CDM Camp Dresser & McKee

City of Greensboro

North Buffalo Creek
Stormwater Best Management Practices
Siting Evaluation

November 2001

WATER Resources
City of Greensboro

Final
Siting Evaluation

CDM Camp Dresser & McKee

Technical Memorandum

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From: *J. Brenan Buckley, P.E.*

Date: *November 28, 2001*

Subject: *City of Greensboro, North Carolina*
North Buffalo Creek Stormwater Best Management Practice Siting Evaluation

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Introduction

The City of Greensboro (City) retained Camp Dresser & McKee (CDM) to assist in the preparation of a Clean Water Management Trust Fund (CWMTF) Application. CDM provided preliminary engineering services for the evaluation and conceptual design of potential stormwater best management practices (stormwater BMPs) along a 3.5 mile stretch of North Buffalo Creek. The purpose of this Technical Memorandum is to present CDM's evaluation of the existing pollutant loading for sediments, bacteria and various nutrients from stormwater runoff into North Buffalo Creek and to recommend potential stormwater BMP alternatives for 27 locations selected by the City.

Site Survey

On November 6, 2001, CDM conducted a windshield survey of the 27 sites to determine the feasibility of installing stormwater BMPs to improve water quality in the stream. The project area followed North Buffalo Creek from the bridge on West Friendly Avenue to the intersection of North Church Street and Tankersley Drive (see Figure 1). In general, the project area was primarily residential with some institutional sites. A majority of the proposed stormwater BMP sites were located along the floodplain in parks or greenways. Major features and potential conflicts were identified along the floodplain of North Buffalo Creek that may impact the design and performance of potential stormwater BMPs. Table 1 describes each of the 27 sites and provides a cursory feasibility analysis for location of a stormwater BMP at each site. Photographs of the sites are provided in Appendix B, with their locations identified on Figures 2-1 and 2-2.

Table 1: Summary of Site Visit Observations

Site ID	Location	Site and Stormwater System Description	Feasible for BMP?
1	South bank near bridge on West Friendly Avenue	Generally open, brush along banks, sanitary sewer and underground cable in the area	Yes
2	North bank along park across from hospital	30-inch RCP from under road, rock outcrops	No
3	North bank along park across from hospital	RCP from under road, emerging stream with wetland vegetation, rock outcrops	No
4	North bank along Benjamin Parkway, near hospital	Steep banks along edge of road, large culvert under road, rock outcrops	No
5	North bank along Benjamin Parkway, near hospital	Steep banks along edge of road, large culvert under road, rock outcrops	No
6	Off south bank of creek, at entrance to Country Club at end of Mimosa Drive	Steep banks, near several private properties, forested	Yes
7	North bank along Benjamin Parkway, near Campus Drive	54-in RCP culvert and stormwater manhole feeding a channel, 8-ft concrete path between manhole and road	Yes
8	South bank near intersection of Mimosa Drive and Catalina Drive	Open floodplain, few trees, brush along steep stream banks, sanitary sewer along top of bank	Yes
9	South bank near intersection of Mimosa Drive and North Tremont Drive	Open floodplain, few trees, brush along steep stream banks, sanitary sewer along top of bank	Yes
10	South bank near intersection of Mimosa Drive and West Radiance Drive	Open floodplain, few trees, brush along steep stream banks, sanitary sewer along top of bank	Yes
11	North bank at Bridge on North Aycock Street	Concrete walking path crosses site	Yes
12	South bank at Bridge on North Aycock Street	Open floodplain, 15+ trees (18-in dia), brush along steep stream banks, sanitary sewer along top of bank	Yes
13	South bank near bridge on Garland Drive	Open floodplain, a few large trees, brush along steep banks, 8-ft concrete path, sanitary sewer across site	Yes
14	North bank along Benjamin Parkway between Garland Drive and Battleground Avenue	Open floodplain across the street from Lake Daniel. The stream banks are covered with tall vegetation and two large power line towers potentially interfere with BMPs	Yes

Site ID	Location	Site and Stormwater System Description	Feasible for BMP?
15	North bank near intersection of Benjamin Parkway Drive and Battleground Avenue	Open floodplain, the stream banks are covered with tall vegetation. Potential interference with two power line towers	Yes
16	South bank of stream in park on Cridland Road	Open floodplain, brush along steep stream banks, sanitary sewer along top of bank	Yes
17	South bank of stream in park on Cridland Road	Open floodplain, brush along steep stream banks, sanitary sewer along top of bank	Yes
18	North bank of stream across from park on Cridland Road	Open floodplain, brush along steep stream banks, sanitary sewer along top of bank, potential power line tower interferences	Yes
19	Culvert under Cridland Road on south bank of stream	Site on stream; controls large watershed	Yes
20	North bank at bridge on West Wendover Avenue	Open floodplain, brush along steep stream banks	Yes
21	Culvert under Latham Road at intersection with Nottingham Road	Box culvert under road with >5-ft banks and open floodplain upstream of culvert	Yes
22	North bank between intersection of Nottingham Road and Parkway Street	Open floodplain, brush along steep stream banks	Yes
23	South bank at bridge on Parkway Street	Open floodplain, brush along steep stream banks, power line towers in vicinity	Yes
24	North Bank near intersection of Meadowbrook Terrance and Edgedale Road	Open floodplain, brush along steep stream banks	Yes
25	North Bank near bridge on North Elm Street	Open floodplain, brush along steep stream banks	Yes
26	Behind Country Club Apartments	Channel with >6-ft high dam and impoundment; steep bank and wooded between dam and creek	Yes
27	Intersection of North Church Street and Tankersley Drive	Street intersection with RCP under road emptying into a wooded/ brushy region with relatively steep terrain	No

Upon completion of the site visits, 5 of the initial 27 sites were eliminated. Sites 2, 3, 4, and 5 were removed due to the existence of bedrock at ground surface. Site 27 was eliminated due to site area limitations. Twenty-two sites remained to be further evaluated using information from site visits and GIS data provided by the City.

Watershed Characteristics

CDM estimated the average annual volume of runoff for each of the candidate sites using GIS data provided by the City. The stormwater runoff from a watershed is dependent on rainfall volume, depression storage, slopes, soils, percent impervious, and other variables. For purposes of estimating the long-term mean event runoff volume used in this procedure, the variables, except for rainfall volume, are incorporated into a runoff coefficient. The runoff coefficient is estimated using a conversion equation with percent imperviousness found in the Federal Highway Administration's (FHWA's) 1989 manual Retention, Detention, and Overland Flow for Pollutant Removal from Highway Stormwater Runoff. CDM estimated the percent imperviousness of each of the candidate site watershed areas using GIS zoning data provided by the City. Percent impervious values were assigned by CDM to each of the zoning classification types, shown in Table 2, and a weighted average was calculated for each candidate site watershed. The watershed areas and their associated percent imperviousness are shown in Table 3.

