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STRATEGIC LANDSCAPE UTILIZATION OF UNDEVELOPED LANDS WITHIN DALLAS EXECUTIVE AIRPORT BOUNDARY: AIRPORT STORMWATER MANAGEMENT

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AIRPORT STORMWATER MANAGEMENT

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To Mr. Saboohi (RIP), my former high school advisor, who encouraged me to have a fruitful life and serve all human beings. To my professors and classmates, who have taught me so much over the years. To my friends and family, whose love and support I will always cherish.

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To the people that may benefit from this article.

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Abstract

STRATEGIC LANDSCAPE UTILIZATION OF UNDEVELOPED LANDS

WITHIN DALLAS EXECUTIVE AIRPORT BOUNDARY:

AIRPORT STORMWATER MANAGEMENT

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The University of Texas at Arlington, 2018

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The purpose of this research is to investigate and propose a sustainable stormwater management improvement for the Dallas Executive Airport future master plan development while carefully considering wildlife preservation and the beautification of the new facility. The literature review draws upon documented research that global aviation growth causes increasing environmental issues. An in-depth review of the history of the airport's environmental impact shows an increasing concern which ultimately lead to the assigned regulations.

The research dives into existing environmental issues caused by air transportation, focusing specifically on stormwater pollutions at small airports and the applicable solutions within the airport boundary to mitigate the negative environmental impacts on site. Taking the approach to aviation environmental problems as a Landscape Architect, mapping, GIS data analysis and technical calculations are the effective methodologies to find the most suitable design solution. The comparison between the existing conditions and the future master plan development increases the importance of the consideration of a strategized

stormwater management system. The analysis shows that the new development increases the amount of impervious surfaces on site which will eventually increase the amount of run-off that carries pollution to the existing water system and threatens the eco-system of North Central Texas region.

In conclusion this thesis provides airport managers, landscape architects, and stormwater specialists with a suitable design solution that can mitigate the amount of stormwater run-off and pollution by employing a bio-filtration swale to respond to the future master plan of the Dallas Executive Airport. The design of the best management practice (BMP) includes two major features. The first feature involves preserving the existing forested lands with a potential hiking trail for the members of adjacent communities and the second involves the employment of an innovative and efficient bio-filtration swale with sufficient capacity to detain and filter stormwater from existing runways and the future development.

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1. Introduction

1.1. Research Background

Airports are major urban facilities that cover an extensive amount of land in our modern cities. However, environmental issues caused by airports are increasing as the air transportation is growing globally. Even though the technology in aircraft manufacturing industry has been successful in reducing the level of negative impacts of the aviation industry on the environment, there are still many areas such as airport stormwater management systems that need significant investigation.

1.2. Problem Statement

While smaller airports, such as Dallas Executive Airport, have less air traffic than heavier trafficked airports, the structural and facility requirements of aviation result in vast impervious areas including runways, taxiways, and ramps. In addition to the large volume of stormwater run-off, the industrial activities (e.g. maintenance, fueling, de-icing and new constructions) can adversely affect stormwater quality and contribute to the flow of pollution to existing water systems. In long term, this problem can become a major threat to wildlife and people’s health.

1.3. Purpose Statement

The purpose of this research is to find the “Best Management Practice” and a landscape design solution that can mitigate stormwater pollution on site within the Dallas Executive Airport vacant land. The objective of this research is to analyze existing site conditions and available data, with a consideration of the future master plan in order to find and conduct the most suitable Best Management Practice on site. The design solution needs to respond to all aviation regulations and construction limitations at the airport. It also should consider wildlife management concerns at Dallas Executive Airport and passive use for adjacent neighborhoods.

1.4. Research Questions

Studying the proposed future master plan development for the Dallas Executive Airport, the ignorance to the environmental impact of the future development raised the following questions:

Question 1: What is the Best Management Practice to upgrade the stormwater quality at Dallas Executive Airport?

Question 2: What are the stormwater pollution sources at Dallas Executive Airport?

Question 3: What are the environmental challenges in airport future master plan development?

1.5. Definition of Terms

ACI: Airport Carbon Accreditation Program is a voluntary global carbon management standard for airports. This standard provides a framework and guidance for implementing best practices in carbon management with the ultimate objective of achieving carbon neutrality.

BMP: Best Management Practice, means a practice, or combination of practices, that is determined to be an effective and practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals. (EPA ,2016)

EPA: The Environmental Protection Agency is an independent agency of the United States federal government for environmental protection. President Richard Nixon proposed the establishment of EPA on July 9, 1970 and it began operation on December 2, 1970, after Nixon signed an executive order.

FAA: Federal Aviation Administration

Habitat Deterrence: is an effort to create an environment around the airport that is unattractive to potentially hazardous animals. (FAA).

ICAO: International Civil Aviation Organization

LID: Low-impact development is a term used in Canada and the United States to describe a land planning and engineering design approach to manage stormwater runoff as part of green infrastructure. LID emphasizes conservation and use of on-site natural features to protect water quality. This approach implements engineered small-scale hydrologic controls to replicate the pre-development hydrologic regime of watersheds through infiltrating, filtering, storing, evaporating, and detaining runoff close to its source. (EPA)

NPDES: National Pollutant Discharge Elimination System.

1.6 Methodology

This research uses Suitability analysis using GIS (Geographic Information System) data based on the McHarg Suitability Analysis Method, stormwater management calculation using Rational run-off calculation method, and interviews with experts that have practiced in fields related to Airport stormwater management.

GIS data have been collected through online sources such as USDA and NCTCOG. The Suitability and data analysis tools in Arch GIS software, lead the research to find the source of problems, applicable solutions, and BMP selections. Also, stormwater management calculation methods are specifically addressed in Bio-filtration Swale Design Guidebook (CDOT 2012) to find an applicable program and design criteria for Dallas Executive Airport. Additionally, interviews with professionals practicing in the related fields conduct another layer of practical information and improve the research quality.

1.7. Significance and Limitations

The significant goal of this research is to provide landscape architects, stormwater specialists, and airport managers with documented research and information regarding the most suitable Stormwater Best Management Practice applicable to small airports and their future development. The landscape architecture perspective on airport future development plans improves the environmental control and management systems including considerations on community accessibility and aesthetic improvement of the border facilities.

The limitations of this study include lack of data that may directly or indirectly impact the suitability of proposed design such as detailed future master plan building footprints. Also the research is based on the existing site condition and available sources for “future master plan” and any new construction and program is not included.

2. Literature Review

2.1. History of Airport Landscape planning

History of the Airport Landscape Planning goes back to late 1960s when many modern cities of the United States had characterized airports and their environments as a "dystopian" (the opposite of pleasant landscapes), even anti-landscapes. Up to that time, aviation had been determined to travel speed rather than quality of the travel experience, and airports became places that one would rather avoid. In 1970, when the first Boeing 747 initiated its journey, it required 1.28 acres of apron area for take-off, landing and parking the airport. As a result, when Dallas/Fort Worth (DFW) international airport was constructed in 1972, its 17,598.85-acre site surpassed the entire size of Manhattan Island, New York. (Duempelmann, 2010)

When the **Airport Beautification Campaign** started in mid 60s, the association of airports and parks seemed logical because earlier flights were considered both a scientific and recreational pursuit, requiring extensive open space. Many plans were made to locate airport within parks and urban park systems and in some cities the parks department administered the airport in the early years. (Duempelmann, 2010)

In the 1920s and 1930s, **landscape architects** had first begun to investigate airports and aviation as design projects. Their goal was to design airport landscapes, and to incorporate the airport as a subject into their design literature. "Airport planners and officials believed that landscape architects contributions to "airport beautification" not only pleased the eye, but due to their psychological effects, could also prevent accidents, including aircraft crashes". (Duempelmann, 2010)

2.2. History of Airport Environmental Concerns

Study in history of airport environmental issues shows that more than 4 decades we have growing concerns about environmental impacts of air transportation. Analyzing the literature of aviation environmental issues shows that these issues have attracted increasing attention among environment-related professionals.

In 1996, the environmental problems caused by civil aircrafts were discussed at a conference in London, involving representatives of twenty-six nations an eleven aeronautical organizations. At that time, the main aviation environmental issue was considered aircraft noise. Later on, ICAO developed international standards for aircraft noise performance.

Beside aircraft noise, Other environmental issues caused by aviation were identified at early stages, including pollution arising from aircraft engine exhaust emissions, de-greasing agents, runway and aircraft de-icing compounds and fire extinguishing substance. In 1971, ICAO adopted Annex 16 (Environmental Protection) 1944 Chicago Convention which covered both emissions and noise. In 1972, at the UN Conference on the Human Environment (UNCHE) in Stockholm, ICAO adopted a resolution to investigate the impact of aviation on the quality of the human environment. “Control of Aircraft-Engine Emissions” was published in 1977 in which ICAO proposed methods to control vented fuel, smoke and other pollutants.

2.3. Environmental Issues Caused by The Airports

The air transport industry is facing a growing challenge in responding adequately to environmental concerns. In 1993 ICAO complied an inventory of the environmental problems associated with civil aviation. Table 1 indicates the list of environmental issues complied by ICAO.

Environmental Impact	Examples
Aircraft noise	Aircraft operations Engine testing Airport sources Sonic boom (due to supersonic aircraft)
Local air pollution	Aircraft engine emissions Emissions from airport motor vehicles Emissions from airport access traffic Emissions from other airport sources
Global phenomena	Long-range air pollution (e.g. acid rain) The greenhouse effect Stratospheric ozone depletion
Airport/infrastructure construction	Loss of land Soil erosion Impacts on water tables, river courses and field drainage Impacts on flora and fauna
Water/soil pollution	**Pollution due to contaminated run-off from airports** **Pollution due to leakage from storage tanks**
Waste generation	Airport waste Waste generated in-flight Toxic materials from aircraft servicing and maintenance
Aircraft accidents/incidents	Accidents/incidents involving dangerous cargo Other environmental problems due to aircraft

Table 1 Airport Environmental Impacts , adapted from Crayston (1992); Price and Probert (1995)

Water and soil pollution is one of the important environmental issues that has been underestimated in the past and needs more attention in the future. Water and soil pollution happens when the stormwater runs off and washes all the emissions and pollutions from the surface and carry it into the natural system. To be able to address a solution, the pollution sources needs to be identified.

2.4. Storm Water Pollution Sources

Stormwater runoff is generated from rain and snowmelt events that flow over land or impervious surfaces, such as paved streets, parking lots, and building rooftops, and does not soak into the ground. The runoff picks up pollutants like trash, chemicals, oils, and dirt/sediment that can harm our rivers, streams, lakes, and coastal waters. (EPA, 2018).

Population growth and the development of urban/urbanized areas are major contributors to the amount of pollutants in the runoff as well as the volume and rate of runoff from impervious surfaces. Together, they can cause "changes in hydrology and water quality that result in habitat modification and loss, increased flooding, decreased aquatic biological diversity, and increased sedimentation and erosion." The benefits of effective stormwater runoff management can include: protection of wetlands and aquatic ecosystems, improved quality of receiving waterbodies, conservation of water resources, protection of public health, and flood control. (EPA, 2018).

The NPDES (National Pollutant Discharge Elimination System) stormwater program regulates some stormwater discharges from three potential sources: municipal separate storm sewer systems, construction activities, and industrial activities. Operators of these sources might be required to obtain an NPDES permit before they can discharge stormwater. This permitting mechanism is designed to prevent stormwater runoff from washing harmful pollutants into local surface waters. (EPA, 2018).

Traditional stormwater management approaches that rely on peak flow storage have generally not targeted pollutant reduction and can exacerbate problems associated with changes in hydrology and hydraulics. "Airports can generate significant water pollution due to their extensive use and handling of jet fuel, lubricants and other chemicals. Airports install spill control structures and related equipment (e.g., vacuum trucks, portable berms, absorbents) to prevent chemical spills, and mitigate the impacts of spills that do occur." (EPA, 2006) To protect these resources, communities, construction companies, industries, and others, use stormwater controls, known as best management practices (BMPs). These BMPs filter out pollutants and/or prevent pollution by controlling it at its source. (EPA, 2018).

2.4.1. Case Study

A valuable case study of Seattle-Tacoma International Airport helps to understand the problem statement and implemented solutions. Seattle Tacoma Airport is the 15th busiest passenger and 21st busiest cargo airport in U.S., requires to detain and treat all water before it leaves the property (on-site). Seattle has an average annual rainfall of over 38 inches per year or 11 million gallons of water per inch of rain, which is a significant number in comparison with US average. The port has to manage over 1650 acres inside the permit boundary. Their water management system categorized into 3 different systems: **Industrial Wastewater System, Non-Construction Stormwater System and Construction Stormwater System**. Industrial water system covers 375 acres of the site, where the storm drainage system takes over 1275 acres of the site.

Industrial Wastewater System: It contains spilled fuel, de-icing/anti-icing fluids, lubricants and wastewater from vehicles/aircrafts. It's collection and conveyance facilities include over 21 miles of piping, 11 pump station, 510 manholes and 79.6 gallons of storage. The wastewater treatment plant includes 6 dissolved air flotation units for treatment. Inline Total Organic Carbon analyzers used to segregate deicing wastewater. Low Biochemical Oxygen Demand processed via the port's treatment plant and discharged to the Puget Sound. High Biochemical Oxygen Demand diverted and sent to local sanitary sewage treatment plant. Treatment effluent discharge options includes: high BOD to sewer district and for secondary treatment, low BOD effluent to Puget sound and recycle back to the system to retreat.

Non-Construction Stormwater Management system: It contains 11 outfalls that discharge to 4 different local streams, 11 flow control facilities providing 113 acre-feet of storage and water quality treatment includes source controls, swales, filter strips, media filtration and wet pools. Water quality testing has some limitations and also includes toxicity testing. Airfield filter strips remove 54-70% total/dissolved copper and 61-76% total/dissolved zinc. In addition to that, Bio-retention swales are consisted with washed drain rocks, amended soil mix and oyster shell media that perform as pollutant removal feature.

Construction Stormwater Management is another important system in any airport since constructions are happening constantly to keep airports maintained and functional. Two treatment options are used in this system: Chitosan polymer, is a natural derivative of chitin and is found in shellfish, used as a flocculent. Chitosan Enhanced Sand filtration utilizes sand filters as part of the polishing process.

2.5. Airport Landscape Planning Regulations

The spaces surrounding the airport boundaries have been affected directly by number of aircraft commercial flights, flight paths for take-off and landing created restrictions on building height and even **landscape** of the sites nearby. These areas also have been affected by air, water, soil and noise pollution. As a result, aircraft manufacturer, environmentalists and regulatory agencies such as the “Federal Aviation Administration (FAA) began to demonstrate concern that the aviation technology was not synced with U.S. culture and environmental needs.” The FAA has implemented many regulations at US airports for environmental management, including, for example, restrictions on sizes and types of vegetation. EPA specially identified the following industrial activities at air transportation facilities as requiring an **NPDES** (National Pollutant Discharge Elimination System) permit: Servicing, repairing, or maintaining aircraft and ground support equipment. Equipment cleaning and maintenance which include vehicle and equipment repair, painting, fueling, and lubrication, Deicing/anti-icing operations.

The FAA defines several **operation zones** with specific requirements for siting and design of **stormwater facilities**, including LID BMPs:

Airport Operations Area (AOA) – The area of an airport used or intended for use for landings, takeoffs, or surface maneuvering of aircraft.

