Florida Department of Transportation – Aviation Office

Statewide Airport Stormwater

Best Management Practices Manual

Clean Water – Safe Airports

March 6, 2013
Revision

FLORIDA STATEWIDE AIRPORT STORMWATER STUDY
BEST MANAGEMENT PRACTICES MANUAL

CONTENTS

SECTION 6 – BEST MANAGEMENT PRACTICES

APPENDICIES:

LIST OF TABLES

LIST OF FIGURES

Section 1 INTRODUCTION

101. PURPOSE AND INTENT

The ***Florida Airports Stormwater Best Management Practices Manual*** is intended for use by consultants, regulators and airport sponsors charged with design, permitting and operation of airside stormwater management facilities. The document is directly referenced in the General Permit for Construction, Operation, Maintenance, Alteration. Abandonment or Removal of Airport Airside Surface Water Management Systems, Chapter 62-330.449, F.A.C., and focuses primarily on airport stormwater quality. It sets forth the procedures and criteria for those facilities eligible for the general permit. It is applicable to most, but not all airside facilities, and its use must consider the site specific conditions. This BMP manual is a stand alone document. However, companion documents, the ***Technical Report for the Florida Statewide Airport Stormwater Study*** and the ***Application Assessment for the Florida Statewide Airport Stormwater Study*** provide additional reference material that may be consulted. Also, Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5320-5C must be consulted for airside specific drainage design and stormwater quantity guidance. These documents can be accessed at http://www.dot.state.fl.us/aviation/stormwater.shtm and http://www.faa.gov/regulations_policies/advisory_circulars/

The goals of airside stormwater management are two-fold. From a regulatory perspective, the stormwater management system must meet statutory and rule requirements intended to protect water quality, limit or prevent flooding, and preserve or maintain healthy ecosystems. From a public transportation perspective, the stormwater management system must be consistent with safe and efficient air transportation. Ultimately, from all perspectives, the public is the intended beneficiary of both stormwater management and transportation system efforts.

This manual was assembled because aircraft and airport operations differ significantly from other regulated development. Airport safety may be directly affected by the choice of stormwater management system. Surface water or wetlands in proximity to the airside can and sometimes do become safety hazards, particularly if they are wildlife attractants. Also, the airside operating environment and procedures result in lower pollutant loadings than most other urban land uses. Temporary flooding in extreme events is allowable on the airside. These issues dictate targeted stormwater management practices. Information on the airport environment is included in the following subsection for familiarization purposes.

Information in this manual is intended for design of individual airside facilities or master planning airport airside stormwater management systems. References in **Appendix A** should be consulted for further information on airside stormwater management.

102. INTRODUCTION TO THE AIRPORT ENVIRONMENT

In its basic configuration an airport consists of airside and landside areas. Airside includes all areas commonly allocated for aircraft operations or servicing. They are often separated by a fence or other barrier from landside areas to limit access. Ground vehicle traffic does occur on the airside. It is normally associated with servicing aircraft and routine inspections, and it is generally confined to aprons/ramps.

Typically the airside includes significant open space/grass areas serving to separate runways and taxiways from each other. Elements of the airport airside are:

- One or more runways for aircraft landing and takeoff operations. These are usually paved, but may be turf for facilities serving light airplanes.
- One or more taxiways allowing aircraft to move between the runway(s) and parking areas
- One or more aprons (also called "ramps") for aircraft to park.

Figure 102-1, excerpted from the Airport Facilities Directory, illustrates a Florida airport serving both light general aviation and commercial jet operations.

Landside areas are those where aircraft do not operate. In the most basic form, the landside area is a roadway for access and an automobile parking lot adjacent to the airside. However, the landside may include a number of alternate uses. Airports often own large tracts of land that are not used for aviation purposes. A goal and requirement for airports is that they be as self-supporting as possible. Consequently, commercial and industrial parks are often constructed on non-aeronautical, airport owned land. Some airports also have shopping centers, recreation areas, and professional sports facilities located on their property. These have characteristics typical of other, similar development in Florida. However, they are subject to the same hazard controls that apply to aviation use areas owned by the airport. The rents they pay help support airport operation, maintenance and capital improvement programs. Figure 102-2 shows an Airport Layout Plan (ALP) illustrating various airside and landside land use, and the relations to each other at a Florida general aviation/limited commercial service airport.

Expansion and improvement projects undertaken by airports that typically require stormwater management permits include the following:

- Runways, including new runways and runway extensions
- Taxiways, including new taxiways, taxiway extensions and taxiway widening
- Aprons/Ramps
- New Hangar Buildings
- Terminals, including new terminals and terminal expansions
- Perimeter Access/Safety Roads
- Automobile parking lots
- Access Roads

The above list is not all-inclusive, but is meant to outline primary categories of projects done by airports. Fuel farms and aircraft wash-racks may require stormwater management permits, but are more commonly regulated through industrial wastewater permits. Private developers and corporations often do other landside development. Landside development is outside the stormwater management scope of this manual, but noted safety considerations may still apply.

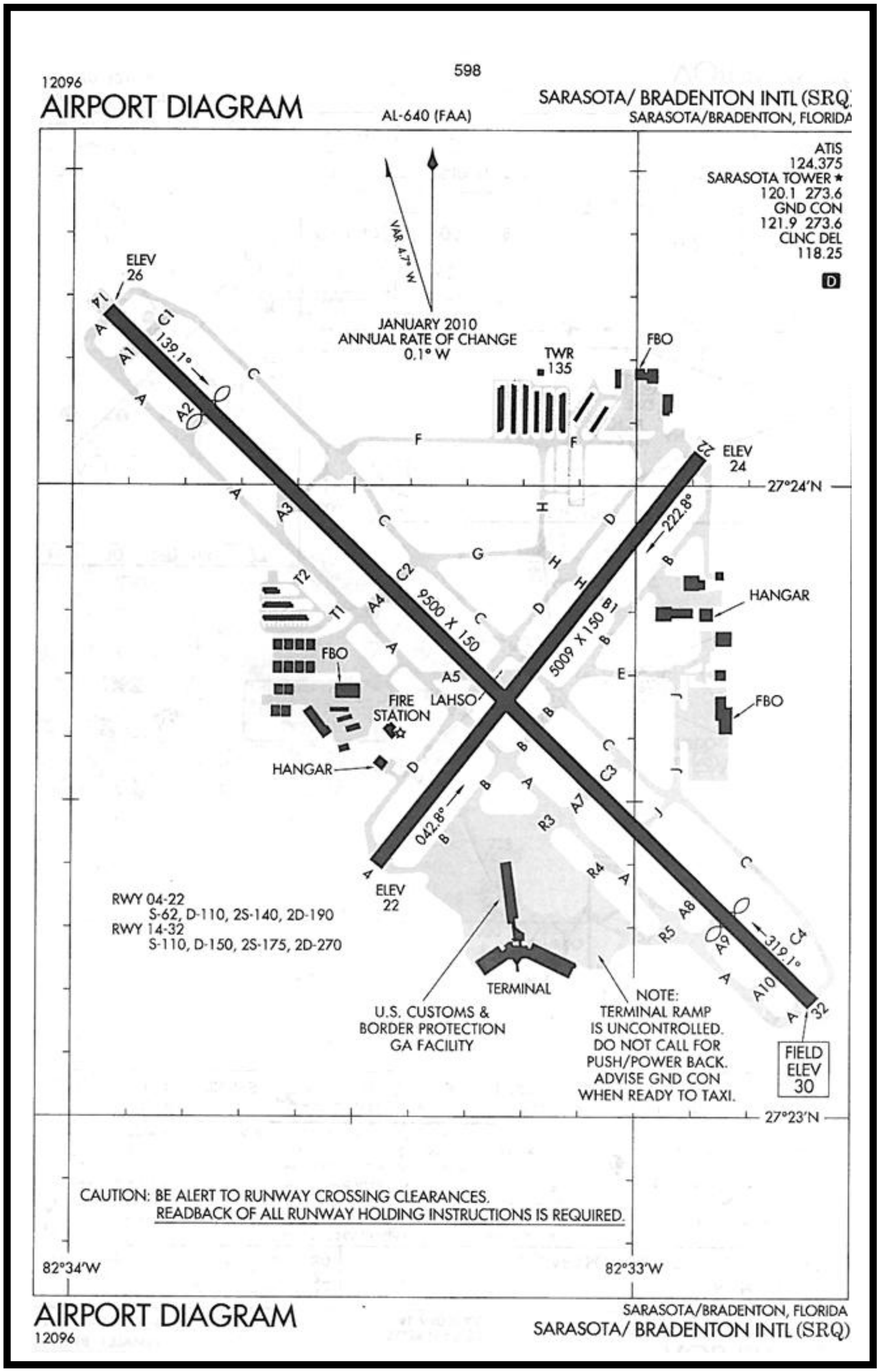
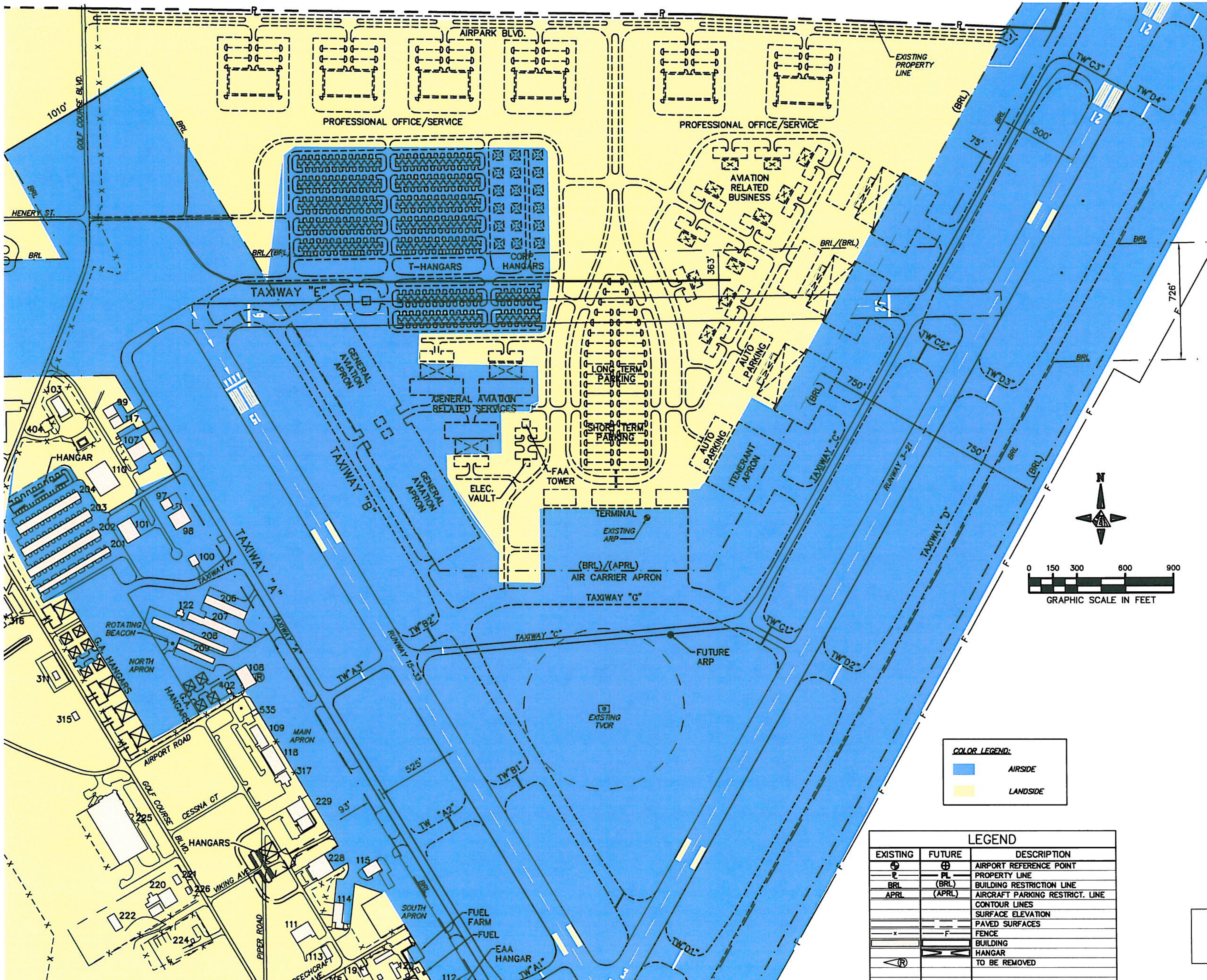


Figure 102-1 Typical Airport Airside and Transitional Facilities



LEGEND

EXISTING	FUTURE	DESCRIPTION
		AIRPORT REFERENCE POINT
— P —	— PL —	PROPERTY LINE
BRL	(BRL)	BUILDING RESTRICTION LINE
APRL	(APRL)	AIRCRAFT PARKING RESTRICT. LINE
		CONTOUR LINES
		SURFACE ELEVATION
		PAVED SURFACES
— x —	— F —	FENCE
		BUILDING
		HANGAR
◁(R)		TO BE REMOVED

FIGURE 102-2: ILLUSTRATION OF AIRSIDE AND LANDSIDE AREAS

\07Jobs\07A0007D\ figure 102-2.dwg Mar 07, 2011 - 1:38pm fehrs01355

A final item of importance in the general airport discussion is access control. Airport security is continually tightening in the wake of the events September 11, 2001. The Transportation Security Administration (TSA) now regulates airside security and access. TSA briefings indicate aviation remains a weapon and target of choice for terror attack. Consequently, airside access is being made “harder” by design. This directly impacts permit conditions regarding observation and inspection of facilities, particularly at commercial service airports. It may also impact design of some stormwater management facilities to preclude these becoming a “soft” entry to the airside.

103. LIMITATIONS

The ***Florida Airports Stormwater Best Management Practices Manual*** and the General Permit for Construction, Operation, Maintenance, Alteration. Abandonment or Removal of Airport Airside Surface Water Management Systems, address only the airport airside stormwater management. They are concerned with runoff from runways, taxiways and aprons. Also, until further research is completed, the manual addresses only infiltration BMPs such as overland flow, swales, and/or dry retention as the primary stormwater quality treatment methods. Wet detention ponds, including those with features recommended by the FAA and the United States Department of Agriculture (USDA) to make them less attractive to wildlife are outside the scope of this document. Landside stormwater management is not included, and must be addressed using other applicable FAA, FDOT, FDEP, and/or Water Management District regulations. However, it is important to consider that the twin needs for safety and stormwater management do not end at the airside when doing landside design and permitting. Land use compatibility around airports is addressed in FAA Advisories Circulars and in Chapter 333, Florida Statutes, both of which should be consulted prior to selecting a stormwater management system – airside or landside.

The Best Management Practices (BMPs) in this Manual must be evaluated and applied with sound engineering judgment. Knowledge of the Conditions of Issuance for an Environmental Resource Permit is a pre-requisite. The manual presumes use by registered professionals and technical professionals with a background that includes hydrology, hydraulics, water quality, geotechnical, transportation and environmental subjects. Of course, applicability of any procedure is specific to the particular airport and its site and operating characteristics. Use of these tools is at the sole discretion and responsibility of the users.

Wildlife management and control are not elements of this document, although reducing standing water attractants is a goal of the stormwater management strategies presented. Users should refer to the Advisory Circulars 150/5200-18, 150/5200-33, 150/4200-36, FAA Rule 49 CFR 139. and to the USDA/FAA Wildlife Hazard Management at Airports Manual for that guidance. Appendices H, K and L present additional information on wildlife hazards. The importance of considering wildlife hazards and attractants when selecting airport stormwater management strategies to the safety of the travelling public is emphasized in the documents in these appendices.

The airport airside stormwater data presented is from the Florida Statewide Airport Stormwater Study, jointly funded by the Federal Aviation Administration (FAA) and the Florida Department of Transportation (FDOT). This project included stormwater monitoring at 13 airports in Florida to characterize their runoff from airside activities. The technical details of the study are included in the ***Technical Report for the Florida Statewide Airport Stormwater Study***. These data and publication were subject to review by the Florida Department of Environmental Protection (FDEP), South Florida Water Management District (SFWMD), Southwest Florida Water Management District (SWFWMD), Suwannee River Water Management District (SRWMD), and the St. John's River Water Management District (SJRWMD) during collection and reduction. These same agencies, along with the Northwest Florida Water Management District (NWFWMD), the FAA, the FDOT and the public have been afforded the opportunity to comment on this BMP Manual and the draft general permit set forth in Chapter 62-330.449, F.A.C.

1.04 ADDITIONAL PERMIT INFORMATION

This document is directed towards the water management design for an Environmental Resource Permit. However, other permits will be required for most new airside construction projects. In most cases new projects will require a **Generic Permit for Stormwater Discharge from Large and Small Construction Activities (CGP)** from the Florida Department of Environmental Protection. This is done under Rule 62-621.300(4) FAC as part of the National Pollution Discharge Elimination System. It is required for projects that:

1. Contribute stormwater discharges to surface waters of the State or into a municipal separate storm sewer system, and
2. Disturbs on or more acres of land including clearing, excavating and grading. If the specific project is less than 1 acre but part of a larger plan of common work that will in aggregate disturb more than one acre a CGP is also required.

Refer to the Florida Department of Environmental Protection NPDES Stormwater Section at www.dep.state.fl.us/water/stormwater/npdes.

As noted in previous sections, this manual does not address activities in wetlands. However, additional to the Environmental Resource Permit requirements for wetlands, these are regulated by the U.S. Army Corps of Engineers. Wetland impacts will also be an issue in the National Environmental Policy Act evaluations for airside projects where federal funds are involved.

Permits may also be required by counties, cities and special districts and these may impose other water quantity management criteria based on specific issues within those jurisdictions.

Section 2 AIRPORT STORMWATER QUALITY CHARACTERISTICS

201. POLLUTANTS

Airside stormwater quality was screened for a series of constituents that might exceed Florida water quality standards as established in Chapter 62-302, F.A.C. By definition, these constituents constitute potential pollutants. The detailed results are summarized and discussed in the ***Technical Report for the Florida Statewide Airport Stormwater Study***. Briefly, only two metals traceable to airport operations are likely to present at concentrations that may cause water quality issues without treatment. These are lead and copper. Two others, cadmium and zinc, will occasionally be found at concentrations that will violate state water quality standards prior to treatment. Total Recoverable Petroleum Hydrocarbons are below state levels for oil and greases in all but the air carrier terminal apron environment, and are not likely to cause or contribute to violations of water quality standards in receiving waters.

Stormwater problems are primarily caused by the stormwater loading that is discharged from a site. Additionally, water quality problems in receiving waters typically result from the cumulative pollutant loading from all land uses and discharges within a watershed not from a single discharge. Consistent with State and Federal emphasis on managing nutrients as both the surrogate for and primary water constituent causing water quality degradation, this manual focuses on reducing Nitrogen and Phosphorus loads in stormwater discharges from airports.

202. EVENT MEAN CONCENTRATION

The following table presents the Event Mean Concentrations (EMC) of Total Nitrogen and Total Phosphorus for use in calculating stormwater loadings from airside pavement. Note that the airside EMC values apply at the edge of pavement - no flow over unpaved surface is reflected in these values. If concerns arise over other constituents during the design and permitting of a stormwater management system under Chapter 62-330.449, F.A.C, the ***Technical Report for the Statewide Airport Stormwater Study*** may be consulted for other constituent EMC values.

Table 202-1 Airside and Natural Nutrient Event Mean Concentration (antilog mean log) mg/L

Airside Type or Feature	Total Nitrogen (TN)	Total Phosphorus (TP)
General Aviation Apron	0.335	0.051
Airline Terminal Apron	0.398	0.057
T-Hangar Apron	0.551	1.836
Ari Cargo Apron	0.259	0.053
General Aviation Runway	0.365	0.081
Air Carrier Runway	0.401	0.049
Taxiways	0.569	0.11
Natural Vegetative Community	0.93	0.10

Nutrient constituents can be sorbed, converted or filtered with overland flow. At low concentrations typical of airport runoff the EMC may remain unchanged or increase as the runoff flows across grassed areas.

Section 3 SITE CHARACTERISTICS AND PROPERTIES

301. GENERAL

Site characteristics needed to analyze stormwater management strategies are associated with establishing rainfall-runoff relations. **Appendix C** provides a checklist that may prove useful while collecting site specific data. References listed in **Appendix A** will also be valuable sources of data and of the proper application of the data.

Typical values provided in this section are not intended as recommended values. They do not and should not supersede those measured by a well designed and executed field and laboratory test program, interpreted by an experienced registered professional. They are guidance values that can be used if the field and laboratory testing are too limited or inconclusive to establish site specific characteristics, or when the difficulty of testing some parameters requires a relation with index properties be used.

302. SOIL PROPERTIES

Establishing infiltration and ground water conditions is a necessary prerequisite to stormwater quantity determinations, which are needed for stormwater loading evaluations as well as drainage design. This section briefly reviews the soil properties that may be needed to estimate infiltration and ground water conditions. When evaluating soil properties for stormwater quantity and quality calculations, care must be taken to differentiate between conditions that exist on the site and those that will be built on the site. The obvious example is when a site will be filled. The fill soil may have very different properties than the soils at the site surface. However, less obvious changes will also affect the soil properties relative to infiltration and ground water movement. Chief among these on most airport airsides is the compaction process. Soils are typically compacted beneath and adjacent to pavement and in safety overrun areas to increase their support capacity. This can reduce porosity, reduce permeability and increase suction among other effects. These possible changes require judgment when establishing a field and laboratory test program to characterize site conditions for surface and ground water calculations.

303. INFILTRATION RATES

Infiltration rates for site soils will vary depending on soil type/mineralogy, moisture content, capillarity/ suction, and porosity among other factors. It will also vary with rainfall rate. Infiltration rate is not the same as soil permeability or hydraulic conductivity, which is more directly a property of the soil matrix. However, field tests for infiltration rate can provide a useful tool to estimate some of the properties, and can provide a boundary rate that infiltration rates based on equations should converge to. The double ring infiltrometer test (formerly ASTM D3385, recently repealed) is the most common method of establishing field infiltration rate.

The Green-Ampt equation discussed in Section 404 estimates infiltration considering soil properties, rainfall rates and accumulated rainfall volume. It requires estimates or determinations of soil porosity, effective porosity, saturation, moisture deficit, saturated vertical permeability and soil suction.

304. PERMEABILITY/HYDRAULIC CONDUCTIVITY

Permeability, used interchangeably with hydraulic conductivity in this manual, expresses the relative ease of movement of a given fluid, in this case water, through a soil matrix. It is reported in units of velocity, and is expressed by the coefficient k in the experimentally derived Darcy equation.

The following equation is Darcy's law, and is the basic relation used to estimate groundwater flow.

$$Q = kiA$$

Where: Q = flow rate
k = permeability
i = hydraulic gradient $\Delta h/L$ (change in hydraulic head/length of flow through soil)
A = cross sectional area

Permeability may be established in-situ by means of field tests. The basic time lag method established by the U.S. Army Corps of Engineers (Reference 25) presents options for isolating vertical and horizontal components. **Appendix D** provides the formulations developed by Hvorslev for the USACOE to estimate permeability using field tests. Cautions with field testing include the effect of compaction during construction.

A supplement or alternate to field tests is the laboratory permeability test. If compaction changes are not likely, undisturbed samples taken with Shelby tube (ASTM D1587-08) or Hvorslev sampler (in very sandy soils) can be used for laboratory testing. When future compaction is an issue, or when fill soils are being imported to the project site, bulk samples of the soil can be laboratory compacted and tested for permeability in the laboratory. Determinations of compacted porosity and even soil suction can be done at the same time.

Soil permeability can also be estimated based on grain size characteristics (determined per ASTM 6913-04), or soil classification determined from either laboratory (ASTM D2487-10) or visual ((ASTM D 2488-09a) classification. Typical values of permeability based on soil classification are presented below in Table 304-1. **Appendix E** presents charts of typical values of permeability based on soil gradation, along with estimates of soil suction, and porosity. Figure 3.4 in Reference 21 is particularly useful in sands of varying density, and can be used to estimate the effects of compaction on permeability for a specific soil.

Table 304-1 Typical Range of Permeability of Natural soil (after Reference 21)

Soil Classification	Range of Permeability, k (ft/day)
Clean, uniform graded gravel (GP)	500 - 2500+
Well graded gravel (GW)	140 - 850
Uniformly graded Sand (SP)	15 - 500
Well Graded sand (SW)	2 - 250
Silty Sand (SM)	2 - 15
Clayey Sand (SC)	0.2 – 2.5
Silt (SC)	0.1 - 0.2
Low Plasticity Clay (CL)	.0.00001 – 0.2

305. POROSITY

Soil is a three phase system, composed of soil, water and air. The block diagram that follows as Figure 305-1 illustrates the relation between the components. Porosity is the ratio of the volume of the voids containing air or water to the total volume of the soil. It is generally expressed as a percentage or a decimal ratio. Effective porosity is a different concept, and recognizes that some water will be bound to soil particles. Only those voids that, when filled with water will free drain under gravity, form effective porosity. This is also described as "Fillable Porosity" in **Appendix F**.

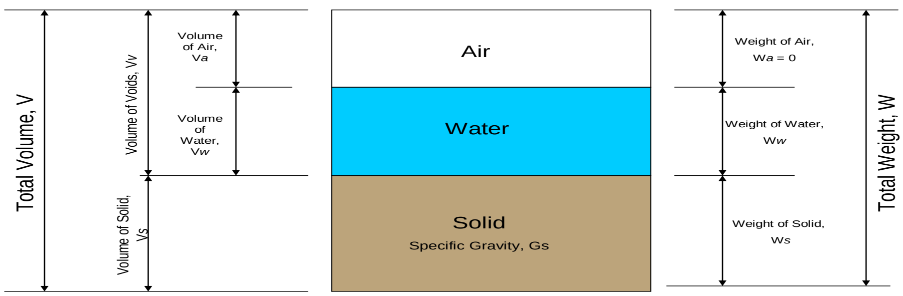


Figure 305-1 Soil Components Block Diagram

The saturation is the volume of the voids filled with water compared to the volume of the voids, expressed as a percentage. The maximum volume of water that can be infiltrated during any event is the difference between the moisture content at the start of a rain event, and the moisture content that represents 100% saturation. The difference is the Moisture Deficit, M_d of the soil.

The soil properties can be evaluated based on field and laboratory testing, but are more commonly estimated based on the soil type or gradation. Table 305-1 following provides typical values of porosity.

Table 305-1 Typical Values of Porosity and Effective Porosity expressed as a Decimal Ratio

Soil Textural Classification	Porosity	Effective Porosity
Sand	0.437	0.417
Loamy Sand	0.437	0.401
Sandy loam	0.453	0.412
Loam	0.463	0.434
Silt Loam	0.501	0.486
Sandy clay loam	0.398	0.330
Clay Loam	0.464	0.309
Silty clay loam	0.471	0.432
Sandy clay	0.430	0.321
Silty clay	0.479	0.423
Clay	0.475	0.385

Moisture content based on weight (W_w/W_s) is easily determined by simple laboratory tests and should be part of each investigation. However, Green-Ampt formulations use moisture content base on volume, expressed as V_w/V in the block diagram nomenclature. When using soil information from a geotechnical exploration, this difference must be understood, and the appropriate moisture content used in the analyses.

Appendix E presents charts of typical values of permeability based on soil gradation, along with estimates of soil suction, and permeability.

306. SOIL SUCTION

Soil suction, expressed in units of length, is generally denoted by the symbol ψ. The parameter is essentially the capilliarity of the soils, and increases as the grain size of the soil decreases. Typical values are provided in Table 306-1 following.

Table 306-1 Typical Values of Soil Suction (Reference 1)

Soil Textural Classification	Typical Wetting Front Suction ψ (inches)
Sand	2.0
Loamy Sand	2.4
Sandy loam	4.3
Loam	3.5
Silt Loam	6.6
Sandy clay loam	8.6
Clay Loam	8.2
Silty clay loam	10.7
Sandy clay	9.4
Silty clay	11.5
Clay	12.5

Appendix E presents charts of typical values of permeability based on soil gradation, along with estimates of soil suction, and porosity.

Field and laboratory tests of soil suction for the surficial soils, most associated with infiltration rates can also be made. Tensiometers can be used to measure the soil suction at a specific point in time. However, they are best installed and measurements of soil suction made over a period of time to establish a typical or seasonal condition. Laboratory tests can establish soil suction relations at various compaction levels and moisture contents. In both cases though, soil suction tests are relatively uncommon and likely to be prohibitively expensive and time consuming. Using typical values is therefore recommended.

307. GROUND WATER

Ground water levels on the site are clearly important in evaluating the infiltration capacity. If underdrains are used to modify ground water levels, the drawdown flows must be estimated to establish the nutrient contribution from the drawdown.

Seasonal High Ground Water Table (SHGWT) estimates are crucial in designing stormwater treatment systems and they are nearly always estimated as part of a site geotechnical study. The estimates should consider the effect of past filling and drainage on a site, and should generally not be based on the unaltered site seasonal high water levels reported in NRCS Soil Surveys, unless the site is, in fact unmodified. This is rarely the case for airfield projects, most of which are done on sites that have served as airports since the 1940's. The NRCS estimates may, however, be useful in determining the site's predevelopment stormwater loadings before it was an airport. Along with the seasonal high estimates, seasonal low and annual median ground water estimates should be established for the site. Unlike the SHGWT, it should be noted that soil indicators (i.e. color, redoximorphic features, depth of root zone, etc.) do not typically provide a basis for accurate Seasonal Low Groundwater Table (SLGWT) estimates.

The estimated SHGWT shall be used for single event modeling for flood management and event quantity management purposes in the absence of compelling, documentable reason to use an alternative. The groundwater elevation used to compute average annual infiltration and runoff will be dependent on the modeling approach selected in harmony with the physical site conditions. Nutrient loading calculations made using continuous simulations using Seasonal High Ground Water elevations will tend to overestimate the runoff volumes and nutrient loads on an average annual basis. Use of SLGWT elevations will do the opposite, and tend to underestimate runoff volumes and nutrient loads on an average annual basis. A median annual elevation will provide a better approximation of physical reality.

Obtaining the ground water elevation to use is a critical component of the process. Most airport sites are disturbed land, often fill, and often artificially drained. In these cases, the SHGWT from NRCS sources will not apply. It may or may not be possible to establish the typical high and low ground water elevations based on the indications typically noted within the soil profile on undisturbed sites. Options available include, but are not limited to:

- Using ground water ranges reported by NRCS for undisturbed soil series in the airport vicinity, and correcting these for changes at the airport including ditching, filling and similar man-made site alterations NRCS groundwater ranges can be obtained from the Official Soil Series Descriptions (OSD) web sites as follows:
  http://soils.usda.gov/technical/classification/osd/index.html
  https://soilseries.sc.egov.usda.gov/osdname.asp
  In addition the OSD web site can be accessed through the NRCS Web Soil Survey as follows: http://websoilsurvey.nrcs.usda.gov/app/
  It should be noted that these NRCS groundwater range estimates are typically limited to the roughly the first 80 inches (2 meters) below the undisturbed / historic ground elevations.

  A cautionary note is that the soil types must be similar with respect to geohydrologic properties. That is, the airport cannot be constructed of clay fill on underlying sands and the comparative sites consist solely of sands.

- Using information obtained from wells that are located within the surficial aquifer and that have been monitored for a period of 10 years or more that are located in the general vicinity of the airport. If the wells are water supply, the drawdown curve must be considered relative to the well and site locations. The data can supply guidance on the range changes between high, low and median ground water levels also, which can be site adapted.

- Ground water and surface water interaction modeling using the site geometries, surficial soil infiltration and lateral ground water movement parameters, and the annual rainfall hyetograph. In this approach, the surface water model is used with a trial ground water elevation and the infiltration volumes on a monthly basis extracted. The monthly infiltrations are applied to a finite difference ground water model and the ground water elevations – high, median and low estimated. The median is then used again in the surface water model for new infiltration volumes. The process is done iteratively until the water balance closes to within 10%.

- Using a model that directly couples the surface and ground water models similar to the above.

When using model data with site geometric, rainfall and soil parameters, a reality check can be made against point observations for reasonableness. For example, if a reported ground water elevation near the end of the wet season in a wet year is lower than the model results for the ground water elevation in a normal year – the model does not adequately approximate reality and must be adjusted. Comparisons with surface water observations on a point basis can also be made, and can provide valuable guidance for model calibration.

Whichever method and ground water elevation is chosen for annual loading calculation, the value of the relative answer will depend on consistent use. That is, if SHGWT is used in existing site evaluations it should also be used in proposed site evaluation, modified, of course, for the site changes the project will induce.

308. TOPOGRAPHY

Topographic information is a given for airport design projects. The caution in stormwater management is the shift in datum from NGVD 1929 to NAVD 1988. Airports, as a matter of policy, use the 1988 NAVD for all mapping and design. However, flood studies, water levels reported for gaged water bodies, and similar information that may be collected is often referenced to 1929 NGVD. The effect on design can be substantial, since the difference can amount to more than 1 foot (0.3 meters), and is variable by location in the state.

309. SLOPES AND GRADING

Airports have defined grading criteria associated with safe and efficient operation of aircraft. These are provided in FAA AC 150/5300-13 (latest version). Within Florida, the minimum slopes for airfield grading are often used. These are beneficial to airport stormwater management as illustrated in the following chart, Figure 309-1.

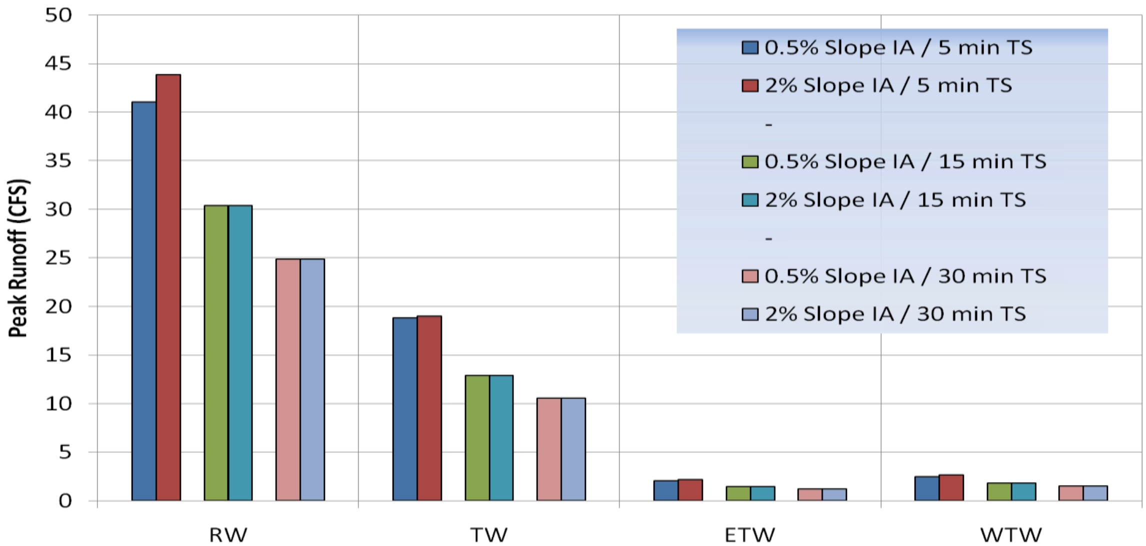


Figure 309-1 Peak Runoff Sensitivity Results for Impervious Areas

Figure 309-1 is derived from computer simulations using the public domain software EPA SWMM. It illustrates the runoff changes that result from nothing more than flattening side slopes along pavement edges. BMP recommendations within this manual consider this result and the benefits it confers in water quality management. It also illustrates the effect of the time step of the rainfall data in computations, discussed further and quantified in the discussion of hyetographs for continuous simulations.