Table 2: Percent Imperviousness Based on Land Use

Category	Percent Impervious
Commercial	85%
Office/Institutional/ Business	65%
Industrial	65%
Multi-Family High Density	55%
Multi-Family Low Density	45%
Single Family High Density	35%
Single Family Low Density	20%

Wet Detention Basin

A wet detention basin is an impoundment formed by constructing a dam or embankment, or by a combination of excavation and an embankment, with an outlet structure to maintain a permanent pool and regulate the outflow of upstream stormwater discharges. In the general literature and State/Federal regulations for stormwater pollution control, a wet detention BMP is also sometimes referred to as a "wet pond" or a "retention basin".

Figure 3 presents a schematic of a typical wet detention basin. The permanent pool is maintained to provide stormwater pollution control benefits. Pollutant removal is achieved through processes which include sedimentation and biological uptake. Wet detention basins can also be designed to provide peak-shaving control (i.e. reductions in peak runoff flows from upstream areas) by regulating the outflow peak discharge and temporarily storing excess flow volumes above the permanent pool storage zone.

Applicability

Wet detention basin BMPs are appropriate options for both residential and nonresidential development. This BMP is often restricted to sites with a minimum drainage area of 10 acres, since dry weather flow is required to minimize the drawdown of the permanent pool during extended dry periods. For this analysis, sites whose watershed areas were less than 10-acres were evaluated by assuming the permanent pool could be maintained by the receiving stream.

The applicability of a wet detention basin to a particular site depends on site topography, drainage area, soil conditions, wetlands constraints, space availability, and accessibility. Soils should not be highly permeable to facilitate maintenance of a permanent pool. Consideration should also be given to bedrock depth, location of existing underground utilities, and minimizing impacts on low marshy areas where wetland permits may be required.

Design Criteria

Wet detention basins are capable of providing water quality control benefits through the process of sedimentation and biological uptake when properly designed. Due to a variety of recommendations in technical literature for wet detention basin design, CDM evaluated two distinct design criteria, the first being the design methodology presented in the North Carolina Division of Environment, Health, and Natural Resources's (NCDENR's) 1995 Stormwater Best Management Practices Design Guidance Manual, and the second being a set of design criteria developed by CDM based on past experiences with stormwater BMP design. The NCDENR and CDM design criteria used in this evaluation are provided in the paragraphs below.

NCDENR Design Criteria
The design of wet detention basins by NCDENR criteria is based on controlling the design runoff from the long-term average storm in order to settle out suspended solids and pollutants. A permanent pool is sized to detain the storm long enough to attain 85 percent removal of total suspended solids (TSS). In addition to the permanent water quality pool, a temporary water quality pool for extended detention is included to control the runoff from a 1-inch storm.

The permanent water quality pool is sized based on a surface area / drainage area (SA/DA) ratio for an average permanent pool depth of 3 feet, provided in Table I.1 in the NCDENR manual. The water quality volume is estimated using the required surface area, a 3-foot mean depth, and 3H:1V side slopes. The temporary water quality pool for extended detention is sized to capture the runoff from the 1-inch storm. The runoff volume is calculated using the Simple Method based on the watershed percent imperviousness. A sediment storage volume equal to 20 percent of the permanent pool volume is also included to allow for sedimentation buildup while retaining high pollutant removal efficiencies. The sediment storage, permanent pool, and temporary water quality pool volumes are summed to obtain the total water quality volume.

The NCDENR manual also recommends a 3L:1W length/width ratio for the surface area to minimize dead storage and short circuiting while maximizing residence time. The outlet structure is sized to release the runoff volume associated with the 1-inch storm over a drawdown period of 48 to 120 hours.

CDM Design Criteria
The design criteria assigned by CDM is a compilation of past CDM experiences with stormwater BMP design and technical literature. The wet detention basin criteria suggest a normal pool of 3 feet with a calculated surface area and wetlands plants along the bank to assist in the capture and uptake of various nutrients. Percent removal estimates are based on the evaluation of collected data for wet detention basins along the eastern United States.

<u>Water Quality Volume</u>: CDM sized each of the 22 storage volumes to capture 1.0 inch of runoff per acre or 3.0 inches of runoff per impervious acre, whichever was greater.

<u>Mean Depth</u>: An average mean depth of three feet was assumed for each of the sites in order to maintain an acceptable environment within the permanent pool for the storage volume and associated average hydraulic residence time.

<u>Length/Width Ratio</u>: An adequate length/width ratio helps to maximize plug flow conditions in order to enhance sedimentation, minimize short-circuiting, and also help prevent vertical stratification. CDM chose a 3L:1W length/width ratio to increase travel time while maximizing pollutant removal.

Peak Flow Control Storage: Each of the wet detention ponds were designed to allow the passage of a 10-year, 24-hour storm event through the outlet structure while maintaining a minimum freeboard of one foot. Less frequent storm events are routed through an emergency spillway.

Embankment: The embankment shall have 3H:1V side slopes and be planted with turf forming grasses.

Emergency Spillway: Each wet detention basin shall be provided with an emergency spillway designed to pass the runoff from the basin's entire drainage area without damage to the impoundment structure. The design storm for the emergency spillway shall be the 100-year, 24-hour storm event. Velocities must be controlled to prevent erosion along the spillway and into the North Buffalo Creek.

Principal Spillway: The principal spillway shall be sized to allow the passage of the 10-year, 24-hour storm event while maintaining a minimum freeboard of one foot. A vertical concrete riser box will be used with an adjoining barrel pipe properly sized to convey flow to the receiving stream.

Information/Warning Sign: Wet detention BMPs should be posted with an information/warning sign identifying the facility as a stormwater control and prohibiting swimming and other activities considered dangerous or inappropriate.

Maintenance Requirements

In order to provide effective stormwater pollution control on a continuing basis, periodic maintenance of the wet detention basin BMP is necessary. Maintenance requirements can be broken down into two categories:

Routine Maintenance: This involves tasks that are performed on some regular basis during the year and are viewed as preventive in nature and are intended to enhance the aesthetic quality of the facility. Examples are periodic site inspections, grass mowing, debris and trash removal, bank stabilization, weed control, insect or mosquito control, fence repair, and record keeping.

Non-Routine Maintenance: This involves tasks that are performed once every specified number of years to correct problems which might reduce the detention facility's structural integrity or effectiveness. Major clean-outs are intended to maintain the required water quality storage capacity, and also to eliminate the build-up of accumulated sediments and debris which might significantly detract from the facility's appearance. Clean-out operations typically include material removal, stabilization of the detention facility, and offsite hauling for sediment disposal. Sediment removal should occur, on average, once every 10 years.