Runway Object Free Area (ROFA) – The defined area centered on the runway enhances the safety of aircraft operations by remaining completely clear of objects, including terrain variations, that protrude above the elevation of the nearest point of the RSA surface.

Runway Safety Area (RSA) – The defined ground space surface that includes and surrounds the runway and is prepared for the express purpose of reducing catastrophic loss of life and damage to aircraft in the event of an undershoot, overshoot, or excursion from the runway surface. At STIA, the RSA for air-carrier operations of Group V aircraft is 500 feet wide, centered on the runway, and extends 1,000 feet beyond the runway ends.

Taxiway Safety Areas and Taxiway Object Free Area (TSA, TOFA) – These areas mirror the intent of the RSA and ROFA, but are centered on taxiways and have smaller dimensional requirements. These areas also define safety zones for aircraft deviating from the paved operational surfaces.

Apron Area (AA) – The defined area outside of the ROFA and TOFA, located adjacent to the terminal, aircraft maintenance and cargo buildings. Its primary function is to:

"1) provide a place to safely accommodate aircraft during loading and unloading of passengers and cargo; 2) provide for circulation of aircraft and ground vehicles; and 3) provide a location for fueling, deicing, maintenance, and aircraft parking." (FAA, 2018).

2.5.1. Dallas Executive Airport Report Summary

The following report published by Dallas Executive Airport discussed their concern about stormwater management for the future masterplan.

Dallas Executive Airport is located within the Headwaters Fivemile Creek watershed; the closest water body is the Trinity River, located approximately seven miles to the north and east. According to the draft drainage study, there are a total of seven different drainage basins on airport property. "**Future development at the airport would create additional impervious surfaces and ground disturbance that could contribute to cumulative water quality impacts**." Therefore, future development projects should be evaluated to address their interface with the airport's stormwater drainage system and should be incorporated into the airport's Storm Water Pollution Prevention Plan. (Dallas Executive Airport Master Plan, 2016, P 18-20).

Most of the development projects associated with the Airport Master Plan Update would avoid the drainages on the airport property. However, "some fill may be **necessary** within onsite drainages, especially southwest of the airfield area, to create buildable pads for future development. Prior to development activities". "Communication with resource agencies during preparation of the previous Airport Master Plan indicated that they were concerned about the potential for airport-related impacts to Crow Creek tributaries and riparian areas." The acreage of both direct and indirect impacts to either wetlands or "waters of the U.S." would need to be determined and an appropriate mitigation plan approved by the affected regulatory agencies prior to the disturbance of any jurisdictional areas." (Dallas Executive Airport Master Plan Report, 2016, P 20-21)

2.5.2. Dallas Executive-Flora and Fauna Report

Wildlife management and airport development impact on flora and fauna should be studied prior to any new development. Dallas Executive Airport published a report on the existing flora and fauna condition on the site and its surroundings.

Several resources can potentially get impacted with future actions at the airport. Fish and wildlife concerns have been reported as:

> "The Fish and Wildlife Coordination Act requires that agencies consult with the state wildlife agencies and the Department of the Interior concerning the conservation of wildlife resources where the water of any stream or other water body is proposed to be controlled or modified. The modification of streams or water bodies is not expected to occur with any of the proposed alternatives. The Migratory Bird Treaty Act (MBTA) prohibits private parties and federal agencies from intentionally taking a migratory bird, their eggs, or nests. The MBTA also prohibits activities that would harm migratory birds, their eggs, or nests unless the Secretary of the Interior authorizes such activities under a special permit. Hundreds of bird species are protected by the MBTA and represent common groups such as wading birds, hawks, blackbirds, songbirds, sparrows, doves and waterfowl. Migratory birds are likely present at the airport, particularly in the less developed areas with grassland, scrub/shrub and trees." (Environmental Assessment Runway Shift and Other Improvements Dallas Executive Airport, 2016 p 88-89)

The land cover and plant material can be impacted by any future action, as well. The report mentions the land cover required changes regarding FAA regulations:

> "There could be cumulative impacts on wildlife and plants from the proposed action, when considered together with past and future actions at the airport. In addition to the 3.6-acre area of maintained grass at the end of Runway 13, several additional parcels would be converted from natural condition to pavement, buildings, and mowed and maintained grassy areas. Additionally, 16.5 acres of trees would need to be removed to meet FAA requirements regarding the ROFA for the proposed action." (Environmental Assessment Runway Shift and Other Improvements Dallas Executive Airport, 2016)

2.6. Conclusion

The literature review indicates the factors that are having most impacts on stated problem throughout history, regulations and site-specific studies. The stormwater management problem has always been discussed in air transportation and environmental conferences around the world. National organizations such as FAA and EPA have specific regulations that address the stated problems and also have suggested solutions that are applicable to the selected site. A recent study on DEA future master plan and development's impact on environment reported that the project needs supplementary studies on stormwater management on site.

3. Methodology

3.1. Research Design

Research design help to understand the processes of the research at each stage and clarify the objective of each chapter. As a landscape architect, looking for the reported issues at local airports such as Dallas Executive Airport, is the initial phase of the research. The issue has different aspects but in order to address the appropriate problem as a landscape architect, the problem statement needs to be defined accurately. After analyzing the data, the research concludes with a design solution.

The following figure is a brief summary of how the research has been conducted:

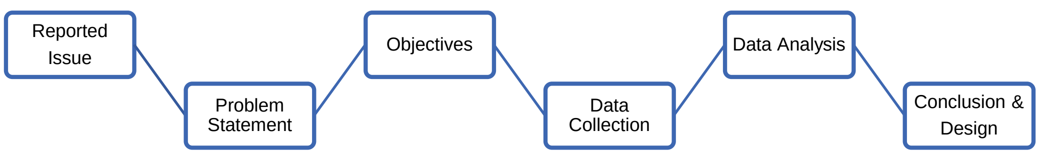

Figure 1 Research design

3.2. Site Selection and Application

Located six miles southwest of downtown Dallas, Dallas Executive Airport (IATA: RBD, ICAO: KRBD, FAA LID: RBD) covers 1,070 acres of land. In 2-mile radius neighborhood 63% of the land uses are residentials. There are two water tributaries within one-mile radius from the airport runway. The airport is not classified as major air transport facility, therefore the stormwater management system follows the minimum required FAA and EPA environmental standards. However, the proposed future master plan for the airport require stormwater pollution prevention plan. Figure 2 indicates the water tributaries and major roads and highways around the site. Also figure 3 illustrates the site location in DFW area with other airports.

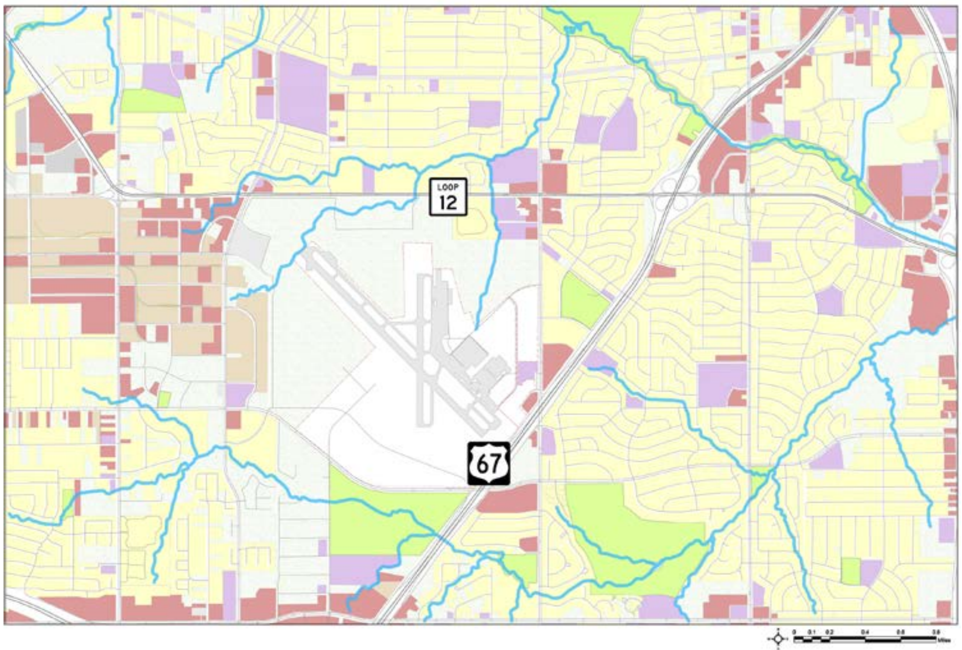

Figure 2 Dallas Executive Airport Surrounding Condition

Figure 3 Dallas Executive Airport Regional Location

3.3. GIS Data Collection

The research inventory is conducted by list of data gathered from databases that provide GIS compatible datasets online. The following table indicates layers of data collected and used in this research:

Layer Name	*Data Source*	*Data Date*
Airports	NCTCOG	2017
Building Footprint	NCTCOG	2017
Contour lines	Created from elevation raster	2016
Highways	NCTCOG	2017
Land Cover	USDA	2016
Land Use	NCTCOG	2017
Rail Roads	NCTCOG	2017

Regulatory Flood Zone	NCTCOG	2017
Roads	NCTCOG	2017
Soil	USDA	2016
Water Body	NCTCOG	2017
Water Shed	NCTCOG	2016
Water Stream	NCTCOG	2017

Table 2 GIS Data Layers and sources

3.4. Suitability Analysis (McHarg Method)

Site selection or suitability analysis is a type of analysis used in data such as GIS data to determine the best site for intended future development. Per McHerg Method, first step is to identify potential land uses and define the needs for the intended land use. The needs should be related to natural factors. After that the analysis should constrain between potential land uses and biophysical processes. Then after overlaying the maps of constrains and opportunities, the result will illustrate the suitability for intended land use. (Steiner, 1999)

When performing site selection analysis, users must set various criteria from which the GIS software can rate the best or ideal sites. Site selection analysis can be performed with vector or raster data but one of the most widely used types of site selection, weighted site selection, uses raster data.

Weighted site selection analysis allows users to rank raster cells and assign a relative importance value to each layer (ESRI). The result is a suitability surface which ranks potential sites from 1 to 10. Sites with a value of 1 are least suitable and those with a value of 10 are most suitable. Weighted site selection is an important site selection method because it includes options for viewing next-best sites.

Regarding the research purpose, to find the Best Management Practice, this analysis helps to find the most suitable location within the site boundary to implement a sustainable LID structure. The specific factors in LID design criteria and each criteria's impact value have shaped the suitability chart. The following figure indicates BMP suitability required data:

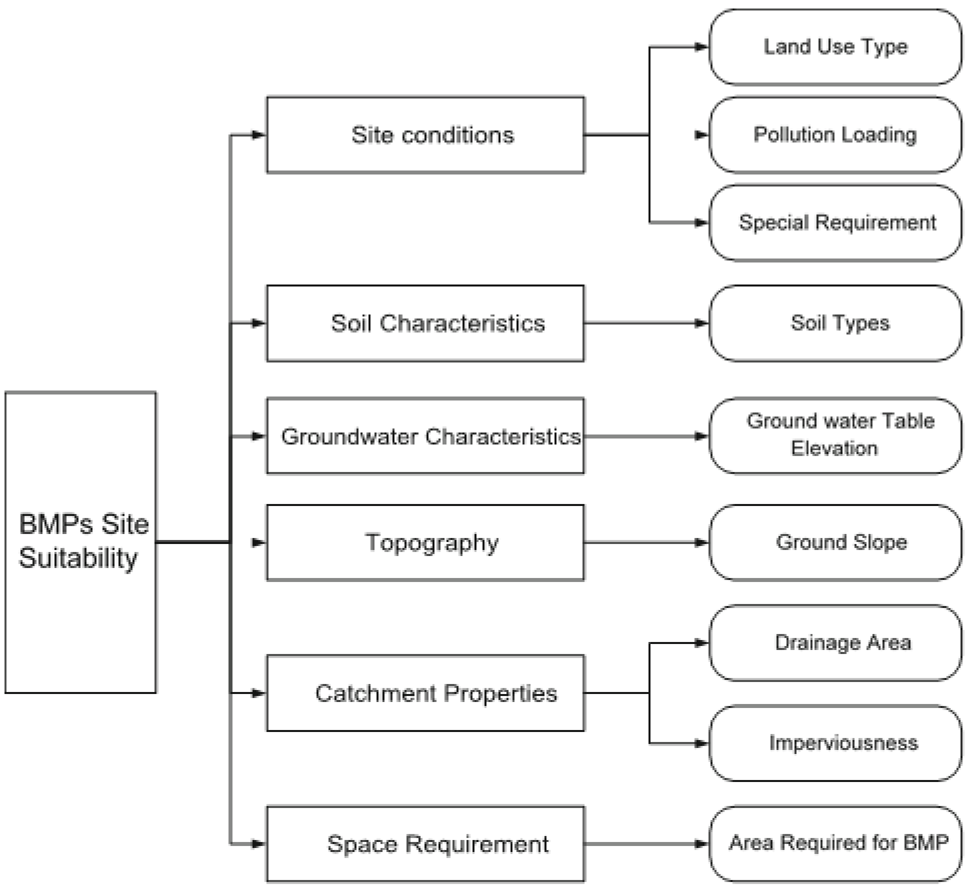

Figure 4 Indicators of BMP site suitability (Environ Monit. Assess (2013))

Limitations:

-The weighting and categorizing of the data have been designated based on secondary data and literature reviews and there is no documented or certain manual for that.

-For a better understanding and comparison possibility the suitability map exceeds the airport boundary.

3.5. Stormwater BMP Calculation

The Bio-filtration Swale is a flow-based Treatment BMP that is designed to convey and treat the runoff pollution during intense water flow events, as long as the Flow Depth, Velocity, Hydraulic Residence Time, and the Interrelationship Formula all met.

Storm Water run-off rate calculation (Rational Method): The Rational Formula is used to calculate the runoff entering the bioswale. The Co-efficient numbers for different materials are referenced from the LARE Reference Manual.

$Q_{WQF} = C \times I \times A$

Where

Q_{WQF} = Water Quality Flow rate (cfs)

C = runoff coefficient

I = WQF rainfall intensity (in/hr)

A = tributary area to the Bioswale (acres)

Runoff Volume Computation (NRCS Methodology): The USDA Natural Resources Conservation Service (NRCS) methodology is perhaps the most widely used method for computing stormwater runoff rates, volumes, and hydrographs. It uses a hypothetical design storm and an empirical nonlinear runoff equation to compute runoff volumes and a dimensionless unit hydrograph to convert the volumes into runoff hydrographs. The methodology is particularly useful for comparing pre- and post-development peak rates, volumes, and hydrographs. The key component of the NRCS runoff equation is the NRCS Curve Number (CN), which is based on soil permeability, surface cover, hydrologic condition, and antecedent moisture.

