13. BMP Toolbox for Public Airports

The Chapter provides general guidance for Best Management Practices (BMPs) for stormwater drainage control and water quality treatment on or near airports. This chapter, based on the Airport BMP Tool Box, is a joint effort by the North Carolina Airports Association (NCAA), the North Carolina Department of Transportation Division of Aviation (NCDOA), North Carolina State University (NCSU), W.K. Dickson and Company, and the North Carolina Division of Water Quality (NCDWQ).

Public airports throughout North Carolina continue to develop to meet the needs of the expanding population of the state. Public airport expansions include the addition of newly constructed hangars, terminal building expansions, runway extensions, and construction of new taxiways and apron or ramp areas. Each airport has a long-term master plan, known as an Airport Layout Plan (ALP). The ALP includes future expansion plans, and shows the impervious surfaces that will be constructed.

Wildlife, including birds and mammals, is a threat to human safety during takeoff and landing, and stormwater BMPs must not increase that threat. Stormwater BMPs should be selected and designed, constructed and maintained to minimize habitat and associated risks. This chapter recommends stormwater practices for projects on or near public airports.

13.1 Wildlife Hazards at Airports

Airports are different from other industrial or commercial sites, and must manage stormwater in a way that will not compromise aircraft safety. Many traditional stormwater BMPs promote standing water, and attract wildlife that may be hazardous to aircraft. Therefore, some BMPs must be altered for use in the airport environment, or eliminated all together.

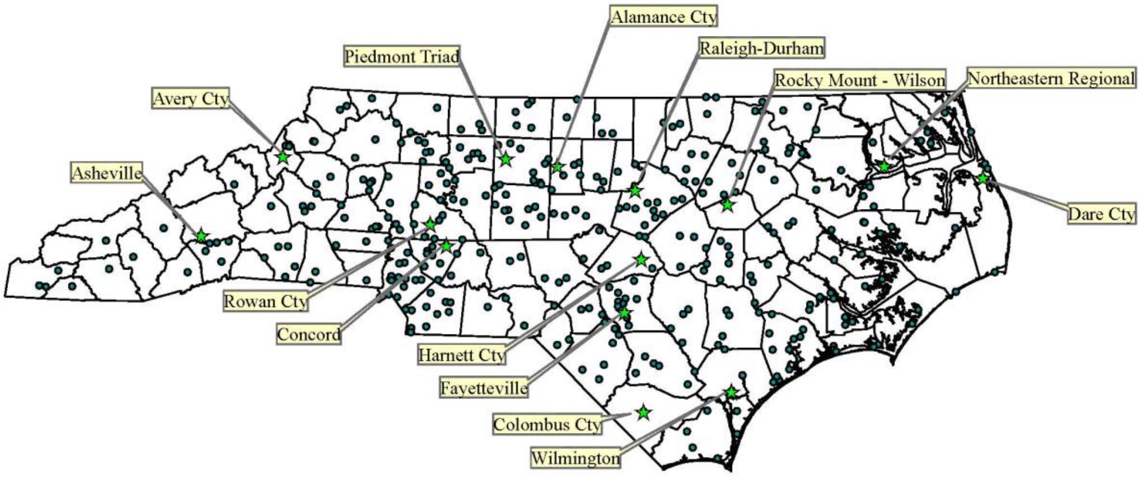
Flight safety must be the first priority at airports. Wildlife, including rodents, larger mammals, and birds, pose a threat to the safety of flight; while wildlife strikes are not common when compared to the number of daily flights in the U.S. (around 40,000 flights/day), it only takes one major incident to cause loss of human life. Between 1990 and 2005, over 66,000 incidents occurred between wildlife and civil aircraft. In 1990, about 1,700 wildlife strikes occurred, while in 2005 over 7,000 strikes were reported (FAA, 2010). The majority of wildlife strikes between 1990 and 2000 involved birds, with 2,395 bird strikes and 443 mammalian strikes causing damage to aircraft (FAA, 2010). Of non-rodent mammals that were struck, 94 percent were deer and five percent were carnivores. This is most likely due to the burgeoning U.S. deer population, which has increased from 350,000 in 1900 to approximately 20 million in 2010 (Curtis and Sullivan, 2001). Of birds that were struck, 32 percent were waterfowl, 30 percent were gulls, 17 percent were raptors, and other species comprised the remaining 21 percent. The most hazardous bird species are those with the greatest body mass, including vultures, geese, pelicans, cranes, and eagles. The Canada goose exists nearly everywhere in North Carolina, as many populations have become permanent residents. This species prefers close-cropped grasses and open bodies of water, which are commonly found at or near some airports.

Natural landscape portions of the airport environment provide food, shelter, and a travel corridor for wildlife. Indirect hazards, such as mice, rabbits, and groundhogs, forage in the grassy areas around the airport. These species attract direct hazards, such as raptors and coyotes, to the airport, which can cause significant damage to aircraft. When stormwater practices that impound water for extended periods are installed, they provide a refuge for birdlife. The presence of multiple wetlands or wet detention ponds at an airport provides travel corridors for birds that often cross runways. Since 73 percent of wildlife strikes occur at altitudes of 500 ft above ground level or less, reducing or eliminating wet detention ponds and wetlands on an airport would substantially reduce the odds of a bird strike (ALPA, 2009). Another important factor in bird strikes is the decreased engine redundancy on commercial aircraft in the U.S. fleet; 75 percent of aircraft had 3-4 engines in 1969, while only 10 percent of commercial airplanes have more than 2 engines today (Wenning et al., 2004). This means that losing one engine has a larger impact on the ability of the airplane to stay airborne. Thus, stormwater features selected for use at airports must not be attractants to wildlife. All engineering and maintenance decisions at airports, including those related to stormwater management, must consider wildlife hazards in order to provide an environment conducive to safe flight.

13.2 Description of Public Airports

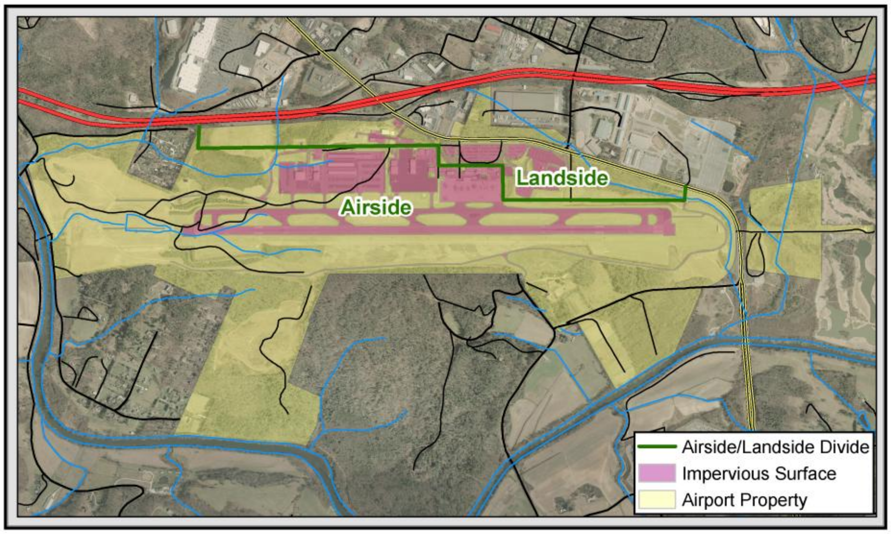
The Airport BMPs within this chapter refers to airside and landside locations at airports. Airside refers to all areas where aircraft are operated or serviced. This area includes runways, taxiways, hangars, ramps, and aprons. Landside refers to all other areas.

