STORMWATER DRAINAGE PLAN

PROPOSED AIRFIELD SAFETY ENHANCEMENT PROJECT ENVIRONMENTAL IMPACT STATEMENT

TUCSON INTERNATIONAL AIRPORT

Tucson, PIMA COUNTY, ARIZONA

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July 27, 2018

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1.0 Introduction

The Federal Aviation Administration (FAA) issued a *Federal Register* Notice on August 19, 2016, announcing its intent to prepare an Environmental Impact Statement (EIS) for the Proposed Airfield Safety Enhancement Project (ASEP) including real property transactions at Tucson International Airport (TUS or Airport) in Pima County, Arizona (the Proposed Action).

The FAA is the lead federal agency for preparation of the EIS and will do so in compliance with National Environmental Policy Act of 1969 (NEPA) and Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (40 Code of Federal Regulations [CFR] Parts 1500-1508), as well as FAA's policies and procedures for complying with NEPA found in FAA Order 1050.1F, *Environmental Impacts: Policies and Procedures* and FAA Order 5050.4B, *NEPA Implementing Instructions for Airport Actions*. The FAA has invited the United States Air Force (USAF) and the National Guard Bureau (NGB) to participate as cooperating agencies as described under 40 CFR § 1501.6 and both have accepted FAA's invitation.

The Proposed Action includes the construction of a new air carrier runway parallel to the primary Runway 11L/29R. This new runway would replace the existing general aviation Runway 11R/29L. The purpose of the project is to enhance the safety of the airfield by eliminating areas in which risk of runway collision and incursion are heightened. Construction of an additional runway will simplify the current airfield's complex geometry, thus, enhancing the overall safety of the runway and its operations.

The key project elements include the following:

- Relocate Runway 11R/29L to the southwest and construct it to a total length of 10,996 feet and width of 150 feet
- Construct new full-length parallel taxiway between Runway 11L/29R and Runway 11R/29L
- Construct supporting connector taxiways between Runway 11R/29L and both outboard and centerline parallel taxiways
- Construct bypass taxiways for Runways 11L and 11R
- Closure of segments of taxiway A2 between taxiway A and Runway 3/21 and taxiway A2 and Runway 3/21
- Construct/maintain Arizona Air National Guard (AANG) extended blast pads for Runways 11L/29R and 11R/29L
- Construction of additional drainage detention areas to support additional impervious pavement areas
- Construction of replacement Earth Covered Magazines on U.S. Air Force Plant 44 (AFP 44)
- Construction of a Munitions Storage Area on land identified as "Parcel H" by the National Guard Bureau

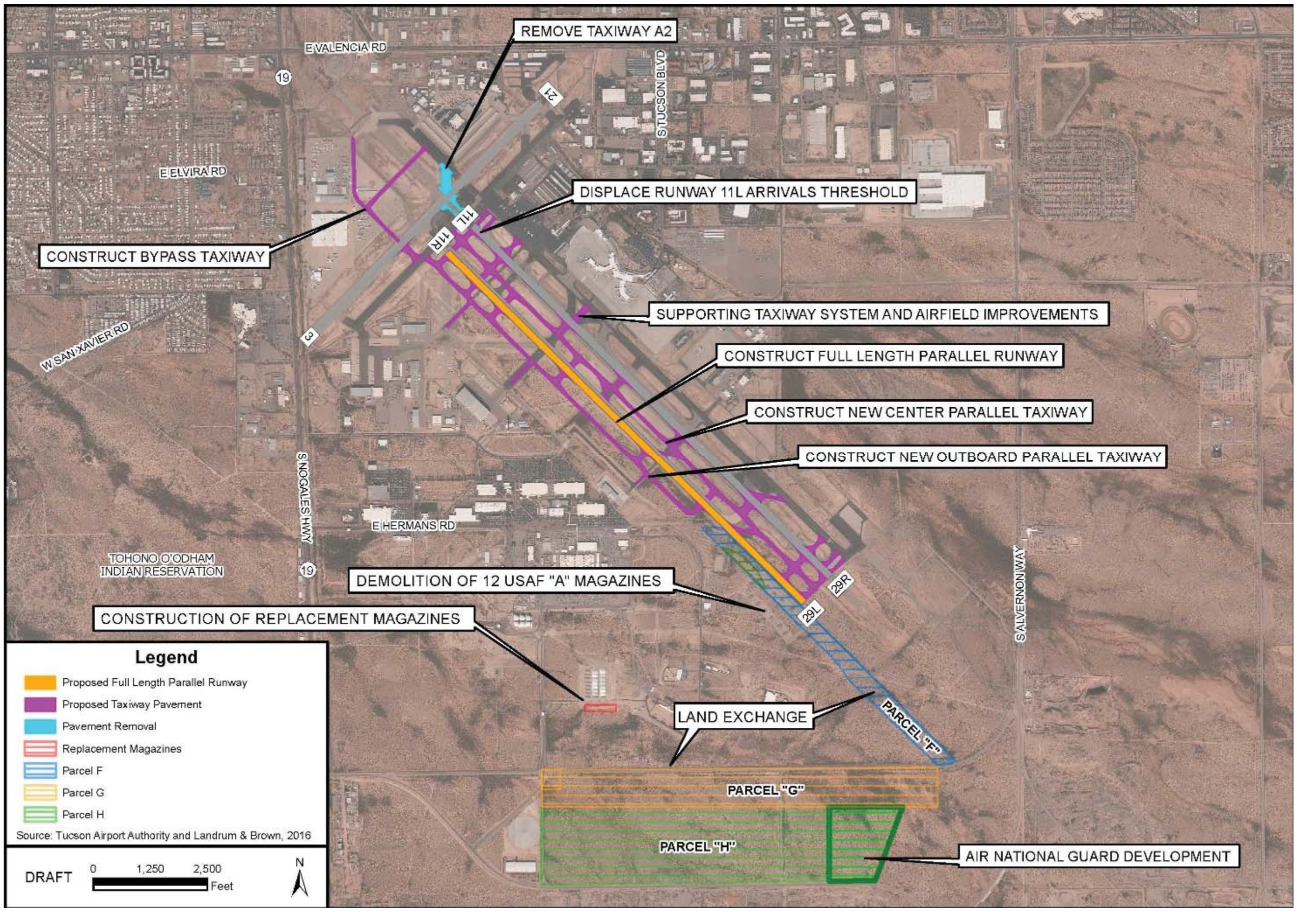

Figure-1: Proposed Airfield Improvements

This Storm water drainage plan is to be used by the FAA to document the conceptual design with recommendations of drainage improvements including conveyance facilities and detention basins to mitigate increases in runoff discharge and volumes associated with the Proposed Action.

1.1 Purpose of Report

This report focuses on development of conceptual drainage improvements in support of the Proposed Action. The report evaluates existing hydrologic conditions and develops a conceptual plan for storm water management including an evaluation of pre versus post runoff conditions at offsite discharge locations. This report documents the conceptual design with recommendations of drainage improvements including conveyance facilities and detention basins to mitigate increases in runoff discharge and volumes.

1.2 Location

The Airport is located on 8,343 acres in Tucson, Arizona in Pima County south of the city of Tucson central business district. The Airport is near both Interstate 10 and Interstate

19. The United States Air Force (USAF) owned land, known as Air Force Plant 44 (AFP 44), is located along the southwest border of the Airport.

The Airport is bounded by Valencia Road (north), Alvernon Way (east), Aerospace Parkway (south) and Nogales Highway (west) within the city of Tucson, Arizona.

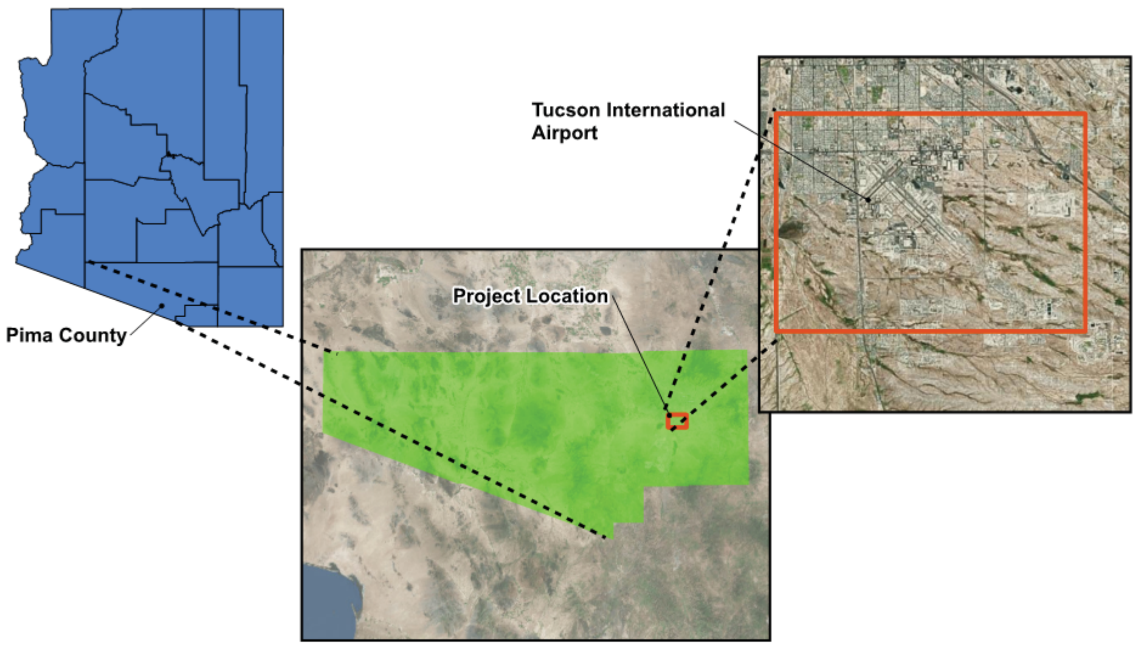

Figure-2: Location Map

2.0 Tucson International Airport

2.1 Existing Conditions

The TUS airfield is comprised of three runways; one set of close parallel runways separated by a distance of 706 feet (oriented in a northwest/southeast direction) and one crosswind runway (oriented in a northeast/southwest direction).

Parallel Runways 11L/29R and 11R/29L measure 10,996 feet long by 150 feet wide and 8,408-feet long by 75-feet wide, respectively. The crosswind runway, Runway 3/21, measures 7,000 feet long by 150-feet wide.

Runway 11L/29R is the primary runway at TUS and is the runway generally used by air carrier and military aircraft. During adverse wind conditions, air carrier and military aircraft occasionally use crosswind Runway 3/21. The crosswind runway is also used for convenience by General Aviation (GA) aircraft when conditions allow. Runway 11R/29L, originally built as a taxiway, has been converted to a runway primarily used by GA aircraft, due to its length and width.

The taxiway system provides aircraft access between the runways and the passenger terminal complex, general and corporate aviation areas, military facilities, airfreight terminals, and other aircraft parking areas.

There are five major drainages close to the Airport, Airport Wash, Valencia Wash, El Vado Wash, Santa Clara Wash, and Hughes Wash, all of which are part of the larger Santa Cruz River watershed. These washes are considered ephemeral streams because they only conduct water during and immediately following precipitation events. Perennial streams conduct water all year long and intermittent streams are dry for part of the year, but conduct water for periods longer than ephemeral streams. During a precipitation event, storm water runoff from the Airport is conveyed by a system of manmade channels and culverts to these drainages, which flow from southeast to northwest toward the Santa Cruz River.

Airport Wash concentrates on the northeast side of the 11L/29R and the terminal area is conveyed around TUS via the Airport Wash channel, which ultimately discharges north of Valencia Road east of Park Avenue. Hughes Wash conveys flow from subbasins 5 and 6 (see Exhibit 5 in Appendix C) as well as flow from AFP 44 which ultimately discharges west of Nogales Highway south of Hermans Road.

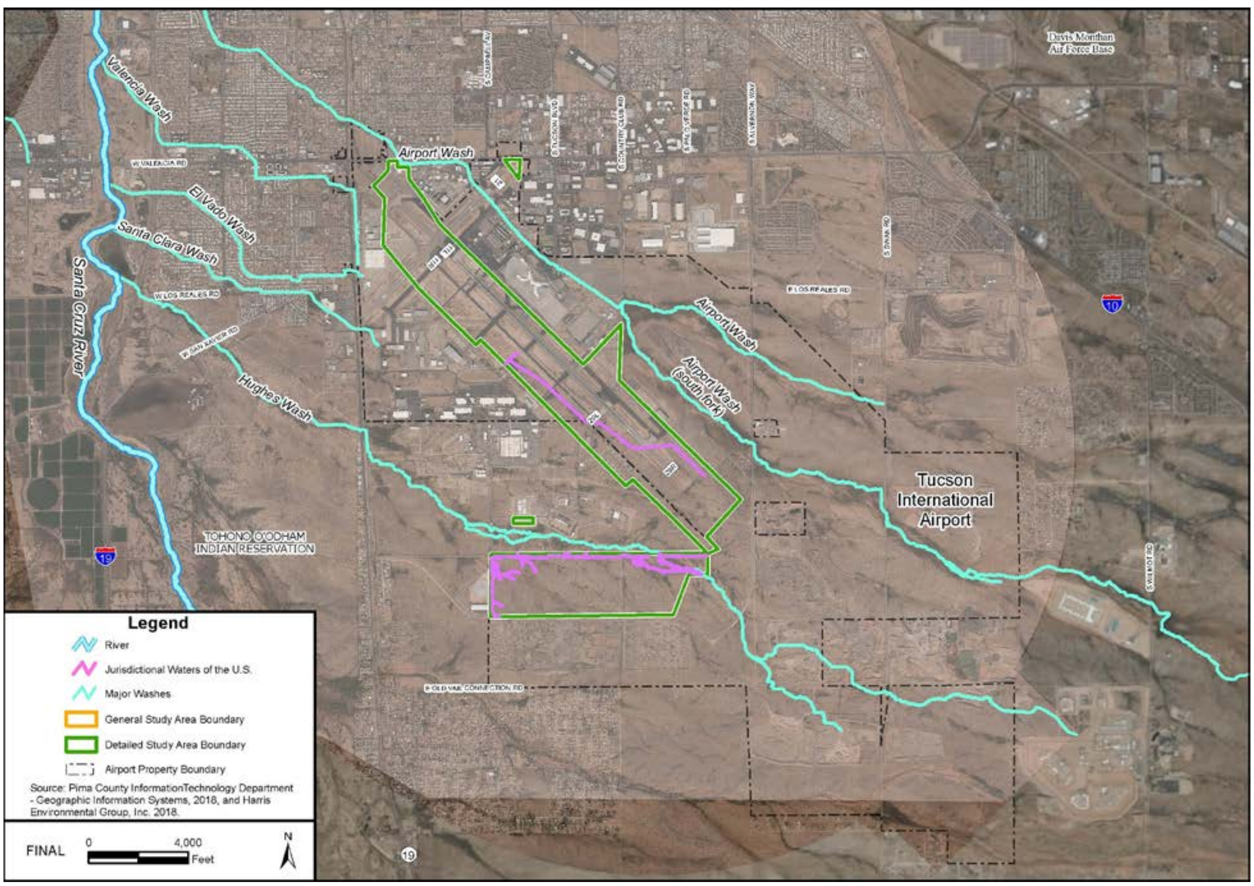

Figure-3: Offsite Drainage Flow Paths

Within the airfield, a smaller local watershed identified as the Airfield watershed collects and conveys onsite runoff from existing airport facilities and currently conveys and discharges storm water runoff at a number of local outfalls located adjacent to the Nogales Highway. Three existing culverted crossings of the railroad and the highway, between Valencia Road and Aero Park Boulevard, discharge flow to the west side of the Nogales Highway where the storm water is typically conveyed within existing natural washes to the northwest toward the Santa Cruz River.

There are four areas where ponding may occur at the Airport during heavy rain events. These are: 1) within the airfield, 2) the area west of Bombardier Aerospace at the railroad, 3) the area west of the Triple Hangars at the railroad, and 4) within Airport Wash. Ponding on the airfield occurs between all runways and taxiways. The ponding is temporary in nature, and only occurs in a significant amount during storms with frequencies greater than 10 years.

2.2 Previous Studies

The following previous studies have developed existing conditions hydrology and hydraulics for the Airport area and were reviewed as part of this effort.

- *Airport Wide Drainage Basin Study (AWDBS). May 1992.*
- *Airport Wide Drainage Basin Update. Stantec Consulting, Inc. August, 2004.* This report is an update of the original 1992 report to incorporate changes in land use, current agency requirements and revised Master Plan conditions.

3.0 Existing Conditions Hydrology

Offsite hydrologic analysis was not performed with this study. Instead, the results of a previous study (*Airport Wide Drainage Update Report* (Report), prepared by Stantec Consulting, Inc. 2004) will be used. This report refers to some data from the *Airport Wide Drainage Basin Study* (AWDBS) completed in May 1992, while providing additional modeling results and updated analysis.

In the 2004 study, U.S. Army Corps of Engineers (USACE) HEC-1, Flood Hydrograph Package computer program was used to determine the storm water runoff discharges of the existing airport conditions for the 2, 5, 10 and 100-year return periods. At the time, the HEC-1 model was used in place of the standard Pima County hydrology methodology because of the nature of the contributing watersheds. The HEC-1 model was used to account for the extensive ponding throughout the watershed, which largely affects the peak discharges.

3.1 Existing Conditions

Per the 2004 report, several watersheds contribute to the study area or adjacent surrounding areas. These watersheds are the Airport Wash, Hughes Wash and the Airfield Wash watersheds. Discharges and projected volumes of the hydrologic analysis can be found in the report. No additional offsite analysis was performed as a part of this study.

3.2 Previous Study Model Results

The existing airfield drainage facilities have generally been designed in accordance with the FAA guidelines. FAA Advisory Circular AC 150/5320-5B, "Airport Drainage," July 1970 recommends that airfield drainage facilities be designed for the 5-year frequency storm runoff. Per the results found in tables 4 & 8 of the report (AWDB-Update), the peak 5-year baseline flows from the site is listed as 222 cubic feet per second (cfs).

Table 3.2 – Airfield Discharge

	Storm Frequency	Baseline Flow	Post-Development Flow	Detention Basin Volume
		[cfs]	[cfs]	[ac.-ft.]
Airfield Watershed (Point C)	2	108	152	4
	5	222	305	4
	10	322	379	5
	100	904	981	5

Notes: 1) Hydrology modeled using HEC-1 hydrographs and stage-storage-discharge relationships.
2) Uncertain if detention basins were constructed. Listed as 'future' development in the Stantec report (2004).
3) Results in table based upon 'on-line' detention basins in Airfield Wash and 20% oversizing.

The detention basin volume shown in Table 3.2 is indicated as future development within the Stantec report. It is not clear if the detention basin was constructed.

3.3 Airfield Wash, Airport Wash, and Hughes Wash Hydrology

There are three distinct outfalls from the Airfield Wash watershed, two distinct storm water outfalls from the Hughes Wash watershed, and one distinct storm water outfall from the Airport Wash watershed (see Exhibit 5 in Appendix C). Each of these outfalls has a distinct drainage area contributing storm water runoff. These six sub-basins of Airfield Wash, Airport Wash, and Hughes Wash watersheds are analyzed to determine the peak discharges reaching each outfall. The City of Tucson's hydrologic method is used to develop onsite discharges with the following results.

Table 3.3 – Airfield Wash, Airport Wash, and Hughes Wash Watersheds Existing Conditions Sub-basin Runoff

Drainage Areas	Outfall Location	Contributing Area	Weighted Runoff C	5-year Discharge	100-year Discharge
		[acres]		[cfs]	[cfs]
1	Valencia Road to Airport Wash	41.8	0.73	80.1	228.8
2	Nogales Hwy to Valencia Wash	160.9	0.85	275.6	787.6
3	Nogales Hwy to El Vado Wash	77.3	0.80	124.3	355.2
4	Nogales Hwy to El Vado Wash	618.7	0.78	609.2	1740.7
5	Hermans Road to Hughes Wash	593.3	0.77	469.9	1342.6
6	Hermans Road to Hughes Wash	64.8	0.86	115.2	329.3

The results of the existing conditions analysis determine the base flow rate which are not to be exceeded by proposed conditions in the Proposed Action.

4.0 Hydrology

4.1 Design Criteria

Section 1.5 of the AWDB-Update designates that future drainage facilities be designed in accordance with the following City of Tucson, Pima County and FAA guidelines:

- Detention basins will hold runoff for a period of time before releasing it to downstream facilities, and must drain within 24-hours per Pima County DOT & Flood Control District (FCD) regulations. *The basins will be designed such that post-development 2, 5, 10 & 100-year peak flows from the site will not exceed the predevelopment values*.
- Detention volumes in onsite ponding areas and detention basins will bleed-off flow such that the basins will drain within 24-hours.
- Per FAA guidelines, future onsite drainage facilities mush have capacity for the 5-year frequency storm runoff. Additionally, temporary ponding from storms with a return period of 10-years will be checked for encroachment into the runway and taxiway safety areas. Ponding in the airfield is allowed only as a result of runoff exceeding the 5-year design capacity. Detention basins within the runway and taxiways will not be allowed. Temporary or short term ponding in the airfield caused by runoff from rainfall events greater than the 5-year event must drain within 24-hours.
- Detention basins shall be located as far from runways as possible.
- Buildings, structures and adjacent facilities shall be protected from the 100-year frequency storm runoff.
- No changes in drainage patterns impacting downstream areas will be allowed.

4.2 Proposed Airfield Improvements

The Proposed Action includes, among other things, construction of a full length parallel runway designated 11R/29L, a new center parallel taxiway, new outboard parallel taxiway, addition of supporting and bypass taxiway systems (see Figure 1). These improvements are entirely located within the Airfield Wash watershed and constitute an overall increase in the total impervious area located within the watershed resulting in a net increase in storm water runoff discharge and volume.

The nature of the improvements can be observed by comparing the existing onsite development (Exhibit 5) with the proposed shown in Exhibit 6 in Appendix C. The change in land use can be classified into three categories:

- Impervious which is now pervious, resulting from the removal of an impervious surface
- Pervious which is now impervious, resulting from the addition of new impervious surfaces; and
- Impervious which will remain impervious, resulting from a modification in the Proposed Action but from one impervious surface to another.

The net increase in impervious surface is approximately 80.0 acres which is primarily split between subbasins 4 & 5. Subbasins 1, 2 and 6 were essentially unchanged while subbasin 3, although modified, resulted in a zero-net change in impervious surface.

4.3 Proposed Conditions Onsite Hydrologic

The three of the six watersheds have been modified to reflect physical changes to the existing conditions. The proposed conditions drainage boundaries between watersheds 4 and 5 are adjusted to account for changes in contributing watershed based upon the runway and taxi way configuration (see the differences between exhibits 3 and 6 in Appendix C).

The drainage analysis follows the guidelines within the *Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona, July 1998* (Tucson Drainage Manual). A base rainfall intensity is found in the Tucson Drainage Manual which is used to calculate 100-year discharges. Other storm frequencies are determined using a factor found in Table 4.5. This methodology applies a weighted runoff coefficient by soils and land use categories, and a rainfall intensity taken from Table 4.1 in the City's manual. The following results are documented in the calculations and this summary:

Table 4.3a – Airfield Wash, Airport Wash, and Hughes Wash Watersheds Proposed Conditions Watershed Runoff

Drainage Areas	Outfall Location	Contributing Area	Weighted Runoff C	5-year Discharge	100-year Discharge
		[acres]		[cfs]	[cfs]
1	Valencia Road to Airport Wash	41.8	0.73	80.1	228.8
2	Nogales Hwy to Valencia Wash	160.9	0.85	275.6	787.6
3	Nogales Hwy to El Vado Wash	77.3	0.80	124.3	355.2
4	Nogales Hwy to El Vado Wash	588.8	0.83	589.7	1684.9
5	Hermans Road to Hughes Wash	623.1	0.84	510.9	1459.8
6	Hermans Road to Hughes Wash	64.8	0.86	115.2	329.3

The discharges for watersheds 1, 2, 3 and 6 are the same as existing conditions (see table 3.3). Even though the impervious cover increased in watershed 4, the area decreased resulting in a net decrease in discharge when compared to existing conditions. The area and the impervious cover for watershed 5 both increased resulting in a net increase of about 120 cfs (see tables 4.3b and 4.3c).