Modified Extended Dry Detention Basin

A modified extended dry detention basin is a two-stage basin with a shallow marsh in the bottom stage to achieve enhanced nutrient removal. The shallow marsh is supported by a permanent pool and overlying extended dry detention zone. In addition to removal or suspended pollutants by sedimentation, the shallow marsh should achieve removal of some dissolved nutrients.

Figure 4 presents a schematic of a modified extended dry detention basin. Pollutant removal is achieved through processes which include sedimentation and biological uptake. The permanent pool for shallow marsh is maintained to provide stormwater pollution control benefits through plant uptake.

Applicability

Modified extended dry detention basins are most often used when pollutant removal is the primary goal and the use of wet detention basins are prohibited by physical constraints and/or policy issues. Modified extended basins are appropriate options for both residential and nonresidential development.

Design Criteria

Modified extended dry detention basins are capable of providing water quality control benefits through the process of sedimentation and biological uptake when properly designed. Due to a variety of recommendations in technical literature for dry detention basin design, CDM evaluated two distinct design criteria, the first being the design methodology presented in the North Carolina Division of Environment, Health, and Natural Resources' (NCDENR's) 1995 Stormwater Best Management Practices Design Guidance Manual, and the second being a set of design criteria developed by CDM based on past experiences with stormwater BMP design. The NCDENR and CDM design criteria used in this evaluation are provided in the paragraphs below.

NCDENR Design Criteria

The NCDENR Stormwater BMP Guidance Manual provides recommended design criteria for a dry detention basin, but not a modified extended dry detention basin as selected by CDM for consideration. To provide an additional nutrient removal capability, the modified extended dry detention basin includes a shallow marsh area with a permanent pool and wetland plant species. The wetlands plants and shallow permanent pool allow for increased nutrient removal through organic and plant uptake that cannot be achieved through particulate settling alone for highly soluble nutrients. Therefore, NCDENR design criteria for the temporary water quality pool were used, and a permanent pool for shallow marsh was included based on CDM design criteria.

The NCDENR manual requires a temporary water quality pool for extended detention sized to capture the runoff from the 1-inch storm. The runoff volume is calculated using the Simple Method based on the watershed percent imperviousness. The shallow marsh system is located within an additional storage volume equal to 20 percent of the temporary storage volume that is intended for sediment storage. A portion of this area will remain inundated to support the shallow marsh plantings. The shallow marsh and temporary water quality pool volumes are combined to obtain the total water quality volume.

The NCDENR manual also recommends a 3L:1W length/width ratio for the surface area to minimize dead storage and short circuiting while maximizing residence time. The outlet structure is sized to release the runoff volume associated with the 1-inch storm over a drawdown period of 48 to 120 hours.

CDM Design Criteria
Modified extended dry detention basins are capable of providing water quality control benefits through the process of sedimentation and biological uptake when properly designed. With that in mind, CDM sized the dry detention basins to obtain optimal pollutant removal benefits and not flood relief. Design criteria were determined based on past CDM experience and literature recommendations.

<u>Two-Stage Design</u>: A two-stage design is required for a modified extended dry detention basin and includes a shallow marsh system with a permanent pool of water and an extended detention basin (see Figure 4). The top stage of the basin is designed for larger flows and is intended to be dry except for runoff from larger more infrequent storm events. The top stage also helps to prevent the possibility of re-suspension of previously settled particles in the shallow marsh zone. The top stage of the basin was sized to store 0.5 inches of runoff per acre or 1.5 inches of runoff per impervious acre, whichever is greater.

The shallow marsh system is located within the bottom stage. The bottom stage is 1.5 feet deep and includes a permanent pool. The shallow marsh was sized for a storage capacity of either 0.25 inches of runoff per acre or 0.75 inches of runoff per impervious acre, whichever is greater. The shallow marsh includes a permanent pool having a volume equivalent to 0.1 inches of runoff per drainage basin acre. This allows for a permanent pool and the ability to support wetland plant life.

<u>Mean Depth:</u> An average mean depth of 1.5 feet was assumed for both the top stage and shallow marsh zone.

<u>Length/Width Ratio</u>: In order to maximize settling of suspended solids, a length/width ratio of 3L:1W was used when possible. The outlet structure is placed at the furthest location from the inlet point to maximize travel time.

Peak Flow Control Storage: Each of the dry detention ponds were designed to allow the passage of the 10-year, 24-hour storm event through the outlet structure while maintaining a minimum freeboard of one foot. Less frequent storm events are routed through an emergency spillway.

Basin Side Slopes: The top stage and marsh zone shall have side slopes of 3H:1V. The floor of the top stage has a slope of 2 percent toward the low flow channel. The floor of the marsh zone is minimized to allow for low flow velocities.

Modified Extended Dry Detention Outlet: A vertical perforated riser pipe is recommended as the dewatering device for the modified extended dry detention outlet. The riser pipes allow for less severe clogging problems than a standard culvert pipe. Gravel should be packed in the shape of a cone around the vertical perforated/slotted riser to protect the modified extended dry detention outlet from clogging due to trash and debris. The perforations should begin at the normal pool depth in the marsh zone, in order to allow for a permanent pool to exist.

Peak Shaving Outlet: The modified extended dry detention basin shall include an outlet to release stormwater discharges which exceed the water quality volume and to satisfy the peak-shaving. This outlet structure shall consist of a vertical riser pipe or concrete box joined by a horizontal barrel pipe extending through the embankment to convey flow to the receiving stream. The outlet shall be sized to allow the passage of the 10-year, 24-hour storm event while maintaining a minimum freeboard of one foot.

Emergency Spillway: Each dry detention basin shall be provided with an emergency spillway designed to pass the runoff from the basin's entire drainage area without damage to the impoundment structure. The design storm for the emergency spillway shall be the 100-year, 24-hour storm event. Velocities must be controlled to prevent erosion along the spillway and into the North Buffalo Creek.

Maintenance Requirements

In order to provide effective stormwater pollution control on a continuing basis, periodic maintenance of the modified extended dry basin BMP is necessary. Maintenance requirements can be broken down into two categories:

Routine Maintenance: This involves tasks that are performed on some regular basis during the year and are viewed as preventive in nature and are intended to enhance the aesthetic quality of the facility. Examples are periodic site inspections, grass mowing, debris and trash removal, clearing around the extended detention outlet structure to prevent clogging, bank stabilization, weed control, insect or mosquito control, fence repair, and record keeping.

Non-Routine Maintenance: This involves tasks that are performed once every specified number of years to correct problems which might reduce the detention facility's structural integrity or effectiveness. Major clean-outs are intended to maintain the required water quality storage capacity, and also to eliminate the build-up of accumulated sediments and debris which might significantly detract from the facility's appearance. Clean-out operations typically include material removal, stabilization of the detention facility, and offsite hauling for sediment disposal. Sediment removal should occur after the shallow marsh storage has been depleted by 20 percent or on average once every 4 years.