To further understand current practices used to drain and treat runoff at airports, site visits were made to airports throughout North Carolina. Generally, runways and taxiways drain through filter strips and into swales. Runoff from the hangars, apron or ramp, and landside generally drained via surface flow to drainage swales, or directly to the piped storm drain network.



Airports visited and/or studied.

The figure below illustrates a substantial amount of permeable and semi-permeable areas on a public airport property. Previous work by WK Dickson calculated impervious cover on airport properties to typically range between eight and 24 percent, which is consistent with low density residential development. Many impervious areas on public airports, namely runways and taxiways, are disconnected (not directly connected hydrologically). After less than 100 feet of flow on a paved surface, runoff enters a grassed buffer with widths often measuring greater than 60 feet. However, other locations on airport grounds, such as the hangar area and affiliated landside parking lots may often have direct discharge (directly connected impervious area) to either ditches or a stormwater conveyance system.



Typical impervious cover at public airports

Maintenance around the airport property should also be performed to reduce wildlife intrusion; this includes planting grasses that do not attract mammals, initiating and maintaining a 10 to 12 foot tall perimeter fence, installing exclusion devices for birds on hangars and towers, and removing all wooded areas within the perimeter fencing.

13.3 Airport Pollutants of Concern

Pollutants of concern at airports include the typical urban pollutants (nitrogen, phosphorus, sediment, hydrocarbons, and heavy metals) and airport-specific pollutants (de-icing fluid, urea, and aviation fuels such as avgas and jet fuel).

Nitrogen and phosphorus from impervious surfaces are generally derived from atmospheric deposition or from wind-blown dust that settles on the surfaces. Both nitrogen and phosphorus are also found in fertilizers; airports should avoid using fertilizers except during vegetation establishment. One source of sediment in stormwater is erosion of poorly-vegetated areas; vegetation establishment in the infield and other vegetated areas is critical to reducing sediment generation. Relatively low concentrations of TN, TP, and TSS were observed in stormwater runoff from public airports (FDOT, 2008). Runoff was characterized from runways, taxiways, aprons near T-hangars, and aprons near terminals, with nitrogen and phosphorus concentrations not exceeding 0.55 mg/L, 0.081 mg/L, respectively. In comparison, nitrogen and phosphorus from eight parking lots in North Carolina had average TN and TP concentrations of 1.63 mg/L and 0.21 mg/L, respectively (Passeport and Hunt, 2009).

Hydrocarbons in stormwater runoff are usually derived from oil or gasoline leaks. Higher concentrations of hydrocarbons may be observed near aviation fuel pumps and near hangars; specifically, lead is still included in some forms of Avgas, and has been noted (0.015 mg/L Pb) in runoff from the apron in front of T-hangars at airports in Florida (FDOT, 2008). Other sources of heavy metals in urban stormwater include tire and brake wear. Therefore, elevated levels of heavy metal may be concentrated at the end of the runways where touchdown occurs.

The vast majority of North Carolina's 63 public general aviation (GA) airports do not use or store any aircraft or runway de-icing fluids, and instead opt to delay operations until temperatures warm sufficiently. Five of these public airports are referred to as "Part 139 Certified" (14 CFR Part 139). These are larger GA (non-commercial service) airports like Concord and Smith Reynolds. Some airports store urea onsite for runway de-icing (nutrient loading). And some aircraft owners /tenants at these airports do individual light spraying of wings.

North Carolina's nine Air Carrier (AC) airports include Raleigh-Durham, Charlotte, Greensboro, Pitt-Greenville, Fayetteville, Wilmington, Asheville, Onslow County (Albert J. Ellis), and Craven County (Coastal Carolina). Of these nine airports, three are already capturing and treating aircraft de-icing fluids (typically composed of ethylene glycol or propylene glycol)—Raleigh Durham, Charlotte, and Greensboro. Of the remaining six, five are in eastern counties which use very small amounts of de-icing chemicals on aircraft, some years none at all. For instance Wilmington airport air carriers used 2,055 gallons of aircraft de-icing fluid during the 2008-2009 cold weather season. Because of its western NC location, the Asheville Regional Airport typically uses aircraft de-icing spray in the winter months and store urea onsite for runway de-icing (nutrient loading).

13.4 Non-Structural Stormwater Management at Airports

While structural stormwater BMPs, such as grassed swales, infiltration trenches, and bioretention areas, will function to improve post-construction hydrology and water quality, there are many non-structural practices that could also improve stormwater management. Non-structural stormwater management practices may include: diffuse flow, open areas that provide infiltration, disconnection of impervious surfaces, reducing the imperviousness of the airport, clustering the impervious areas, providing proper storage of chemicals, posting signage for hazardous materials, disseminating proper mowing guidance, educating staff about stormwater, and using defined snow removal and de-icing locations. Additionally, many non-structural practices can be implemented during day-to-day operations on the airport. These include source control practices and maintenance practices. Leaks should be fixed promptly, and care should be taken to place snow and de-icing operations in a single location. Chemicals used to melt snow should be stored inside to avoid contact with stormwater. Also, proper mowing guidance, such as mowing when the ground is dry, and varying the mowing pattern (to avoid creating ruts), should be discussed with maintenance staff. These practices will ensure that vegetative filter strips and swales function properly. Non-structural stormwater practices help to reduce the impact of the airport on the environment.

Examples of non-structural BMPs - Urea used to melt snow is stored inside a maintenance facility (left). Rutting due to mowing during wet conditions should be avoided (right).

13.5 Why Not Wet Detention Ponds and Stormwater Wetlands?

The foremost concern at airports is safety. As such, it is imperative that designers choose practices that do not attract waterfowl or other animals that are a danger to aircraft. The primary habitat features of ponded open water are vegetative cover, shelter, and access to water. In general, vegetation that provides food and/or cover for wildlife species identified as hazardous to aircraft should be avoided at airports. Also, vegetation with berries, nuts, desirable forage, attractive flowers, edible tubers or roots, or large, abundant or high-nutrient seeds is a potential wildlife attractant and should be avoided. Structural features that provide shelter for wildlife species identified as hazardous to aircraft should also be avoided at airports.