The net change in impervious area is calculated and reported as approximately 80 acres. In order to attenuate the increase in storm water runoff (both discharge and volume), storm water storage is needed within the Airfield watershed to attenuate both the discharge and the volume of runoff released from the watershed. Table 4.3b summarizes the change in 5 and 100-year discharges.

Table 4.3b – Pre vs. Post Discharges

	Existing Conditions				Proposed Conditions			
Watershed ID	Contributing Area	Weighted Runoff C	5-year Discharge	100-year Discharge	Contributing Area	Weighted Runoff C	5-year Discharge	100-year Discharge
	[acres]		[cfs]	[cfs]	[acres]		[cfs]	[cfs]
1	41.8	0.73	80.1	228.8	41.8	0.73	80.1	228.8
2	160.9	0.85	275.6	787.6	160.9	0.85	275.6	787.6
3	77.3	0.8	124.3	355.2	77.3	0.80	124.3	355.2
4	618.7	0.78	609.2	1740.7	588.8	0.83	589.7	1684.9
5	593.3	0.77	469.9	1342.6	623.1	0.81	510.9	1459.8
6	64.8	0.85	115.2	329.3	64.8	0.86	115.2	329.3

Table 4.3c – Net Change in Discharges

	Existing Conditions		Proposed Conditions			
Watershed ID	5-year Discharge	100-year Discharge	5-year Discharge	100-year Discharge	5-year change	100-year change
	[cfs]	[cfs]	[cfs]	[cfs]	[cfs]	[cfs]
1	80.1	228.8	80.1	228.8	0.0	0.0
2	275.6	787.6	275.6	787.6	0.0	0.0
3	124.3	355.2	124.3	355.2	0.0	0.0
4	618.7	1740.7	589.7	1684.9	-29.0	-55.8
5	469.9	1342.6	510.9	1459.8	+41.0	+117.2
6	115.2	329.3	115.2	329.3	0.0	0.0

Since the improvements were restricted to watersheds 4 and 5 there is no change in peak discharge for Watersheds 1-3 and 6. It is important to note that the rational methodology in the Tucson Drainage Manual does not account for retention/detention. Retention/Detention is handled external to the runoff calculations.

New detention basins are proposed for watersheds 4 and 5 and are further discussed in Section 5.4. The basins are designed to provide specific attenuation of the runoff from the proposed improvements. The following table includes the proposed conditions discharges at the outfall points of the watersheds after attenuation.

Table 4.3d – Airfield Wash, Airport Wash, and Hughes Wash Watershed Proposed Conditions Watershed Discharge

Drainage Areas	Outfall Location	Contributing Area	Weighted Runoff C	5-year Discharge	100-year Discharge
		[acres]		[cfs]	[cfs]
1	Valencia Road to Airport Wash	41.8	0.73	80.1	228.8
2	Nogales Hwy to Valencia Wash	160.9	0.85	275.6	787.6
3	Nogales Hwy to El Vado Wash	77.3	0.80	124.3	355.2
4	Nogales Hwy to El Vado Wash	588.8	0.83	572	1487
5	Hermans Road to Hughes Wash	623.1	0.81	517	1327
6	Hermans Road to Hughes Wash	64.8	0.86	115.2	329.3

5.0 Hydraulics

5.1 Proposed Drainage Improvements

In many respects the airfield drainage will be similar to existing conditions in that storm water will still collect in the infield areas between the runways and taxiways. However, the collection system to convey the storm water away from the airfield will, by necessity, be revised to meet the needs of the airfield improvements.

There are currently two outfalls for storm water runoff within the airfield. These are:

1. An existing channel located approximately mid-field near Aero Park Boulevard conveys storm water runoff southwesterly and discharges to a retention/detention area on the south side of Hermans Road adjacent to Nogales Highway. This discharges to Hughes Wash (Subbasin 5).
2. An existing channel located near the norther end of the airfield, south of and nearly adjacent to runway 3/21. This channel conveys flow westerly to an existing crossing of Nogales Highway located approximately 1500-feet south of Los Reales Road (Subbasin 4).

The proposed drainage concept (see Exhibit 6 in Appendix C) connects the infield areas between the runways and taxi ways using culverted crossings and discharge to the two existing conveyance channels. New in-line detention facilities will be located within open/available spaces (away from the airfield) to mitigate discharges to acceptable pre-project rates to meet drainage design guidelines.

5.2 Pipe Culverts

In order to accommodate and effectively convey the onsite flows through the infield areas of the airfield, pipe culverts are required to route storm water through the infield areas. The size, length and dimensions of the pipe are determined based upon the conveyance of the accumulated 5-year discharge reaching each culvert. The pipe material is to-be-determined based upon available cover and airport loading over the top of the pipe. It is recommended that Class V rubber gasket reinforced concrete pipe (RGRCP), or a suitable material able to withstand aircraft loading, be used with a minimum of 3-feet cover.

Local onsite hydrology methods are used to determine the discharge based upon an accumulating contributing watershed and a lengthening time of concentration. These local discharges determine the required conveyance capacity for culverts located within subbasins 4 and 5 (see table 5.2).

Table 5.2 – Culvert Summary

Subbasin ID	Culvert ID	5-year Discharge [cfs]	Culvert Diameter [inches]
4	C-1	19.0	30
4	C-2	24.9	30
4	C-3	41.6	36
4	C-4	52.2	42
4	C-5	50	42
4	C-6	20	30
4	C-7	20.7	30
4	C-8	48.7	36
4	C-9	35.5	36
4	C-10	47.3	36
4	C-11	56.4	42
4	C-12	31.7	36
4	C-13	59.7	42
4	C-14	89.4	48
4	C-15	186.7	60

Subbasin ID	Culvert ID	5-year Discharge [cfs]	Culvert Diameter [inches]
5	C-16	108.2	48
5	C-17	130.6	54
5	C-18	21.3	30
5	C-19	41	36
5	C-20	171.1	60
5	C-21	170.7	60
5	C-22	185	60
5	C-23	37.9	36
5	C-24	52.3	42
5	C-25	112	54
5	C-26	20.9	30
5	C-27	279.5	2-54
5	C-28	98.4	48
-	-	-	-
-	-	-	-

Per the drainage design guidelines in Section 4.1, culverts shall have, at a minimum, the ability to convey the 5-year discharge. The 10-year is allowed to temporarily pond as long as storm water does not pond into the runway or taxiways. This is an important distinction and special care should be taken during final design to ensure that the culverts are sized properly to meet both criteria.

Culverts can also become blocked due to debris, so regular maintenance should be performed. A minimum pipe diameter should be considered (recommend at least 24-inches in diameter) so that the culverts are less susceptible to debris blockage. Upsizing the culvert diameter a half size (6-nches) should also be considered if regular maintenance is problematic.

5.3 Channels

The existing channels identified in Section 5.1 have been evaluated for capacity based upon a rough estimate of top and bottom width, sideslope, depth and longitudinal slope. The channel segments may need to be enlarged depending upon existing capacity, proposed conveyance and detention basin location.

Based upon existing conditions, it is estimated that the existing channel network has capacity for between a 5 and 10-year storm event based upon physical location, dimensions depth and longitudinal slope. Storm water runoff in excess of the capacity of the channel would sheet flow generally following the slope of the terrain and between built up areas.

In some areas the channel is relatively clean with a consistent trapezoidal shape. In others areas the channels are roughly graded with varying levels of vegetation. The capacity of the existing channel can be improved through maintenance by removing dense sections of vegetation in multiple reaches. Channel capacity could also be improved by through consistent grading and dimensioning of the channel shape and slope.

5.4 Detention Basins

Pima County's method for sizing detention and retention storage facilities is used to attenuate peak discharges to below that of existing conditions. Calculations are provided in Appendix A and B.

The net change in impervious area is determined through review of changes in the Land Use as described in Section 4.2 which alters the proposed conditions runoff coefficient. Other adjustments include a change in the contributing drainage area within each subbasin based upon modifications to the flow patterns within the runway and taxiway areas.

The hydrologic results were used to identify locations with increase in peak discharges and then 100-year detention facilities were developed to reduce the outflow of watersheds 4 and 5. The project improvements generated 28 new sub-basins within the two watersheds which runoff, collect and convey onsite discharge through a network or channels located within the infield areas. Culverts convey flow between infield areas in a generally westerly direction. Once the flows have progress beyond the proposed airfield improvements the discharge is routed through inline detention basins. The outfall of the basins are designed to attenuate the inflow while discharging a much smaller baseflow which is conveyed to the ultimate outfalls for each watershed. Due to the layout, watershed 4 has three detention basins, while watershed 5 only has one.

Table 5.4 – Detention Basin Summary

Watershed ID	Area	Weighted Runoff Coefficient	100-year 1-hour Rainfall[1]	100-yr **Retention** Volume	100-yr **Detention** Volume	Duration of Ponding	
						Discharge Rate	Ponding Duration
	[acres]		[inches]	[acre-ft]	[acre-ft]	[cfs]	[hours]
4	28.3	0.81	2.45	4.7	4.1	19	2.6
4	50.4	0.86	2.45	8.8	8.2	20.0	5.0
4	122.1	0.83	2.45	20.7	19.1	40.0	5.8
5	249.5	0.80	2.45	40.8	36.7	80.0	5.5

The outflow from each detention basin is counted as baseflow and added directly to the runoff from the remainder of each watershed resulting in the proposed lowered discharges reported in Table 4.3d.

Detention Basin sizes and locations (see Exhibit 7) are proposed which would effectively attenuate the storm water discharge and volume as a result of the Proposed Action.

Detention facilities are sized based upon the available footprint of the basin, the design depth with a positive slope to the outfall which will reasonably allow for detention only, the availability of an adjacent outfall, and a strategic location to design a bleed-off facility which will allow for release of detained flow such that the basin will discharge all runoff within a 24-hour period.

Four detention basins are proposed. Three in Watershed 4, one in Watershed 5 and are identified on Exhibit 7 as Basins 1-4 respectively. These basins are approximately sized to meet the needs of the Proposed Action, however, adjustments to size, shape and location can be made to avoid utilities, planned development, safety areas, etc. However, it is important to maintain the connectivity between the collection and delivery channels /pipes which bring storm water to the basin, and then from the basin downstream conveyance to the outfalls.

6 References

1. *Airport Wide Drainage Basin Study (AWDBS). May 1992.*
2. *Airport Wide Drainage Basin Update. Stantec Consulting, Inc. August, 2004.*
3. Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona. City of Tucson. Revised July 1998.
4. Stormwater Detention/Retention Manual. Pima County Department of Transportation and Flood Control. June 2014.
5. Airport Drainage, Federal Aviation Authority – AC 150/5320-5B. July 1970.

Appendix A – Onsite Calculations

Appendix A.1 – NOAA Atlas 14

NOAA Atlas 14, Volume 1, Version 5
Location name: Tucson, Arizona, USA*
Latitude: 32.1192°, Longitude: -110.9428°
Elevation: 2592.28 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.252 (0.226-0.284)	0.324 (0.291-0.366)	0.428 (0.382-0.481)	0.507 (0.449-0.569)	0.614 (0.537-0.687)	0.695 (0.599-0.779)	0.779 (0.661-0.877)	0.862 (0.720-0.975)	0.974 (0.792-1.11)	1.06 (0.844-1.22)
10-min	0.383 (0.344-0.433)	0.493 (0.443-0.558)	0.651 (0.580-0.732)	0.772 (0.682-0.866)	0.935 (0.816-1.05)	1.06 (0.912-1.19)	1.19 (1.01-1.34)	1.31 (1.10-1.49)	1.48 (1.21-1.69)	1.61 (1.28-1.85)
15-min	0.475 (0.426-0.536)	0.611 (0.549-0.692)	0.808 (0.719-0.908)	0.956 (0.846-1.07)	1.16 (1.01-1.30)	1.31 (1.13-1.47)	1.47 (1.25-1.66)	1.63 (1.36-1.84)	1.84 (1.49-2.10)	2.00 (1.59-2.30)
30-min	0.639 (0.574-0.722)	0.823 (0.739-0.931)	1.09 (0.969-1.22)	1.29 (1.14-1.45)	1.56 (1.36-1.74)	1.77 (1.52-1.98)	1.98 (1.68-2.23)	2.19 (1.83-2.48)	2.48 (2.01-2.82)	2.69 (2.14-3.09)
60-min	0.791 (0.710-0.894)	1.02 (0.914-1.15)	1.35 (1.20-1.51)	1.59 (1.41-1.79)	1.93 (1.69-2.16)	2.19 (1.88-2.45)	2.45 (2.08-2.76)	2.71 (2.26-3.07)	3.06 (2.49-3.50)	3.33 (2.65-3.83)
2-hr	0.917 (0.827-1.03)	1.17 (1.06-1.32)	1.52 (1.37-1.70)	1.79 (1.59-2.00)	2.17 (1.91-2.41)	2.46 (2.14-2.73)	2.76 (2.36-3.07)	3.06 (2.57-3.42)	3.48 (2.84-3.92)	3.79 (3.04-4.32)
3-hr	0.973 (0.877-1.09)	1.23 (1.11-1.38)	1.58 (1.42-1.77)	1.86 (1.66-2.08)	2.25 (1.98-2.50)	2.55 (2.22-2.84)	2.88 (2.45-3.22)	3.21 (2.68-3.61)	3.69 (2.98-4.19)	4.06 (3.20-4.66)
6-hr	1.10 (0.993-1.24)	1.38 (1.24-1.55)	1.73 (1.55-1.94)	2.03 (1.80-2.26)	2.43 (2.13-2.71)	2.75 (2.38-3.07)	3.09 (2.63-3.45)	3.44 (2.88-3.86)	3.93 (3.19-4.45)	4.33 (3.45-4.95)
12-hr	1.24 (1.12-1.38)	1.55 (1.41-1.73)	1.93 (1.73-2.15)	2.23 (2.00-2.48)	2.66 (2.35-2.95)	2.99 (2.61-3.33)	3.33 (2.86-3.72)	3.68 (3.11-4.14)	4.16 (3.43-4.72)	4.54 (3.67-5.20)
24-hr	1.39 (1.28-1.53)	1.74 (1.60-1.91)	2.17 (1.99-2.38)	2.52 (2.30-2.77)	3.00 (2.72-3.30)	3.38 (3.04-3.72)	3.78 (3.36-4.18)	4.18 (3.68-4.65)	4.74 (4.11-5.33)	5.17 (4.43-5.86)
2-day	1.52 (1.40-1.67)	1.90 (1.75-2.09)	2.37 (2.18-2.60)	2.76 (2.52-3.02)	3.28 (2.99-3.60)	3.70 (3.33-4.07)	4.14 (3.69-4.57)	4.58 (4.05-5.10)	5.19 (4.51-5.85)	5.67 (4.85-6.46)
3-day	1.62 (1.49-1.77)	2.02 (1.86-2.22)	2.53 (2.32-2.77)	2.95 (2.69-3.23)	3.54 (3.21-3.88)	4.02 (3.61-4.42)	4.52 (4.02-5.01)	5.05 (4.43-5.63)	5.79 (4.97-6.53)	6.39 (5.39-7.28)
4-day	1.71 (1.58-1.88)	2.14 (1.96-2.35)	2.68 (2.45-2.94)	3.14 (2.86-3.44)	3.80 (3.43-4.17)	4.34 (3.88-4.78)	4.91 (4.34-5.44)	5.52 (4.81-6.16)	6.40 (5.43-7.22)	7.11 (5.92-8.11)
7-day	1.97 (1.81-2.17)	2.46 (2.25-2.71)	3.10 (2.83-3.41)	3.64 (3.31-4.00)	4.42 (3.98-4.87)	5.06 (4.51-5.60)	5.76 (5.07-6.41)	6.50 (5.64-7.30)	7.57 (6.42-8.62)	8.45 (7.04-9.74)
10-day	2.21 (2.02-2.42)	2.75 (2.52-3.02)	3.45 (3.14-3.78)	4.03 (3.67-4.42)	4.86 (4.38-5.34)	5.54 (4.94-6.11)	6.27 (5.52-6.95)	7.04 (6.11-7.88)	8.14 (6.90-9.22)	9.04 (7.52-10.4)
20-day	2.88 (2.65-3.15)	3.60 (3.30-3.94)	4.51 (4.12-4.93)	5.25 (4.78-5.73)	6.27 (5.67-6.85)	7.08 (6.34-7.76)	7.92 (7.02-8.73)	8.81 (7.71-9.78)	10.0 (8.61-11.3)	11.0 (9.29-12.5)
30-day	3.50 (3.24-3.80)	4.36 (4.03-4.74)	5.38 (4.96-5.84)	6.19 (5.69-6.71)	7.27 (6.64-7.90)	8.10 (7.36-8.83)	8.95 (8.07-9.80)	9.81 (8.76-10.8)	11.0 (9.64-12.2)	11.9 (10.3-13.3)
45-day	4.26 (3.95-4.61)	5.30 (4.92-5.74)	6.47 (6.00-7.00)	7.35 (6.81-7.96)	8.49 (7.83-9.20)	9.32 (8.55-10.1)	10.1 (9.25-11.0)	10.9 (9.89-11.9)	11.9 (10.7-13.1)	12.6 (11.2-14.0)
60-day	4.83 (4.47-5.22)	6.01 (5.56-6.51)	7.33 (6.78-7.93)	8.33 (7.69-9.01)	9.62 (8.85-10.4)	10.6 (9.69-11.5)	11.5 (10.5-12.5)	12.4 (11.2-13.6)	13.5 (12.1-15.0)	14.3 (12.7-16.0)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.
Please refer to NOAA Atlas 14 document for more information.

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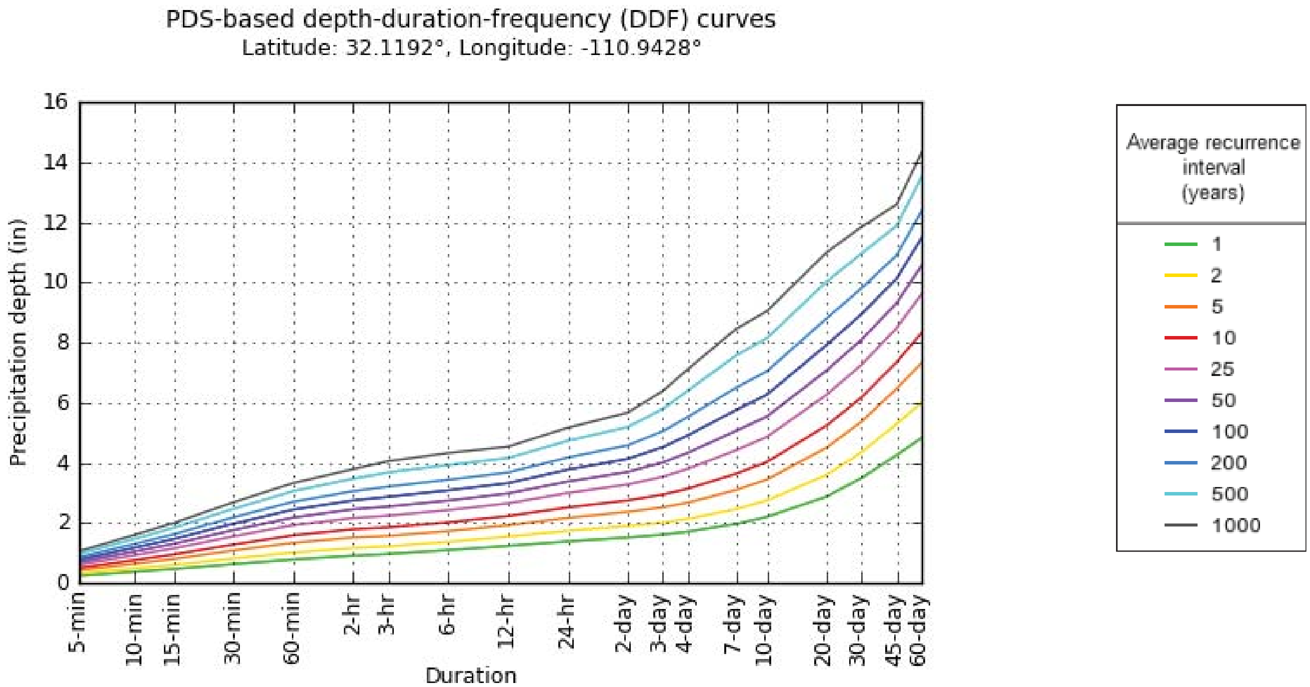
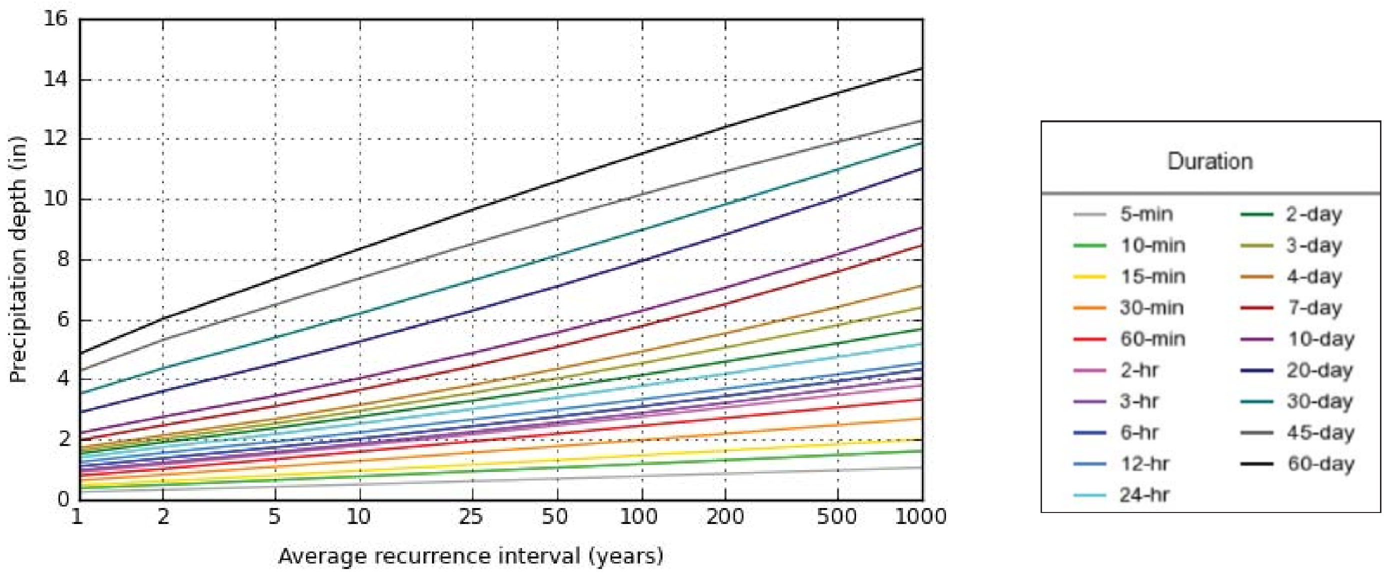
PF graphical





