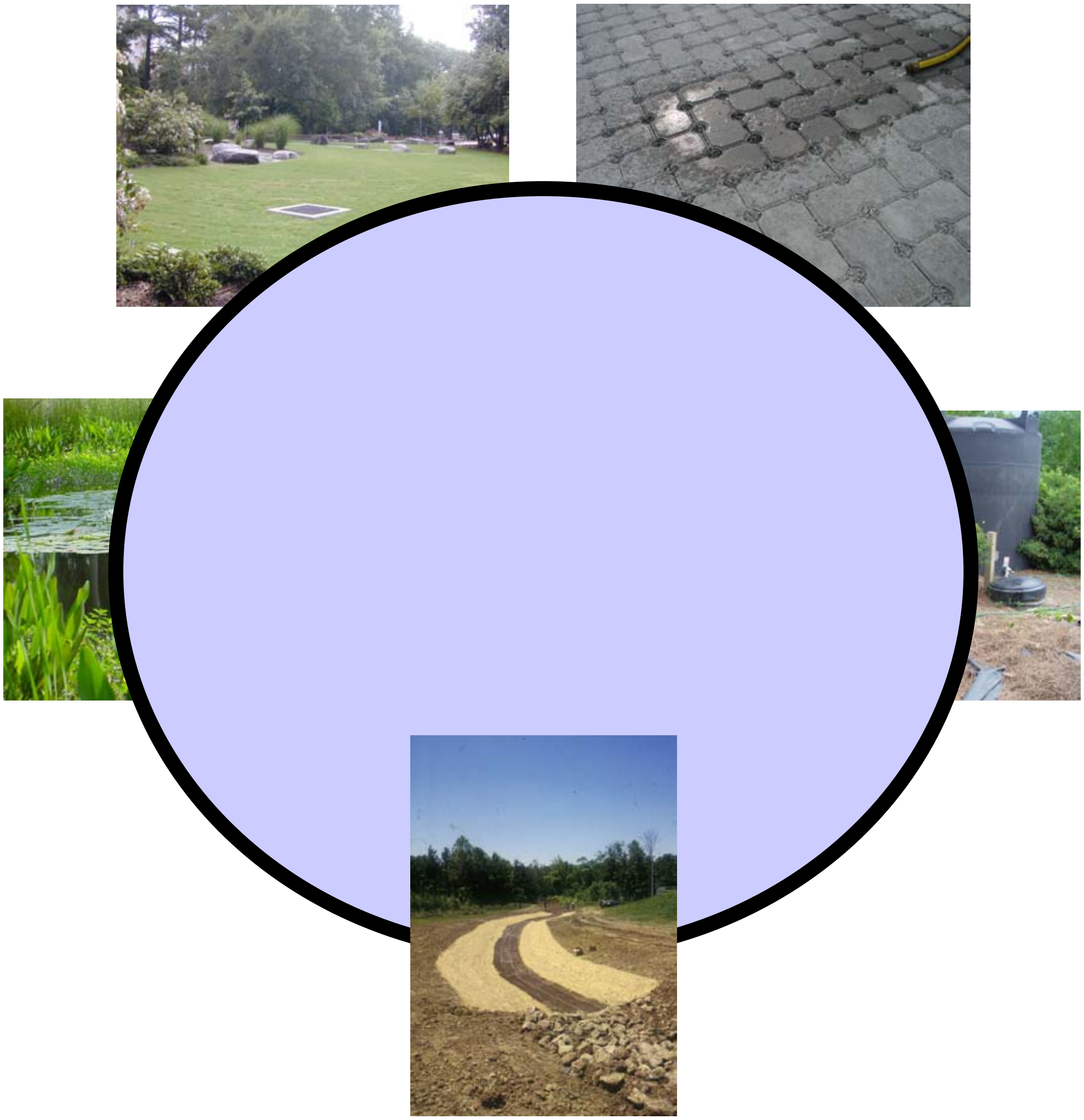
Stormwater BMP Costs

Division of Soil & Water Conservation
Community Conservation Assistance Program



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Outline:

1.0 Introduction

This document provides the North Carolina Division of Soil and Water Conservation (DSWC) with an estimate of the cost of installing urban “backyard” BMPs. This information will be used as part of DSWC’s Community Conservation Assistance Program. Some of the urban BMPs that will be used for the program are as follows: bioretention areas (rain gardens), cisterns (water harvesting), greenroofs, impervious pavement removal, permeable pavements, swales, and pocket wetlands.