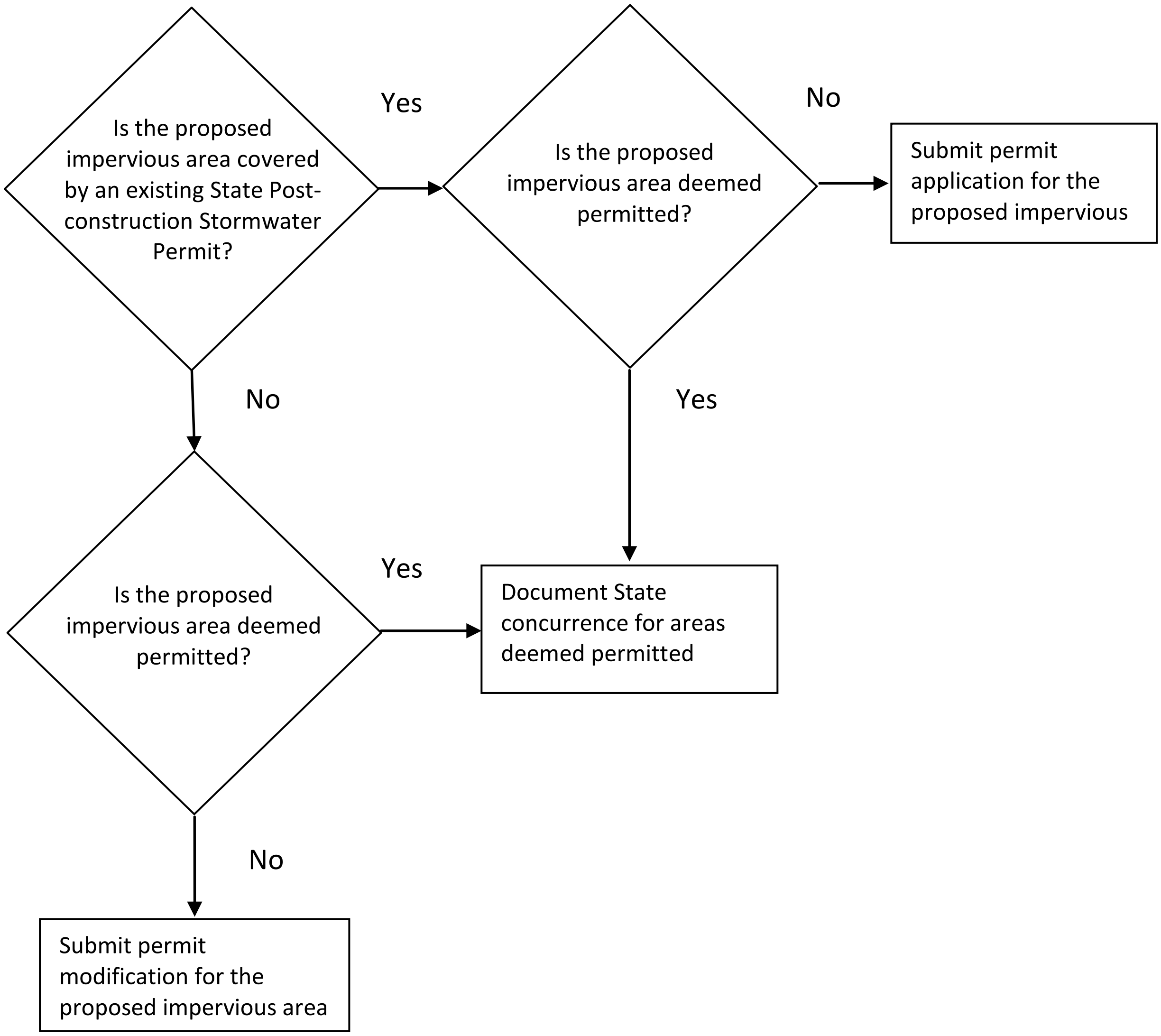
13.6 Stormwater Control Measures that Promotes Standing Water

Pursuant to G.S. 143-214.7, the Department shall not require the use of stormwater retention ponds, stormwater detention ponds, or any other stormwater control measure that promotes standing water in order to comply with this section at public airports that support commercial air carriers or general aviation services. Further, development projects located within five statute miles from the farthest edge of an airport air operations area, as that term is defined in 14 C.F.R. § 153.3 (July 2011 Edition), shall not be required to use stormwater retention ponds, stormwater detention ponds, or any other stormwater control measure that promotes standing water in order to comply with this section. Existing stormwater retention ponds, stormwater detention ponds, or any other stormwater control measure that promotes standing water at public airports or that are within five statute miles from the farthest edge of an airport operations area may be replaced with alternative measures.

Applicants are asked to work with airports to utilize BMPs that do not promote standing water in or around airports. Any replacement of existing stormwater control measure that promotes standing water shall be considered a minor modification to the State stormwater permit.

13.7 Deemed Permitted

Pursuant to SB 229, the Department shall deem runways, taxiways, and any other areas that provide for overland stormwater flow that promote infiltration and treatment of stormwater into grassed buffers, shoulders, and grass swales permitted pursuant to the State post-construction stormwater requirements.



Overland Flow

Overland flow of stormwater runoff from runways, taxiways, and other impervious surface such as rooftops, hangers, and parking lot allows a significant portion of the run-off to be filtered and infiltrate; thus reducing both pollution and peak flows.

Soil Evaluation

No soil evaluation is required for overland flow on relatively permeable soils such as HSGs Type A and Type B). For less permeable soils such as Type HSGs Type C and Type D, where soils have been compacted and/or where fill has been provided, a qualified professional must evaluate the soils to determine if an infiltration device is needed or the soils need to be amended to compensate for poor infiltration capability.

Seasonal High Water Table (SHWT)

There is no separation from the SHWT for overland flow. However, the elevation of the vegetated area must be at or above the elevation of the SHWT.

Soil Amendments

Where the soils are not suitable for infiltration the airport can amend the soils. However, in a *Runway Safety Area (RSA)*, where soils must be compacted to ensure safety (FAA Specification P-152, FAA 2009), soil amendments may only be utilized in the uppermost four inches of the soil.

Installation of soil amendments in a vegetative filter strip

Soil amendments may be utilized in conjunction with either vegetative filter strips, or grassed swales. Soil amendments typically increase infiltration rates by introducing coarse-grained, washed sand amendments into the in-situ soil. Soil amendments will improve infiltration by increasing soil pore space near the surface. Soil amendments are typically installed by tilling sand-size particles into the existing soil up to a depth of 12 to 18 inches. A backhoe (or similar shovel-based machine) may be utilized. An under drain can be included in the design to allow the soil to drain between storm events. Soil amendments can be sized to provide volume control, depending on the ratio of impervious area to the area that receives the stormwater runoff. If soil amendments are incorporated, they should be considered as a supplement to, or performance enhancer for, filter strips and swales.

13.8 Low Density Projects (T15A: 02H .1003 (d)(1))

Projects permitted as low density projects must be designed to meet and maintain the applicable low density requirements specified in T15A: 02H .1005 through .1007. Under the current Phase II and Coastal Rules (Session Law 2008-211 and Session Law 2006-246), a project with an overall density at or below the low density thresholds, but containing areas with a density greater than the overall project density, may be considered low density as long as the project meets or exceeds the following post-construction model practices for low density projects mandated in Session Law 2006-246 and 2008-211:

- Use vegetated conveyances to the maximum extent practicable to transport stormwater runoff. Pipe conveyance is minimized.
- Locates the higher density areas are located away from surface waters and drainage ways to the maximum extent practicable, i.e., disconnects surfaces, promotes infiltration, sheet flow, and overland flow, and lengthening flow paths to the maximum extent practicable.
- Stormwater runoff from built upon areas that is directed to flow through any wetlands shall flow into and through these wetlands at a non-erosive velocity

Development designed to meet the low density requirements must demonstrate that no areas within the project site are of such high density that stormwater runoff threatens water quality.

