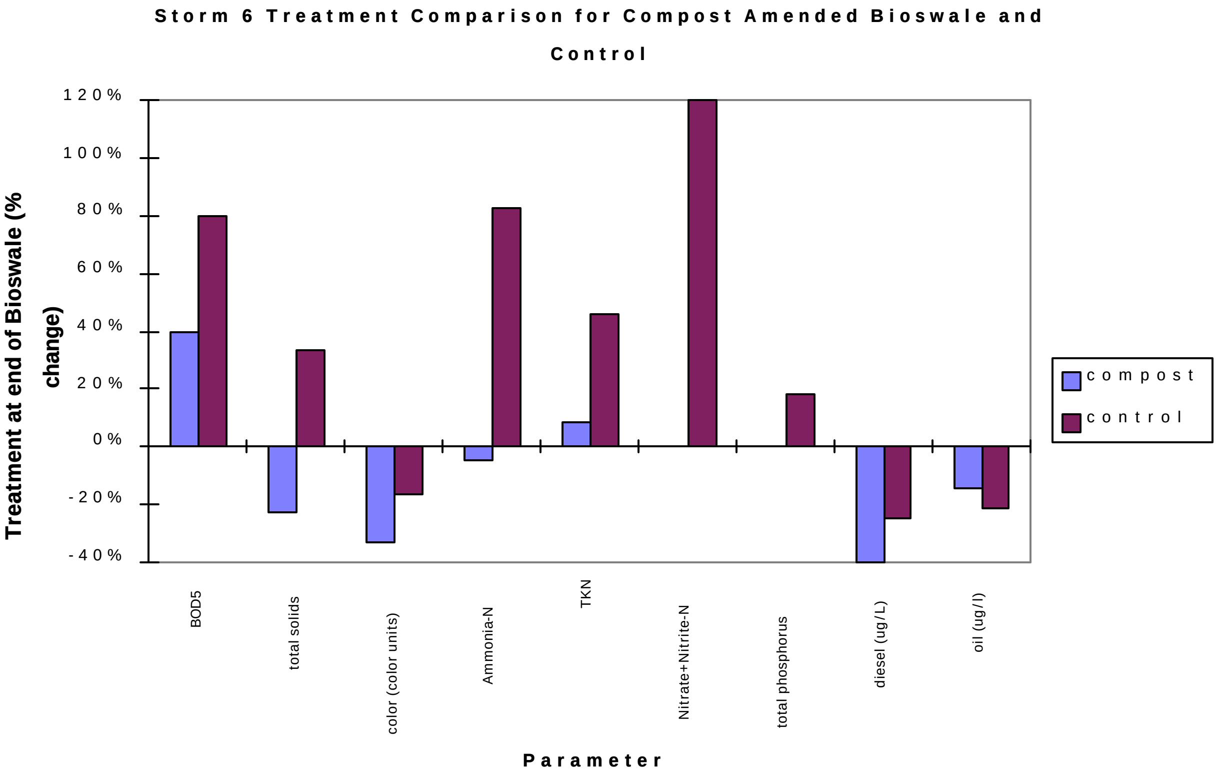
3.6 STORM 6 DATA

As can be seen in the two previous data sets, the strength of the runoff is substantially less than for the previous three storm events. Figure 6 shows the percent removal differences for the samples taken to represent Storm 6. Although the event appears to have substantial percent increases at the end of the swale compared to the pipe discharge analysis, this is mainly due to the fact that the initial levels from the pipe are low. Therefore, an incremental increase could translate to a large percent increase. For example, as seen in Table 13, the pipe discharge BOD level is 5 mg/l while the BOD level at the control swale end is 9 mg/l. In reality, there is a relatively small difference between these two levels, but the 9 ppm represents an 80% increase over the pipe discharge.

Table 13 - Testing Results for Storm 6

Parameters	Pipe	Compost	Control
BOD_5 (mg/l)	5	7	9
Total Solids (mg/l)	156	120	208
Color (color units)	30	20	25
Nutrients (mg/l)			
Ammonia-N	1	1	1
TKN	2	3	4
Nitrate+Nitrite-N	1	1	1
Total Phosphorus	1	1	1
TPH			
Diesel (*u*g/L)	650	390	490
Oil (*u*g/l)	1080	920	850