It should be noted that the cost estimates given in this document are intended to be used for small, residential and commercial areas (watersheds less than 2 acres). It is possible, due to economies of scale, that these systems will be more expensive than larger applications on a cost per area basis. Caution should be used when applying these numbers to applications other than those specified.

The cost estimates presented herein were developed from over 70 installations of “small BMPs” conducted by the North Carolina Cooperative Extension Service (NCCES) across North Carolina. It has been observed that BMP installation is least expensive in the coastal plain and Sandhills, more expensive in the Piedmont, and further still in the mountains. Costs are presented for each of these four regions. Certain unit costs were compared to those supplied by R.S. Means (2006), the construction industry standard for cost estimates. All but 1 BMP are applicable in every region of North Carolina. Due to the common presence of low permeability soils, permeable pavement is not included as a potential BMP in the piedmont or mountains.

2.0 Bioretention (Rain Gardens)

2.1 BMP Description

Bioretention is essentially a vegetated sand filter, and is designed so that it quickly dries after rain events. A properly functioning bioretention area will not have ponded water for more than 12 hours. A typical bioretention area will include a set of underdrains overlain by a specialized sandy fill media that ranges from 2 to 4 feet deep. In sandy soil landscapes, the fill media and underdrains are often omitted. Vegetation, grown in the media, is surrounded by a mulch layer. At the surface, bioretention looks like a depressed garden that fills with runoff when it rains, giving its other name: rain garden. Bioretention is most typically used in medians or along the perimeter of parking lots. However, smaller bioretention areas, or rain gardens, can be used for small impervious watersheds such as residential rooftops and driveways. Figure 1 is an example of a bioretention area installed in a small watershed. The costs for bioretention areas discussed herein are for the small watershed variety. These rain gardens may or may not need underdrains or special fill material, which dramatically impacts their cost.

Figure 1. Small bioretention area (rain garden) treating rooftop runoff from a firehouse in Holden Beach, NC.

2.2 BMP Selection Guidelines

- Bioretention areas should be sited in areas where the water table is at least two feet below the surface of the bioretention area. This will ensure proper draining and maintain the hydrologic integrity of the system.
- When the water table is at or just below the ground surface, other BMPs are more suitable.

- In citing these BMPs, choose an area of the landscape to which stormwater naturally drains to or through.
- It is suggested that DSWC construct 5 to 10 of these systems at a time to make the projects more cost effective.
- Bioretention areas function more effectively in soils with a high sand content.
- More information on bioretention (rain garden) construction is available on the NCCES Backyard Rain Garden website: (http://www.bae.ncsu.edu/topic/raingarden/)

2.3 Cost Analysis

The average cost breakdown shown in Table 1 is for applications in the piedmont. The excavation depth is assumed to be one foot. The drainage way from the impervious area to the BMP is assumed to be already in place. A berm is formed along the downslope edge of the bioretention cell (Figure 2) in order to pond the water, thus, the soil that is excavated can likely stay on site.

Figure 2. Backyard Rain Garden with downslope berm, in Raleigh, NC.

An underdrain may be used in both piedmont and mountain locations, as will a sandy soil amendment[1]. In coastal applications, underdrains and soil amendments are not needed, thus, the cost will be reduced. Table 2 shows the expected cost of installation for various sizes of bioretention in the various regions of North Carolina.

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[1] A Simple test may be performed to determine if the soils at a given site have suitable infiltration capabilities. This test is illustrated in the NCCES Backyard Rain Garden website.

Table 1: Average Cost Breakdown for Bioretention Areas in the Piedmont

Item	**Unit**	**Cost ($)**
Excavation	sf	0.25
Soil Amendment - Sand	sf	0.50
Mulch	sf	0.75
Plants	sf	1.00
Plant Installation	sf	0.50
Underdrain	per	50
Underdrain Installation	per	200
Total[1] =	sf	**Varies*

1: Total is dependent on BMP size

Table 2: Cost for Various Sizes of Bioretention in Regions of North Carolina (in Dollars)

	Practice Surface Area[2]		
Location	**25 to 50 sf'**	**50 to 100 sf'**	**100 to 200 sf'**
Coastal Plain	150	300	525
Sandhills	150	300	525
Piedmont	400	550	775
Mountains	520	715	1000