13.9 High Density Projects (T15A: 02H .1003 (d)(2))

Projects permitted as high density projects must be designed to meet the applicable high density requirements specified in 02H .1005 through 02H .1008. Paragraph (c)(5) does allow for other designs if these designs are shown by the applicant, to the satisfaction of the Director, to provide equivalent protection.

Also, under 02H .1008 (h) stormwater management systems consisting of other control options or series of control options may be approved by the Director on a case-by-case basis where the applicant can demonstrate that the Alternative Design Criteria provides equal or better stormwater control, equal or better protection of waters of the state, and result in no increased potential for nuisance conditions.

Compensatory Treatment

Where overland flow cannot be established or low density requirements cannot be met, i.e., density requirements and/or vegetated conveyances, stormwater management should be designed to treat locations with the greatest pollutant generation to achieve the greatest benefit-cost ratio. For instance, more water quality benefits could result from treating an existing impervious area of equal or greater area elsewhere on the airport property to compensate for stormwater runoff from a new runway or apron extension.

Operation and Maintenance Plan

A sustainable stormwater program must have a viable mechanism to ensure practices are installed and maintained over time. Under T15A; 02H .1008 (i), prior to approval of the project by the Division an operation and maintenance plan or manual shall be provided by the applicant for stormwater systems, indicating the operation and maintenance actions that shall be taken, specific quantitative criteria used for determining when those actions shall be taken, and who is responsible for those actions. The plan must clearly indicate the steps that shall be taken and who shall be responsible for restoring a stormwater system to design specifications if a failure occurs and must include an acknowledgment by the responsible party. Development must be maintained consistent with the requirements in these plans and the original plans and any modifications to these plans must be approved by the Division.

For alternative designs and projects that are to be approved on a case-by-case basis maintenance plan or manual for that *system* must indicate:

- What inspections and maintenance must be taken,
- When inspections and maintenance must be taken,
- Who is responsible for inspections and maintenance, and
- Who is to be trained, when they are to be trained, and how they are to be trained.

North Carolina Occupational Licensing Requirements

Under T15A; 02H .1008 (j), high density stormwater systems must be designed by an individual who meets any North Carolina occupational licensing requirements for the type of system proposed. Upon completion of construction, the designer must certify that the system was inspected during construction, was constructed in substantial conformity with plans and specifications approved by the Division and complies with the requirements specified in T15A; 02H .1005 through 02H .1008.

13.10 Stormwater Master Plan Approach

Airport projects in North Carolina have typically been planned, designed, and permitted individually. Many successful projects have been constructed in this manner. However, as the environmental permitting rules and requirements have evolved, this piecemeal process increases limitations, and typically reduces acceptable design alternatives from a regulatory perspective.

Alternatively, a Stormwater Master Plan approach takes into account the stormwater challenges and needs across the entire airport property, and provides a comprehensive plan to address all the issues concurrently. This approach provides the owner, designer, and regulator with a larger data set of variables over a longer period of time, which can be used to streamline the stormwater drainage design and make the permitting process less cumbersome. For example, instead of obtaining separate permits for several individual stormwater projects, using the master plan approach, several stormwater projects could be designed to work in concert as one larger project, thereby increasing the likelihood that the projects will be effective, and limiting the number of permits required. Planning for and consideration of issues related to both the quantity and quality of stormwater runoff in conjunction with the traditional Airport Layout Plan (ALP) will facilitate not only stormwater drainage design alternatives that provide equal or better storm water control but also construction schedules, regulatory reviews and permit approval.

13.11 Engineered Best Management Practices (BMPs)

This section discusses the aspects of various BMP related to their use at airports. Specific design, construction, and maintenance is presented in other Chapters herein.

The BMP toolbox for public airports is presented in table on Pages 22 and 23. The toolbox includes benefits, costs, maintenance, and potential drawbacks associated with each BMP type. The functionality of these stormwater BMPs will depend to a large extent on the soil type and the location of the seasonal high water table (SHWT). Provided the SHWT is not restrictive, infiltration BMPs, such as bioretention, infiltration trenches, permeable pavement, and filter strips will function best for water quality and hydrologic improvements in a sandy-type soil. Clayey soils lead to reduced infiltration rates, resulting in larger required infiltration areas and may require amended soils.

Sheet flow, Level Spreaders, and Filter Strips and Vegetative Filter Strip[1]

A vegetative filter strip is a shallow-sloped area of land that sustains sheet flow across its width. Flow is typically conveyed through a filter strip using a level spreader; however, the edge of a runway is often nearly level, and typically provides sheet flow to the adjacent filter strip. Vegetative filter strips are located adjacent to runways in the form of grassed shoulders which are part of the runway safety area (RSA); they have a shallow slope for added safety during landing. These filter strips should be densely vegetated with grass to allow for filtration of particulate pollutants as well as infiltration. The FAA airport design guidance states that the RSA on either side of the runway must be graded and have no humps or depressions (FAA, 1989). This chapter recommends the use of filter strips adjacent to the runway at all airports in North Carolina. The RSA width varies from 120 to 500 feet, depending upon other runway dimensions (FAA, 1989). The RSA width greatly exceeds minimum requirements for filter strips in North Carolina (30 and 50 ft). Maximum slope for grassed filter strips varies from 5 percent to 8 percent depending on the applicable North Carolina Regulation. The maximum cross slope of runway and taxiway safety areas is 5 percent, which is within the limits of the this BMP manual (FAA, 1989).

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[1] Reference Chapter 8

Mowing height is important for habitat reduction; grass height should be kept seven to 14 inches tall to reduce habitat for birds and mammals. Recommended grasses by region are provided in the NCDENR stormwater BMP manual and include blue grass and tall fescue in the mountains, tall fescue and common bermuda in the Piedmont, and centipede and common bermuda in the coastal plain. Grass seed containing millet should be avoided, as it is a wildlife attractant.

Vegetative filter strips at airports in North Carolina.

<u>Grassed Swale</u>[2]

Grass swales can be effective tools for removing pollutants. A grassed swale is a shallow, open-channel drainage way that is designed both to filter pollutants and convey water. Swales often run parallel to the runway, but are beyond the limits of the RSA as required in FAA AC 5300-13 (1989). During construction, consistent grade should be provided along the length of the swale to avoid low spots that could pond water near the runway or taxiway. Maintenance involves mowing, removal of trash and debris and re-vegetating eroded banks and channels. Swales could also be designed to store some water using check dams or other measures; however, check dams should be avoided on airports unless an underlying soil with a high infiltration rate is present. Mowing height is important for habitat reduction; grass height should be kept seven to 14 inches tall to reduce habitat for birds and mammals.

Grassed swales at a Brunswick County development (left) and the Harnett County Airport (right).

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[2] Reference Chapter 14

Lengthening Flow Paths

A grassed swale typically does not provide any active volume capture or peak flow attenuation. A grassed swale does provide some passive volume control capabilities by providing pervious surface and therefore reducing the total runoff volume to be controlled. Lengthening the grass swale will lengthen the flow path, reducing flow velocities, increasing infiltration, increasing a site's time of concentration, and reducing runoff peaks.