Figure 6



3.7 STORM 7 DATA

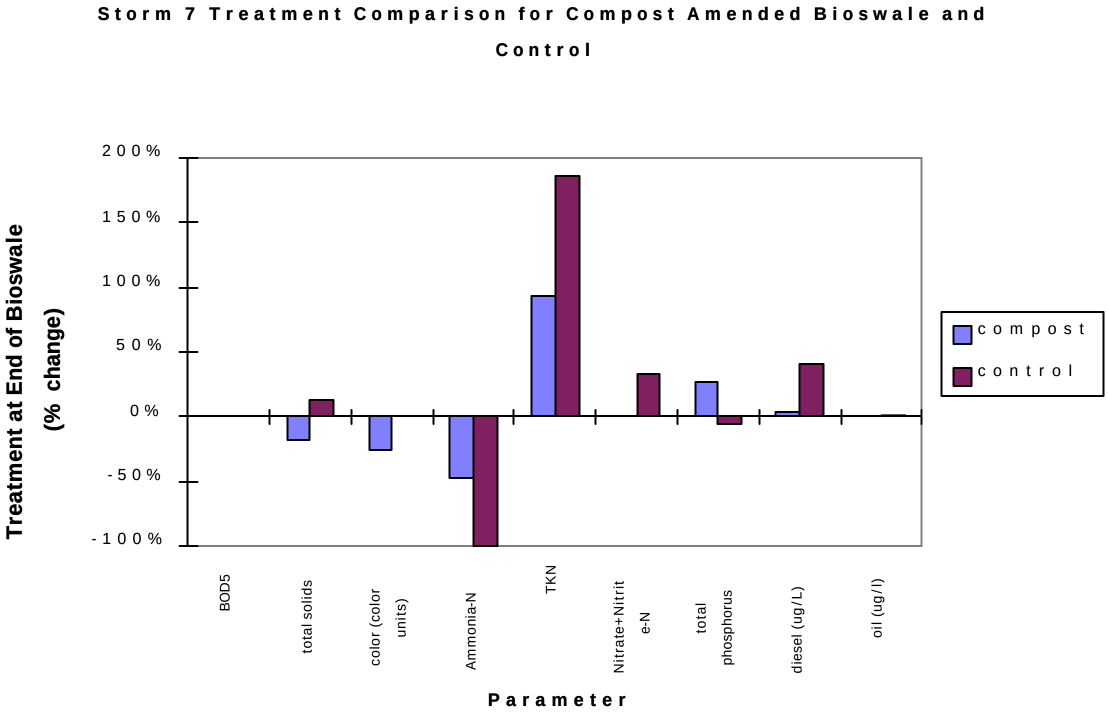
The data shown in Table 14 is for the last storm event, Storm 7. Figure 7 shows the percent change between the pipe discharge and the swale outlet for each of the parameters tested. The graph indicates that for several parameters there were significant changes between the discharge and the swale end. For instance, the nutrients appear to be changing dramatically (some higher, some lower). However, the data in Table 14 shows that the levels of these pollutants are very low, and therefore the changes appear to be significantly high. The changes are actually quite small - in the case of TKN, a change from 1.5 mg/l to 4.3 mg/l is seen. This small change represents a 186% increase. The differences are so small they could be attributed to variations in the flow.

For the compost side, the diesel levels showed a very slight increase and the oil levels showed no change when compared to the pipe outlet readings. For the control side, the diesel showed a 40% increase and the oil showed a very slight increase. This may be a result of the earlier incident described in Section 3.5 in which an oily residue was discharged into the bioswale. While the swale seemed to be cleaning itself out in the two previous storms, there was also some erosion occurring. Because the control side did not establish roots as well as the compost side (see Section 3.9 for further detail), the control side experienced greater erosion and inferior coverage. The greater erosion experienced by the control side may explain the transport of the TPH to the end of the swale. The compost side did not see these increases, which means that any TPH introduced to the compost side of the swale likely stays and is treated, as is intended, rather than being flushed through to the end. The thicker growth and better coverage in the compost side shows the benefit of the use of compost, since the swale is designed to slow down flow and trap pollutants.