P = Stormwater Quality Design Storm = 1.25 inches

A = Total drainage area = X acres

Pervious cover = mixture of lawn and woods Pervious CN = 65

Pervious cover = mixture of lawn and woods Impervious CN = 98

Average S = 1000/CN – 10

Average initial abstraction = I_a = 0.2 S

Runoff volume = Q = (P - 0 .2 S)^2

Cover Type and Hydrologic Soil Group	**A**	**B**	**C**	**D**
Open space (lawns, parks, golf courses, cemeteries, etc.)	49	69	79	84
Paved parking lots, roofs, driveways, etc.	98	98	98	98
Streets and roads:	98	98	98	98
Paved, curbs and storm drains	83	89	92	93
Paved, open ditches	76	85	89	91

Gravel Dirt	72	82	87	89
Urban areas: Commercial and business (85% impervious) Industrial (72% impervious)	89 81	92 88	94 91	95 93
Developing urban areas: Newly graded areas(pervious areas only, no vegetation)	77	86	91	94

Table 3 Soil Groups (Adapted from TXDOT Hydraulic Design Manual)

Flow depths at (Water Quality Flow) WQF, during Design Event: The flow depth during WQF and the Design Event can be calculated using Manning's Equation, as shown below:

Q = (1.486/n) x A x R2/3 x S1/2

Q = flow at defined event (Q_{WQF} or Q25)

n = Manning's coefficient; recommend using "n" = 0.24 for Q_{WQF}

and 0.05 for the Design Event Q25

A = Cross-sectional area of the flow in the channel

R = Hydraulic Radius = "A" / Wetted Perimeter ("P")

S = longitudinal slope, length drop per unit length run

Hydraulic Residence Time: The minimum travel time within the Bioswale, termed the Hydraulic Residence Time [HRT]) is 5 minutes. This can be checked after the proposed

Bioswale site is analyzed using Manning's Equation, as discussed above. The velocity associated with the Q_{WQF} is determined, and the HRT calculated using the proposed length of the Bioswale:

$HRT = L / (60 \times V_{WQF})$

L = proposed length of the Bioswale (ft.)

HRT = Hydraulic Residence Time (minutes)

V_{WQF} = velocity at Q_{WQF} (ft./sec)

60 = conversion from seconds to minutes

Interrelationship Formula during WQF: Upon determining that the HRT, d_{WQF}, and V_{WQF} meet their respective design criteria, the Interrelationship Formula shown here, also must be satisfied, as the maximum allowed depth of flow and velocity may be restricted if the HRT is less than 5 minutes:

$(HRT \times 60)/(d_{WQF} \times V_{WQF}) \geq C$

HRT = Hydraulic Residence Time during Q_{WQF} (minutes)

60 = conversion factor from minutes to seconds

d_{WQF} = depth of flow at Q_{WQF} (ft)

V_{WQF} = velocity of flow at Q_{WQF} (fps)

C = constant: 1,300 (sec^2/ft^2)

3.6. Interviews and IRB

Interview with professionals adds practical information and real-world experiences related to our topic. The interview questions have been conducted and approved by IRB protocols. The questioner includes profile questions and technical questions; as listed below:

Profile Questions:

1. What is your professional degree?

2. What is your professional practice?

3. How long have you been working in your field?

4. Have you had any other experiences or projects related to airport landscaping or storm water management projects?

Technical Questions:

1. Is there any future environmental improvement plan for the Dallas Executive Airport?

2. What type of utilizations or constructions are allowed on undeveloped lands within Dallas Executive Airport?

3. Do we have flooding issues reported in Dallas Executive Airport history?

4. Does Dallas Executive Airport have a stormwater treatment system?

5. Do we have any stormwater pollution reported from Dallas Executive Airport?

6. Do neighborhood residents around Dallas Executive Airport concern or complain about any environmental issues caused by the airport?

7. Do you know about bio-filtration systems such as bio-swales? Are they a good solution for stormwater treatment for Dallas executive airport?

8. What are other alternatives that are applicable in Dallas Executive Airport to mediate storm water pollution?

9. Is there any special soil material or plant list suggested for “airport bio-filtration systems” specifically?

10. Is there any additional information or resources you would like to add?

4. Analysis and Findings

4.1. Site Analysis

Dallas Executive Airport is located within the Headwaters Fivemile Creek watershed; the closest water body is the Trinity River, located approximately seven miles to the north and east. According to the site topography analysis map, the airport is drained on all sides by tributaries of Fivemile Creek (DEA Master Plan, 2016). In order to analyze the site condition accurately, the following maps are created with GIS data and each illustrate specific feature on the site:

Regional Hydrology map indicates the location of the site and its relation to the existing water sheds, minor and major tributaries. Two water tributaries are surrounding the airport. The water running out from the site flows into these two tributaries. These tributaries flows into a major water stream which catches water from water shed and carry it to the trinity river.

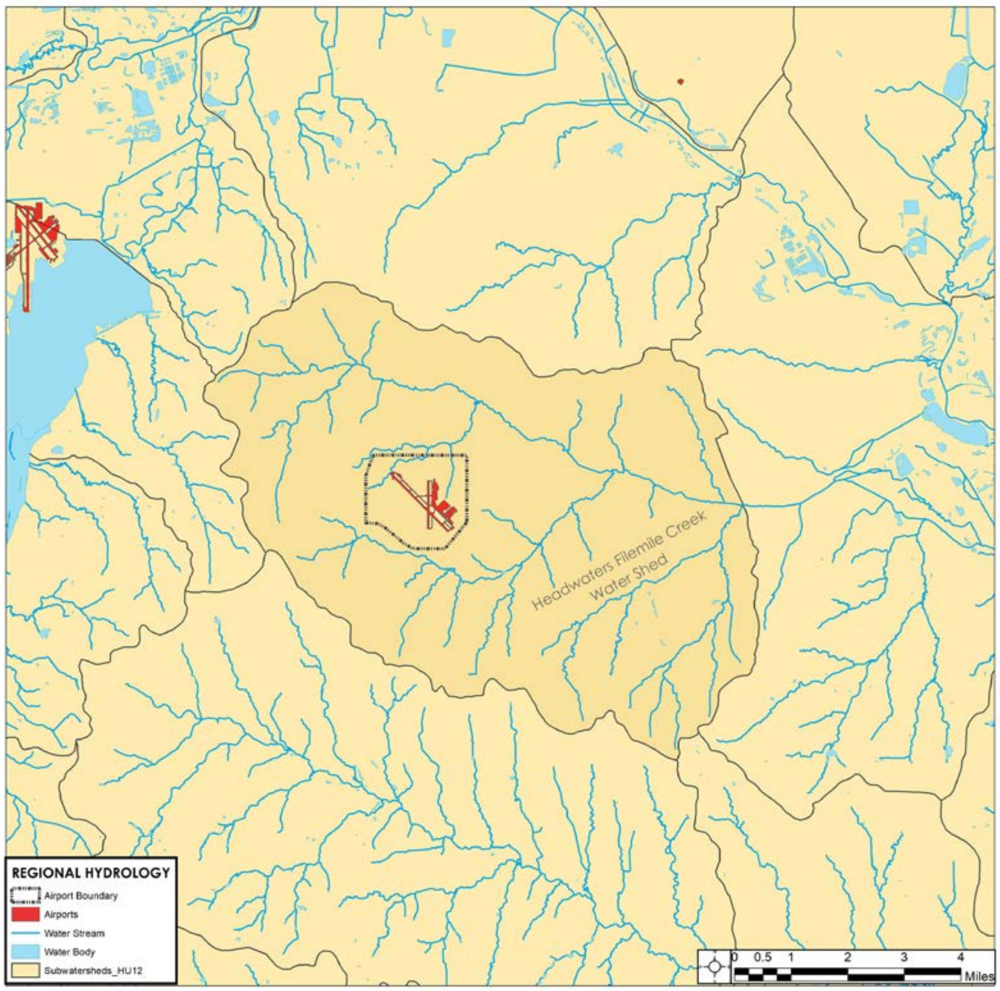

Figure 5 Regional Hydrology

Site topography map illustrates the site elevation, contour lines and regulatory flood zones of the existing water streams. The flood zones indicated the level of water raised during severe rainfall and flooding seasons. The darker brown indicated higher elevation and lower lands are indicated in light brown. It shows that the site elevation goes from high to low from west to east. The contour lines indicates the berms and valleys of the natural site topography.

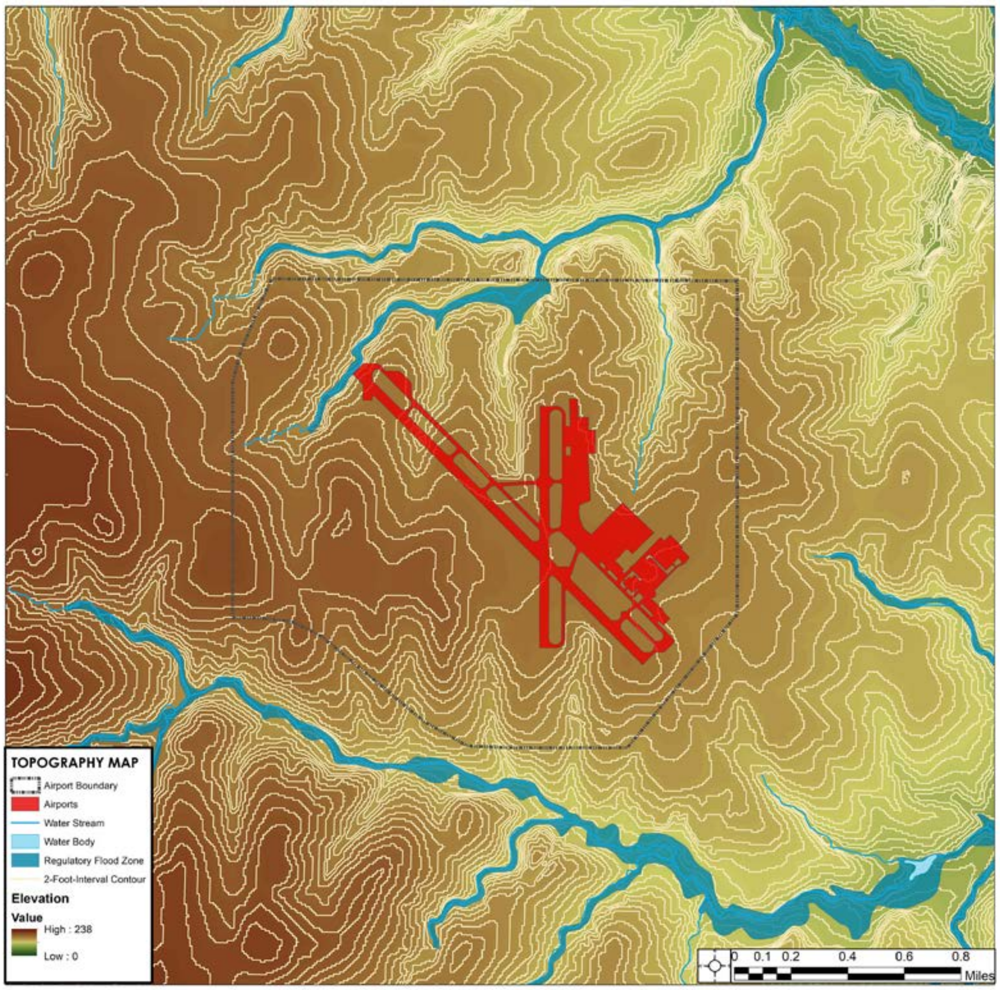

Figure 6 Site Hydrology and Flood Zones

The slope map indicates the slope degree between contour lines on existing topography of the site. When the contour lines are closer that means the elevation change or slope is more and when the contour lines are further apart, that means the site has less slope and a flatter land. The green areas are flatter, and the red areas are steeper. Bio-filtration process needs to happen on a flatter terrain so the flowing water have enough time to infiltrate. The analysis shows about 18% percent of the site has a steep slope which is not suitable for a Biofiltration swale construction. The most extended part of the flat land is located West side of the main runway which has the most suitable slope for a Biofiltration swale.

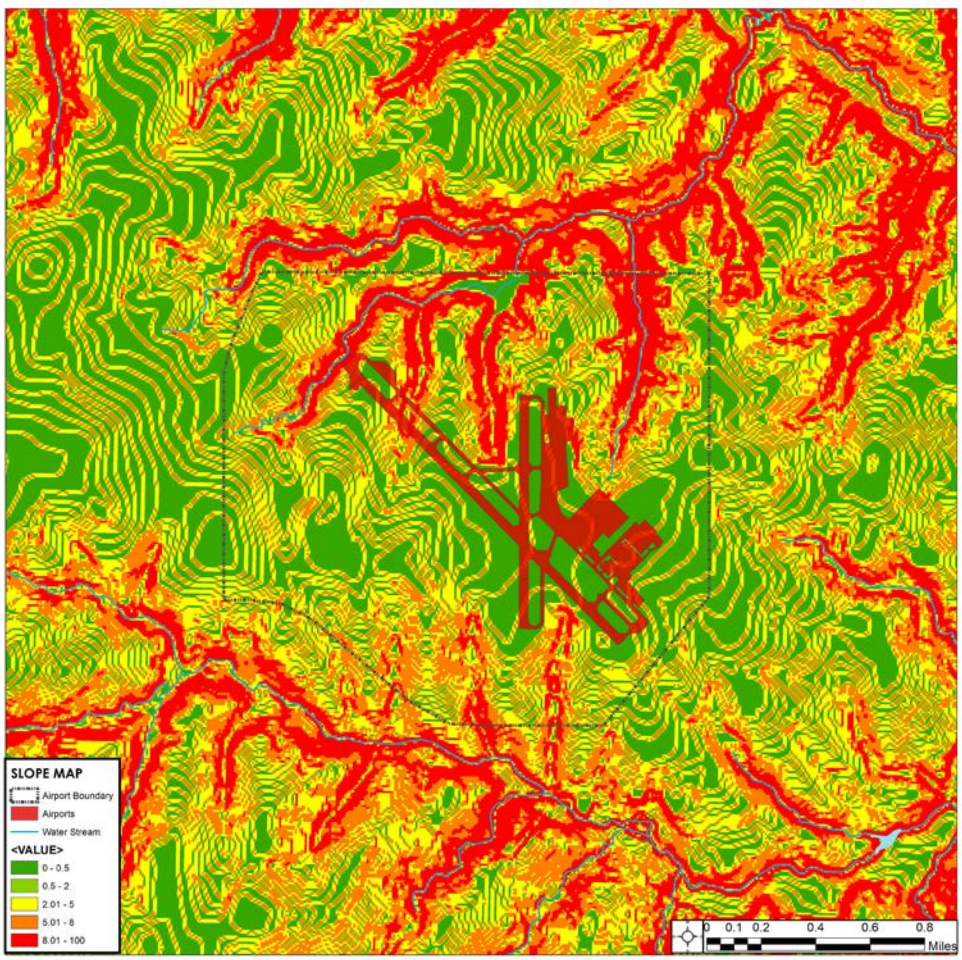

Figure 7 Site Slope Map

Water flow direction map illustrates the direction of water running-off from each point on the map. Pixels with black color means the water will flow between North to East. Dark gray pixels show the water will flow between East to South. Following that, light gray pixels indicates water flowing South to West and white pixels means water flows between West to North. This map shows that 73% of water inside captured boundary flows between East and South. The flow direction map helps to locate the suitable land for Bio-filtration system, since the system needs to happen in an up-stream location, to let he polluted flowing water filtrate before it enters the existing water system.