The effectiveness of a swale in both reducing the flow rates and volume of runoff, and removing pollutants, is a function of the size and composition of the drainage area, the slope and cross section of the channel, the permeability of the soil, the density and type of vegetation in the swales, and the length of the swale. Broad swales on flat slopes with dense vegetation are the most effective. Removal efficiencies are highest for sediment-bound pollutants.

Conveyance swales may include roadside swales and primary outlet swales. Roadside swales are usually on both sides of a road. They are typically interconnected with cross pipes, and empty into a primary outlet swale(s) carrying runoff off site. These swales often receive sheet flow from parking lots and other impervious surfaces and therefore can carry heavy hydraulic and pollutant loads. Primary outlet swales usually collect drainage from roadside swales and sheet flow from parking lots and other impervious surfaces. Because of the heavy hydraulic load, they are usually deeper, wider, and longer than roadside swales. These swales usually serve the same function as low-density curb outlet swales.

Check Dams

A check dam is constructed of earth, stone, or timber 3 to 6 inches high to retain runoff from routine events. A weep hole may be added to enable the area behind an earthen or timber dam to drain slowly. However, the weep hole may be subject to clogging.

Elevated Drop Inlets

A drop inlet can be used when a combined system of swales and storm sewers is being used. The swales would serve as the collector system, and the inlet into the main storm sewer system would be elevated slightly to retain runoff from routine events. The height of elevation would depend on the soil, the slope of the swale, and the tolerance for ponding. Wetland vegetation may develop in the ponded areas if the underlying soils are poorly drained.

Elevated Culverts

Elevated culverts are used for the same purpose as check dams and elevated drop inlets, to retain runoff from routine events. As with elevated drop inlets, wetland vegetation may develop in the ponded areas if the underlying soils are poorly drained.

Depression Storage

Small depressions along the bottom of the swale will trap and store stormwater for later infiltration into the soils. These depressions will also likely accumulate sediment at a quicker pace than other parts of the swale, and will also probably develop wetland vegetation if not properly maintained.

Under Drains

Underdrains can enhance the performance of swales by providing additional filtration through soil similar to the process that takes place in bioretention facilities. These "bioretention" swales have a layer of engineered soil underlain by a gravel layer surrounding a perforated pipe. This configuration also reduces ponding time.

Bioretention[3]

Bioretention cells may be utilized to treat runoff from any impervious surface type on an airport. Bioretention cells are depressed areas in the landscape with specialized fill media designed to infiltrate and treat stormwater runoff. They must be utilized outside of the RSA, as grades must be positive and sloped away from any AOA without any depressions. Ponded water should drain into the soil within 12 hours following a rainfall event when the bioretention basins are designed, installed, and maintained per Chapter 12 of this manual. Maximum ponded depth would typically not exceed 12 inches. A geotechnical engineer should be consulted if attempting to use bioretention to drain the runway to ensure that the runway will remain structurally sound. When using bioretention on the airside, vegetation should *always* be grass. By eliminating mulch, the chance for foreign object damage (FOD), such as mulch being sucked into an engine, is reduced. Other benefits of grassed cells include: views free of obstruction for the pilots, and reduced wildlife habitat. On the landside, a shrub-mulch system is permissible, though trees should be avoided.

Typical tree-shrub-mulch (left) and grassed (right) bioretention cells in North Carolina.

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[3] Reference Chapter 12

Rain gardens are similar to bioretention cells, without the engineered soils. Rain gardens are typically incorporated into landscape.

Bioretention Swales

A bioretention swale (or biofiltration trench) is a bioretention system that is located within the base of the swale. Bioretention swales provide a conveyance function, remove fine and coarse sediments, remove hydrocarbons and other soluble or fine particulate contaminants from biological uptake, provide low levels of extended detention, provide flow retardation for frequent rainfall events. Bioretention systems are well suited to a wide range of soil conditions. Vegetation that grows in the filter media enhances its function by preventing erosion of the filter medium, continuously breaking up the soil through plant growth to prevent clogging of the system.

Bioslopes

Bioslopes, also known as ecology embankments, are modified filter strips that contain a special soil called an ecology mix to improve water quality, reduce the runoff volume, and reduce the tendency for erosion to occur. They can be incorporated into standard fill slopes and resemble a basic grass filter strip when completed. Like bioretention cells, bioslopes promote infiltration, retain runoff volume, and use a variety of physical, chemical, and biological processes to reduce runoff pollutant loadings. They are designed as flow-through devices.

For storms with an intensity greater than the design rainfall intensity, some runoff will not be captured and infiltrated, but instead will flow over the surface of the bioslope. Stormwater not captured by the bioslope can be detained through auxiliary surface or subsurface storage at the base of the bioslope. A ponding area or gravel storage bed (similar to an infiltration trench) can be constructed at the base of the bioslope to store excess runoff. It is important to emphasize that storm intensity, not rainfall depth, will determine the volume of “excess” stormwater that will need to be stored at the base of the bioslope. For the bioslope itself and the auxiliary storage area, the permeability of the subsoil will determine whether captured runoff will exfiltrate into the subsoil or flow into an underdrain connected to a conventional conveyance system.

Additional subsurface storage can be provided within the bioslope itself by enlarging the gravel underdrain trench. This can be used to store water that would otherwise flow directly into the underdrain pipe.

Bioslopes are appropriate for use on medians and side slopes of access roads or sites. Bioslopes are intended for use on stable slopes only. Bioslopes cannot be used where the side slope exceeds 4:1, or on unstable slopes. To avoid erosion, runoff must flow onto the bioslope via sheet flow only. Any type of flow besides sheet flow can lead to erosion and cause flows to bypass the ecology mix bed.

Bioslopes consist of a gravel level spreader adjacent to the pavement to evenly distribute flows and trap sediments, an optional vegetated filter strip to provide additional pretreatment if space allows, an ecology mix bed which provides the majority of water quality improvement, and an optional gravel underdrain trench with an underdrain pipe. The existing soils will dictate whether an underdrain is needed. The need for an underdrain will influence the rest of the design.

If subsoils have a low permeability but no underdrain is provided, the bioslope will drain poorly and bypass flow will be more frequent. Underdrains may be needed on Hydrologic Soil Group (HSG) C and D soils. Soil amendments may be applied in the filter strip to increase its permeability.

Do not construct bioslopes in a zone of seasonal groundwater inundation.

High Flow Rate Bioretention Systems

High Flow Rate Bioretention Systems incorporates a specialized media that treats stormwater at with flow rates of about 30 inches per hour.

High flow rate media devices reduce the space required and can treat and convey larger volumes of water. Conventional slow flow rate media filtration devices often require large area to treat runoff volumes. Compared to slow flow rate bioretention systems, High Flow Rate Bioretention Systems use a relatively small footprint and are capable of achieving similar pollutant removal efficiencies.

Further, conventional slow flow rate media filtration devices are prone to clogging and long draw down times. Clogging of conventional slow flow rate media, like wet swales, encourages standing water and wet conditions that not only encourage bacteria survival or growth but create wildlife habitat.

The best application for high flow rate media is in the design of bioslopes and or bioswales. A number of modifications are possible, but in general the best option is filling and regrading the swales to prevent standing water and filtering within the swales, creating a bioretention swales and bioslope. The typical bio-swales design is a good starting point for a standard swale design that would not only discourage bacteria growth but would also filter and remove bacteria from the runoff. Further, a high flow rate media bioswale can be strategically located in small sections to reduce cost and optimize treatment.