NOAA Atlas 14, Volume 1, Version 5 Created (GMT): Thu Jul 20 16:18:00 2017

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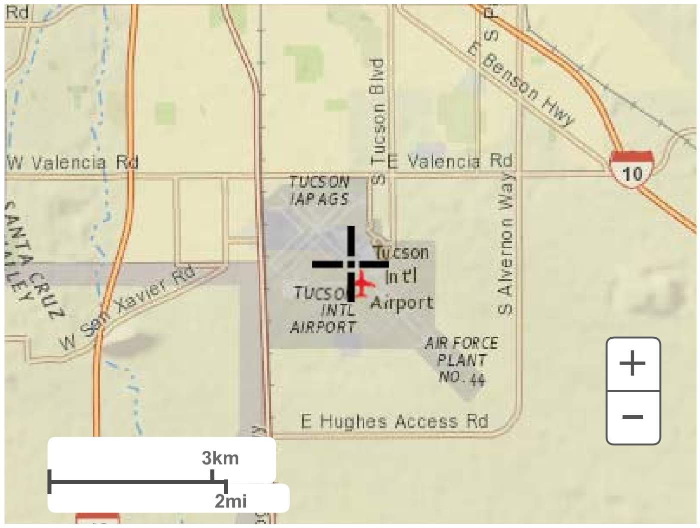
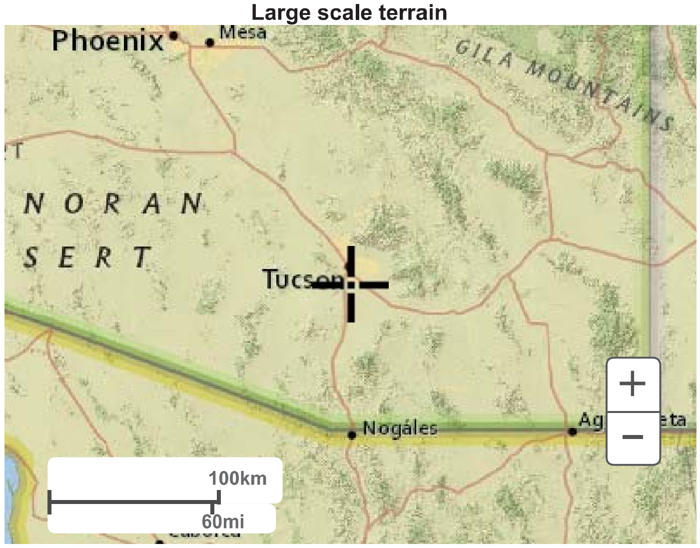
Maps & aerials

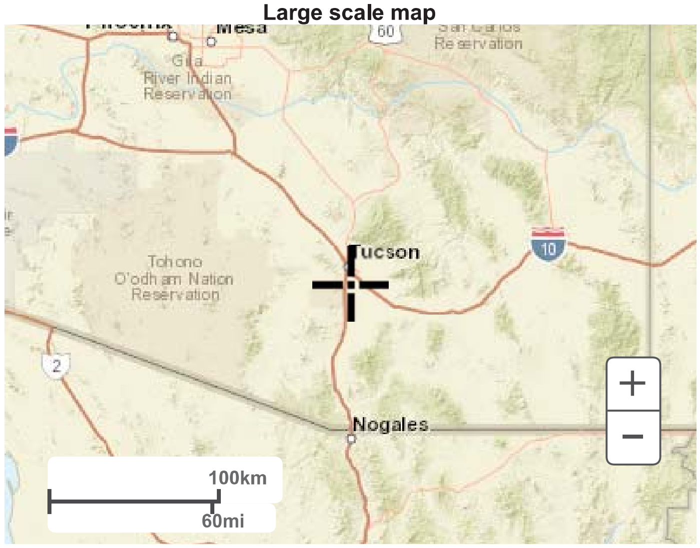
Small scale terrain



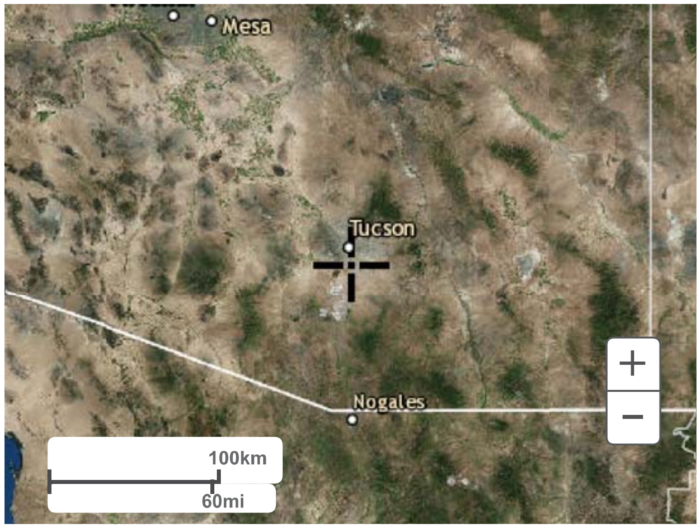
Large scale terrain



Large scale map



Large scale aerial



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NOAA Atlas 14, Volume 1, Version 5
Location name: Tucson, Arizona, USA*
Latitude: 32.1192°, Longitude: -110.9428°
Elevation: 2592.28 ft**
* source: ESRI Maps
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POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**3.02** (2.71-3.41)	**3.89** (3.49-4.39)	**5.14** (4.58-5.77)	**6.08** (5.39-6.83)	**7.37** (6.44-8.24)	**8.34** (7.19-9.35)	**9.35** (7.93-10.5)	**10.3** (8.64-11.7)	**11.7** (9.50-13.3)	**12.7** (10.1-14.6)
10-min	**2.30** (2.06-2.60)	**2.96** (2.66-3.35)	**3.91** (3.48-4.39)	**4.63** (4.09-5.20)	**5.61** (4.90-6.27)	**6.35** (5.47-7.12)	**7.11** (6.04-8.01)	**7.87** (6.57-8.91)	**8.90** (7.23-10.2)	**9.68** (7.70-11.1)
15-min	**1.90** (1.70-2.14)	**2.44** (2.20-2.77)	**3.23** (2.88-3.63)	**3.82** (3.38-4.29)	**4.64** (4.05-5.18)	**5.24** (4.52-5.88)	**5.88** (4.99-6.62)	**6.51** (5.43-7.36)	**7.35** (5.97-8.39)	**8.00** (6.37-9.18)
30-min	**1.28** (1.15-1.44)	**1.65** (1.48-1.86)	**2.18** (1.94-2.45)	**2.58** (2.28-2.89)	**3.12** (2.73-3.49)	**3.53** (3.04-3.96)	**3.96** (3.36-4.46)	**4.38** (3.66-4.96)	**4.95** (4.02-5.65)	**5.39** (4.29-6.18)
60-min	**0.791** (0.710-0.894)	**1.02** (0.914-1.15)	**1.35** (1.20-1.51)	**1.59** (1.41-1.79)	**1.93** (1.69-2.16)	**2.19** (1.88-2.45)	**2.45** (2.08-2.76)	**2.71** (2.26-3.07)	**3.06** (2.49-3.50)	**3.33** (2.65-3.83)
2-hr	**0.458** (0.414-0.515)	**0.586** (0.528-0.658)	**0.761** (0.682-0.852)	**0.897** (0.796-1.00)	**1.08** (0.954-1.21)	**1.23** (1.07-1.37)	**1.38** (1.18-1.54)	**1.53** (1.29-1.71)	**1.74** (1.42-1.96)	**1.90** (1.52-2.16)
3-hr	**0.324** (0.292-0.363)	**0.409** (0.369-0.460)	**0.524** (0.472-0.589)	**0.618** (0.551-0.692)	**0.748** (0.659-0.834)	**0.849** (0.738-0.946)	**0.958** (0.816-1.07)	**1.07** (0.893-1.20)	**1.23** (0.992-1.39)	**1.35** (1.07-1.55)
6-hr	**0.184** (0.166-0.206)	**0.230** (0.207-0.258)	**0.289** (0.259-0.324)	**0.338** (0.301-0.378)	**0.406** (0.356-0.453)	**0.459** (0.398-0.512)	**0.516** (0.439-0.576)	**0.575** (0.481-0.644)	**0.656** (0.533-0.742)	**0.723** (0.575-0.826)
12-hr	**0.103** (0.093-0.115)	**0.129** (0.117-0.144)	**0.160** (0.144-0.178)	**0.185** (0.166-0.206)	**0.221** (0.195-0.245)	**0.248** (0.217-0.276)	**0.276** (0.238-0.309)	**0.306** (0.258-0.344)	**0.345** (0.285-0.392)	**0.377** (0.305-0.432)
24-hr	**0.058** (0.053-0.064)	**0.073** (0.067-0.080)	**0.091** (0.083-0.099)	**0.105** (0.096-0.115)	**0.125** (0.113-0.138)	**0.141** (0.127-0.155)	**0.157** (0.140-0.174)	**0.174** (0.153-0.194)	**0.197** (0.171-0.222)	**0.215** (0.184-0.244)
2-day	**0.032** (0.029-0.035)	**0.040** (0.036-0.043)	**0.049** (0.045-0.054)	**0.057** (0.053-0.063)	**0.068** (0.062-0.075)	**0.077** (0.069-0.085)	**0.086** (0.077-0.095)	**0.095** (0.084-0.106)	**0.108** (0.094-0.122)	**0.118** (0.101-0.135)
3-day	**0.022** (0.021-0.025)	**0.028** (0.026-0.031)	**0.035** (0.032-0.038)	**0.041** (0.037-0.045)	**0.049** (0.045-0.054)	**0.056** (0.050-0.061)	**0.063** (0.056-0.070)	**0.070** (0.061-0.078)	**0.080** (0.069-0.091)	**0.089** (0.075-0.101)
4-day	**0.018** (0.016-0.020)	**0.022** (0.020-0.024)	**0.028** (0.026-0.031)	**0.033** (0.030-0.036)	**0.040** (0.036-0.043)	**0.045** (0.040-0.050)	**0.051** (0.045-0.057)	**0.058** (0.050-0.064)	**0.067** (0.057-0.075)	**0.074** (0.062-0.084)
7-day	**0.012** (0.011-0.013)	**0.015** (0.013-0.016)	**0.018** (0.017-0.020)	**0.022** (0.020-0.024)	**0.026** (0.024-0.029)	**0.030** (0.027-0.033)	**0.034** (0.030-0.038)	**0.039** (0.034-0.043)	**0.045** (0.038-0.051)	**0.050** (0.042-0.058)
10-day	**0.009** (0.008-0.010)	**0.011** (0.010-0.013)	**0.014** (0.013-0.016)	**0.017** (0.015-0.018)	**0.020** (0.018-0.022)	**0.023** (0.021-0.025)	**0.026** (0.023-0.029)	**0.029** (0.025-0.033)	**0.034** (0.029-0.038)	**0.038** (0.031-0.043)
20-day	**0.006** (0.006-0.007)	**0.008** (0.007-0.008)	**0.009** (0.009-0.010)	**0.011** (0.010-0.012)	**0.013** (0.012-0.014)	**0.015** (0.013-0.016)	**0.017** (0.015-0.018)	**0.018** (0.016-0.020)	**0.021** (0.018-0.024)	**0.023** (0.019-0.026)
30-day	**0.005** (0.004-0.005)	**0.006** (0.006-0.007)	**0.007** (0.007-0.008)	**0.009** (0.008-0.009)	**0.010** (0.009-0.011)	**0.011** (0.010-0.012)	**0.012** (0.011-0.014)	**0.014** (0.012-0.015)	**0.015** (0.013-0.017)	**0.016** (0.014-0.019)
45-day	**0.004** (0.004-0.004)	**0.005** (0.005-0.005)	**0.006** (0.006-0.006)	**0.007** (0.006-0.007)	**0.008** (0.007-0.009)	**0.009** (0.008-0.009)	**0.009** (0.009-0.010)	**0.010** (0.009-0.011)	**0.011** (0.010-0.012)	**0.012** (0.010-0.013)
60-day	**0.003** (0.003-0.004)	**0.004** (0.004-0.005)	**0.005** (0.005-0.006)	**0.006** (0.005-0.006)	**0.007** (0.006-0.007)	**0.007** (0.007-0.008)	**0.008** (0.007-0.009)	**0.009** (0.008-0.009)	**0.009** (0.008-0.010)	**0.010** (0.009-0.011)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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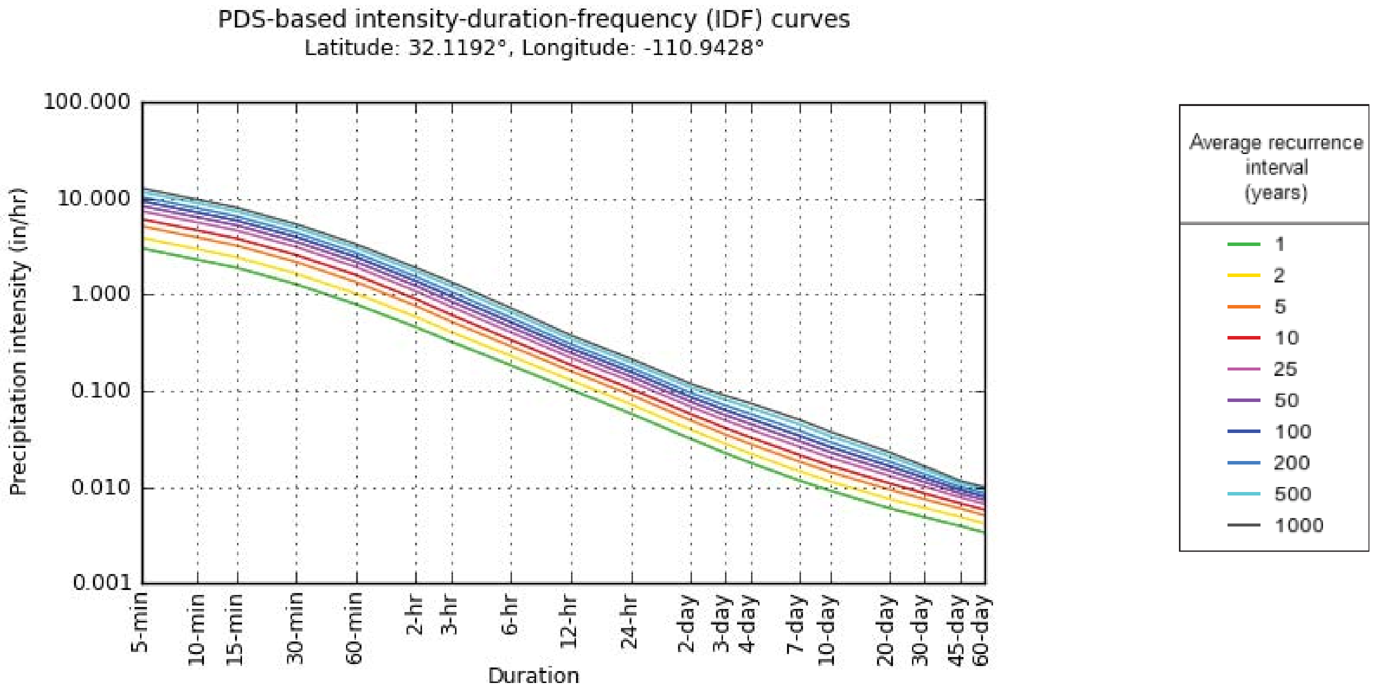
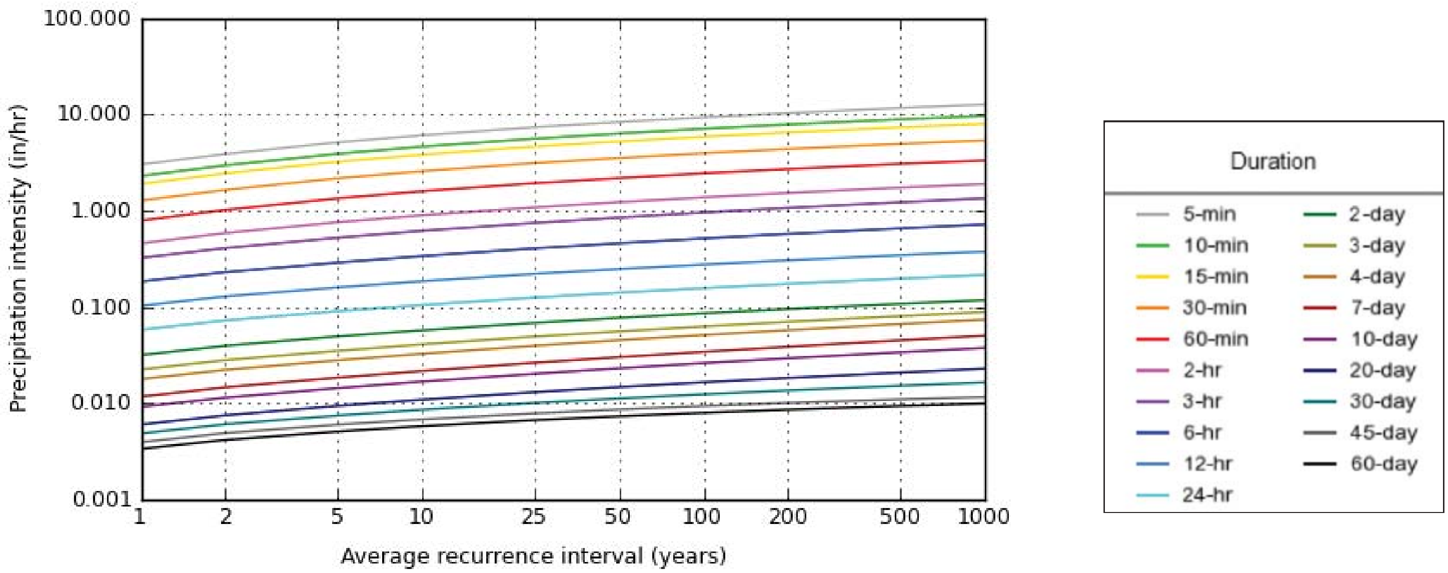
PF graphical





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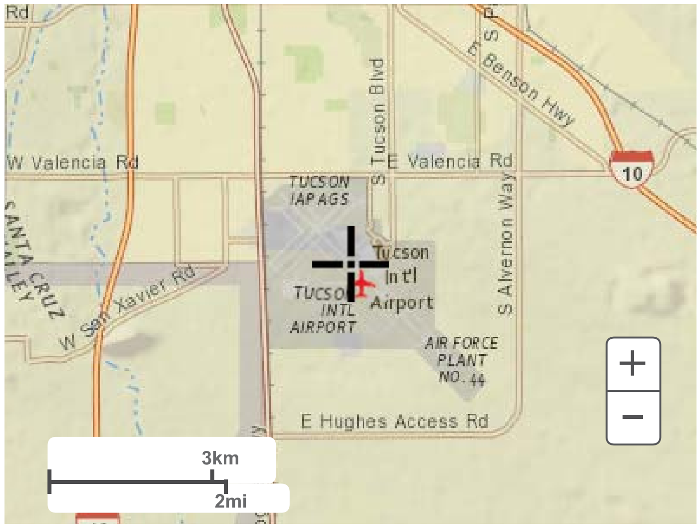
Maps & aerials

Small scale terrain



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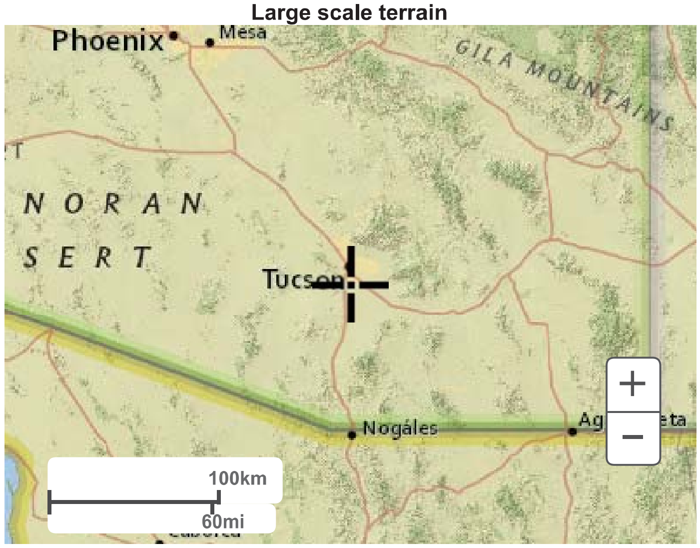

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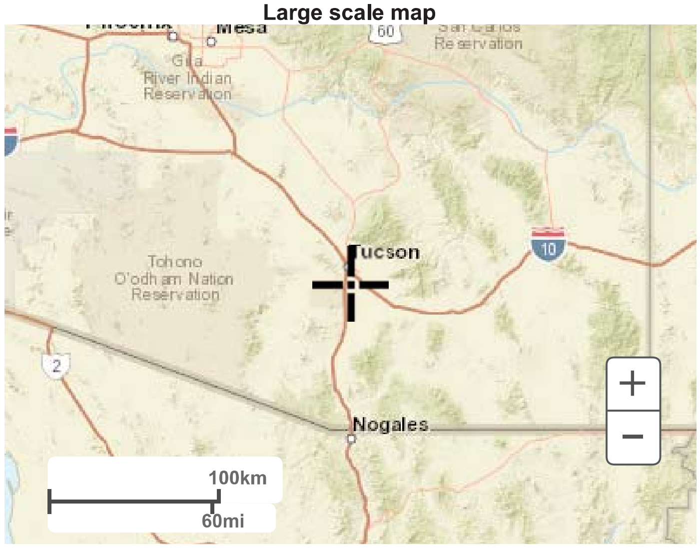
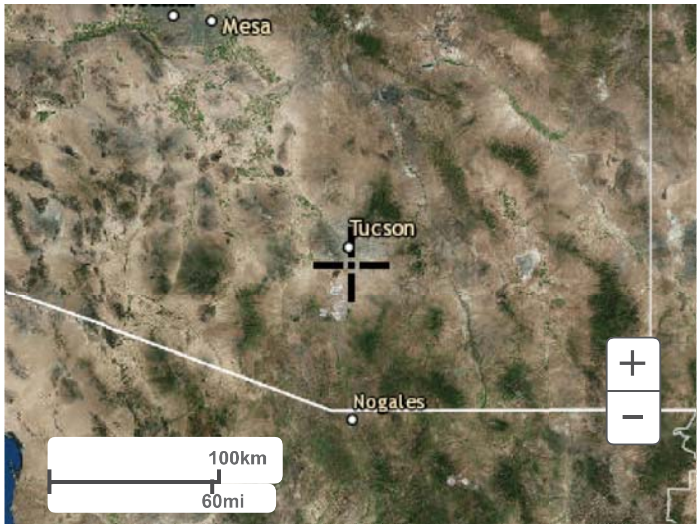


Large scale aerial



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Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

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Appendix A.2 – Calculations

Tucson International Airport

Culvert Summary Table

Pipe ID	Contributing Subbasins	Coeff.	Slope	Depth	Diameter	5-Year Discharge	Velocity	Froude No.	Flow Type
			[ft/ft]	[ft]	[inches]	[cfs]	[ft/s]		
C-1	DA - 8	0.013	0.0030	1.76	30	19.0	5.1	0.71	SubCritical
C-2	DA - 8,5	0.013	0.0050	1.78	30	24.9	6.6	0.91	SubCritical
C-3	DA - 8,5,3	0.013	0.0050	2.19	36	41.6	7.5	0.92	SubCritical
C-4	DA - 8,5,3,2	0.013	0.0040	2.41	42	52.2	7.4	0.88	SubCritical
C-5	DA - 1	0.013	0.0039	2.36	42	50.0	7.3	0.88	SubCritical
C-6	DA - 6	0.013	0.0050	1.53	30	20.0	6.4	0.99	SubCritical
C-7	DA - 7	0.013	0.0050	1.56	30	20.7	6.4	0.98	SubCritical
C-8	DA - 6,7,4	0.013	0.0050	2.56	36	48.7	7.6	0.77	SubCritical
C-9	DA - 11	0.013	0.0050	1.94	36	35.5	7.3	0.99	SubCritical
C-10	DA - 11,10	0.013	0.0050	2.47	36	47.3	7.6	0.81	SubCritical
C-11	DA - 11,10,9	0.013	0.0050	2.35	42	56.4	8.2	1.00	SubCritical
C-12	DA - 15	0.013	0.0040	1.94	36	31.7	6.6	0.89	SubCritical
C-13	DA - 15,14	0.013	0.0050	2.45	42	59.7	8.3	0.97	SubCritical
C-14	DA - 15,14,13	0.013	0.0050	2.91	48	89.4	9.1	0.97	SubCritical
C-15	DA - 15,14,13,11,10,9,12	0.013	0.0050	4.15	60	186.3	10.7	0.87	SubCritical
C-28	DA-27 OFF	0.013	0.0050	3.17	48	98.4	9.2	0.89	SubCritical
C-16	DA - 27,27-OFF	0.013	0.0050	3.60	48	108.2	9.1	0.72	SubCritical
C-17	DA - 24,27,27-OFF	0.013	0.0039	4.03	54	130.6	8.7	0.66	SubCritical
C-18	DA - 26	0.013	0.0050	1.59	30	21.3	6.5	0.97	SubCritical
C-19	DA - 26,25	0.013	0.0044	2.28	36	41.0	7.1	0.83	SubCritical
C-20	DA - 23,24,25,26,27,27-OFF	0.013	0.0038	4.50	60	171.1	9.2	0.65	SubCritical
C-21	DA - 21,23,24,25,26,27,27-OFF	0.013	0.0050	3.80	60	170.7	10.7	0.97	SubCritical
C-22	DA - 20,21,23,24,25,26,27,27-OFF	0.013	0.0050	4.12	60	185.0	10.7	0.88	SubCritical
C-23	DA - 22	0.013	0.0050	2.04	36	37.9	7.4	0.97	SubCritical
C-24	DA - 19,22	0.013	0.0040	2.42	42	52.3	7.4	0.88	SubCritical
C-25	DA - 18,19,22	0.013	0.0040	3.34	54	112.0	8.9	0.87	SubCritical
C-26	DA - 16	0.013	0.0050	1.57	30	20.9	6.4	0.98	SubCritical
C-27	DA - 16-27 & 27-OFF	0.013	0.0050	3.72	2-54	279.5	10.0	0.87	SubCritical

Project: Tucson International Airport
Subject: Summary
Author: CGC
Location: Tucson, Arizona
Date: 7/27/2018

Reference: Standards Manual for Drainage Design and Floodplain Management In Tucson, Arizona; July 1998 (eff).