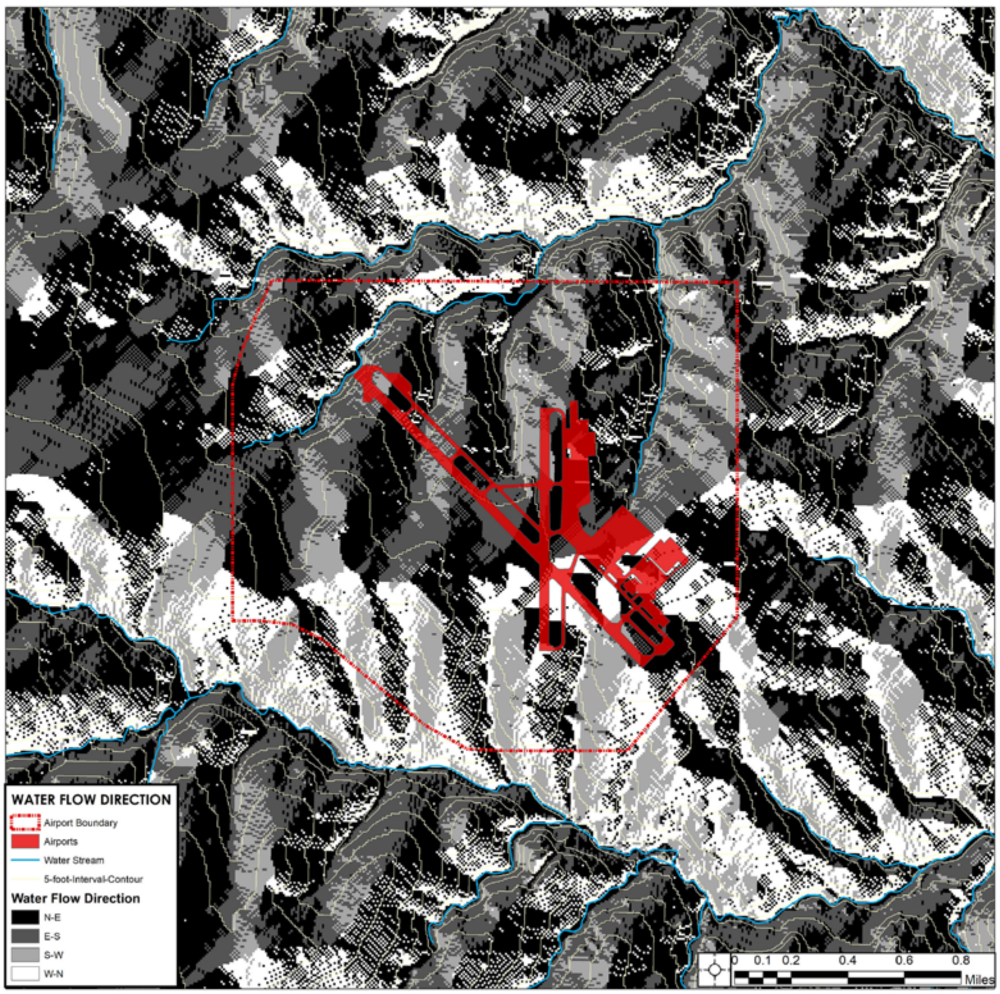

Figure 8 Water Flow Direction

Land cover maps indicates existing condition of the site land cover. The developed areas are buildings ,devided into high, low and medium dencity and also roads and heighways. Green pixels show the diffrent vegetation density and open land coverage. The developed land cover is not easy to change and should be considered constant condition. The open spaces are the opportunistic lands for future develompnet, how ever the high dencity vegitated lands worth preserving. Within the aiport boundy 24% of the land is covered by high density vegetation which can potencialy be preserved since it already functions as a biofiltration system and can mitigate stormwater pollution.

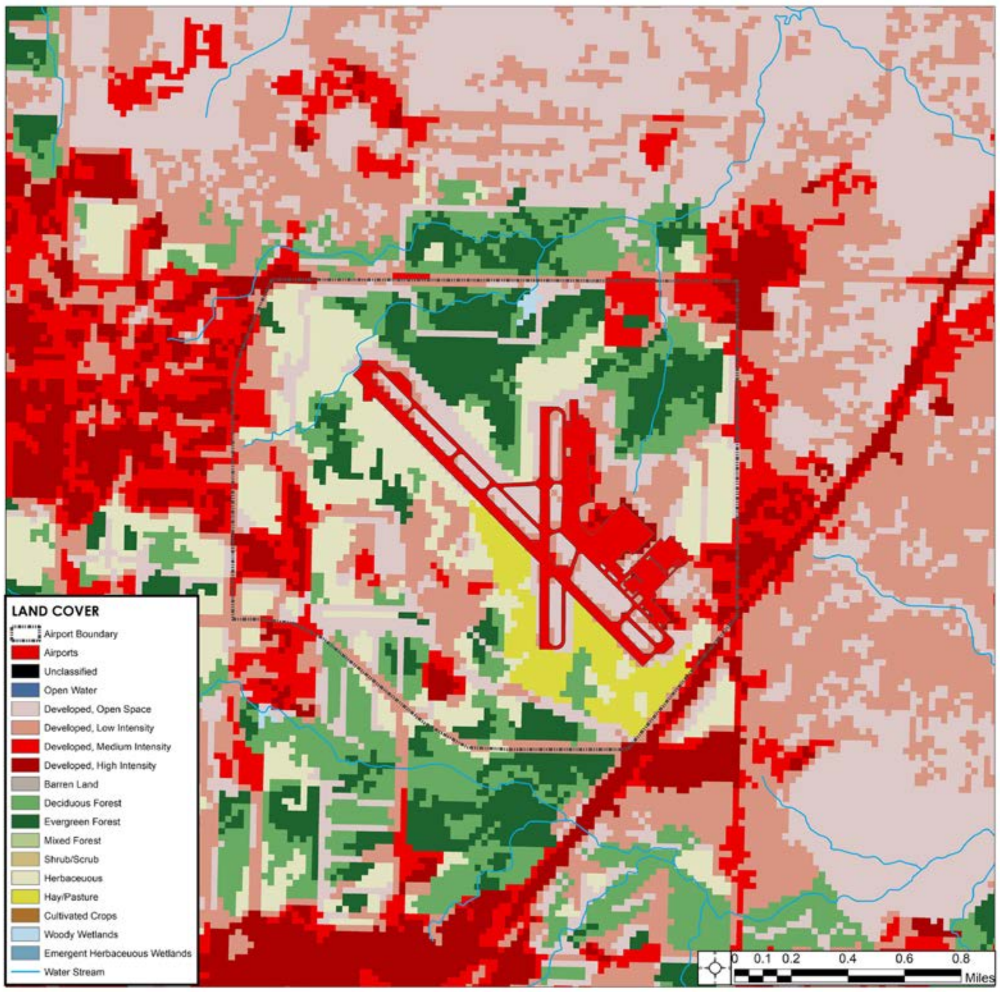

Figure 9 Land Cover Map

The soil map illustrates soil quality based on soil groups of A (silty clay, sandy clay, clay loam), B (silt, silty loam, sandy loam), C (sandy clay loam, low infiltration) or D (clay loam, silty clay loam, sandy clay or clay) which is categorized based on the percentage of clay, sand and loam in soil texture. Soils with high percentage of clay is very typical in our site. Clay soil has low level of permeability and causes flooding but has low level of erosion. The highly erodible and low permeable soil is not suitable for a bio-filtration system. As a result, the soil texture needs major transformation for new bio-filtration system construction.

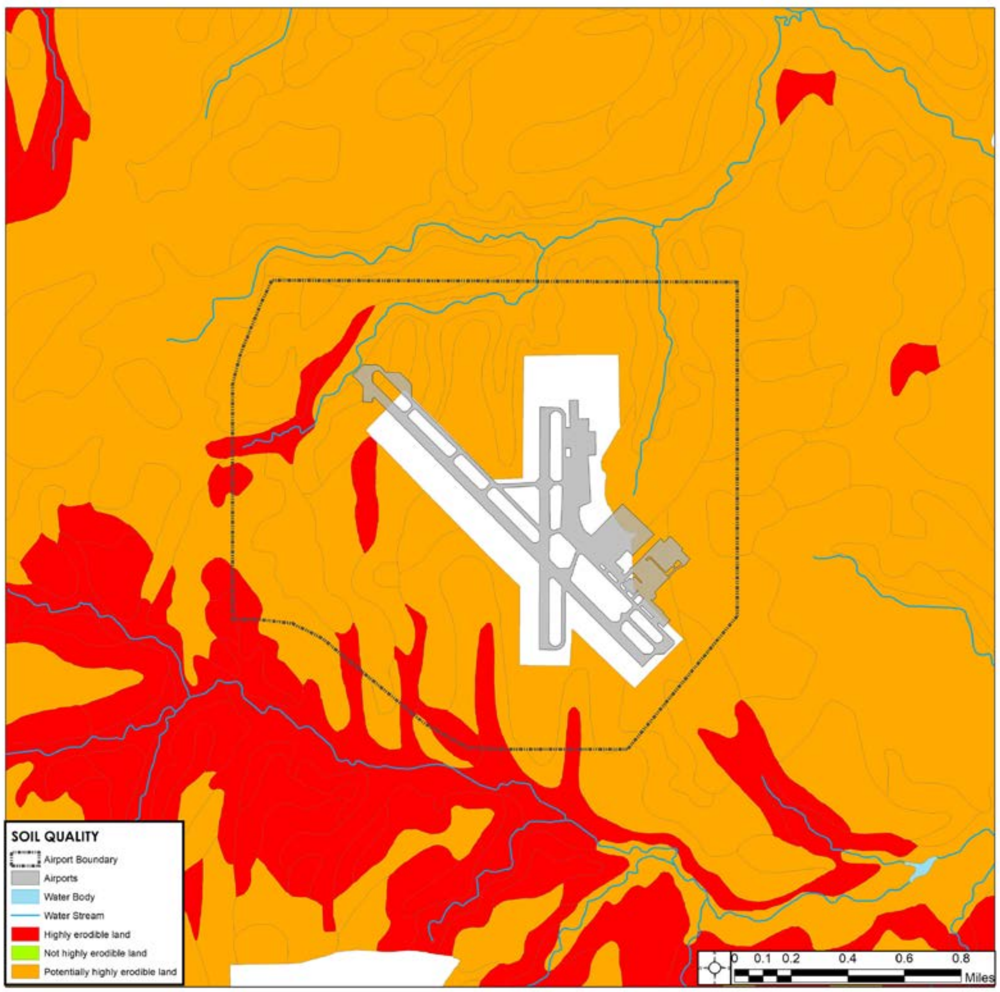

Figure 10 Soil Categories

The site circulation map illustrates the active vehicular roads and entrances to the site. There are two major entrances to the airport, the one on the North East side is used by passengers and airport employees and the one on South West corner is used for services and access to the military camp. The airport is fenced-off all around the perimeter. Minor gates are not regularly used and they are conducted for safety and regulation reasons.

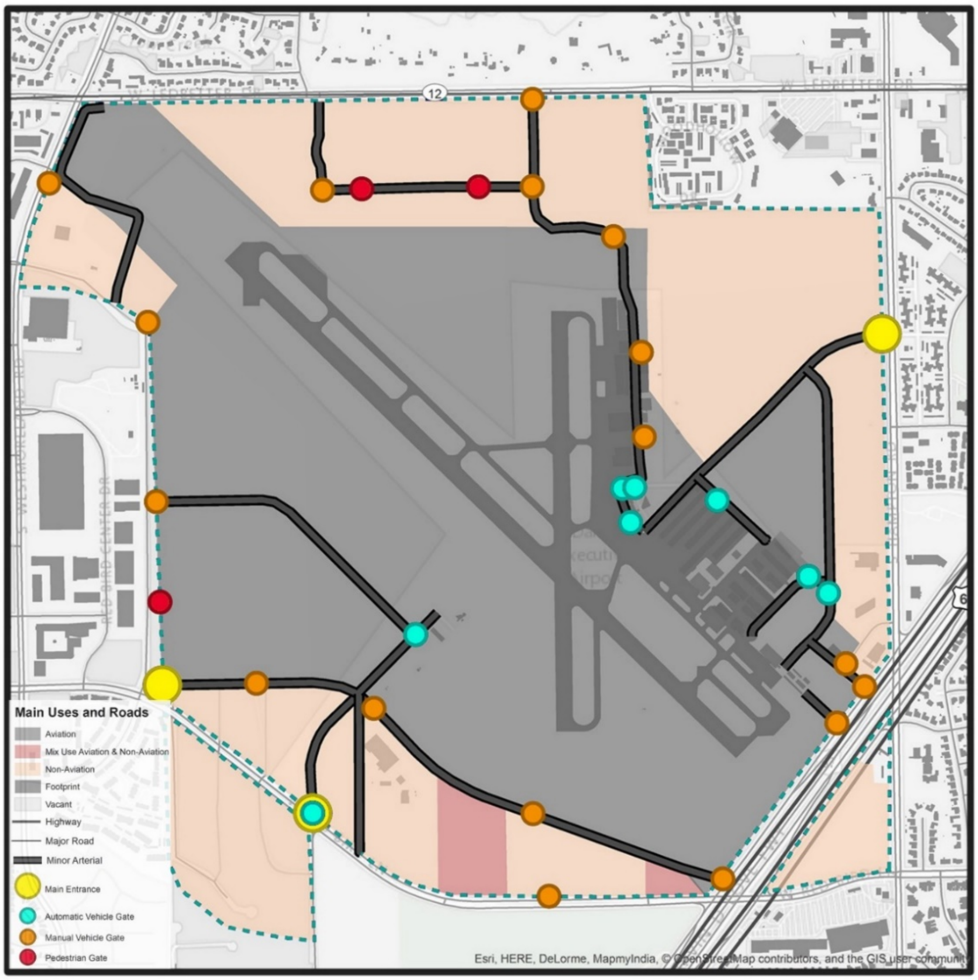

Figure 11 Current Land Use and Roads (DEA future master plan, City of Dallas, 2017)

Proposed future master plan indicated 5 major land uses inside airport boundary. Open space areas will have the same vegetation and can be considered as conservation portion of the BMP. Airfield operation zone has potential space for future runway expansion but cannot be changed for any other uses. Aviation related development includes additional aircraft parking, hangers and taxi way. This is going to be developed with impervious surfaces and buildings. Mix-Use development are leasable lands that can be short office building for activities such as pilot schools or community centers. (Mentioned by airport manager) Non-navigation development will remain the lands with open space but the land cover may be disturbed.