A cautionary note when defining basins with nearly flat longitudinal and/or transverse slopes is in order for those modeling existing systems. The data collection phase of the Statewide Airport Stormwater Study found that drainage basins with nearly flat slopes will change irrespective of the topographic elevations that apparently define them. Wind effects in thunderstorms were a commonly observed cause of the drainage pattern shifts. High grass and sediment buildup along a single edge of some pavements also caused observed changes to actual basin boundaries as opposed to limits based solely on pavement elevation data. In cases the effects measured were substantial, increasing contributing areas on the downwind side or on the side opposite built up edges by over 10%. Visual observation of flow paths during several rain events may be needed to reasonably represent the actual basin limits on some existing pavement.

Section 4 RAINFALL AND RUNOFF RELATIONS

401. EVENT vs. CONTINUOUS SIMULATION

Most designers and regulators are familiar with the event based analysis and design used to size conveyance systems, establish flood protection criteria and size detention systems for flow rate attenuation. Event based design establishes maximum rainfall amounts or intensities that may be expected in an area using statistical analyses of past rainfall events. The rainfall is usually expressed in terms of the expected recurrence interval of a storm, for example, a 5-year storm. The event durations may range from 10 minutes to 3 days, or in some cases from 8 minutes to 10-days. The rainfall hyetograph distribution is predefined within rules of the various water management districts or by FDOT within its variously defined regions. The five water management districts and the FDOT establish design events for rate control and flood protection. FDOT procedures are appropriate when discharging into FDOT stormwater conveyance and right-of-way.

FAA guidance is to use event based design to size drainage inlets and pipes to convey water away from airside pavement. FAA AC 150/5320-5C, paragraph 2-2.4.2 recommends a 5-year recurrence interval storm for airside pavement, with inlet surcharges less than 4 inches on aprons where personnel will operate or passengers and crew walk across.

Stormwater quality analysis and design is based on the annual behavior of the system, not the behavior in an extreme event such as those used for design of conveyance and flood protection. Continuous simulation requires rainfall information that represents a typical year, derived from several years of historical data. Table 401-1 on the following page provides non-parametric statistics for daily rainfall events at a series of representative Florida airports. **Appendix G** presents annual rainfalls in greater detail graphically. The annual rainfall totals shown in **Appendix G** or in Table 401-1 may be used to normalize or as a check upon the 15-minute hyetographs described in Section 402 that are used for continuous simulation surface water models. The annual volume of rainfall in the models should closely approximate the average annual rainfall of **Appendix G**.

Table 401-1 also presents the typical seasonal distribution of rainfall at the listed airports. Contrasting the rainfall characteristics in the table with the 10-year and 25-year, 24-hour design event rainfalls established by FDOT, included in the tables final two rows for convenience, clearly shows the difference between design event and typical rainfall. Additional discussion and recommendations for rainfall hyetographs for stormwater quality calculations is included in the next section of this document.

Continuous simulation computations and estimates require rainfall – runoff relations that reflect the highly variable intensities and volumes that Table 401-1 implies. They must also consider changes in soil moisture and recovery, evaporation effects and similar that happen for the typical annual rain distributions. A following section on Rational Method Runoff Coefficient (C), Natural Resource Conservation Service (NRCS – formerly Soil Conservation Service {SCS}) Curve Number (CN) and the Green-Ampt equation describes the differences and provide the recommended approach for airside stormwater management.

Table 401-1 Daily Rainfall Characteristics at Select Florida Airports and Comparison with Published Design Storm Events

	RSW	GNV	JAX	MIA	MCO	PNS	TLH	TPA	PBI
Modal Rainfall (inches)	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**0.01**
Median Rainfall (inches)	**0.24**	**0.19**	**0.2**	**0.18**	**0.19**	**0.3**	**0.24**	**0.19**	**0.17**
Percent Rain less than 0.5 inches	**67%**	**73%**	**71%**	**72%**	**71%**	**62%**	**66%**	**71%**	**72%**
80th Percentile Rainfall (inches)	**0.83**	**0.68**	**0.72**	**0.70**	**0.73**	**0.98**	**0.87**	**0.72**	**0.66**
90th Percentile Rainfall (inches)	**1.33**	**1.10**	**1.23**	**1.22**	**1.17**	**1.55**	**1.44**	**1.16**	**1.20**
95th Percentile (inches)	**1.83**	**1.52**	**1.81**	**1.74**	**1.55**	**2.41**	**2.04**	**1.56**	**1.70**
Average Interval Between Rain Events during the Rainy Season June 1 - September 30 (Hours)	**22**	**25**	**26**	**21**	**24**	**29**	**27**	**26**	**23**
Percent of Rain during the Rainy Season June 1 -September 30	**65%**	**48%**	**51%**	**54%**	**52%**	**41%**	**45%**	**58%**	**47%**
Average Annual Rainfall, **1985-1999** (inches**)**	**55**	**49**	**54**	**62**	**52**	**67**	**61**	**46**	**62**
Design Rainfall (inches) for 10-year, 24-hour Event (ref___)	***6.5***	***7***	***7.5***	***8***	***8***	***9.5***	***8.5***	***8***	***9***
Design Rainfall (inches) for 25-year, 24-hour Event (ref___)	***7.8***	***8***	***8.5***	***9***	***8.5***	***10.5***	***9.5***	***9.5***	***10***

Data source same as companion Technical Report and is based on 1984 – 1999 daily rainfall records

RSW is located in Fort Myers
GNV is located in Gainesville
JAX is located in Jacksonville
MIA is located in Miami
MCO is located in Orlando
PNS is located in Pensacola
TLH is located in Tallahassee
TPA is located in Tampa
PBI is located in West Palm Beach

402. HYETOGRAPHS

Hyetographs used for continuous simulation must, as a minimum, include the entire defined rainy season, if one is established for the region. A better simulation can be done using the historical rainfall records of nearby weather stations, and this is the recommended approach. Daily rainfall values, without further reduction into smaller time intervals, are generally not suitable for continuous simulation computer models, but may not be useful for hand calculation depending on the loss and infiltration method used.

Table 402-1 following illustrates the difference in runoff rates and volumes estimated based on 5-minute, 15-minute and 30-minute increment rainfall hyetographs. The table is derived from computer simulations using the public domain software EPA SWMM.

Table 402-1 Comparison of Time Step Effect on Calculated Runoff

	5-minute	15-minute	30-minute
Impervious Area Peak Runoff Rate	baseline	30% less	43% less
Impervious Area Runoff Volume	baseline	0.1% less	0.1% less
Overland Flow Peak Runoff Rate	baseline	13% less	33% less
Overland Flow Runoff Volume	baseline	10% less	24% less

Two methods are available to establish hyetographs – synthetic generation and historical record. Combinations of the two are also possible, and often needed, to provide a sufficiently detailed record if computer analysis is used. The recommended time increment for the rainfall record is 5-minutes or 15-minutes depending on the available data set. The computed error between the 5-minute and the 15-minute data are well within other modeling uncertainties. Increments of 30-minutes and larger, while usable, begin to diverge from the 5-minute information at levels that require more care when interpreting results.

Figure 402-1 following illustrates a 5-minute rainfall record for Orlando International Airport for a 20 month period.

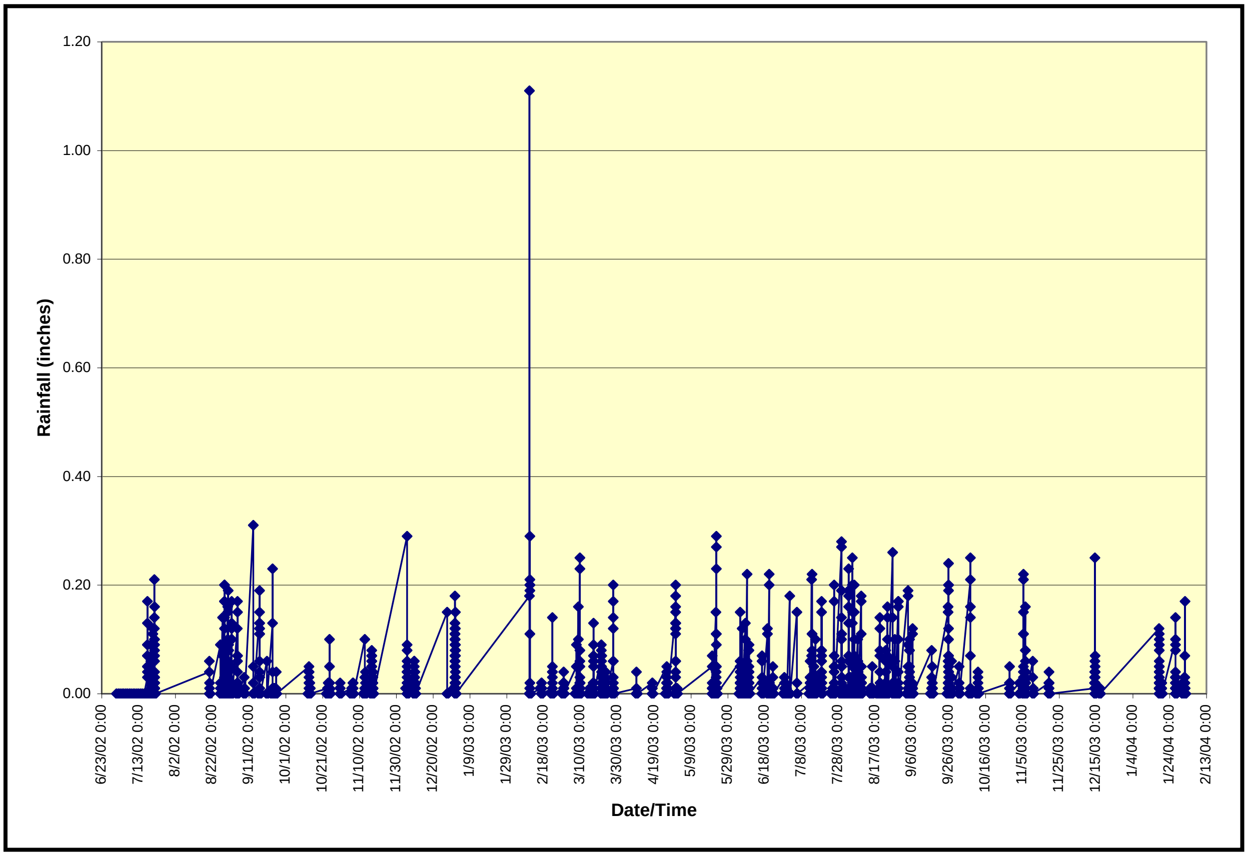


Figure 402-1 Recorded 5-minute Rainfall Record for Orlando International Airport

403. EVAPORATION AND EVAPOTRANSPIRATION

Evaporation and evapotranspiration are needed in most continuous simulations since these are often major components in the recovery of soil storage. The simulations do not need these parameters defined to the same intervals as the rainfall hyetographs, since they predominantly influence the soil storage recovery, not the immediate runoff established by rainfall – runoff relations. An evapotranspiration data set is shown in Figure 403-1. Evaporation and evapotranspiration records can be obtained from: Florida Automated Weather Network, (FAWN), http://fawn.ifas.ufl.edu/ .

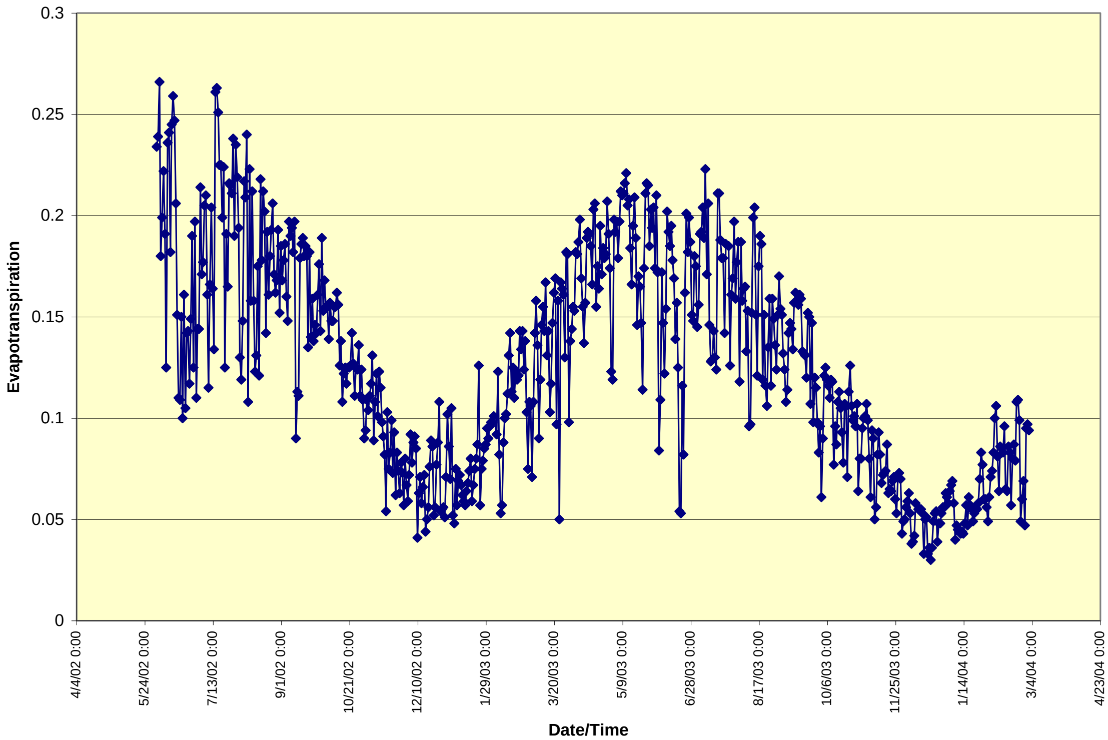


Figure 403-1 Plot of Daily Evapotranspiration Measured in Central Florida

404. C vs. CN vs. GREEN-AMPT

Event based water conveyance, rate control, or flood protection design is generally done using the NRCS Curve Number to relate the runoff to rainfall. On specific airside areas and for short duration, high intensity convective storms, the Rational Method is often used to size inlets and pipes. These methods, within the site limits they derive from, can provide good estimates of the peak runoff rates and volumes during more intense storms and when applied with experienced judgment. However, they can dramatically mis-estimate the runoff on an annualized basis. The data from the Florida Statewide Airport Stormwater study found Rational Method C varied from 0.01 to 1.00 for direct pavement runoff depending on storm volume and intensity, with a median that averages 0.7. Generally, the lower the storm intensity and the lower the total rain volume the lower the measured value of C. Comparing these ranges with the typically accepted ranges of C for pavement, 0.95 to 1.00, it is evident that C for continuous simulation modeling is likely to substantially overestimate runoff and loads

Curve Number, CN, was also back figured from measured rainfall-runoff relations found in the Statewide Airport Stormwater Study. Using a pavement example as before, calculated CN ranged from 72 to 95. The typically accepted CN for pavement is Florida in 95. Lower intensity and volume rains yield lower CN. Using CN for continuous simulation modeling is likely to substantially overestimate runoff and loads.

Figure 404-1 following illustrates the measured runoff for pavement and overland flow compared with the runoff estimated using Green Ampt equation for one year of recorded information. Actual measured runoff was 3.61 inches; Green Ampt equation predicted runoff was 3.65 inches. Note that on any given event the estimated and measured values will differ, but overall agreement is excellent.

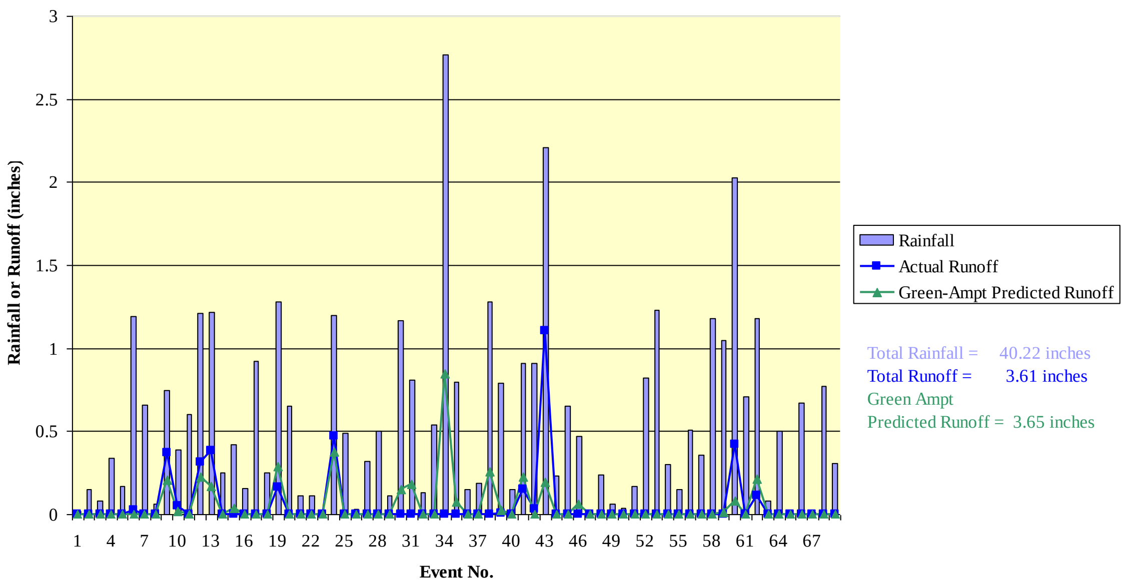


Figure 404-1 Comparison of Actual and Green-Ampt Predicted Runoff

The Green Ampt equation is discussed in references 1 and 6. Its basic form is:

$$f = K_s\,(1 - M_d\psi / LM_d)$$

Where: f = infiltration rate
K_s = saturated vertical hydraulic conductivity
M_d = initial moisture deficit further defined as the saturated moisture content minus the initial moisture content
Ψ = soil suction
and, L = depth to the infiltrating wetting front which varies with infiltration volume

It is iteratively solved, and is available in several software packages, including EPA SWMM used in the ***Application Assessment for the Statewide Airport Stormwater Study***. The equation also lends itself to spreadsheet solution, where iterative calculations can be rapidly performed. The parameters that go into the equation can be directly measured, or surrogate measures such as gradation and soil classification can be used to estimate the parameters with guidance provided in this manual and references listed in **Appendix A.**

Section 5 STORMWATER QUALITY CALCULATIONS

501. RUNOFF LOAD AND CONCENTRATION

Basic stormwater quality calculations using Event Mean Concentrations are straightforward. The load (units of weight) is the EMC (units of weight per volume) multiplied by the volume of runoff, with appropriate unit conversions. Conversely, concentration can be calculated as the load divided by the volume of runoff, again with appropriate unit weight conversions.

Airside pavement EMC values for nutrients, at the pavement edge with no overland flow considered, are given in Table 202-1. The distinction that these are direct pavement EMC is important in modeling or hand computations. As discussed in the section on BMP efficiencies following, overland flow alters the EMC, generally within a distance of 25 feet based on the data collected in the Florida Statewide Airport Stormwater Study. If the basin definition includes, as is typical, both pavement and a section of overland flow, the EMC changes due to the overland flow must be reflected in the computation.

502. GROUNDWATER CONTRIBUTIONS

If dewatering is needed for either pavement structure protection or for site improvement for stormwater management, the ground water discharged from the site will have nutrients that must be accounted for in stormwater loading calculations. Underdrains placed immediately at the outside edge of pavement will likely have lower nutrient concentrations, but may have higher metal concentrations and possibly PAH in particulate phase. Consequently, underdrains for airside pavement should be moved either 25 feet away outside the pavement edge or beneath the pavement. Note that artificially lowering the ground water table may be precluded in some areas of the state and by some jurisdictional agencies for management and resource conservation reasons. Also, if underdrains are used, General Permit 62-330.449 does not apply.

Nutrient load in ground water was not measured during the Statewide Airport Stormwater Study. Table 502-1 contains the values to be used when calculating ground water nutrient loadings and were supplied by FDEP.

Table 502-1. Median Nutrient Concentrations in Ground Water by County

COUNTY	NITRATE and NITRATE+NITRITE as N mg/L	TOTAL PHOSHORUS as P mg/L
ALACHUA	0.16	0.0625
BAKER	0.02	0.03
BAY	0.025	0.004
BRADFORD	0.05	0.105
BREVARD	0.02	0.19
BROWARD	0.02	0.07
CALHOUN	0.4	0.004
CHARLOTTE	0.02	0.05
CITRUS	0.27	0.07

COUNTY	NITRATE and NITRATE+NITRITE as N mg/L	TOTAL PHOSHORUS as P mg/L
CLAY	0.02	0.021
COLLIER	0.015	0.022
COLUMBIA	0.02	0.045
DADE	0.022	0.02
DE SOTO	0.02	0.24
DUVAL	0.06	0.019
ESCAMBIA	0.17	0.01
FLAGLER	0.02	0.195
FRANKLIN	0.02	N/A
GADSDEN	0.084	0.009
GILCHRIST	0.02	0.091
GLADES	0.012	0.035
GULF	0.023	N/A
HAMILTON	2.6	1.1
HARDEE	0.02	0.37
HENDRY	0.02	0.08
HERNANDO	0.0505	0.06
HIGHLANDS	3.905	0.033
HILLSBOROUGH	0.02	0.02
HOLMES	0.059	N/A
INDIAN RIVER	0.02	0.35
JACKSON	4.25	0.018
JEFFERSON	1.6	0.01
LAFAYETTE	5.8	0.337
LAKE	0.1	0.036
LEE	0.015	0.034
LEON	0.0395	0.03
LEVY	0.057	0.08
LIBERTY	0.017	0.014
MADISON	0.042	0.097
MANATEE	0.02	0.058
MARION	0.789	0.42
MARTIN	0.014	0.12
MONROE	0.02	0.01
NASSAU	0.008	0.12
OKALOOSA	0.14	0.007
OKEECHOBEE	0.0105	0.034
ORANGE	0.035	0.194
OSCEOLA	0.0115	0.065
PALM BEACH	0.015	0.057
PASCO	0.01	0.012
PINELLAS	0.06	0.15
POLK	12	0.03
PUTNAM	0.01	0.055
SANTA ROSA	0.15	0.004

COUNTY	NITRATE and NITRATE+NITRITE as N mg/L	TOTAL PHOSHORUS as P mg/L
SARASOTA	0.02	0.19
SEMINOLE	0.02	0.2
ST. JOHNS	0.02	0.051
ST. LUCIE	0.015	0.111
SUMTER	0.04	0.05
SUWANNEE	2.9	0.1
TAYLOR	0.048	0.134
UNION	0.3	0.07
VOLUSIA	0.062	0.19
WAKULLA	0.008	0.19
WALTON	0.98	0.004
WASHINGTON	0.04	0.004

503. BMP EFFICIENCIES

BMP effectiveness can be measured as either reductions in load and/or concentration. However, for the purposes of Florida's stormwater regulatory program the focus is on annual average load reduction. During the Florida Statewide Airport Stormwater study load reductions were measured for all parameters, including nutrients. Concentration reductions were measured for all parameters except nutrients during overland flow.

Load reductions can occur via two primary methods. First, the stormwater volume that is discharged from a site can be reduced. This typically is done by using infiltration BMPs in which the stormwater soaks into the ground. Given the low concentrations of nutrients in airport airside runoff, it is assumed that 100% of the nutrient loading is removed when the stormwater is retained on-site. Second, source control BMPs can be used to reduce the concentration of pollutants that get into the stormwater. An example is using Florida-friendly fertilizers or reusing or properly disposing of aircraft fuel during fuel sumping.

In some cases, a third load reduction method occurs such as during overland flow. Concentration changes with overland flow reflect either a decrease or an increase in the EMC during overland flow. It is calculated as:

Concentration Reduction (%) = [(Pavement Concentration – BMP Concentration)/Pavement Concentration] x 100%

Depending on the site, reducing concentrations during overland flow may involve one or more or the following mechanisms: infiltration, adsorption, particulate entrapment, re-suspension or other. Metals concentration reduction varies from a low of about 35% to a high of just more than 65%. Nutrients, however, exhibited an increase in concentration of 5% for phosphorus up to 50% for nitrogen. Understanding the reason for the results and their significance are critical to proper application of the data and good modeling practice. The decrease or increase measured represents low levels of constituents in the pavement runoff that rapidly approach the background or pristine site concentration. This must be used with care when establishing the

BMP induced concentration changes, and can affect the choice of basin limits for water quality computation. The effect is most pronounced in the first 25 feet of overland flow, beyond that the observed concentrations tend to stabilize Consult the ***Technical Report for the Statewide Airport Stormwater Study*** (Reference 14, **Appendix A**) for detailed information.

504. Pre and Post Development Load Calculations

The pre and post development load calculations that are the basis of this manual are predicated on using continuous simulation, numerical modeling methods. The US EPA SWMM software package that was used exclusively in doing the ***Application Assessment*** is well suited to this analysis. Commercial software products with continuous simulation capability may also be used.

The most difficult component of the model is to define the pre-development load that would result from a natural vegetative community, if present at the airport site. This difficulty stems from establishing the Green Ampt parameters, the ground water elevations and the corresponding rainfall-runoff relation that would prevail if the airport were not present. Most public use airports in Florida were constructed in the 1940's or earlier, and the sites and drainage were extensively altered at that time. Generally, the site modifications were a combination of lowering extant ground water levels through drainage and raising site elevations with earthfill. Removing muck and peat type soils and replacing these with sands for better structural support also altered the drainage properties. In cases, the sites were cleared but not grubbed, and clean earthfill was placed directly on the stumps, vegetation, and site soils. The net effect is that most airport sites now exhibit soil and ground water conditions that have lower runoff potential than the original, natural vegetative communities. Two approaches are recommended to establish the pre-development parameters for a natural vegetative community. These are:

1. If historical information or site geotechnical studies with a combination of borings and test pits can define the extent of the alterations, the rainfall-runoff relations estimated based on this information can be used with the EMC data from Table 202-1.
2. If nearby areas still contain natural vegetative communities that can be reasonably inferred to be representative of regional conditions, the rainfall-runoff relations of these may be used, with the EMC data from Table 202-1, to establish the natural vegetative community loading for an equivalent area.

The parameters establishing the rainfall-runoff relations for the pre development condition are particularly important to the analyses, and the need to establish and agree upon them early in the process requires a pre-application meeting with the jurisdictional Water Management District. The recommended modeling technique to estimate the pre-development, natural vegetative community load follows. The discussion is generic since the specific model software or approach may vary project to project.

1. Define basins for the project site initially by topography and outfall locations. Further define basins by areas of different projected ground water elevation and soils types if necessary. Since the pre-development site is considered a natural vegetated community, it will not be necessary to further define basins by land use.
2. The EMC data from Table 202-1 will be used, and no BMP efficiencies are applied.

3. Run the continuous simulation, surface water model with rainfall records defined on 15-miute or smaller intervals for a one year period.
4. If necessary, run a ground water model or equation to help validate the infiltration volumes. These generally use a daily or monthly rate based on the volume the surface water model indicates was infiltrated. They do not use 15-minute data. The necessity is determined by the proximity of the ground water to the ground surface. If the estimated SHGWT is closer than 2 feet to the ground surface, ground water modeling or long term physical data is usually needed. If the results are substantially different than used in the surface water model, another iteration of surface and ground water modeling is needed..
5. Review the results for reasonableness. Revise the models as necessary
6. Establish the pre-development target loads based on the model and calculation.

Post development Green Ampt and groundwater parameters are established as described in Section 3. The recommended continuous simulation surface water models will define rainfall runoff relations using the information discussed in Sections 3 and 4 preceding. The model will also use the EMC data from Section 2. The recommended generic modeling technique for the post-development airside, when designed following the criteria of Section 6 is as follows:

1. Define basins for the developed project site by topography and outfall locations, projected ground water elevations, soils types, airside pavement limits and land use. The pavement areas should include the first 25 feet of overland flow within their defined basins in those models that permit an impervious over pervious flow simulation.
2. Define the EMC's for each different pavement type associated with the project (air carrier runway and taxiway, for example) using Table 202-1
3. Define the BMP efficiencies for overland flow, using Reference 14, **Appendix A**, or other treatment as appropriate. The definition may be load or concentration based, depending on the selected model. In all cases the ultimate requirement is discharge load calculation. Where concentrations change through the BMP, and where the constituent load is explicitly reduced 100% for all infiltration by the model, a concentration BMP is appropriate. Where load BMP changes must be implicitly modeled, it will generally be necessary to use the infiltration volumes from Step 4, considering 100% of all infiltrated water to be 100% treated.
4. Run the continuous simulation, surface water model with rainfall records defined on 15-minute or smaller intervals for a one year period. If necessary, run a ground water model or equation to help validate the infiltration volumes. These generally use a daily or monthly rate based on the volume the surface water model indicates was infiltrated. They do not use 15-minute data. The necessity is determined by the proximity of the ground water to the ground surface. If the estimated SHGWT is closer than 2 feet to the ground surface, ground water modeling or long term physical data is usually needed. If the results are substantially different than used in the surface water model, another iteration beginning with step 1 should be done.
5. Review the results for reasonableness.
6. Compare the post-development load to the target loads based on the model and calculation. If the post development loads exceed the target loads, add design features to reduce the post development load, and re-evaluate.

References in **Appendix A** may be consulted for additional information, along with specific user manuals for software products used for modeling. Also, a training session on this BMP Manual, including the theoretical concepts involved, was held on March 10, 2011. A complete recording of the presentation is available from the Florida Department of Transportation, Central Aviation Office.

Section 6 BEST MANAGEMENT PRACTICES

601. OVERVIEW

Best Management Practices for airside stormwater management must satisfy both aviation safety and water quality and quantity management criteria. Aviation safety requires that the Best Management Practices avoid or minimize attracting hazardous wildlife. Water quality management is best satisfied with no increase of pollutants above pristine site levels in waters leaving a project site and entering waters of the state. Water quantity management is generally rate based, with no increase of calculated discharges above those from the pre-project site during a specified design storm. Structural and Procedural Best Management Practices presented in this section are available tools for airside Best Management Practice stormwater design and permitting for Florida airports.

602 MINIMUM LEVEL OF STORMWATER TREATMENT

Florida has implemented a technology-based stormwater rule which is based on three principles:

- A "performance standard" that sets the minimum level of treatment
- BMP design criteria that can achieve the performance standard, either alone or through a BMP treatment train, and
- A rebuttable presumption that a stormwater treatment system designed to the appropriate BMP design criteria will not cause or contribute to violations of water quality standards.

The performance standards for Florida's stormwater rules are set forth in Section 62-40.432, F.A.C. They include:

- For construction activities, no violation of the turbidity water quality criterion which is 29 NTUs above background for most waters, but zero (0) N.T.U's above background in an Outstanding Florida Waterbody (OFW)
- For stormwater discharges, a minimum of 80% average annual removal of pollutants that cause or contribute to violations of water quality standards
- For stormwater discharges to Outstanding Florida Waters, a minimum of 95% average annual removal of pollutants that cause or contribute to violations of water quality standards.
- For stormwater discharges to verified impaired waters, the project must achieve "net environmental improvement" which means the stormwater pollutant load after development must be less than the stormwater pollutant load before development.

For the purposes of this BMP manual and as set forth in Chapter 62-330.449, F.A.C., the performance standard for airside airport activities shall be:

The nutrient load after development shall not exceed the nutrient loading from natural vegetative communities.

603. FLOOD CONTROL REQUIREMENTS

All projects must be designed to prevent adverse flood impacts. The five Water Management Districts prescribe specific design events that must be evaluated and design criteria that apply to meet the flood control requirements. **Appendix J** provides a listing of public airports by jurisdictional Water Management District, and website information where the criteria are published. Discharges from the site will be limited by these criteria. Floodplain impacts and compensating/mitigating design criteria are also established.

The Florida Department of Transportation establishes flood protection criteria for its various roadways and their criteria apply to discharge to their right of way and drainage systems. These may require checks of multiple design events up to a specified level to determine a controlling discharge. FDOT criteria and methodologies are available in manuals and handbooks at http://www.dot.state.fl.us/rddesign/dr/Manualsandhandbooks.shtm.

Additionally, Water Control Districts and local government may have criteria for flood protection that are more stringent than Water Management District criteria. These should be contacted for their specific requirements that will influence project design. The most stringent of the Water Management District or local criteria must be met with respect to protecting areas away from the airside from adverse flood impacts.

The Water Management District and local criteria are intended to protect offsite areas from specified flood events, but also typically address on-site flooding. However, the flood protection criteria are not appropriate to airside pavements. Specifically, FAA Advisory Circular 150/5320-5 apply to airside pavement. The circular allows temporary flooding of airfield pavement to specific depths for storms with a 5-year recurrence interval. Joint use civil-military airfields may be designed for flooding under more frequent events, sometimes those with a 1-year recurrence interval. This is the basis for infield ponding or even pavement flooding as design features used to reduce peak flows leaving the site.

604. REQUIRED SITE INFORMATION

Successful design of retention BMPs depends greatly upon knowing conditions at the site, especially information about the soil, geology, and water table conditions. Specific data and analyses required for the design of a retention BMPs required in this manual, including details related to safety factors, mounding analyses, and required soil testing, are set forth in **Appendix F** of this Manual**.**

605. STRUCTURAL BEST MANAGEMENT PRACTICES

The following Structural Best Management Practices may be used alone, or as part of a BMP treatment train that combines structural and/or Procedural BMPs to meet the minimum stormwater treatment requirements for airside improvements. In particular, this means meeting the performance standard discussed in Section 602 above. Other BMPs not listed in this manual may be appropriate but they were not specifically evaluated as part of the Florida Statewide Airport Stormwater study. Specifically excluded are wet detention or pond systems. While these may be a necessity for some or all projects at an airport, the necessary research and testing of wet ponds designed to meet the FAA/USDA criteria to reduce wildlife attractants has not been completed. Use of other wet pond criteria generally established for all land uses and project types may be required until the FAA/USDA criteria have been fully evaluated. However, the potential wildlife attractant hazard of wet ponds must be evaluated when they are proposed for use.

a. <u>Overland Flow</u>
An overland flow system is BMP in which the runoff moves off the runway or taxiway and sheet flows over the adjacent grassed area allowing the stormwater to infiltrate into the ground. Overland flow is the preferred Best Management Practice for runway and taxiway stormwater management. It may also be applicable to aprons depending on specific site geometry and conditions

1. Applicability

Favorable Site Conditions

- Contributing pavement area is comparable to or less than the overland flow area. Runways and taxiways with flows to both sides of centerline most easily satisfy this condition.
- Soils on the site are sands with stabilized infiltration rates greater than 3 inches/hour and horizontal hydraulic conductivities greater than 20 feet/day.
- Topography permits flat (.5% -3%) transverse slopes
- Seasonal High Ground Water Table (SHGWT) elevations are more than 3 feet beneath the ground surface at the lowest point of the infield or overland flow area.

Usable Site Conditions **-** may require site modification including lowering the water table with underdrains. Note that artificially lowering the ground water table may be precluded in some areas of the state and by some jurisdictional agencies for management and resource conservation reasons.