2: Contributing watershed is at least 20 times larger than the Bioretention surface area

3.0 Cisterns/ Water Harvesting System

3.1 BMP Description

Cisterns are one of the oldest rainwater treatment practices. They are used to capture runoff, primarily from roof tops. Sometimes runoff from pavement is also temporarily held in cisterns. A cistern is a tank that stores runoff. These tanks range in size from thousands of gallons to as small as 50 gallons. The small version of a cistern is known as a rain barrel. Cisterns can be employed above or below ground, with the former type of cistern typically being cheaper to purchase and install. The cistern is part of a larger system, consisting of gutter diversions, outlet lines and often a pump. This system is referred to as a rainwater harvesting system. Rainwater captured in cisterns is used, or harvested, for uses such as irrigation, toilet flushing, vehicle washing, and clothes washing. The demand for cistern water and the size of the cistern relative to the contributing watershed (rooftop) tends to govern how much runoff reduction the water harvesting system provides. While the required size of a cistern varies, a general rule of thumb for a cistern that effectively captures and treats runoff is to provide 1 gallon of cistern for each 1 square foot of contributing rooftop. Because rain barrels tend to be very undersized, they often do not provide as much runoff reduction as larger varieties of cisterns. A 550-gallon cistern, treating several hundred square feet of roof area, is shown in Figure 3.

Figure 3. A 550-gallon cistern is installed at the Craven County Agricultural Center near New Bern, NC.

3.2 BMP Selection Guidelines

- Cisterns are appropriate stormwater management practices for applications where the captured rooftop runoff can be used.

- Frequently, water from these systems is used for irrigating nearby lawns and landscaped areas.
- If the stormwater is not emptied in between storm events, the function of the cistern as a stormwater BMP is severely reduced.

3.3 Cost Analysis

It is assumed that the BMP location is equipped with gutters which are able to transport stormwater to the cistern. A large portion of the cistern costs are material items. Cistern costs are likely to be consistent throughout the regions of North Carolina. Thus, the variation in costs from region to region will primarily be due to the cost of cistern installation. Table 3 shows the breakdown of costs for cisterns installed in the Sandhills / coastal plain regions. North Carolina State University has installed the majority of its cisterns in these regions. Costs for the distribution and usage of the captured rooftop runoff are not included (e.g. pump purchase and installation). Table 4 shows the expected cost variation for cistern installation in the various regions of North Carolina.

Table 3: Average Cost Breakdown for Cisterns in the Sandhills or Coastal Plain

Item	**Unit**	**Cost ($)**
Site Preparation[1]	sf	1.39
Hose and Accessories	per	15
Modify Gutters	per	30
Rain Barrel		
Rain Barrel	per	150
Rain Barrel Installation	per	100.00
Various Cisterns		
Cistern (550 gallon)	per	564
Cistern (1000 gallon)	per	874
Cistern (2500 gallon)	per	1349
Cistern Installation	per	568.20
Concrete Pad for Cistern[2]	sf	3.58
Attachments	per	90.00
Average (Rain Barrel) =	**$317.24**	
Average (550 gallon) =	**$1446.12**	
Average (1000 gallon) =	**$1756.12**	
Average (2500 gallon) =	**$2411.28**	

1: Assumed footprint for rain barrel is 4'X4'
Assumed footprint for 550 gallon cistern is 6'X6'
Assumed footprint for 1000 gallon cistern is 6'X6'
Assumed footprint for 2500 gallon cistern is 8.5'X8.5'

2. Concrete pad may not be necessary, can potentially use gravel
Assume pad footprint is same area as site preparation footprint

Table 4: Cost for Various Sizes of Cisterns in Regions of North Carolina
(Values in dollars per unit)

Location	Rain Barrel	550 gallon	1000 gallon	2500 gallon
Coastal Plain	300	1410	1720	2340
Sandhills	300	1410	1720	2340
Piedmont	350	1640	1950	2620
Mountains	380	1800	2110	2820