DA Group - Discharge Pt.	Drainage Area ID	Area (acres)	Outlet Slope (ft/ft)	Discharge - 5 yr (cfs)	Pipe Size Required (in)
1	8	7.1	0.0098	19.0	24
	8,5	10.5	0.0062	24.9	30
	8,5,3	20.3	0.0058	41.6	36
	8,5,3,2*	27.5	0.0060	52.2	42
	1*	28.3	0.0039	50.0	42
2	6	8.1	0.0060	20.0	30
	7	8.2	0.0061	20.7	30
	6,7,4*	22.9	0.0058	48.7	36
3	11	16.5	0.0072	35.5	36
	11,10	23.4	0.0066	47.3	36
	11,10,9	30.3	0.0061	56.4	42
	15	14.0	0.0073	31.7	36
	15,14	32.5	0.0064	59.7	42
	15,14,13	50.9	0.0068	89.4	48
	15,14,13,11,10,9,12*	122.1	0.0068	186.3	60
4	27, 27-OFF	77.5	0.0118	104.1	48
	24,27,27-OFF	91.5	0.0058	130.6	54
	26	8.4	0.0123	21.3	30
	25,26	20.7	0.0085	41.0	36
	23,24,25,26,27,27 OFF	122.0	0.0061	171.1	60
	21,23,24,25,26,27,27 OFF	134.5	0.0064	170.7	60
	20,21,23,24,25,26,27,27 OFF	149.9	0.0065	185.0	60
	22	17.8	0.0069	37.9	36
	19,22	32.6	0.0069	52.3	42
	18,19,22	67.4	0.0061	112.0	54
	16	9.0	0.0049	20.9	30
	16-27 & 27-OFF	249.5	0.0064	279.5	2-54

Project: Tucson International Airport
Subject: Onsite Calculations
Author: LAV
Location: Tucson, Arizona
Date: 7/27/2018
Reference: Standards Manual for Drainage Design and Floodplain Management In Tucson, Arizona; Revised July 1998

															Table 4.1		Table 4.2		Table 4.3	Table 4.4				Table 4.5
Drainage Area ID	Area (acres)	*L_c (ft)	*ΔH (ft)	L_{ca} (feet)	*ΔL_1 (feet)	*ΔH_1 (feet)	*ΔL_2 (feet)	*ΔH_2 (feet)	*ΔL_3 (feet)	*ΔH_3 (feet)	*ΔL_4 (feet)	*ΔH_4 (feet)	G	S_c (ft/ft)	*$P_{1.100}$	*Watershed Type	*n_{b100}	*Soil Type	Runoff Coefficient	F_{acw}	T_{c100} (minutes)	i_{100} (in/hr)	Q_{p100} (cfs)	Q_{p5} (cfs)
DA-01	28.3	2064	8	1032	516	2	516	2	516	2	516	2	33152.749	0.0039	3.0	Comm./Ind.	0.038	C	0.81	0.96	16.9	6.5	143.0	50.0
DA-02	7.2	606	4	303	151.5	1	151.5	1	151.5	1	151.5	1	7458.9714	0.0066	3.0	Comm./Ind.	0.038	C	0.84	0.94	5.9	9.3	53.0	18.6
DA-03	9.9	847	6	424	211.75	1.5	211.75	1.5	211.75	1.5	211.75	1.5	10063.51	0.0071	3.0	Comm./Ind.	0.038	C,D	0.83	0.96	7.0	8.9	70.1	24.5
DA-04	6.6	737	4	369	184.25	1	184.25	1	184.25	1	184.25	1	10003.944	0.0054	3.0	Comm./Ind.	0.038	C	0.85	0.94	7.1	8.9	47.0	16.5
DA-05	3.3	403	2	202	100.75	0.5	100.75	0.5	100.75	0.5	100.75	0.5	5720.613	0.0050	3.0	Comm./Ind.	0.038	D	0.92	0.92	5.1	9.6	27.0	9.5
DA-06	8.1	829	5	415	207.25	1.25	207.25	1.25	207.25	1.25	207.25	1.25	10674.482	0.0060	3.0	Comm./Ind.	0.038	C	0.85	0.94	7.3	8.8	57.2	20.0
DA-07	8.2	822	5	411	205.5	1.25	205.5	1.25	205.5	1.25	205.5	1.25	10539.566	0.0061	3.0	Comm./Ind.	0.038	C,D	0.87	0.94	7.2	8.8	59.1	20.7
DA-08	7.1	818	8	409	204.5	2	204.5	2	204.5	2	204.5	2	8271.5131	0.0098	3.0	Comm./Ind.	0.038	D	0.87	0.95	6.0	9.2	54.3	19.0
DA-09	6.9	716	6	358	179	1.5	179	1.5	179	1.5	179	1.5	7821.5695	0.0084	3.0	Comm./Ind.	0.038	C	0.86	0.94	5.9	9.3	51.7	18.1
DA-10	6.9	699	5	350	174.75	1.25	174.75	1.25	174.75	1.25	174.75	1.25	8264.7698	0.0072	3.0	Comm./Ind.	0.038	D	0.89	0.94	6.1	9.2	53.2	18.6
DA-11	16.5	1946	14	973	486.5	3.5	486.5	3.5	486.5	3.5	486.5	3.5	22943.002	0.0072	3.0	Comm./Ind.	0.038	D	0.85	0.96	11.7	7.6	101.5	35.5
DA-12	40.9	2004	14	1002	501	3.5	501	3.5	501	3.5	501	3.5	23976.322	0.0070	3.0	Comm./Ind.	0.038	C	0.78	0.97	12.6	7.4	228.1	79.8
DA-13	18.4	1912	13	956	478	3.25	478	3.25	478	3.25	478	3.25	23187.833	0.0068	3.0	Comm./Ind.	0.038	C	0.83	0.95	12.0	7.5	108.5	38.0
DA-14	18.4	1911	14	956	477.75	3.5	477.75	3.5	477.75	3.5	477.75	3.5	22326.827	0.0073	3.0	Comm./Ind.	0.038	D	0.86	0.95	11.4	7.6	115.6	40.4
DA-15	14.0	1636	12	818	409	3	409	3	409	3	409	3	19102.241	0.0073	3.0	Comm./Ind.	0.038	D	0.85	0.96	10.3	7.9	90.7	31.7
DA-16	9.0	1225	6	613	306.25	1.5	306.25	1.5	306.25	1.5	306.25	1.5	17503.645	0.0049	3.0	Comm./Ind.	0.038	D	0.88	0.94	10.0	8.0	59.6	20.9
DA-17	23.2	2416	16	1208	604	4	604	4	604	4	604	4	29688.305	0.0066	3.0	Comm./Ind.	0.038	C	0.82	0.95	14.4	7.0	126.6	44.3
DA-18	17.0	2064	10	1032	516	2.5	516	2.5	516	2.5	516	2.5	29652.72	0.0048	3.0	Comm./Ind.	0.038	D	0.86	0.95	14.7	6.9	96.4	33.7
DA-19	14.8	1726	12	863	431.5	3	431.5	3	431.5	3	431.5	3	20700.01	0.0070	3.0	Comm./Ind.	0.038	D	0.86	0.96	10.9	7.8	93.8	32.8
DA-20	15.4	1619	14	810	404.75	3.5	404.75	3.5	404.75	3.5	404.75	3.5	17410.3	0.0086	3.0	Comm./Ind.	0.038	C	0.83	0.95	9.6	8.1	98.7	34.6
DA-21	12.5	1369	8	685	342.25	2	342.25	2	342.25	2	342.25	2	17908.54	0.0058	3.0	Comm./Ind.	0.038	C	0.84	0.95	10.2	7.9	78.6	27.5
DA-22	17.8	2032	14	1016	508	3.5	508	3.5	508	3.5	508	3.5	24480.571	0.0069	3.0	Comm./Ind.	0.038	D	0.86	0.95	12.3	7.4	108.4	37.9
DA-23	9.8	1315	5	658	328.75	1.25	328.75	1.25	328.75	1.25	328.75	1.25	21325.716	0.0038	3.0	Comm./Ind.	0.038	C	0.84	0.95	12.1	7.5	58.7	20.5
DA-24	14.0	1543	6	772	385.75	1.5	385.75	1.5	385.75	1.5	385.75	1.5	24744.191	0.0039	3.0	Comm./Ind.	0.038	C,D	0.85	0.95	13.3	7.2	82.2	28.8
DA-25	12.3	1358	6	679	339.5	1.5	339.5	1.5	339.5	1.5	339.5	1.5	20430.266	0.0044	3.0	Comm./Ind.	0.038	C,D	0.85	0.94	11.5	7.6	75.0	26.3
DA-26	8.4	1629	20	815	407.25	5	407.25	5	407.25	5	407.25	5	14701.669	0.0123	3.0	Comm./Ind.	0.038	D	0.92	0.92	8.0	8.6	60.9	21.3
DA-27	6.9	1626	20	813	406.5	5	406.5	5	406.5	5	406.5	5	14661.075	0.0123	3.0	Comm./Ind.	0.038	C	0.89	0.93	8.1	8.5	48.9	17.1
DA-27 OFF	70.6	4300	40	2150	1075	10	1075	10	1075	10	1075	10	44583.349	0.0093	3.0	Comm./Ind.	0.038	B,C,D	0.68	1.00	20.7	5.9	281.0	98.4
WS-1 (PROP)	41.8	2236	16	1118	559	4	559	4	559	4	559	4	26,433	0.0072	3.0	Comm./Ind.	0.038	C,D	0.78	0.98	13.5	7.2	228.8	80.1
WS-2 (PROP)	160.9	4027	28	2014	1006.75	7	1006.75	7	1006.75	7	1006.75	7	48,294	0.0070	3.0	Comm./Ind.	0.038	C,D	0.87	0.94	20.1	6.0	787.6	275.6
WS-3 (PROP)	77.3	3962	24	1981	990.5	6	990.5	6	990.5	6	990.5	6	50,906	0.0061	3.0	Comm./Ind.	0.038	B,C	0.84	0.95	21.7	5.8	355.2	124.3
WS-4 (PROP)	588.8	9456	52	4728	2364	13	2364	13	2364	13	2364	13	127,514	0.0055	3.0	Comm./Ind.	0.038	B,C,D	0.83	0.96	46.8	3.6	1684.9	589.7
WS-5 (PROP)	623.1	15701	110	7850.5	3925.25	27.5	3925.25	27.5	3925.25	27.5	3925.25	27.5	187,583	0.0070	3.0	Comm./Ind.	0.038	B,C,D	0.84	0.96	62.6	2.9	1459.8	510.9
WS-6 (PROP)	64.8	3528	22	1764	882	5.5	882	5.5	882	5.5	882	5.5	44,677	0.0062	3.0	Comm./Ind.	0.038	C,D	0.88	0.94	19.1	6.1	329.3	115.2
WS-4P partial	388.7	6000	32	3000	1500	8	1500	8	1500	8	1500	8	82,158	0.0053	3.0	Comm./Ind.	0.038	C,D	0.83	0.95	32.5	4.6	1408.2	492.9
WS-5P partial	391.9	9000	60	4500	2250	15	2250	15	2250	15	2250	15	110,227	0.0067	3.0	Comm./Ind.	0.038	B,C,D	0.84	0.95	40.2	4.0	1247.3	436.6
WS-1 (EXIST)	41.8	2236	16	1118	559	4	559	4	559	4	559	4	26,433	0.0072	3.0	Comm./Ind.	0.038	C,D	0.78	0.98	13.5	7.2	228.8	80.1
WS-2 (EXIST)	160.9	4027	28	2014	1006.75	7	1006.75	7	1006.75	7	1006.75	7	48,294	0.0070	3.0	Comm./Ind.	0.038	C,D	0.87	0.94	20.1	6.0	787.6	275.6
WS-3 (EXIST)	77.3	3962	24	1981	990.5	6	990.5	6	990.5	6	990.5	6	50,906	0.0061	3.0	Comm./Ind.	0.038	B,C	0.84	0.95	21.7	5.8	355.2	124.3
WS-4 (EXIST)	618.7	9456	52	4728	2364	13	2364	13	2364	13	2364	13	127,514	0.0055	3.0	Comm./Ind.	0.038	B,C,D	0.82	0.96	47.2	3.6	1740.7	609.2
WS-5 (EXIST)	593.3	15701	110	7850.5	3925.25	27.5	3925.25	27.5	3925.25	27.5	3925.25	27.5	187,583	0.0070	3.0	Comm./Ind.	0.038	B,C,D	0.82	0.96	63.5	2.9	1342.6	469.9
WS-6 (EXIST)	64.8	3528	22	1764	882	5.5	882	5.5	882	5.5	882	5.5	44,677	0.0062	3.0	Comm./Ind.	0.038	C,D	0.88	0.94	19.1	6.1	329.3	115.2

Notes:
1) * = User Input Required

Project: Tucson International Airport
Subject: Ratio Factors from Table 4.5
Author: CGC
.ocation: Tucson, Arizona
Date: 11/21/2017
Reference: Standards Manual for Drainage Design and Floodplain Management In Tucson, Arizona; July 1998 (eff).

Drainage Area ID	*Factor from Table **4.5**
DA-01	0.35
DA-02	0.35
DA-03	0.35
DA-04	0.35
DA-05	0.35
DA-06	0.35
DA-07	0.35
DA-08	0.35
DA-09	0.35
DA-10	0.35
DA-11	0.35
DA-12	0.35
DA-13	0.35
DA-14	0.35
DA-15	0.35
DA-16	0.35
DA-17	0.35
DA-18	0.35
DA-19	0.35
DA-20	0.35
DA-21	0.35
DA-22	0.35
DA-23	0.35
DA-24	0.35
DA-25	0.35
DA-26	0.35
DA-27	0.35
DA-28	0.35
DA-29	0.35
DA-30	0.35
DA-31	0.35
DA-32	0.35
DA-33	0.35
DA-34	0.35
DA-35	0.35
DA-36	0.35
DA-37	0.35
(PROP) AF-DA-1	0.35
(PROP) AF-DA-2	0.35
(PROP) AF-DA-3	0.35
(PROP) AF-DA-4	0.35
(PROP) AF-DA-5	0.35
(PROP) AF-DA-6	0.35
(EX) AF-DA-1	0.35
(EX) AF-DA-2	0.35
(EX) AF-DA-3	0.35
(EX) AF-DA-4	0.35
(EX) AF-DA-5	0.35
(EX) AF-DA-6	0.35

Project: Tucson International Airport
Subject: Pipe Sizing
Author: LAV
Location: Tucson, Arizona
Date: 7/27/2018
Reference: Standards Manual for Drainage Design and Floodplain Management In Tucson, Arizona; Revised July 1998

															Table 4.1		Table 4.2		Table 4.3	Table 4.4				Table 4.5		
Watershed	Drainage Area ID	Area (acres)	*L_c (ft)	*ΔH (ft)	L_{ca} (feet)	*ΔL_1 (feet)	*ΔH_1 (feet)	*ΔL_2 (feet)	*ΔH_2 (feet)	*ΔL_3 (feet)	*ΔH_3 (feet)	*ΔL_4 (feet)	*ΔH_4 (feet)	G	S_c (ft/ft)	*$P_{1,100}$	*Watershed Type	*n_{b100}	*Soil Type	Area Weighted C_{w100}	Area Weighted F_{ac}	T_{c100} (minutes)	i_{100} (in/hr)	Q_{p100} (cfs)	Q_{p5} (cfs)	Pipe Size Needed (Inches)[2]
	8	7.1	818	8	409	204.5	2	204.5	2	204.5	2	204.5	2	8271.5	0.0098	3.0	Comm./Ind.	0.038	D	0.87	0.95	6.0	9.2	54.3	19.0	24
	8,5	10.5	1286	8	643	321.5	2	321.5	2	321.5	2	321.5	2	16304.8	0.0062	3.0	Comm./Ind.	0.038	D	0.89	0.94	9.3	8.2	71.3	24.9	30
4	8,5,3	20.3	2073	12	1036.5	518.25	3	518.25	3	518.25	3	518.25	3	27246.3	0.0058	3.0	Comm./Ind.	0.038	C,D	0.86	0.95	13.5	7.2	118.9	41.6	36
	8,5,3,2*	27.5	2654	16	1327	663.5	4	663.5	4	663.5	4	663.5	4	34181.5	0.0060	3.0	Comm./Ind.	0.038	C,D	0.86	0.95	15.9	6.7	149.3	52.2	42
	1*	28.3	2064	8	1032	516	2	516	2	516	2	516	2	33152.7	0.0039	3.0	Comm./Ind.	0.038	C,D	0.81	0.96	16.9	6.5	143.0	50.0	42
	6	8.1	829	5	415	207.25	1.25	207.25	1.25	207.25	1.25	207.25	1.25	10674.5	0.0060	3.0	Comm./Ind.	0.038	C	0.85	0.94	7.3	8.8	57.2	20.0	30
4	7	8.2	822	5	411	205.5	1.25	205.5	1.25	205.5	1.25	205.5	1.25	10539.6	0.0061	3.0	Comm./Ind.	0.038	C,D	0.87	0.94	7.2	8.8	59.1	20.7	30
	6,7,4*	22.9	1728	10	864	432	2.5	432	2.5	432	2.5	432	2.5	22715.1	0.0058	3.0	Comm./Ind.	0.038	C,D	0.86	0.94	11.9	7.5	139.2	48.7	36
	11	16.5	1946	14	973	486.5	3.5	486.5	3.5	486.5	3.5	486.5	3.5	22943.0	0.0072	3.0	Comm./Ind.	0.038	D	0.85	0.96	11.7	7.6	101.5	35.5	36
	11,10	23.4	2416	16	1208	604	4	604	4	604	4	604	4	29688.3	0.0066	3.0	Comm./Ind.	0.038	D	0.86	0.95	14.1	7.0	135.1	47.3	36
	11,10,9	30.3	2933	18	1466.5	733.25	4.5	733.25	4.5	733.25	4.5	733.25	4.5	37439.7	0.0061	3.0	Comm./Ind.	0.038	C,D	0.86	0.95	16.9	6.5	161.1	56.4	42
4	15	14.0	1636	12	818	409	3	409	3	409	3	409	3	19102.2	0.0073	3.0	Comm./Ind.	0.038	D	0.85	0.96	10.3	7.9	90.7	31.7	36
	15,14	32.5	3124	20	1562	781	5	781	5	781	5	781	5	39043.8	0.0064	3.0	Comm./Ind.	0.038	D	0.86	0.95	17.4	6.4	170.7	59.7	42
	15,14,13	50.9	3525	24	1762.5	881.25	6	881.25	6	881.25	6	881.25	6	42720.2	0.0068	3.0	Comm./Ind.	0.038	C,D	0.85	0.95	18.6	6.2	255.4	89.4	48
	15,14,13,11,10,9,12*	122.1	4731	32	2365.5	1182.75	8	1182.75	8	1182.75	8	1182.75	8	57524.7	0.0068	3.0	Comm./Ind.	0.038	C,D	0.83	0.96	23.7	5.5	532.3	186.3	60
	27-OFF	70.6	4300	40	2150	1075	10	1075	10	1075	10	1075	10	44583.3	0.0093	3.0	Comm./Ind.	0.038	B,C,D	0.68	1.00	20.7	5.9	281.0	98.4	48
	27, 27-OFF	77.5	5926	70	2963	1481.5	17.5	1481.5	17.5	1481.5	17.5	1481.5	17.5	54524.7	0.0118	3.0	Comm./Ind.	0.038	B,C,D	0.69	0.99	23.2	5.6	297.3	104.1	48
	24,27,27-OFF	91.5	3472	20	1736	868	5	868	5	868	5	868	5	45746.2	0.0058	3.0	Comm./Ind.	0.038	B,C,D	0.72	0.99	21.8	5.7	373.1	130.6	54
	26	8.4	1629	20	815	407.25	5	407.25	5	407.25	5	407.25	5	14701.7	0.0123	3.0	Comm./Ind.	0.038	D	0.92	0.92	8.0	8.6	60.9	21.3	30
	25,26	20.7	3054	26	1527	763.5	6.5	763.5	6.5	763.5	6.5	763.5	6.5	33099.2	0.0085	3.0	Comm./Ind.	0.038	C,D	0.88	0.93	14.7	6.9	117.2	41.0	36
	23,24,25,26,27,27 OFF	122.0	4252	26	2126	1063	6.5	1063	6.5	1063	6.5	1063	6.5	54375.5	0.0061	3.0	Comm./Ind.	0.038	B,C,D	0.76	0.97	24.1	5.4	488.8	171.1	60
5	21,23,24,25,26,27,27 OFF	134.5	5596	36	2798	1399	9	1399	9	1399	9	1399	9	69769.5	0.0064	3.0	Comm./Ind.	0.038	B,C,D	0.76	0.97	29.1	4.9	487.8	170.7	60
	20,21,23,24,25,26,27,27 OFF	149.9	6117	40	3058.5	1529.25	10	1529.25	10	1529.25	10	1529.25	10	75644.6	0.0065	3.0	Comm./Ind.	0.038	B,C,D	0.77	0.97	30.8	4.7	528.6	185.0	60
	22	17.8	2032	14	1016	508	3.5	508	3.5	508	3.5	508	3.5	24480.6	0.0069	3.0	Comm./Ind.	0.038	D	0.86	0.95	12.3	7.4	108.4	37.9	36
	19,22	32.6	3758	26	2895	939.5	6.5	939.5	6.5	939.5	6.5	939.5	6.5	45180.2	0.0069	3.0	Comm./Ind.	0.038	D	0.86	0.95	22.8	5.6	149.5	52.3	42
	18,19,22	67.4	3951	24	1975.5	987.75	6	987.75	6	987.75	6	987.75	6	50693.8	0.0061	3.0	Comm./Ind.	0.038	D	0.86	0.95	21.4	5.8	319.9	112.0	54
	16	9.0	1225	6	613	306.25	1.5	306.25	1.5	306.25	1.5	306.25	1.5	17503.6	0.0049	3.0	Comm./Ind.	0.038	D	0.88	0.94	10.0	8.0	59.6	20.9	30
	16-27 & 27-OFF	249.5	7855	50	3927.5	1963.75	12.5	1963.75	12.5	1963.75	12.5	1963.75	12.5	98454.2	0.0064	3.0	Comm./Ind.	0.038	B,C,D	0.80	0.96	37.7	4.2	798.5	279.5	2-54