Table 14 - Testing Results for Storm 7

Parameters	**Pipe**	**Compost**	**Control**
BOD_5 (mg/l)	0	6	7
Total Solids (mg/l)	40	33	45
Color (color units)	40	30	40
Nutrients (mg/l)			
Ammonia-N	0.25	0.13	0.00
TKN	1.5	2.9	4.3
Nitrate+Nitrite-N	0.3	0.3	0.4
Total Phosphorus	0.33	0.42	0.31
TPH			
Diesel (*u*g/L)	676	700	950
Oil (*u*g/l)	1080	1080	1090

Figure 7



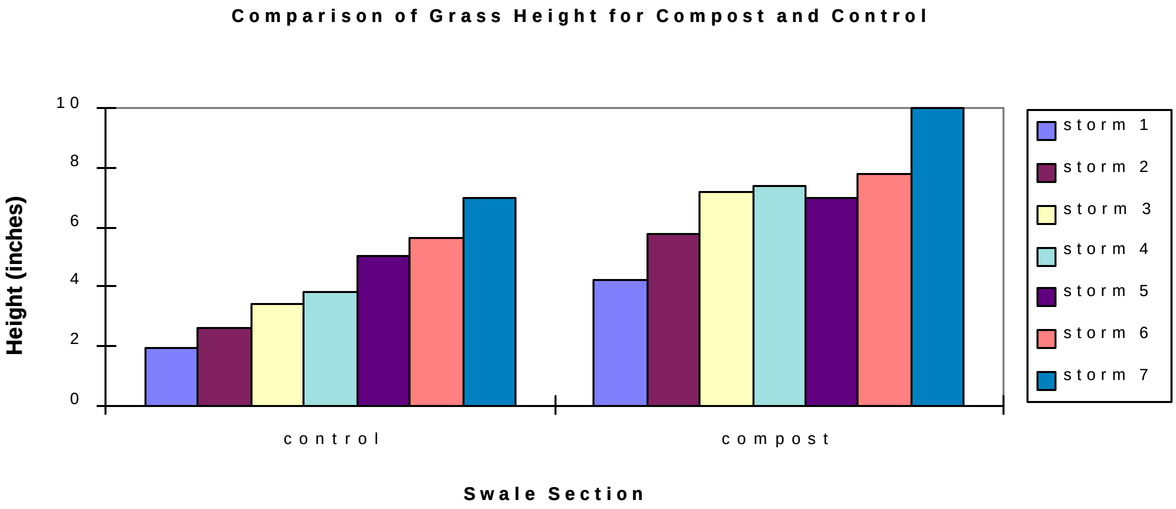
Storm 7 Treatment Comparison for Compost Amended Bioswale and Control

3.8 AVERAGE GRASS HEIGHT COMPARISON

The swale grass is designed to grow to an optimum height to slow down flow without being too tall. The optimum height is 6" - 9” and should be maintained with mowing of some sort. If the grass height is higher than this optimum range, the blades tend to bend and the water flows over the top. When this occurs, the flow velocity increases (maximum design flow is 1.5 ft/sec) and inferior treatment occurs. The sooner this optimum height is obtained, the sooner the optimum treatment will occur. The level of treatment is also dependent upon the coverage of the grass, which is discussed in greater detail in Section 3.9.

Figure 8 shows the average grass height over time in both the compost-amended and the control sides of the swale. The grass height and the grass coverage indicate the speed of establishment of the grass in the swale. As can be seen from the figure, the height increased (as expected) over time. In addition, the compost side clearly established the optimum grass length (6") sooner than the control side. This earlier establishment likely provided the improved treatment seen in the storm data.