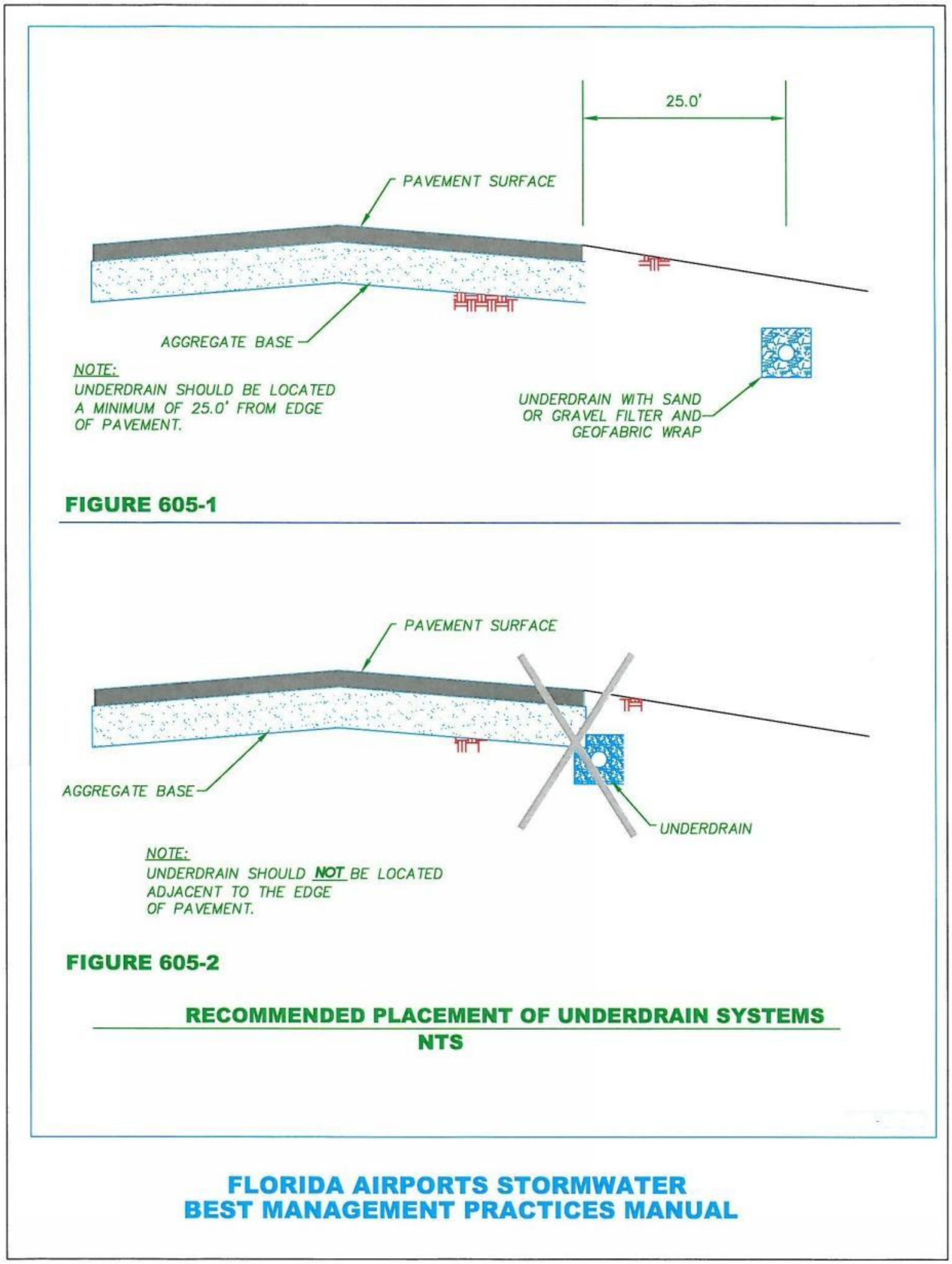
- Contributing pavement area is not more than 50 % larger than the overland flow area.
- Soils on the site are silty sands, or sands with organics, with stabilized infiltration rates greater than 0.5 inches/hour and horizontal hydraulic conductivities greater than 10 feet/day
- Topography permits flat to moderate (0.5% - 5%) transverse slopes
- SHGWT elevations are between 1 and 3 feet beneath the ground surface
- Discharge is available for underdrains, if needed and ground water contributions of nutrient load do not increase total nutrient loading significantly

Unfavorable Site Conditions - require site modification such as filling with more pervious soil or lowering the ground water table. Note that artificially lowering the ground water table may be precluded in some areas of the state and by some jurisdictional agencies for management and resource conservation reasons. Without site modification, wet detention systems are likely needed. Use wet detention systems with caution and follow FAA design requirements to minimize wildlife impacts.

- Contributing pavement area is more than 50% larger than the overland flow area. Aprons often fall in this category.
- Soils are silts and clays with infiltration rates less than 0.5 inches/hour and hydraulic conductivities less than 2 feet/day
- Topography requires steep transverse slopes (5% -25%)
- SHGWT elevations are at the ground surface at the lowest point of the infield or overland flow area.

2. Design Criteria

- Overland flow distance shall be 25 feet or greater. This is typically achieved on all runway and taxiway infield areas and is needed to reduce metals concentrations and allow infiltration of the treatment volume to meet the required load reductions.
- Slopes shall be as flat as possible with .5% - 3.0% recommended in the first 25 feet of overland flow.
- Design inlets and conveyance pipes for the 5-year post development storm using the Rational Method. Ponding should be less than 4-inches in apron areas. These criteria are expressed in Advisory Circular 150/5320-5C, Paragraph 2-2.4.2.
- Evaluate the pre- and post-development peak flows from the project using the design storm event specified by the jurisdictional water management district. This is typically a 10-, 25-, or 100-year recurrence interval storm of 1 to 3 days duration. Verify post project discharge is less than pre-project discharge for this event and method.
- Set inlets (at grade or in the infield, if needed and consistent with airfield safety, up to 3 inches above grade to achieve required load reductions).
- Based on the evaluation of annual nutrient loads for the predevelopment and post development conditions, establish the design features to achieve the required load reductions.
- If SHGWT levels must be lowered using underdrains, place underdrains at least 25 feet from the edge of pavement (see Figure 605-1). Underdrains placed directly adjacent to pavement (see Figure 605-2 should not be used for stormwater management or pavement base protection, since these may transport higher pollutant loads from the pavement edge directly to the stormwater conveyance. Underdrains placed under the pavement are an option for pavement structure or base protection, and loads may be calculated as described for those placed 25 feet away. Include underdrain nutrient loads in the post-development discharge loading calculations as appropriate. Note that artificially lowering the ground water table may be precluded in some areas of the state and by some jurisdictional agencies for management and resource conservation reasons.
- The overland flow system shall be appropriately stablilized to minimize or prevent erosion.
- Follow all Turf Management Procedural BMPs described in Section 606.b.
- Employ street sweeping, aircraft fuel sumping controls and other appropriate source controls as needed reduce pollutants that can get into the stormwater.


25.0'
PAVEMENT SURFACE
AGGREGATE BASE
NOTE:
UNDERDRAIN SHOULD BE LOCATED A MINIMUM OF 25.0' FROM EDGE OF PAVEMENT.
UNDERDRAIN WITH SAND OR GRAVEL FILTER AND GEOFABRIC WRAP
FIGURE 605-1
PAVEMENT SURFACE
AGGREGATE BASE
UNDERDRAIN
NOTE:
UNDERDRAIN SHOULD NOT BE LOCATED ADJACENT TO THE EDGE OF PAVEMENT.
FIGURE 605-2
RECOMMENDED PLACEMENT OF UNDERDRAIN SYSTEMS
NTS
FLORIDA AIRPORTS STORMWATER
BEST MANAGEMENT PRACTICES MANUAL

b. Dry Retention Basin

A dry retention basin is the preferred Best Management Practice for aprons. It is also applicable to runways and taxiways. A "retention system" is a recessed area within the landscape that is designed to store and retain a defined quantity of runoff, allowing it to evaporate or percolate through permeable soils into the shallow ground water aquifer. This section discusses the requirements for retention systems, historically referred to as "dry retention basins", which are constructed or natural depressional areas, often integrated into a site's landscaping, where the bottom is typically flat, and turf, natural ground covers or other appropriate vegetation, or other methods are used to promote infiltration and stabilize the basin slopes and help maintain infiltration rates.

Soil permeability and water table conditions must be such that the retention basins can percolate the required treatment runoff volume within a specified time following a storm event. After drawdown has been completed, the basin does not hold any water, thus the system is normally "dry." Unlike detention basins, the treatment volume for retention systems is not discharged to surface waters. Like all infiltration BMPs, dry retention systems are assumed to remove 100% of the nutrient load for all of the runoff volume that is fully retained within the system. Lesser removals occur for those storms that exceed the treatment volume of the retention basin and bypass the system to be discharged offsite unless the retention basin is designed as an offline BMP.

1. Applicability

Favorable Site Conditions

- Soils on the dry retention site are clean sands with stabilized infiltration rates greater than 6 inches/hour and horizontal hydraulic conductivities greater than 30 feet/day. These permeable soils extend at least 20 feet beneath the basin bottom before encountering an aquitard or aquiclude.
- SHGWT elevations are more than 6 feet beneath the proposed bottom of the dry retention site. This is to assure that mounding does not adversely affect the retention system operation and performance.
- Retention system is located at least 25 feet from a swale or other stormwater or surface water feature to minimize possibility of pollutant migration, but within 100 feet of such a feature to help dissipate ground water mounds beneath the system. Figure 605-3 illustrates this separation.

Usable Site Conditions - may require site modification including lowering the SHGWT with underdrains on the exterior of the basin. Note that artificially lowering the ground water table may be precluded in some areas of the state and by some jurisdictional agencies for management and resource conservation reasons.

- Soils on the dry retention basin site are silty with stabilized infiltration rates greater than 3 inches/hour and horizontal hydraulic conductivities greater than 20 feet/day. These permeable soils extend 20 feet beneath the pond bottom before encountering an aquitard or aquiclude.
- SHGWT elevations are between 3 and 6 feet beneath the proposed bottom of the dry retention basin.

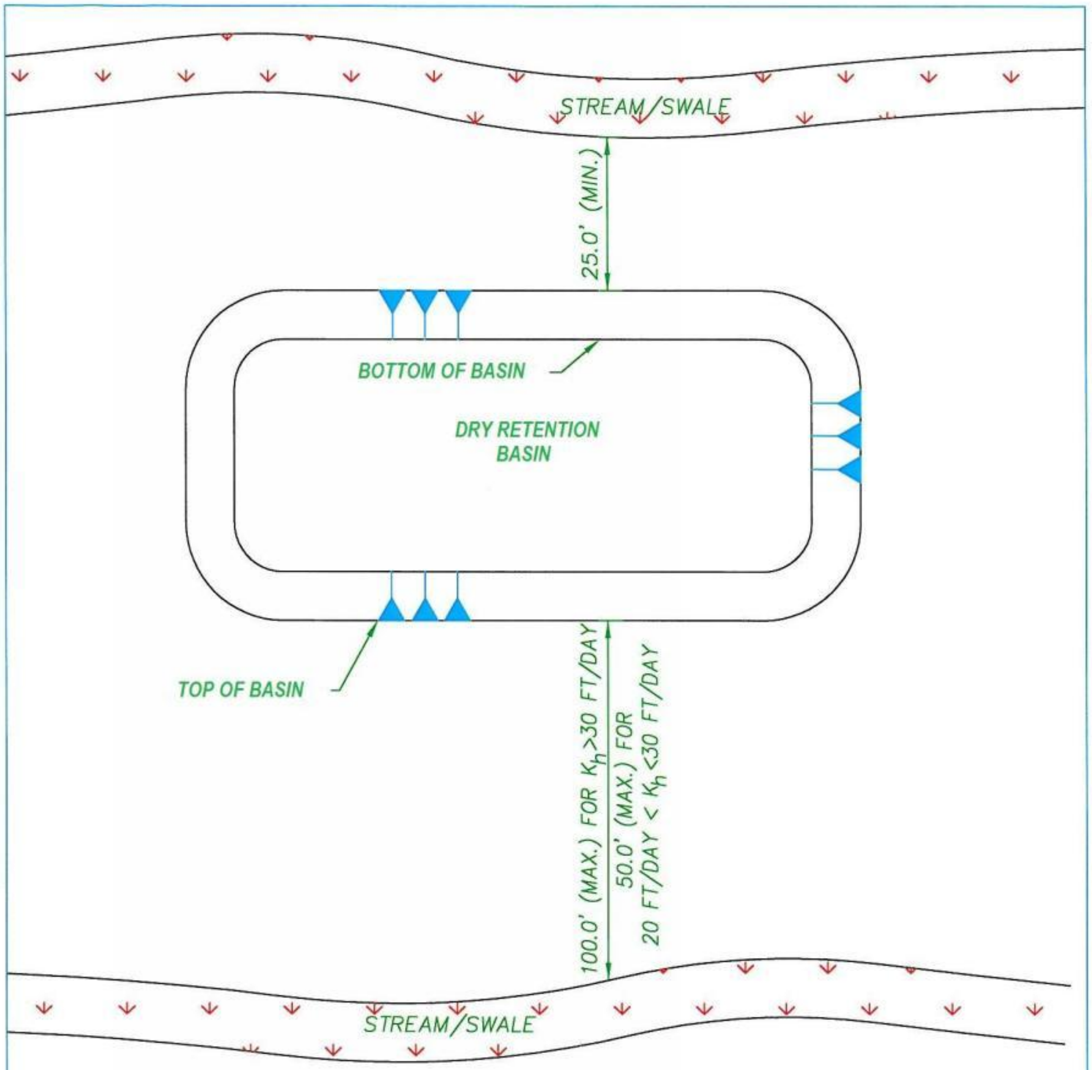


FIGURE 605-3: RETENTION/SWALE PLACEMENT
NTS

**FLORIDA AIRPORTS STORMWATER
BEST MANAGEMENT PRACTICES MANUAL**

- Retention system is located at least 25 feet from a swale or other stormwater or surface water feature to minimize possibility of pollutant migration, but within 100 feet of such a feature to help dissipate ground water mounds beneath the system.

Unfavorable Site Conditions - may require selection of a different BMP

- Soils are silts and clays of with stabilized infiltration rates less than 1.0 inches/hour and horizontal hydraulic conductivities less than 10 feet/day.
- Aquitard or aquiclude is located within 10 feet of the proposed retention system bottom
- SHGWT elevations are less than 3 feet beneath the proposed bottom of the dry retention system.
- The area beneath the proposed retention system contains gravels, shells or similar highly permeable material that connects directly to an aquifer allowing pollutants to migrate rapidly into the ground water.
- Site is in a Karst Sensitive Area or an area of significant sinkhole activity.

2. Design Criteria

- The Required Treatment Volume (RTV) necessary to achieve the required treatment efficiency shall be routed to the retention basin and percolated into the ground
- Design the retention system to completely recover the treatment volume within 24 to 36 hours depending upon the location and the area’s wet season interevent dry season (Figure 605-4). Also, the design should avoid standing surface water for more than 48-hours, consistent with Advisory Circular 150/5200-33 *Hazardous Wildlife Attractants On or Near Airports*.
- The seasonal high ground water table shall be at least two feet beneath the bottom of the retention basin unless the applicant demonstrates, based on plans, test results, calculations or other information, that an alternative design is appropriate for the specific site conditions.
- The retention basin sides and bottom shall be stabilized with permanent vegetative cover, some other pervious material, or other methods acceptable to the Agency that will prevent erosion and sedimentation.
- Required Site Information **-** Successful design of a retention system depends greatly upon knowing conditions at the site, especially information about the soil, geology, and water table conditions. Specific data and analyses required for the design of a retention system including details related to safety factors, mounding analyses, and required soil testing are set forth in **Appendix F** of this Manual.

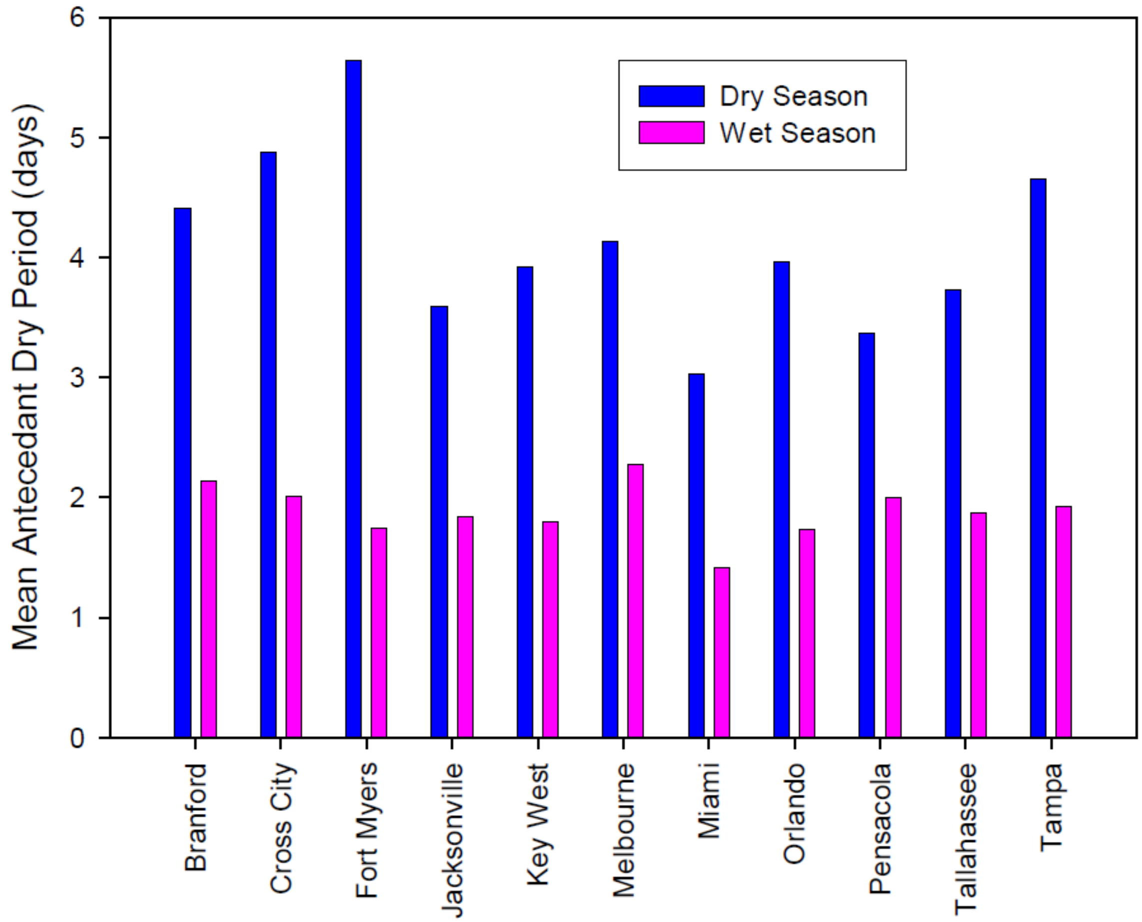


Figure 605-4 Interevent Time at Selected Florida Weather Stations

- Evaluate ground water mounding on a continuous simulation instead of a single event basis using one of the methods in Table 605-1 below. The mounding recovery is evaluated using the Horizontal Saturated Flow methodologies, and generally use infiltration rates averaged over the rainy season. The maximum mound from this analysis should remain at least 1 foot beneath the pond bottom.

Table 605-1 Accepted Methodologies for Recovery Analyses

Infiltration	Horizontal Saturated Flow
Green Ampt Equation	Simplified Analytical Method with Darcy Equation
Richards Equation	Hantush Equation
Phillips Equation	MODFLOW
Horton Equation	Finite difference spreadsheet with Dupuit assumption
Commercial Software Products	Commercial Software Products

- If SHWGWT levels must be lowered using underdrains, recommended underdrain location is at least 25 feet from the bottom edge of the retention system (see Figure 605-5A). Underdrains placed directly in the retention system bottom (see Figure 605-5B) shall not be used for stormwater management, since these may transport more soluble pollutants directly to the stormwater conveyance. Include underdrain loads in the post-development discharge load calculations. Note that artificially lowering the ground water table may be precluded in some areas of the state and by some jurisdictional agencies for management and resource conservation reasons. Also, General Permit 62-330.449 is not applicable for designs incorporating underdrains.
- Design the retention system to retain or detain, as appropriate, the design storm so that post-development peak flows from the project site do not exceed pre-development peak flows for the design event. The design storm is typically a 10-, 25- or 100-year recurrence interval event of 1 to 3 days duration. It is not necessary to retain the entire design storm but the required treatment volume shall be retained and not discharged. Total volume controls may be applied by some local jurisdictions and may control the design.

c. Swales

Swales are an important part of the stormwater conveyance system at most airports and can function as the BMP for the project or as part of the water quality treatment train. Swales are defined in Section 403.803, F.S. as a manmade trench which:

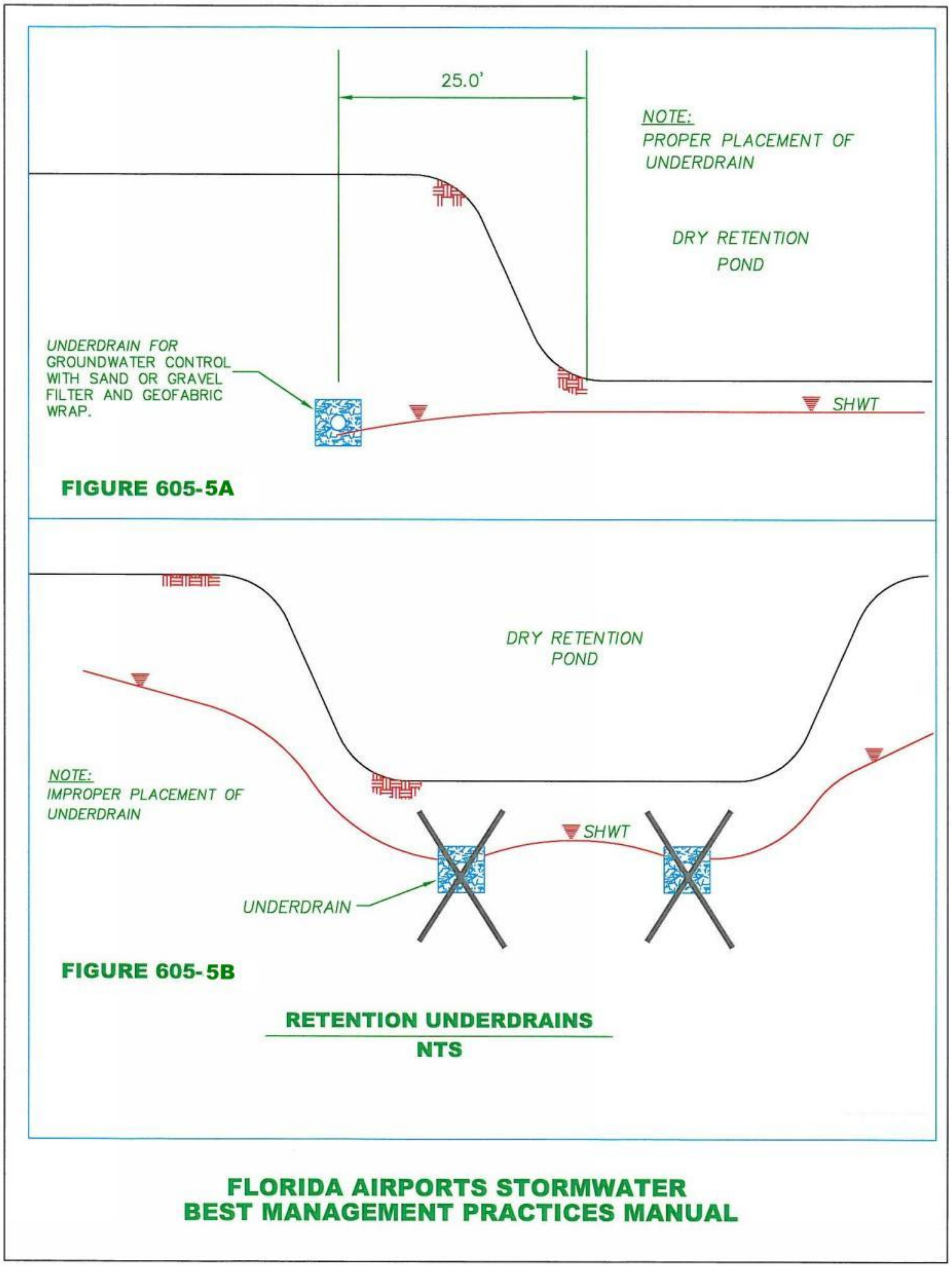
(a) Has a top width-to-depth ratio of the cross section equal to or greater than 6:1 or side slopes equal to or greater than 3 feet horizontal to 1 foot vertical;
(b) Contains contiguous areas of standing or flowing water only following a rainfall event;
(c) Is planted with or has stabilized vegetation suitable for soil stabilization, stormwater treatment, and nutrient uptake; and
(d) Is designed to take into account the soil erodibility, soil percolation, slope, slope length, and drainage area so as to prevent erosion and reduce pollutant concentration of any discharge.

Swales function similar to overland flow with respect to reducing stormwater pollutant concentrations and loads that is, treatment occurs via infiltration of the stormwater. High flow events may re-suspend trapped pollutants previously removed in both systems.

1. **Applicability**

   Swale Favorable Site Conditions

   - Soils on the site are sands with stabilized infiltration rates greater than 3 inches/hour and horizontal hydraulic conductivities greater than 20 feet/day, and
   - SHGWT levels are more than 2 feet beneath the swale bottom averaged over the swale length
   - Drainage permits flat (.1 -.5%) longitudinal and flatter than 3H:1V side slopes


25.0'
NOTE:
PROPER PLACEMENT OF
UNDERDRAIN
DRY RETENTION
POND
UNDERDRAIN FOR
GROUNDWATER CONTROL
WITH SAND OR GRAVEL
FILTER AND GEOFABRIC
WRAP.
SHWT
FIGURE 605-5A
DRY RETENTION
POND
NOTE:
IMPROPER PLACEMENT OF
UNDERDRAIN
SHWT
UNDERDRAIN
FIGURE 605-5B
RETENTION UNDERDRAINS
NTS
FLORIDA AIRPORTS STORMWATER
BEST MANAGEMENT PRACTICES MANUAL

Unfavorable Swale Site Conditions – require site modification such as filling with more pervious soil or lowering the ground water table. Without site modification, wet detention systems are likely needed. Use wet detention systems with caution and follow FAA design requirements to minimize wildlife impacts.

- Contributing pavement area is more than 50% larger than the swale area
- Soils are silts and clays with infiltration rates less than 0.5 inches/hour and hydraulic conductivities less than 2 feet/day
- Drainage or topography requires slopes over 1%.
- SHGWT elevations are at the ground surface at the lowest point of the infield or swale
- Location does not interfere with crash-fire-rescue access on the airside

2. Design Criteria for Swales

- Side Slopes of 3H:1V or flatter
- Longitudinal slopes should be as flat as possible with .1% - .5% recommended
- Limit swale flow velocity to 1.0 feet per second during a 0.5 inch storm and below the erodible velocity of site soils (Table 605-2) during the 25-year storm event

Table 605-2 Erosion Velocity Limits

Channel Bottom and Side Condition	Maximum Velocity (feet per second)
Grass/Plants on Sand	4
Grass/Plants on Clay	5

- Based on the evaluation of annual nutrient loads for the predevelopment and post development condition and the resulting required nutrient load reduction, determine the annual volume of runoff that must be infiltrated within the swale.
- Swale blocks may be used if necessary to reduce flow velocity and promote infiltration. However, check ground water mounding effects and avoid designs that retain water in the swale for more than 24 hours after any rainfall.
- Design outfall control structure to limit post-development peak flows to pre-development peak flows for the design storm. This is typically a 10-, 25-, or 100-year recurrence interval storm of 1 to 3 days duration event. Avoid designs that retain water in the swale for more than 24 hours following the event.

d. Wet Detention Systems (Ponds)

Wet detention ponds are excluded from the Airport BMP Manual at this time. Research on the water quality efficiency of a wet detention pond designed with FAA and USDA recommended features to reduce wildlife attractants is underway. Depending on the results of that research, incorporation of FAA/USDA wet pond criteria may occur in the future.

e. Other Retention Treatment Methods

Other treatment systems that retain and infiltrate stormwater may be incorporated into the BMP treatment train to achieve the load reduction or water quality specified in Florida Administrative Code. Items such as underground retention and exfiltration systems can reduce stormwater pollutant concentrations and/or loads. These are not part of General Permit 62-330-449 F.A.C., buy may be permittable under the various criteria of specific water management districts. The load reduction efficiencies of these BMPs should be used based on Florida-based monitoring and literature, and documented in the project calculations. Specifically, refer to Reference 10 in **Appendix A** or to the Basis of Review Manuals for the various Water Management Districts for design criteria applicable to these systems.

f. <u>Off-site Equivalent Treatment</u>

Off-site equivalent treatment is a valid option for airport stormwater management where hazard reduction is the primary concern and other options are not available. This is not included in General Permit 62-330-449, but is an option under an individual permit. For example, there are airport sites where a wet detention system is the only BMP that will work given the site's conditions. It is often the most expensive option and may be precluded solely by cost. Basin definition may also preclude the option such as when direct airport discharge to an already flooding area at the upstream of a watershed normally requires detention on the airport to avoid worsening the flood condition.

Where site, drainage basin, or hazard conditions suggest Off-site Equivalent Treatment is appropriate, however, conferencing with the Water Management District in advance of design is essential. It is necessary to identify facilities or areas within the drainage basin that can be built or retrofitted to provide Equivalent Treatment. A Benefit Cost Analysis should precede the decision to go-ahead with this option.

1. Applicability

- Other airside stormwater management options are not feasible as a result of hazard issues or land availability
- The drainage basin containing the airport includes facilities that can be retrofitted to achieve equivalent pollutant load reduction and flood attenuation
- The airport location within the drainage basin is consistent with off-site stormwater management. Airports that discharge directly to areas with flooding problems or impaired waters may be unable to use this option.
- Benefit Cost Analysis indicates a favorable ratio for this approach.

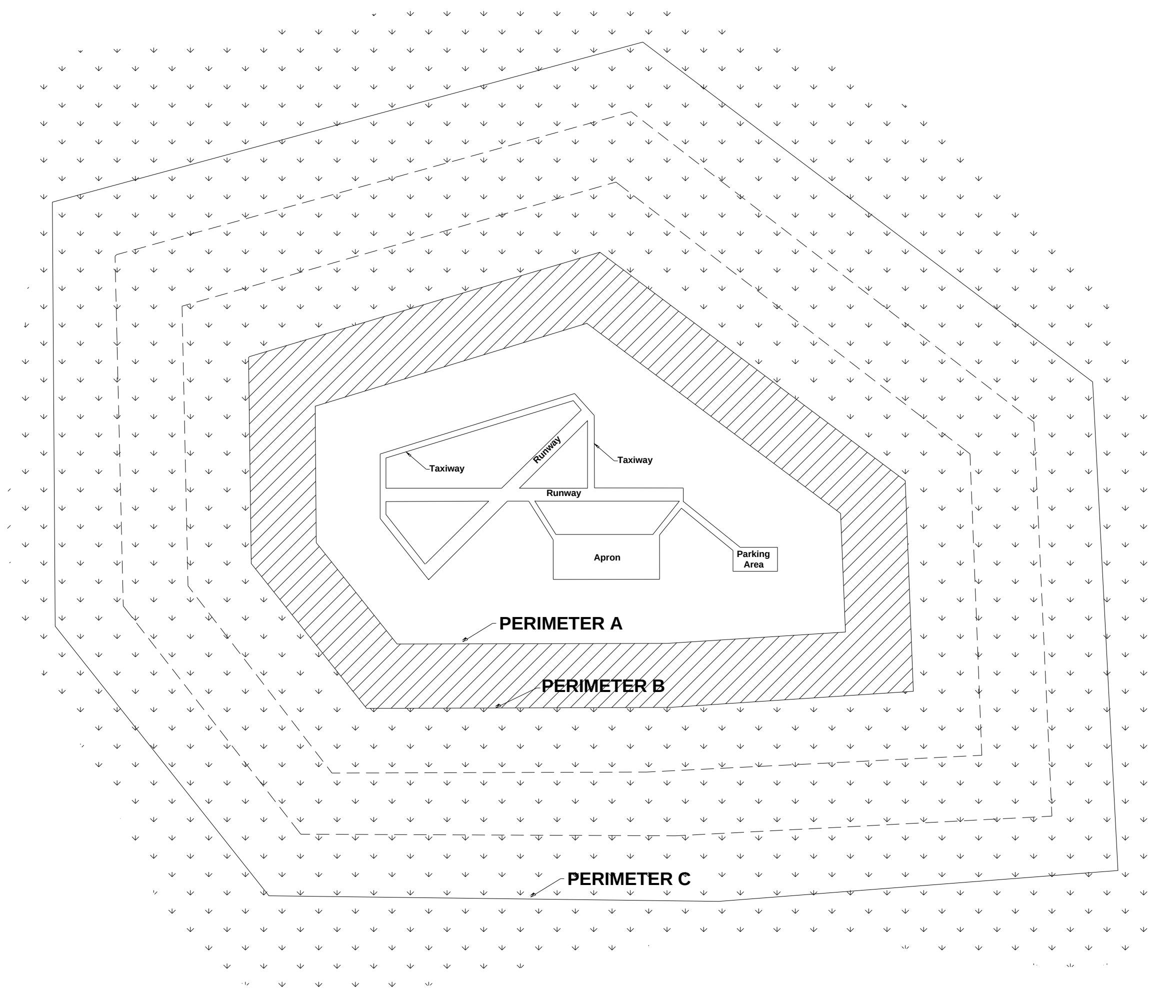
2. Design Criteria

- Water quantity modeling must extend into the drainage basin sufficiently to evaluate the effect of discharge from the airport and the effectiveness of off-site stormwater quantity management. Typically, the 10-, 25-, and/or 100-year events of 1 to 3 days duration require evaluation. Other events may also require evaluation.
- Water quality evaluation must include the following steps:
    1. Calculate the predevelopment and post-development loadings expected from the airport development using the Event Mean Concentrations and the method of Section 505 of this Manual
    2. Calculate the required load reduction to meet the loads from the natural vegetative community.
    3. Estimate the existing annual loads expected from the off-site area to be treated.

4. Calculate the load reduction necessary and select a treatment train to provide the load reduction from the off-site area.

- The off-site equivalent treatment area should be located outside the hazard limits shown in Figure 605-6 to the maximum extent practicable.

Separation distances within which hazardous wildlife attractants should be avoided, eliminated, or mitigated.



PERIMETER A: For airports serving piston-powered aircraft, hazardous wildlife attractants must be 5,000 feet from the nearest air operations area.

PERIMETER B: For airports serving turbine-powered aircraft, hazardous wildlife attractants must be 10,000 feet from the nearest air operations area.

PERIMETER C: 5-mile range to protect approach, departure and circling airspace.

FIGURE 605-6 Hazard Zones for Wildlife Attractants Around Airports
(excerpted directly from FAA Advisory Circular 150/5200-33B Hazardous Wildlife Attractants On or Near Airports)

606. PROCEDURAL BEST MANAGEMENT PRACTICES

The following Procedural Best Management Practices shall be used on all projects unless the Airport demonstrates that they are not appropriate. The listing is not intended as an exclusive set of available Procedural Best Management Practices, and other approaches not listed may be equally valid.

Procedural Best Management Practices are source control BMPs. They are intended to prevent pollutants from getting into the stormwater on the airside through airport management and operational procedures. There must be a commitment on the part of the airport's management to actively assure compliance. Incorporation of Procedural BMPs in the airport's Storm Water Pollution Prevention Plan (SWPPP) is strongly recommended. Training and education, compliance monitoring, and record keeping are elements needed for successful procedural controls.

a. Aircraft Fuel Sumping Control

An operational item affecting stormwater quality on general aviation aprons/ramps is fuel sumping. This is a standard pre-flight procedure for small, piston-powered aircraft. The procedure involves draining several ounces of the airplane's low-lead, high-octane gasoline (100LL AvGas) from low points (sumps) in the fuel system. There may be as few as one to as many as 13 sump points on the airplane.

The purpose of sumping is to prevent fuel contaminated with water or debris, which collects at the low points in the fuel system, from entering the engine during flight. Fuel contamination is particularly hazardous during takeoff. Historically, sumped fuel has been discarded directly onto the pavement surface. On some aircraft models this is unavoidable. However, a majority of aircraft can be sumped into a sight-glass or other container that permits fuel disposal options. This procedural control is applicable to those aircraft and those airports that have implemented this BMP.

1. **Applicability**
   - General aviation aprons/ramps and fueling areas for small, piston powered aircraft using low-lead aviation fuel
   - Aircraft that have sumps that can be drained by one person into a sight-glass or other device
2. **Procedure**
   - Use special devices that permit replacing the sump fuel directly into the aircraft fuel tank while preventing contaminants and water from being reintroduced into the fuel system.
   - The airport provides waste fuel tanks at specific locations on the general aviation aprons/ramps and at self-service fuel facilities. These tanks may be used to dispose of sump or contaminated fuel where the pilot-in-command determines the fuel cannot be safely re-introduced into the airplane fuel system.
   - Provide appropriate signage directing use of special devices or fuel disposal in designated containers surrounding the apron and in the general aviation terminal facilities.