Notes:
1) an * indicates a discharge point
2) although more slope may be available, the pipes are designed with a maximum slope of 0.5% to promote subcritical flow regime

Appendix A.3 – Airfield C-Values Calculations

Project: Tucson International Airport
Subject: Weighted C-Values
Author: LAV
Location: Tucson, Arizona
Date: 7/27/2018
Reference: Standards Manual for Drainage Design and Floodplain Management In Tucson, Arizona; Revised July 1998
Table 4.3 with rainfall depth P_1 = 3.0 inches

Soil Type	Runoff Coefficient
B	0.6
C	0.7
D	0.77
Impervious	0.96

Area ID	Total Area [acres]	Area by Soil Type				Percentage of Soil Type				Weighted Runoff Coefficient	F_{acw}
		B (Ac)	C (Ac)	D (Ac)	I (Ac)	B (%)	C (%)	D (%)	I (%)		
WS-1	50.14	0.00	14.15	27.00	8.99	0.0	28.2	53.8	17.9	0.78	0.98
WS-2	160.987	0.00	37.30	24.73	98.96	0.0	23.2	15.4	61.5	0.87	0.94
WS-3	75.8	2.49	32.15	0.00	41.17	3.3	42.4	0.0	54.3	0.84	0.95
WS-4	575.416	1.29	210.87	98.13	265.12	0.2	36.6	17.1	46.1	0.83	0.95
WS-5	649.89	25.23	129.16	201.24	294.26	3.9	19.9	31.0	45.3	0.84	0.95
WS-6	63.265	0.00	1.04	26.04	36.19	0.0	1.6	41.2	57.2	0.88	0.94
DA-1	27.594	0.00	16.05	0.00	11.54	0.0	58.2	0.0	41.8	0.81	0.96
DA-2	7.18	0.00	3.23	0.00	3.95	0.0	45.0	0.0	55.0	0.84	0.94
DA-3	9.86	0.00	2.79	2.72	4.35	0.0	28.3	27.6	44.1	0.83	0.96
DA-4	6.64	0.00	2.90	0.00	3.74	0.0	43.7	0.0	56.3	0.85	0.94
DA-5	3.44	0.00	0.00	0.80	2.64	0.0	0.0	23.3	76.7	0.92	0.92
DA-6	8.1	0.00	3.37	0.00	4.73	0.0	41.6	0.0	58.4	0.85	0.94
DA-7	8.16	0.00	1.43	1.84	4.89	0.0	17.5	22.5	59.9	0.87	0.94
DA-8	7.1	0.00	0.00	3.23	3.87	0.0	0.0	45.5	54.5	0.87	0.95
DA-9	6.89	0.00	2.63	0.00	4.26	0.0	38.2	0.0	61.8	0.86	0.94
DA-10	6.93	0.00	0.00	2.60	4.33	0.0	0.0	37.5	62.5	0.89	0.94
DA-11	16.472	0.00	0.00	9.44	7.03	0.0	0.0	57.3	42.7	0.85	0.96
DA-12	40.88	0.00	27.78	0.00	13.10	0.0	68.0	0.0	32.0	0.78	0.97
DA-13	18.41	0.00	9.38	0.00	9.03	0.0	51.0	0.0	49.0	0.83	0.95
DA-14	18.43	0.00	0.00	9.41	9.02	0.0	0.0	51.1	48.9	0.86	0.95
DA-15	14.11	0.00	0.00	7.88	6.23	0.0	0.0	55.8	44.2	0.85	0.96
DA-16	8.98	0.00	0.00	3.68	5.30	0.0	0.0	41.0	59.0	0.88	0.94
DA-17	23.15	0.00	12.11	0.00	11.04	0.0	52.3	0.0	47.7	0.82	0.95
DA-18	16.97	0.00	0.00	8.84	8.13	0.0	0.0	52.1	47.9	0.86	0.95
DA-19	14.79	0.00	0.00	8.15	6.64	0.0	0.0	55.1	44.9	0.86	0.96
DA-20	15.43	0.00	7.63	0.00	7.80	0.0	49.4	0.0	50.6	0.83	0.95
DA-21	12.44	0.00	5.78	0.00	6.66	0.0	46.5	0.0	53.5	0.84	0.95
DA-22	17.84	0.00	0.00	9.72	8.12	0.0	0.0	54.5	45.5	0.86	0.95
DA-23	9.83	0.00	4.43	0.00	5.40	0.0	45.1	0.0	54.9	0.84	0.95
DA-24	14	0.00	1.54	5.66	6.80	0.0	11.0	40.4	48.6	0.85	0.95
DA-25	11.83	0.00	4.65	0.52	6.66	0.0	39.3	4.4	56.3	0.85	0.94
DA-26	8.39	0.00	0.00	1.89	6.50	0.0	0.0	22.5	77.5	0.92	0.92
DA-27	6.94	0.00	1.90	0.00	5.04	0.0	27.4	0.0	72.6	0.89	0.93
DA-27 OFF	70.6	35.10	10.10	25.40	0.00	49.7	14.3	36.0	0.0	0.68	1.00

Aggregate Subbasin

Areas	Weighted $C_{w\text{-}area}$	Weighted $F_{w\text{-}acw}$
8	0.87	0.95
8,5	0.89	0.94
8,5,3	0.86	0.95
8,5,3,2	0.86	0.95
1*	0.81	0.96
6	0.85	0.94
7	0.87	0.94
6,7,4*	0.86	0.94
11	0.85	0.96
11,10	0.86	0.95
11,10,9	0.86	0.95
15	0.85	0.96
15,14	0.86	0.95
15,14,13	0.85	0.95
15,14,13,11,10,9,12*	0.83	0.96
27-OFF	0.68	1.00
27,27-OFF	0.69	0.99
24,27,27-OFF	0.72	0.99
26	0.92	0.92
26,25	0.88	0.93
23,24,25,26,27,27-OFF	0.76	0.97
21,23,24,25,26,27,27-OFF	0.76	0.97
20,21,23,24,25,26,27,27-OFF	0.77	0.97
22	0.86	0.95
19,22	0.86	0.95
18,19,22	0.86	0.95
16	0.88	0.94
16 through 27, 27-OFF	0.80	0.96

Appendix B – Basin Sizing

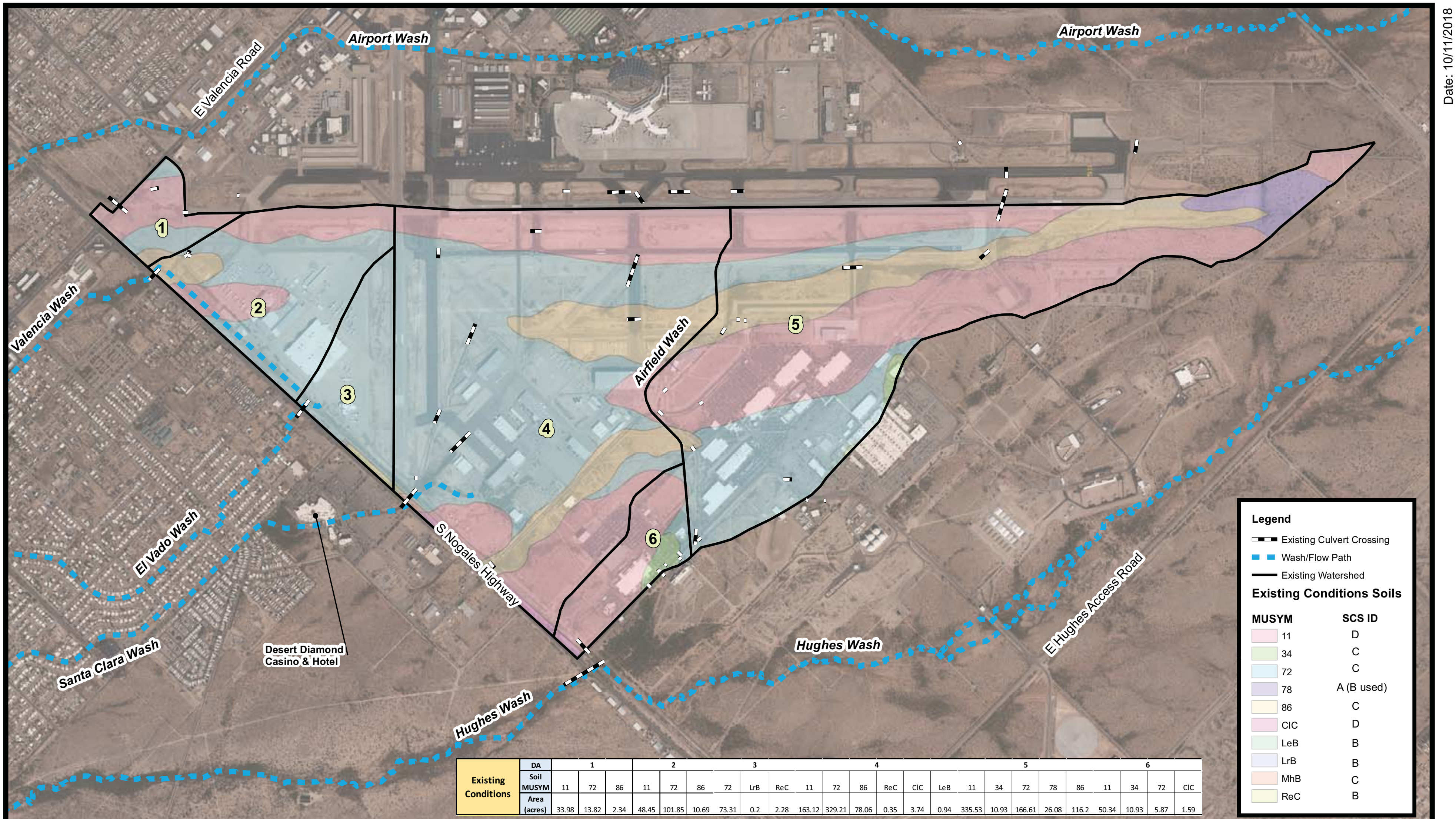
Project: Tucson International Airport
Subject: Detention Basin Sizing
Author: LAV
Location: Tucson, Arizona
Date: 7/27/2018
Reference: Design Standards for Stormwater Detention and Retention; Pima County Regional Flood Control District; June 2014

Watershed ID	Drainage Areas ID	Contributing Area	Weighted Runoff Coefficient	100-year 1-hour Rainfall[1]	100-yr **Retention** Volume	100-yr Inflow Discharge Q_i	Outflow Discharge Q_o	Ratio 1-[Qi/Qo]	100-yr **Detention** Volume	Duration of Ponding		
										Ponded Volume	Discharge Rate	Ponding Duration
		[acres]		[inches]	[acre-ft]	[cfs]	[cfs]		[acre-ft]	[cu-ft]	[cfs]	[hours]
4	DA-1	28.3	0.81	2.45	4.7	143.0	19.0	0.87	4.1	176,779	19	2.6
4	DA's 2-8	50.4	0.86	2.45	8.8	288.5	20.0	0.93	8.2	358,757	20.0	5.0
4	DA-9 to 15	122.1	0.83	2.45	20.7	532.3	40.0	0.92	19.1	833,566	40.0	5.8
5	DA's 16-27 & 27-OFF	249.5	0.80	2.45	40.8	798.5	80.0	0.90	36.7	1,597,295	80.0	5.5

Notes: 1) 100-year 1-hour NOAA 14 Rainfall used

Appendix C – Exhibits

Appendix C.1 – Exhibit 1 – Soils Map – Existing Conditions



Existing Conditions	DA	1			2			3			4						5					6			
	Soil MUSYM	11	72	86	11	72	86	72	LrB	ReC	11	72	86	ReC	ClC	LeB	11	34	72	78	86	11	34	72	ClC
	Area (acres)	33.98	13.82	2.34	48.45	101.85	10.69	73.31	0.2	2.28	163.12	329.21	78.06	0.35	3.74	0.94	335.53	10.93	166.61	26.08	116.2	50.34	10.93	5.87	1.59

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Soils Map - Existing Conditions

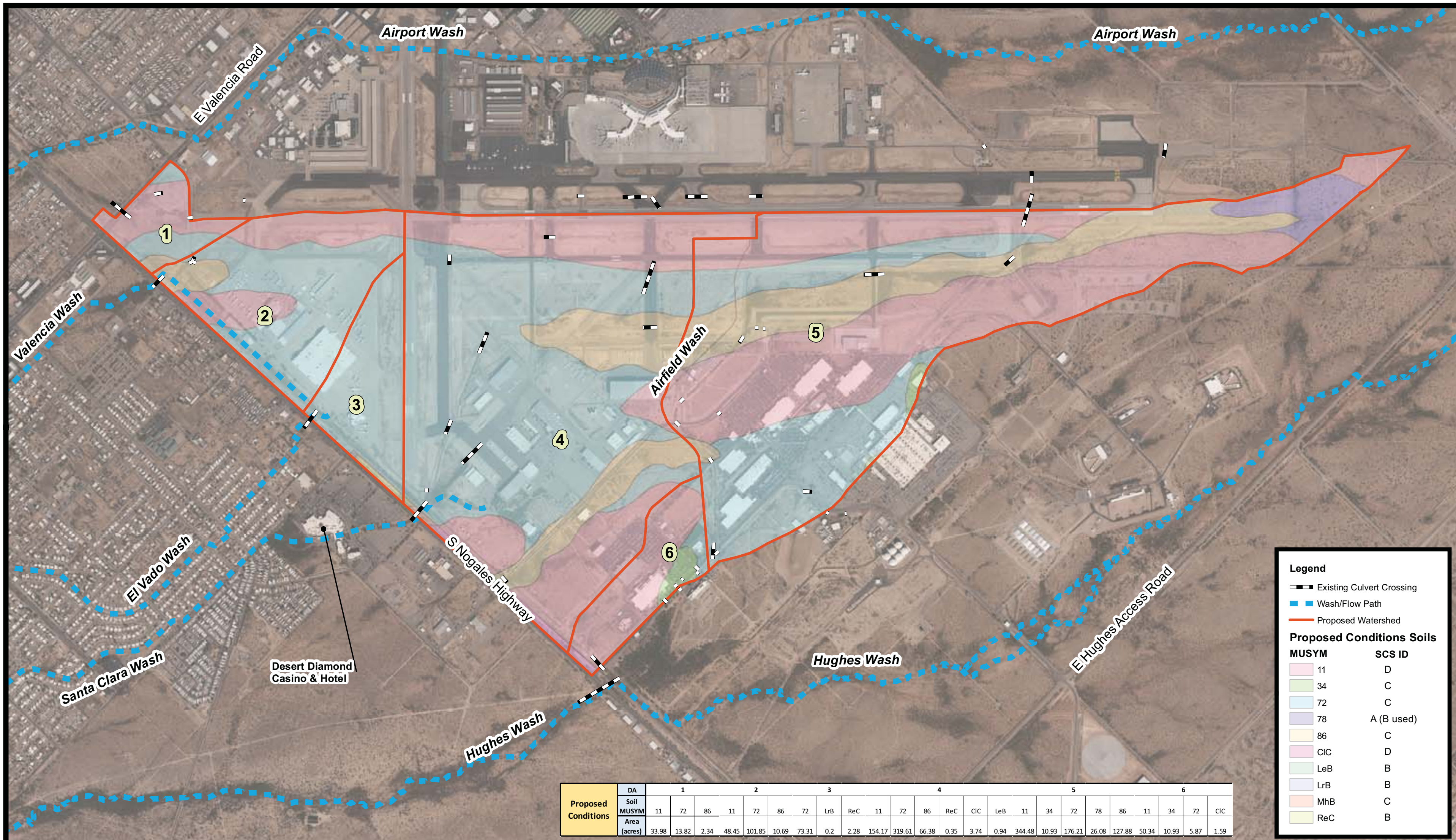
Exhibit
1

0 750 1,500 3,000 Feet

Drawn by: R.Halligan

Appendix C.2 – Soils Map – Proposed Conditions

Date: 10/11/2018



Proposed Conditions	DA	1			2			3			4						5					6			
	Soil MUSYM	11	72	86	11	72	86	72	LrB	ReC	11	72	86	ReC	ClC	LeB	11	34	72	78	86	11	34	72	ClC
	Area (acres)	33.98	13.82	2.34	48.45	101.85	10.69	73.31	0.2	2.28	154.17	319.61	66.38	0.35	3.74	0.94	344.48	10.93	176.21	26.08	127.88	50.34	10.93	5.87	1.59

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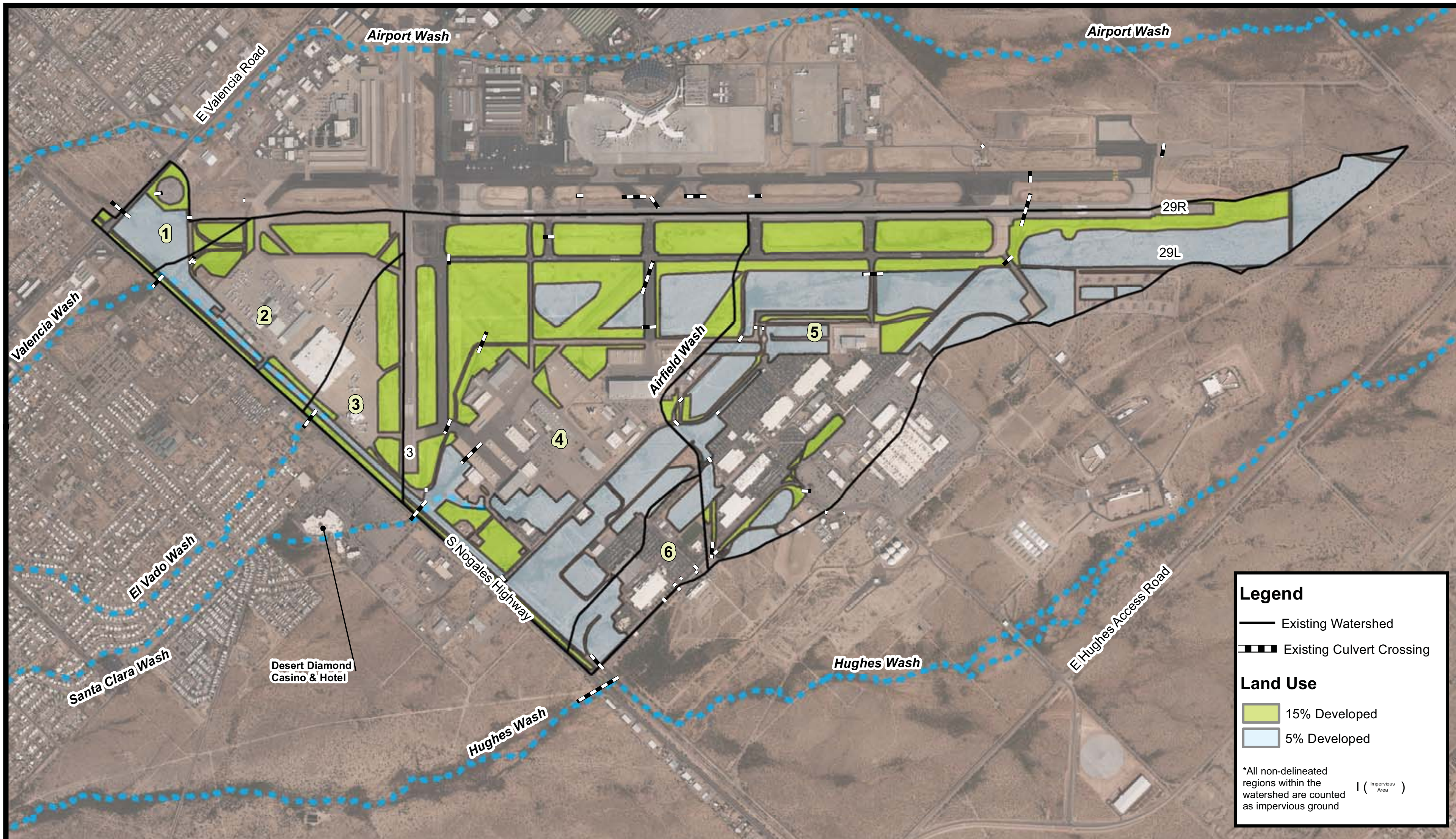
Soils Map - Proposed Conditions

Exhibit
2

Drawn by: R.Halligan

Appendix C.3 – Land Use – Existing Conditions



Date: 10/11/2018

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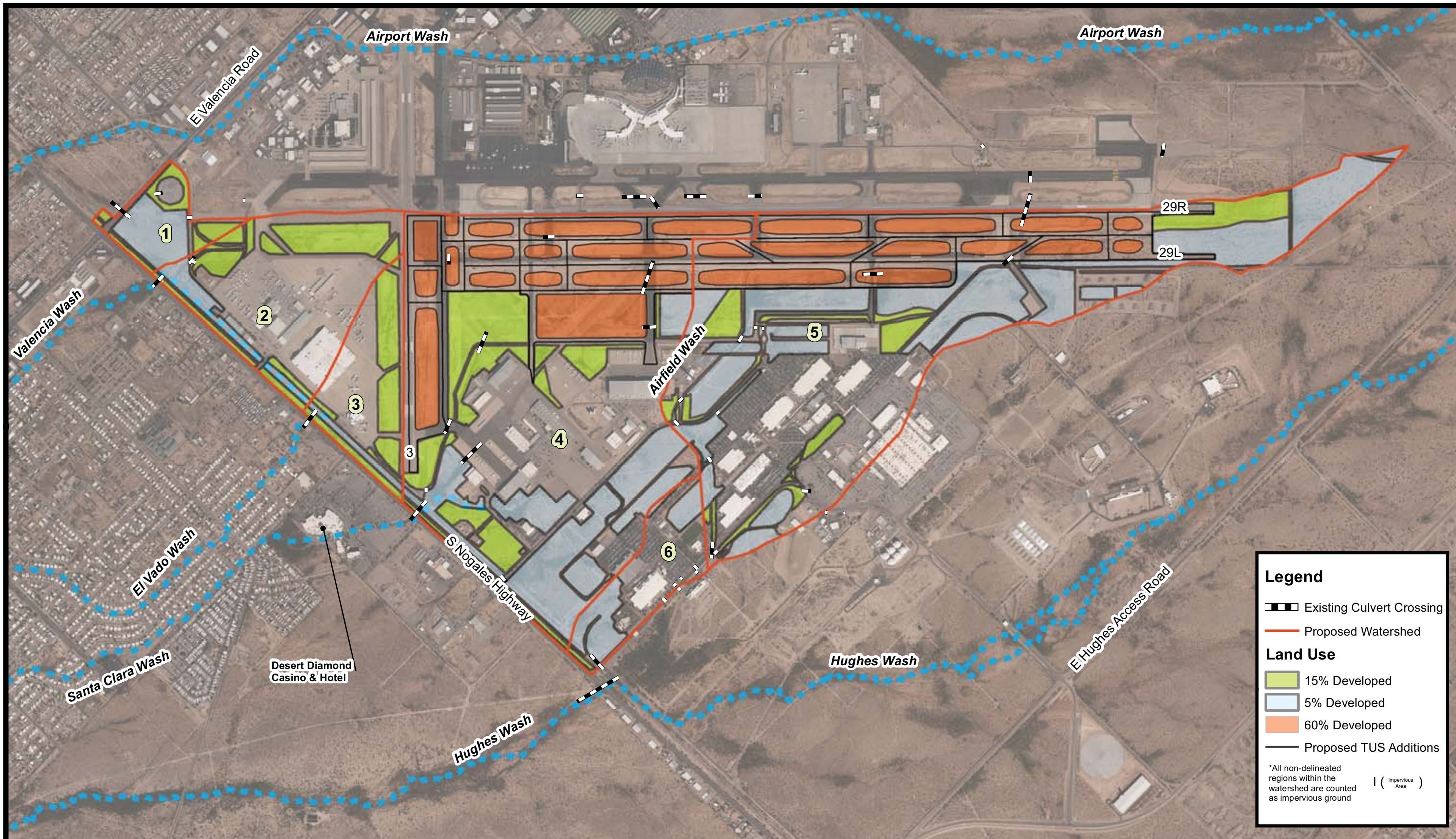
Tucson International Airport
Land Use - Existing Conditions