Constructed Wetlands

Constructed wetlands (Figure 5) can be highly effective BMPs for removing pollutants from urban storm water when constructed and maintained properly. The predominant mechanisms of pollutant removal in wetland systems are through sedimentation and biological uptake. The advantage of a wetland over other BMPs (e.g. wet and dry detention basins) is the high pollutant removal due to various biological mechanisms. These mechanisms include filtration by aquatic vegetation, biological conversion of organic compounds by microorganisms, uptake of nutrients by aquatic plants and algae, uptake of metals by plant tissue, adsorption of metals by clay soils, and volatilization of hydrocarbons and volatile organics. Constructed wetlands also provide natural areas that can be aesthetically pleasing.

CDM identified possible locations for constructed wetlands based on available site area and a minimum drainage area of 10 acres. Wetlands are typically fed by groundwater and stormwater runoff, but due to the difficulty of excavation to the water table at the sites, the constructed wetlands are assumed to be fed predominately by stormwater runoff. The large number of wetland plant species requires adequate runoff volume, therefore eliminating sites whose watersheds are less than ten acres.

Design Criteria

Stormwater wetlands are complex ecosystems, and variations in design and watershed factors can have significant impacts on performance. They require careful planning, design and maintenance. Due to a variety of recommendations in technical literature for constructed wetland design, CDM evaluated two distinct design criteria, the first being the design methodology presented in the North Carolina Division of Environment, Health, and Natural Resources' (NCDENR's) 1995 Stormwater Best Management Practices Design Guidance Manual, and the second being a set of design criteria developed by CDM based on past experiences with stormwater BMP design. The NCDENR and CDM design criteria used in this evaluation are provided in the paragraphs below.

NCDENR Design Criteria

The surface areas required for constructed wetlands is very similar to that of a wet detention basin. The permanent water quality pool is sized based on a surface area / drainage area (SA/DA) ratio for an average permanent pool depth of 3 feet. CDM elected to use this relationship in lieu of the sizing criteria for pocket wetlands included in the NCDENR manual to ensure the wetland included adequate surface area for forebays, marsh zones, and micropools. Refer to the design requirements for wet detention ponds included in this technical memorandum for additional information.

CDM Design Criteria

Constructed wetlands can be highly effective BMPs for removing pollutants from urban storm water when constructed and maintained properly. Stormwater wetlands are complex ecosystems, and variations in design and watershed factors can have significant impacts on performance. They require careful planning, design and maintenance. The design criteria assigned by CDM is a compilation of past CDM experiences with stormwater BMP design and technical literature.

Water Quality Volume: CDM assumed the same footprint for constructed wetland as that of wet detention basins.

Mean Depth: An average mean depth between 6 to 12 inches around the shoreline with a maximum depth of three feet for the micropool and forebay sections. The maximum depth was chosen to allow for plant growth to occur in all areas of the wetland.

Length/Width Ratio: An adequate length/width ratio helps to maximize plug flow conditions in order to enhance sedimentation, minimize short-circuiting, and also help prevent vertical stratification. Due to the large number of plant life, velocities must be kept to a minimum to avoid destruction and removal of plant life. A length/width ratio of 3H:1V was chosen for wetlands, resulting in an increased travel time.

Peak Flow Control Storage: Each of the wetlands were designed to allow the passage of the 10-year, 24-hour storm event through the outlet structure while maintaining a minimum freeboard of one foot. Less frequent storm events are routed through an emergency spillway.

Embankment: The embankment shall have 3H:1V side slopes and be planted with turf forming grasses and wetland plant life.

Principal Spillway: The principal spillway shall be sized to allow the passage of the 10-year, 24-hour storm event while maintaining a minimum freeboard of one foot. A vertical concrete riser box was used with an adjoining barrel pipe properly sized and out letting into sheet flow before entering the receiving stream. The drawdown time was kept below 72 hours in order to prevent long-term inundation of the wetland plant life.

Emergency Spillway: Each constructed wetland shall be provided with an emergency spillway designed to pass the runoff from the basin's entire drainage area without damage to the impoundment structure. The design storm for the emergency spillway shall be the 100-year storm event. Velocities must be controlled to prevent erosion along the spillway and into the North Buffalo Creek.

Wetland Plant Selection

A vigorous stand of emergent macrophytic vegetation is the most important feature affecting the consistent performance of wetland treatment systems. The type, spacing, method, and timing all play an important role in successfully constructing wetlands. According to previous CDM experience, the following species are particularly suited for use in storm water wetlands in the Piedmont Region of North Carolina.

Common Name	Scientific Name
Sweetflag	Acorus calamus
Water-plantain	Alisma subcordatum
Bushy Beardgrass	Andropogon glomeratus
Tussock Sedge	Carex stricta
Dwarf-bamboo, Three-way Sedge	Dulichium arundinaceum
Spikerush	Eleocharis quadrangulata (perennial Eleocharis spp.)
Yellow Iris, Yellow-flag	Iris pseudacorus
Blue-flag Iris, Southern Blue Flag	Iris virginica
Soft Rush	Juncus effusus
Rice Cutgrass	Leersia oryzoides
Switchgrass	Panicum virgatum
Arrow Arum	Peltandra virginica
Pickerelweed	Pontederia cordata
Arrowhead, Duck potato	Sagittaria latifolia
Lizard-tail	Saururus cernuus
Wool-grass	Scirpus cyperinus
Soft Stem Bulrush	Scirpus validus
Ironweed	Vernonia noveboracensis

Scirpus validus (soft stem bulrush) is particularly recommended for the channel areas due to its capability of high pollutant removal and its rapid colonization.

Plants were not individually specified for the wetland to allow flexibility in selection. Final plant selection will be partially based on availability and cost. Part of the wetland can be seeded as an alternative to planting container plants or plugs. Successful seedings of switchgrass or Envirens wet-mix as ground cover in the wetland have been used successfully in similar installations. Broadcasting or hydroseeding can aid in establishing these species in the ridge areas (above normal pool elevation) of the wetland.

Maintenance Requirements

A major disadvantage of constructed wetlands is the frequent and costly operation and maintenance requirements. Maintenance requirements can be broken down into two categories:

Routine Maintenance: This involves tasks that are performed on some regular basis during the year and are viewed as preventive in nature and are intended to enhance the aesthetic quality of the facility. Examples are periodic site inspections, grass mowing, debris and trash removal, clearing around the extended detention outlet structure to prevent clogging, bank stabilization, weed control, insect or mosquito control, fence repair, and record keeping.

Periodic harvesting of vegetation may allow for greater vegetative diversity, especially if a vegetative monoculture has been established. Harvesting will also remove nutrients and other pollutants from the wetland system while they are bound up in the vegetative monocultures. It is recommended that this occur each year before the onset of fall in order to prevent the decay of plant species and re-entrance of pollutants into the system previously removed through plant uptake.