- Partner with airport users to arrange training and education for line personnel, pilots and airport staff on the appropriate fuel sumping procedure.

3. Expected Concentration Reduction Efficiencies

This procedure has the potential to reduce the amount of leaded fuel discarded onto general aviation aprons/ramps by an average of 2 gallons per year per aircraft.

b. Turf Management

Overland flow is effective in reducing non-nutrient pollutants common in stormwater from the airport airside on both a concentration and load basis. However, nutrients of the nitrogen and phosphorus series may actually increase in concentration as water flows overland. Any load reduction from overland flow of these is then solely from infiltration. Moreover, excepting dry retention, no structural system effectively reduces both the nitrogen and phosphorus components to required levels. Consequently, source control is the best option for managing these pollutants. It is much easier to prevent nutrients from getting into stormwater than it is to remove them. Airside turf management should be used to reduce nutrient loading in existing and developing areas.

1. Applicability

- All airside infield and vegetated areas.

2. Procedure

- Test soil to determine fertilizer needs for phosphorus, potassium and micro-nutrients.
- Nitrogen shall be applied at a rate not exceeding 1 pound per 1,000 square feet and at least 50% of the nitrogen in fertilizer shall be slow release.
- Mow grasses with mulching mowers to heights of 3 to 4 inches every 7 to 10 days during the growing season. Leave clippings in place except for a 3-foot buffer zone around inlets (Figure 606-1). If practicable, remove grass cuttings in the buffer zone. As grass clippings accumulate during mowing, less fertilizer of all types may be needed.
- Reference the *Florida Yards and Neighborhoods* and *Florida Green Industries Best Management Practices for Protection of Water Resources in Florida* publications available from the University of Florida Extension Service for turf management guidelines. These publications can be downloaded from:
  http://www.dep.state.fl.us/water/nonpoint/pubs.htm
  http://www.floridayards.org/index.php

c. Sweeping

Airfield aprons/ramps and rarely runways and taxiways are subject to sweeping as a safety measure at most air carrier and some general aviation airports. The procedure can be modified to serve as a water quality BMP.

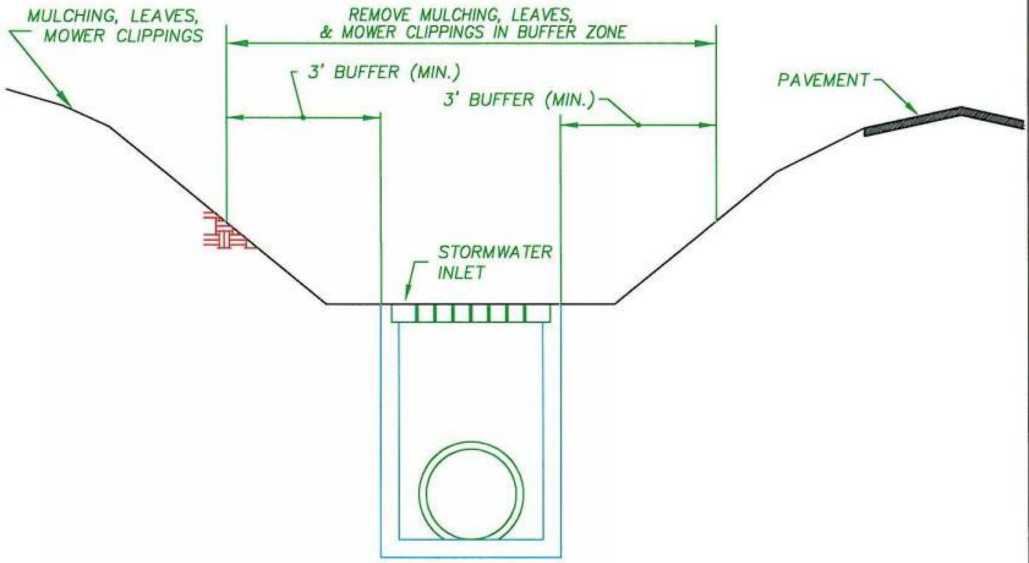


FIGURE 606-1: MOWING BUFFER AROUND INLETS
NTS

FLORIDA AIRPORTS STORMWATER
BEST MANAGEMENT PRACTICES MANUAL

1. **Applicability**
   - Terminal, cargo and general aviation aprons/ramps where the airport is equipped to do the procedure.

2. **Procedure**
   - Sweep the apron with a vacuum sweeper that collects dust and debris from the pavement for maximum benefit. Broom only sweepers that collect the sweepings may also be used at reduced effectiveness. Sweepers that simply clear debris from the pavement into adjacent grass areas do not qualify as a BMP since the material is not removed. Sweepings should be collected and sent to the appropriate landfill.
   - Sweeping should be as frequent as possible. Refer to Table 605-1 to evaluate probable benefits of sweeping daily or weekly. Less frequent sweeping is beneficial, but not sufficiently so to qualify as a BMP as opposed to a simple safety practice.

3. **Expected Concentration Reduction Efficiencies**

Table 606-1
Expected Concentration Reduction from Sweeping with Collecting Vacuum and Broom Sweepers (References 4 and 22 in Appendix A)

Constituent Category	Vacuum		Mechanical	
	Daily	Weekly	Daily	Weekly
Particulate Matter	60 - 90	40 -60	30 -50	20-30
Metals	40 - 80	30 -60	20 -30	15-20
Nutrients	30 - 80	20 -60	10 -30	10-20

d. <u>System Maintenance</u>

The stormwater management system at any airport is a major infrastructure investment, on a par with the airfield pavement system. Airfield pavement management is required by FAA if an airport receives Airport Improvement Program grants. It is an established management program and requirement. The stormwater management system must also be managed, but this requirement of Florida's Environmental Resource Permit system is not as well understood or practiced. Regular maintenance of all BMPs is required by the general permit. Additionally, a common sense approach to maintaining BMPs can increase the effectiveness and reliability of the airport stormwater management system.

1. **Applicability**
   - All airport stormwater management systems.

2. **Procedure**
   - Clean oil-water separators to prevent excess accumulations of petroleum products and possible overflows of the product out of the system and dispose with licensed petroleum waste handler.
   - Clean inlets and sediment traps of accumulated solids periodically and dispose of the material at appropriate landfills.

- Remove sediments from pipes and outlet structures through flushing and collection for disposal.
- Verify structures and controls are in good repair and condition and not hydraulically blocked.
- Remove sediment buildup in overland flow areas, swales and retention system bottoms and dispose of at appropriate landfills.
- Assure that overland flow areas, swales, and retention systems are stabilized with good vegetative cover that is maintained appropriately.
- Test operate active systems such as pumps and gates and perform regularly maintenance.
- Inspect retention systems and infiltration areas to verify they continue to operate and infiltrate as designed. Check that drawdowns occur within the recommended 24 50 36 hours.
- Visually survey wet systems for unwanted vegetation. Remove nuisance or wildlife attractant vegetation and replace with suitable plantings before these species become extensive or dominant.
- Establish a record system of observation and maintenance of the stormwater system similar to that for pavement management and maintenance.

APPENDIX A

REFERENCES

APPENDIX A
References

1) Bedient, P.B. and W.C. Huber, Hydrology and Floodplain Analysis, Third Edition, Prentice Hall, Inc., New Jersey, 1992

2) Bras, R.L and Ignacio Rodriguez-Iturbe, Random Functions and Hydrology, Dover Publications, Mineola, NY, 1993

3) Brater, E.F. and Horace Williams King, Handbook of Hydraulics, for the Solution of Hydraulic Engineering Problems, Sixth Edition, McGraw-Hill Book Company, New York, 1976

4) Breault R.F., Smith, K.P., Sorenson, J.R. (2005) Residential Street-Dirt Accumulation Rates and Chemical Composition, and Removal Efficiencies by Mechanical - and Vacuum-Type Sweepers, Scientific Investigations Report 2005-5184, U.S. Department of the Interior, U.S. Geological Survey

5) Chow, V.E., Ph.D., Open-Channel Hydraulics, McGraw-Hill Company, New York, 1959

6) Chow, V.E., Ph.D., David R. Maidment and Larry W. Mays, Applied Hydrology, McGraw-Hill Company, New York, 1988

7) Cleary, Edward C and Richard A. Dolbeer, Wildlife Hazard Management at Airports, U.S. Department of Transportation and U.S. Department of Agriculture, January, 2000

8) DeWiest, Roger J.M., Geohydrology, John Wiley & Sons, Inc., New York, 1965

9) Florida Automated Weather Network, (FAWN), http://fawn.ifas.ufl.edu/, last accessed on 20 December 2010.

10) Federal Aviation Administration, Advisory Circular 150/5200-33B, *Hazardous Wildlife Attractants on or Near Airports*, Superintendent of Documents, U.S. Government Printing Office, Washington, DC, August, 2007

11) Federal Aviation Administration, Advisory Circular 150/5320-5C, *Surfact Drainage Design*, Superintendent of Documents, U.S. Government Printing Office, Washington, DC, September, 2006

12) Florida Department of Environmental Protection and Water Management District, "Environmental Resource Permit Stormwater Quality Applicant's Handbook – Design Requirements for Stormwater Treatment Systems in Florida."

13) Florida Department of Transportation, "Application Assessment for the Florida Statewide Airport Stormwater Study," Tallahassee, Florida, 2007.

14) Florida Department of Transportation, "Technical Report for the Florida Statewide Airport Stormwater Study," Tallahassee, Florida, April 2008 revision.

15) Florida Department of Transportation, "FAA Pond Design Criteria, Water Treatment Modeling Report", Tallahassee, Florida, December, 2010

16) Hantush, M.S., "Growth and Decay of Groundwater-Mounds in Response to Uniform Percolation", Water Resources Research, Volume 3, No. 1, First Quarter, 1967, pp. 227-234

17) Jack H. Berryman Institute, Human-Wildlife Conflicts, Volume 3, Number 2 – *Special Topic: Bird Strikes*, Utah, 2009

18) Lambe, T. William, Soil Mechanics, John Wiley & Sons, Inc., New York, 1969

19) Mitchell, J.K., Fundamentals of Soil Behavior, John Wiley & Sons, Inc., New York, 1976

20) Parmley, R.O., P.E., Hydraulics Field Manual, McGraw-Hill, Inc., New York, 1992

21) Powers, J. Patrick, Construction Dewatering, New Methods and Applications, Second Edition, John Wiley & Sons, Inc, New York, 1992

22) Selbig W.R., and Bannerman R., "Evaluation of Street Sweeping as a Stormwater- Quality-Management Tool in Three Residential Basins in Madison, Wisconsin," Scientific Investigations Report 2007–5156, U.S. Department of the Interior, U.S. Geological Survey, 2007

23) Sowers, G.B., and George F. Sowers, Introductory Soil Mechanics and Foundations, Third Edition, MacMillan Publishing Co., New York, 1970

24) Todd, D.K., Groundwater Hydrology, Second Edition, John Wiley & Sons, New York, 1980

25) U.S. Dept. of the Army, Corps of Engineers "Time Lag and Soil Permeability in Groundwater Observations, Bulletin No. 36," Waterways Experiment Station, Vicksburg, Mississippi (written by M. Juul Hvorslev), 1951

26) United States Environmental Protection Agency, Preliminary Data Summary of Urban Storm Water Best Management Practices, United States Environmental Protection Agency, Office of Water, Washington, DC, August, 1999

27) Wang, H.F., and Mary P. Anderson, Introduction to Groundwater Modeling, Finite Difference and Finite Element Methods, W.H. Freeman and Company, San Francisco, 1982

28) Wanielista, M.P. and Y.A. Yousef, Stormwater Management, John Wiley & Sons, New York, 1993

APPENDIX B

GLOSSARY

APPENDIX B
Glossary

AIRPORT DISTRICT OFFICE (ADO). Administrative regional office of FAA that oversees airport development projects.

ADVISORY CIRCULAR (AC). A series of external FAA publications consisting of all non-regulatory material of a policy, guidance, and informational nature.

AIRPORT LAYOUT PLAN (ALP). The plan of an airport showing the layout of existing and proposed airport facilities.

AIR CARGO. Freight, mail, and express packages transported by air. Includes perishable foods and livestock.

AIR CARRIER. A person who holds or who is required to hold an air carrier operating certificate issued by FAA while operating aircraft having a seating capacity of more than 30 passengers.

AIR CARRIER AIRCRAFT. An aircraft with a seating capacity of more than 30 passengers that is being operated by an air carrier.

AIR CARRIER OPERATION. The takeoff or landing of an air carrier aircraft that includes the period of time from 15 minutes before and until 15 minutes after the takeoff or landing.

AIRPORT. Any area of land or water, or any manmade object or facility located therein, which is used, or intended for public use, for the landing and takeoff of aircraft, and any appurtenant areas which are used, or intended for public use, for airport buildings or other airport facilities or rights-of-way.

AIRPORT HAZARD. Any structure or object or ***WILDLIFE HAZARD*** found on or in the vicinity of a public-use airport, or any use of land near such airport, which obstructs or causes an obstruction to the airspace required for the flight of aircraft in landing or taking off at such airport, has the potential for damaging aircraft collision, or is otherwise hazardous to operating at such airport.

AIRPORT IMPROVEMENT PROGRAM (AIP). The AIP provides federal funding from the Aviation Trust Fund for airport development, airport planning, noise compatibility planning, and similar programs. The AIP is implemented under various authorization acts that cover a specific time period.

AIRPORT MASTER PLAN. Concept of the ultimate development of a specific airport. It presents the research and logic from which the plan evolved and displays the plan in graphic and written form.

AIRSIDE FACILITIES (AIRFIELD). Aircraft operations side of an airport including runways, taxiways, aprons, gate areas, and the terminal area airspace for approach and departure paths.

ALTERNATIVE DESIGN CRITERIA. Stormwater management system design criteria that offer reasonable assurance of meeting the pollutant load reductions, water quality standards, and flood protection requirements of the "Conditions of Issuance" for a permit. This is synonymous with "Non-Presumptive Design Criteria."

APPLICANTS HANDBOOK. A document incorporated by reference in the Environmental Resource Permitting rules of the FDEP or Water Management Districts that provides design, administrative and technical criteria for permit applicants.

APPROACH and DEPARTURE AIRSPACE. The airspace, within 5 statute miles of an airport, through which aircraft move during takeoff or landing.

APRON (also RAMP, TARMAC). Holding bay located at various points off a taxiway for loading or unloading of passengers or cargo, refueling, maintenance, or storage of aircraft.

ATTENUATION. With respect to stormwater, storage and/or a controlled release of discharge to an approximate a pre-determined rate of flow.

BMP (BEST MANAGEMENT PRACTICE). A structural or procedural control implemented to reduce stormwater pollutant loadings and minimize flooding. Structural BMPs are physical systems or structures such as ponds, swales or overland flow that reduce pollutant loadings and are technology based. That is, the best available and applicable technology, which may involve one or more systems or structures for pollutant load reduction, should be used. Procedural BMPs are activities and processes followed to reduce or eliminate exposure or introduction of pollutants to storm or surface waters.

BASIS OF REVIEW. A document incorporated by reference in the rules of the SFWMD and the SWFWMD that provides design, administrative and technical criteria for permit applicants.

CLEARWAY (CWY). A defined rectangular are beyond the end of runway cleared or suitable for use in lieu of a runway to satisfy takeoff distance requirements.

CLOSED DRAINAGE BASIN. A closed drainage basin is an internally drained watershed in which the runoff does not have a surface outfall up to the 100-year level.

COMMERCIAL SERVICE AIRPORTS. Public-use airports receiving scheduled passenger service and certified under FAR Part 139.

COMPENSATION. Measures provided to offset adverse impacts to wetlands, including one or more of the following:

(a) Mitigation;
(b) Inclusion of upland areas, beyond any required buffer zones, to maintain upland/wetland habitat diversity
(c) Establishment of vegetated littoral zones in on-site open waterbodies;
(d) Protection of exempt wetlands;
(e) Restoration of wetlands that have been previously impacted;
(f) Compensation on off-site lands; and
(g) Other reasonable measures, such as providing unlike wetland habitat.

CONCEPTUAL APPROVAL. Conceptual Approval or Letter of Conceptual Approval means an Environmental Resource Permit issued by the Water Management District approving the concepts of a master plan for a surface water management system. Conceptual approvals are binding upon the District and the permittee based upon the rules in effect at the time the conceptual application is filed on the public record. Construction and operation permits for each phase will be reviewed under the permitting criteria in effect when the application for conceptual approval was filed. A Conceptual Approval does not authorize construction.

CONDITIONS OF ISSUANCE. A set of impacts, standards and considerations that a stormwater management system and its owner/operator and designer must successfully address to receive a permit allowing construction and operation of the system.

CONSTRUCTION PERMIT. An Environmental Resource Permit issued by the Water Management District or FDEP authorizing construction, alteration or abandonment of a surface water management system in accordance with the terms and conditions of the permit.

CONTINUING FLORIDA AVIATION SYSTEM PLANNING PROCESS (CFASPP). CFASPP is the structured process for preparing and maintaining a statewide, twenty-year plan for aviation facility development in Florida. Guiding CFASPP are one statewide and nine regional Steering Committees make aviation system improvement recommendations to the Department of Transportation. These are ad hoc committees composed of volunteer professionals representing airport, airport authorities, local and regional planners, local government, and private enterprise.

CONTROL TOWER. A central operations facility in the terminal air traffic control system consisting of a tower cab structure (including an associated IFR room if radar-equipped) using air/ground communications and/or radar, visual signaling, and other devices to provide safe and expeditious movement of terminal air traffic.

DESIGN STORMS. For modeling purposes, a storm of such magnitude that its probability of occurrence is only once in a specified interval (e.g., 25 years, 100 years, etc.)

DETENTION. The collection and temporary storage of stormwater with subsequent gradual release.

DETENTION VOLUME. The volume of open surface storage upstream of the discharge structure, measured between the overflow elevation and control elevation.

EPA United State Environmental Protection Agency

ENVIRONMENTAL RESOURCE PERMIT (ERP). Environmental Resource Permitting, formerly called Management and Storage of Surface Waters, or MSSW permitting, requires permits for construction and operation of "new" surface water management systems, or alteration to an existing system. In simple terms, a "system" is a collection of project related facilities, man-made or natural, that collect, convey, contain or control surface waters. An Environmental Resource Permit (ERP) must be obtained before beginning construction or an activity that would affect wetlands, alter surface water flows, or contribute to water pollution. The ERP combines wetland resources permitting and MSSW permitting into a single surface water permit in an effort to streamline the permitting process.

EXFILTRATION. A stormwater system that uses perforated pipe to store stormwater and allow it to exfiltrate out of the pipe, through the surrounding gravel envelope, and into the soil.

FAA. Federal Aviation Administration

FAC. Federal Administrative Code

FAR. Federal Aviation Regulations

FBO. Fixed-Base Operator

FDEP. Florida Department of Environmental Protection

FDOT. Florida Department of Transportation

F.S. Florida Statutes

FLORIDA AVIATION SYSTEM PLAN (FASP). The aviation plan for Florida that provides documentation related to airports and related facilities needed to meet current and future statewide aviation demands.

GENERAL AVIATION AIRPORT. Those airports used exclusively by private and business aircraft not providing common-carrier passenger service.

HANGAR. A hangar is a closed structure to hold aircraft in protective storage. Most hangars are built of metal. They are used for protection against weather, direct sunlight, maintenance and repair, assembly and storage of aircraft on airfields.

HAZARDOUS WILDLIFE. Species of wildlife (birds, mammals, reptiles) including feral animals and domesticated animals not under control, that are associated with aircraft strike problems, are capable of causing structural damage to airport facilities, or act as attractants to other wildlife that pose a strike hazard. Lists and examples can be found in the FAA/USDA Manuals Wildlife Hazard Management at Airports.

HUB AIRPORT. An airport that serves several metropolitan areas.

HYDROLOGIC SOIL GROUPS. Refers to soils grouped according to their runoff-producing characteristics following the system promulgated by the U.S. Soil Conservation Service/National Resource Conservation Service. The chief consideration is the inherent capacity of soil bare of vegetation to permit infiltration. Soils are assigned to four groups. ***Group A*** soils have high infiltration when thoroughly wet and have a low runoff potential. ***Group D*** soils have very low infiltration and have a high runoff potential. ***Group B*** and ***Group C*** soils are intermediate between the Group A and Group D limits.

IDF CURVES. Curves developed by the Florida Department of Transportation, or other agency, to determine rainfall Intensity-Duration-Frequency.

IMPERVIOUS. Land surfaces which do not allow, or minimally allow, the penetration of water; examples are buildings, non-porous concrete and asphalt pavements, and some fine grained soils such as clays.

LANDSIDE FACILITIES. Those parts of an airport serving passengers, including surface transportation.

LARGE HUBS. Those airports that account for at least 1 percent of total U.S. passenger enplanements.

LITTORAL SHELF. A shallow gradual slope of a wet detention system that contains emergent vegetation, provides for a simulation of nutrients, and is a habitat for fish and wildlife.

MEDIUM HUBS. Airports that account for between 0.25 percent and 1 percent of the passenger enplanements.

METHOD DETECTION LIMIT (MDL). The minimum concentration of an element or compound that can be measured and reported with 99% confidence that the concentration is greater than zero. The values are determined following a defined procedure or are pre-specified for certain laboratory tests.

MOVEMENT AREA. The runways, taxiways, and other areas of an airport which are used for taxiing or hover taxiing, air taxiing, takeoff, and landing of aircraft, exclusive of loading ramps and aircraft parking areas.

NATIONAL PLAN OF INTEGRATED AIRPORT SYSTEMS (NPIAS). The Federal Aviation Administration's long-range national plan for airport development as established in the federal Airport and Airway Improvement Act of 1982. An airport must be included in the NPIAS to be eligible for federal funding.

NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM (NPDES). The 1972 Amendments to the Federal Water Pollution Control Act (commonly known as the Clean Water Act or CWA) prohibit the discharge of any pollutant to waters of the United States from a point source unless the discharge is authorized by a National Pollutant Discharge Elimination System (NDPES) permit. The NPDES permitting program was originally designed to track point sources, monitor the discharge of pollutants from specific sources to surface waters, and require the implementation of the controls necessary to minimize the discharge of pollutants. The 1987 Clean Water Act Amendment included certain storm water discharges for new and existing facilities. The NPDES Stormwater Program has been delegated to Florida Department of Environmental Protection.

NON-PRESUMPTIVE DESIGN CRITERIA. Refer "Alternative Design Criteria."

NORMAL WATER LEVEL. The design starting water elevation used when determining stage/storage design computations in a retention or detention area. A retention or detention system may have two (2) designated "normal water levels" associated with it if the system is designed for both water quality and water quantity.

OBSTACLE FREE ZONE (OFZ). The airspace defined by the runway OFZ and, as appropriate, the inner-approach OFZ and the inner-transitional OFZ, Which is clear of object penetrations other than frangible NAVAIDs.

OBSTRUCTION. Any object/obstacle exceeding the obstruction standards specified by FAR Part 77.

OBJECT FREE AREA (OFA). An area on the ground centered on a runway, taxiway, or taxilane centerline provided to enhance the safety of aircraft operations by having the area free of objects except for objects that need to be located in the OFA for air navigation or aircraft ground maneuvering purposes.

PERCOLATION. To seep, drain or permeate through a porous substance or filter, such as the infiltration of water into sand/soil.

PERMEABILITY (k). Also used interchangeably with ***HYDRAULIC CONDUCTIVITY*** is proportionality constant depending on the properties of a soil that reflects its transmission of water. The units are velocity (i.e. feet/day, centimeter/second, etc.)

POLLUTANT. Any substance that is harmful to plant, animal or human life. Stormwater is the major source of pollutants to Florida's lakes, estuaries and streams.

PRACTICAL QUANTIFICATION LIMIT (PQL). The lowest level of measurement than can be reliably achieved during routine laboratory operating conditions within specified limits of precision and accuracy. If not reported, the PQL is calculated as 4 times the ***MDL.***

PRESUMPTIVE DESIGN CRITERIA. Stormwater management system design criteria published by the Florida Department of Environmental Protection or the Water Management Districts that, if followed, are rebuttably presumed to meet the water quality standards and pollutant load reductions required by FAC 62-302 and 62-40, respectively.

RELIEVER AIRPORT. A specially designated general aviation airport that reduces congestion at busy commercial service airports by alternate landing areas for business aircraft.

RETENTION. A stormwater treatment system designed to prevent the discharge of a given volume of stormwater runoff into surface waters by complete, on site storage of that volume.

RUNWAY SAFTEY AREA (RSA). A defined surface surrounding the runway prepared or suitable for reducing the risk of damage to airplanes in the event of an undershoot, overshoot, or excursion from the runway.

RUNWAY. A defined rectangular surface on an airport prepared or suitable for the landing or take off of airplanes.

SEAPLANE BASE. A body of water licensed for operation and basing of seaplanes.

SHOULDER. An area adjacent to the edge of paved runways, taxiways, or aprons providing a transition between the pavement and the adjacent surface; support for aircraft running off the pavement; enhanced drainage; and blast protection.

SMALL HUBS. Airports that enplane 0.05 percent to 0.25 percent of the total passenger enplanements.

SURFACE WATER MANAGEMENT SYSTEM. The collection of facilities, improvements, or natural systems whereby surface waters are collected, controlled, conveyed, impounded, or obstructed. The term includes dams, impoundments, reservoirs, appurtenant works and works as defined in Subsections 373.403(1)-(5), Florida Statutes.

SWPPP (STORMWATER POLLUTION PREVENTION PLAN). A document which identifies sources of and activities at a particular facility that may contribute pollutants to stormwater and commits the operator to specific control measures and time frames to prevent or treat such pollutants.

TSA. Transportation Security Agency

TAXILANE. The portion of the aircraft parking area used for access between taxiways and aircraft parking positions.

TAXIWAY. A defined path established for the taxiing of aircraft from one part of the airport to another.

T-HANGAR. An aircraft hangar in which aircraft are parked alternately tail to tail, each in the T-shaped space left by the other row of aircraft or aircraft compartments.

TOTAL MAXIMUM DAILY LOAD (TMDL). The maximum allowable pollutant loading of a pollutant into a water body such that the water body will meet its applicable water quality standards and designated uses. TMDLs are established for waters that are impaired and not meeting standards.

WATERS OF THE STATE. Those surface waters regulated pursuant to subsection 403.031(12), Florida Statutes.

WET DETENTION SYSTEM. A stormwater management BMP that includes a permanent water pool to provide flood control and to remove pollutants through settling, adsorption by soils and nutrient uptake by the vegetation.

WETLANDS. Those areas that are inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils. Soils present in wetlands generally are classified as hydric or alluvial or possess characteristics that are associated with reducing soil conditions described above. These species, due to morphological, physiological or reproductive adaptations, have the ability to grow, reproduce, or persist in aquatic environments or anaerobic soil conditions. Florida wetlands generally include swamps, marshes, bayheads bogs, cypress domes and strands, slough, wet prairies, riverines, swamps and marshes, hydric seepage slopes tidal marshes, mangrove swamps and other similar areas.

WILDLIFE ATTRACTANTS. Any man-made structure, land-use practice, or man-mad or natural geographic feature which can attract or sustain ***HAZARDOUS WILDLIFE*** within the ***APPROACH or DEPARTURE AIRSPACE***, ***MOVEMENT AREA***, or ***APRONS*** of an ***AIRPORT***. These attractants can include but are not limited to architectural features, landscaping, waster disposal sites, wastewater treatment facilities, agricultural or aquacultural activities, surface mining or ***WETLANDS***.

WILDLIFE STRIKE. A wildlife strike is deemed to have occurred when:

1. A pilot reports striking one or more birds or other wildlife;
2. Aircraft maintenance personnel identify aircraft damage as having been caused by a wildlife strike;
3. Personnel on the ground report seeing an aircraft strike one or more birds or other wildlife;

4. Bird or other wildlife remains, whether in whole or in part, are found within 200 feet of a runway centerline, unless another reason for the animal's death is identified;
5. The animal's presence on the airport had a significant negative effect on a flight such as aborted takeoff, aborted landing, high-speed emergency stop, aircraft left pavement area to avoid collision with animal, or similar.

WMD. Water Management District. One of the five Water Management Districts chartered in the State of Florida. These are: Northwest Florida Water Management District (NWFWMD), South Florida Water Management District (SFWMD), Southwest Florida Water Management District (SWFWMD), St. John's River Water Management District (SJRWMD), and Suwannee River Water Management District (SRWMD). They issue Environmental Resource Permits under Chapter 40, Florida Administrative Code (FAC), and operate under Chapter 373, 403 and 120 Florida Statutes (FS).

APPENDIX C

SITE EVALUATION CHECKLIST

APPENDIX C
Site Evaluation Checklists

C-1 GENERAL

Water Management analysis and design for airfields are based on a variety of site data for both the existing condition and the proposed project(s). The data needs are physical, operational and regulatory. This appendix provides a general outline of those needs. It is not a comprehensive guide. It does provide a framework for competent engineers and scientists to plan and execute a data acquisition program for Airport Stormwater Best Management Practice design and implementation. Many data acquisition tasks will require specialty consultants to plan and execute the effort.

C-2 SITE RECONNAISSANCE

Reconnaissance of the project site and surroundings is a critical element for planning the data acquisition program. It is also important at subsequent review stages of design and permitting. Two elements make up the reconnaissance. These are: Collection of Existing and Published Data, and Visual Reconnaissance.

a. Collection of Existing and Published Data. Public use airports typically have existing data that is useful for water management analysis and design. Additionally, there are several common federal, state and local publications that can provide data either directly usable or useful for planning the project specific data acquisition program.

(1) *Existing Data*. Common data sources are the Airport Master Plan, the Airport Layout Plan (ALP), prior project plans, geotechnical studies, Engineer Reports, and the Stormwater Pollution Prevention Plan (SWPPP). The airport may have other documents from which useful information can be extracted. Master Drainage Plans, prior Water Management Permits, Wildlife Hazard Management Plans, Environmental Assessments (EA), Environmental Impact Statements (EIS), Development of Regional Impact (DRI) Studies, Contamination Reports, and similar documents should be requested and reviewed if available. Data that can be extracted and summarized may include:

- ❑ General land use on the airport and surrounding areas.
- ❑ Existing and forecast aircraft operations on the airport.
- ❑ Existing airside and landside pavement and buildings
- ❑ Major drainage basins and directions of surface flow.
- ❑ Existing water management structural controls, such as ponds.
- ❑ Stormwater conveyance details such as inlets, pipes and swales.
- ❑ Expected peak runoff rates and volumes from prior projects.
- ❑ Previously defined tailwater and/or seasonal high water elevations.
- ❑ Procedural Best Water Management Practices recommended at the airport.
- ❑ Jurisdictional agencies for Water Management Permitting. Note that this may include local and special jurisdictional agencies such as cities, counties and special flood control districts. The

list of airports and jurisdictional Water Management District in Appendix J of this manual does not show these local and special agencies.

- Special water management permit conditions in effect for prior projects at the airport.
- Pre-defined wetlands limits and characteristics.
- Soil and groundwater information for prior projects.
- Areas of known or suspected hazardous materials contamination.
- Floodplain limits previously defined.
- Wildlife surveys, including wildlife and bird strike problems and control needs at the airport.

(2) ***Published Data***. Published data that may be available includes aerial topographic maps with contour intervals of 1 or 2 feet. These may be available from the Water Management Districts, the Florida Department of Transportation, or the local government. Also, local government may have city-, county- or special district-wide master drainage plans, flood studies, groundwater data, or water management computer models that can be used. Contact the local government for availability of these products. Published data generally available includes:

- Soil Surveys for individual counties published by the National Resource Conservation Service (NRCS), formerly Soil Conservation Service (SCS). These are usually available at the NRCS office in the county.
- Rainfall records published by the National Weather Service. These can be airport specific for those airports with either Automated Surface Observation Systems (ASOS) or weather/rainfall measuring and reporting procedures.
- Florida Department of Transportation (FDOT) Drainage handbooks. This document includes rainfall amounts, intensities and standard distributions for design use. It also includes procedures for drainage design. This is available from: FDOT Maps and Publications On-line Store at www.dot.state.fl.us
- Quadrangle topographic maps available from the United States Geological Survey.
- National Wetland Inventory Maps published by the US Fish and Wildlife Service will be available in the future. Wetland information may currently be found on the National Map viewer of the USGS site under Hydrography.
- Aerial photography, possibly including color and infrared, available from the National High Altitude Photography program from the United States Geological Survey (USGS). Historical aerials for prior land use.
- Flood Insurance Rate Maps (FIRM) available from the Federal Emergency Management Agency (FEMA).
- Tide data from NOAA.
- Landside water quality data.

b. Visual Reconnaissance. Visual reconnaissance of the project site for water management issues should be conducted as part of the data planning process. As data collection and the water management concept progress, additional visual reconnaissance is a valuable and sometimes necessary tool in the permitting process. It is a recommended part of a permit preapplication meeting, and is usually necessary when wetland issues are involved.

The information collected in site visual reconnaissance will vary with the project. The following lists suggest information that can benefit the data acquisition planning process and subsequent design and analysis.

- Topography
  - Level, rolling, sloping, sinkholes/karst, gullies, erosion
  - Elevation difference across site
  - General direction of runoff flow or ground slope
- Ground Cover
  - Cleared, wooded, pavement, grass, debris, building
  - Grass height, density, coverage, bare soil
  - Estimate Manning's n for overland flow
- Surface Soil
  - Sand, silt, clay, gravel, peat, muck, rock outcrops
  - Hard, loose, wet, dry, color
  - Site has appearance of fill, cut, original ground
- Surface Water
  - Streams, creeks, ditches, wetlands, ponds
  - Water elevation
  - Flow direction
  - Evidence of high water or floods, stain lines, debris/rack lines
  - Estimate Manning's n for channel flow at low, normal and flood stages
- Groundwater
  - Wells, springs, artesian wells,
  - Seepage lines in cuts, ditches
- Rainfall Conditions
  - Previous weather, wet, dry
  - Comparison with typical year, wet dry
- Drainage Structures
  - Inlets – grates, types, size, condition
  - Pipes – types, size, condition, any base flow
  - Outlets – types, condition, stain lines, special structures
  - Underdrains – type, size, approximate depth, any base flow
- General
  - Evidence of conflicting underground utilities
  - Past experience in the area, recollection of airport personnel

- o Note differences between collected documents and observed site, if any
- o General appearance of site

C-3 TOPOGRAPHY AND SURVEY

Drainage and water management are highly dependent on topography and ground surface characteristics. The typical survey program for the design of an airfield paving project may not provide sufficient information for water management. Specifically, topographic survey limits may need extension beyond the boundary of the project to define drainage basins. Data may be needed for water management control structures distant from the project boundaries. Conveyance systems such as inlets, pipes, swales and open channels both upstream and downstream of the project location will likely be required. Elements of topographic evaluation and survey programs may include:

a. USGS Quadrangle Topographic Maps. The very flat terrain typical of many Florida airports often limits the usefulness of this tool to broad definitions of flow direction and identification of receiving waters.

b. Aerial Topographic Maps. When available or included with the project, aerial topographic maps are a very valuable tool for water management analysis and design. General guidelines for aerial topographic maps for water management planning and design are:

- ❑ Extend aerial topography beyond the project limits to encompass estimated upstream basins contributing flow, and adjacent areas that may provide flood storage.
- ❑ Contour intervals of 1 foot accurate to ± ½ foot for vertical information should be obtained
- ❑ Horizontal accuracy of ± 5 feet should be required
- ❑ Obtain rectified aerial photography at a scale appropriate to the project site.
- ❑ Rectified color infrared photography at the same scale as the rectified aerial photograph are useful in identifying wetlands and drainage features when properly interpreted and should be obtained if possible.

c. Field Survey. Ground survey is required in almost all cases. The field survey may include boundary survey components as well as topographic and engineering surveys. Boundary surveys sufficient for legal description and land area calculations will be needed if wetlands are present on the project(s) site. Topographic and engineering surveys may include data collection of the following types:

- ❑ Topographic survey based on discrete data points at 3rd Order accuracy. Pavement data is generally recorded to the 0.01^{foot} and ground surface data to the 0.1^{foot} precision.
- ❑ Aerial target setting for aerial photogrammetry.
- ❑ Drainage conveyance system surveys. These should include:

  - Inlet locations, elevations, openings, details, and pipe size, type, location and invert elevations connected to the inlet.
  - Outlet locations, elevations, openings, details and pipe size, type, location, number and invert elevations connected to the outlet.
  - Elevation of water standing or flowing in pipes
  - Elevations of stain lines or rack lines on inlet and outlet structures.
  - Elevation of blockage or siltation reducing pipe effective area.
  - Location and details of control structures including weir lengths and elevations, notch angles, orifice dimensions and inverts, skimmer top and bottom elevations and arrangements, outlet pipe type, size and inverts, underdrain connections, spillway characteristics, and similar.
  - Cross-sections of open channels. Spacing of the sections is based on the project size and the level of detail needed. Spacing of sections does affect the computed water surface elevation, sometimes by significant amounts. The cross section surveys may include:
    - Top of bank, toe of slope and information sufficient to define the cross section of the channel
    - Information extending away from top of bank on both sides sufficient to define overflow storage limits/ floodplains during high water
    - Current water elevations and recent high water elevations based on staked indicators, rack/debris or stain lines.
- Wetland limits and elevations based on staking by environmental professionals <u>after</u> concurrence from jurisdictional agencies. This should be sufficient to prepare a boundary survey and legal description.
- Dimensions of any existing water management ponds, wet or dry, sufficient to calculate storage volume versus elevation data (stage-storage relation) for the facility.