The subgrade should be approximately 16 to 20 inches below the proposed surface grade depending on the need for an intermediate layer. If the subsoil is unstable geotextile fabrics may be used as a barrier between the subsoil and the gravel blanket. Depending on the infiltration rates of the existing subgrade, it may be necessary to provide drainage trenches and/or under drains. Trenches approximately 6 inches wide and 8 inches deep can be cut into a compacted subgrade so that under drains, if required, maintain a consistent slope to the outlet of at least 0.5%. It may be deeper, as necessary, to ensure minimal slope requirements. A layer of gravel should be placed in the trench to a minimum depth of 1 inch. All underdrains should be placed on the gravel bed. The trenches should then be backfilled with additional gravel. Cover the entire subgrade with a layer of clean, washed, crushed stone or pea gravel to a minimum thickness of four inches. If the properly sized gravel cannot be found, an intermediate layer must be used. The proper sized gravel without an intermediate layer should have no particles greater than 12 mm, with not more than 10% less than 2 mm and not more than 5% less than 1 mm. If an intermediate layer is required, at least 90% of the particles should be between 1 mm and 4 mm. The intermediate layer should be spread to a uniform thickness of two to four inches over the gravel drainage blanket. The root zone should be spread to a uniform thickness of 12 inches over the intermediate layer. Soil used in the root zone mix shall have a minimum sand content of 60%, and a clay content of 5% to 20%.

On April 19, 2012, the North Carolina Rules Review Commission approved revisions of the criteria and standards applicable to injection wells, which will become effective on May 1, 2012. Rule 15A NCAC 02C .0227 was adopted to address a regulatory conflict between State stormwater BMPs that encourage onsite stormwater infiltration and the injection well rules adopted in 1997, which prohibit stormwater injection. As established in the federal injection well regulations, stormwater infiltration systems that use infiltration galleries, perforated piping, or other subsurface distribution systems are considered to be a Class 5 injection well. These systems are regulated as an injection well due to the potential to adversely affect groundwater quality, especially from industrial and commercial facilities. A separate permit from the NC UIC Program is not required. However, in order for the NC UIC Program to comply with federal requirements, owners or operators of certain stormwater infiltration systems are to submit basic information needed to fulfill reporting obligations with the EPA. Additional guidance and information is available online at http://portal.ncdenr.org/web/wq/aps/gwpro/injection_stormwater.

Infiltration Devices (Infiltration Basin and InfiltrationTrench)[4]

Infiltration devices enhance percolation to groundwater by directing surface runoff to locations where it can come into contact with pervious underlying soils and then detaining that runoff until it can soak into the underlying soil. Infiltration devices reduce runoff volume, recharge groundwater, and have high removal efficiencies for sediment and for pollutants adsorbed onto sediment particles. Infiltration devices transfer more stormwater to the soil than any other type of BMP, and they more closely mimic the natural hydrology of the area by taking a portion of concentrated flow and allowing it to infiltrate into the soil.

Infiltration trenches are structural BMPs that fill with stormwater and allow it to exfiltrate into the surrounding soil. These systems could be sited parallel to runways or taxiways, outside the limits of RSA and TSA, but require either pretreatment or a minimum of 30 feet of vegetative filter upslope. NCDENR (2007) guidance recommends avoiding the use of infiltration trenches in locations with an expected presence of oils and greases.

Sand Filter[5]

Runoff percolates through a sand filter, allowing for filtration of pollutants. These systems can be utilized to treat hangar or landside areas. Sand filters are often used in small, highly impervious watersheds, and are effective in removing sediment and nutrients. However, they are a comparatively expensive practice, and do not mitigate the peak flow from a storm event. The bottom of the sand filter must have a separation of two feet from the seasonally high water table. At airports located in the mountains of North Carolina, these systems could be located near snow disposal areas to treat snowmelt runoff. Reference Chapter 11

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[4] Reference Chapter 16

[5] Reference Chapter 11

Water Harvesting and Cisterns[6]

Water harvesting or the use of cisterns to store and reuse stormwater, are emerging technologies that can be used for any structure with a rooftop, such as a hangar or a terminal building. Downspouts can be routed to either above- or below-ground cisterns, capturing stormwater before it enters the storm drain network. However, water harvesting requires a reliable water use (or demand) for it to provide a benefit. Suggested water uses on airports include landscape irrigation near a terminal building, washing out hangars, flushing of commodes, and washing airplanes and cars. For some of these uses, advanced filtration will be required. The more efficient water harvesting systems will have automatic uses, such as commode flushing or landscape irrigation with a backup water supply from the potable water system. Land application of the harvested water should be avoided near runways and taxiways; saturated soils force earthworms and grubs to the surface, which attracts birds.

Water harvesting systems utilizing cisterns in North Carolina.

Extended Dry Detention[7]

An extended dry detention BMP is typically a large basin designed to store stormwater temporarily and reduce the peak discharge from a storm event. The advantage of this system is that it does not pond water for extended periods. However, infrequent or nonexistent maintenance of these systems often causes the outlet structure to become clogged, which can lead to ponding of water, the creation of wetland conditions, and habitat for wildlife. The geometry of the dry detention basin will have an impact on habitat; increasing the length to width ratio of the dry detention basin is recommended. Because airports are linear environments, fitting a long and narrow dry detention system is quite possible. The detention basin should be vegetated with grass appropriate for the physiographic region of North Carolina; maintenance should include mowing to keep the grass 7-14” tall to reduce habitat for birds and mammals. Potentially, specific designs for airports should be considered, including elimination of the small

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[6] Reference Chapter 19 and Technical Guidance Document for rainwater harvesting and Appendix C-1 of the NC Plumbing Code.

[7] Reference Chapter 17

permanent pool near the outlet structure, using steeper side slopes to reduce wildlife attraction, and using alternate pre-treatment (other than a forebay). Airports with dry detention ponds will need to have an active wildlife mitigation program to keep the habitat and population to a minimum. These systems are not the preferred BMPs at airports due to wildlife concerns, but may be needed for peak flow mitigation. Without ponds and wetlands, dry detention is often the only large-footprint BMP option available at airports. The risk of wildlife in dry detention is substantially less than that of their wetter counterparts, and dry detention facilities do mitigate peak flows. Because the FAA strongly discourages detaining water for greater than 48 hours, the drawdown time associated with dry detention at airports should range betweeen 40 and 48 hours.

Extended dry detention basin at airports in Wilmington, NC (left) and Concord, NC (right).

Permeable Pavement[8]

Permeable pavement can be used to reduce stormwater runoff from parking lots and runoff from other surfaces. It typically consists either of a permeable interlocking paver, pervious concrete, or pervious asphalt. The paving layer is underlain with gravel layers, providing both structural support and storage volume for stormwater runoff. Recent changes to the permeable pavement section in this Manual does allow permeable pavement to accept runoff from other surfaces. Permeable pavement does require maintenance; therefore, it is best implemented in areas that receive relatively infrequent traffic, such as public airport terminal parking lots, rental car lots, Fixed Base Operators (FBOs), and employee parking lots (all of which are landside). Permeable pavement should not be used on the airside because of FOD concerns.