Non-Routine Maintenance: This involves tasks that are performed once every specified number of years to correct problems which might reduce the detention facility's structural integrity or effectiveness. Major clean-outs are intended to maintain the required water quality storage capacity, and also to eliminate the build-up of accumulated sediments and debris which might significantly detract from the facility's appearance. Clean-out operations typically include material removal, stabilization of the wetland facility, and offsite hauling for sediment disposal.

The cost of sediment removal is more costly than that of a wet detention basin because of the large volume of plant life that must be replaced. The upper zone of the existing plant life should be kept when possible and replanted upon completion. Any plant life lost should be replaced by living vegetation and not seedlings.

Large storm events can lead to the massive destruction of plant life. Site inspections should occur after each storm event and replanting should be performed when necessary. Sediment removal should, on average, be performed once every 10 years.

Gravity Separator

Gravity separators were identified by CDM as possible BMP solutions for stormwater runoff from small watersheds with limited available area. The gravity separator is a stormwater separator that efficiently removes sediment and free oil from stormwater and stores these pollutants for removal. Gravity separators use an internal by-pass to prevent re-suspension of trapped pollutants during storm events.

Normal Operating Conditions

A fiberglass insert separates the upper (by-pass) and lower (separator) chambers. In areas where oil or chemical spills accumulate prior to cleaning, the fiberglass insert provides dual wall containment of floating oils and chemicals inside the treatment chamber. Under normal conditions, stormwater flows into the upper by-pass chamber and is diverted down a pipe into the separator/holding chamber, by a U-shaped weir. This downward flow is directed by a tee outlet around the circular walls of the chamber – located horizontally to the outlet pipe. Above and below this through-flow, oil and sediment (in particular) accumulate in relative quiescence. Inflowing sediments settle to the floor of the chamber, while petroleum products rise and become trapped underneath the fiberglass insert.

By-Pass Operating Conditions

During storm events, flows pass over a diverting weir and continue into a downstream storm sewer system. This by-pass activity creates pressure equalization across the by-pass chamber, preventing scouring and re-suspension of previously trapped pollutants.

Design Criteria

In order to acquire the optimal 85 percent TSS removal efficiency, one gravity separator unit is recommended for every four-watershed acres. Due to cost and construction purposes, applicable watersheds were limited to a 12 acre maximum, resulting in no more than three gravity separators per site. The stormwater runoff would be divided equally among the gravity separators, allowing for maximum pollutant removal efficiencies from each of the units.

Maintenance Requirements

Maintenance for a gravity separator can be performed from the surface, without entry into the unit. In order to maintain optimal removal efficiencies, it is recommended that cleanout occur once the sediment tank reaches 15% capacity, or immediately in the event of a spill.

Maintenance intervals vary depending on the watershed area and pollutant loading rates. CDM estimated cleanout rates for each of the candidate gravity separator sites based on estimated pollutant loading and removal rates. A decreased storage volume for gravity separators, versus other stormwater BMP's, result in more frequent cleanout rates. A typical cost of $1,500 per cleanout was used and included in operation and maintenance cost.

Conceptual Design Procedure

CDM completed a conceptual design that included identifying conflicts negating optimal design criteria for each of the four stormwater BMP alternatives. Each candidate site was evaluated under a prioritized design procedure that included four levels, or groups. Conceptual designs were prepared using both CDM and NCDENR design criteria to determine the differences in area requirements and opinions of probable construction cost related to the two unique design procedures. Group I included sites that met the optimum BMP sizing criteria for surface area, volume, length-to-width ratio, and relative invert with the stream. Group II included sites that did not meet optimum sizing criteria for length-to-width ratio and required baffling or other measures to meet travel time requirements to achieve the target pollutant removal efficiencies. Group III included sites that did not meet optimum sizing requirements and represent "best-fits" for the given site constraints. Finally, Group IV included sites that were removed from consideration due to their inability to support any of the four BMP alternatives considered in a cost-effective and useful manner. Table 4 provides a brief description of why ten of the original sites were eliminated from consideration.

Table 4: Site Elimination for Preliminary Screening

Preliminary Site ID	***Drainage Basin Area acres***	***Comments***
2	-	Site eliminated due to bedrock at ground surface
3	-	Site eliminated due to bedrock at ground surface
4	-	Site eliminated due to bedrock at ground surface
5	-	Site eliminated due to bedrock at ground surface
7	34.8	Site eliminated due to existing 32-inch water line running through potential site area
16	22.6	Site eliminated due to existing development (athletic fields)
17	27.2	Site eliminated due to existing development (athletic fields)
19	196.2	Site eliminated due to existing development (athletic fields)
26	104.4	Site eliminated due to presence of existing lake with no additional area to increase water quality volume (private development)
27	-	Site eliminated due to area limitations

Group I Criteria

Group I represents potential sites capable of meeting all design criteria assigned by CDM for the particular stormwater BMP evaluated. For example, it was assumed a wet detention basin must have a length to width ratio of 3 to 1 (L to W), a mean depth of 3 feet, basin side slopes of 3 to 1 (horizontal to vertical), and the ability to pass the 10-year, 24-hour storm through the principal spillway. Similar criteria apply to constructed wetlands and modified extended dry detention basins as discussed in the discussion of recommended BMP alternatives. Gravity separators can be effective stormwater BMPs when their associated watershed areas are 4 acres or less, but become cost-prohibitive with the addition of multiple units. Sites meeting all recommended design criteria are capable of being effective stormwater BMPs in removing sediment, nutrients and bacteria.

Group II Criteria

Group II represents sites with the potential to meet desired removal efficiencies without the ability to meet all specified design criteria of a Group I site. For example, various sites were limited by construction conflicts including: developed areas, water lines, sanitary sewer lines, and power line towers and poles, thus requiring atypical configurations. Conflicts such as these prevented the use of standard rectangular shaped basins having 3 to 1 length-to-width ratios, but did not prevent the site from providing adequate travel times for removing pollutants. CDM evaluated the option of adding baffles to maintain optimal travel times by increasing the hydraulic length within the basin and maintaining the required surface area and water quality volume, resulting in increased pollutant removal efficiencies. Sites meeting Group II criteria did not meet the specified Group I design criteria, but are capable of being effective stormwater BMPs in removing sediment, nutrients, and bacteria.

Group III Criteria

Group III represents sites having available water quality volume that is less than the required volume needed to obtain the desired pollutant removal efficiencies from the selected stormwater BMP. These sites are assumed to maintain their designed mean depth, but are incapable of meeting surface area requirements due to site limitations. Baffles can be used to increase the hydraulic length and associated residence time, allowing for some pollutant removal. While these sites do not meet desired pollutant removal efficiencies, some benefit can still be obtained with the use of a less than optimally-sized BMP by considering removal efficiencies based on the available water quality volume and BMP dimensions.