C-4 LAND COVER AND USE

Land use and cover information is associated with stormwater runoff quantity and quality. Specific land cover information is needed to assess runoff volumes and rates, infiltration potential, and parameters associated with runoff quantity management. This usually consists of the amount of pervious and impervious surface, vegetation coverage and condition. Land cover and use data also permit estimates of pollutant types and amounts, which is critical to Airport Best Water Management Practice design and permitting.

C-5 WETLANDS

Florida's physiography is such that wetlands are often located on or adjacent to airports and the airside. They are a major natural and national resource. In fact, the federal government is endeavoring to increase the available wetland resource by 100,000 acres per year. However, they are also potential attractants to hazardous wildlife, and may be incompatible with safe airport operation if too near the airside area. Wetland type, limits, function, value and hazard potential must be assessed by qualified environmental professionals as part of water management planning, design and permitting. Generally, this assessment includes the following elements:

- Initial review of the USGS Topographic Map, the National Wetland Inventory Map, Soil Survey data, and aerial photographs for the project site and locales.
- Field review of likely wetland areas. Preliminary staking of wetland boundaries, evaluation of function, condition, type and value. Also, preliminary review of wildlife using the wetland. Field review can include estimates of seasonal high water levels based on plant indicators.
- Site visits with Jurisdictional Agency environmental professionals to confirm preliminary findings and wetland limits. Boundary survey and legal descriptions of staked wetland limits normally follow this effort.
- Possible assessment of wildlife hazard by qualified biologists.
- Possible assessment of off-site mitigation options and banks in the region.

C-6 GEOTECHNICAL

Geotechnical exploration and testing for water management are directed toward groundwater impacts on and from the water management system. Airside compatible stormwater best management uses systems that do not create standing water for extended periods. Key to airside water management planning and design is knowledge and estimation of groundwater levels and response. The geotechnical program should be designed to yield information on infiltration rates and capacity, seasonal high groundwater levels, hydraulic conductivity or permeability, and groundwater mounding or drawdown response.

a. Soil Survey Reports. The NRCS Soil Survey for a County can yield important preliminary data for water management system planning. Soil Surveys group surficial soils into general taxonomic groups and suggest typical agricultural and engineering properties for each group. Information is developed from a combination of aerial photo-interpretation and field truthing. It is necessarily coarse, since mapping units are areally large and construction changes conditions significantly between mapping efforts. However, the reports can provide initial guidance information of the following types. It is emphasized this must be supplemented with field exploration and field and laboratory testing for design. The data may not be relevant if the site has been disturbed, drained, or if engineered fills have been placed on it.

- Typical soil profile for the upper 6 feet of material.
- Engineering classification for soils in the upper 6 feet by the AASHTO and/or Unified Soil Classification System. Estimated gradation and Atterberg Limits for materials are usually provided along with the classification.
- Estimated seasonal high water table levels for the soils and the typical occurrence times and durations of the high levels.
- Estimated permeability for each layer in the profile for the upper 6 feet.

b. Field Exploration and Testing. Field exploration and testing are needed to evaluate the groundwater levels and response for design. The specific elements needed in the geotechnical exploration program must be developed on a project specific basis. The following are some typical elements:

- Soil Borings with Standard Penetration Tests (ASTM D 1586) and visual classification per the Unified Soil Classification System (ASTM D2488-00). Borings should include initial and 24-hour/stabilized ground water levels if the boring can remain open overnight before backfilling. Borings should extend at least 15 feet beneath the deepest excavation planned or to auger refusal if that occurs first. If dry retention ponds are planned, borings should extend at least 25 feet beneath the expected bottom elevation of the ponds.
- Test Pits with identification of soil layers and visual classification per the Unified Soil Classification System (ASTM D2488-00). Test pits are typically excavated to depths of 10 feet by backhoe and are most useful in areas where random or uncontrolled fill is suspected. Ground water levels and seepage lines in the test pit should be recorded on initial excavation. Usually safety concerns on the airfield preclude leaving a test pit open for 24-hour/stabilized ground water level measurements.
- Field Permeability Tests. Field permeability tests can be conducted in borings designated for the purpose. Generally, these tests provide a better measure of the in-situ permeability of the soils than laboratory permeability tests on undisturbed samples. Also refer to Appendix D
- Laboratory Permeability Tests. Laboratory tests for permeability are generally constant head (ASTM D2434-68) types and are most appropriate for sands. They are best used for assessing the properties of earthfill or backfill soils needed for the site or site features. They may be done on samples that are remolded to the expected compaction levels of the earthfill/backfill.

- Grain Size Analysis of Soils (ASTM D422-63 (2002)) may be done on returned soil samples representative of those encountered by borings and test pits. They may also be done on potential fill material that will be used on the site. Grain size analysis and Atterberg Limits permit direct classification of samples per the Unified Soil Classification System (ASTM D2487-00). They also provide a useful, indirect estimate of soil permeability/hydraulic conductivity.
- Atterberg Limits (ASTM D4318-00) are meaningful on soils containing a significant percentage of fines (soil passing the U.S Standard No. 200 sieve). It allows differentiation of silt and clay soils and, in combination with grain size data, provides an indirect estimate of permeability of these fine-grained soils.
- Geotechnical Report. This document should provide recommendations addressing:
    - Seasonal High Groundwater Levels
    - Groundwater mounding or drawdown expected from the project water management system
    - Temporary dewatering needed for construction
    - Permeability/hydraulic conductivity of in-situ and compacted soils, including fill material
    - Infiltration parameters for in-situ and compacted soils, including fill material
    - Sinkhole potential and impacts from water management concepts

C-7 FLOODPLAINS AND FLOODWAYS

Floodplain and floodway information is needed to recognize and plan for adverse flooding impacts that can occur when projects encroach into either. The initial data source for most determinations is the Flood Insurance Rate Map (FIRM) for the project and surrounding area. However, it is important to note that many floodplain areas are not fully indicated or defined in the FIRM maps. Consequently, consult the Jurisdictional Water Management District <u>and</u> county or city government for detailed and/or supplemental information on known floodplains and floodways on and around the airport.

C-8 RECEIVING WATERS

The level of water management needed is, in part, a function of the characteristics of the water bodies the project(s) discharge to. Primary issues for receiving waters are: water quality class per FAC 62-302, flood sensitivity, and tailwater elevation in the receiving waters for the design storm event. Flood sensitivity and tailwater information can be obtained from the Jurisdictional Water Management District, and local government. Prior permits, studies and FIRM's for the project can also be of assistance in defining receiving water conditions.

APPENDIX D

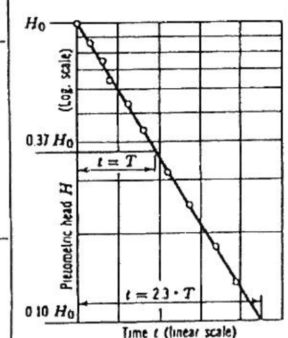
FORMULAS FOR PERMEABILITY FIELD TESTS

Case	Constant Head	Variable Head	Basic Time Lag
A	$k_v = \dfrac{4 \cdot q \cdot L}{\pi \cdot D^2 \cdot H_c}$	$k_v = \dfrac{d^2 \cdot L}{D^2 \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ $k_v = \dfrac{L}{t_2 - t_1} \ln \dfrac{H_1}{H_2}$ for $d = D$	$k_v = \dfrac{d^2 \cdot L}{D^2 \cdot T}$ $k_v = \dfrac{L}{T}$ for $d = D$
B	$k_m = \dfrac{q}{2 \cdot D \cdot H_c}$	$k_m = \dfrac{\pi \cdot d^2}{8 \cdot D \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ $k_m = \dfrac{\pi \cdot D}{8 \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ for $d = D$	$k_m = \dfrac{\pi d^2}{8 \cdot D \cdot T}$ $k_m = \dfrac{\pi \cdot D}{8 \cdot T}$ for $d = D$
C	$k_m = \dfrac{q}{2.75 \cdot D \cdot H_c}$	$k_m = \dfrac{\pi \cdot d^2}{11 \cdot D \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ $k_m = \dfrac{\pi \cdot D}{11 \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ for $d = D$	$k_m = \dfrac{\pi \cdot d^2}{11 \cdot D \cdot T}$ $k_m = \dfrac{\pi \cdot D}{11 \cdot T}$ for $d = D$
D	$k_v' = \dfrac{4 \cdot q\left(\dfrac{\pi}{8} \cdot \dfrac{k_v'}{k_v} \cdot \dfrac{D}{m} + L\right)}{\pi \cdot D^2 \cdot H_c}$	$k_v' = \dfrac{d^2 \cdot \left(\dfrac{\pi}{8} \cdot \dfrac{k_v'}{k_v} \cdot \dfrac{D}{m} + L\right)}{D^2 \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ $k_v = \dfrac{\dfrac{\pi}{8} \cdot \dfrac{D}{m} + L}{t_2 - t_1} \ln \dfrac{H_1}{H_2}$ for $\begin{cases} k_v' = k_v \\ d = D \end{cases}$	$k_v' = \dfrac{d^2 \cdot \left(\dfrac{\pi}{8} \cdot \dfrac{k_v'}{k_v} \cdot \dfrac{D}{m}\right) + L}{D^2 \cdot T}$ $k_v = \dfrac{\dfrac{\pi}{8} \cdot \dfrac{D}{m} + L}{T}$ for $\begin{cases} k_v' = k_v \\ d = D \end{cases}$
E	$k_v' = \dfrac{4 \cdot q \cdot \left(\dfrac{\pi}{11} \cdot \dfrac{k_v'}{k_v} \cdot \dfrac{D}{m} + L\right)}{\pi \cdot D^2 \cdot H_c}$	$k_v' = \dfrac{d^2 \cdot \left(\dfrac{\pi}{11} \cdot \dfrac{k_v'}{k_v} \cdot \dfrac{D}{m} + L\right)}{D^2 \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ $k_v = \dfrac{\dfrac{\pi}{11} \cdot \dfrac{D}{m} + L}{t_2 - t_1} \ln \dfrac{H_1}{H_2}$ for $\begin{cases} k_v' = k_v \\ d = D \end{cases}$	$k_v' = \dfrac{d^2 \cdot \left(\dfrac{\pi}{11} \cdot \dfrac{k_v'}{k_v} \cdot \dfrac{D}{m} + L\right)}{D^2 \cdot T}$ $k_v' = \dfrac{\dfrac{\pi}{11} \cdot \dfrac{D}{m} + L}{T}$ for $\begin{cases} k_v' = k_v \\ d = D \end{cases}$
F	$k_h = \dfrac{q \cdot \ln\left[\dfrac{2mL}{D} + \sqrt{1 + \left(\dfrac{2mL}{D}\right)^2}\right]}{2 \cdot \pi \cdot L \cdot H_c}$	$k_h = \dfrac{d^2 \cdot \ln\left[\dfrac{2mL}{D} + \sqrt{1 + \left(\dfrac{2mL}{D}\right)^2}\right]}{8 \cdot L \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ $k_h = \dfrac{d^2 \cdot \ln\left(\dfrac{4mL}{D}\right)}{8 \cdot L \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ for $\dfrac{2mL}{D} > 4$	$k_h = \dfrac{d^2 \cdot \ln\left[\dfrac{2mL}{D} + \sqrt{1 + \left(\dfrac{2mL}{D}\right)^2}\right]}{8 \cdot L \cdot T}$ $k_h = \dfrac{d^2 \cdot \ln\left(\dfrac{4mL}{D}\right)}{8 \cdot L \cdot T}$ for $\dfrac{2mL}{D} > 4$
G	$k_h = \dfrac{q \cdot \ln\left[\dfrac{mL}{D} + \sqrt{1 + \left(\dfrac{mL}{D}\right)^2}\right]}{2 \cdot \pi \cdot L \cdot H_c}$	$k_h = \dfrac{d^2 \cdot \ln\left[\dfrac{mL}{D} + \sqrt{1 + \left(\dfrac{mL}{D}\right)^2}\right]}{8 \cdot L \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ $k_h = \dfrac{d^2 \cdot \ln\left(\dfrac{2mL}{D}\right)}{8 \cdot L \cdot (t_2 - t_1)} \ln \dfrac{H_1}{H_2}$ for $\dfrac{mL}{D} > 4$	$k_h = \dfrac{d^2 \cdot \ln\left[\dfrac{mL}{D} + \sqrt{1 + \left(\dfrac{mL}{D}\right)^2}\right]}{8 \cdot L \cdot T}$ $k_h = \dfrac{d^2 \cdot \ln\left(\dfrac{2mL}{D}\right)}{8 \cdot L \cdot T}$ for $\dfrac{mL}{D} > 4$

Notation

D = Diam, intake, sample (cm)
d = Diameter, standpipe (cm)
L = Length, intake, sample (cm)
H_c = Constant piez. head (cm)
H_1 = Piez. head for $t = t_1$ (cm)
H_2 = Piez. head for $t = t_2$ (cm)
q = Flow of water (cm³/sec)
t = Time (sec)
T = Basic time lag (sec)
k_v' = Vert. perm. casing (cm/sec)

k_v = Vert. perm. ground (cm/sec)
k_h = Horz. perm. ground (cm/sec)
k_m = Mean coeff. perm. (cm/sec)
m = Transformation ratio
$k_m = \sqrt{k_h \cdot k_v}$ $m = \sqrt{k_h/k_v}$
$\ln = \log_e = 2.3 \log_{10}$

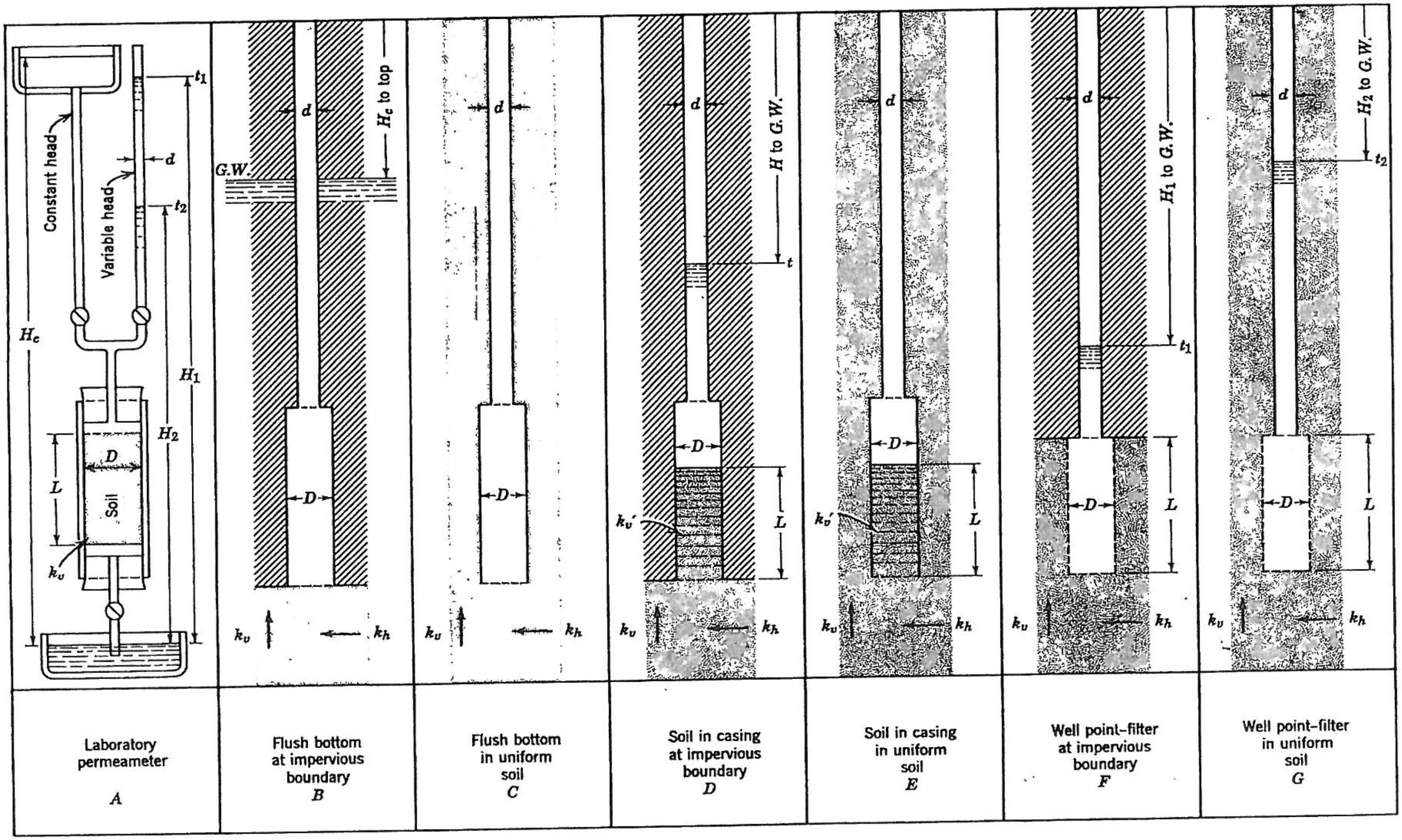


Determination basic time lag T

ASSUMPTIONS

Soil at intake, infinite depth, and directional isotropy (k_v and k_h constant). No disturbance, segregation, swelling, or consolidation of soil. No sedimentation or leakage. No air or gas in soil, well point, or pipe. Hydraulic losses in pipes, well point, or filter negligible.

Formulas for determination of permeability (From Hvorslev, 1951).

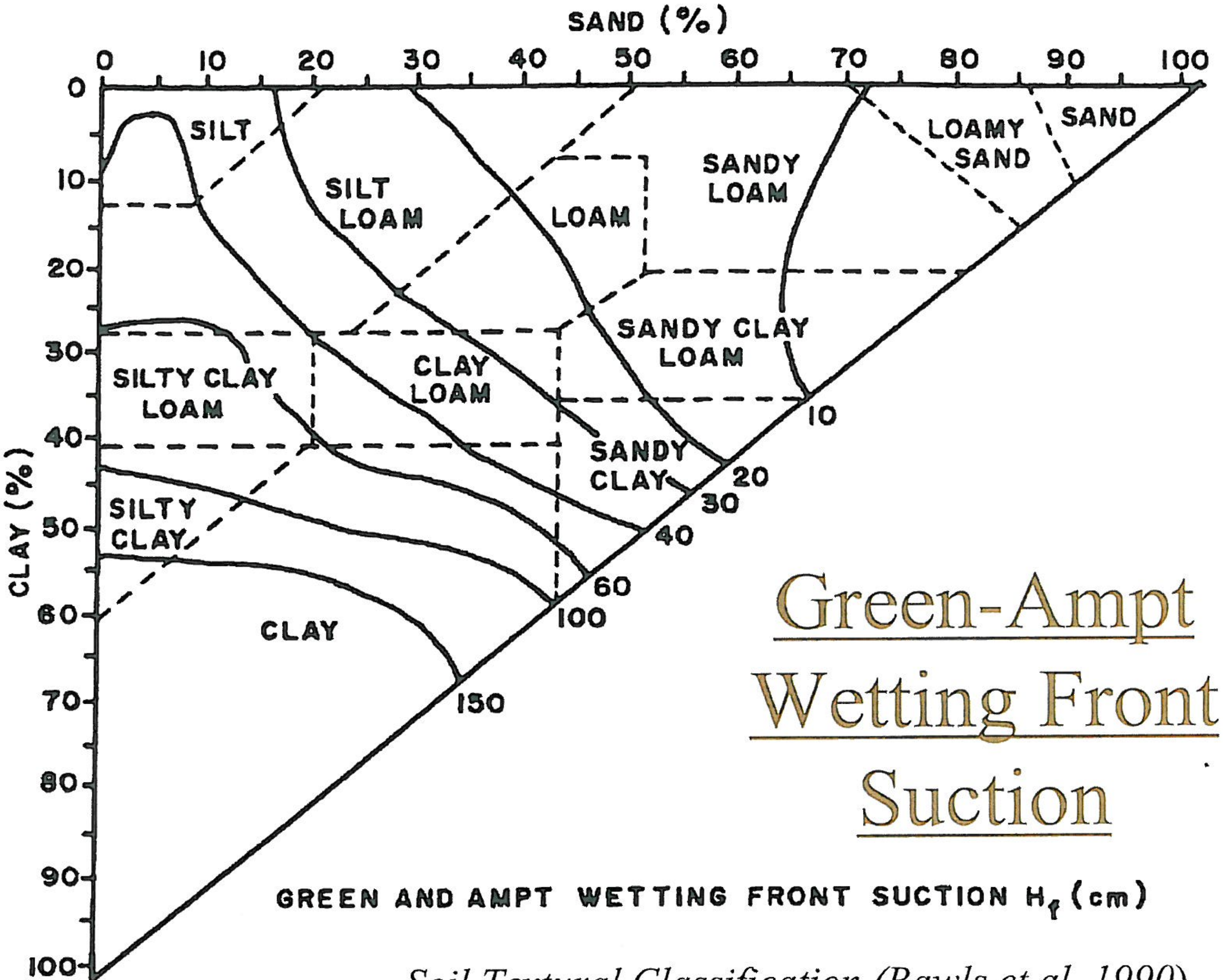


Constant head
Variable head
Soil
t_1
t_2
d
D
L
H_c
H_1
H_2
k_v
G.W.
H_c to top
k_h
H to G.W.
t
k_v'
H_1 to G.W.
H_2 to G.W.
Laboratory permeameter
A
Flush bottom at impervious boundary
B
Flush bottom in uniform soil
C
Soil in casing at impervious boundary
D
Soil in casing in uniform soil
E
Well point-filter at impervious boundary
F
Well point-filter in uniform soil
G

APPENDIX E

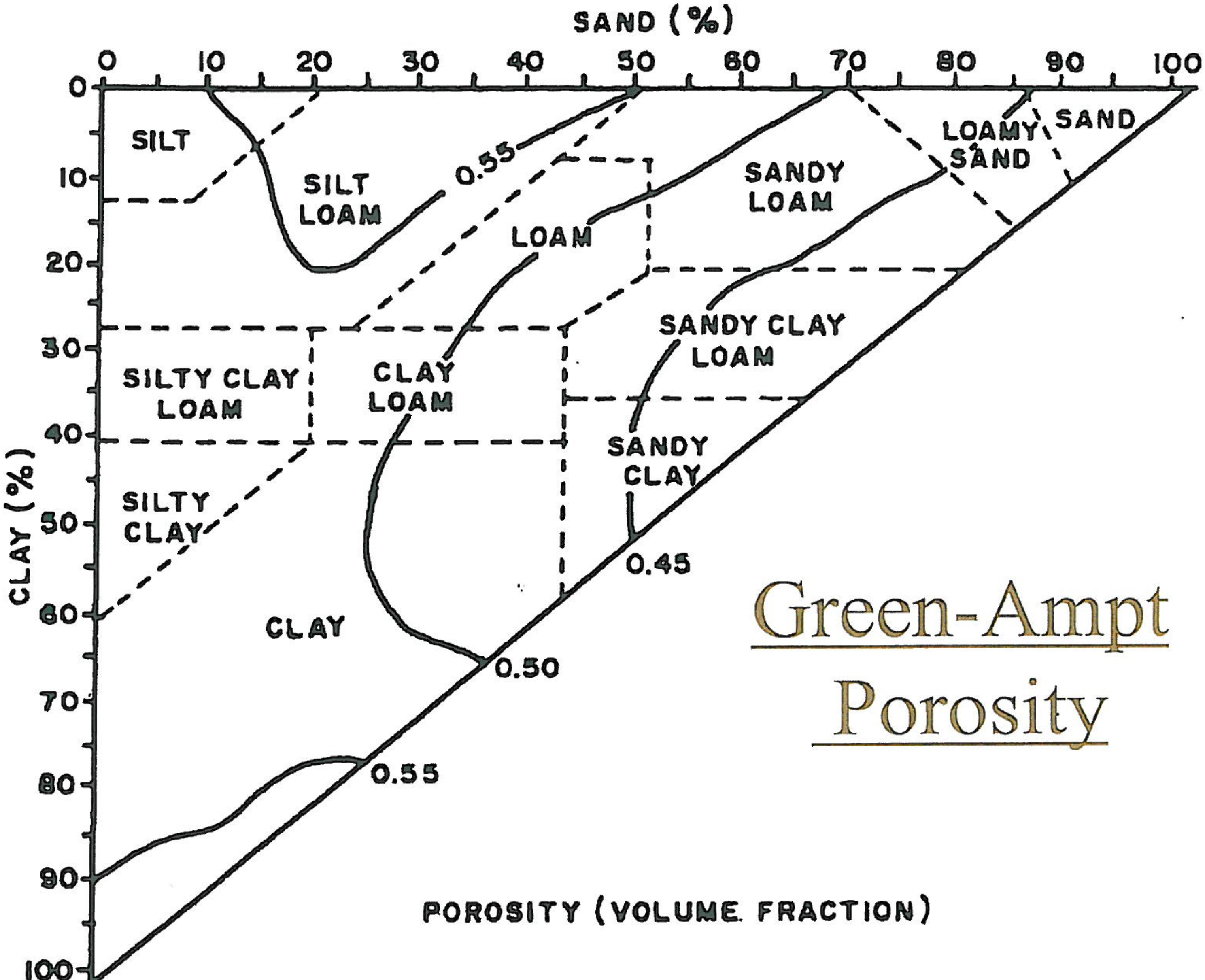
TYPICAL GREEN AMPT PARAMETERS BASED ON GRAIN SIZE ANALYSIS

Green-Ampt Wetting Front Suction



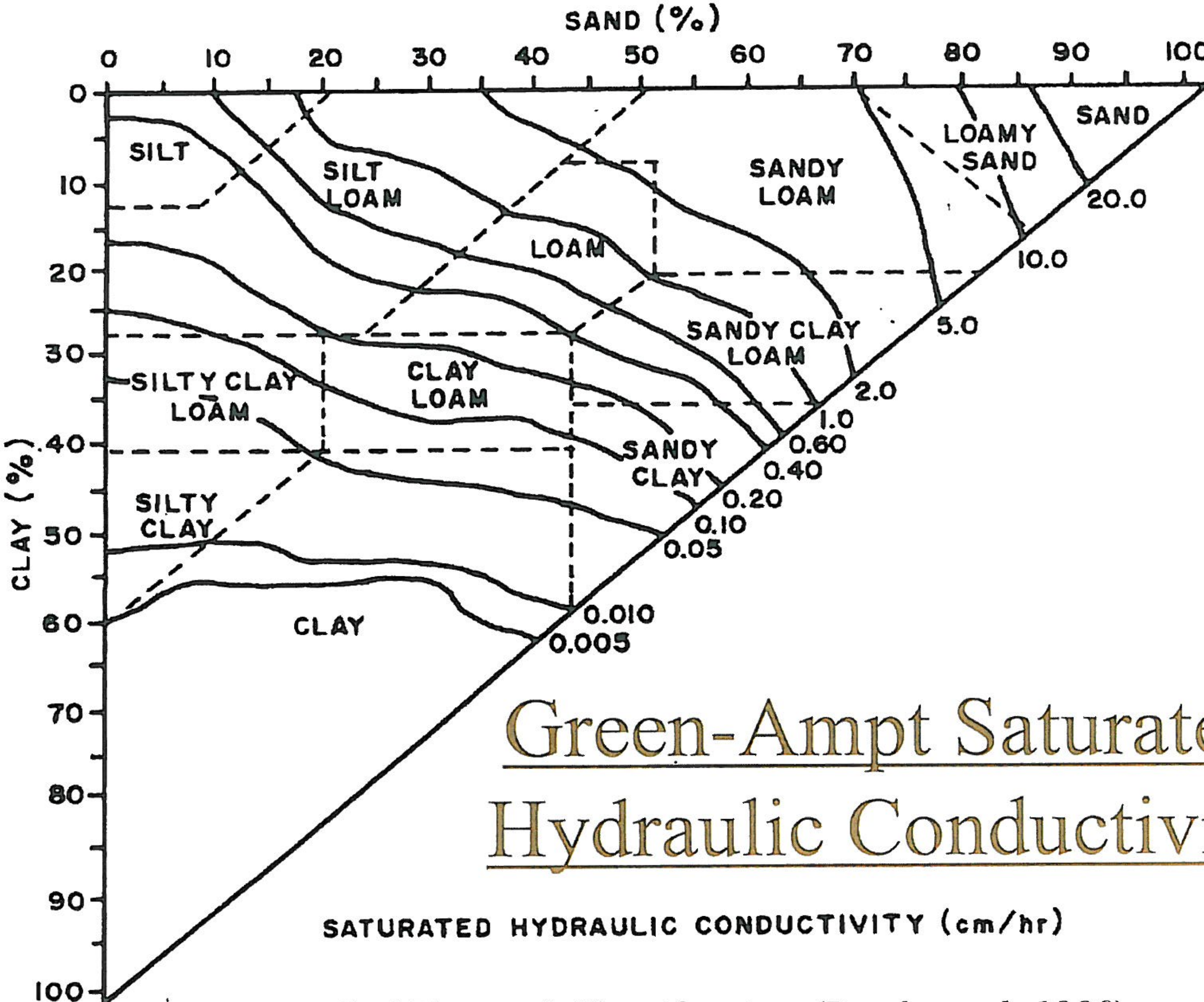
Soil Textural Classification (Rawls et al, 1990)

Green-Ampt Porosity



Soil Textural Classification (Rawls et al, 1990)

Green-Ampt Saturated Hydraulic Conductivity



Soil Textural Classification (Rawls et al, 1990)

APPENDIX F

METHODOLOGIES, RECOVERY ANALYSIS AND SOIL TESTING FOR RETENTION SYSTEMS

Adapted from information furnished by FDEP and Water Management Districts (See Reference 12)

APPENDIX F
Methodologies, Recovery Analysis, and Soil Testing for Retention Systems

Description

"Retention systems" are a family of Best Management Practices (BMPs) designed to store a defined quantity of runoff, allowing it to percolate through vegetation and permeable soils into the shallow ground water aquifer, evaporate, or evapotranspire. Stormwater retention works best using a variety of BMPs throughout the project site. Examples of common retention BMPs include (but are not limited to):

- Retention basins which are constructed or natural depressional areas where the basin bottom is graded as flat as possible and turf, seed & mulch (or other equivalent materials) are established to promote infiltration and stabilize the basin slopes.

- Underground Exfiltration Trenches.

- Underground Retention Systems

- Underground Vaults/Chambers.

- Vegetated Swales with or without swale blocks.

The soil's saturated hydraulic conductivity, depth to the Seasonal High Ground Water Table (SHGWT) and depth to the confining unit (i.e., clay, hardpan, etc.) must be such that the retention system can percolate the Required Treatment Volume (RTV) within a specified time following a storm event. After drawdown has been completed, retention BMPs do not hold any water, thus the systems are normally "dry." Unlike detention BMPs, the RTV for retention systems is not discharged to surface waters.

Retention systems provide excellent removal of many stormwater pollutants. Substantial amounts of suspended solids, oxygen demanding materials, heavy metals, bacteria, some varieties of pesticides and nutrients such as phosphorus may be removed as runoff percolates through the soil profile. All infiltration systems are assumed to remove 100% of the nutrient load for all of the runoff volume that is fully retained within the system. Lesser removals occur for those storms that exceed the treatment volume of the retention basin and bypass the system to be discharged offsite unless the retention basin is designed as an offline BMP.

Besides pollution control, retention systems can be used to promote the recharge of ground water, to prevent saltwater intrusion in coastal areas and maintain ground water levels in aquifer recharge areas. Retention systems can also be used to help meet the runoff volume criteria for systems that discharge to closed basins or land-locked lakes. However, the use of retention systems are not appropriate if they contribute to a violation of Minimum Flows or Levels in the receiving waters, or if they adversely impact wetlands by hydrologic alteration.

Required Treatment Volume (RTV)
The Required Treatment Volume is the volume of runoff that must be infiltrated in the specific BMPs to achieve the required load reductions. It is determined through the continuous simulation model results. The RTV necessary to achieve the required treatment efficiency shall be routed to the retention BMP and percolated into the ground.

Recovery Time of the RTV
All retention systems must provide the capacity for the RTV of stormwater to recover to the bottom of the system within 24 to 36 hours following a design storm event, assuming an average Antecedent Runoff Condition (ARCII). A safety factor of two (2.0) must be used in the recovery analysis of the RTV. Two possible ways to apply this safety factor are:

(a) Reducing the design saturated hydraulic conductivity rates by half; or

(b) Designing for the required RTV drawdown to occur within half of the required drawdown time.

The safety factor of two (2.0) is based on the high probability of
- Soil compaction during clearing and grubbing operations,
- Normal construction techniques that result in additional soil compaction under the retention BMP,
- Inadequate long term maintenance of the retention BMP, and
- Geologic variations and uncertainties in obtaining the soil test parameters for the recovery / mounding analysis (noted in subsequent sections below). These variations and uncertainties are especially suspect for larger retention BMPs.

Additional to the requirement for the RTV to recover to the bottom of the system within 24 to 36 hours following a design storm, the ground water mounding that occurs during the rainy season (see **Table 401-1**) must not adversely impact functioning of the system.

In retention systems, the RTV recovers (is drawn down or dissipated) by infiltration into the ground water table, evaporation, evapotranspiration, or horizontal flow of groundwater. The opposite is true for underdrain effluent detention systems, which rely on artificial recovery methods such as underground perforated drainage pipes. These underdrained systems are <u>NOT</u> presumed to remove 100% of loads in stormwater that infiltrates.

Antecedent Runoff Condition (ARC), formally known as Antecedent Moisture Condition (AMC), refers to the amount of moisture and storage in the soil profile prior to a storm event. Antecedent soil moisture is an indicator of wetness and availability of soil to infiltrate water. The ARC can vary from dry to saturated, depending on the amount of rainfall received prior to a given point in time. Therefore, "average ARC" (ARCII) means the soil is neither dry nor saturated, but at an average moisture condition at the beginning of a storm event when calculating recovery time for retention systems.

Infiltration and Saturated Horizontal Flow Processes
When stormwater runoff enters the retention BMP, standing water begins to infiltrate. This water percolates into and through the soil in two distinct stages, either vertically (Stage One) through the BMP bottom (infiltration), or horizontally (Stage Two) (horizontal saturated flow). One flow direction or the other will predominate depending (primarily) on:

- The rainfall or pond inflow rate (usually normalized per unit area of pond bottom footprint),
- The cumulative inflow volumes to the pond
- The depths to the water table and confining unit (i.e., clay or hardpan) below the bottom of the retention BMP, and
- The soil's saturated hydraulic conductivity.