Figure 8



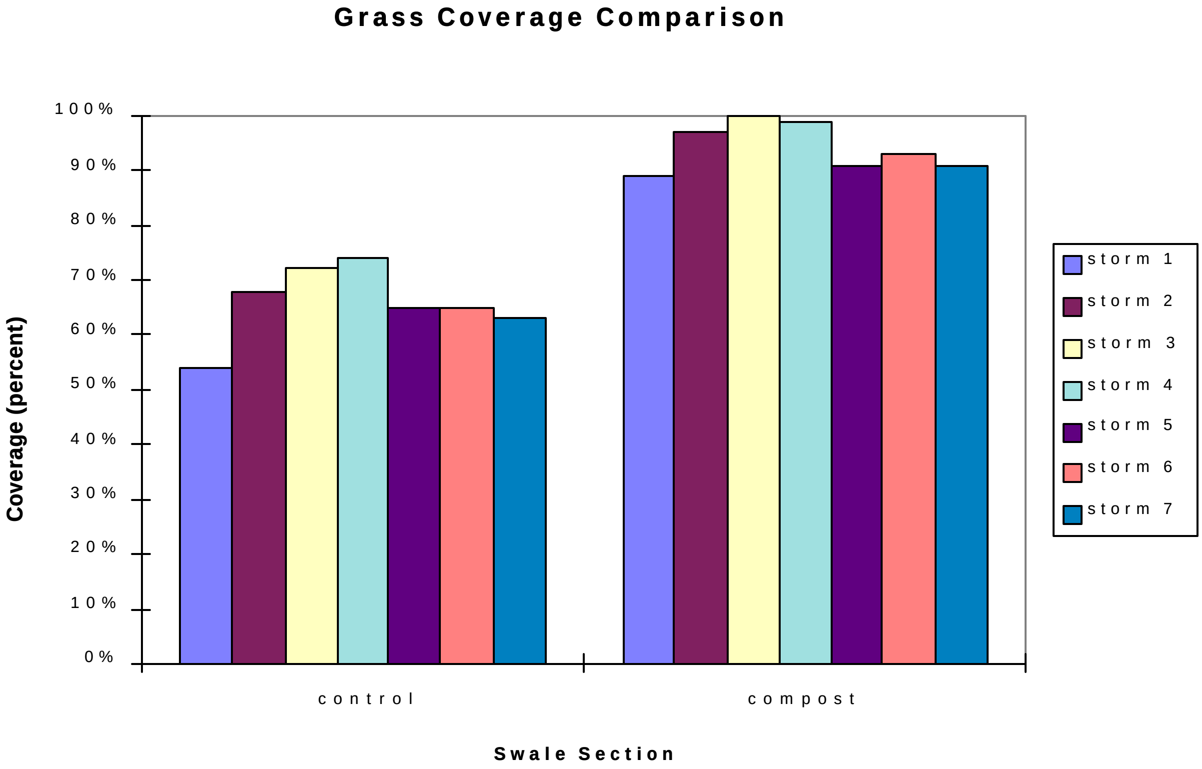
3.9 *AVERAGE PERCENT COVERAGE COMPARISON*

The percent coverage in grass is an indicator of the health of the swale. The greater the coverage, the better the treatment. Water will seek the path of least resistance, and if complete coverage is not maintained, the water will erode rivulets into the swale, stripping out grass seeds and not allowing for growth in those areas. The water will flow at a rate greater than prescribed in the initial design in these bare areas because there is no resistance from the grass. When the flow rate is greater than the maximum allowed for proper treatment (1.5 ft/sec), inferior treatment occurs.

The experimental swale was examined for coverage during the sampling period. In addition, qualitative observations were noted concerning the root growth from each side of the swale. A small section of the swale was excavated and examined to determine if a difference could be seen. Although measurements were not taken, in each case the root clump was distinctly larger and longer from the compost side. In addition, the clump from the compost side was darker and richer in organic matter due to the addition of the compost. Due to this deeper, stronger root growth, the swale side with the compost held its grass better than the control side. The control side showed greater signs of erosion and rivulets where flow had run with little resistance.

Figure 9 shows the average grass area coverage over time in both the compost-amended and the control sides of the swale. The grass coverage, along with grass height, indicate the speed of establishment of the grass in the swale. As can be seen from the figure, the coverage increased (as expected) over time. In addition, the compost side clearly established complete coverage sooner than the control side. This earlier establishment likely provided the improved treatment seen in the storm data.