Group IV Criteria

Group IV represents stormwater BMPs that have been eliminated based on various conflicts identified through site visits and GIS data. Examples of conflicts relating to detention basins and constructed wetlands include extensive sanitary sewer lines, power line towers and poles, and insufficient area. Sites with adequate area and minimal construction conflicts were sometimes eliminated as potential modified extended dry detention basins because the elevation of the outlet structure from the detention basin would enter the receiving stream below the normal dry-day water surface elevation in the stream. This condition would cause tail water conditions to occur, preventing the basin from draining.

Table 5 provides a summary of the final and preliminary site identification numbers and their associated group number assuming CDM design criteria. In general, it was determined that the CDM design criteria were more stringent and required more surface area for BMP construction than the NCDENR criteria.

Design criteria recommended by the NCDENR Stormwater BMP Guidance Manual estimate a smaller surface area for the wet detention basin, modified extended dry detention basin, and stormwater wetland than that of CDM's design criteria. Therefore, only two of the final 16 sites were incapable of meeting optimal design criteria (group 1) assigned by the NCDENR. Sites S-5 and S-14 required baffling due to construction conflicts including sanitary sewer lines and/or power line tower interferences, but were capable of obtaining optimal water quality volumes (group 2).

Pollutant Loading Estimates

To evaluate the potential water quality benefits for each of the BMPs, CDM determined pollutant loadings produced by non-point sources within each of the drainage basins. Non-point source contributing watershed pollutant loads for nitrate and nitrite (NO23), total Kjeldahl nitrogen (TKN), total suspended solids (TSS), total phosphorus (TP), dissolve phosphorus (DP), total ammonia, total lead (Pb), total zinc (Zn), total cadmium (Cd), total chromium, fecal coliform bacteria, hydrocarbons or oil/grease, and organic carbon (BOD/COD) were estimated using the Watershed Management Model (WMM), a public-domain model developed by CDM for the Environmental Protection Agency (EPA).

WMM uses event mean concentrations (EMCs) of various pollutants, based on land use, to predict total annual pollutant loads as shown in Table 6. EMCs for Cd, Pb, Zn, ammonia, BOD, Nitrate, DP, TP, TSS, and TKN were provided by the City and obtained through stormwater sampling from various land uses performed by the City of Greensboro as part of their National Pollutant Discharge Elimination System (NPDES) Phase I permitting program. CDM assigned EMC values for total chromium, fecal coliform, and hydrocarbons based on past CDM experience and literature values from the Metropolitan Washington Council of Government's 1987 manual, "Controlling Urban Runoff". The fecal coliform EMCs were developed based on 121 samples taken from an urban watershed during a study conducted in Fulton County, Georgia by CDM. The results of the WMM analysis for each of the 22 potential BMP sites and associated EMC input values are provided in Table 7.

Table 5
City of Greensboro
Conceptual Design Evaluation of Stormwater Best Management Practices along North Buffalo Creek
Best Management Practice Summary
November 2001

Preliminary Site ID	Final Site ID	Drainage Basin Area (acres)	Watershed Imperviousness	Conceptual Design Group Number			
				Wet Detention Pond	Dry Detention Pond	Constructed Wetland	Gravity Separator
1	S-1	11	52%	4	4	4	1
6	S-2	21	41%	2	2	2	4
8	S-3	13	20%	1	1	1	1
9	S-4	3.3	45%	1	1	1	1
10	S-5	18	41%	3	3	3	4
11	S-6	13	68%	2	2	2	1
12	S-7	3.6	35%	4	4	4	1
13	S-8	9.7	35%	1	1	1	1
14/15	S-9	8.8	48%	1	1	1	1
18	S-10	8.3	51%	1	1	1	1
20	S-11	3.8	20%	1	1	1	1
21	S-12	8.0	20%	1	1	1	1
22	S-13	9.6	20%	2	2	2	1
23	S-14	47	68%	3	4	3	4
24	S-15	40	20%	2	2	2	4
25	S-16	10	20%	2	2	2	1

Notes:

Represents recommended CDM design criteria

Group Numbers Represent:

Group I. Assuming optimal pollutant efficiency and sizing criteria (i.e. 3L:1W length/width ratio and standard rectangular shape)

Group II. Assuming optimal pollutant efficiency by altering optimal sizing criteria (i.e. adding baffles while maintaining volume and surface area requirements)

Group III. Optimal pollutant efficiency and sizing criteria not met, reduced removal efficiency and volume available.

Group IV. BMP not optional due to site constraints

Table 6
City of Greensboro
Conceptual Design Evaluation of Stormwater Best Management Practices on North Buffalo Creek
Event Mean Concentrations
November 2001

Pollutant	*Land Use Type*							
	Commercial mg/L	*Office/Institutional mg/L*	*Business mg/L*	*Industrial mg/L*	*Single Family High Density mg/L*	*Multi-Family Low Density mg/L*	*Multi-Family High Density mg/L*	*Single Family Low Density mg/L*
Cadmium	0.0009	0.001	0.001	0.0005	0.0002	0.0002	0.0002	0.0003
Lead	0.01	0.02	0.02	0.02385	0.0093	0.0093	0.0093	0.0035
Zinc	0.29	0.14	0.14	0.725	0.06275	0.06275	0.06275	0.05
Ammonia Nitrogen	0.65	0.65	0.65	0.575	0.5	0.5	0.5	0.5
BOD	28.375	10.05	10.05	41.25	15.025	15.025	15.025	7.13
NO23	1.095	1.47	1.47	1.695	1.045	1.045	1.045	1.27
DP	0.258	0.11	0.11	0.272	0.333	0.333	0.333	0.24
TP	0.39	0.31	0.31	0.225	0.36	0.36	0.36	0.34
TSS	47.75	21.1	21.1	43.75	55.5	55.5	55.5	35.67
TKN	2.8	1.43	1.43	2.215	1.425	1.425	1.425	1.03
Chromium	0.005	0.005	0.005	0.006	0.0042	0.0042	0.0042	0.0042
Fecal Coliform	2,306	2,306	2,306	1,403	3,773	3,773	3,773	3,773
Hydrocarbons	10	10	10	10	10	10	10	10

Notes:
F-Coli units in counts/100mL
Data provided by the City of Greensboro based on sampling data obtained for NPDES Phase I compliance for North Buffalo Creek.
See Greensboro Stormwater Manual for further information.
EMC data for Chromium and Fecal Coliform based on previous studies performed by CDM
EMC data for Hydrocarbons referenced from Thomas R. Schueler's Controlling Urban Runoff Manual

Pollutant Removal Efficiencies

Table 8 summarizes the anticipated percent pollutant removal for each of the four types of structural BMPs identified for use by CDM. Removal efficiencies used by CDM in this analysis represent typical average removal efficiencies for properly designed, constructed and maintained structural BMPs as determined from past CDM experience, literature values, and NCDENR guidelines. Removal efficiencies for facilities designed by both CDM and NCDENR design criteria were assumed to be the same in recognition of the range of removal efficiencies reported by various agencies. In the event it is determined that the implementation of the structural BMP program is cost-effective, it is recommended that facilities designed by both design criteria be constructed and monitored to evaluate their pollutant removal efficiencies in an effort to determine which design criteria is most cost-effective and appropriate for this particular watershed.