The following paragraph briefly describes the two stages, and subsequent subsections present accepted methodologies for calculating infiltration rates and recovery times for infiltration (Stage One) and saturated horizontal (Stage Two) flow.

Initially, the subsurface conditions are assumed to be:

- The depth to the initial water table below the bottom of the BMP.
- Unsaturated soils above the water table.

When the water begins to infiltrate, it is driven downward as unsaturated flow by the combined forces of gravity and capillary action (also expressed as Soil Suction, ψ). Once the unsaturated soil below the BMP becomes saturated (fills the voids in the soil), the water table "mound" (refer to **Figure F-1**) intersects the ground surface. At this time, saturation below the BMP limits vertical movement to the horizontal groundwater flow rate. For successful designs of retention BMPs, both the infiltration and saturated, horizontal flow must be accounted for and incorporated into the analysis.

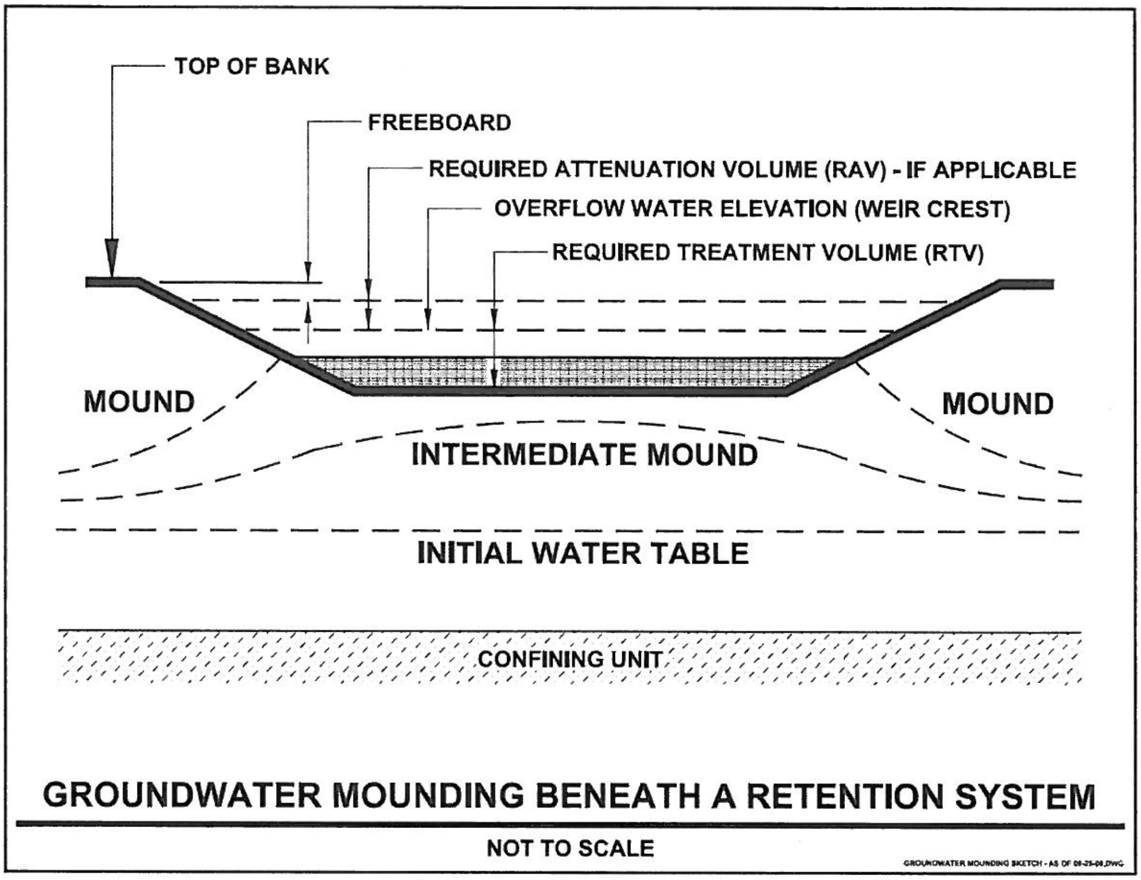


Figure F-1 Ground Water Mounding Beneath a Retention System

Accepted Methodologies for Determining Retention BMP Recovery

Acceptable methodologies for calculating retention BMP recovery are presented in **Table 605-1** reproduced below in **Table F-1**.

Table F-1 Accepted Methodologies for Retention BMP Recovery

Infiltration	Horizontal Saturated Flow
Green and Ampt Equation	Simplified Analytical Method with Darcy Equation
Richards Equation	Hantush Equation
Phillips Equation	MODFLOW
Horton Equation	Finite difference spreadsheet with Dupuit Assumption

Several of these methodologies are available in commercial software products. The Agencies can neither endorse any software program nor certify software results.

Additional requirements for calculating retention BMP recovery
Unless the normal Seasonal High Ground Water Table (SHGWT) is greater than or equal to 2 feet below the bottom of the BMP system, unsaturated vertical flow prior to saturated horizontal mounding shall be conservatively ignored in the recovery analyses. This is not an unrealistic assumption since the height of the capillary fringe in fine sands is on the order of six (6) inches, and a partially mounded water table condition may be remnant from a previous storm event.

The potential for the ground water mound growth to intersect the pond volume over a season must also be evaluated. This shall be done using one of the Horizontal Saturated Flow methodologies of **Table F-1** (also **605-1**). The recommended seasonal evaluation is to use the total volume of inflow to the pond less any surface outflow from the pond from the continuous simulation model during the wet season (June 1 – Sept 30). The volume is converted to a uniform, daily application rate by dividing by 122 days and by the pond bottom area. The ground water mound growth that occurs during the 122 day wet season must not intersect the ground surface. This is additional to the recovery analysis for a design event. Designing only for an event recovery using the SHGWT without evaluating the enhanced recharge that happens directly at the BMP over the entire rainy season has high potential cause the BMP to remain wet for extended periods during the wet season. This can become a wildlife attractant hazard on an airport.

Requirements, Guidance and Recommendations for Field and Laboratory Test Data for Manual Computations or Computer Simulations
Computer-based ground water flow models and/or analytic equations are routinely used by practicing engineers and hydrogeologists to predict the time for percolation of the Required Treatment Volume (RTV) and the recovery and ground water mound dissipation for the BMP. The reliability of the output of these models or the calculation from the equations cannot exceed the reliability of the input data. **Input data assessment is probably the most neglected single task in the ground water modeling process.** The accuracy of computer simulations or analytic equations hinges on the quality and completeness of the input data.

The methods listed in the previous section require input values of the retention BMP dimensions, retained stormwater runoff volume (the RTV) and some or all of the following set of aquifer parameters:

- Thickness or elevation of base of mobilized (or effective) aquifer
- Weighted horizontal saturated hydraulic conductivity of mobilized aquifer
- Weighted vertical saturated hydraulic conductivity of layers in the mobilized aquifer
- Soil Suction (ψ)
- Fillable (or effective) porosity of mobilized aquifer
- Ambient water table elevation which, for design event purposes, is usually the normal Seasonal High Ground Water Table (SHGWT), but which for seasonal

ground water mound analysis will be the average ground water elevation that prevails at the start of the rainy season (refer Section 307)

Calculated recovery times are most sensitive to the input value for the aquifer's **saturated hydraulic conductivity.** The following subsections provide additional details on

Determination of Aquifer Thickness

Standard Penetration Test (SPT) borings (ASTM D1586) are recommended for definition of the aquifer thickness, especially where the ground water table is deep. This type of boring provides discrete interval estimates of the relative density or consistency of the soil (as manifested by the SPT "N" values). In concert with soil classification (ASTM D2487-10 laboratory or ASTM D 2488-09 visual), and sieve analysis (percent passing the U.S. Standard No. 200 sieve) better identifies an aquitard or confining unit.

Manual "bucket" auger borings (when supplemented with classification testing) can also be used to define the thickness of the uppermost aquifer (i.e., the depth to the confining unit), especially for small retention ponds and swales.

Additional soil exploration methods include the Cone Penetration Test (CPT) (ASTM D3441-05, ASTM D5778-07 and ASTM D6067-10), auger borings (ASTM D 1486) and test pits. The CPT returns a continuous record of resistance that can be used to evaluated relative density or consistency of very fine strata, and with supplement auger borings can define soil types with a fair degree of accuracy. They are particularly valuable where thin layers of low permeability materials interbed with sands. Test pits, generally excavated with a backhoe, enable detailed observation and bulk sampling of soil strata, but are normally limited to depths of 8 to 12 feet depending on equipment. Machine advanced auger borings return bulk samples of material and provide general indications of soil layering, but must normally be done in conjunction with SPT, CPT or test pits to provide information of the quality needed for aquifer property evaluations.

Definition of SPT "N" Values

The Standard Penetration Test (SPT) consists of driving a split-barrel sampling "spoon" or sampler a distance of 30 cm (12 in) after first "seating" the sampler 15 cm (6 in) by dropping a 63.5 kg (140 lb) hammer from a height of 76 cm (30 in). In field practice, the sampler is driven to a designated depth through a borehole using a long rod, and the hammer strikes the top end of the rod above the ground surface. The operator counts the number of blows that it takes to advance the sampler each of three 15 cm (6 in) increments. When the sampler has penetrated 45 cm (18 in) into the soil at the bottom of the borehole, the operator adds the number of blows for the second and third increments. This combined number of blows to drive the spoon the last 12 inches is the Standard Penetration Test resistance and is called the **"blow count" and is customarily designated as "N" or the "N value"**. It directly reflects the penetration resistance of the ground or the soil under investigation. The blow counts or N value is empirically correlated to relative density of sands and non-plastic silts, or consistency of clays and plastic silts.

Definition of a Confining Unit

The confining unit is a hydraulically restrictive layer (i.e., a clay layer, hardpan, etc.). For many recovery / mounding simulations, the confining unit can be considered as a restrictive layer that has a saturated hydraulic conductivity an order of magnitude (10 times) less that the soil strata (sands) above. In some cases, the "Physical & Chemical Properties table" [within the older NRCS soil surveys (legacy documents)] identifies these soil strata as having a vertical hydraulic conductivity (permeability by NRCS) of 0.06 to 0.6 inches per hour, with the soil above having a permeability of 0.6 to 6.0 inches per hour.

In other cases, such as layered sands or sands subject to dynamic compaction, the various layers comprising the aquifer will differ in vertical saturated hydraulic conductivity by an order of magnitude; while the confining layer will differ by three or more orders of magnitude (refer to **Section 304**). In these cases, the vertical conductivities of the aquifer layers may be combined using the following equation:

$$k_v = \frac{z_1 + z_2 + \cdots z_n}{\frac{z_1}{k_{v1}} + \frac{z_2}{k_{v2}} + \cdots \frac{z_n}{k_{vn}}}$$

Where:
k_v is the composite vertical permeability,
z_n is the thickness of layer n, and
k_{vn} is the vertical permeability of layer n.

Another method to supplement the identification of a confining unit is to carefully review the SPT boring logs for increases in the SPT "N" values, or CPT logs for CPT resistance increases. SPT "N" values (blow counts) or CPT resistance alone should be avoided as the primary method to identify a confining unit.

Definition of a Hardpan

A hardpan is a hardened or cemented soil horizon or layer. The soil material is sandy, loamy, or clayey and is cemented by iron oxide, silica, calcium carbonate or other substances.

Definition of a Spodic Horizon

Florida's pine Flatwoods areas typically have a spodic horizon into which organic matter has accumulated. In many cases, this spodic horizon is locally called a hardpan. Pine Flatwoods are the most predominant natural landscape in Florida, comprising approximately 8.4 million acres.

Estimated Normal Seasonal High Ground water Table (SHGWT)

In estimating the normal SHGWT, the contemporaneous measurements of the water table are adjusted upward or downward taking into consideration numerous factors, including:

- Antecedent rainfall
- Soils on the project site.
- Examination of the soil profile, including redoximorphic features, SPT "N" values, depth to "hardpan" or other impermeable horizons (such as clayey fine sands and clays), etc.

- Consistency of water levels with adjacent surface water bodies and knowledge of typical hydraulic gradients (water table slopes).

- Vegetative indicators

- Effects of existing and future development, including drainage ditches, modification of land cover, subsurface drains, wells in the surficial aquifer, irrigation, septic tank drainfields, etc.

- Hydrogeologic setting, including the potentiometric surface of Floridan aquifer and degree of connection between the water table aquifer and the Floridan aquifer.

- Soil Morphological Features

In general, the measurement of the depth to the ground water table is less accurate in SPT borings when drilling fluids are used to maintain an open borehole. Therefore, when SPT borings are drilled, it may be necessary to drill an auger boring adjacent to the SPT to obtain a more precise stabilized water table reading. In poorly drained soils, the auger boring should be left open, preferably using Piezometer pipe, long enough (at least 24 hours) for the water table to stabilize in the open hole.

If there is ground water relief (a sloping potentiometric surface) within the footprint of the pond, the average ground water contour should be considered representative of the pond.

Estimation of Horizontal Hydraulic Conductivity of Aquifer
The following hydraulic conductivity tests are required for retention BMPs:

- Laboratory hydraulic conductivity test on an undisturbed sample (constant or falling head)
- Laboratory tests on a remolded or compacted sample (where compaction is likely to occur during construction)
- Basic time lag method (USACOE – refer **Section 304** and **Appendix D**)
- Uncased or fully screened auger hole
- Cased hole with uncased or screened extension with the base of the extension at least one (1) foot above the confining layer
- Pump test, when accuracy is important and hydrostratigraphy is conducive to such a test method.
- Slug Test(s)

Of the above methods, the most cost-effective is the laboratory hydraulic conductivity test on an undisturbed horizontal sample. However, it becomes difficult and expensive to obtain undisturbed, hydraulic conductivity tube samples under the water table or at depths greater than 5 feet below ground surface.

Pump tests are the most expensive of the recommended hydraulic conductivity test methods. Therefore, it is recommended that pump tests be used in cases where the effective aquifer is relatively thick (greater than 10 feet) and where the environmental, performance, or size implications of the system justifies the extra cost of such a test.

When the aquifer is layered, it is possible to combine several layers and consider the resulting medium as homogenous. If the flow through such layers is mainly horizontal, the arithmetic mean of the hydraulic conductivity estimates of the individual layers should be used to obtain the weighted horizontal hydraulic conductivity of the mobilized aquifer as follows:

$$k_h = \frac{k_1 z_1 + k_2 z_2 + \cdots k_n z_n}{Z}$$

where the formation consists of n horizontal isotropic layers of different thickness z, and Z is the combined thickness. Note that these layers are above the restrictive layer of hardpan or clayey material. Since the most permeable layer will control the value of the weighted hydraulic conductivity, it is important that the hydraulic conductivity of this layer be tested.

For design purposes of all retention BMPs, a saturated hydraulic conductivity value over forty (40) feet per day will not be allowed for fine-grained sands, and sixty (60) feet per day for medium-grained sands.

If the mobilized aquifer is thick with substantial saturated and unsaturated zones, it is worthwhile to consider performing a laboratory permeameter test on an undisturbed sample from the upper unsaturated profile and also performing one of the in-situ tests to characterize the saturated portion of the aquifer.

Estimation of Fillable Porosity
In Florida, the receiving aquifer system for retention BMPs predominantly comprises poorly graded (i.e., relatively uniform particle size) fine sands. In these materials, the water content decreases rather abruptly with the distance above the water table and thus has a well-defined capillary fringe.

Unlike the hydraulic conductivity parameter, the fillable porosity of the poorly graded, fine sand aquifers in Florida are in a narrow range (20 to 30%), and can be estimated with much more reliability.

For fine sand aquifers, it is therefore recommended that a fillable porosity in the range of 20% to 30% be used in infiltration calculations.

The higher values of fillable porosity will apply to the well- to excessively-drained, hydrologic group "A" fine sands, which are generally deep, contain less than 5% by weight passing the U.S. No. 200 (0.074 mm) sieve, and have a natural moisture content of less than 5%.

No specific field or laboratory testing requirement is recommended, unless there is a reason to obtain a more precise estimate of fillable porosity. In such a case, it is recommended that the following equation be used to compute the fillable porosity:

$$\textbf{Fillable porosity} = (0.9\ N) - (w\ \gamma_d / \gamma_w)$$

Where N = total porosity
W = natural moisture content (as a fraction)
γ_d = dry unit weight of soil
γ_w = unit weight of water

Maximum depth to the SHGWT and confining unit for the required recovery/mounding analysis
The maximum depths that will be allowed to the SHGWT and the top of the confining unit will be the higher values of:

- The field confirmed SHGWT or confining unit depth(s) from the boring(s) / test pit(s), or
- The termination depth of the field boring / test pit if a SHGWT or confining unit is not encountered.

Requirements and recommendations regarding constructed breaches in the confining unit

- A detention or retention BMP shall not be excavated to a depth that breaches an aquitard such that it would allow for lesser quality water to pass, either way, between the two systems. In those geographical areas where there is not an aquitard present, the depth of the pond shall not be excavated to within two (2) feet of the underlying limestone which is part of a drinking water aquifer.
- Standard Penetration Test (SPT) borings will be required for any type of deep BMP that has the potential for breaching an aquitard.

Requirements, Guidance and Recommendations for BMP Soil Testing
One of the most important steps in the evaluation of a stormwater BMPs is determining which test methods and how many tests should be conducted per system. Typically, soil borings and saturated hydraulic conductivity measurements are conducted for each BMP. **Soil testing requirements listed in this Section of the Manual represent the minimum. It is the responsibility of the registered professional to determine if additional soil borings and hydraulic saturated conductivity tests beyond the minimum are needed due to site conditions. Additional tests shall be required if initial testing results deviate to such an extent that they do not provide reasonable assurance that the site conditions are represented by the data provided.**

Standard Penetration Test (SPT) borings or auger borings are commonly used to determine the subsurface soil and ground water table conditions. Test borings provide a reasonable soil profile and an estimate of the relative density of the soils. However, measurement of the ground water table depth from SPT borings is usually less accurate than from auger borings. Measurement of hydraulic conductivity requires more specialized tests as described in the previous section.

To measure saturated infiltration, several methods are employed in both the laboratory and in the field. Generally, laboratory tests require collection of an "undisturbed" sample of soil, in either the vertical or horizontal condition, often by means of a Shelby tube. Measurements are performed on the sample via a constant head or falling head condition in a laboratory permeameter. Other methods that involve "remolding" of the soil sample are generally not as accurate as the undisturbed sample methodology, except where compaction is likely to occur, in which case the remolded sample is probably a better estimator of the final, "as-built" conditions.

Field methods for measuring saturated hydraulic conductivity include auger hole tests, piezometer tests, and pumping tests. Although these tests can be more time consuming, they test a larger volume of soil and generally provide more representative results.

Restrictions on the use of double ring infiltrometer tests
The double-ring infiltrometer field test (formerly ASTMD3385, recently repealed) is used for estimating in-situ infiltration rates. If used, these tests must be conducted at the depth of the proposed pond bottom, and shall only be used to obtain the initial "unsaturated" hydraulic conductivity. Once the ground water mound rises to the BMP bottom, the results of a double-ring infiltrometer test are not valid.

Requirements for soil testing
Information related to soils must include the following:

- Soils test results shall be included as part of a supporting soils/geotechnical report of a project's ERP application. This report must be certified by the appropriate Florida registered professional.

- For all soil borings that are used to estimate the depth to the Seasonal High Ground Water Table (SHGWT), the soil colors shall be denoted by both their English common name and their corresponding Munsell color notation (i.e., light yellowish brown – 10YR 6/4).

- Soil test locations shall be located on the construction drawings, or as an option, the permit review drawings that are submitted as part of the ERP application to the Agency. The horizontal locations of the soil borings/tests shall be placed on the appropriate plan sheet(s), and vertical locations of the soil borings/tests shall be placed on the appropriate retention BMP cross-section(s). The designation number of each test on the plan or cross-section sheets shall correspond to the same test number in the supporting soils/geotechnical report (i.e., SPT #1, Auger boring #2, hydraulic conductivity test #3, etc.).

- The vertical datum of the soil tests results shall be converted to the same datum of the plan sheets and retention BMP cross-sections. For instance, the geo-technical consultant's certified report shows the top of the confining unit in SPT #1 as six (6.0) feet Below Land Surface (BLS). The design consultant of record must then convert this BLS data to the vertical datum of the cross-section sheet for the BMP

(NGVD29, NAVD88, or another vertical datum specified by the appropriate regulatory agency).

The location and number of soil borings and saturated hydraulic conductivity tests performed are usually based on the various site characteristics and requires considerable professional judgment and experience in the decision process. **At a minimum, the following number of tests will be required for each proposed BMP unless the specific BMP design criteria do not require soil testing:**

The minimum number of required Soil Borings - The greater of the following two criteria:

- One (1) for each BMP, drilled to at least ten (10) feet below the bottom of the proposed BMP system. For instance, if a BMP has a pond bottom 5 feet below existing land surface, the minimum boring depth will be 15 feet below existing land surface.

- For BMPs larger than 0.25 acre, retention systems within Sensitive Karst Areas, complex hydrogeology, appreciable topographic relief under the retention BMP, or areas that been filled or otherwise disturbed to change the site's soil characteristics such as in certain urban areas or reclaimed mined lands:

$$B = 1 + \sqrt{2A} + \frac{L}{2\pi W}$$

Where:

B = number of required borings under each retention BMP, drilled to at least ten (10) feet below the bottom of the proposed BMP system. For instance, if a retention pond has a pond bottom 5 feet below existing land surface, the minimum boring depth will be 15 feet below existing land surface (rounded up or down to the next whole number).
A = average BMP area in acres (measured at the control elevation)
L = length of the BMP in feet (length is the longer of the dimensions)
W = width of the BMP, in feet
π = PI, approximately 3.14

- For swales, a minimum of one boring shall be taken for each 500 linear feet or for each soil type that the swale will be built on.

For the recovery / mounding analysis, SPT borings should be continuously sampled at least two (2.0) feet into the top of the hydraulically restrictive layer. If a restrictive layer is not encountered, the boring shall be extended to at least ten (10) feet below the bottom of the pond / system. As a minimum, the depth of the exploratory borings should extend to the base elevation of the aquifer assumed in analysis, unless nearby deeper borings or well logs are available.

Minimum number of required Saturated Hydraulic Conductivity tests - At a minimum, the following number of tests will be required for each proposed BMP unless the specific BMP design criteria do not require saturated hydraulic conductivity testing. The greater of the following two criteria:

- One (1) for each BMP, taken no shallower than the proposed bottom of the BMP system, or deeper if determined by the design professional to be needed for the particular site conditions. However, if the system will be built on excessively drained soils, the applicant may propose a lesser number of tests based on plans, test results, calculations or other information, that the number of tests is appropriate for the specific site conditions.

- For BMPs larger than 0.25 acre, retention systems within Sensitive Karst Areas, complex hydrogeology, appreciable topographic relief under the retention BMP, or urbanized (or reclaimed mining) areas that have undergone previous soil disturbance:

$$P = 1 + (B / 4)$$

Where:

P = number of saturated hydraulic conductivity tests for each retention BMP, taken no shallower than the proposed bottom of the retention system, or deeper if determined by the design professional to be needed for the particular site conditions (rounded up or down to the next whole number). However, if the system will be built on excessively drained soils, the applicant may propose a lesser number of tests based on plans, test results, calculations or other information, that the number of tests is appropriate for the specific site conditions.

B = number of required borings (from above).

- For wet detention, stormwater harvesting, or underdrain BMPs that have the potential for impacting adjacent wetlands or potable water supply wells, the hydraulic conductivity tests will be required between the location of the BMP and the adjacent wetlands or well.

APPENDIX G

ANNUAL RAINFALL DATA

Information furnished by FDEP and Water Management Districts (See Reference 12)

RAINFALL DATA

Average annual rainfall amounts from **Reference 12** and expressed in inches are provided for Florida in this Appendix. As discussed in **Section 401**, these and/or the data in **Table 401-1** shall be used to check the annual rainfall applied in continuous simulation modeling done with EPA SWMM, commercial software or other acceptable, continuous simulation modeling software. **Figure G-1** shows the State's five designated meteorological zones. A listing of the counties included in each meteorological zone is given in **Table G-1**. **Figure G-2** is a rainfall isopleth map for the state while **Figures G-3** through **G-6** are expanded rainfall isopleth maps for different parts of Florida.

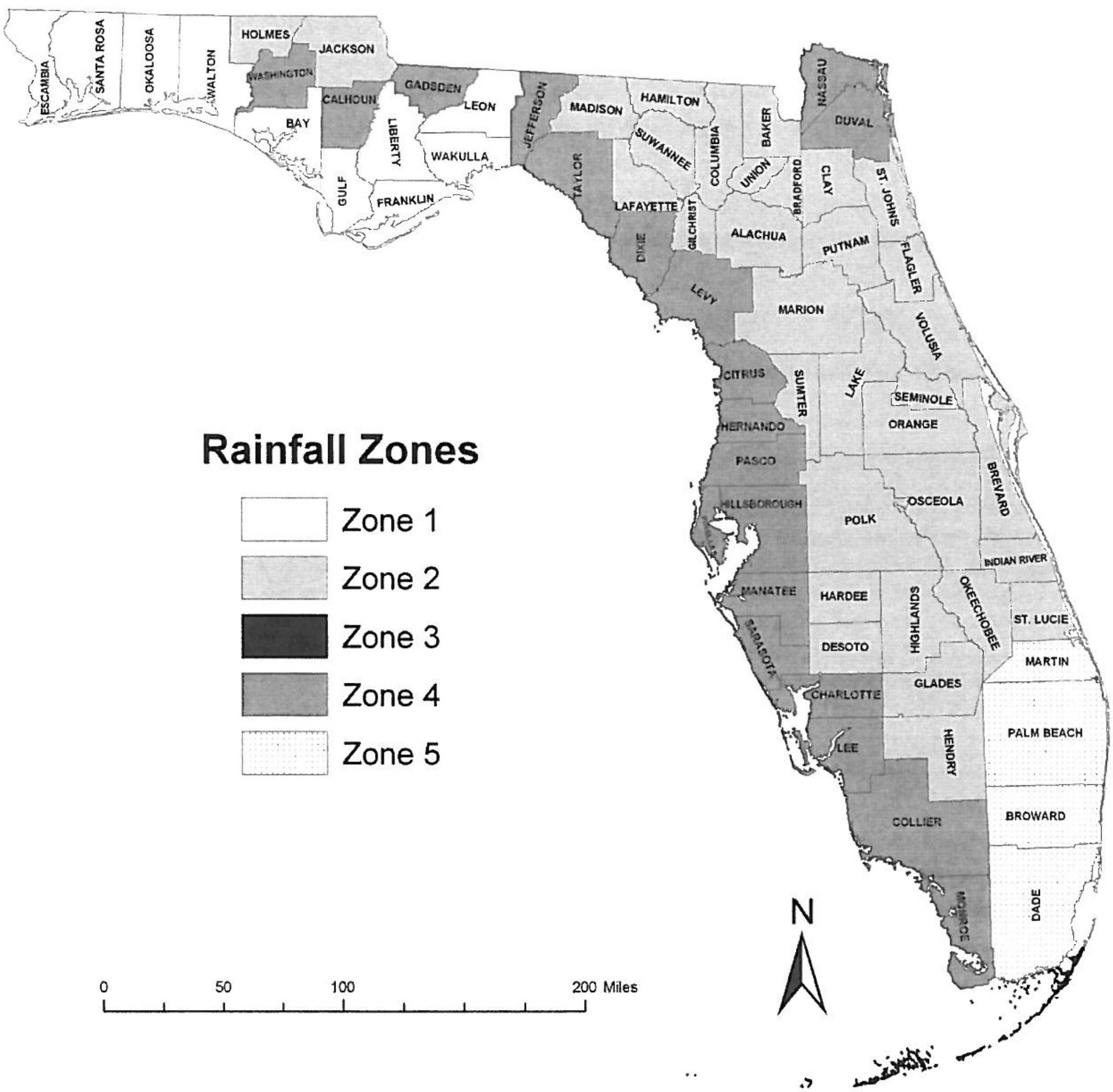


Figure G-1. Designated Meteorological Regions (Zones) in Florida

Table G-1 Counties Included in the Designated Meteorological Zones

Meterological Zone				
ZONE 1	**ZONE 2**	**ZONE 3**	**ZONE 4**	**ZONE 5**
Bay	Alachua	Monroe County - Florida Keys from Key Largo to Key West	Charlotte	Broward
Escambia	Baker		Citrus	Miami-Dade
Franklin	Bradford		Collier	Martin
Gulf	Brevard		Dixie	Palm Beach
Leon	Calhoun		Duval	
Liberty	Clay		Hernando	
Okaloosa	Columbia		Hillsborough	
Santa Rosa	Desoto		Jefferson	
Wakulla	Flagler		Lee	
Walton	Gadsden		Levy	
	Gilchrist		Manatee	
	Glades		Mainland	
	Hamilton		Monroe	
	Hardee		Nassau	
	Hendry		Pasco	
	Highlands		Pinellas	
	Holmes		Sarasota	
	Indian River		Taylor	
	Jackson		Washington	
	Lafayette			
	Lake			
	Madison			
	Marion			
	Okeechobee			
	Orange			
	Osceola			
	Polk			
	Putnam			
	Seminole			
	St. Johns			
	St. Lucie			
	Sumter			
	Union			
	Volusia			