Exhibit 3

0 750 1,500 3,000 Feet

Drawn by: R.Halligan

Appendix C.4 – Land Use – Proposed Conditions



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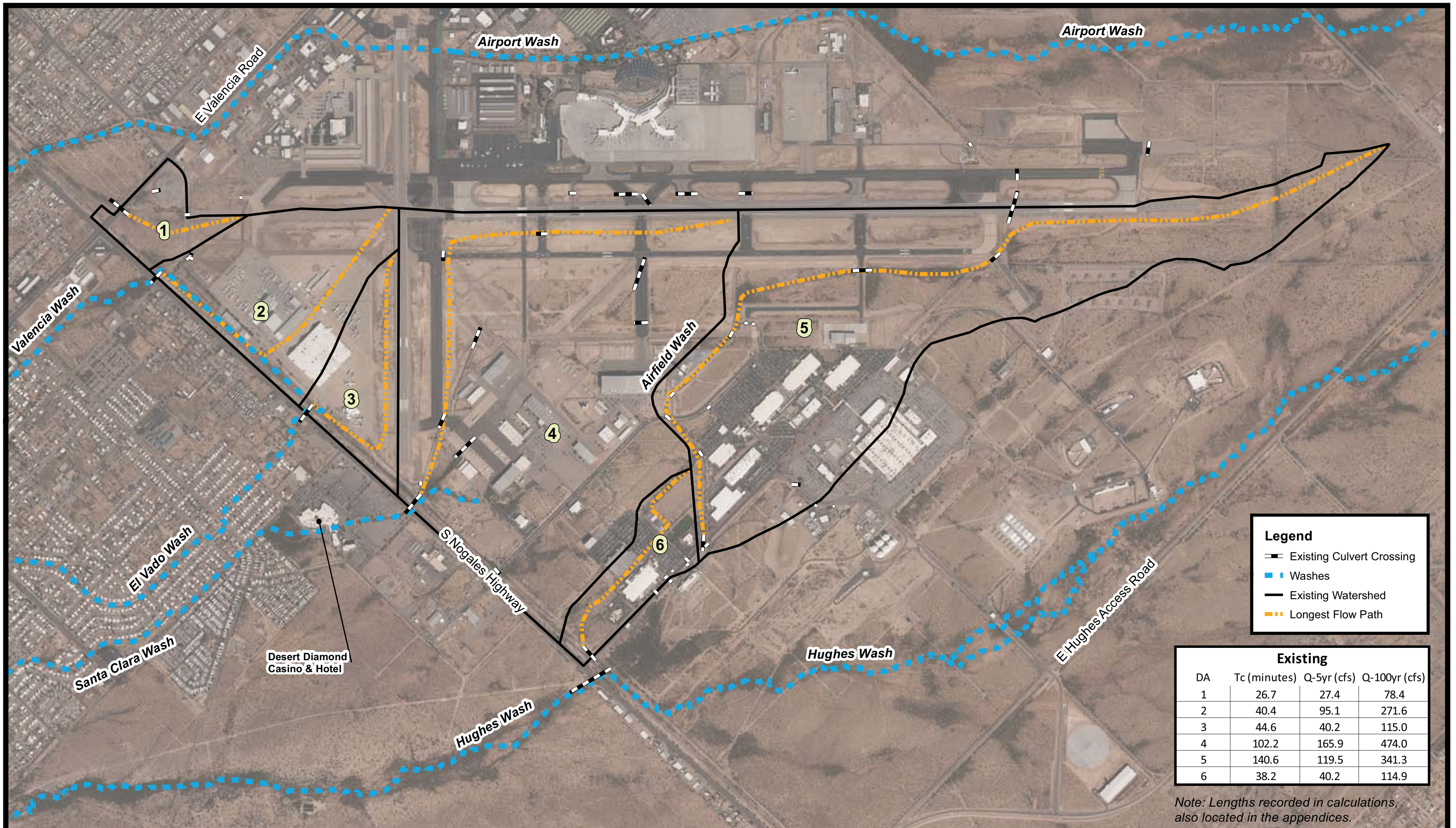
Land Use - Proposed Conditions

Exhibit 4

N
0 750 1,500 3,000 Feet
Drawn by: R.Halligan

Appendix C.5 – Longest Flow Path - Existing



Existing

DA	Tc (minutes)	Q-5yr (cfs)	Q-100yr (cfs)
1	26.7	27.4	78.4
2	40.4	95.1	271.6
3	44.6	40.2	115.0
4	102.2	165.9	474.0
5	140.6	119.5	341.3
6	38.2	40.2	114.9

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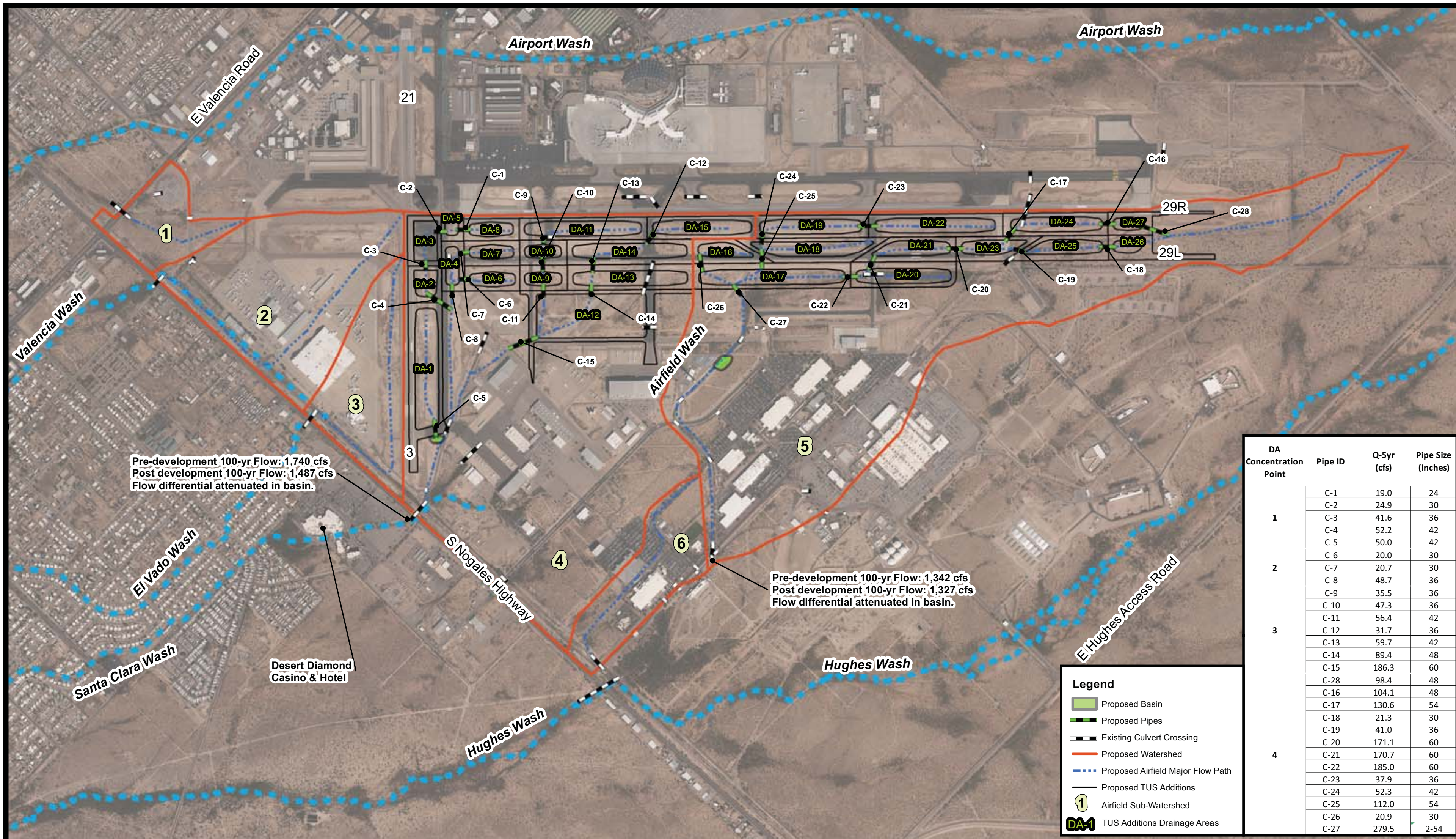
Longest Flow Path - Existing

Exhibit
5

Appendix C.6 – Proposed Conditions - Workmap



DA Concentration Point	Pipe ID	Q-5yr (cfs)	Pipe Size (Inches)
1	C-1	19.0	24
	C-2	24.9	30
	C-3	41.6	36
	C-4	52.2	42
	C-5	50.0	42
2	C-6	20.0	30
	C-7	20.7	30
	C-8	48.7	36
3	C-9	35.5	36
	C-10	47.3	36
	C-11	56.4	42
	C-12	31.7	36
	C-13	59.7	42
	C-14	89.4	48
	C-15	186.3	60
4	C-28	98.4	48
	C-16	104.1	48
	C-17	130.6	54
	C-18	21.3	30
	C-19	41.0	36
	C-20	171.1	60
	C-21	170.7	60
	C-22	185.0	60
	C-23	37.9	36
	C-24	52.3	42
	C-25	112.0	54
	C-26	20.9	30
	C-27	279.5	2-54

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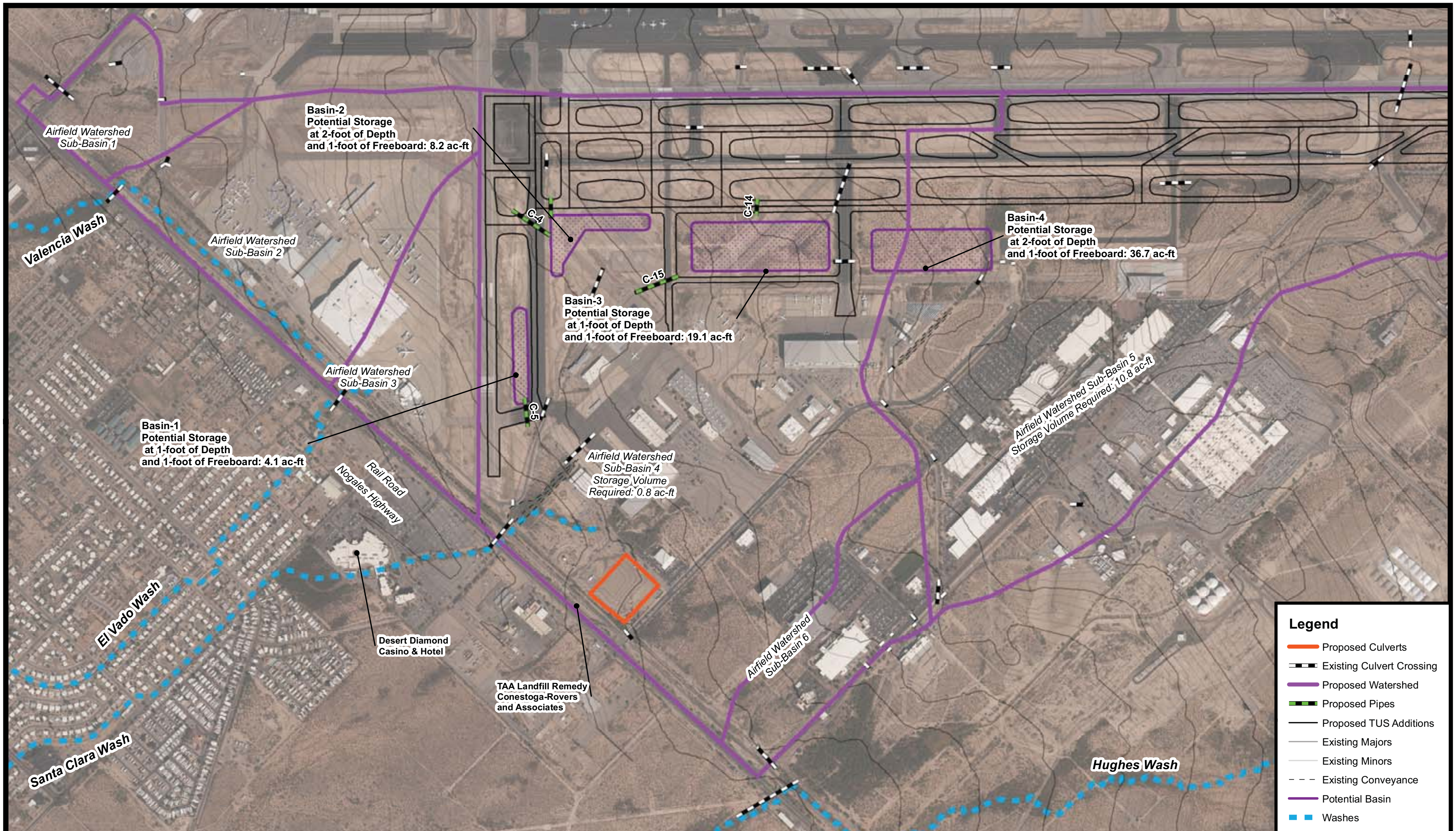
Proposed Conditions - Workmap

Exhibit 6

Appendix C.7 – Basin Exhibit

Date: 10/11/2018



TYLININTERNATIONAL engineers | planners | scientists	**Potential Basin Locations Exhibit**	*Exhibit 7*	N 0 500 1,000 2,000 Feet

Appendix D – FlowMaster (Pipe Sizing)

Tucson International Airport

Culvert Summary Table

Pipe ID	Contributing Subbasins	Coeff.	Slope [ft/ft]	Depth [ft]	Diameter [inches]	Discharge [cfs]	Velocity [ft/s]	Froude No.	Flow Type
C-1	DA - 8	0.013	0.003	1.76	30	19	5.13	0.71	SubCritical
C-2	DA - 8,5	0.013	0.005	1.78	30	24.9	6.64	0.91	SubCritical
C-3	DA - 8,5,3	0.013	0.005	2.19	36	41.6	7.53	0.92	SubCritical
C-4	DA - 8,5,3,2	0.013	0.004	2.41	42	52.2	7.38	0.88	SubCritical
C-5	DA - 1	0.013	0.0039	2.36	42	50	7.25	0.88	SubCritical
C-6	DA - 6	0.013	0.005	1.53	30	20	6.37	0.99	SubCritical
C-7	DA - 7	0.013	0.005	1.56	30	20.7	6.42	0.98	SubCritical
C-8	DA - 6,7,4	0.013	0.005	2.56	36	48.7	7.59	0.77	SubCritical
C-9	DA - 11	0.013	0.005	1.94	36	35.5	7.33	0.99	SubCritical
C-10	DA - 11,10	0.013	0.005	2.47	36	47.3	7.61	0.81	SubCritical
C-11	DA - 11,10,9	0.013	0.005	2.35	42	56.4	8.2	1	SubCritical
C-12	DA - 15	0.013	0.004	1.94	36	31.7	6.55	0.89	SubCritical
C-13	DA - 15,14	0.013	0.005	2.45	42	59.7	8.28	0.97	SubCritical
C-14	DA - 15,14,13	0.013	0.005	2.91	48	89.4	9.12	0.97	SubCritical
C-15	DA - 15,14,13,11,10,9,12	0.013	0.005	4.15	60	186.3	10.69	0.87	SubCritical
C-28	DA-27 OFF	0.013	0.005	3.17	48	98.4	9.21	0.89	SubCritical
C-16	DA - 27,27-OFF	0.013	0.005	3.6	48	108.2	9.09	0.72	SubCritical
C-17	DA - 24,27,27-OFF	0.013	0.0039	4.03	54	130.6	8.69	0.66	SubCritical
C-18	DA - 26	0.013	0.005	1.59	30	21.3	6.46	0.97	SubCritical
C-19	DA - 26,25	0.013	0.0044	2.28	36	41	7.11	0.83	SubCritical
C-20	DA - 23,24,25,26,27,27-OFF	0.013	0.0038	4.5	60	171.1	9.19	0.65	SubCritical
C-21	DA - 21,23,24,25,26,27,27-OFF	0.013	0.005	3.8	60	170.7	10.65	0.97	SubCritical
C-22	DA - 20,21,23,24,25,26,27,27-OFF	0.013	0.005	4.12	60	185	10.69	0.88	SubCritical
C-23	DA - 22	0.013	0.005	2.04	36	37.9	7.42	0.97	SubCritical
C-24	DA - 19,22	0.013	0.004	2.42	42	52.3	7.38	0.88	SubCritical
C-25	DA - 18,19,22	0.013	0.004	3.34	54	112	8.85	0.87	SubCritical
C-26	DA - 16	0.013	0.005	1.57	30	20.9	6.43	0.98	SubCritical
C-27	DA - 16-27 & 27-OFF	0.013	0.005	3.72	2-54	279.5	9.96	0.87	SubCritical

Appendix E – Stantec Report

1.0 INTRODUCTION

1.1 Goals and Objectives

The objective of this study is to provide the Tucson Airport Authority (TAA) with an updated stormwater drainage management plan for the Tucson International Airport (TIA) and its adjacent landside facilities. The current Airport Wide Drainage Basin Study (AWDBS) was completed in May 1992. In the subsequent 10-years, significant property has been acquired, new development and improvements have been constructed on both the air and landside aspects of the airport, and future development plans have changed. An update is warranted to address the new development and future development for the planning period through 2023. The goals of the updated report are to maintain the existing format of the 1992 AWDBS, incorporate the current appended drainage reports/statements, address locations of detention basins and other drainage facilities in relation to the Airport Master Plan Update (Master Plan), and address the 100-year floodplain along Airport Wash downstream of Tucson Blvd., and upstream of the box culverts under Taxiway D. The TAA has developed an updated Master plan for the Year 2023, which includes future airport improvements and its landside development at the TIA. The purpose of the stormwater drainage management plan is to develop conceptual drainage plans consistent with the Master Plan. In addition, the drainage management plan must consider the effects of on-site runoff on the areas downstream of the airport. The drainage management plan will allow for future development and airfield improvements at the TIA without causing a significant drainage impact on the airport facilities or the areas downstream on the airport.
A current aerial photo was obtained (flight dates 3/6/03 and 4/18/03) for TIA in conjunction with the updated AWDBS and was utilized to update exhibits and to evaluate Master Plan improvements.

The AWDBS is specifically for drainage on and across the TIA facilities. The objective is to update a management plan that controls drainage runoff impacting the airport and runoff from the airport impacting downstream areas. This study does not address water quality issues and/or permitting. A brief discussion of the regulatory requirements of the Arizona Pollutant Discharge Elimination System (AZPDES) program are included in Section 5.4.

1.2 Location and Description of Study Area

The study area includes the Tucson International Airport and the surrounding land within the future property boundary as defined by TAA's adopted Master Plan for the year 2023. More specifically, the area includes Sections 16 thru 22, 26 thru 30, and 32 thru 35, Township 15 South, Range 14 East and Sections 2, 3 and 11 of Township 16S, Range 14E within Pima County, Arizona. The sub-watersheds within the study area consist of both developed and undeveloped areas. Developed areas include the airfield (runways, taxiways, and aprons) and adjacent landside facilities (terminals, hangers, industrial facilities, access roads, parking lots, etc). Development within these areas is predominantly industrial. The remaining portion of the study area constitutes undeveloped areas, which are predominantly of natural vegetation.

1.3 Description of Surrounding Area

The watersheds downstream of the study area cover approximately 8 square miles and extend approximately 2.5 miles west to the Santa Cruz River. The area north of Los Reales Road is mostly residential with some small commercial developments. South of Los Reales Road, the area is predominantly undeveloped and consists of natural vegetation.

The three major watersheds upstream of the study area are the Airport Wash, the Hughes Wash, and the Franco Wash (see Figure 2). The Airport Wash watershed extends approximately 10 miles east of the developed portion of the airport (at Country Club Road) and covers about 18 square miles. The Hughes Wash watershed is south of Airport Wash and extends approximately 6 miles east from Old Nogales Highway. The Hughes Wash watershed covers about 6.5 square miles. The Franco Wash watershed is south of the Hughes Wash watershed and extends approximately 27 miles east of Old Nogales Highway. The Franco Wash watershed covers about 37 square miles. The land within the upstream portions of the watersheds is mostly undeveloped with natural vegetation except for a portion of the Hughes Wash watershed which contains the Raytheon Missile Systems Facilities. A fourth watershed, the Airfield watershed, begins on-site and extends westward to the Santa Cruz River. This watershed is almost entirely developed.

1.4 Background

The TIA is located on property owned by the City of Tucson and leased to the TAA. However, the majority of the airport is located in Pima County. A coordination meeting was held between representatives of the City of Tucson (COT) Department of Transportation, the Pima County Department of Transportation and Flood Control District (PCDOT&FCD), and the Tucson Airport Authority. All agreed that the City of Tucson will function as the review agency for drainage related projects at TIA (see letter in Appendix A). City of Tucson involvement and concurrence on developments within the airport is necessary because of potential downstream impacts in the City. The Federal Aviation Administration (FAA) and the Arizona Department of Transportation (ADOT) Aeronautic Division provide improvement funding and review of the airport Master Plan and airport improvements.

In addition to the City, County and State, the Union Pacific Transportation Company (UPTC) and the Tohono O'Odham Nation have properties west of the airport. The UPTC has the Nogales Spur, which abuts the airport property on the west. Permits are required from the UPTC for any work on their right-of-way. Any construction activity directly related to their facilities must be reviewed by the UPTC and can take many months to complete. The Tohono O'Odham Nation San Xavier District must also be notified of any development or improvements that would affect their land.

PCDOT&FCD and COT design standards call for consideration of the 100-year frequency storm event, retention for most commercial development, and detention in areas with known drainage problems, which have been designated as “balanced”, or “critical basins”. In 1992, only a portion of the TIA site was located in a designated “balanced basin” (Airport Wash Watershed). Because significant drainage problems exist downstream, within the City of Tucson, PCDOT&FCD believed the remainder of the TIA site should be designated as a “balanced basin”. (See Appendix A for PCDOT&FCD letter dated March 20, 1990). The policy for balanced basins is that, at a minimum, the post-development two-, ten-, and 100-year peak discharges from a site shall not exceed the predevelopment values. The policy for retention in commercial developments is that the increase in runoff volume (as a result of development) for a five-year storm event shall be retained for infiltration purposes.

Although the aforementioned PCDOT&FCD March 20, 1990 letter suggested designating the remainder of TIA as a “balanced basin”, that portion will remain a non-designated basin. Discussions with PCDOT&FCD revealed that there are no downstream problems within the Hughes Wash drainage basin. As a result, no detention is required in the Hughes Wash. However, retention is necessary. (See Appendix A for PCDOT&FCD letter dated December 2, 1991). No development is proposed in the Franco Wash Watershed. Detention/Retention in the Franco Wash Watershed will be addressed in the future, at such time development is anticipated.

Pima County also has a policy, which requires that some form of mitigation be provided in the event retention is not feasible. One form of mitigation is the use of over-detention. In a July 22, 1992 letter from PCDOT&FCD (see Appendix A), the County stated that if over-detention is the selected alternative to not utilizing retention, then, “peak flows for future development at the TIA site must be restricted to no greater than 90% of existing flows.”

TAA has a policy that does not allow retention or long-term detention basins on the airport property, as they may attract birds, which pose a danger to aircraft. Additionally, because of the existing volatile organic compound (VOC) – contaminated shallow groundwater concerns along the western side of the airport, retention is not desirable since retained stormwater could be a potential source of recharge.