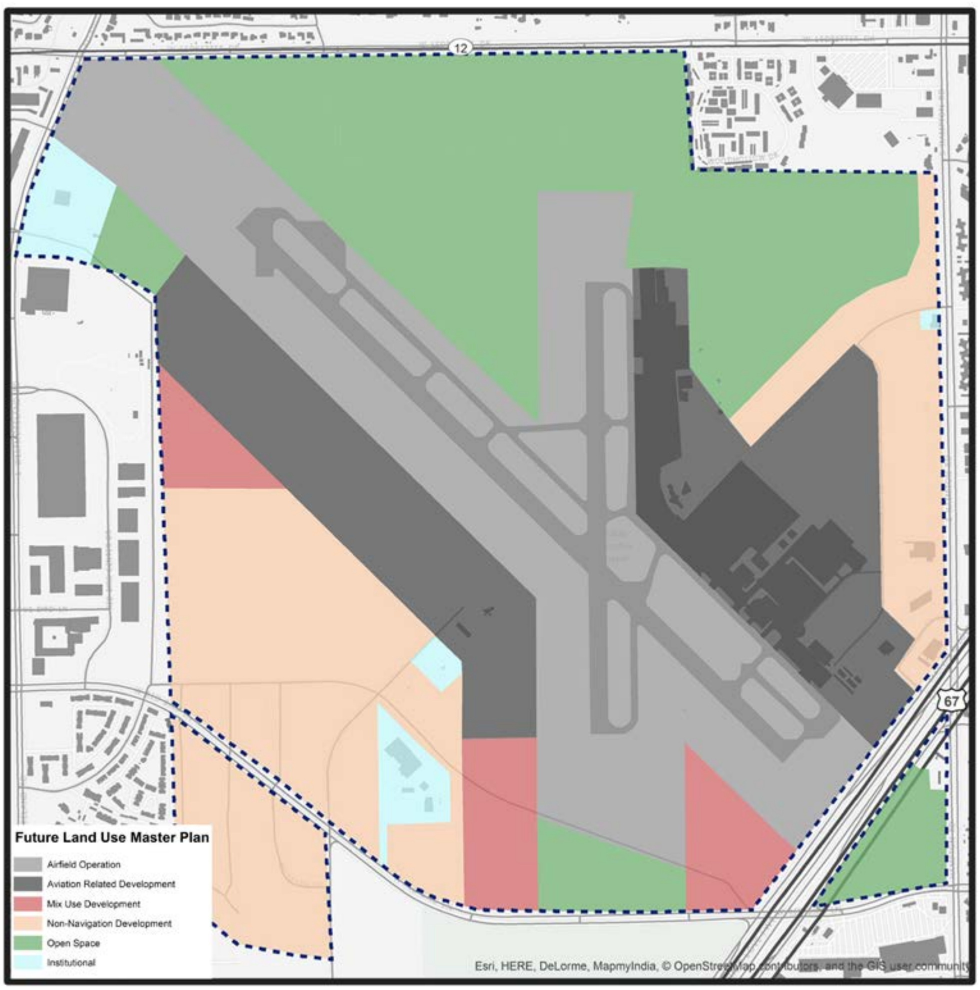

Figure 12 Proposed Future Land Use (DEA future master plan, City of Dallas, 2017)

4.2. Suitability Analysis (McHerg Method)

The result of the weighted overlaid rasterized data sets is the suitability map that indicates locations on map that have variable level of suitability for a BMP in Dallas Executive Airport.

The following illustration will show the layers of re-classified data that have been overlaid in suitability analysis:

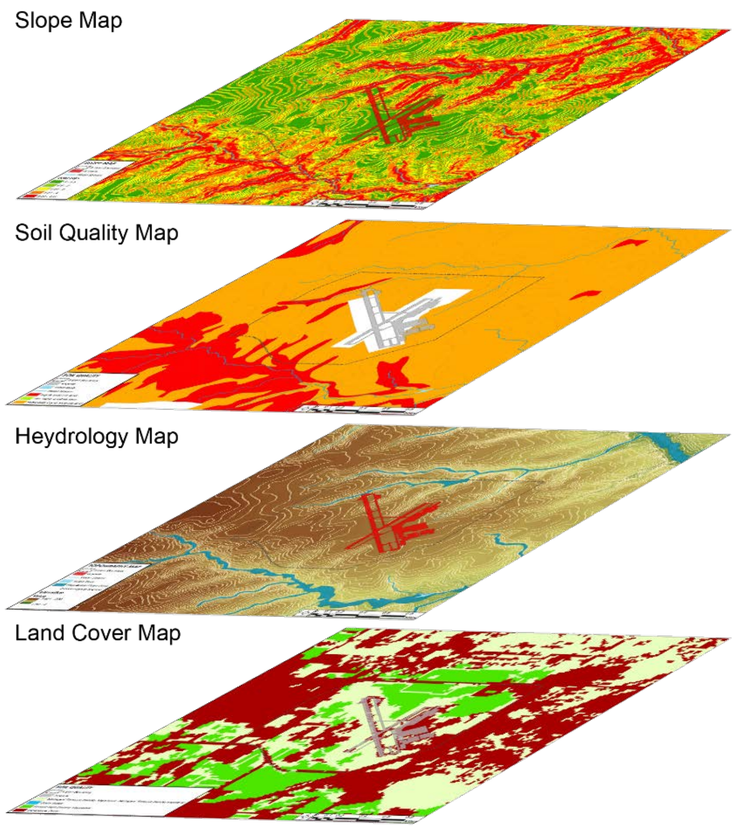

Figure 13 Suitability Data Map Layers

In order to evaluate the influence grade for each factor, list of features have been considered; such as: The adjustability, cost of change in condition and data accuracy. For example; the developed land cover is not adjustable or the cost of change in grading condition is cheaper than changing the soil quality.

Table 4 illustrates the composite suitability chart with weighted values based on analyses above: Physiographic conditions, Hydrology features, Soil quality and existing Land cover. In order to have enough time for flowing water to infiltrate the slope should be less than 2%. As the table indicates the slope between 0-2% is highly suitable. The areas with the slope of 2-8 % are not suitable for a Biofiltration swale, but the grading can be change by construction which leads to a moderate suitability grade.

In order to construct the Biofiltration swale, areas with erodible soil needs to be avoided because erodible soil get washed away with flowing and running water which is undesirable for a bio swale. However, areas with potential erodible soil are moderately suitable because the soil can be removed and changed with a desirable soil texture.

Since most of the stormwater run-off will flow to the catch basin areas, those are the most suitable locations for a Biofiltration swale. The 30 feet buffer zone from the creeks are not suitable for any development because the riparian corridor which expands to 30 feet from the creek bank controls flooding and prevents erosion during high waters and severe rain events.

The land cover map shows the site has over 18% of high density vegetation which is not suitable for any construction and should be preserved. The buildings and reads are existing and cannot be moved so those areas are not suitable either. This site contains about 45% of managed turf and open spaces that is the most suitable land cover for new construction of a Biofiltration swale.

BMP SYSTEM SUITABILITY ANALYSIS				
			Grade	Percentage
Environmental Factors				
Physiography	Slope	0-0.5%	10	15%
		0.5-2%	8	
		2-5%	6	
		5-8%	3	
		>8%	1	
Soil	Soil Erodibility	Not erodible	10	30%
		Potentialy erodible	5	
		Highly erodible	1	
Hydrology	Flood plain	out of zone	9	20%
		100 year	10	
	Catch Basin Zone	0-30'	10	
		30-50'	9	
		>50'	8	
	Exposure from creek	0-30'	1	
		>30'	10	
Land Cover	Forest	Shrubs	1	35%
		Tree Canopy	0	
	Managed Turf	Turf	10	
		Crops	9	
	Developed	Building	0	
		Impervious Surface	0	
				100%

Highly Suitable	9-10
Very Suitable	8-9
Suitable	7-8
Moderatly Suitable	5-7
Preffarably not Suitable	2-4
Not Suitable	1-2
Restricted	0-1

Table 4 Suitability Chart

The following figure is the result of suitability analysis that illustrates the suitable location rating for application of the best stormwater BMP on our site:

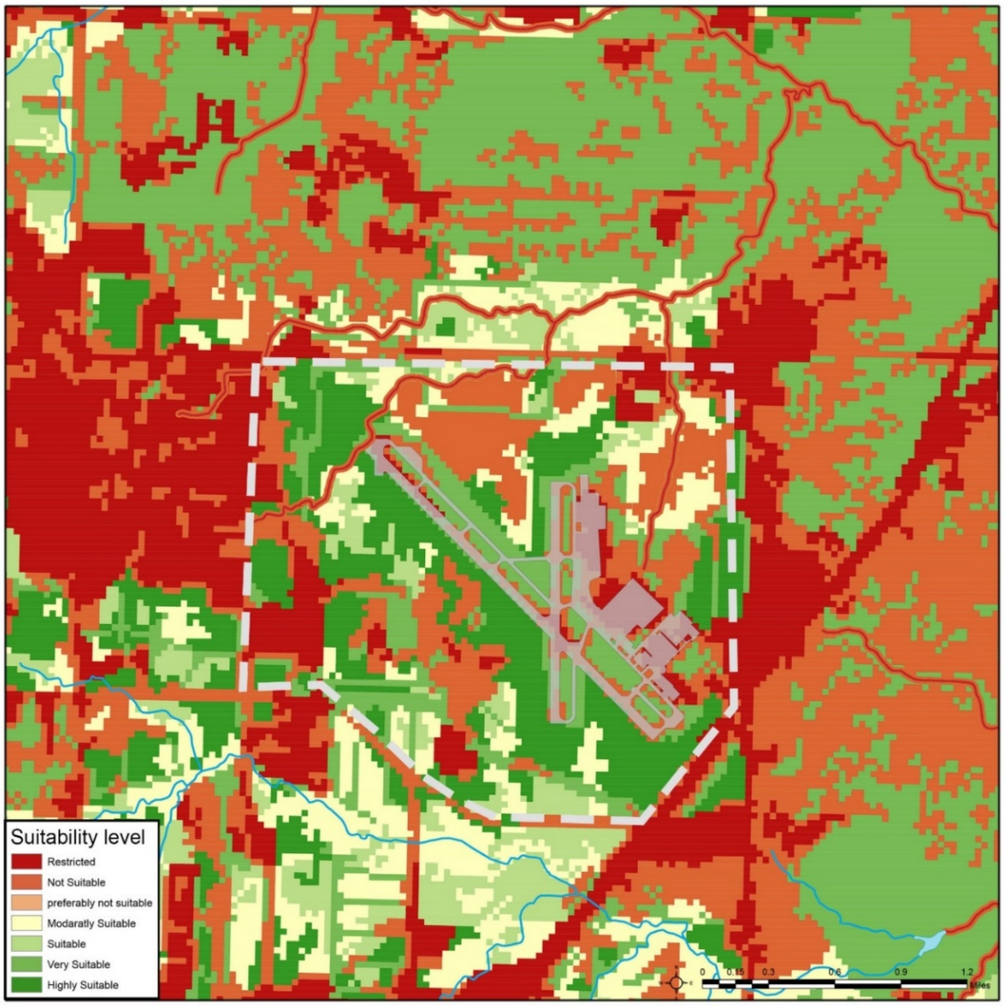

Figure 14 Suitability Analysis Map-BMP

The suitability analysis result map indicated that the site has different suitability condition for implementation of a BMP structure. For example, the darker red areas are the least suitable condition for any BMP implementation of site. At the same time the dark green areas are the most suitable lands for a BMP implementation. However, the lighter green and lighter red areas are not absolutely suitable or not suitable and they need further consideration in order to be suitable for BMP implementation. For example, the light-red areas can be a suitable location but some features such as soil texture or slope needs to change before any BMP implementation.

4.3. BMP Calculation

Storm Water run-off calculation: The area used in the following calculation is converted into acres. The area of an acre is equivalent to 43,560 sq. ft.

Pre-Development Stormwater Runoff – Dallas Executive Airport					
Description	Area (sq. ft.)	I (inches/hour)	Area (Acres)	C (co-efficient number)	Q=CiA (cu. ft/sec)
Paving/concrete	4466298	2	102.5	0.80	164
Turf/ Planting	38352553	2	880.5	0.20	352.2
Total	42818851	-	983	-	**516.2**

Table 5 Pre-Development Stormwater Runoff Calculation-pre-development

Post-Development Stormwater Runoff – Dallas Executive Airport					
Description	Area (sq. ft.)	I (inches/hour)	Area (Acres)	C (co-efficient number)	Q=CiA (cu. ft/sec)
Paving/concrete	8167400	2	187.5	0.80	300
Turf/ Planting	34651880	2	795.5	0.20	318.2
Total	42818851	-	983	-	**618.2**

Table 6 Post-Development Stormwater Runoff Calculation-pre-development

The New Development will **increase 102 $ft.^3$/sec of run-off** and adds 85 acres of impervious surfaces.

Run-off Volume after development:

The volume (Q) of run-off water from 85 acre (A) additional impervious surface (CN=98) in a 1.5 inch (P) rain (average in DFW) event is:

$S = 1000/98 – 10 = 0.2$

$0.2 \times S = 0.2 \times 0.2 = 0.04$ $0.8\ S = 0.8 \times 0.2 = .16$

$Q = (P - 0 .2\ S)^2\ / (P + 0.8\ S) = (1.5-0.04)^2 / (1.5 + 0.16) = 2.13 / 1.34 = 1.59$ inches

Q = 1.59 / 12 x 85 x 43.56 = **49060 cubic feet**

Flow depths: While Q, n, and S are known values in the equation, based on the project's specifics, the area and wetted perimeter (and therefore the hydraulic radius) are unknowns. For this reason, it is easier to set up as a spreadsheet and assign various depths, which allows the area, the wetted perimeter, and the hydraulic radius to be calculated. From these values Q can be calculated for each of the depths as illustrated on following Table. The row that represents the site is the row that has the nearest Q that has been calculated to enter the Bioswale during WQF events, from which the depth and velocity can be read. Various hydraulic references present such parametric tables for trapezoidal cross sections. For example, with the site parameters shown in Methodology (note that Manning's n is for the WQF conditions), and with the Q_{WQF} as 0.51 cfs, the depth in the Bioswale would be approximately 2.4 inches, and the velocity would be 0.23 ft/sec.

depth inches max = 6 inches	y (=Depth) (ft)	A (ft^2)	P (feet)	R (feet)	Q_{WQF} (ft^3 / sec)	Velocity (ft/s) max = 1.0 ft/s
1.2	0.10	1.04	10.82	0.096	0.157	0.15
1.8	0.15	1.59	11.24	0.141	0.311	0.20
2.4	0.20	2.16	11.65	0.185	0.507	0.23
3	0.25	2.75	12.06	0.228	0.740	0.27
3.6	0.30	3.36	12.47	0.269	1.011	0.30
4.2	0.35	3.99	12.89	0.310	1.317	0.33
4.8	0.40	4.64	13.30	0.349	1.659	0.36
5.	0.45	5.31	13.71	0.387	2.035	0.38
6	0.50	6.0	14.12	0.425	2.446	0.41

Table 7 Manning's Equation solved for particular conditions by assuming depth values

4.4. Analysis Conclusion: **Preservation** and **Suitable BMP location** Boundaries

In conclusion of the analysis, there are 2 major BMPs that are applicable to Dallas Executive Airport boundaries: 1) Preservation 2) LID structure in Suitable areas

The Excising site has 11.6% impervious surfaces and over 88% pervious lands. Preservation of the existing pervious surfaces is the priority in the proposed BMP application (Fig. 16).

Figure 15 BMP Location Analysis Conclusion Diagram

The proposed future land use master plan for the airport needs to be updated based on suitability analysis in order to achieve best result for BMP structure. The figure 17 shows the suitable BMP location overlapping with portion of the proposed future master plan development. The proposed future master plan needs adjustment based on suitability analysis and needs to provide required amount of land for employment of the BMP structure.