Figure G-2 Rainfall Isopleth Map for Florida

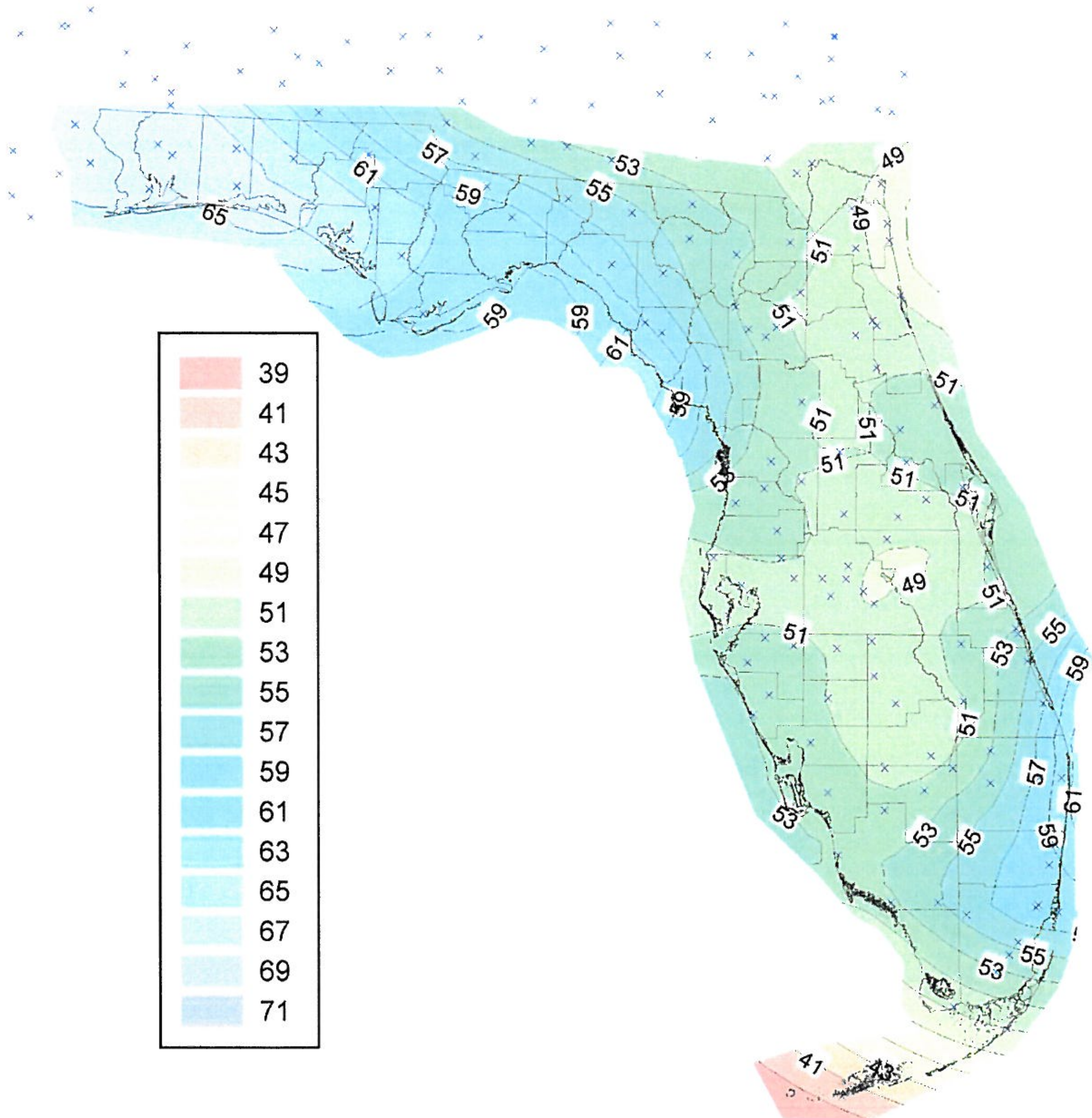


Figure G-3. Expanded Rainfall Isopleth Map for Northwest Florida

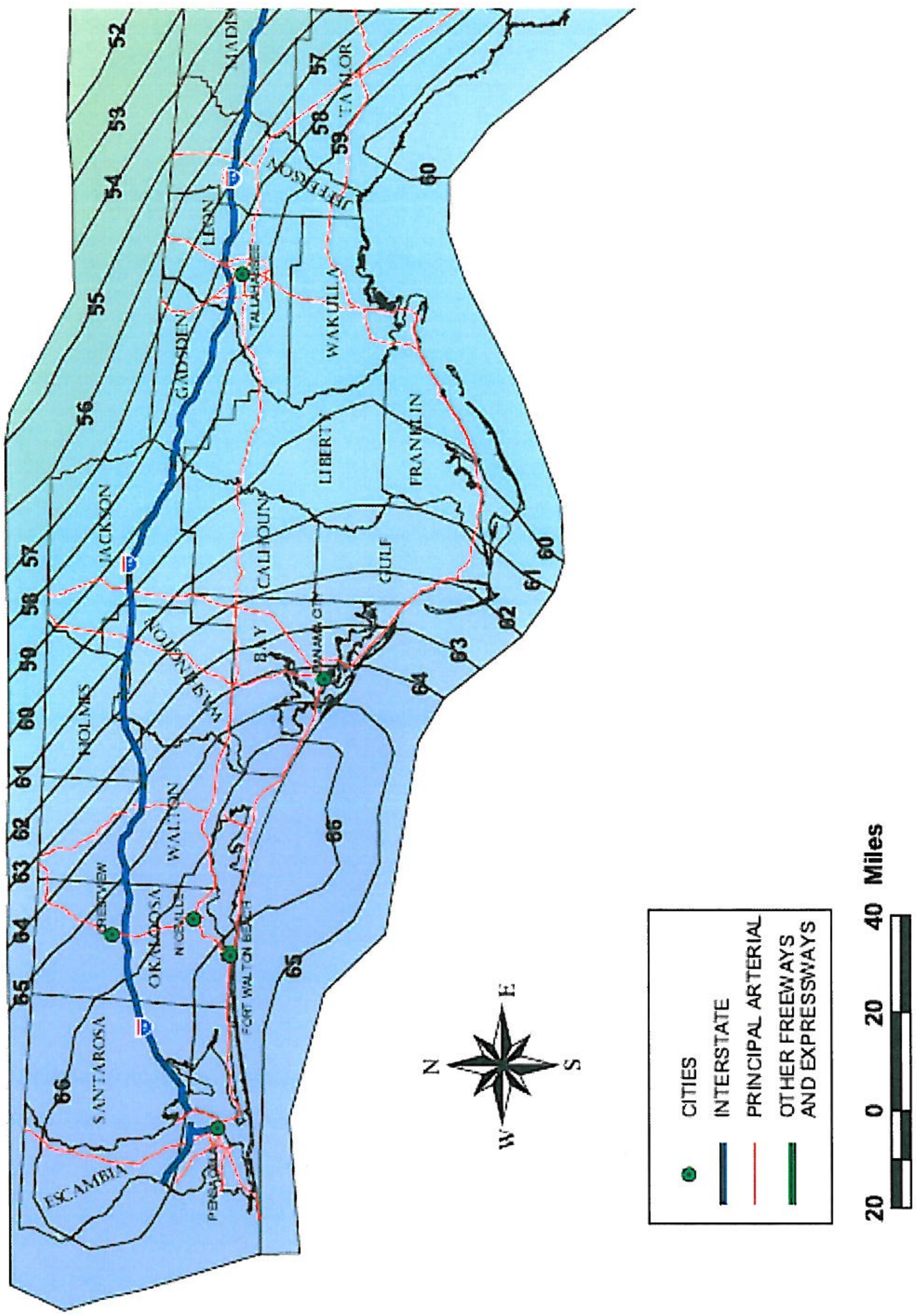


Figure G-4. Expanded Rainfall Isopleth Map for Central Florida

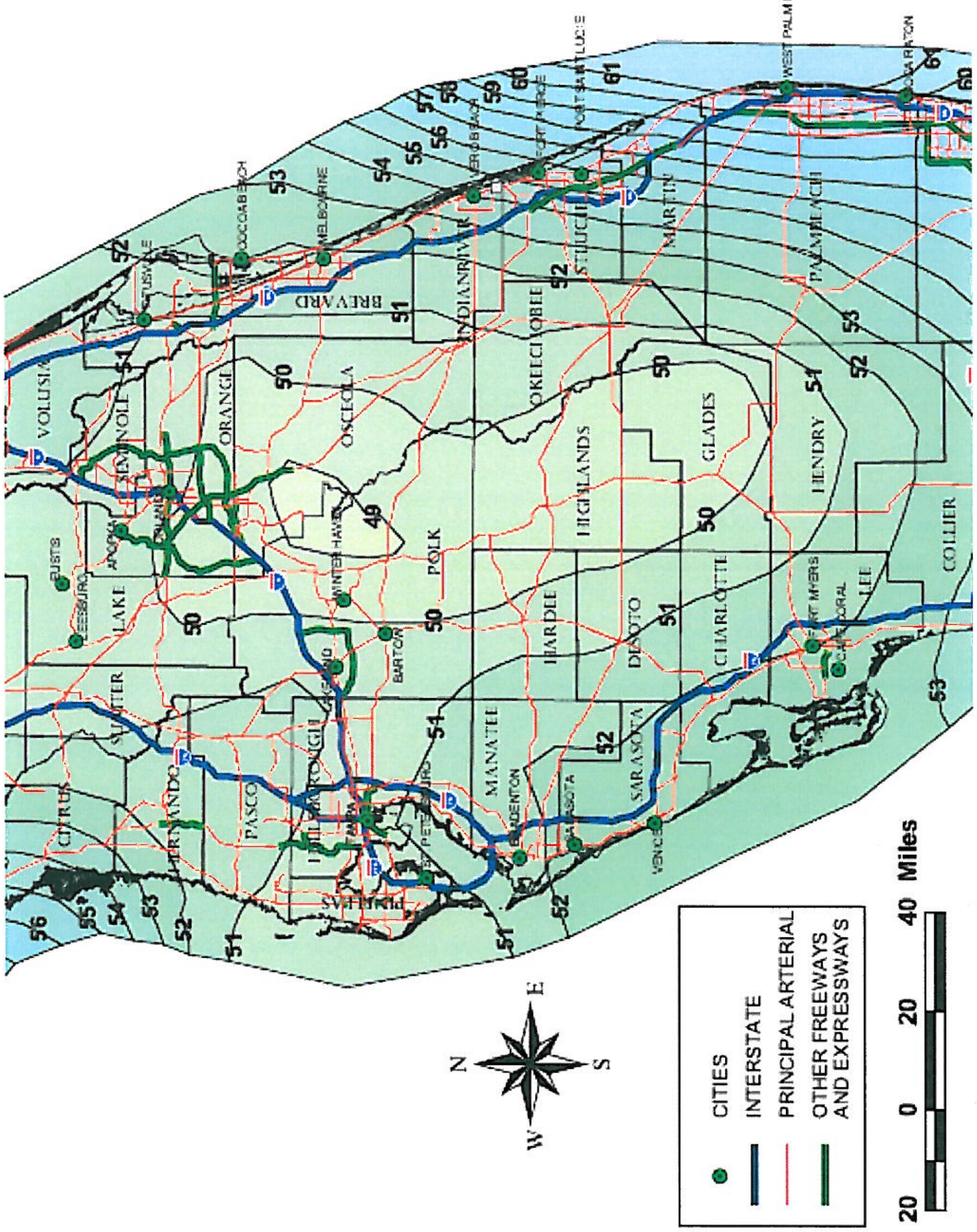


Figure G-5. Expanded Rainfall Isopleth Map for North Central Florida

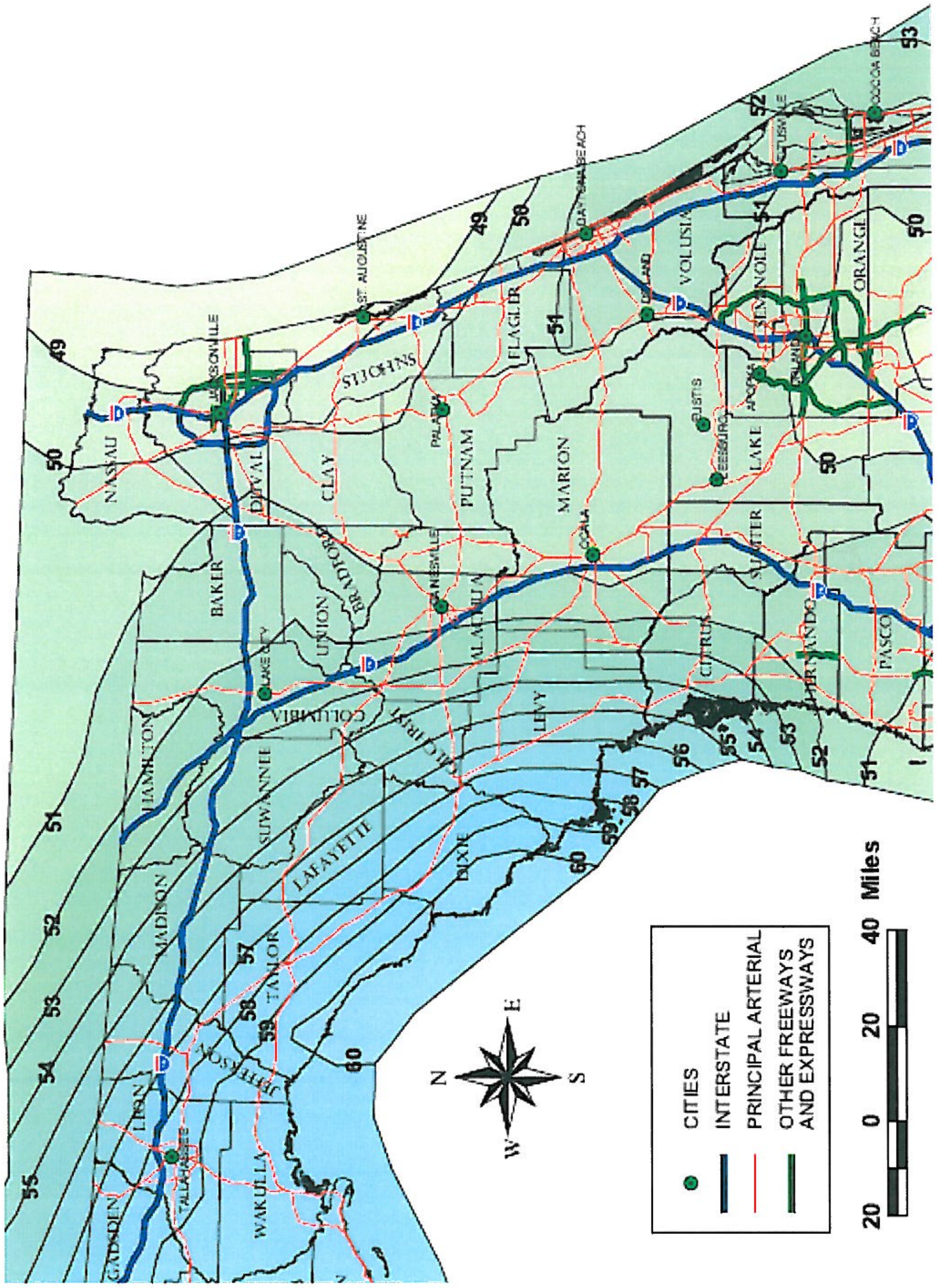
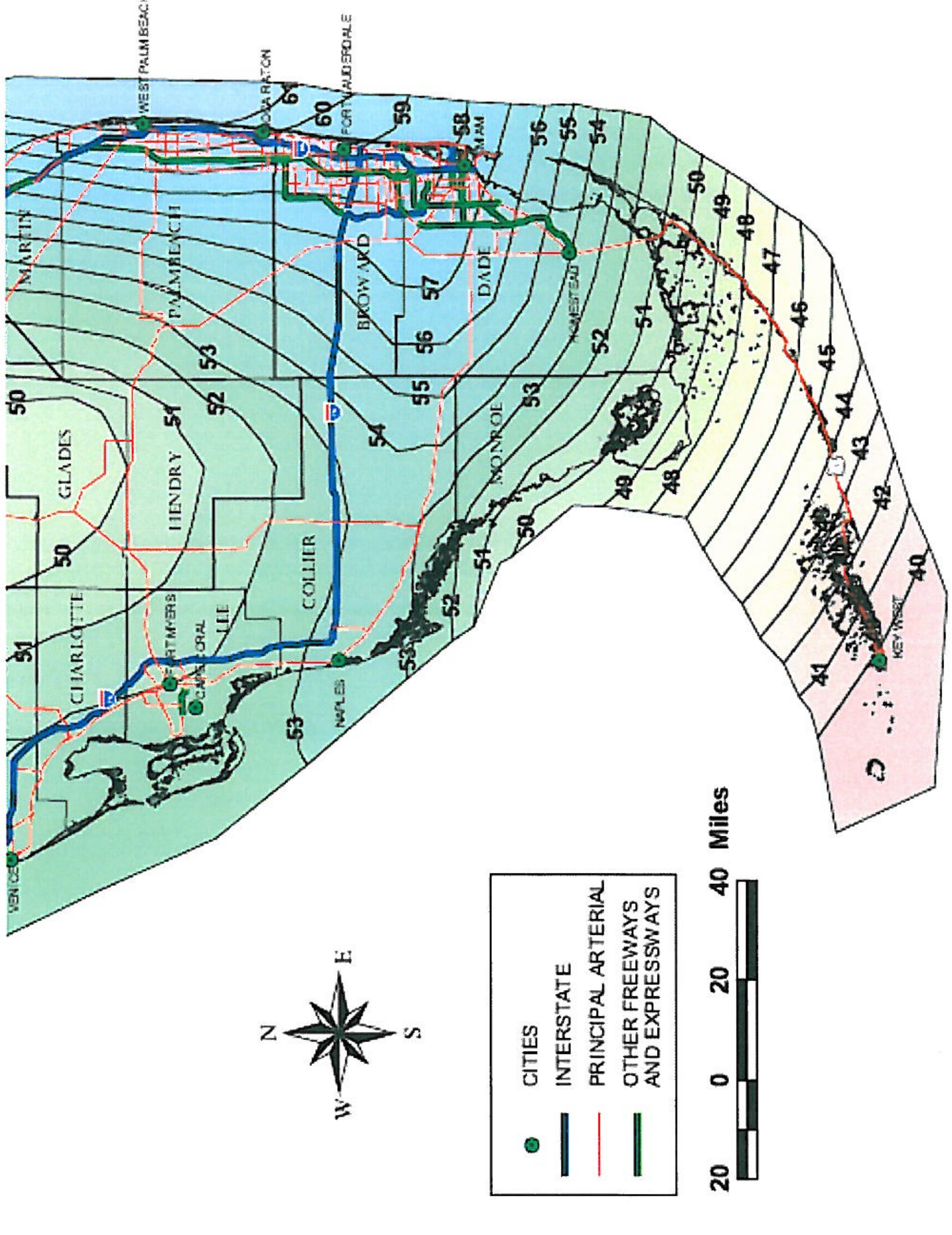


Figure G-6. Expanded Rainfall Isopleth Map for South Florida



APPENDIX H

AIRLINE SAFETY AND WILDLIFE PROTECTION ACT OF FLORIDA

A bill to be entitled

An act relating to aircraft safety; providing a short title; creating s. 379.2293, F.S.; providing legislative findings and intent; exempting airport authorities and other entities from penalties, restrictions, or sanctions with respect to authorized actions taken to protect human life or aircraft from wildlife hazards; defining the term "authorized action taken for the purpose of protecting human life or aircraft safety from wildlife hazards"; providing that federal or state authorizations for such actions prevail over certain other regulations, permits, comprehensive plans, and laws; providing immunity from penalties with respect to authorized action for certain individuals; providing exceptions; providing an effective date.

Be It Enacted by the Legislature of the State of Florida:

Section 1. This act may be cited as the "Airline Safety and Wildlife Protection Act of Florida."

Section 2. Section 379.2293, Florida Statutes, is created to read:

379.2293 Airport activities within the scope of a federally approved wildlife hazard management plan or a federal or state permit or other authorization for depredation or harassment.--

(1) The Legislature finds and declares that the ability of airports to manage wildlife hazards in a manner consistent with

state and federal law is necessary to prevent jeopardy to human life or aircraft safety. It is the intent of the Legislature that actions taken by airports within the scope of authorizations to manage wildlife for such purposes not be subject to penalties, restrictions, liabilities, or sanctions and that such authorizations not be superseded by actions of other state or local agencies.

(2) An airport authority or other entity owning or operating an airport, as defined in s. 330.27(2), is not subject to any administrative or civil penalty, restriction, or other sanction with respect to any authorized action taken in a non-negligent manner for the purpose of protecting human life or aircraft safety from wildlife hazards.

(3)(a) For purposes of this section, an "authorized action taken for the purpose of protecting human life or aircraft safety from wildlife hazards" is an action authorized by or within the scope of any of the following:

1. The airport's wildlife hazard management plan, as approved by the Federal Aviation Administration.

2. A depredation permit issued by the United States Fish and Wildlife Service.

3. A standing order of the United States Fish and Wildlife Service.

4. Rule 68A-9.010(4) or rule 68A-27.002, Florida Administrative Code, or a permit authorizing the harassment of wildlife issued by the Fish and Wildlife Conservation Commission.

(b) The term "authorized action taken for the purpose of protecting human life or aircraft safety from wildlife hazards" does not include:

1. Dredging or filling of wetlands or other surface waters or alteration of a stormwater management system, unless authorized by and performed in compliance with a permit issued under part IV of chapter 373 or an emergency order under chapter 373. However, such a permit or emergency order is not required prior to the activity when the airport authority or other entity described in subsection (2) determines that an emergency condition exists which requires immediate action to protect human life and the airport authority or other entity described in subsection (2) obtains the appropriate permit under part IV of chapter 373 within one year after conducting the emergency action.

2. Trespass on lands or unauthorized interference with an easement not owned or leased by the airport authority or other entity referred to in subsection (2).

(4) If an authorized action taken for the purpose of protecting human life or aircraft safety from wildlife hazards as defined in subsection (3) conflicts or appears to conflict with a development permit, land development regulation, local comprehensive plan, or other environmental or land-use law, rule, restriction, or requirement, the authorization described in subsection (3) shall prevail.

(5) In addition to applying to the airport authority or other owner or operator of the airport, the immunities conferred by this section also apply to any officer, employee, contractor, or employee of a contractor of the airport authority or other

owner or operator of the airport, or any member of the airport's governing body, to the extent that the actions of the officer, employee, contractor, contractor's employee, or member are authorized by or within the scope of one or more of the legal authorities described in subsection (3).

(6) Nothing in this section is intended to provide immunity from liability with respect to intentional or negligent torts, and nothing in this section is intended to affect the waiver of sovereign immunity under s. 768.28.

Section 3. This act shall take effect upon becoming a law.

APPENDIX I

DRAFT FAC 62-330.449

62-330.449 General Permit for Construction, Operation, Maintenance, Alteration, Abandonment or Removal of Airport Airside Stormwater Management Systems.

(1) A general permit is granted to the owner of a public or private airport for the construction, alteration, abandonment, removal, operation, and maintenance of stormwater management systems that serve permanently-paved airside activities, which, for the purposes of this rule, are defined as those components of an airport used for aircraft taxiing, landing, takeoff, loading, unloading, service materials storage and service equipment parking.

(2) The stormwater management systems shall be:

(a) Designed such that the stormwater nutrient loading does not exceed the stormwater nutrient loading from natural vegetative communities. The calculation of such loadings shall be done using the methodology and data set forth in *The Florida Airports Stormwater Best Management Practices Manual*, ("Airside BMP Manual") Florida Department of Transportation (October 2012), incorporated by reference herein (URL). A copy may be obtained from the Agency, as described in subsection 62-330.010(5), F.A.C.

(b) Constructed, altered, operated, and maintained such that the runoff from airside activities drains directly to pervious areas that employ one or more of the following applicable structural Best Management Practices (BMPs):

1. Overland flow, as described in Section 605.a of the Airside BMP Manual.
2. Dry retention, as described in Section 605.b of the Airside BMP Manual.
3. Dry swales, as described in Section 605.c of the Airside BMP Manual.

(c) This general permit is only authorized for use where post development site conditions comply with the criteria set forth above.

(3) The projects in subsection (2)(b), above, must also be constructed, operated, and maintained to comply with the following design criteria and performance standards:

(a) There shall be no dredging or filling in wetlands or other surface waters other than those within existing stormwater management systems.

(b) Discharges cannot adversely affect the conveyance capacity of receiving waters, and cannot increase flooding of off-site property or to property not owned by the permittee, based on the design storm specified for the site locale.

(4) Stormwater management systems serving airside areas that consist of underdrains, wet detention systems, other retention methods, and/or alternative treatment systems do not qualify for authorization under this general permit.

Rulemaking Authority 373.026(7), 373.043, 373.118(1), 373.118(6), 373.406(5), 373.4131, 373.414(9), 373.418, 403.805(1) FS. Law Implemented 373.118(1), (6), 373.406(5), 373.413, 373.4131, 373.414(9), 373.416, 373.418 FS. History–New ____.

APPENDIX J

JURISDICTIONAL AGENCIES

APPENDIX J
Jurisdictional Agencies

Water management criteria are not uniform or uniformly applied within Florida. This is partly due to physical differences between regions, and partly to rule and legal constraints of the jurisdictional agencies. Consequently, it is necessary to identify all agencies jurisdictional to water management of an airport project and the specific issues of those agencies. Contact with the county, city and any special districts jurisdictional to the airport is a required data collection task. Table J-1 lists agencies that are normally involved on a state and federal level.

TABLE J-1 STATE AND FEDERAL AGENCIES INVOLVED IN FLORIDA WATER MANAGEMENT PERMITTING

ISSUE	*Regulatory Agency*							
	FAA	**EPA**	**ACOE**	**FDOT**	**FDEP**	**FFWCC**	**WMD**	**USDA**
Wetland Impacts		**O**	**P**		**P**		**P**	
Flood Protection			**C**		**P**		**P**	
Water Quality		**O**			**P**		**P**	
Water Quantity	**C**			**P**	**P**		**P**	
Wildlife	**O**			**C**	**C**	**P**	**C**	**O**
Airport Safety	**O**			**O**		**C**	**C**	**C**

Legend
P - Permitting
C - Concern
O - Other Authority

The remainder of this Appendix is solely concerned with the Water Management Districts Jurisdictional to the airports. Figure J-1 broadly outlines the jurisdictional boundaries of the five Water Management Districts in the state. Tables J-2 through J-6 list the Jurisdictional Water Management District for each of Florida's public airports.

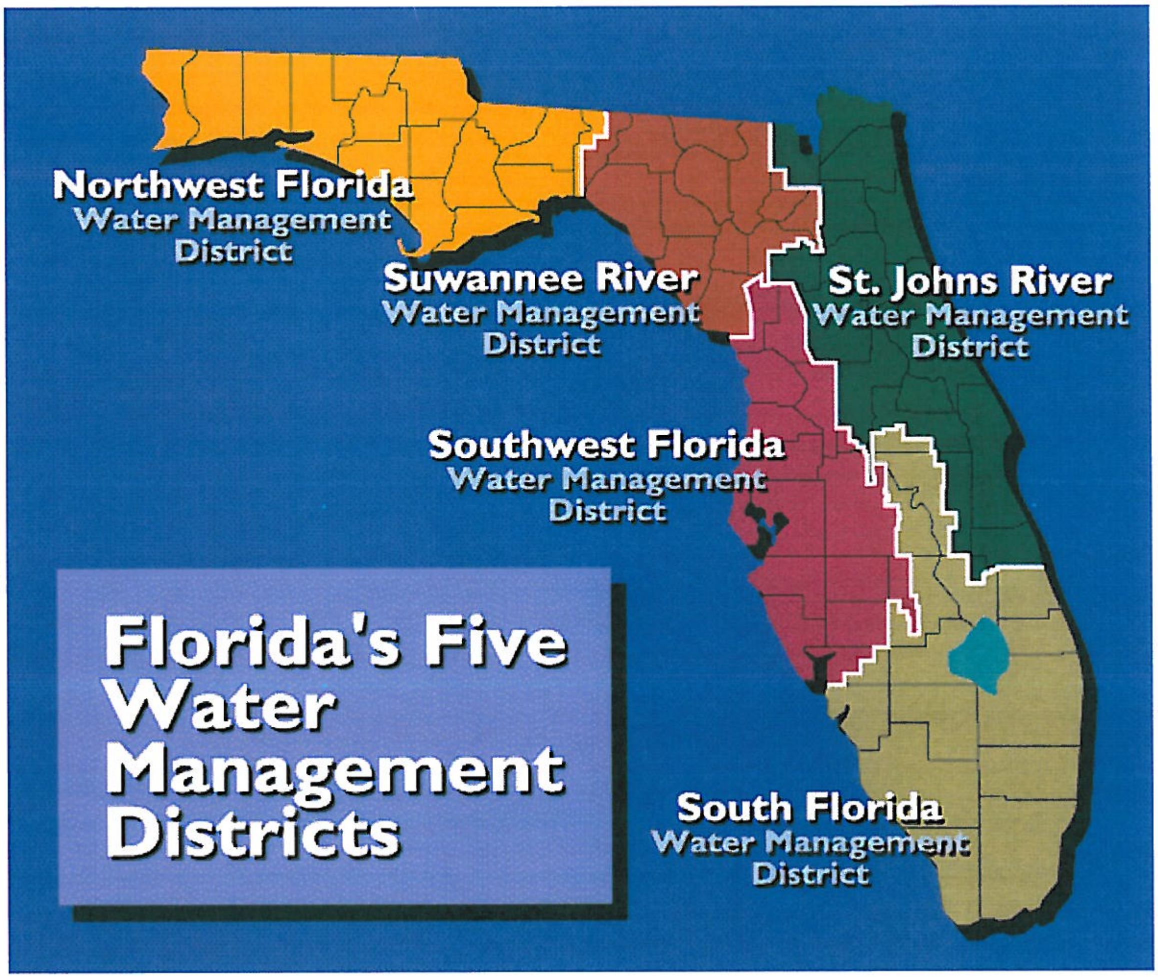


Figure J-1 Outline of Florida Water Management District Jurisdictional Boundaries

TABLE J-2 PUBLIC AIRPORTS SERVED BY THE ST. JOHN'S RIVER WATER MANAGEMENT DISTRICT

Archer Flying Ten Airport
Alachua County OJ8
3906 S.W. 15th Street
Archer 32618

Bunnell, Flagler County Airport
Flagler County X47
1200 E Moody Blvd., # 1
Bunnell 32110

Cocoa, Merritt Island Airport
Brevard County COI
355 Golden Knights Blvd.
Titusville 32780

Daytona Beach International Airport
Volusia County DAB
700 Catalina Dr. Ste. 300
Daytona Beach 32114

Deland Bob Lee Flight Strip
Volusia County 1J6
5000 Boblee Airport
Deland 32724

Deland Municipal Airport
Volusia County DED
1777 Langley Avenue
Deland 32724

Eustis Mid-Florida Airport
Lake County X55
19708 Eustis Airport Road
Eustis 32736

Fernandina Beach Municipal Airport
Nassau County 55J
P.O. Box 668
Fernandina Beach 32034

Gainesville Regional Airport
Alachua County GNV
3880 N. E. 39 Ave., Ste A
Gainesville 32609

High Springs Rudy's Airport
Alachua County 6J8
12623 199th N.E.
Waldo 32694

Hillard Airpark
Nassau County 01J
P.O. Box 549
Hilliard 32046

Jacksonville Craig Municipal Airport
Duval County CRG
P.O. Box 3005
Jacksonville 32206-3005

Jacksonville Herlong Airport
Duval County 23J
P.O. Box 3005
Jacksonville 32206-3005

Jacksonville International Airport
Duval County JAX
P.O. Box 3005
Jacksonville 32206-3005

Leesburg Regional Airport
Lake County LEE
P.O. Box 490630
Leesburg 32749-0630

Melbourne International Airport
Brevard County MLB
One Air Terminal Pkwy. Ste. 220
Melbourne 32901-1888

New Smyrna Beach Massey Ranch Airpark
Volusia County X50
P.O. Box 949
New Smyrna, Bch. 32170

New Smyrna Beach Municipal Airport
Volusia Count EVB
210 Sams Avenue
New Smyrna, Bch. 32168

Orlando Executive Airport
Orange County ORL
501 G Hermdon Avenue
Orlando 32803

Orlando Sanford Airport
Seminole County SFB
1 Red Cleveland Blvd
Sanford 32772-0818

Ormond Beach Municipal Airport
Volusia County OMN
P.O. Box 277
Ormond Beach 32175

Palatka Kay Larkin Airport
Putnam County 28J
201 N, 2nd Street
Palatka 32177

Pierson Municipal Airport
Volusia County 2J8
P.O. Box 527
Pierson 32180

St. Augustine Airport
St. Johns County SGJ
4796 U.S. 1 North
St Augustine 32095

Sebastian Municipal Airport
Indian River County X26
1225 Main Street
Sebastian 32958

Titusville Arthur Dunn Airpark
Brevard County X21
355 Golden Knights Blvd
Titusville 32780

Titusville Space Coast Regional Airport
Brevard County TIX
355 Golden Knights Blvd
Titusville 32780

Umatilla Municipal Airport
Lake County X23
P.O. Box 2286
Umatilla 32784-2286

Valkaria Airport
Brevard County X59
2865 Greenbrooke St.
Valkaria 32950

Vero Beach New Hibiscus Airpark
Indian River County X52
P.O. Box 690772
Vero Beach 323969

Vero Beach Municipal Airport
Indian River County VRB
P.O. Box 1389
Vero Beach 32951-1389

Zellwood Bob White Field
Orange county X61
P.O. Box 494
Zellwood 32798-0494

TABLE J-3 PUBLIC AIRPORTS SERVED BY THE SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Belle Glade State Airport
Palm Beach County X10
P.O. Box 401
Belle Glade, 33430

Boca Raton Airport
Palm Beach County BCT
3700 Airport Road, Suite 204
Boca Raton, 33431-6403

Clewiston Airglades Airport
Hendry County 2IS
P. O. Box 787
Clewiston, 33440

Everglades Airpark
Collier County X01
P. O. Box 689
Everglades City, 34139

Fort Lauderdale Executive Airport
Broward County FXE
1401 W. Commercial Blvd., Suite 200
Ft. Lauderdale, 33301

Fort Lauderdale/Hollywood Int'l Airport
Broward County FLL
320 Terminal Drive
Ft. Lauderdale, 33315

Fort Myers Southwest Florida Int'l Airport
Lee County RSW
16000 Chamberlain Parkway, Suite 8671
Ft. Myers, 33913

Fort Myers Page Field
Lee County FMY
501 Danley Drive
Ft. Myers, 33907

Fort Pierce St. Lucie County Int'l Airport
St. Lucie County FPR
2300 Virginia Avenue
Ft. Pierce, 34982-5652

Hollywood North Perry Airport
Broward County HWO
7750 Hollywood Blvd., Box 13
Pembroke Pines, 33024

Homestead General Aviation Airport
Dade County X51
28700 S.W. 217 Avenue
Homestead, 33030

Homestead Regional Airport
Dade County HST
P. O. Box 592075
Miami, 33159

Immokalee Regional Airport
Collier County IMM
165 Airpark Blvd.
Immokalee, 34142

Indiantown Airport
Martin County X58
P. O. Box 144
Palm City, 34991

Key West International Airport
Monroe County EYW
3491 S. Roosevelt Blvd.
Key West, 33040

LaBelle Municipal Airport
Hendry County X14
P. O. Box 1607
LaBelle, 33935-1607

Marathon Airport
Monroe County MTH
9400 Overseas Hwy, Suite 200
Marathon, 33050

Marco Island Executive Airport
Collier County MKY
2003 Mainsail Drive
Naples, 34114

Miami Dade-Collier Training & Transition Airport
Dade and Collier Counties TNT
12800 S.W. 137 Avenue
Miami, 33186

Miami Kendall-Tamiami Executive Airport
Dade County TMB
12800 S. W. 137 Avenues
Miami, 33186

Miami Heliport
Dade County X48
444 S. W. 2nd Avenue
Miami, 33130

Miami International Airport
Dade County MIA
P. O. Box 592075
Miami, 33159

Miami Opa-locka Airport
Dade County OPF
14300 N. W. 41 Avenue
Opa-locka, 33054

Miami Opa-locka West Airport
Dade County X46
14300 N.W. 41 Avenue
Opa-locka, 33054

Naples Municipal Airport
Collier County APF
160 Aviation Drive North
Naples, 34104-3568

Okeechobee County Airport
Okeechobee County OBE
2800 N.W. 20 Trail
Okeechobee, 34972

Orlando International Airport
Orange County MCO
One Airport Blvd
Orlando 32827-4399

Orlando Kissimmee Municipal
Osceola County ISM
301 N. Dyer Blvd., Suite 101
Kissimmee, 34741-4613

Pahokee Palm Beach County Glades Airport
Palm Beach County PHK
PBIA, Bldg. 846
West Palm Beach, 33406

Pompano Beach Airpark
Broward County PMP
1001 N.E. 10th Street
Pompano Beach, 33060

Stuart Whitham Field
Martin County SUA
1805 S.E. Airport Road
Stuart, 34996

West Palm Beach North Palm Beach County General Aviation Airport
Palm Beach County F45
PBIA, Building 846
West Palm Beach, 33406

West Palm Beach County Park
Palm Beach County LNA
PBIA, Building 846
West Palm Beach, 33406

West Palm Beach International Airport
Palm Beach County PBI
PBIA, Building 846
West Palm Beach, 33406

TABLE J-4 PUBLIC AIRPORTS SERVED BY THE SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Arcadia Municipal Airport
DeSoto County X06
P.O. Box 351
Arcadia, 33821

Avon Park Municipal Airport
Highlands County AVO
110 E. Main St.
Avon Park, 33825

Bartow Municipal Airport
Polk County BOW
P.O. Box 650
Bartow, 33831

Brooksville
Hernando County Airport, BKV
16110 Aviation Loop Drive
Brooksville, 34609

Brooksville, Pilot Country Airport
Pasco County X05
11500 Pilot Country Drive
Spring Hill 34610

Clearwater Airpark
Pinellas County CLW
P.O. Box 4748
Clearwater 33758-4748

Crystal River Airport
Citrus County X31
P.O. Box 2050
Crystal River 34423

Dunnellon/Marion County Airport
Marion County X35
15070 S.W. 111th St
Dunnellon 34432

Englewood, Buchan Airport
Sarasota County X36
100 Cattlemen Road,
Sarasota 34232

Inverness Airport
Citrus County X40
3600 Sovereign Path, Ste.212
Lecanto, 34461

Lakeland Linder Regional Airport
Polk County LAL
3400 Airfield Drive West
Lakeland 33811-1240

Lake Wales, Chalet Suzanne Airport
Polk County X25
3800 Chalet Suzanne Dr.
Lake Wales, 33853-7000

Lake Wales Municipal Airport
Polk County X07
P.O. Box 1320,
Lake Wales 33859-1320

Mulberry, South Lakeland Airport
Polk County X49
7500 Coronet
Mulberry 33860-8314

Ocala Regional Airport
Marion County OCF
P.O. Box 1270
Ocala 34478-1270

Palmetto Airport
Manatee County 48X
P.O. Box 554
Palmetto, 34221

Plant City Airport
Hillsborough County PCM
P.O. Box 22287
Tampa 33622

Punta Gorda, Charlotte County Airport
Charlotte County PGD
28000 Airport Road,
Punta Gorda 33982

Punta Gorda, Shell Creek Airpark
Charlotte County F13
36880 Washington Loop Rd.
Punta Gorda 33982

River Ranch Resort Airport
Polk County 2RR
P.O. Box 30030
River Ranch 33867-0030

St Petersburg Albert Whitted Municipal Airport
Pinellas County SPG
107 8th Avenue S. E.
St. Petersburg 33701

St Petersburg-Clearwater Int'l Airport
Pinellas County PIE
Administration blvd Ste. 221
Clearwater 33762

Sarasota-Bradenton International Airport
Sarasota & Manatee Counties SRQ
6000 Airport Circle
Sarasota 34243-2105

Sebring Regional Airport
Highlands County SEF
128 Authority Lane
Sebring 33870

Tampa, Peter O. Knight Airport
Hillsborough County TPF
P.O. Box 22287
Tampa 33622

Tampa International Airport
Hillsborough County TPA
P.O. Box 22287
Tampa 33622

Tampa North Aero Park
Pasco County X39
4241 Birdsong Blvd.
Lutz 33549-6294

Tampa Vandenberg Airport
Hillsborough County X16
P.O. Box 22287
Tampa 33622

Trenton Ames Field
Levy County 8J2
17551 N. W. 60 Avenue
Trenton 32693

Venice Municipal Airport
Sarasota County VNC
150 East Airport Avenue
Venice 34285

Wauchula Municipal Airport
Hardee County FD06
726 East Green Street,
Wauchula 33873

Williston Municipal Airport
Levy County X60
P.O. Drawer 160
Williston 32696

Winter Haven
Jack Brown Seaplane Base
Polk County F57
2704 Hwy. 92 West
Winter Haven 33881

Winter Haven Municipal Airport
Polk County GIF
3000 21st Street N.W.
Winter Haven 33881

Zephyrhills Municipal Airport
Pasco County ZPH
39450 South Ave., Box 2
Zephyrhills 33540

TABLE J-5 PUBLIC AIRPORTS SERVED BY THE SUWANNEE RIVER WATER MANAGEMENT DISTRICT

Cedar Key George T. Lewis Airport
Levy County CDK
P. O. Box 294
Cedar Key, 32625

Cross City Airport
Dixie County CTY
P. O. Box 1206
Cross City, 32628

Lake City Municipal Airport
Columbia County 31J
P. O. Box 1687
Lake City, 32055

Live Oak Suwannee County Airport
Suwannee County 24J
224 Pine Avenue
Live Oak, 32060

TABLE J-6 PUBLIC AIRPORTS SERVED BY THE NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Apalachicola Municipal Airport
Franklin County AAF
P. O. Box 340
Apalachicola, 32320

Apalachicola St. George Island Airport
Franklin County F47
1712 Magnolia Road
St. George Island, 32328

Blountstown Calhoun County Airport
Calhoun County F95
P. O. Box 38
Altha, 32421

Bonifay Tri-County Airport
Holmes County 1J0
P. O. Box 756
Bonifay, 32425

Carrabelle-Thompson Airport
Franklin County X13
P. O. Drawer 569
Carrabelle, 32322

Crestview Bob Sikes Airport
Okaloosa County CEW
State Road 85
Eglin AFB, 32542-1413

De Funiak Springs Municipal Airport
Walton County 54J
P. O. Box 685
DeFuniak Springs, 32435

Destin-Fort Walton Beach Airport
Okaloosa County DTS
State Road 85
Eglin AFB, 32542-1413

Marianna Municipal Airport
Jackson County MAI
P. O. Box 936
Marianna, 32447

Navarre Fort Walton Beach
Santa Rosa County 1J9
P. O. Box 1075
Ft. Walton Beach, 32549

Panacea Wakulla County Airport
Wakulla County 2J0
P. O. Box 1263
Crawfordville, 32326-1263

Panama City-Bay County International
Bay County PFN
3173 Airport Road, Box A
Panama City, 32405

Pensacola Regional Airport
Escambia County PNS
2430 Airport Blvd., Suite 225
Pensacola, 32504

Pensacola Ferguson Airport
Escambia County 82J
9750 Aileron Avenue
Pensacola, 32506

Pensacola Coastal Airport
Escambia County 83J
6001 W. 9 Mile Road
Pensacola, 32526

Port St. Joe Costin Airport
Gulf County FD51
2724 Apalachee Parkway
Tallahassee, 32301

Quincy Municipal Airport
Gadsden County 2J9
P. O. Box 1905
Quincy, 32353

Tallahassee Regional Airport
Leon County TLH
3300 Capital Circle SW
Tallahassee, 32310

Tallahassee Commercial Airport
Leon County 68J
Route 9, Box 60
Tallahassee, 32303

Milton Peter Prince Field
Santa Rosa County 2R4
6065 Old Bagdad Highway
Milton, 32583

APPENDIX K

FEDERAL AGENCIES MEMORANDUM OF AGREEMENT ON AIRCRAFT-WILDLIFE STRIKES

Memorandum of Agreement Between the Federal Aviation Administration, the U.S. Air Force, the U.S. Army, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, and the U.S. Department of Agriculture to Address Aircraft-Wildlife Strikes

PURPOSE

The signatory agencies know the risks that aircraft-wildlife strikes pose to safe aviation.