To satisfy retention requirements without the use of over-detention, a compromise has been reached between PCDOT&FCD and TAA. The solution is to allow for threshold retention volume within the detention basins and on-site ponding areas. Furthermore, as is outlined in an October 2, 1991 letter from PCDOT&FCD (see Appendix A), “Instead of containing the volume within the basin such that only outflow occurs as infiltrating through the basin bottom, the retention volume will drain at a slow rate through outflow constructed in the side of the basin, such that the basin will drain within the required 24 hours”. In a separate letter (see Appendix A) from PCDOT&FCD (also dated October 2, 1991), the County has agreed that “the retention volume can be used as part of the detention storage volume when determining the stage-storage-discharge relationship for routing.”

PCDOT&FCD policy regarding flooding near buildings is that structures, which will be inhabited, shall be protected from the 100-year frequency storm runoff. PCDOT&FCD does not have a policy regarding drainage in runway and taxiway systems. Therefore, flooding within the airfield is not a concern of the PCDOT&FCD.

Existing airfield drainage facilities have generally been designed in accordance with Federal Aviation Administration (FAA) guidelines. FAA Advisory Circular AC 150/5320-5B, "Airport Drainage," July 1970 recommends that airfield drainage facilities be designed for the five-year frequency storm runoff: "The drainage or inconvenience which may be caused by greater storms is insufficient to warrant the increased cost of a drainage system large enough to accommodate a storm expected once in a period longer that 5 years".

The FAA guidelines also make a provision for temporary accumulation of runoff or "ponding" between runways, taxiways and aprons from storm return periods longer than 5 years. The FAA Advisory states, "Ponding of more than a temporary nature may be acceptable on an airport site other than between runways, taxiways, and aprons. A frequency curve for 10 years should also be plotted for verifying ponding capacity". Although FAA guidelines maintain it is desirable to keep ponding away from the runway and taxiway safety areas, the Advisory states, " …gentle drainage swales, ...which because of their function, require location in the runway safety area, may be permitted." The safety areas for runways and taxiways are 250 ft and 85.5 ft, respectively, either side of the runway or taxiway centerline.

1.5 Design Criteria

The following design criteria and considerations have been developed for this study. These criteria and considerations take into account the concerns of the TAA, the City of Tucson, PCDOT&FCD and ADOT.

1. Detention basins will hold the runoff for a period of time before releasing it to downstream facilities and will be permitted as long as they drain within 24 hours per PCDOT&FCD regulations. The basins will be designed such that post-development two, 10- and 100-year peak flows from the site will not exceed the predevelopment values per PCDOT&FCD policies. The baseline values for predevelopment peak discharges will be the runoff from the development and drainage facilities existing on the study area on January 1, 1991.

2. Strict threshold retention requirements will not be implemented because it has the potential of attracting birds and exacerbating groundwater contamination. However, retention volumes will be incorporated into on-site ponding areas and detention basins such that the basins drain within 24 hours.

3. Future drainage facilities on the airfield will continue to be designed in accordance with FAA guidelines to have capacity for the five-year frequency storm runoff. Per FAA guidelines, temporary ponding from storms with a return period of 10-year will be checked for encroachment into the runway and taxiway safety areas. Ponding in the airfield is allowed only as a result of

runoff exceeding the five-year design capacity. Detention basins within the runways and taxiways will not be allowed. Temporary or short-term ponding in the airfield caused by runoff from rainfall events greater than 5 years must drain within 24 hours.

4. Detention basins should be located as far from runways as possible. Detention will not be required in the Hughes Wash watershed (see December 2, 1991 letter in Appendix A).

5. Proposed airport buildings and structures and adjacent facilities will be protected from the 100-year frequency storm runoff.

6. No changes in drainage patterns impacting downstream areas will be allowed.

2.0 EXISTING CONDITIONS

2.1 Existing Drainage Patterns

As stated previously, the majority of runoff from the study area flows into three watersheds crossing the study area: the Airport Wash, Hughes Wash, and the Airfield watershed (see Figure 3). In addition to these three watersheds, a small portion of the study area in the south half of Section 32 and southwest corner of Section 33 and portions of Sections 2 and 3 flow into the Franco Wash watershed.

Runoff from the study area flows to the west into the Santa Cruz River. The lands between the study area and the Santa Cruz River are either under the jurisdiction of Pima County, City of Tucson, State of Arizona, or the San Xavier District of the Tohono O'Odham Nation.

Airport Wash Watershed

Generally, the sub-watersheds within the airfield northeast of the main runway, runway 11L-29R (see Figure 3), flow into the Airport Wash watershed. Airport Wash flows northwest from the airport into the Santa Cruz River within the corporate limits of the City of Tucson.

Airfield Watershed

Runoff from the sub-watersheds southwest of runway 11L-29R and northwest of the diversion channel (see Figure 3) flow into the Airfield watershed. Flow from the Airfield watershed crosses the Union Pacific Railroad Nogales Spur and the Old Nogales Highway at three locations south of Valencia Rd. and continues west to the Santa Cruz River in existing drainage facilities and as overland flow in roadways.

Hughes Wash Watershed

Runoff from the sub-watershed southwest of runway 11L-29R and southeast of the diversion channel flows into the Hughes Wash watershed. Flow from the airfield is carried in the diversion channel to Hughes Wash at Old Nogales Highway, and continues west to the Santa Cruz River.

Franco Wash Watershed

Runoff from a small, undeveloped portion of the airport property flows into the Franco Wash watershed. The Franco Wash also traverses the southeast portion of the undeveloped airport property. Flow from the Franco Wash watershed also crosses the railroad and the Old Nogales Highway before reaching the Santa Cruz River.

2.2 Existing Drainage Problems

<u>On-Site Flooding</u>

Drainage problems within the study area occur in the airfield, along the western boundary, and along the Airport Wash. Drainage problems include: 1) ponding and overtopping of runways and taxiways in the airfield: 2) ponding at the railroad, Old Nogales Highway, and Valencia Road along the western boundary; 3) and flows overtopping runway 3-21, taxiway 2 and the Valencia Road bridge at the Airport Wash crossings.

Drainage problems in the airfield are due to insufficient capacity of existing drainage facilities. The airfield drainage facilities are designed for a five-year rainfall event. Runoff from rainfall events greater than 5 years temporarily accumulates at the drainage structures causing ponding between the runways and taxiways. The ponding is temporary in nature and is typically gone within 24 hours.

Drainage facilities under the railroad also have limited capacity. The railroad is elevated along the southern reaches and approaches adjacent grade elevations toward the north at Valencia Road. Ponding occurs at the undersized culverts and where the tracks are elevated. Flows continue north until they are able to cross under the railroad and the Old Nogales Highway just south of Valencia Road. This excess water overburdens the existing culvert under the railroad and Old Nogales Highway.

Drainage problems at runway 3-21 and taxiway 2 are caused by insufficient capacity of the culvert crossings at Airport Wash. The runway and taxiway culverts are overtopped and the surrounding area is subject to backwater when the capacity of the culverts is exceeded. The capacity of both Airport Wash culverts is estimated to be between the 10- and 100-year flood events.

<u>Downstream Flooding</u>

Numerous drainage problems exist downstream of the airport. In particular, the area west of Old Nogales Highway and south of Valencia Road is prone to flooding. This area is relatively flat and sheet flooding commonly occurs when the capacities of existing roadway and area drainage facilities are exceeded.

Additional downstream flooding problems have occurred due to the construction of berms by area residents to protect personal property. The berms redirect flows onto adjacent properties and cause flooding. Clogged catch basin inlets and clogged culverts are also responsible for flooding problems downstream. A summary of the drainage complaints filed with the City of Tucson between 1987 and 1990 is listed in Table 1.

Table 1

Summary of Drainage Complaints
City of Tucson

Location	Description	Complaint No.
Santa Clara Wash	Trailer Parked in Wash Blocking Flow	649
Santa Clara Wash	Debris Clogging Drainage	679
Santa Clara Apts.	Ponding in Parking Lot	687
Elvira Elementary School	Clogged Storm Drain	763
Drexel at 12th Avenue	House in low-lying area flooded	783
Nogales Highway & Medina	Clogged box culvert	798
5950 South Park	Ponding in Parking Lot	806
El Vado & Valencia	Flooding due to illegal berming	855
Bilby & Randall	Road Washing away	895
826 W. Nebraska	Bridge clogged with debris	897
El Vado & Nogales Hwy	Flooding due to illegal berming	904
Nogales Hwy & Drexel	Clogged Unit	924
6965 S. Missiondale	Ponding in low-lying area	961
El Vado & Nogales Hwy	Flooding due to illegal berming	987
802 Calle Colorado	Flooding in low-lying area	1006
Nebraska & 17th Avenue	Clogged strom drain	1016
967 West Valencia	Ponding	1214
31 West Los Reales Road	Pipes from Indian Reservation directing flows into street casuing flooding	1232
Valenica & 12th Avenue	Clogged Storm Drain	1265

2.3 Previous Drainage Reports

Previous drainage reports have been written for downstream development and development on the airport. These reports were reviewed for possible flooding considerations downstream of and on the airport. Previous reports on the downstream watersheds include:

- George M. Feltovic “Drainage Report for Tierra Del Sol Apartments”, November 18, 1983.
- Greiner Engineering, “Valencia Road – Old Nogales Highway Drainage Study”, 1985
- CMG Drainage Engineering, “Drainage Report for American Fence Company, Valencia Road/Park Avenue Property”, February 25, 1987.
- Jerry Jones & Associates, “Master Drainage Report for Patmor International Business Park”, October 25, 1988.

Previous drainage reports on the airport prior to 1992 include:

- Camp Dresser & McKee – "Hydrologic Report of the Tucson Airport Parking Structure", October 1988.

- Parsons Brinckerhoff – "Drainage Report for Lockheed Aeromod Center", April 1990.

Drainage reports on the airport after 1992 to the present are summarized in Appendix G

2.4 Tucson Stormwater Management Study (TSMS)

A citywide Stormwater Master Plan was completed in 1995 by the City of Tucson as part of The City of Tucson Stormwater Management Study (TSMS). The Stormwater Master Plan includes citywide HEC-1 modeling for 59 TSMS watersheds. TSMS HEC-1 concentration points or nodes are indicated on Figure 3. The associated 100-year peak discharge values are summarized in Appendix C.

2.5 404 Permits

The U.S. Army Corps of Engineers (COE) conducted a field investigation of the Airport and Hughes Washes to determine the limits of jurisdiction of the COE for Section 404 permit authority in 1991. The letter of determination from the COE is contained in Appendix B. Jurisdictional limits of the COE are shown in Figure 2. Figure 2 includes the areas studied during the field investigations, and the upstream or downstream areas could also be considered as part of the jurisdictional limits. The COE should be notified of construction activities affecting tributaries of the areas shown in Figure 2. The jurisdictional limits established by the COE remain in effect for 3-years. After 3-years, the COE reserves the authority to retain or establish new limits. Therefore, the COE should be contacted prior to activities in the Airport, Hughes and additionally, Franco Washes.

The application process for a Section 404 permit is described in detail in Section 6.1. An application for an individual Section 404 permit will be required for any construction activity within; or any activity that discharges dredged or fill material into, the jurisdictional limits.

3.0 HYDROLOGIC ANALYSIS

3.1 Existing Conditions Analysis

Boundaries and parameters for major upstream watersheds were defined using 7.5 minute quadrangle maps available from the United States Geological Survey (U.S.G.S.). Existing aerial photographs were also used in conjunction with the quadrangle maps to define the major watersheds.

Watershed boundaries and parameters for the sub-watersheds in the Airfield and Airport Wash watersheds were defined using 1”=200’ scale, two-foot contour mapping prepared specifically for the 1992 study by Cooper Aerial Survey Company. The mapping covered approximately 9 square miles of the airfield and surrounding area and was based on aerial photography dated October 1990. The mapping was supplemented by ground survey of existing storm drain structures. Quadrangle maps (7.5 minute) were used for the remainder of the airport property outside the limits of the aerial mapping.

Approximately 8 square miles of downstream watersheds between the airport and the Santa Cruz River were delineated. Downstream watersheds extending beyond the airport were delineated using existing 1”=200’ scale, two-foot contour maps, dated May 1983 to July 1984. Quadrangle maps (7.5 minute) were used where 200-scale mapping was not available.

Entire watershed boundaries have been delineated on 7.5 minute quadrangle maps. The maps have been spliced together and are included in Appendix C as Figure 12.

Stormwater runoff for existing conditions on all watersheds was determined using the U.S. Army Corps of Engineers HEC-1, Flood Hydrograph Package Computer Program. The Soil Conservation Service (SCS) Unit Hydrograph method was used. Runoff for existing conditions was calculated for storms with a two-, five-, 10- and 100-year return period.

HEC-1 was utilized in place of the Standard Pima County hydrology method because of the nature of the contributing watersheds. There is extensive ponding throughout, which effectively delays and/or reduces peak discharges. Consequently, HEC-1 was used because it yields more accurate values for this type of watershed.

It is important to note that the HEC-1 program was calibrated to match flow generated using the Pima County method, (see hydrologic data sheets on appendix C) as outlined in the PCDOT&FCD “Hydrology Manual for Engineering Design and Floodplain Management within Pima County, Arizona”, September 1979. SCS curve numbers were calibrated so the peak runoff was within 10 percent of that determined using the County method. The curve numbers were calibrated based on the watershed size, imperviousness, and cover using pairs of watersheds with similar characteristics. The resultant curve number was used in the HEC-1 for all watersheds having similar characteristics. Five representative watershed groups were selected for calibration. A comparison of the five representative sub-watershed flows using the County method versus the HEC-1, is shown in Table 2.

HEC-1 was used to compute runoff hydrographs and perform storage-routing through the existing drainage structures within the developed portion of the airport, the airfield, and the Union Pacific Railroad Nogales Spur and Old Nogales Highway crossings. Rating curves were developed for each structure based on ground survey data collected in November 1990. Capacities of the structures at varying water surface elevations were rated using Federal Highway Administration, HDS No. 5, "Hydraulic Design of Highway Culverts". Culvert hydraulics have been summarized in a table in Appendix E. The HEC-1 routing procedure allowed hydrograph detention and approximate ponding elevations to be determined.

Table 2

Comparison of Flows Determined Using HEC-1 and Pima County Method

Watershed	10-Year Flow			100-Year Flow		
Designation	County	HEC-1	%Diff.	County	HEC-1	%Diff.
18	77	73	+5	152	146	+4
21	96	92	+4	189	187	+1
22	187	182	+3	458	455	+1
49	251	244	+3	577	586	-2
46	184	198	-7	338	359	-6
47	103	92	+11	200	190	+5
29	99	104	-5	219	218	+1
30	105	102	+3	244	236	+3
50	47	45	+4	76	70	+8
53	43	43	0	66	65	+2

Parameters used in the HEC-1 program were:

1. Rainfall, “SCS Type II rainfall distribution for large basins, and the SCS Type IIA distribution for the smaller basins less that 0.5 square miles.

2. Lag Time (TLAG) = 0.6 Time of Concentration. Time of Concentration was estimated utilizing City of Tucson, “Standards Manual for Drainage Design and Management in Tucson, Arizona”, December 1989.

3. Runoff curves based on SCS method. Runoff curves were calibrated by utilizing the Pima County Hydrology Method.

4. Basin Factors used in the Pima County Method for calibration:

Runway/Taxiway Areas:	0.028
Undeveloped Areas:	0.030 to 0.035
Developed Airport Areas:	0.018 to 0.025

5. Mannings “n” values for routing runoff through various conveyance facilities:

Storm Drains:	0.020
Overland Flow Between Runways and Taxiways:	0.025
Natural Channels:	0.040 to 0.070

The HEC-1 storage routing procedure was used to model the runoff storage occurring between runways and taxiways. The SA, SE, and SQ records were used to identify the sub-watershed storage and discharge characteristics. The ST, SW, and SE records were used to describe the “top-of-dam” geometry of the runways and taxiways. Rating curves developed for each sub-watershed and 200-scale topography mapping were used to develop the record data. In addition, field survey information was used for culvert invert data.

The HEC-1 diversion procedure was used when flows overtopped the runways and taxiways into sub-watersheds other than those receiving the culvert-directed flow. The DI and DQ records were used to identify sub-watershed inflow and corresponding outflow over the runways and taxiways. The outflow was determined by subtracting the culvert capacity under the available head from the corresponding peak flow. The available head and peak flow were obtained from the dam overtopping summary at the end of each HEC-1 computer printout (See Appendix F).

The HEC-1 kinematic wave channel routing was used to route flow from one sub-watershed to the concentration point of the next. Data for the RK records was obtained from 200-scale topography maps and the U.S.G.S maps. In some instances multiple RK records were required due to a program warning requesting shorter lengths on the RK record.

Drainage structures for downstream watersheds were rated for maximum capacity utilizing record drawings and the HDS No. 5 “Hydraulic Design of Highway Culverts”. No verification of existing downstream structure size and capacity was made. The results of the rating curves are approximate only.

3.2 Future Conditions Analysis

The hydrologic analysis for future conditions was performed utilizing the same methodology as in the existing conditions analysis. The approved Airport Master Plan for the Year 2005 (dated August 1996) was used to determine future land use and development for the airport (see Appendix B for Year 2005 Airport Layout Plan) for future condition HEC-1 analyses. The areas of future landside development were assumed to be fully developed. The future condition modeling is applicable to the Master Plan Update. Future land uses and future overall airfield development is essentially unchanged (from a hydrologic standpoint) and the landside areas are already considered fully developed. Therefore, a revision to the future conditions HEC-1 models was not warranted with the Master Plan Update. The 2023 Master Plan is attached as Figure 4. Development that has occurred post May 1992, and the Master Plan impacts are examined further in Section 6.

Future landside developments were modeled by utilizing watershed parameters for developed industrial areas. Flood hydrographs for the two-, five-, 10-, and 100-year frequency storm were developed for future conditions and routed through the airport storm drain facilities, the Union Pacific Railroad culverts, and the Old Nogales Highway culverts.

The proposed terminal and airfield complex located south and east of the existing complex was analyzed to estimate the potential increase in runoff due to the increased impervious areas of runways, taxiways, aprons, and structures. Because the proposed terminal complex is schematic at this time, a detailed hydrologic and routing analysis was not performed.

Future expansion of airfield facilities (taxiways, runways and aprons) was based on the Airport Master Plan. Culverts for the future airfield facilities were sized on a preliminary basis to provide capacity for runoff from a five-year storm, per FAA guidelines. Ponding areas were estimated based on existing topography. Rating curves were developed for the proposed culverts utilizing HDS No. 5. Proposed culvert sizes are shown in Table 3, and the culvert locations are shown in Figure 5. Culvert hydraulics are included in a table in Appendix E.

Table 3

Culvert Sizes for Future Airfield Facilities

Sub-watershed Number	Culvert size	Five-Year Flow (cfs)
13B	2-42" RCP	46
22A	3-42" RCP	137
22B	2-48" RCP	111
22C	1-36" RCP	26
22E	1-48" RCP	62
22F	1-30" RCP	18
27A	1-42" RCP	28
28A	1-48" RCP	47
30A	4-48" RCP	220
30B	2-42" RCP	66
31B	1-48" RCP	47
31C	3-48" RCP	164
55A	1-36" RCP	26
54A	1-36" RCP	26
28B	1-36" RCP	26

For final project designs, the proposed culvert sizes should be verified based on runway/taxiways elevations, grades, ponding areas, etc. determined at the time of design. For example, an arch pipe with the same capacity may be required because of limited vertical clearance. If future culverts are designed with the same criteria utilized herein; i.e. capacity for the five-year frequency storm, the impact on this hydrological analysis will be negligible. Drainage patterns should be maintained, however. The estimated cost for the Airfield culverts is approximately $785,000.

3.3 Results of Analysis

Existing Conditions

The results of the analysis indicate there are four areas where ponding occurs within the study area. These are: 1) the airfield, 2) the area west of Bombardier Aerospace/Learjet Corporation at the railroad, 3) the northwest corner of the airport at Valencia and Old Nogales Highway, and 4) the Airport Wash. The approximate existing ponding areas caused by the 10- and 100-year frequency storm are shown in Figures 6 and 7, respectively.

Ponding on the airfield occurs between all runways and taxiways. The ponding is temporary in nature, and only occurs in a significant amount during storms with frequencies greater than 10 years.

Ponding west of Bombardier Aerospace/Learjet Corporation occurs at the Southern Pacific Nogales Spur where the existing culvert capacity is insufficient for flow greater than a two-year event. When the capacity of the railroad culvert is exceeded, flow overtops the airport maintenance road on the north and continues north along the railroad, adding to the ponding in the northwest corner of the airport at Valencia Road and Old Nogales Highway. The flow then overtops Old Nogales Highway and sheet flows to downstream roadways and drainage facilities.

Ponding (backwater) along the Airport Wash occurs at structures that do not have sufficient capacity to convey the larger flows. Structures along Airport Wash that are impacted include the bridge at Valencia Road, the culverts under runway 3-21 and taxiway 2, and the culvert crossing on Los Reales Road. Capacities of the bridge at Valencia Road and the culvert crossings are estimated to be between the 10 and 100-year events.

Ponding also occurs at the Hughes Wash crossing of the Old Nogales Highway. On-site flows contributing to the Hughes Wash watershed are detained by ponding in the airfield. The contributing flow, together with the flows from the entire watershed, overtop Old Nogales Highway and continue to the Santa Cruz River when the culvert capacity is exceeded. Ponding at this location does not affect the TIA.

Future Conditions

Under future conditions, ponding occurs in the same areas as the existing conditions. However, because of development, runoff is increased and ponding in some areas is increased. Figures 8 and 9 show the approximate ponding areas for the 10- and 100- year future condition peak flows with no drainage improvements to the existing system. Ponding in the existing airfield is not affected by the future development, and ponding areas do not change from existing conditions. However the HEC-1 indicates ponding elevations west of Bombardier Aerospace/Learjet Corporation and at Valencia and Old Nogales Road increase slightly due to the additional runoff created by future landside development. Ponding areas also increase where Airport Wash crosses under Taxiway 2 and Runway 3-21.

The addition of future runways and taxiways does not significantly change runoff from the airfield itself. The ponding areas created by the future runways and taxiways offset the increased runoff from additional impervious areas. The results of the analysis comparing existing baseline flows to post-development flows for the Airfield watershed is shown in Table 4 at the end of this section.

Ponding volumes at runways and taxiways associated with the future five-year storm event are part of the solution to satisfy threshold retention requirements for the TIA site. Volumetric calculations for these ponding areas as well as calculations for required retention volumes are included herein (see Tables 5 and 6).

Apron and landside developments within the Airport Wash watershed downstream of the confluences of the North and South Fork do not significantly impact peak runoff in the Airport Wash for return intervals greater than five years. This is due to the difference in time of concentration between the Airport Wash watershed and the sub-watersheds on the airport. Another reason is that there are no significant improvements downstream of the confluence. Runoff form rainfall event less that a five-year return interval are contained in the Airport Wash channel and do not affect the airport or downstream structures.

The future terminal and airfield complex upstream of the confluence of the North and South Fork of the Airport Wash increase flows into the watershed. The results of the analysis comparing existing baseline to post-development flows in the Airport Wash watershed is shown in Table 4 at the end of this section. In addition, the 100-year floodplain for the Airport Wash impacts these areas and future channel improvements will be required. It should be noted that application for a Section 404 permit will be necessary for development within the Airport Wash. A detailed description of the 404 process is included in Section 6.1.

Future landside development in the Hughes Wash watershed increases runoff from the watershed. The contributing area from the sub-watersheds is small (0.9 square miles) in comparison to the entire watershed area (6.5 square miles). The sub-watershed 100-year peak flow of 552 cfs is also small in comparison to that of the Hughes Wash watershed (3579).

No future landside developments are planned in the Franco Wash watershed at this time. However, in the future, any new development that is planned should address future drainage conditions, including detention/retention requirements.