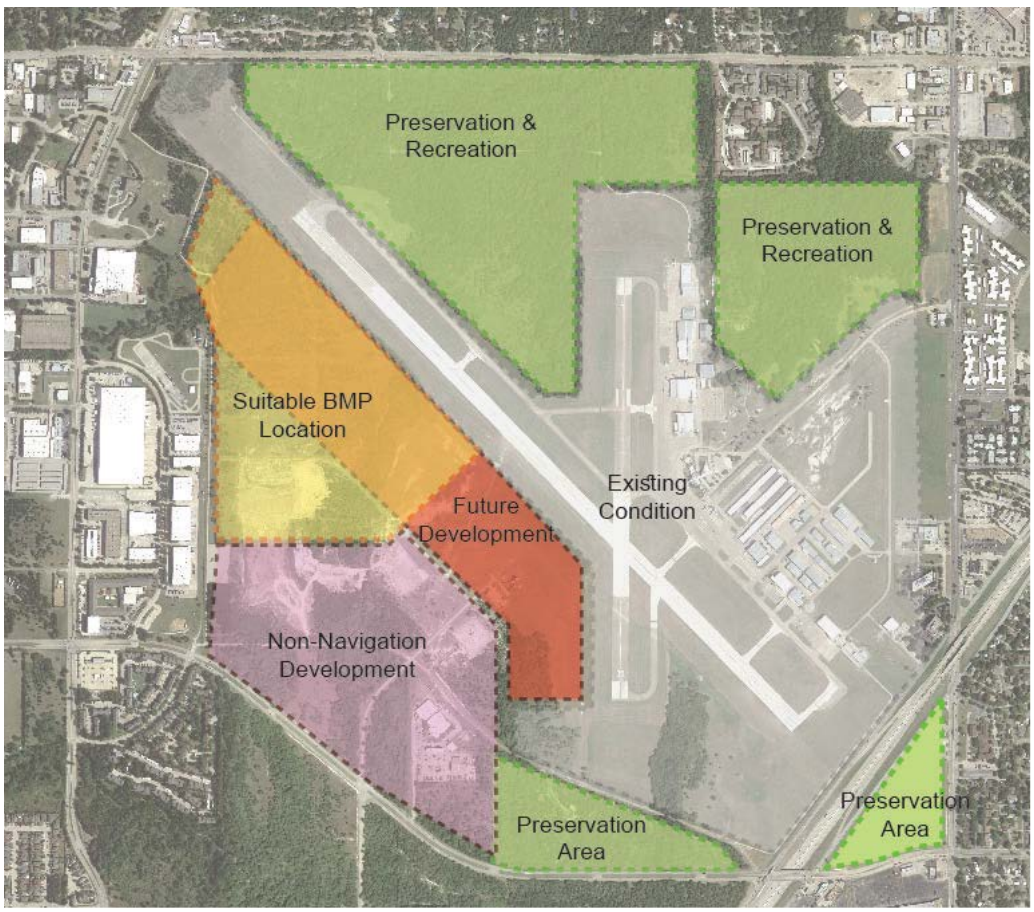

Figure 16 Future Development vs. BMP Suitable Locations

4.5. Interview Findings

4.6.1 Interview with Airport Manager

The following bullets are a summary of important factors that have been discussed by the City Airport Manager:

The Airport manager started the conversation with a statement saying that the Airport landscaping and storm water management being two of the biggest challenges they face. She emphasized that anything that attracts birds or wildlife is not a good thing. She mentioned that the airport is under a wildlife hazard management plan which is a FAA regulation required by FAA and the purpose of that is to minimize the dangers that wildlife can create on airport like: birds, coyote, large mammals etc.After asking about stormwater management plan at the airport and landscape as a solution, she mentioned that they are trying to do is to encourage growth of Bermuda grass in safety areas and targeting to eliminate the weeds because the seed heads are the bird's attractants. She also said that new construction inside airport boundary is allowed, but again the plants and the soil would have to be very specific and would have to comply with the wildlife hazard management plan. She added that the requirements for that change is depending on the length and width of the runway and also where taxi ways are located because the FAA requirements are going to be based on everything from the type of traffic and airport takes. She discussed her concern on wildlife management and said that they have a quite bit of natural water around and that's a challenge not for flooding but it is for wildlife management. She responded to the question about deicing and said they use deicing for runways and taxi ways but not for aircrafts. She noticed that all airports are required by NEPA (National Environmental Protection Act) so even something as simple as building a hanger on an airport requires an environmental questioner be filled out that deals with a number of environmental issues including storm water.

4.6.2. Interview with Hydrology Specialist:

The following bullets are a summary of important factors that have been discussed by the AgriLife Institute professor and hydrology specialist:

The initial suggestion of the interviewee was that: “The new generation of airports need to be greener and more sustainable”. He mentioned that there are specific design criteria for a rain garden or bio-swale. He also referred to the fast that different type of LID structures can be used for stormwater management. He encouraged that the design should address and consider the additional stormwater caused by new construction, as well. He emphasized on the importance of the technical calculations. Besides that, he mentioned that the plant list and soil structure are the most important part of a rain garden or any bio-filtration system. He added that If there are wildlife issues at the airport, the plant list need to exclude plants with bird attraction.

4.6. Design Criteria:

To perform as an effective Treatment BMP, the Bio-filtration System must meet certain design criteria; the primary factors to be incorporated into the design are mentioned in the following table:

Parameter	Min. Value	Max. Value
Flow Rate	For water quality treatment: WQF	For roadway drainage ("Design Event")
Bottom Width	0 ft, as v-ditch 2 ft, as trapezoid	Consult with District Hydraulics and District Maintenance
Side Slope (sides of the Bioswale, in cross section)	4H:1V	3H:1V with District Maintenance approval
Longitudinal Slope	0.25%	1% to 2 % preferred. 6% maximum. The resulting depth, velocity and HRT must meet the Interrelationship formula
Hydraulic Residence Time (HRT) at WQF	5 minuets	No maximum
Length of flow path	As required by minimum HRT	No maximum
Flow Depth during WQF	No minimum	6 inches
Velocity	No minimum	During WQF: 1.0 ft/sec During HDM flow: 4.0 ft/sec
Interrelationship Formula for HRT, depth and velocity	1300 sec^2/ft^2	No maximum
Manning's n value	During WQF: 0.20 to 0.30 but 0.24 recommended During HDM flow: 0.05	
Hydraulic conductivity of the soils in the Biofiltration Swale	There is no minimum set of this parameter at this time set for water treatment purposes.	

Figure 17 Biofilteration Design Criteria, Source: CDOT (2012)

Additional comments for biofiltration design:

-The Bioswale should be designed with the maximum length (in direction of flow) as allowed by the site. In general, the flatter the slope, the shorter the Bioswale length required to meet Treatment BMP requirements.

-The width of the Bioswale is often the most easily changed site variable if the original proposed dimensions do not satisfy depth, velocity and Hydraulic Residence Time (HRT) criteria at WQF, but sometimes the slope may be reduced.

-The tributary area upstream of Bioswales is usually not as large as the tributary areas for volume-based Treatment BMPs.

-Calculations for the Bioswale, especially the HRT, are easier if most or all of the QWQF enters at a discrete location at the upstream, rather than at distributed locations along the length of the Bioswale. However, if the flow enters the Biofiltration Swale continuously along the length of the swale or at multiple discrete locations, other rational methods should be employed. In the case of continuous flow entering the swale, the PE may wish to initially calculate the depths and velocities at selected points along the swale to verify that the depth or velocity has not exceeded the maximum allowed values. This same calculation could also be used if there is a change of grade. The length of the swale that would qualify as a Biofiltration Treatment BMP must be upstream of the location where either the maximum depth or velocity was exceeded. The calculation of the HRT when the WQF enters at multiple (actual entry points or discretized from continuous flow) entry points could be done by calculating the HRT for the flow from each of the discrete entry points, and then taking a weighted average of the HRTs for the entire flow over the length that qualifies as a Biofiltration Treatment BMP; velocity and depth criteria would still need to be met.

-To provide adequate hydraulic function, a swale should also be sized as a conveyance system calculated according to criteria and procedures for conveyance of design storm flows and scour associated with the peak drainage facility design event.

-Check dams within the Bioswale may be considered if the HDM criteria are met, but the HRT, velocity, or length requirements are not met due to the steepness of the proposed Bioswale. Follow the guidance for Temporary Check Dams located in the Caltrans Construction Site BMP Manual. Additionally, check dams should be constructed of soil, placed a maximum of 20 ft apart, have 4H:1V slopes, be a maximum height of 9 inches and be vegetated. Placement should not impede the flow of the HDM Design Event. Check dams must be maintained. (California Department of Transportation (2012))

4.7. Integrated Design Criteria:

The following table integrates the general bio-swale design criteria with site specific and practical consideration achieved through literature review and interviews.

	Literature Notes	Airport Manager's Opinion	Hydrologist Opinion	Conclusion
Stormwater management	Bioswale size should be calculated	It needs improvement	Biofiltration swale is affective in larger scales	Biofiltration swale needs to have right capacity and structure
Plant selection	Plants for filtrating pollutants	Seedless-should overcome weed	drought tolerant and capable of filtration	Rain garden plant list with no bird attractant plants
Soil Quality	Hydraulic conductivity of the soil	Soil can be excavated & changed	Clays soil should change to mixture of soils	Change clay with crushed shell & gravel
Construction Ordinances	FAA regulations-avoid aviation zones	Safety zone/buffer is non-constructible	consider future construction	The suitable location needs to follow ordinances
Maintenance	Maintenance should not add more pollutants	Restricted areas are not regularly maintainable	Native plants & suitable soil reduces maintenance	Suitable design reduces maintenance

Table 8 Integrated Design Criteria

5. Design and Planning

5.1. Site Plan and application

The design solution is responding to the future master plan development. As mentioned in analysis and findings section, preserving the existing forested area which already captures and filtrate stormwater before it enters the stream on the North side. This portion of the site has recreational opportunity since it is located adjacent to residential neighborhood. The suitable BMP location is located North-West side of the new development to capture and filtrate additional run-off water from impervious surfaces.

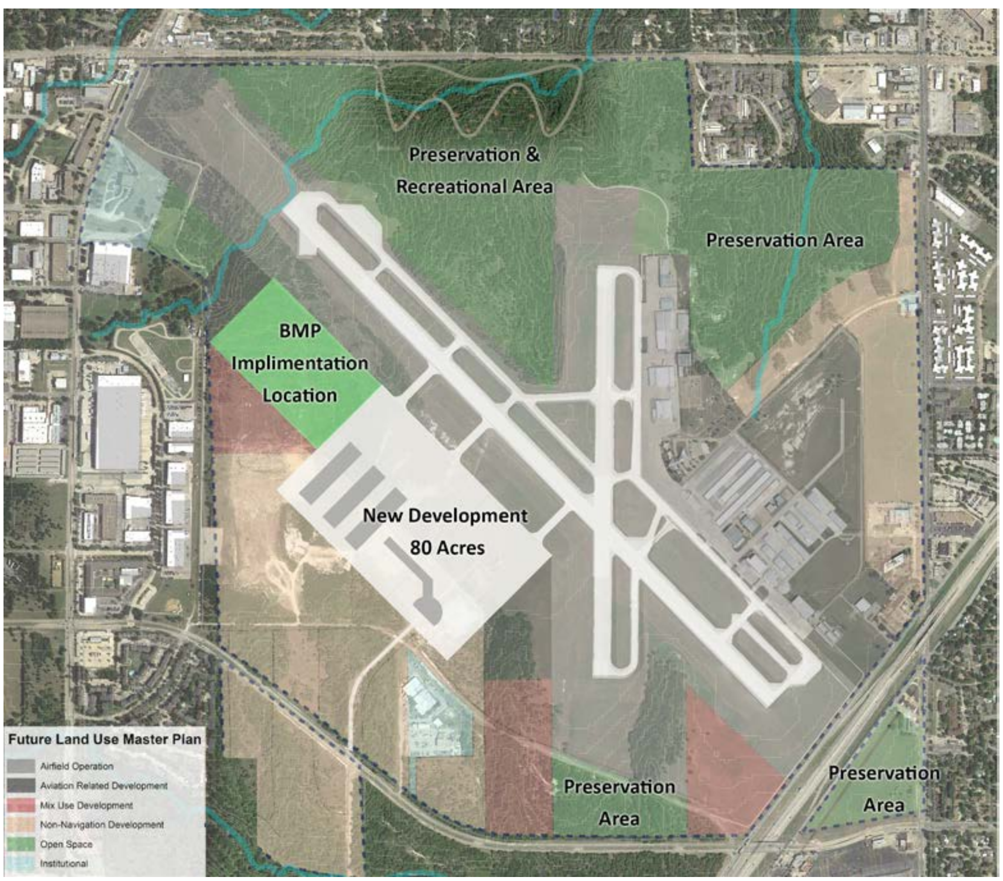

Figure 18 Site Plan and Application

5.2. Biofiltration Design

The Analysis and Findings chapter leads to Low Impact Development as best Stormwater Management Practice on specific and suitable location as indicated in Figure 17. The new development will add 49060 cubic feet of stormwater run-off. The LID structure should be designed to mitigate the additional run-off produced by construction of new impervious surfaces. The Biofiltration swale requires to be placed in the right location and with constructed with the right size and structure.

5.2.1. Biofiltration Suitable Location

In Dallas Executive site, based on the suitability analysis, slope and soil hydrologic group, the most suitable location for a LID structure is on the North-West side of the new development which act as a catch basin. 2/3 of the stormwater running off from the new development area will flow into this area. Referring to California Department of Transportation manual:

> "Biofiltration Swales, and the related Biofiltration Strips, are probably the least expensive Treatment BMPs for an area, if the proposed location is suitable. They can be placed as a stand-alone device or can be placed usually as the first BMP encountered in a "treatment train" and should be considered upstream of other Treatment BMPs that benefit from pretreatment to reduce sediment loading, such as Infiltration Devices, Detention Devices, and Wet Basins. However, to provide effective treatment of runoff, the proposed location must be able to support the chosen vegetation; locations should be sought that have sufficient open space, adequate sunlight for vegetation growth, and topography to meet the hydraulic requirements". (Biofiltration Swale Design Guidance, 2012. P-5)

Figure 21 indicated the suitable location for a Biofiltration Swale and its relation to existing site condition and future master plan.