4.0 Greenroofs

4.1 BMP Description

Greenroofs are vegetated rooftops; although, they may not always be green. Other names for green roofs are roof gardens, landscape roofs, and eco-roofs. Greenroofs are designed to temporarily capture rainfall, allowing some water to be used by the plants while the remainder of the captured water is released to the atmosphere by evapotranspiration. A properly functioning green roof will not stay wet after the completion of a storm. There are two types of green roofs, intensive and extensive. The major differences between the two are the depth of media and the types of vegetation that these media support. Intensive green roofs can be comprised of several feet of soil media and allow trees and shrubs to grow. Extensive green roofs have media depths ranging from 3 to 6 inches and support drought tolerant vegetation. The type of green roof discussed herein is extensive. A green roof cross section from the bottom up is comprised of a moisture barrier, a water storage layer, a separating filter fabric, a media layer, and then vegetation. The final product, when viewed from the surface is a vegetated carpet (Figure 4). One main concern regarding green roofs is that they will add weight to an existing roof. Not all rooftops were designed to be strong enough to support green roof loads in addition to snow loads, wind loads, etc. A structural engineer should be consulted if green roofs are retrofit onto existing roof tops.

Figure 4. An extensive green roof on top of an office at 701 N. Person Street in Raleigh, NC.

4.2 BMP Selection Guidelines

- ❖ The most important requirement for greenroof installation is a roof top that can handle the additional weight of the greenroof. A structural engineer should review the roof prior to BMP installation to check for structural stability.
- ❖ These systems should typically only be used on roofs with a small pitch (less than 8%) to increase stormwater storage within the soil media.

4.3 Cost Analysis

This cost analysis does *not* include any modifications to the roof structure that may be necessary. Additionally, many of the materials required for the greenroof are only available in certain quantities, thus, the costs may be increased due to the requirement to purchase more material than is needed. Likewise, the cost estimate for soil installation given in Table 5 is for a four inch layer of soil installed by a powered blower system. There may be a minimum quantity of soil that is mandatory in order to obtain these services. There are other options for soil installation, but they are labor intensive. The values in Table 5 are for Piedmont applications, the average price given in Table 5 is manipulated to determine estimates for other regions in Table 6.

Table 5: Average Cost Breakdown for Greenroofs in the Piedmont

Item	**Unit**	**Cost ($)**
Impermeable Layer	sf	1.00
Drainage Layer	sf	1.50
Soil – Fines (4” depth)	sf	0.60
Soil Installation	sf	1.25
Plants	sf	6.00
Plant Installation	sf	3.00
Total =	**sf**	**13.35**

Table 6: Cost for Various Sizes of Bioretention in Regions of North Carolina
(Values in dollars per square foot)

Location	**Minimum**	**Average**	**Maximum**
Coastal Plain	9.60	10.70	12.00
Sandhills	9.60	10.70	12.00
Piedmont	12.00	13.40	15.00
Mountains	15.60	17.40	19.50

An additional consideration when installing greenroof is the edging. Edging includes any runoff collection materials and barriers between the greenroof and the “normal” roof surface. In part, edging is required because the soil media is built up at least 4 inches over the roof surface and must be contained. The shape of the greenroof impacts the edging cost so a standard cost per area value is not practical. As a result, the following edging costs are provided (Table 7).

Table 7: Edging Costs for Greenroofs in Regions of North Carolina
(Values in dollars per linear foot)

Location	Edging Cost
Coastal Plain	2.00
Sandhills	2.00
Piedmont	2.50
Mountains	3.00

5.0 Impervious Removal

5.1 BMP Description

Impermeable surfaces such as driveways, walkways, and patios contribute runoff to adjoining swales or ditches, often causing erosion. Sometimes these permeable surfaces are not needed or are no longer used. Un-used concrete and asphalt impermeable surfaces can be removed and replaced by permeable surfaces such as gardens or turf. Additionally, they may be replaced by permeable pavement, which is discussed in a following section.

5.2 BMP Selection Guidelines

- ❖ In removing impervious area from a property, proper assurances must be made that this area will not be repaved within a DSWC-specified amount of time. It is recommended that the intended use of the previously impervious area should be explicitly documented.
- ❖ This is a reasonable practice for concrete or asphalt driveways and parking lots, these cost estimates are not intended for removal of impervious surfaces other than these two.

5.3 Cost Analysis

The breakdown of costs in Table 8 is for the removal of a concrete or asphalt driveway or parking lot. Included in this analysis is removal of any underlying gravel and replacement with soil. It is anticipated in this cost analysis that the area will be seeded and returned to a vegetated state. Table 9 shows the expected costs of removing impervious area in various regions of the state. Cost items such as fill soil purchase and hauling/disposal of waste debris may have associated minimum quantities, thus, costs for these items for removal of small impermeable surfaces may be higher due to the need to purchase more material or services than needed.