This Memorandum of Agreement (MOA) acknowledges each signatory agency's respective missions. Through this MOA, the agencies establish procedures necessary to coordinate their missions to more effectively address existing and future environmental conditions contributing to aircraft-wildlife strikes throughout the United States. These efforts are intended to minimize wildlife risks to aviation and human safety, while protecting the Nation's valuable environmental resources.

BACKGROUND

Aircraft-wildlife strikes are the second leading causes of aviation-related fatalities. Globally, these strikes have killed over 400 people and destroyed more than 420 aircraft. While these extreme events are rare when compared to the millions of annual aircraft operations, the potential for catastrophic loss of human life resulting from one incident is substantial. The most recent accident demonstrating the grievous nature of these strikes occurred in September 1995, when a U.S. Air Force reconnaissance jet struck a flock of Canada geese during takeoff, killing all 24 people aboard.

The Federal Aviation Administration (FAA) and the United States Air Force (USAF) databases contain information on more than 54,000 United States civilian and military aircraft-wildlife strikes reported to them between 1990 and 1999[1]. During that decade, the FAA received reports indicating that aircraft-wildlife strikes, damaged 4,500 civilian U.S. aircraft (1,500 substantially), destroyed 19 aircraft, injured 91 people, and killed 6 people. Additionally, there were 216 incidents where birds struck two or more engines on civilian aircraft, with damage occurring to 26 percent of the 449 engines involved in these incidents. The FAA estimates that during the same decade, civilian U.S. aircraft sustained $4 billion worth of damages and associated losses and 4.7 million hours of aircraft downtime due to aircraft-wildlife strikes. For the same period,

[1] FAA estimates that the 28,150 aircraft-wildlife strike reports it received represent less than 20% of the actual number of strikes that occurred during the decade.

USAF planes colliding with wildlife resulted in 10 Class A Mishaps[2], 26 airmen deaths, and over $217 million in damages.

Approximately 97 percent of the reported civilian aircraft-wildlife strikes involved common, large-bodied birds or large flocks of small birds. Almost 70 percent of these events involved gulls, waterfowl, and raptors (Table 1).

About 90 percent of aircraft-wildlife strikes occur on or near airports, when aircraft are below altitudes of 2,000 feet. Aircraft-wildlife strikes at these elevations are especially dangerous because aircraft are moving at high speeds and are close to or on the ground. Aircrews are intently focused on complex take-off or landing procedures and monitoring the movements of other aircraft in the airport vicinity. Aircrew attention to these activities while at low altitudes often compromises their ability to successfully recover from unexpected collisions with wildlife and to deal with rapidly changing flight procedures. As a result, crews have minimal time and space to recover from aircraft-wildlife strikes.

Increasing bird and wildlife populations in urban and suburban areas near airports contribute to escalating aircraft-wildlife strike rates. FAA, USAF, and Wildlife Services (WS) experts expect the risks, frequencies, and potential severities of aircraft-wildlife strikes to increase during the next decade as the numbers of civilian and military aircraft operations grow to meet expanding transportation and military demands.

SECTION I.

SCOPE OF COOPERATION AND COORDINATION

Based on the preceding information and to achieve this MOA's purpose, the signatory agencies:

A. Agree to strongly encourage their respective regional and local offices, as appropriate, to develop interagency coordination procedures necessary to effectively and efficiently implement this MOA. Local procedures should clarify time frames and other general coordination guidelines.

B. Agree that the term "airport" applies only to those facilities as defined in the attached glossary.

C. Agree that the three major activities of most concern include, but are not limited to:

1. airport siting and expansion;

---

[2] See glossary for the definition of a Class A Mishap and similar terms.

2. development of conservation/mitigation habitats or other land uses that could attract hazardous wildlife to airports or nearby areas; and

3. responses to known wildlife hazards or aircraft-wildlife strikes.

D. Agree that "hazardous wildlife" are those animals, identified to species and listed in FAA and USAF databases, that are most often involved in aircraft-wildlife strikes. Many of the species frequently inhabit areas on or near airports, cause structural damage to airport facilities, or attract other wildlife that pose an aircraft-wildlife strike hazard. Table 1 lists many of these species. It is included solely to provide information on identified wildlife species that have been involved in aircraft-wildlife strikes. It is not intended to represent the universe of species concerning the signatory agencies, since more than 50 percent of the aircraft-wildlife strikes reported to FAA or the USAF did not identify the species involved.

E. Agree to focus on habitats attractive to the species noted in Table 1, but the signatory agencies realize that it is imperative to recognize that wildlife hazard determinations discussed in Paragraph L of this section may involve other animals.

F. Agree that not all habitat types attract hazardous wildlife. The signatory agencies, during their consultative or decisionmaking activities, will inform regional and local land use authorities of this MOA's purpose. The signatory agencies will consider regional, local, and site-specific factors (e.g., geographic setting and/or ecological concerns) when conducting these activities and will work cooperatively with the authorities as they develop and implement local land use programs under their respective jurisdictions. The signatory agencies will encourage these stakeholders to develop land uses within the siting criteria noted in Section 1-3 of FAA Advisory Circular (AC) 150.5200-33 (Attachment A) that do not attract hazardous wildlife. Conversely, the agencies will promote the establishment of land uses attractive to hazardous wildlife outside those siting criteria. Exceptions to the above siting criteria, as described in Section 2.4.b of the AC, will be considered because they typically involve habitats that provide unique ecological functions or values (e.g., critical habitat for federally-listed endangered or threatened species, ground water recharge).

G. Agree that wetlands provide many important ecological functions and values, including fish and wildlife habitats; flood protection; shoreline erosion control; water quality improvement; and recreational, educational, and research opportunities. To protect jurisdictional wetlands, Section 404 of the Clean Water Act (CWA) establishes a program to regulate dredge and/or fill activities in these wetlands and navigable waters. In recognizing Section 404 requirements and the Clean Water Action Plan's goal to annually increase the Nation's net wetland acreage by 100,000 acres through 2005, the signatory agencies agree to resolve aircraft-wildlife conflicts. They will do so by avoiding and minimizing wetland impacts to the maximum extent practicable, and will work to compensate for all associated unavoidable wetland impacts. The agencies agree to work with landowners and communities to encourage and support wetland restoration or enhancement efforts that do not increase aircraft-wildlife strike potentials.

H. Agree that the: U.S. Army Corps of Engineers (ACOE) has expertise in protecting and managing jurisdictional wetlands and their associated wildlife; U.S. Environmental Protection Agency (EPA) has expertise in protecting environmental resources; and the U.S. Fish and Wildlife Service (USFWS) has expertise in protecting and managing wildlife and their habitats, including migratory birds and wetlands. Appropriate signatory agencies will cooperatively review proposals to develop or expand wetland mitigation sites, or wildlife refuges that may attract hazardous wildlife. When planning these sites or refuges, the signatory agencies will diligently consider the siting criteria and land use practice recommendations stated in FAA AC 150/5200-33. The agencies will make every effort to undertake actions that are consistent with those criteria and recommendations, but recognize that exceptions to the siting criteria may be appropriate (see Paragraph F of this section).

I. Agree to consult with airport proponents during initial airport planning efforts. As appropriate, the FAA or USAF will initiate signatory agency participation in these efforts. When evaluating proposals to build new civilian or military aviation facilities or to expand existing ones, the FAA or the USAF, will work with appropriate signatory agencies to diligently evaluate alternatives that may avoid adverse effects on wetlands, other aquatic resources, and Federal wildlife refuges. If these or other habitats support hazardous wildlife, and there is no practicable alternative location for the proposed aviation project, the appropriate signatory agencies, consistent with applicable laws, regulations, and policies, will develop mutually acceptable measures, to protect aviation safety and mitigate any unavoidable wildlife impacts.

J. Agree that a variety of other land uses (e.g., storm water management facilities, wastewater treatment systems, landfills, golf courses, parks, agricultural or aquacultural facilities, and landscapes) attract hazardous wildlife and are, therefore, normally incompatible with airports. Accordingly, new, federally-funded airport construction or airport expansion projects near habitats or other land uses that may attract hazardous wildlife must conform to the siting criteria established in the FAA Advisory Circular (AC) 150/5200-33, Section 1-3.

K. Agree to encourage and advise owners and/or operators of non-airport facilities that are known hazardous wildlife attractants (See Paragraph J) to follow the siting criteria in Section 1-3 of AC 150/5200-33. As appropriate, each signatory agency will inform proponents of these or other land uses about the land use's potential to attract hazardous species to airport areas.

The signatory agencies will urge facility owners and/or operators about the critical need to consider the land uses' effects on aviation safety.

L. Agree that FAA, USAF, and WS personnel have the expertise necessary to determine the aircraft-wildlife strike potentials of various land uses. When there is disagreement among signatory agencies about a particular land use and its potential to attract hazardous wildlife, the FAA, USAF, or WS will prepare a wildlife hazard assessment. Then, the appropriate signatory agencies will meet at the local level to review the assessment. At a minimum, that assessment will:

1. identify each species causing the aviation hazard, its seasonal and daily populations, and the population's local movements;

2. discuss locations and features on and near the airport or land use attractive to hazardous wildlife; and

3. evaluate the extent of the wildlife hazard to aviation.

M. Agree to cooperate with the airport operator to develop a specific, wildlife hazard management plan for a given location, when a potential wildlife hazard is identified. The plan will meet applicable FAA, USAF, and other relevant requirements. In developing the plan, the appropriate agencies will use their expertise and attempt to integrate their respective programmatic responsibilities, while complying with existing laws, regulations, and policies. The plan should avoid adverse impacts to wildlife populations, wetlands, or other sensitive habitats to the maximum extent practical. Unavoidable impacts resulting from implementing the plan will be fully compensated pursuant to all applicable Federal laws, regulations, and policies.

N. Agree that whenever a significant aircraft-wildlife strike occurs or a potential for one is identified, any signatory agency may initiate actions with other appropriate signatory agencies to evaluate the situation and develop mutually acceptable solutions to reduce the identified strike probability. The agencies will work cooperatively, preferably at the local level, to determine the causes of the strike and what can and should be done at the airport or in its vicinity to reduce potential strikes involving that species.

O. Agree that information and analyses relating to mitigation that could cause or contribute to aircraft-wildlife strikes should, whenever possible, be included in documents prepared to satisfy the National Environmental Policy Act (NEPA). This should be done in coordination with appropriate signatory agencies to inform the public and Federal decision makers about important ecological factors that may affect aviation. This concurrent review of environmental issues will promote the streamlining of the NEPA review process.

P. Agree to cooperatively develop mutually acceptable and consistent guidance, manuals, or procedures addressing the management of habitats attractive to hazardous wildlife, when those habitats are or will be within the siting criteria noted in Section 1-3 of FAA AC 5200-33. As appropriate, the signatory agencies will also consult each other when they propose revisions to any regulations or guidance relevant to the purpose of this MOA, and agree to modify this MOA accordingly.

SECTION II.
GENERAL RULES AND INFORMATION

A. Development of this MOA fulfills the National Transportation Safety Board's recommendation of November 19, 1999, to form an inter-departmental task force to address aircraft-wildlife strike issues.

B. This MOA does not nullify any obligations of the signatory agencies to enter into separate MOAs with the USFWS addressing the conservation of migratory birds, as outlined in Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, dated January 10, 2001 (66 *Federal Register*, No. 11, pg. 3853).

C. This MOA in no way restricts a signatory agency's participation in similar activities or arrangements with other public or private agencies, organizations, or individuals.

D. This MOA does not alter or modify compliance with any Federal law, regulation or guidance (e.g., Clean Water Act; Endangered Species Act; Migratory Bird Treaty Act; National Environmental Policy Act; North American Wetlands Conservation Act; Safe Drinking Water Act; or the "no-net loss" policy for wetland protection). The signatory agencies will employ this MOA in concert with the Federal guidance addressing wetland mitigation banking dated March 6, 1995 (60 *Federal Register*, No. 43, pg. 12286).

E. The statutory provisions and regulations mentioned above contain legally binding requirements. However, this MOA does not substitute for those provisions or regulations, nor is it a regulation itself. This MOA does not impose legally binding requirements on the signatory agencies or any other party, and may not apply to a particular situation in certain circumstances. The signatory agencies retain the discretion to adopt approaches on a case-by-case basis that differ from this MOA when they determine it is appropriate to do so. Such decisions will be based on the facts of a particular case and applicable legal requirements. Therefore, interested parties are free to raise questions and objections about the substance of this MOA and the appropriateness of its application to a particular situation.

F. This MOA is based on evolving information and may be revised periodically without public notice. The signatory agencies welcome public comments on this MOA at any time and will consider those comments in any future revision of this MOA.

G. This MOA is intended to improve the internal management of the Executive Branch to address conflicts between aviation safety and wildlife. This MOA does not create any right, benefit, or trust responsibility, either substantively or procedurally. No party, by law or equity, may enforce this MOA against the United States, its agencies, its officers, or any person.

H. This MOA does not obligate any signatory agency to allocate or spend appropriations or enter into any contract or other obligations.

I. This MOA does not reduce or affect the authority of Federal, State, or local agencies regarding land uses under their respective purviews. When requested, the signatory agencies will provide technical expertise to agencies making decisions regarding land uses within the siting criteria in Section 1-3 of FAA AC 150/5200-33 to minimize or prevent attracting hazardous wildlife to airport areas.

J. Any signatory agency may request changes to this MOA by submitting a written request to any other signatory agency and subsequently obtaining the written concurrence of all signatory agencies.

K. Any signatory agency may terminate its participation in this MOA within 60 days of providing written notice to the other agencies. This MOA will remain in effect until all signatory agencies terminate their participation in it.

SECTION III. PRINCIPAL SIGNATORY AGENCY CONTACTS

The following list identifies contact offices for each signatory agency.

Federal Aviation Administration
Office Airport Safety and Standards
Airport Safety and
Compliance Branch (AAS-310)
800 Independence Ave., S.W.
Washington, D.C. 20591
V: 202-267-1799
F: 202-267-7546

U.S. Air Force
HQ AFSC/SEFW
9700 Ave., G. SE, Bldg. 24499
Kirtland AFB, NM 87117
V: 505-846-5679
F: 505-846-0684

U.S. Army
Directorate of Civil Works
Regulatory Branch (CECW-OR)
441 G St., N.W.
Washington, D.C. 20314
V: 202-761-4750
F: 202-761-4150

U.S. Environmental Protection Agy.
Office of Water
Wetlands Division
Ariel Rios Building, MC 4502F
1200 Pennsylvania Ave., SW
Washington, D.C. 20460
V: 202-260-1799
F: 202-260-7546

U.S. Fish and Wildlife Service
Division of Migratory Bird Management
4401 North Fairfax Drive, Room 634
Arlington, VA 22203
V: 703-358-1714
F: 703-358-2272

U.S. Department of Agriculture
Animal and Plant Inspection Service
Wildlife Services
Operational Support Staff
4700 River Road, Unit 87
Riverdale, MD 20737
V: 301-734-7921
F: 301-734-5157

Signature Page

Associate Administrator for Airports,
Federal Aviation Administration

12/17/02
Date

Chief of Safety,
U. S. Air Force

27 May 2003
Date

Acting Assistant Secretary of the Army
(Civil Works)
Department of the Army

December 9, 2002
Date

Assistant Administrator, Office of Water,
U.S. Environmental Protection Agency

1/17/03

Paul R. Schmidt
Assistant Director, Migratory Birds
and State Programs,
U.S. Fish and Wildlife Service

7/29/03
Date

Acting Deputy Administrator, Wildlife Services
U.S. Department of Agriculture

09 January 2003
Date

GLOSSARY

This glossary defines terms used in this MOA.

Airport. All USAF airfields or all public use airports in the FAA's National Plan of Integrated Airport Systems (NPIAS). Note: There are over 18,000 civil-use airports in the U.S., but only 3,344 of them are in the NPIAS and, therefore, under FAA's jurisdiction.

Aircraft-wildlife strike. An aircraft-wildlife strike is deemed to have occurred when:

1. a pilot reports that an aircraft struck 1 or more birds or other wildlife;
2. aircraft maintenance personnel identify aircraft damage as having been caused by an aircraft-wildlife strike;
3. personnel on the ground report seeing an aircraft strike 1 or more birds or other wildlife;
4. bird or other wildlife remains, whether in whole or in part, are found within 200 feet of a runway centerline, unless another reason for the animal's death is identified; or
5. the animal's presence on the airport had a significant, negative effect on a flight (i.e., aborted takeoff, aborted landing, high-speed emergency stop, aircraft left pavement area to avoid collision with animal)

(Source: *Wildlife Control Procedures Manual*, Technical Publication 11500E, 1994).

Aircraft-wildlife strike hazard. A potential for a damaging aircraft collision with wildlife on or near an airport (14 CFR 139.3).

Bird Sizes. Title 40, Code of Federal Regulations, Part 33.76 classifies birds according to weight:

small birds weigh less than 3 ounces (oz).
medium birds weigh more than 3 oz and less than 2.5 lbs.
large birds weigh greater than 2.5 lbs.

Civil aircraft damage classifications. The following damage descriptions are based on the *Manual on the International Civil Aviation Organization Bird Strike Information System*:

Minor: The aircraft is deemed airworthy upon completing simple repairs or replacing minor parts and an extensive inspection is not necessary.

Substantial: Damage or structural failure adversely affects an aircraft's structural integrity, performance, or flight characteristics. The damage normally requires major repairs or the replacement of the entire affected component. Bent fairings or cowlings; small dents; skin punctures; damage to wing tips, antenna, tires or brakes, or engine blade damage not requiring blade replacement are specifically excluded.

Destroyed: The damage sustained makes it inadvisable to restore the aircraft to an airworthy condition.

Significant Aircraft-Wildlife Strikes. A significant aircraft-wildlife strike is deemed to have occurred when any of the following applies:

1. a civilian, U.S. air carrier aircraft experiences a multiple aircraft-bird strike or engine ingestion;
2. a civilian, U.S. air carrier aircraft experiences a damaging collision with wildlife other than birds; or
3. a USAF aircraft experiences a Class A, B, or C mishap as described below:

    A. **Class A Mishap:** Occurs when at least one of the following applies:
      1. total mishap cost is $1,000,000 or more;
      2. a fatality or permanent total disability occurs; and/or
      3. an Air Force aircraft is destroyed.

    B. **Class B Mishap:** Occurs when at least one of the following applies:
      1. total mishap cost is $200,000 or more and less than $1,000,000; and/or
      2. a permanent partial disability occurs and/or 3 or more people are hospitalized;

    C. **Class C Mishap:** Occurs when at least one of the following applies:
      1. cost of reported damage is between $20,000 and $200,000;
      2. an injury causes a lost workday (i.e., duration of absence is at least 8 hours beyond the day or shift during which mishap occurred); and/or
      3. an occupational illness causing absence from work at any time.

Wetlands. An ecosystem requiring constant or recurrent, shallow inundation or saturation at or near the surface of the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation or saturation at or near the surface and the presence of physical, chemical, and biological features indicating recurrent, sustained inundation, or saturation. Common diagnostic wetland features are hydric soils and hydrophytic vegetation. These features will be present, except where specific physiochemical, biotic, or anthropogenic factors have removed them or prevented their development.

(Source the 1987 Delineation Manual; 40 CFR 230.3(t)).

Wildlife. Any wild animal, including without limitation any wild mammal, bird, reptile, fish, amphibian, mollusk, crustacean, arthropod, coelenterate, or other invertebrate, including any part, product, egg, or offspring there of (50 CFR 10.12, *Taking, Possession, Transportation, Sale, Purchase, Barter, Exportation, and Importation of Wildlife and Plants*). As used in this MOA, "wildlife" includes feral animals and domestic animals while out of their owner's control (14 CFR 139.3, *Certification and Operations: Land Airports Serving CAB-Certificated Scheduled Air Carriers Operating Large Aircraft (Other Than Helicopters)*)

Table 1. Identified wildlife species, or groups, that were involved in two or more aircraft-wildlife strikes, that caused damage to one or more aircraft components, or that had an adverse effect on an aircraft's flight. Data are for 1990-1999 and involve only civilian, U.S. aircraft.

Birds	No. reported strikes
Gulls (all spp.)	874
Geese (primarily, Canada geese)	458
Hawks (primarily, Red-tailed hawks)	182
Ducks (primarily Mallards.)	166
Vultures (primarily, Turkey vulture)	142
Rock doves	122
Doves (primarily, mourning doves)	109
Blackbirds	81
European starlings	55
Sparrows	52
Egrets	41
Shore birds (primarily, Killdeer & Sandpipers)	40
Crows	31
Owls	24
Sandhill cranes	22
American kestrels	15
Great blue herons	15
Pelicans	14
Swallows	14
Eagles (Bald and Golden)	14
Ospreys	13
Ring-necked pheasants	11
Herons	11
Barn-owls	9
American robins	8
Meadowlarks	8
Buntings (snow)	7
Cormorants	6
Snow buntings	6
Brants	5
Terns (all spp.)	5
Great horned owls	5
Horned larks	4
Turkeys	4
Swans	3
Mockingbirds	3
Quails	3
Homing pigeons	3
Snowy owls	3
Anhingas	2

Birds	No. reported strikes
Ravens	2
Kites	2
Falcons	2
Peregrine falcons	2
Merlins	2
Grouse	2
Hungarian partridges	2
Spotted doves	2
Thrushes	2
Mynas	2
Finches	2
Total known birds	2,612

Mammals	No. reported strikes
Deer (primarily, White-tailed deer)	285
Coyotes	16
Dogs	10
Elk	6
Cattle	5
Bats	4
Horses	3
Pronghorn antelopes	3
Foxes	2
Raccoons	2
Rabbits	2
Moose	2
Total known mammals	340

Ring-billed gulls were the most commonly struck gulls. The U.S. ring-billed gull population increased steadily at about 6% annually from 1966-1988. Canada geese were involved in about 90% of the aircraft-goose strikes involving civilian, U.S. aircraft from 1990-1998. Resident (non-migratory) Canada goose populations increased annually at 13% from 1966-1998. Red-tailed hawks accounted for 90% of the identified aircraft-hawk strikes for the 10-year period. Red-tailed hawk populations increased annually at 3% from 1966 to 1998. Turkey vultures were involved in 93% of he identified aircraft-vulture strikes. The U.S. Turkey vulture populations increased at annually at 1% between 1966 and 1998. Deer, primarily white-tailed deer, have also adapted to urban and airport areas and their populations have increased dramatically. In the early 1900's, there were about 100,000 white-tailed deer in the U.S. Current estimates are that the U.S. population is about 24 million.

APPENDIX L

WILDLIFE HAZARDS AND AIRPORT SAFETY

APPENDIX L
Wildlife Hazards and Airport Safety

This appendix discusses the rationale for minimizing or eliminating hazardous wildlife attractants at Florida's airports. The choice of water management system can further that goal.

Continually growing air travel in faster and quieter aircraft, coincident with successful wildlife enhancement and management efforts, has resulted in an increasing hazard of aircraft-wildlife collision. About 80% of the wildlife strikes occur within 1,000 feet of the ground, in the *approach and departure airspace* for airports. Figure L-1 shows the most critical area for birdstrikes based on research by Transport Canada.

The vast majority of wildlife are birds, with nearly 22,000 bird strikes reported between 1990 and 1998 in the United States alone. An additional 580 mammal and 35 reptile strikes were reported in the U.S. in the same period.

Damage is both injury/loss of life and economic. Loss of life in the United States due to aircraft-wildlife collisions averages about 2 per year for civilian and 3 per year for military aircraft. Although even wide body jet airliners have been totally destroyed following bird collisions in the U.S, to date there have been no major civilian airliner losses of life in single incidents here.

The total estimated cost to U.S. civil aviation due to wildlife strikes is $250 million direct and $130 million indirect annually. These costs do not consider environmental damage. For example: *On August 27, 2001 a Boeing 747 departing Los Angeles ingested birds and suffered an engine failure. The aircraft was forced to dump over 165,000 pounds of fuel over the Pacific Ocean to return for a safe landing.* Pieces of the engine fell on nearby beaches, but no persons on the ground were injured. The environmental damages and costs of this event and others like it, including crashes with fuel release, are not considered in the $380 million annual *wildlife strike* costs.

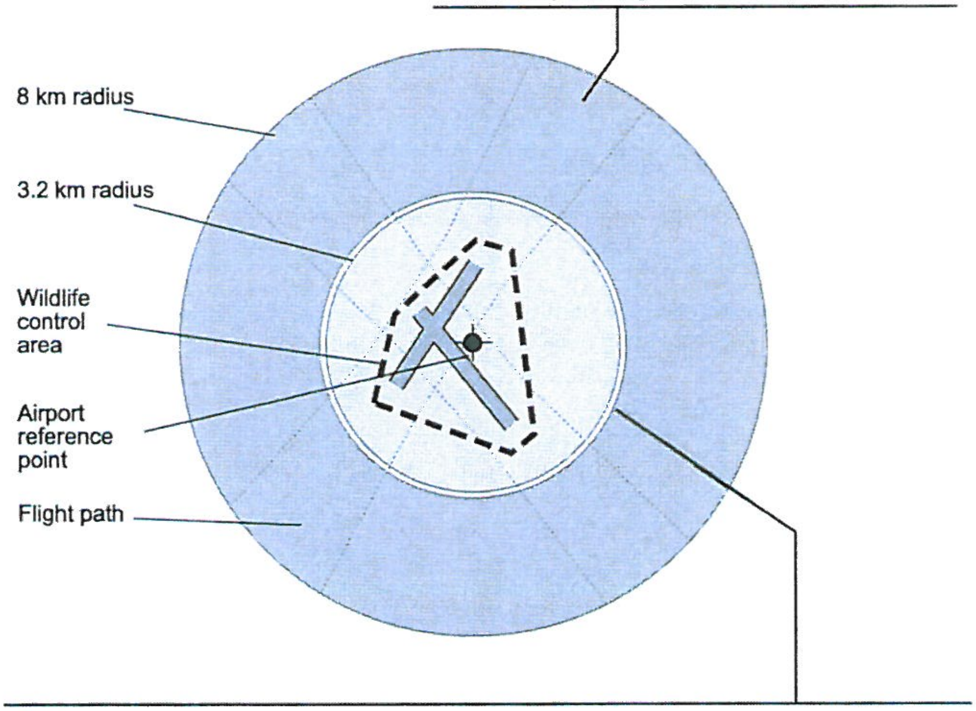
The problem is not limited to the State of Florida, which consistently ranks in the top 3 states for wildlife strikes, or to the United States. Further, it is becoming a source of legal liability both within and outside the U.S. For example, on June 3, 1995 an Air France Concorde ingested 1 or 2 Canada geese into the Number 3 engine about 10 feet above the runway while landing. The engine burst (uncontained failure) and the resulting shrapnel destroyed the Number 4 engine. It also cut several control cables and hydraulic lines. A safe landing was effected, but the aircraft had $7 million damage. The French Aviation Authority sued the Port Authority of New York and New Jersey for failure to manage the bird hazard and/or to warn the aircraft of the hazard. The case was settled for $5.3 million before trial. Cases taken to trial have been decided against the airport operator in the U.S., England and other countries, with decisions that a duty of due diligence is owed in managing an airport's wildlife hazards. Criminal charges have been filed in at least one European country over a fatal crash attributed to wildlife hazards.

Extremely Hazardous

Not recommended for areas within 8 km of an airport reference point:

- garbage dumps
- food waste landfill sites
- coastal commercial fish processing plants
- crops that may attract birds

These areas are attractive to "hazardous" birds, i.e., birds that pose the greatest danger to aircraft.



Moderately Hazardous

Not recommended for areas within 3.2 km of an airport reference point:

- grain crops, e.g., barley, oats, wheat (particularly Durum), corn and sunflower
- fruit orchards, e.g., berries, cherries, grapes and apples
- feedlots, e.g., beer fed cattle and piggeries
- drive-in theatres
- migratory waterfowl and game refuges or feeding stations
- daytime plowing activities
- unchecked infestations of mice and insects
- sewage lagoons and storm-water retention ponds

These areas and practices are moderately attractive to birds — mainly smaller birds such as starlings, sparrows and Snow Buntings — that are not drawn to airports from long distances to feed. These birds are most hazardous during migration or when favourable feeding conditions arise such as insect infestations, plowing or harvesting.

Some hazardous land use practices increase the attractiveness of existing geographic features, such as open bodies of water or wetlands which serve as nesting areas for gulls, shorebirds and waterfowl. For example, when airports lie between landfill sites (feeding areas) and natural bodies of water (nesting areas), birds will regularly fly back and forth over the airport, adding to the bird strike hazard.

FIGURE L-1 BIRDSTRIKE HAZARD AREAS
(Excerpted from "Sharing the Skies" Manual Published by Transport Canada)

Florida Statute Chapter 333 *Airport Zoning* recognizes bird attractants as one of several hazards to airport operations. Section 333.02 of the Statute states, in part:
"(1) It is hereby found that an airport hazard endangers the lives and property of users of the airport and of occupants of land in its vicinity…. Accordingly, it is hereby declared:
(a) That the creation or establishment of an airport hazard and the incompatible use of land in airport vicinities are public nuisances and injure the community served by the airport in question;
(b) That it is therefore necessary in the interest of the public health, public safety, and general welfare that the creation or establishment of airport hazards and incompatible land uses be prevented…"
The Statute is principally concerned with zoning ordinances to promote compatible land use adjacent to airports and out to 10 nautical miles (11.5 statute miles) for specific land uses.

The FAA Advisory Circular 150/5200-33B Hazardous Wildlife Attractants On Or Near Airports states, in Section 4-3.a:
"Airports that have received Federal grant-in-aid assistance are required by their grant assurances to take appropriate actions to restrict the use of land next to or near the airport to uses that are compatible with normal airport operations. The FAA recommends that airport operators to the extent practicable oppose off-airport land-use changes or practices within the separations identified in Sections 1-2 through 1-4 [see Figure 605-6, this manual] that may attract hazardous wildlife. Failure to do so may lead to noncompliance with applicable grant assurances. The FAA will not approve the placement of airport development projects pertaining to aircraft movement in the vicinity of hazardous wildlife attractants without appropriate mitigating measures. Increasing the intensity of wildlife control efforts is not a substitute for eliminating or reducing a proposed wildlife hazard. Airport operators should identify hazardous wildlife attractants and any associated wildlife hazards during any planning process for new airport development projects."

The state wildlife organization, the Florida Fish and Wildlife Conservation Commission (FWCC), also recognizes the serious nature of wildlife hazards to aircraft. FAC 68A-12.009 allows harassment of any wildlife within 300 feet of active runways, taxiways and aprons to avoid aircraft collision. Taking of certain species on airports is also authorized by this rule.

Federal agencies concerned with environmental protection, including the U.S. Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACOE), the United States Department of Agriculture (USDA), and the U.S. Fish and Wildlife Service (FWS) are all signatory to a memorandum of understanding on the problem. A copy of this document is included in Appendix K. The goals are similar to those of this project – to provide safe air transport and sound stewardship of national water, wetland and wildlife resources.

Impact Forces and Damage

Bird or other wildlife strikes on aircraft exert large forces on the impacted structure. Fundamentally, these forces are given by Newton's Third Law that Force = Mass x Acceleration. It is possible to approximate the forces based on aircraft velocity and bird weight. Table L-1 summarizes the bird impact forces for various aircraft velocities and typical bird species and weights.

TABLE L-1 APPROXIMATE BIRD IMPACT FORCES

	Approximate Impact Forces in Pounds for Given Speed				
Bird Species & Weight	**60 Knots (69 mph)**	**100 Knots (115 mph)**	**150 Knots (173 mph)**	**200 Knots (230 mph)**	**250 Knots (288 mph)**
Starling (3 ozs)	359	995	2,238	3,978	6,216
Snowy Egret (13 ozs)	517	1,436	3,230	5,743	8,973
Ring-Billed Gull (1.5 lbs)	994	2,775	6,244	11,100	17,343
Duck (4.0 lbs)	2,186	6,078	13,676	24,314	37,990
Black Vulture (4.4 lbs)	2,799	7,775	17,493	31,099	48,592
Great Blue Heron (6.5 lbs)	2,953	8,204	18,459	32,815	51,274
Canada Goose (15 .0 lbs)	3,268	9,118	20,515	36,471	56,985

An example of the damage a birdstrike can cause even a relatively slow speeds is shown in Figure L-2 on the following page. The strike occurred on approach, probably at a speed of less than 100 knots, and was most likely a duck. The aircraft landed safely, but sustained serious damage.

FIGURE L-2 BIRDSTRIKE DAMAGE TO PIPER SEMINOLE DURING LANDING APPROACH TO A FLORIDA AIRPORT (MARCH 2003)

Site Factors

Bird and wildlife strike prevention requires generally requires a combination of active and passive controls. Active controls include wildlife harassment and take options as provided in FAC 68A-9.012. Passive controls relate to the site conditions on and around the airports. The goal is to eliminate or minimize as many wildlife attractants as possible, particularly in the approach and departure airspace around the airport. Passive controls can include the creation of more attractive habitats away from the airport approach and departure airspace as part of the strategy.

Studies in the U.S. and abroad have identified various site conditions that act as attractants to hazardous wildlife. These can be broadly grouped into three categories: food source, habitats and cover/safe areas. FAA AC 150/5200-33B discusses many of these, as does the USDA/FAA *Wildlife Hazard Management At Airports* manual. Table L-2 following combines data from these sources and Transport Canada's *Sharing the Skies* manual to list attractants.

TABLE L-2 WILDLIFE ATTRACTANTS

Food Source	**Habitat**	**Cover/Safe Area**
Fish/Amphibians	Wetlands	Brush/Wooded Areas
Insects	Ponds/Lakes/Open Water	Ponds/Lakes
Rodents	Drainage Ditches	Open Structures/Sheds
Seed Producing Grasses	Temporary Ponding Areas	Abandoned Pavement
Agricultural Crops	Woodlots and Trees	Grassed Fields
Litter/Garbage		
Food Processing Activities		