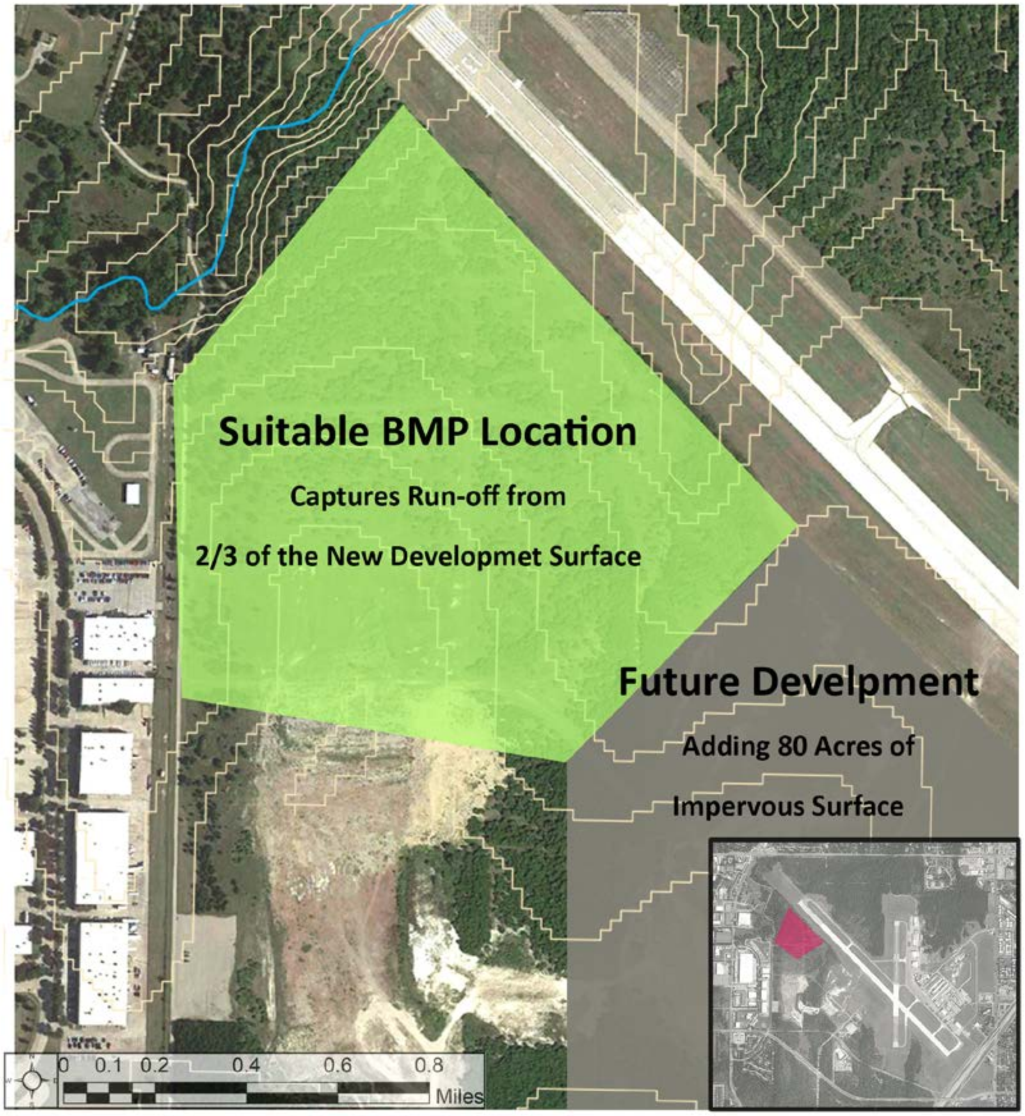

Figure 19 Biofiltration Location

5.2.2 Biofiltration Swale Structure Size

A typical Bio-filtration system holds up to 12 inches of rain. The new development area creates 49060 cubic feet of storm water in a 1.5-inch rain event. 2/3 of this volume

(32706 ft.^{3}) will flow to the allocated bio-filtration location. In order to calculate the required area (size) for the applicable bio-filtration system, the following calculation is used:

Runoff volume / water depth = Surface area of Bio-filtration system

32706 / 1 = 32706 ft.^{2}

In order to capture the stormwater produced by the new development, the required surface **area** of the Biofiltration Swale structure has to be: **32706 ft.^{2}**

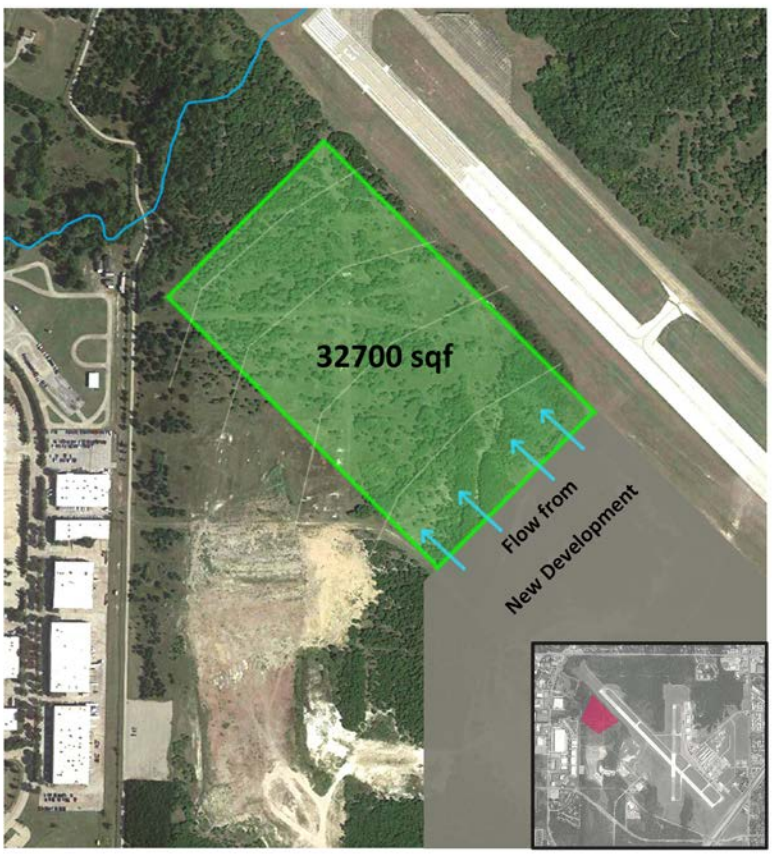

Figure 20 Biofiltration Structure Sizing

5.2.3. Biofiltration Site Plan

Figure 22 illustrates the designed site plan of the Biofiltration system and its relationship with the site condition and future development. The grading around the Biofiltration swale needs to change to make sure that stormwater run-off will flow through the system before it enters to the existing water body.

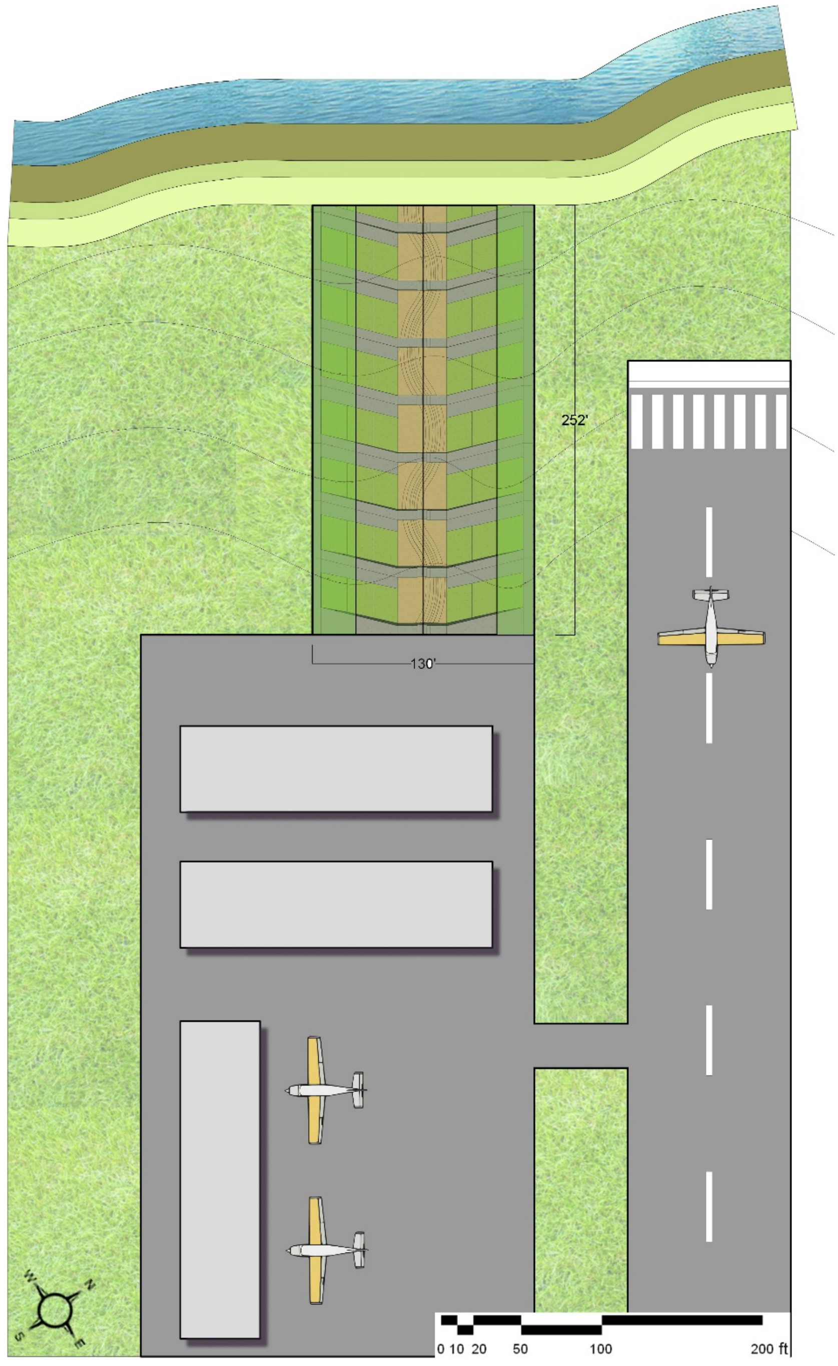

Figure 21 Biofiltration Design: Site Plan

5.2.4. Biofiltration Swale Section

Referring to analysis and calculations, the cross section of the bio-filtration system that can mediate storm-water run-off from the new development area and existing runways is illustrated in figure 23. The figure illustrates the water flow direction into the Biofiltration Swale. The Gabion Dam is designed to increase the Biofiltration capacity and also to mitigate the stormwater run-off rate peak amount. The plants alongside the runway should be low-growing in order to avoid visual distraction for aviators.

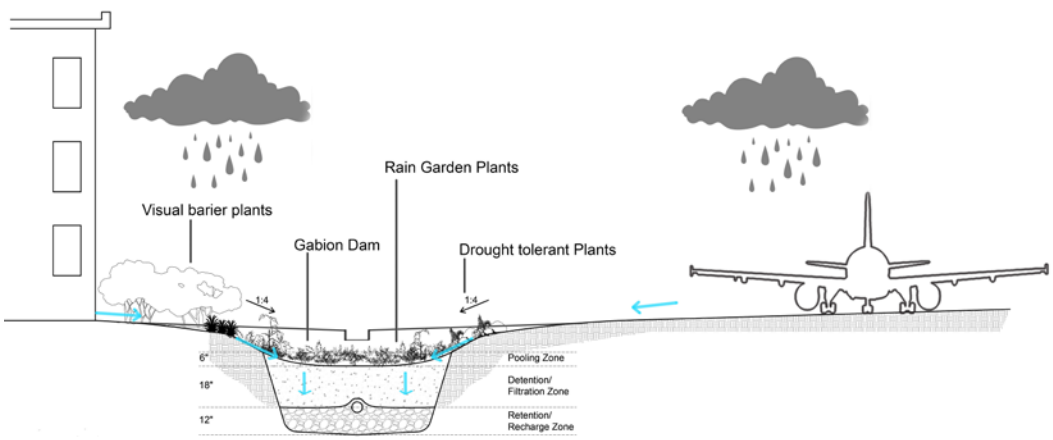

Figure 22 Biofiltration Design: Section View (not to scale)

5.2.5. Biofiltration Swale Diagram

The diagram in figure 24 illustrates the operation process of the bio-filtration system in relation to the airport new development and runways. The diagram also shows that the riparian corridor is protected and any flowing stormwater will be treated through the Biofiltration swale before it enters into that area. Figure 25 is the rendering view of the Biofiltration swale implemented to the Dallas Executive Airport.

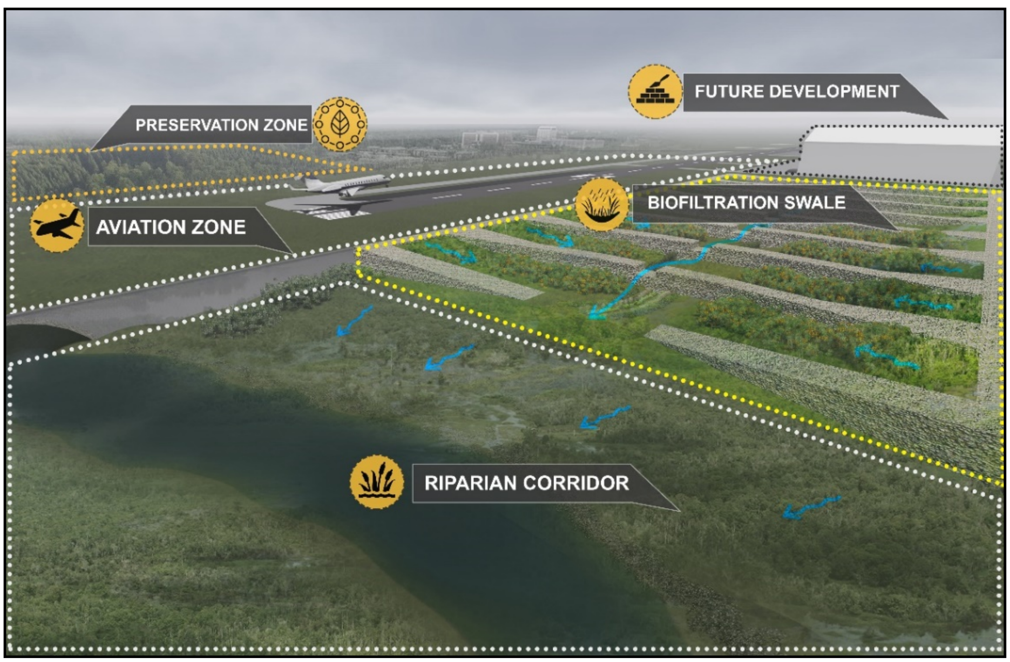

Figure 23 Biofiltration Design: Diagram

Figure 24 Bird's eye view from South West corner

5.2.6. Plant List for Bio-filtration System

Texas AgriLife Institute introduces a list of plant list that can mediate stormwater run-off flow as well as filtrating the polluted water. In order to make the plant list applicable to Dallas Executive Airport Boundary, the plants with bird attraction (with seeds) and tall plants needs to be removed from the list. The adjusted plant list is illustrated in the following table:

Botanical Name	Common Name	Height/Width	Sun/Shade	Wet/Dry
Perennials				
Achillea millefolium	Yarrow	1 ft/1 ft	S	D
Acorus calamus	Sweet flag	4 ft/2 ft	S	W
Alstroemeria pulchella	Peruvian	3 ft/2 ft	S/PSH	W/D
Aquilegia hinckleyana	Texas columbine	12 in./12 in.	S	W/D
Asclepias tuberosa	Butterfly weed	3 ft/6 in.	S	D
Aspidistra elatior	Cast iron plant	24 in./24 in.	SH	W/D
Amorpha fruticiosa	False indigo	5 ft to 10 ft/8 in.	S/PSH	W
Calyptocarpus vialis	Horseherb	4 in./18 in.	SH	W/D
Canna generalis	Canna	2 ft to 6 ft/2 ft to 6 ft	S	W
Coreopsis verticillata 'Moonbeam'	Moonbean coreopsis	1 ft/1 ft	S/PSH	W/D
Dichondra argentea 'Silver Falls'	Silver falls	2 in./4 in.	S/PSH	D
Echinacea purpurea	Purple cone flower	2 ft/2 ft	S	W/D
Eupatorium coelestinum	Blue mistflower	8 in./16 in.	S	W/D
Eupatorium purpureum	Joe-Pye weed	4 in. to 4 ft/2 ft	S/SH	W
Heliopsis helianthoides	Ox-eyed sunflower	3 in. to 5 in./30 in.	S	W
Hibiscus moscheutos	Swamp rose mallow	3 ft to 4 ft	S	W/D
Hymenocallis liriosme	Spider lily	2 ft/1 ft	S	W/D
Ipomopsis rubra	Standing cypress	2 ft to 6 ft/6 in. to 12 in.	S	W
Iris spp. *bearded* and hybrids	Iris	12 in./6 in.	S	D