Table 8: Average Cost Breakdown for Impervious Removal in the Piedmont

Item	**Unit**	**Cost ($)**
Surface Removal	sf	1.50
Removal of Underlying Gravel	sf	0.25
Hauling and Disposal	sf	0.40
Purchase Load of Soil	sf	1.00
Fill Void with Soil	sf	0.25
Regrading	sf	0.30
Grass Seed Application	sf	0.30
Total =	**sf**	**4.00**

Table 9: Cost for Impervious Removal in Regions of North Carolina
(Values in dollars per square foot)

Location	Minimum	Average	Maximum
Coastal Plain	2.4	3.2	4
Sandhills	2.4	3.2	4
Piedmont	3	4	5
Mountains	3.9	5.2	6.5

6.0 Permeable Pavement

6.1 BMP Description

Traditionally paved surfaces are impermeable, forcing nearly all rainfall to become runoff. These pavements were designed to be strong, able to withstand heavy traffic. Permeable pavement allows water to pass through it, reducing runoff. These pavements are best used in low traffic situations similar to those found in patios, parking pads, and driveways, making them a good “backyard” BMP. Permeable pavements may be constructed of permeable asphalt, pervious concrete, permeable interlocking concrete pavers, and grassy pavers. They are typically underlain by a gravel support layer ranging in thickness from 4 to 12 inches. Permeable pavements work best when sited on sandy soils, such as those found on barrier islands, the coastal plain, and the Sandhills. Care must be taken to make sure permeable pavements are not placed near active construction zones, as they are prone to clog. An example of a patio constructed of permeable pavement is shown in Figure 5.

Figure 5. Permeable pavement patio outside a café in Swansboro, NC. Sandy soils, a light traffic loading, and a relatively deep water table make this an ideal location for permeable pavement.

6.2 BMP Selection Guidelines

- Permeable Pavements should only be used in applications where the underlying soils have high permeability (sandy). Thus, the use of these pavements should be restricted to the Sandhills and coastal regions of North Carolina.
- Permeable pavements should be sited away from construction or other activities that can produce sediment laden runoff. Soil clogs permeable pavement, making it ineffective.

- Geotechnical analysis of the underlying soils should be performed to determine the correct depth of the underlying gravel layers; however, the underlying gravel depth should be at least six inches.
- Permeable pavement applications work best when flat. Pavement slopes should not exceed 0.5%.

6.3 Cost Analysis

These cost estimates apply to both pervious concrete and permeable interlocking concrete pavers. The values represented in Table 10 are based on a gravel layer depth of six inches. Permeable pavement should only be used in the coastal plain and Sandhills, thus, Table 11 does not include values for the piedmont or the mountains. For small applications (<200 sf), pervious concrete may prove more expensive as a concrete truck that is not full will have to be sent to the project site. There are certain fixed costs associated with the operation of a concrete truck that will be incurred regardless of project size.

Table 10: Average Cost Breakdown for Permeable Pavement in Coastal Plain and Sandhill Applications

Item	Unit	Cost ($)
Excavation	sf	0.25
Hauling	sf	0.25
Fine Grading	sf	0.36
Gravel Underlayer	sf	0.75
Pavement Installation	sf	8.00
Total =	**sf**	**9.61**

Table 11: Cost for Permeable Pavement Installation in North Carolina (Values in dollars per square foot)

Location	Minimum	Average	Maximum
Coastal Plain	8.00	9.60	12.00
Sandhills	8.00	9.60	12.00

7.0 Swales

7.1 BMP Description

Swales are grassed conveyance channels for stormwater runoff. They are typically shallow (no more than 1 foot deep) and are designed to be mowed (side slopes no steeper than 3:1, with 4:1 preferred). Swales are perhaps the simplest backyard BMP to construct. They are v-shaped features formed into the landscape by small- to medium-sized earth moving equipment. Once the earthwork is complete, the swales are vegetated by seed or by sod. Occasionally, if the swale is treating several acres of watershed or is sited on erosive soil, a turf reinforcement mat (TRM) is laid directly over the seeded soil and anchored to the earth. This mat provides additional stability to the plants that grow and the soil underneath. With time the mat will "disappear" to most observers as grass will grow through it, eventually visually obscuring it (Figure 6). Costs for swales with and without TRM are presented herein. When complete, swales are a pleasant landscape feature. Swales can be designed to treat runoff from watersheds ranging in size from small rooftop to 5 - 10 acre watersheds. Costs presented herein are for watersheds ranging from 2 to 4 acres.