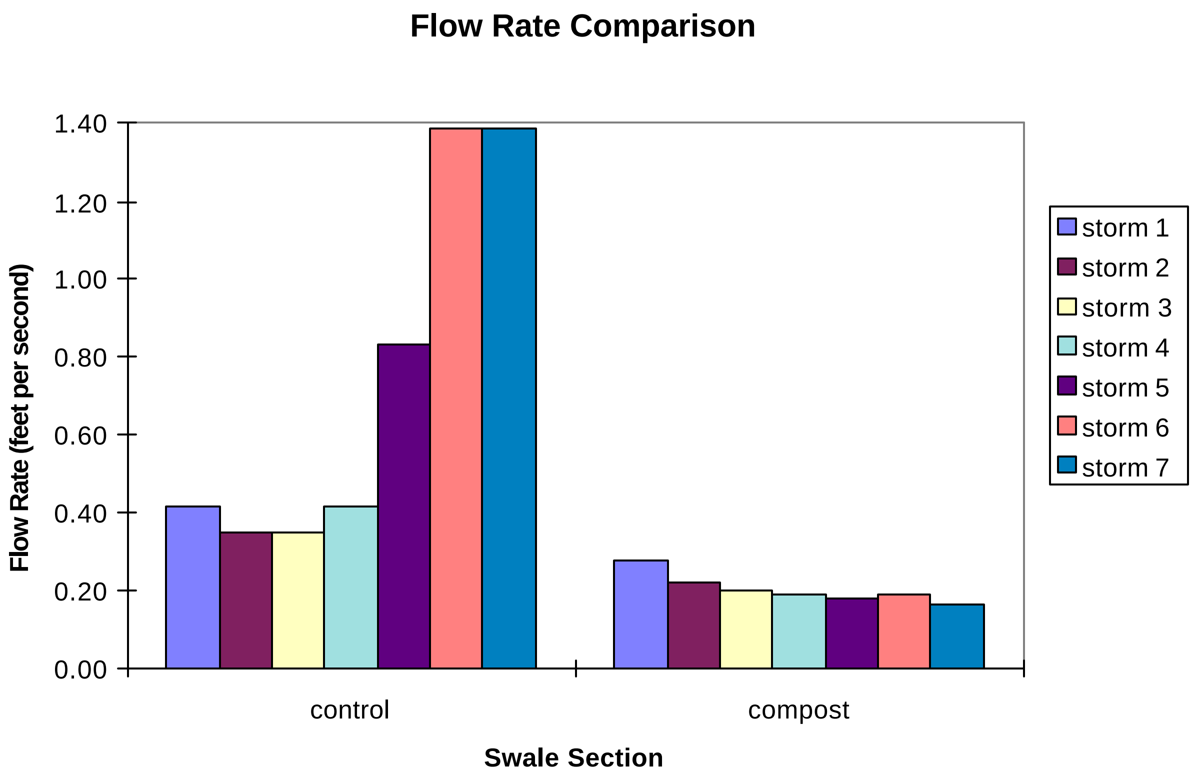
Figure 9



3.10 FLOW RATE COMPARISON

Another parameter which is used for performance evaluation is the flow rate of runoff through the bioswale. The maximum velocity of 1.5 ft./second which has been established is recognized as a limit which should not be exceeded. A comparison of flow rate on the two sides of the bioswale for each of the seven storms is shown in Figure 10. As can be seen, the compost side shows a slower flow rate, which is desirable, since more settling and contact will occur with a slower flow. This reduced velocity is likely caused by thicker, taller growth of the grass in the compost-amended swale.