As shown in Table 8, constructed wetlands are predicted to provide the greatest removal efficiencies for all 13 analyzed pollutants due to biological uptake expected in the wetland system. A comparison of modified extended dry detention basin and wet detention basin efficiencies reflects the additional biological and physical/chemical processes which enhance pollutant removal in wet detention basins. For TSS and metals such as lead, cadmium, zinc, and chromium, which are primarily associated with particulates, the efficiencies of modified extended dry detention basins and wet detention basins are similar. For more soluble pollutants such as nitrate and nitrite, dissolved phosphorus, total Kjeldahl nitrogen, etc. wet detention basins will typically have a greater removal efficiency. Gravity separators are capable of removing pollutants such as total suspended solids and hydrocarbons, but are likely not effective at removing various pollutants such as dissolved solids and nutrients, which require long detention times.

Opinions of Probable Construction Cost

CDM performed site-specific planning-level quantity estimates based on the recommended stormwater BMP for each site to estimate the total project capital cost. Total project capital costs were prepared for facilities designed by both CDM and NCDENR criteria. Quantities such as general excavation, sanitary sewer relocation, and tree removal were estimated from data collected through CDM's site visits and GIS data provided by the City. CDM assigned unit costs for each construction task based on past CDM experience and R.S. Means 2000 Building Construction Cost Data. Each construction task and its associated unit cost are provided on site-specific summary sheets in Appendix A. The quantity estimates provided in Appendix A are based on NCDENR design criteria. Opinions of probable total project cost for each site were estimated by including allowances for bonds, mobilization, and insurance; contingencies; and engineering, legal, and administrative costs. These opinions of probable total project cost are included in the final site summary tables in Appendix A. Table 9 summarizes the total project cost for design criteria recommended by both CDM and NCDENR.

Operation and Maintenance Cost Determination

Recommended operation and maintenance (O&M) tasks have been provided for each of the stormwater BMP alternatives designed by both CDM and NCDENR criteria. A cost analysis performed by CDM estimates probable annual O&M costs for both routine and non-routine maintenance activities for each of the BMPs over a 20-year planning period. O&M costs were reported in 2001 dollars using a present worth analysis and a discount rate of four percent.

O&M costs for the recommended technologies were determined from CDM experience, vendor recommendations, and information provided in the MWCOG manual. O&M costs for wet ponds and modified extended detention ponds were assumed to include an annual allowance of $500 per maintained acre (equal to three times the surface areas of the facility) and an annual non-routine allowance equal to 1.5 percent of the original opinion of probable construction cost. O&M costs for wetlands included an allowance of $400 per maintained acre and an annual non-routine allowance of 1.5 percent of the original opinion of probable construction cost, plus a replanting cost equal to $120,000 per acre. The replanting was assumed to be performed once every five years. Gravity separators were assumed to have an annual routine maintenance cost of $1500 per unit. No provision was included for non-routine maintenance over the assumed 20-year planning period. Results of the O&M cost analysis reflecting the NCDENR design criteria are included in Appendix A. Table 9 summarizes the 20-year operation and maintenance cost in 2001 dollars for both CDM and NCDENR design criteria.

Summary and Recommendations

CDM performed a preliminary evaluation on 27 stormwater best management practice (BMP) locations along North Buffalo Creek as part of a Clean Water Management Trust Fund (CWMTF) Application being prepared by the City. CDM began its evaluation by performing a windshield survey of the project reach from Church Street to Friendly Avenue and providing digital photographs of general locations in Appendix B. Figures 2-1 and 2-2 illustrate the location and direction of each of the photographs on two maps dividing the watershed. Through the use of notes and photographs obtained during the site visits and GIS data provided by the City, 10 of the initial 27 sites were eliminated from further consideration based on various conflicts including: bedrock at the ground surface, site area limitations, and utility conflicts.

CDM developed conceptual designs for 16 locations (Figure 6) along North Buffalo Creek, comparing and evaluating the feasibility of four separate stormwater BMPs (wet detention basin, modified extended dry detention basin, constructed wetlands, and gravity

Table 9
City of Greensboro
Conceptual Design Evaluation of Stormwater Best Management Practices on North Buffalo Creek
Summary Table
November 2001

Final Site ID	*Best Management Practice Type*	NCDENR DESIGN CRITERIA[1]				CDM DESIGN CRITERIA[2]			
		Capital Cost (dollars)	*Total Project Cost[3] (dollars)*	*20-yr O&M Cost[4] (dollars)*	*Total Program Cost[5] (dollars)*	*Capital Cost (dollars)*	*Total Project Cost[3] (dollars)*	*20-yr O&M Cost[4] (dollars)*	*Total Program Cost[5] (dollars)*
S-1	Gravity Separator	$99,000	$147,000	$18,693	$165,693	$99,000	$147,000	$18,690	$165,690
S-2	Dry Detention Basin	$130,000	$192,000	$40,004	$232,004	$184,000	$273,000	$58,840	$331,840
S-3	Dry Detention Basin	$57,000	$84,000	$16,637	$100,637	$85,000	$126,000	$26,870	$152,870
S-4	Dry Detention Basin	$49,000	$73,000	$13,272	$86,272	$54,000	$80,000	$15,190	$95,190
S-5	Dry Detention Basin	$140,000	$207,000	$41,125	$248,125	$176,000	$260,000	$141,190	$401,190
S-6	Constructed Wetland	$222,000	$328,000	$159,092	$487,092	$353,000	$523,000	$305,587	$828,587
S-7	Gravity Separator	$100,000	$148,000	$18,693	$166,693	$100,000	$148,000	$18,690	$166,690
S-8	Wet Detention Basin	$71,000	$105,000	$19,815	$124,815	$119,000	$177,000	$35,870	$212,870
S-9	Wet Detention Basin	$83,000	$124,000	$23,180	$147,180	$155,000	$229,000	$46,500	$275,500
S-10	Dry Detention Basin	$52,000	$76,000	$16,824	$92,824	$67,000	$98,000	$22,550	$120,550
S-11	Wet Detention Basin	$39,000	$58,000	$10,094	$68,094	$57,000	$84,000	$15,630	$99,630
S-12	Dry Detention Basin	$45,000	$67,000	$12,711	$79,711	$64,000	$95,000	$19,310	$114,310
S-13	Dry Detention Basin	$40,000	$59,000	$11,777	$70,777	$64,000	$95,000	$20,290	$115,290
S-14	Constructed Wetland	$442,000	$653,000	$484,257	$1,137,257	$633,000	$938,000	$954,200	$1,892,200
S-15	Dry Detention Basin	$87,000	$128,000	$30,283	$158,283	$162,000	$239,000	$60,290	$299,290
S-16	Dry Detention Basin	$33,000	$50,000	$10,468	$60,468	$51,000	$75,000	$18,780	$93,780
	Total =	$1,689,000	$2,499,000	$926,927	$3,425,927	$2,423,000	$3,587,000	$1,778,477	$5,365,477