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[8] Reference Chapter 18

Permeable interlocking concrete pavers (left) and pervious concrete (right).

Proprietary Systems and Innovative Technologies[9]

Proprietary systems include a broad category of manufactured BMPs where stormwater is pre-treated before entering another BMP, or discharging to surface waters. These systems are typically installed below-grade and designed to remove sediment and gross solids from stormwater. NCDENR requires these proprietary systems to be monitored for one year, and from these data NCDENR determines what credit, if any, the particular system should receive for pollutant removal. If NCDENR determines the BMP is not functioning as intended, a new BMP must be installed to replace the non-functional one. For these reasons, these systems are difficult to use in North Carolina. As more proprietary systems are tested and approved, however, their use may increase. Proprietary systems have been approved for use at both the Charlotte (CLT) and Wilmington (ILM) airports.

13.12 BMPs in Series[10]

Some of the practices discussed herein may be most applicable for use in series, creating a “treatment train.” One of the most likely treatment trains would be a filter strip leading to a swale, which then carries water to a dry detention facility. The filter strip and/or swale could utilize soil amendments. “Treatment trains” can be used to link practices so that both water quality and peak flow mitigation goals are met.

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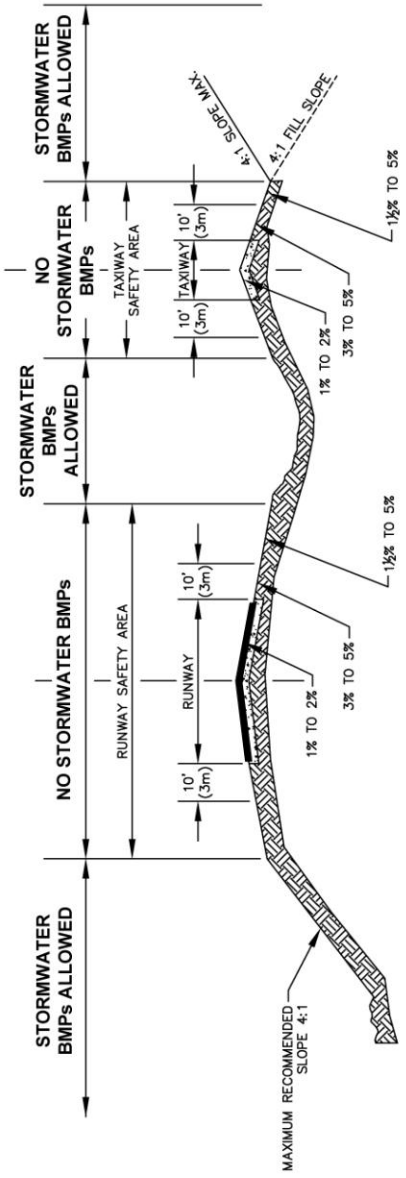
[9] Reference Chapter 20

[10] Reference Charter 3, Section 3.9.4

13.13 Stormwater BMP Placement

Stormwater BMPs must be places outside the runway and taxiway safety areas as depicted below.



LOCATION OF DITCH, SWALE OR HEADWALL DEPENDS ON SITE CONDITION BUT IN NO CASE WITHIN LIMITS OF RUNWAY SAFETY AREA.

TRANVERSE SLOPES SHOULD BE ADEQUATE TO PREVENT THE ACCUMULATION OF WATER ON THE SURFACE. SLOPES SHOULD FALL WITHIN THE RANGES SHOWN ABOVE. THE RECOMMENDED 1½" (4cm) PAVEMENT EDGE DROP IS INTENDED TO BE USED BETWEEN PAVED AND UNPAVED SURFACES. IT IS DESIRABLE TO MAINTAIN A 5% SLOPE FOR THE FIRST 10' (3m) OF UNPAVED SURFACE IMMEDIATELY ADJACENT TO THE PAVED SURFACE.

Stormwater BMP locations and tranverse grade limitations for aircraft approach categories A & B

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NC LICENSE NO. F-0374

FAA ADVISORY CIRCULAR
150/5300-13
AIRPORT DESIGN

Table 2. Airport Stormwater BMP Toolbox

BMP Type	General Description	Benefits	Installation Cost	Maintenance Activities	Maintenance Costs	Potential Drawbacks	Other Notes
Sheet flow, Level Spreaders, and Vegetative Filter Strip	Grade slope from runway to swale, aerate soil, plant sod or seeding with grass that does not produce large seed pods	Provides infiltration, removes sediment and sediment-bound pollutants from stormwater runoff, conveys runoff to grassed swale.	M	Mow, revegetate bare soil, remove trash/debris	L	Requires treatment train.** Not effective for soluble pollutants	Amending soils expected to improve performance
Grassed Swale	Grade trapezoidal channel with low longitudinal slopes. Plant sod or seeding with grasses that do not produce large seed pods	Provides treatment of runoff through interaction with vegetation, conveys runoff to storm sewers or surface waters, prevents flooding of runways and taxiways	L	Mow, remove trash/debris, re-establish eroded areas	L	Ponds water temporarily following rainfall	Could use check dams to slow flow, provide more surface storage
Bioretention	Grade to create a depressed area that is filled with engineered soil media. Underdrains may need to be installed. Ensure that sediment will not clog cell during construction	Removes TN, TP, TSS, heavy metals, and hydrocarbons from stormwater runoff through infiltration, filtration, and sedimentation.	M/H	Mow, remove sediment, flush underdrains, refresh top 2-3 inches of fill media as needed	M/H	Ponds water temporarily following rainfall, requires, 2' (min) separation from SHWT	Stand alone BMP. Vegetation should be grass. Should have a very shallow (3-6" ponding depth). 12 hr max drawdown from bowl. Could have deeper (9-12") ponding depths.
Bioretention (Rain Gardens)	Similar to bioretention cells without engineered soils, typically incorporated into landscape	Removes TN, TP, TSS, heavy metals, and hydrocarbons from stormwater runoff through infiltration, filtration, and sedimentation.	M/H	Mow, remove sediment, flush underdrains, refresh top 2-3 inches of fill media as needed	M/H	Ponds water temporarily following rainfall, requires, 2' (min) separation from SHWT	Stand alone BMP. Vegetation should be grass. Should have a very shallow (3-6" ponding depth). 12 hr max drawdown from bowl. Could have deeper (9-12") ponding depths.
Bioretention (Swales)	Combines bioretention cells with swale incorporating engineered soils	Provides treatment of runoff through interaction with vegetation, conveys runoff to storm sewers or surface waters, prevents flooding of runways and taxiways	M	Mow, remove trash/debris, re-establish eroded areas	L	Ponds water temporarily following rainfall	Could use check dams to slow flow, provide more surface storage
Bioretention (Bioslopes)	Bioslopes are embankments that treat runoff by rapid filtering through an engineered soil media commonly known as an ecology mix.	The ecology mix bed is a flow-through device and does not provide significant detention and only minimal retention storage.	M	Mow, remove trash/debris, re-establish eroded areas	L	Bioslope may become unstable because of friction limitations when side slopes approach 25%.	Bioslopes are intended for use on stable slopes only.
Bioretention (High Flow Rate Bioretention Systems)	Incorporates a specialized media that treats stormwater at a high flow rate using a relatively small footprint compared to slow flow rate bioretention systems.	Capable of achieving similar pollutant removal efficiencies when compared to conventional slow flow rate bioretention systems. Can treat and convey larger volumes of water when compared to conventional slow flow rate bioretention systems.	M	Mow, remove trash/debris, re-establish eroded areas	L	Requires engineered filter media	Filling and regrading the swales with high flow rate media reduces standing water. Provides the same water quality improvements and bacteria removal benefits as slow flow rate media.
Infiltration Devices (Infiltration Basin and/or Trench)	Excavate and haul soil, fill with crushed stone to create storage for stormwater; precast concrete vaults with open bottoms are typical	Provides groundwater recharge, particulate pollutant removal, can reduce runoff volumes and peak flow rates.	M/H	Remove sediment and debris using vacuum truck as needed	M	Restricted to areas with permeable soils and low SHWT	Stand-alone BMP.