Iris brevicaulis Louisiana species and hybrids	Louisiana iris	Up to 40 in./6 in.	S/PSH	W
Liatris spicata	Gayfeather	2 in./18 in.	S	W
Lobelia cardinalis	Cardinal flower	2 ft to 4 ft/2 ft	S/PSH	W
Lythrum salicaria	Loosestrife	3 ft/3 ft	S	W/D
Monarda fistulosa	Bee balm	2 ft/2 ft	S	W/D
Rudbeckia hirta	Black-eyed Susan	1 ft to 2 ft/1 ft	S	W/D
Rudbeckia fulgida 'Goldstrum'	Black-eyed Susan	2 ft/2 ft	S	W/D
Rudbeckia maxima	Giant coneflower	4 ft to 6 ft/2 ft to 3 ft	S	W
Ruellia brittoniana 'Katie's'	Ruella Katie	6 in./12 in.	S	W/D
Salvia coccinea	Scarlet sage	3 ft to 5 ft/1 ft to 2 ft	S/SH	W/D
Setcreasea pallida	PurpleHeart	12 in./24 in.	S/PSH	W/D
Sisyrinchium angustifolium	Blue-eyed grass	6 in. to 12 in./12 in.	S	W/D
Solidago altissima	Goldenrod	2 ft to 4 ft/3 ft to 5 ft	S	W/D
Tradescantia occidentalis	Spiderwort	2 ft/1 ft	SH/PSH	W/D
Zephyranthes spp.	Rain lily	6 in. to 10 in.	S	W
Grasses				
Carex spp.	Sedge	Varies	Varies	W/D
Chasmanthium latifolium	Inland seaoats	2 ft to 4 ft	SH	W
Muhlenbergia reverchonii	Seep muhly	2 ft to 4 ft	S	W
Panicum virgatum	Switch grass	3 ft to 4 ft	S	W/D
Itea virginica	Virgina sweetspire	3 ft to 5 ft/3 ft	PSH	W/D
Leucothoe recemosa	Leucothoe, Sweetbell	3 ft to 10 ft/6 ft	S/PSH	W/W/D
Sabal minor	Dwarf palmetto	4 ft/5 ft	SH	W/D
Symphoricarpos orbiculatus	Coralberry	1 ft to 6 ft/1 ft to 2 ft	PSH/SH	D
Spirea x bumalda 'Anthony Waterer'	Anthony water spirea	2 ft to 3 ft/3 ft	S	D

Table 9 Bio-filtration plant list (AgriLife Extension Texas A&M 2013)

5.3. Recreational Opportunity

As mentioned in chapter 4.4 Preserving forested lands with their existing condition will respond to research objective and help mediate stormwater run-off in site. This opportunity can also be re-utilized with recreational function, as well. The forested land on the North side of the site has direct access to Loop 12. It also is adjacent to the residential neighborhood to the north. The design proposal program for this area includes:

1. Wooden paved bike and hike trail that creates berms and valleys with the existing site contours and crosses the creek with light structure bridges.

2. Gazebo structured with wood and recycled composites, located along side of the trail and elevated 4 feet above the ground.

3. Series of 7-foot-tall hedging plans along the fence to improve neighborhood aesthetics and street scape.

Limitation:

The access to the runway needs to be restricted regarding state law. The existing metal fence should be replaced with controlled gates at two access point to the trail.

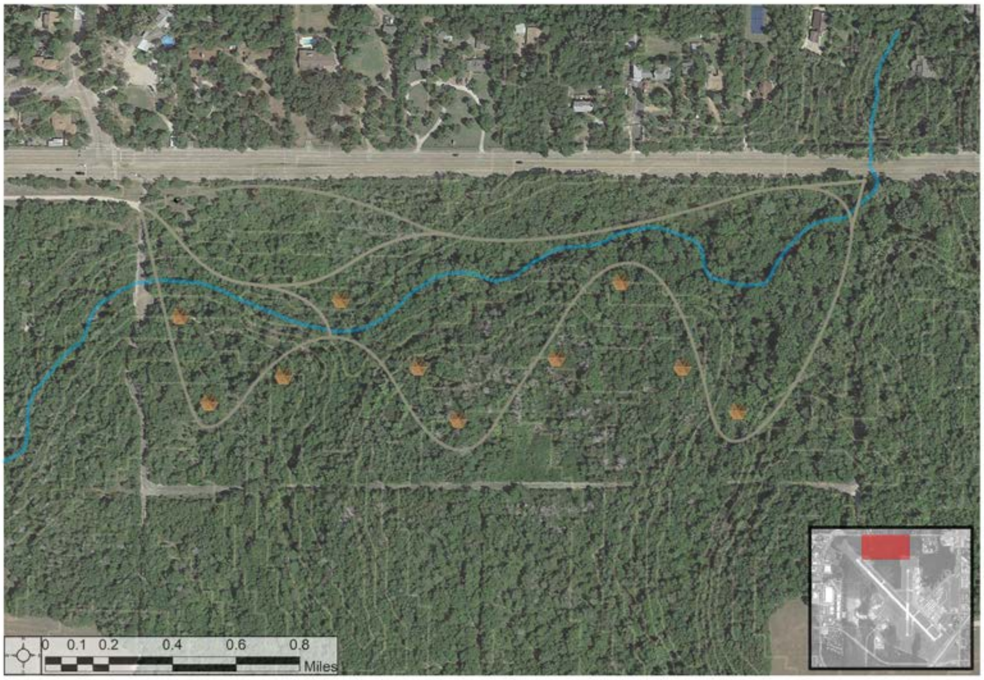

Figure 25 Recreational Design: Site Plan

Figure 26 Recreational Design: Rendering

6. Conclusion

6.1. The Future Master Plan

In conclusion, this design thesis responds to the necessity for a stormwater Best Management Practice solution for Dallas Executive Airport Future Master Plan. The future master plan suggests new development on the site which will add over 85 acres of impervious surfaces to the airport and which contributes and additional **102 ft^3/sec** of run-off water from the airport. The proposed BMP will mitigate run-off from the runways and the new construction that will happen in future airport development.

6.2. Research Question Reviews

A brief review on research questions provides a better understanding of the research conclusion.

Question 1: What is the Best Management Practice to upgrade the stormwater quality at Dallas Executive Airport?

Our site has 2 applicable options; Preservation of the existing forested lands that and Implementing LID structure such as Biofiltration Swale system on suitable areas. The Biofiltration swale needs to has the appropriate design features to respond to future development on the site.

Question 2: What are the stormwater pollution sources at Dallas Executive Airport?

During the severe rain events the amount of run-off from the runway and apron areas will wash off all the pollutions from industrial activities, constructions and aviation maintenance related activities and will carry them to the existing water system which end in Trinity river at the end. The construction of the proposed new phase at the airport will significantly increase amount of pollution from construction activities and also will increase amount of impervious surfaces and more polluted run-off.

Question 3: What are the environmental challenges in airport future master plan development?

Any new landscape development at the airport needs to follow regulation and restrictions adopted by FAA and EPA. For example, planting any vegetation that attract birds is not allowed around airport boundaries or any water body may attract wildlife which is unlikely for the air transportation safety. At the same time, the vast amount of land has been captured by and airport and if it is restricted from any wildlife, then it will become a habitat fragmenting problem. As a result, obtaining the balance between wildlife management and airport environmental improvements has been a challenge that solves with a suitable design application and program.

6.3. Design Recommendations for Small-Scale Airports

This research document suggests landscape architect and airport managers some critical points regarding future small-airport development projects. While designing for future social and economic benefits, environmental impacts should not be underestimated. Small airports are usually located in a residential context therefore environmental management at these airports has direct impact in human health and life quality. In addition, the airport can protect its own micro climate by preventing pollutions and emission produced within its boundary to spread to other locations. Biofiltration swale system can mitigate stormwater pollution in a site with the scale of a local airport. A suitable environmental application can improve sustainability and success of future development of small size airports.

The design recommendations for sustainable stormwater management strategies for small-scale airports include:

- Planning sustainable stormwater management for small-scale airport should be placed in the most suitable location primarily considering existing land cover, site topography and soil quality.
- To make the stormwater management facility more attractive, planners should consider the integration of effectiveness of the stormwater treatment facility and aesthetic features of the LID structure by implementation of an attractive and eye-pleasing planting design.
- The Biofiltration swale design needs to consider future maintenance accessibility. The soil and plants need to be accessible for maintenance facilities.
- Planners should look for opportunities to provide multi-functional programs (such as hiking trail in a protected forested area, leisure programs within stormwater facilities, etc.) to consider adjacent communities as implementing and reinforcing stormwater management on site.
- The bio swale at a small-scale airport needs to implement an object that can distract birds from the planting area. It can be another opportunity to provide identity to the site with creative strategies.

6.4. Future Research

Airport can cause social and financial issues beside the studied environmental issues based on the reports and surveys published by the Dallas Executive Airport website. A future thesis topic can investigate design solutions to improve social benefits of the airport in a residential context. It can also research about the resident's influence on airport future master plan and try to include their ideas and demands in the proposal. A future design thesis can investigate a suitable landscape solution to mitigate air pollution caused by aviation emissions.

The design can be integrated with suggested Stormwater management plan. Also, other types of LID structure could be studied in airport context. As a note for future designers, the proposed design can be implemented with adjustment to same-scale urban facilities in order to improve stormwater quality and avoid long term negative impact on global environment

Appendix A

IRB Approval Letter:

UNIVERSITY OF TEXAS ARLINGTON | OFFICE OF RESEARCH ADMINISTRATION REGULATORY SERVICES

October 31, 2018

Ali Khoshkar
Dr. Joowon Im
School of Architecture
The University of Texas at Arlington
Box 19108

Protocol Number: 2019-0030
Protocol Title: *Strategic Landscape Utilization of Undeveloped Lands within Dallas Executive Airport Boundary: Airport Storm Water Management*

APPROVAL OF MINIMAL RISK HUMAN SUBJECTS RESEARCH WITHOUT FEDERAL FUNDING

The University of Texas Arlington Institutional Review Board (UTA IRB) or designee has reviewed your protocol and made the determination that this research study involving human subjects is approved in accordance with UT Arlington's Standard Operating Procedures (SOPs) for minimal risk research. You are therefore authorized to begin the research as of **October 30, 2018.**

Note that this project is not covered by UTA's Federalwide Assurance (FWA) and the researcher has indicated it will not receive federal funding. You must inform Regulatory Services immediately if the project may or will receive federal funding in the future, as this will require that the protocol be re-reviewed in accordance with the federal regulations for the protection of human subjects.

As Principal Investigator of this IRB approved study, the following items are your responsibility throughout the life of the study:

UNANTICIPATED ADVERSE EVENTS
Please be advised that as the Principal Investigator, you are required to report local adverse (unanticipated) events to The UT Arlington Office of Research Administration; Regulatory Services within 24 hours of the occurrence or upon acknowledgement of the occurrence.

INFORMED CONSENT DOCUMENT
The IRB approved version of the informed consent document (ICD) must be used when prospectively enrolling volunteer participants into the study. Unless otherwise determined by the IRB, all signed consent forms must be securely maintained on the UT Arlington campus for the duration of the study plus a minimum of three years after the completion of all study procedures (including data analysis). The complete study record is subject to inspection and/or audit during this time period by entities including but not limited to the UT Arlington IRB, Regulatory Services staff, OHRP, FDA, and by study sponsors (as applicable).

REGULATORY SERVICES
SERVICES

The University of Texas at Arlington, Center for Innovation
202 E. Border Street, Ste. 300, Arlington, Texas 76010, Box#19188
(T) 817-272-3723 (F) 817-272-5808 (E) regulatoryservices@uta.edu (W) www.uta.edu/rs

Figure 27 IRB Approval Letter P.1

UNIVERSITY OF TEXAS ARLINGTON | OFFICE OF RESEARCH ADMINISTRATION REGULATORY SERVICES

MODIFICATIONS TO THE APPROVED PROTOCOL
All proposed changes must be submitted via the electronic submission system and approved prior to implementation, except when necessary to eliminate apparent immediate hazards to the subject. Modifications include but are not limited to: Changes in protocol personnel, changes in proposed study procedures, and/or updates to data collection instruments. Failure to obtain prior approval for modifications is considered an issue of non-compliance and will be subject to review and deliberation by the IRB which could result in the suspension/termination of the protocol.

ANNUAL CHECK-IN EMAIL / STUDY CLOSURE
Although annual continuing review is not required for this study, you will receive an email around the anniversary date of your initial approval date to remind you of these responsibilities. Please notify Regulatory Services once your study is completed to begin the required 3-year research record retention period.

HUMAN SUBJECTS TRAINING
All investigators and personnel identified in the protocol must have documented Human Subjects Protection (HSP) training on file prior to study approval. HSP completion certificates are valid for 3 years from completion date; the PI is responsible for ensuring that study personnel maintain all appropriate training(s) for the duration of the study.

CONTACT FOR QUESTIONS
The UT Arlington Office of Research Administration; Regulatory Services appreciates your continuing commitment to the protection of human research subjects. Should you have questions or require further assistance, please contact Regulatory Services at regulatoryservices@uta.edu or 817-272-3723.

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Figure 28 IRB Approval Letter P.2

Appendix B

Detailed Interview Report:

Q: Would you please introduce yourself?

- My name is Karen Vanwinkle and I am the airport manager here in Arlington, Texas.

Q: Would you please share your educational and professional background?

- My educational background, I have a BBA in accounting and an MBA in management. I've been at this airport for 10 years and I've been a manager since 2012. My background is generally not aviation; I've worked at city hall before coming out here. But before I was with aerospace manufacturing side for many years before that.

Q: Have you had any experience in airport landscaping and stormwater management?

- Yes, airport landscaping and storm water management are two of the biggest challenges we face. In fact, we have a grant request now to study our drainage patterns on the south end of the airport because we are retaining water which is a good thing normally but its bad thing for an airport; because anything that attracts birds or wildlife is not a good thing. The airport is under a wildlife hazard management plan which is a FAA regulation required by FAA and the purpose off that is to minimize the dangers that wildlife can create on airport, birds obviously but also coyote, we don't have dears here but large mammals can be stroke and almost anything can do damage to an aircraft. But what we are trying to avoid is catastrophic incident.

- We have a stormwater drainage project on the north end of the airport that it is just about to kick off and then we can have stormwater management study on the south end of the airport, probably will kick off in the next six months. We also have a vegetation management program going now. What we are trying to do is to encourage growth of Bermuda grass in what we call our safety area and what we are doing in targeting spring to eliminate the weeds so Bermuda grass can grow and we want to eliminate weeds because the seed heads are the bird's attractants.

Q: Any Contraction allowed on the airport land?

- You could but again the plants and the soil would have to be very specific and would have to comply with our wildlife hazard management plan. Nothing has a seed pot to it, we discourage trees, we discourage ornamental bushes, anything for a bird could roost or nest or small rabbits or such could hide.

Q: What is the requirement for new constructions on airport?

- The requirements for that change is depending on the length and width of the runway and also where your taxi ways are located because the FAA requirements are going to be based on everything from the type of traffic you take. If your runway is capable of taking larger aircraft, then your buffer areas are going to be bigger so it is just depending on what type of aircraft that your airport is capable of landing. Airports are designed based on what we call "aircraft design group". For example, our airport takes up to 737 and MDAD, probably the largest aircraft we take, so our design group will be 3. But for narrower and shorter runways the design group may be 2 or even 1. You can say tree line over on the width is our buffer area. you can also see the streams running on aerial map. We got a quite bit of natural water around and that's a challenge not for flooding but it is for wildlife management.

Q: Do you use de-icing material?

- We use deicing for our runways and taxi ways but not for aircrafts.

Q: Are de-icing materials hazardous to environment?

- All of our de-icing products that we use, are environmentally friendly.

- All airports are required by NEPA (National Environmental Protection Act) so even something as simple as building a hanger on an airport requires an environmental questioner be filled out that deals with a number of environmental issues including storm water.

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