Figure 6. This swale, located at Hillandale Elementary School in Durham, NC, is supported by TRM. Prior to construction this was an eroded rip-rap ditch.

7.2 BMP Selection Guidelines

- Swales should be sited in areas where water flows during storm events.
- Slopes up to 20% are ok for most "simple" swales. Swales on steeper slopes will need artificial support/reinforcement.

7.3 Cost Analysis

The cost analysis is based on a swale that is roughly six to eight feet wide with a depth of 1 ft (sideslopes between 3:1 and 4:1). This sized swale would be appropriate in most applications; however, the exact dimensions of the swale should be calculated via proper design methods. If the slope of the swale is such that high velocities (>4.0 ft/s) will be experienced, turf reinforcement matting will be needed.

Table 12: Average Cost Breakdown for Swales in the Piedmont

Item	Unit	Cost ($)
Excavation	sf	0.09
Hauling	sf	0.21
Grading	sf	0.36
Grass	sf	0.29
Total =	**sf**	**0.95**

Table 13: Cost for Swales in the Piedmont
(Values in dollars per square foot)

Location	Minimum	Average	Maximum
Coast	0.60	0.76	1.20
Sandhills	0.60	0.76	1.20
Piedmont	0.75	0.95	1.50
Mountains	0.98	1.24	1.95

Note: Add 0.50 per square foot if turf reinforcement matting is required

8.0 Pocket Wetlands

8.1 BMP Description

A pocket wetland, also referred to as a “backyard wetland” or a “wetland garden,” is built in an area that is perennially moist. The wetland is designed such that it will usually be wet, even several days after a rain event. A properly functioning pocket wetland will be much wetter than a bioretention area and is usually constructed as an alternative to bioretention. A typical backyard wetland will be a shallow excavated bowl ranging from 6 to 12 inches deep. Inside this bowl a variety of vegetation is planted. It is essential that many different types of plants are grown in the wetland to avoid a monoculture and potential mosquito hazard. Wetland vegetation tends to grow densely. Stormwater wetlands are most frequently used to treat large watersheds such as shopping centers and residential communities; however, in locations with high water tables, pocket wetlands can capture runoff from small watersheds such as an individual property. Figures 7a and 7b show a wet spot in a yard (an ideal location for a pocket wetland) and types of vegetation found in a pocket wetland, respectively.

Figure 7a. A perennially wet spot in a yard is a good location for a pocket wetland. Figure 7b. This pocket wetland, in Tarboro, NC, features vegetation such as lily pads, pickerelweed, and joe pye weed.

8.2 BMP Selection Guidelines

- ❖ Pocket wetlands should be placed in areas where the water table is at or near the ground surface (within one foot). This will ensure proper hydrology within the wetland and provide water for wetland plants during drought conditions.
- ❖ If these conditions are met, a liner will not be needed. Wetlands should be sited in areas where stormwater naturally drains, this eliminates the need for expensive piping systems.
- ❖ Pocket wetlands are sited in low-lying areas of the property.

8.3 Cost Analysis

These cost estimates are based on an excavation depth of 9 inches, which is a reasonable amount of ponding for wetlands used in "backyard" applications. It is anticipated that the excavated soil will need to be hauled offsite. The average cost breakdown shown in Table 14 is for applications in the piedmont. Table 15 shows the expected cost of installation for various sizes of wetlands in North Carolina.

Table 14: Average Cost Breakdown for Wetlands in the Piedmont

Item	**Unit**	**Cost ($)**
Excavation	sf	0.25
Hauling	sf	0.25
Grading	sf	0.36
Plants	sf	2
Plant Installation	sf	0.3
Outlet Structure[1]	per	50
Total[2] =	per	**varies**

1: Made of pressure treated lumber
2: Total is dependent on BMP size

Table 15: Cost for Various Sizes of Wetlands in Regions of North Carolina (in Dollars)

	Practice Surface Area		
Location	**25 to 50 sf**	**50 to 100 sf**	**100 to 200 sf**
Coastal Plain	170	290	550
Sandhills	170	290	550
Piedmont	210	370	680
Mountains	270	480	890