Table 2. Airport Stormwater BMP Toolbox (continued)							
BMP Type	**General Description**	**Benefits**	**Installation Cost**	**Maintenance Activities**	**Maintenance Costs**	**Potential Drawbacks**	**Other Notes**
Sand Filter	Buried concrete trench. Sedimentation basin is an open basin, while sand filter itself is filled with washed, coarse masonry sand (ASTM C33).	Removes TSS and hydrocarbons. Useful in areas where space is limited for BMP installation.	H	Remove and reinstall sand media as needed. Remove debris, solids, and oil and grease from sedimentation chamber	H	Requires 2' (min) separation from SHWT	Stand-alone BMP. Some form of pre-treatment needed to reduce maintenance costs
Water Harvesting and Cisterns	Store and reuse stormwater from rooftop of hangar or terminal building. Route downspouts to cisterns. Install gravel or concrete pad for cistern. Install pump and associated plumbing.	Reduces runoff volume, stores runoff for future use	L/M	Clean cistern filters, maintain pumps	L	Requires gutters on building to route water to cistern, requires filter to remove debris from runoff	Volume reduction practice, not a stand-alone BMP. Water could be reused to wash out hangars, wash aircraft and vehicles, and flush commodes
Extended Dry Detention	Grade and haul soil, install culverts and outlet riser structure	Provides peak flow mitigation, moderate reduction of particulate-bound pollutants, and little to no nutrient reduction.	L	Remove trash and debris, inspect inlet pipes and outlet structure for clogging, remove sediment when ponding depth is 75 percent of design depth	L/M	Requires treatment train. Typically not aesthetically pleasing, 2' (min) separation from SHWT, relatively permeable soils	Ponds water 40-48 hrs after rain event, longer duration ponding of water may occur if maintenance is not consistent
Permeable Pavement	Grade/haul soil, install gravel bedding courses, underdrains, and paving layer	Allows for infiltration and storage of stormwater below grade, receives impermeable surface credit.	H	Sweep street quarterly, flush underdrains	H	High initial and maintenance costs	Requires sandy soil with low SHWT. Effective Volume Reduction measure.
Proprietary Systems and Innovative Technologies	Highly variable and dependent upon type of system installed	Removes trash, solids, and sediment.	M/H	Remove trash/debris/sediment	M	Limits peak flow rate attenuation, removes sediment-bound pollutants only. Requires performance monitoring to receive credit in NC	Performance varies based upon type of device; minimal credible research available

References

Stormwater BMP Toolbox for Public Airports in North Carolina, June 2011, Authors: Ryan J. Winston, E.I. Extension Associate, N.C. State University, William F. Hunt, Ph.D., P.E. Associate Professor and Extension Specialist, N.C. State University, Ken Carper, P.E., CPSWQ Director, Watershed Services, W.K. Dickson and Company, Inc., Paul Smith, P.E., Aviation Program Manager, W.K. Dickson and Company, Inc.

Air Line Pilots Association, International (ALPA). (2009). “Wildlife hazards mitigation strategies for pilots.” ALPA White Paper, Washington, D.C.

Chang, Y.-M., Chou, C.-M., Su, K.-T., and Tseng, C.-H. (2005). “Effectiveness of street sweeping and washing for controlling ambient TSP.” *Atmospheric Environment*. 39(10), 1891-1902.

Curtis, P.D. and Sullivan, K.L. (2001). “White-tailed deer.” Wildlife damage management fact sheet series, Cornell Cooperative Extension.

Federal Aviation Administration. (1989). Advisory Circular: Airport Design. AC No. 150/5300-13. <http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/ecdda8e7a6687c6a8625747200695eda!OpenDocument&Highlight=5300-13#_Section1 > (March 19, 2010).

Federal Aviation Administration. (2007). Advisory Circular: Hazardous wildlife attractants on or near airports. AC No. 150/5200-33B. <http://www.faa.gov/documentLibrary/media/advisory_circular/150-5200-33B/150_5200_33b.pdf> (March 18, 2010).

Federal Aviation Administration (2009). Advisory Circular: Standards for specifying construction of airports. AC No. 150/5370-10E. <http://www.faa.gov/documentLibrary/media/advisory_circular/150-5370-10E/150_5370_10e.pdf> (June 30, 2010).

Federal Aviation Administration (2010). National wildlife strike database. <http://wildlife-mitigation.tc.faa.gov/wildlife/database.aspx> (March 20, 2010).

Florida Department of Transportation (2008). Technical report for the Florida statewide airport stormwater study, clean water – safe airports. Tallahassee, FL.

Hunt, W.F., J.T. Smith, S.J. Jadlocki, J.M. Hathaway, and P.R. Eubanks. (2008). Pollutant removal and peak flow mitigation by a bioretention cell in urban Charlotte, NC. *Journal of Environmental Engineering.* 134(5): 403.

NCDENR. (2007). Stormwater best management practices manual. Raleigh, NC. <http://h2o.enr.state.nc.us/su/bmp_updates.htm> .

NCDENR. (2010). Stormwater best management practices manual: Level Spreader – Vegetative Filter Strip Systems Chapter. Raleigh, NC. <http://h2o.enr.state.nc.us/su/bmp_updates.htm> (March 9, 2010).

Passeport, E. and W.F. Hunt. (2009). Asphalt Parking Lot Runoff Nutrient Characterizationfor Eight Sites in North Carolina, USA. *Journal of Hydrologic Engineering*, 14(4): 352-361.

Transportation Synthesis Report (June 2007), CTC & Associates LLC and WisDOT Researce & Library Unit.

U.S. EPA (2009). Environmental impact and benefit assessment for proposed effluent limitation guidelines and standards for the airport de-icing category. <http://www.epa.gov/guide/airport/Airport_EIB_Proposed_2009.pdf> (March15, 2010).

USGA (2004), USGA Recommendations for a Method of Putting Green Construction

Washington State Department of Transportation (2008). Aviation Stormwater Design Manual: Managing Wildlife Hazards Near Airports.

Wenning, K.M., Begier, M.J., and Dolbeer, R.A. (2004). “Wildlife hazard management at airports: fifteen years of growth and progress for wildlife services.” In *Proc. Of 21st Vertebrate Pest Conference*. Published at University of California at Davis.