Notes:

1.) BMP Design Criteria based on the North Carolina Department of Environment, Health and Natural Resources Stormwater Best Management Practices Guidance Manual 1995

2.) BMP Design Criteria based on past CDM experience

3.) Total Project Cost includes allowances for bonds, mobilization, insurance, contingency, engineering, etc.

4.) 20-yr operation and maintenance cost represented in present worth dollars

5.) Total Program Cost is the sum of the Total Project Cost and 20-yr O&M Cost separators). A site-specific evaluation based on constructability for each of the stormwater BMPs at the preliminary locations was performed based on design criteria recommended by both CDM and NCDENR.

Appendix A provides a summary table for each of the sites showing pollutant loads, associated removal efficiencies for the optimal stormwater BMP chosen, pollutant removal, design criteria, total project cost and operation and maintenance cost based on design criteria recommended by the NCDENR's Stormwater Management Guidance Manual. Table 9 provides a summary of total project costs (opinions of probable construction costs and operation and maintenance costs) for each of the sites, as well as a total program cost for all of the recommended sites. The recommended suite of stormwater BMPs includes two gravity separators, three wet detention ponds, two constructed wetlands, and eight modified extended dry detention basins. The total estimated project cost (in 2001 dollars) to design and construct these facilities using NCDENR design criteria is $2,499,000. The projected 20-year total program cost (including allowances for construction, design, and operation and maintenance costs) is $3,426,000. Using CDM design criteria, the total estimated project cost is $3,587,000 and the projected 20-year total program cost is $5,365,000.

It can be seen in Table 10 that the implementation of all 16 sites is predicted to reduce the pollutant discharge into North Buffalo Creek by 33,648 pounds for total suspended solids (an 84% reduction over current conditions) and 711 pounds of total nitrogen (a 24% reduction) over 226 acres of protected watershed. The entire North Buffalo Creek watershed (to the stream segment included in this study) is approximately 16 square miles. Additional pollutant loads and reductions are provided in the attached tables.

Table 10
City of Greensboro
Conceptual Design Evaluation of Stormwater Best Management Practices on North Buffalo Creek
Pollutant Removal Estimates
November 2001

Final Site ID	BMP Alternative	Drainage Area (acres)	CDM Surface Area (acres)[1]	NCDENR Surface Area (acres)[2]	POLLUTANT Cd lbs/yr	Pb lbs/yr	Zn lbs/yr	Ammonia lbs/yr	BOD lbs/yr	NO23 lbs/yr	DP lbs/yr	TP lbs/yr	TSS lbs/yr	TKN lbs/yr	Chromium lbs/yr	HydroC lbs/yr	Fecal C x 10^{12} counts/yr
S-1	Gravity Separator	11	-	-	0.01	0.33	1.8	3.2	117	6.9	0.0	4.0	2204	8.3	0.09	537	0.00
S-2	Dry Detention Basin	21	0.71	0.48	0.05	0.75	5.0	6.0	233	14	0.0	8.0	2312	13	0.21	401	0.26
S-3	Dry Detention Basin	13	0.35	0.16	0.01	0.11	0.9	2.1	75	5.3	0.0	3.5	1267	4.3	0.08	167	0.14
S-4	Dry Detention Basin	3.3	0.12	0.08	0.00	0.12	0.5	0.84	63	1.8	0.0	1.5	791	2.4	0.03	67	0.06
S-5	Dry Detention Basin	18	0.60	0.41	0.02	0.59	2.3	4.2	319	8.9	0.0	7.8	4004	12	0.16	339	0.29
S-6	Constructed Wetland	13	0.73	0.35	0.07	1.50	6.3	19	396	55	7.8	18	1987	50	0.28	784	0.65
S-7	Gravity Separator	3.6	-	-	0.00	0.07	0.4	0.8	36	1.7	0.0	1.2	751	2.3	0.02	143	0.00
S-8	Wet Detention Basin	9.7	0.28	0.15	0.01	0.30	1.4	6.4	192	14	9.1	7.5	2011	18	0.08	256	0.00
S-9	Wet Detention Basin	8.8	0.35	0.17	0.01	0.58	8.6	7.5	392	19	9.1	7.0	1969	26	0.10	280	0.00
S-10	Dry Detention Basin	8.3	0.36	0.24	0.01	0.32	1.4	2.3	174	4.9	0.0	4.3	2185	6.6	0.09	186	0.16
S-11	Wet Detention Basin	3.8	0.11	0.04	0.00	0.03	0.3	2.2	32	7.2	2.0	2.6	410	4.6	0.04	115	0.14
S-12	Dry Detention Basin	8.0	0.22	0.10	0.01	0.09	1	13	191	34	6	9	955	28	0.11	268	0.46
S-13	Dry Detention Basin	9.6	0.27	0.12	0.01	0.08	0.9	1.6	57	4.1	0.0	2.8	970	3.3	0.06	128	0.11
S-14	Constructed Wetland	47	2.65	1.25	0.23	3.75	24	70	1528	193	30	66	7753	187	1.14	2845	2.05
S-15	Dry Detention Basin	40	1.10	0.51	0.03	0.35	3.2	6.6	235	17	0.0	11	4002	14	0.25	528	0.45
S-16	Dry Detention Basin	10	0.28	0.13	0.01	0.09	0.9	1.7	61	4.3	0.0	3.0	1035	3.5	0.06	137	0.12
		226															
				Total Pollutant Removed =	0.46	9.0	57	148	3,910	356	58	149	33,648	355	2.8	7,180	4.9
				Total Load =	0.63	12	130	614	13,614	1,396	238	366	39,877	1,560	5.0	10,958	15
				Percent Reduction =	72%	72%	44%	24%	29%	26%	24%	41%	84%	23%	56%	66%	32%

Note:
1.) CDM Surface Area represents the recommeded surface area to obtain 85 percent TSS removal based on past CDM experience
2.) NCDENR Surface Area represents the North Carolina Department of Environment, Health, and Natural Resources _Stormwater Best Management Practices Guidance Manual's_ *recommended surface area to obtain 85 percent TSS removal*