Figure 10

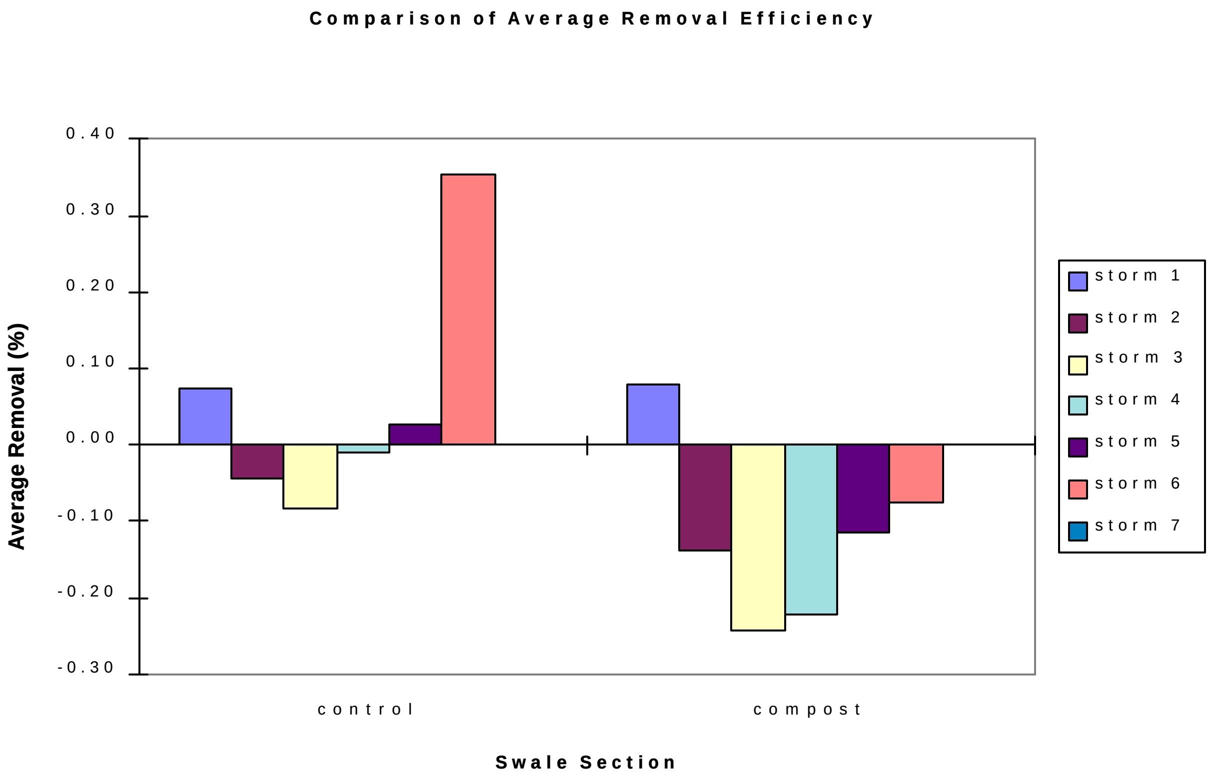


3.11 AVERAGE REMOVAL PERCENTAGE COMPARISON

While the comparison of the average removal percentage of all parameters for each storm may not accurately depict the efficiency of the bioswale, it does show a trend of increased removal as grass is established in both sides of the swale. In addition to the growth over time and early establishment, Figure 11 shows the improved treatment seen in the compost side of the swale. As summer progressed, the removal efficiency improved, and then decreased somewhat over time.

As can be seen in Figure 11, the compost side showed greater average removal than the control side. This is due to stronger, thicker growth of grass which prevented erosion and allowed for maximum detention and contact time. The data in this report shows that better treatment can be achieved sooner through the use of compost. The establishment of a strong organic base helps prevent erosion, as is shown in the coverage figure (Figure 9).

Figure 11


Comparison of Average Removal Efficiency
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
Average Removal (%)
control
compost
Swale Section
storm 1
storm 2
storm 3
storm 4
storm 5
storm 6
storm 7

4. RECOMMENDATIONS

The data in this report shows that the use of compost in bioswales will help eliminate pollutants from runoff discharge, produce a healthier stand of grass (grows in faster and taller, with better coverage) which will survive inclement weather, and slow down flow in order to ensure better treatment. The recommended application rates of compost seem to be sufficient for the purposes of design, and no detrimental effects were seen in the runoff analyses. The health of the swale on the compost side was due to the additional organics provided by the compost. The compost not only provides nutrients, but the organic matter increases water holding capacity and keeps the root mass moist and cool.

The volume of compost used in this experiment was calculated based on the nutritional needs of the grass seeds used to plant this swale. A compost volume of 7.9 cubic yards was used on 1300 square feet of swale area. Using these numbers, the prescribed application rate is 0.164 feet (2 inches) of compost per square foot of area. The compost should be applied and tilled-in to a depth of 6 inches. Grass seed should be applied at a rate of 5 lbs. per 1000 square feet of area.

A 10' wide bioswale, 200 feet long would require 12.3 cubic yards of finished compost in order to meet the prescribed 2" depth of compost. This calculation is made by multiplying the area (2000 square feet) times the depth (2" x 12 in/ft) which equals 333 cubic feet (12.3 cubic yards) of compost. The 12.3 cubic yards of compost, at approximately $15/cubic yard delivered, would cost under $200. This is a small investment for the dividends seen from the addition of the compost. Faster establishment of grass, thicker growth, and better root establishment all lead to better treatment of the runoff sent through the swale.

A swale which has thick growth and does not erode is more likely to succeed in removing pollutants from the runoff directed through it. A bioswale which is not functioning properly needs to be rehabilitated. In addition to a complete redesign, this rehabilitation could include re-seeding and excavation. This work will require labor, time, and materials, all of which will incur additional cost to the owner. The use of compost will help prevent possibility of bioswale failure and therefore help avoid these extra costs.

This report indicates that for the grass types recommended for bioswales, an application rate of 2" of compost tilled to a depth of 6" will provide a good strong organic base and will help improve treatment and prevent grass die off. The compost used in this project was a yard debris compost produced by LRI, Inc. at the Pierce County composting facility in Purdy, Washington. This compost is similar to other composts available from facilities in the state, and the prescribed application rate of 2" will be appropriate in most situations.

APPENDIX A

Photographic Record

(Not included in this electronic file, but available upon request)

APPENDIX B

Laboratory Data

(Not included in this electronic file, but available upon request)

APPENDIX C

Graphs of Individual Parameters by Storm

(Not included in this electronic file, but available upon request)

APPENDIX D

King County Surface Water Design Manual

Bioswale Section

(Not included in this electronic file but available upon request)