The results of the analysis for existing baseline flow conditions and post-development flow conditions without constructing detention facilities or improving existing facilities are shown in Table 4. The corresponding concentration points are shown in Figure 9.

Table 4

Runoff From Basins Affecting the Airport
(cfs)

Concentration Points	Baseline Flows 2	5	10	100	Post-Development Flows* 2	5	10	100
	Storm Frequency							
A	733	1529	2108	6763	898	1614	2497	7589
B	304	1201	2091	6939	463	1428	2479	7715
C	108	222	322	904	152	305	379	981
D	113	119	127	181	122	171	173	206
E	128	206	250	369	45	80	88	183
F	67	111	143	207	187	207	225	275
G	230	354	394	701	340	418	496	689
H	228	861	1255	3938	458	995	1539	4313

*Assumes no detention facilities constructed.

Table 4 shows that runoff for each return interval generally increases with development. Therefore, basin management strategies will be needed in some areas to satisfy the design criteria of a reduction in peak runoff, after development, back to existing values. Detention facilities could be used to decrease post-development flows to meet the design criteria. The detention facilities would decrease the post-development flows to the baseline flows shown in Table 4.

3.4 Retention Discussion

Threshold retention requirements are such that increased runoff volumes resulting from development for a five-year storm must be retained on-site. This volumetric determination is included in the HEC-1 analysis (see Appendix F). Review and comparison of the existing and future five-year HEC-1 models reveal the increased runoff volumes.

Points of comparison used to determine retention volumes are at the confluence of the North and South Fork of the Airport Wash, the Airfield watershed at Nogales Highway, and the Hughes Wash at Nogales Highway. The North and South Fork confluence was used because future development in the Airport Wash, within the project limits, occurs upstream of that point. Future and existing runoff volumes are shown in the HEC-1 models FAP5 (Future Airport 5 Year) and AP5 (Airport 5 Year), respectively.

Airfield watershed (Hec-1 Watershed 33) development impacts (i.e., increased runoff volume) can be seen by reviewing HEC-1 models 5YR33 (existing) and N5YR433 (Future; New 5 Year Watershed 33).

The Hughes Wash watershed has been modeled into the HEC-1 runs 5YR44 and N5YR44 for existing and future conditions, respectively. Future development is expected within the Hughes Wash upstream area as well as in local watersheds 42 and 45. As a result, the increased volume within the Hughes Wash watershed was utilized for retention requirements.

The following table summarizes retention volumes for the project area.

Table 5

Retention Volumes

	Five-Year Runoff Volumes (ac. ft.)		
Watershed	**Existing**	**Future**	**Increase**
Airport	441	464	23 ac. ft.
Airfield	19	24	5 ac. ft.
Hughes – 183	218		35 ac. ft.
Total			**63 ac. ft.**

As was discussed in Sections 1.4 and 1.5 of this report, strict retention (i.e., for infiltration) is not required at TIA. Instead, retention volumes will be contained in onsite detention basins. Rather than capturing and retaining the runoff volume until it has percolated into the ground, the runoff will be allowed to discharge at a slow rate (approximate rate of 30 cfs). By controlling the runoff volume at the slow discharge rate, impacts to downstream properties resulting from increased volumes will be mitigated.

Future and existing drainage facilities within TIA will contain the required 63 ac. ft. of retention volume. A portion of the volume will be contained within the existing and future ponding areas between runways and taxiways. The remaining volumes will be contained in the future detention basins.

In calculating the portion of the volume at runways and taxiways, the average discharge of 30 cfs was used as a guideline. As a result, all ponding areas within TIA were analyzed for volumetric capacity equating to a discharge of 30 cfs or less during a FIVE-YEAR STORM EVENT. Volumes are included in three future condition HEC-1 models; they are 5YR1, N5YR33 and N5YR44. Results of the volumetric analysis are shown in the following table. Volumes were determined from information shown on the SA, SQ, and SE records in the HEC-1 runs. Volumes were calculated from equations for pyramids (1/3 height times base) and frustrums of pyramids (1/3 height times (top)+(bottom)+ sq. rt (top)(bottom)).

Table 6

Five-Year Storage Volumes

Subbasin	Water Elevations	Surface Area (acres)	Discharge (cfs)	Volume (ac. ft.)
In Airport Watershed (5 YR1)				
55	2620.37	0.36	30*	0.12
54	2608.06	0.17	30*	0.06
53	2603.31	0.87	22	0.56
52	2597.84	0.35	19	0.40
51	2591.32	0.11	26	0.08
50	2586.60	0.86	25	0.50
10	2605.44	0.63	25	0.43
9	2595.09	0.30	30*	0.32
8	2593.06	0.04	30*	0.02
7	2582.47	0.02	30*	0.00
6	2583.08	0.74	13	0.62
5	2574.86	0.68	10	0.48
4	2572.53	0.52	10	0.32
3	2570.40	0.31	11	0.05
2	2568.50	0.40	11	0.43
1	2565.97	0.24	12	0.12
			Total	**4.51**
In Airfield Watershed (N5YR33)				
19	2592.71	1.17	24	0.60
29A	2584.95	0.30	20	0.30
29B	2583.03	0.05	30*	0.05
26	2574.17	0.01	26	0.00
18	2582.00	0.09	30*	0.06
17	2580.00	0.10	30*	0.03
16	2572.97	3.97	3	2.8
27A	2577.25	0.17	30*	0.13
28A	2572.30	0.23	30*	0.20
27B	2575.19	1.02	30*	0.64
24	2559.37	0.11	30*	0.07
15	2569.02	0.81	3	0.46
23	2560.52	1.42	16	0.94
37	2556.06	0.56	30*	0.37
38	2555.40	1.27	30*	0.65
48	2550.44	0.01	30*	0.00
35	2548.36	0.05	30*	0.02
36	2547.58	0.04	30*	0.01
34	2550.97	0.25	30*	0.04
33	2537.68	0.45	30*	0.12
			Total	**7.49**

Table 6 (continued)

Five-Year Storage Volumes

Subbasin	Water Elevations	Surface Area (acres)	Discharge (cfs)	Volume (ac. ft.)
In Hughes Watershed (N5YR44)				
22D	2635.59	0.17	19	0.09
14	2638.72	0.35	30*	0.14
22B	2627.25	0.23	30*	0.10
13B	2629.43	0.26	30*	0.12
13A	2629.67	1.16	29	0.88
22A	2622.95	0.62	30*	0.20
22E	2640.42	0.83	17	0.39
22C	2628.49	1.15	13	0.80
31C	2618.83	0.04	30*	0.01
31A	2606.83	0.11	30*	0.03
12	2624.16	0.48	2	0.33
11	2613.13	0.02	30*	0.00
21	2610.62	0.09	30*	0.02
30A	2596.63	0.28	30*	0.06
20	2602.63	0.29	30*	0.10
31B	2608.96	0.33	30*	0.22
30B	2591.43	0.43	30*	0.20
30C	2590.71	0.01	30*	0.00
			Total	**3.69**

*Correspond to maximum outflow = 30 cfs

Volumes in the preceding table do not account for volumes in those areas that are planned for development (areas 25, 39, 40, 42, 45, 47, and 49), because grading changes will likely occur. Volumes within each separate watershed area will be applied toward the overall retention requirement for that area.

Results are as follows:

Airport Wash:	23 ac. ft. – 4.5 ac. ft. = 18.5 ac. ft.
Airfield Watershed:	5 ac. ft. – 7.5 ac. ft. = 0 ac. ft.
Hughes Wash:	35 ac. ft. – 3.7 ac. ft. = 31.3 ac. ft.

Retention volumes will be incorporated into detention basins. Discharge from the retention portion of the major basins must insure drainage within 24 hours. The following equations were used to determine average outflows to insure a ponding duration of less than 24 hours in the detention basins.

Airport Wash:

$$\frac{18.5\text{ ac. ft.}}{24\text{ hrs}} \quad X \quad \frac{43560\text{ cu. ft.}}{\text{ac. ft.}} \quad X \quad \frac{\text{hr.}}{3600\text{ sec.}} = 9.3\text{ cfs}$$

Airfield Wash:

Requirement is fulfilled.

Hughes Wash:

$$\frac{31.3\text{ ac. ft.}}{24\text{ hrs}} \quad X \quad \frac{43560\text{ cu. ft.}}{\text{ac. ft.}} \quad X \quad \frac{\text{hr.}}{3600\text{ sec.}} = 15.8\text{ cfs}$$

The above calculated outflows are the average discharges over a 24-hour period. The maximum outflow can be as much as 30 cfs per PCDOT&FCD requirements for this project (see October 2, 1991 letter in Appendix 1)

4.0 FUTURE DEVELOPMENT

4.1 Selection of Detention Alternative

In the 1992 AWDBS, detention basin management alternatives were selected and evaluated to meet design criteria as outlined in Section 1.4. In summary the criteria were:

1.0 No retention for infiltration purposes. Instead, retention will be accommodated within detention basins and airfield ponding areas.

2.0 Post-development runoff rates from TIA Airport and Airfield watersheds do not exceed runoff rates from baseline conditions (January 1, 1991).

3.0 Retention, but no detention, is required for the Hughes Wash.

4.0 Airfield facilities designed to have capacity for runoff from the five-year frequency storm per FAA design guidelines.

5.0 Proposed building and structures should be protected from the 100-year frequency storm runoff (i.e., by means of elevating buildings above the regulatory flood levels, or strategic location of detention facilities).

The basin management alternatives considered were:

1. Two detention basins which would control discharge into the basins downstream of the Airport Wash and Airfield watersheds, and a retention basin within the Hughes Wash watershed.

2. A detention basin associated with each increment of development that will limit flow from each development to baseline conditions.

3. No detention basins. Improve all downstream drainage facilities to convey increased post-development runoff without flooding.

Alternative 1 was the chosen alternative, which consists of utilizing two subregional detention basins, and one retention basin to control flows in each of the three major watersheds crossing the study area. Figure 10 shows approximate locations for the detention and retention basins in the Hughes, Airport and Airfield watersheds. The basin locations shown in Figure 10 were selected based on, runway centerline locations, proposed future development and location in watersheds to ensure sufficiently attenuated flow peaks. The basin locations are general and the number and size of basins can be varied as long as adequate capacity is provided. The detention or retention basin locations should be determined at the time conceptual plans for any developments are being considered.

Detention basin sizes have been developed in accordance with the estimating volume procedures outlined in the PCDOT&FCD/COT "Stormwater Detention/Retention Manual. Table 8 summarizes parameters used to determine storage volumes. Basins were assumed to be fenced, unlined and uncovered. The detention basin areas are based on a 6-foot depth with 4 to 1 side slopes. Table 9 lists the area requirements and estimated construction costs for each basin. The costs include engineering, construction, construction administration, and inspection.

Table 8

Detention Basin Storage Volumes

Watershed	Storm (Yr)	Total Volume of Runoff (ac. ft.)	Qi (cfs)	Qo (cfs)	Storage Volume (ac. ft)
Airport Wash	2	312	898	733	13
(PT A)	10	817	2497	2108	24
	100	1588	7589	6763	23
Airfield	2	12	152	113	4
Watershed	10	28	379	322	5
(Pt. C)	100	53	981	904	5

Note: Table is based on "off-line" detention for Airport and " on-line" for Airfield Wash. See "Stormwater Detention/Retention Manual" (see References) for equations. However, in the equation, the value for the total volume of runoff has been replaced by HEC-1 volumes.

Qi = Post-Development Flows (see Table 4)
Qo = Baseline Flows (see Table 4)

Storage Volume = Result of calculation plus 20%. The largest value per watershed was used for area determination.

Table 9

Detention and Retention Basin Sizes and Costs

Detention Basin	Type	Area Required (Acres)	Estimated Cost ($)*
			2004
Airport Wash Basin	Off-line	8	788,000
Airfield Watershed Basin	On-line	3	301,000
**Hughes Wash Basin	On-line	9	970,000

*Based on one basin per watershed; earthwork at $10.00/cu. Yd.; 6 ft high fencing with access gate at $20.00/linear ft.; outlet structure at $90,000/each (2004); and a factor of 1.5 for contingencies, engineering, construction, construction administration, and inspection.

**RETENTION ONLY (no detention required). Size is based on 31.3 ac-ft of volume.

Figure 11 depicts a typical detention basin.

The detention basins can be covered, if desired. The costs vary with the type of cover used and the size of basin. The type of cover used can vary from a plastic floating cover at approximately $7.50 per square foot to a concrete decking that can withstand traffic loads at approximately $75.00 per square foot. For instance, covering the Airfield detention basin would increase the total costs to $1,280,000 for a plastic cover and $10,100,000 for concrete decking.

4.2 Staged Detention Requirements

Discussions between TAA and Pima County led to an agreement which allows for implementation of staged detention basin construction at TIA. Construction must follow the staging sequence outline in a February 12, 1992 letter to Pima County. The sequencing was agreed to by Pima County in a February 24, 1992 response letter. Both letters are contained in Appendix D.

Appendix D also contains the staged detention basin analysis. The analysis was performed to determine hydrologic results relating to 10%, 30%, 50% and 100% level of development at TIA. Results were used to determine the construction sequencing.

Hydrologic results summarized in the February 12, 1992 letter are not meant to supersede those provided in this report. The results presented in the letter are for comparison purposes only in determining levels of staged development. The analysis was performed using the South Fork of the Airport Wash only. Future development will occur in the North Fork as well.

Concentration points utilized for this analysis were chosen at points downstream of all planned development within TIA. These points are:

1. the Airport Wash at the confluence of the South and North Fork;
2. the downstream end of watershed 47 which includes areas 25, 39, 40, 46 and 49 of the Airfield watershed.

Table 11 lists the individual sub-watershed areas with future development in each major watershed (circa 1992). Both the sub-watersheds with future industrial development and runway\taxiway development are listed. The areas listed are at 0%, 10%, 30%, 50% and 100% level of development with zero percent being the current baseline developed acreages (refer to Figures 2 and 10, aerial photographs of existing development at TIA). The total areas of development (both existing and future) according to levels of development are also shown for each major watershed.

Table 11

Total Development Area in Stages (Acres)

Watershed		Total Area	Baseline Area Developed	10%	30%	50%	100%
Airport	North Fork	130	0	13	39	65	130
Wash	South Fork	480	0	48	144	240	480
	Airport (101F)	61	6	11.5	22.5	33.5	61
Airport Wash Total		671	6	72.5	205.5	338.5	671
Airfield	25	19	10	10.9	12.7	14.5	19
Wash	27& 28*	21	9	10.2	12.6	15	21
	29*	20.4	10.4	11.4	13.4	15.4	20.4
	38	17	13	13.4	14.2	15	17
	39	32	13.5	15.4	19.1	22.8	32
	40	38	28	29	31	33	38
	46	58	36.6	38.7	43	47.3	58
	47	51	32.2	34.1	37.8	41.6	51
	49	128	34	43.4	62.2	81	128
Airfield Wash Total		384.4	186.7	206.5	246	285.6	384.4
Hughes	13*	14.2	12.9	13	13.3	13.6	14.2
Wash	22*	45.4	8.4	12.1	19.5	26.9	45.4
	30*	20.4	10.4	11.4	13.4	15.4	20.4
	31*	27.4	26.2	26.3	26.6	26.8	27.4
	42	38	20	21.8	25.4	29	38
	45	6	1	1.5	2.5	3.5	6
	south	544	0	54.4	163.2	272	544
Hughes Wash Total		695.4	78.9	140.5	263.9	387.2	695.4

*Watersheds with runway/taxiway development only. Staged construction numbers shown for comparison only.

Table 12 summarizes hydrologic results specific to the staged detention analysis. Peak discharges are shown for the baseline, 10%, 30%, 50% and 100% levels of development.

Table 12

Hydrologic Results for Staged Detention

Watershed	Baseline Flow (cfs)	10% cfs	10% %*	30% cfs	30% %*	50% cfs	50% %*	100% cfs*
Airport								
- North Fork	3826	3828	2	3859	30	3875	44	3937
- South Fork	3427	3479	12	3568	32	3653	52	3681
Airfield Wash	986	1057	9	1195	26	1346	45	1784

*Indicates percent increase between baseline flow and 100% development.

The Hughes Wash watershed is not included in Table 12 because detention is not required. However, retention is required. The following table shows the retention volumes based on the 10%, 30%, 50% and 100% level of development.

Table 13

Hydrologic Results for Staged Retention

Watershed	10% (ac ft)	30% (ac ft)	50% (ac ft)	100% (ac ft)
Hughes Wash	3.5	10.5	17.5	35.0

The February 12, 1992 letter includes a staged construction schedule based on percentage of new development. The recommended schedule stated therein is "that construction begins at TIA after 30% of development occurs and that the basin be built to the 50% level at that time. Development beyond 50% should relate to staged construction either by matching the percentage of increased development or in 10% increments." "Development", as defined by Pima County in the February 24, 1992 letter included herein, "includes any disturbance to an area such as roads, runways or taxiways, grading, etc." Graded areas that are subsequently successfully revegetated will not be considered as development areas.

Table 14 summarizes the total area of development within each major watershed according to level of development based upon 1992 development levels. The total areas shown do not include the baseline development areas.

Table 14

New Development Area (Acres) 1992

Watershed	30%	50%	60%	70%	80%	90%	100%
Airport Wash	199.5	332.5	399	465.5	532.0	598.5	665.0
Airfield Wash	59.3	98.9	118.6	138.4	158.2	177.9	197.7
Hughes Wash	185	308.3	369.9	431.6	493.2	554.9	616.5

To verify the amount of post 1992 development, drainage reports on file with the Tucson Airport Authority (TAA) were reviewed and summarized. The summary of total area of development within each major watershed according to the current level of development was updated and is summarized below in Table 15. A detail summary of post 1992 development is included in Appendix G.

Table 15

Post 1992 New Development Area (Acres)

Watershed	30%	50%	60%	70%	80%	90%	100%
Airport Wash	189.8	322.8	389.5	455.8	522.3	588.8	655.3
Airfield Wash	28.2	67.8	87.5	107.3	127.1	146.8	166.6
Hughes Wash	175.1	298.4	360	421.7	483.3	545	606.6

The information provided herein is intended as a baseline reference to the detention and retention basin staged construction. The staged construction schedule must be followed in accordance with the Pima County letter as development occurs.

4.3 Airport Master Plan

Detention/Retention Basins

As previously stated, the detention/retention basins have been located in consideration of the proposed Airport Layout Plan (ALP). Based upon the 2023 Master Plan, TAA proposed development in the next 20-years will result in an increase of approximately 201 acres of impervious areas in the Airport Wash Watershed (includes approximately 160 acre ground cargo area) and approximately 89 acres in the Airfield watershed (includes approximately 80 acres of future 11R/29L runway. No TAA development is currently proposed in the Hughes watershed through the 20-year planning period and beyond. Based upon the Planning Demand Level (PDL), the Airport Wash detention will not be required within the 15-year planning period. The Airport Wash basin will be required when the Ground Cargo area is developed in PDL 4, 2018-2023. The Airfield basin(s) will need to be constructed when the future runway 11R/29L is constructed during PDL 2, 2008-2013.

Airport Wash

Several planned facilities are impacted by the Airport Wash. The General Aviation (GA) area to be developed east of Airport Wash south of Taxiway D (PDL 1, 2004-2008), the TSA police office buildings (PDL1, 2001-2008), the Airfield Maintenance area (PDL 1, 2004-2008) and the Country Club Rd. extension (PDL 2, 2008-2013) are planned within the 100-year floodplain for the Airport Wash. In addition, future taxiway F (2023+) will require a drainage structure across the Airport Wash. The finished floor elevations for habitable structures must be elevated 1 ft above the 100-year water-surface elevation for the Airport Wash and outside of the erosion hazard setback for unprotected channel banks (approximately 70 ft). Previous preliminary HEC-RAS analyses (see Appendix H and Reference Section) indicated that encroachment into the 100-year floodplain for the GA area is acceptable, provided structures are constructed outside of the erosion hazard setbacks. Preliminary analysis for the police office buildings (Mannings ratings of the Airport Wash utilizing 1998, 2 ft. contour interval topography, see Appendix H), and their proximity to the wash indicate that bank protection may be required in the vicinity of these structures. A preliminary cost of $162,000 is estimated for gunite bank protection. The impacts of the proposed Airport Maintenance area on the Airport Wash floodplain needs to be evaluated once current topography is obtained. Development of this building must be considered in conjunction with the extension of Country Club Rd. A drainage crossing may be desired at Country Club and the construction of this structure could impact the downstream airfield maintenance area. To adequately determine the impacts of the Airport Wash on future development, a detailed hydraulic model of the reach of the Airport Wash from Country Club to Taxiway D and associated drainage structures is recommended prior to plan preparation for these facilities. Wash improvement may require Army Corps of Engineers 404-permitting and W.A.S.H. Ordinance mitigation (see Section 5). A Federal Emergency Management Agency (FEMA) Letter of Map Revision (LOMR) is also recommended. See Section 5 for further LOMR discussion.

5.0 AGENCY REQUIREMENTS FOR FUTURE DEVELOPMENT

Development at the TIA will require coordination with several agencies. The Corps of Engineers will be involved through the Section 404 permit process; the City will issue building permits and review development projects for drainage compliance; Pima County will require permitting for altered riparian habitat and the Arizona Department of Environmental Quality (ADEQ) will require compliance with the Arizona Pollutant Discharge Elimination System (AZPDES) program.

5.1 Section 404 Permits

Future development which impacts COE jurisdictional limits is subject to the Section 404 Permit process. Currently there are approximately 12 Nationwide Permits (NWP) relevant to airport development however, the maximum acreage limits for impacts to jurisdictional areas for the Nationwides are 0.1 acres without preconstruction notification (PCN) to 0.5 acres with PCN. The use of more than one NWP for a single and complete project is prohibited, therefore use of NWP is limited. An individual permit will be required once jurisdictional impacts surpass the NWP threshold within the airport boundary.

The individual permit process includes application for 401-certifciation from ADEQ. Public notice is issued and the application for individual permits is reviewed by the public, special interest groups local, state and federal agencies. In addition, endangered species and archaeological surveys are required. Currently, a time frame of six months to one year is estimated to obtain an individual 404-permit.

It is strongly recommended that a pre-application meeting be held with all review agencies for any development within the jurisdictional limits on the Airport property. The conceptual plans should be presented to obtain preliminary comments for possible mitigation. The issues which should be addressed for the 404 permit and at the pre-application meeting include whether the area can be avoided by locating the facility elsewhere, whether the impact can be minimized by re-orienting the improvements, and what type of mitigation is possible.

5.2 City of Tucson Requirements

During preparation of conceptual development plans, a pre-submittal meeting should be arranged through the Development Services Center. The purpose of the meeting is to inform the appropriate City agencies of the proposed development and generate relevant input prior to submitting any plans for review. Depending on the complexity of the project, the review process could take from two to four weeks. The project will be reviewed by the City to verify compliance with pertinent codes and ordinances effective at the time of development.

A drainage report referencing this study will be required. The COT will verify compliance with this drainage study and other effective codes and ordinances. A floodplain use permit may be required depending on the location, type, and extent of proposed site improvements. The permit may reference new regulatory measures, recommend finished floor elevations, or include discussion of ordinances for maintaining natural washes. These requirements should be verified when site plans are developed. The review process generally requires two to three weeks per submittal.

The Watercourse Amenities, Safety and Habitat (WASH) ordinance and Environmental Resource Zone (ERZ) Ordinance include regulations which strive to maintain the natural integrity of existing washes within the City. A portion of the Airport Wash is classified as a W.A.S.H Ordinance wash. Portions of the Franco Wash and associated tributaries and tributaries to the Hughes wash are classified as ERZ washes (see Figure 2).

5.3 Pima County Requirements

PCDOT&FCD has agreed that City of Tucson will be the reviewing agency for projects within TIA, which include drainage components. The City of Tucson will be responsible to include Pima County on specific projects per their discretion.

Portions of the Airport, Hughes and Franco washes are identified as Xeroriparian Habitat (A, B and C) on the Pima County Watercourse and Riparian Habitat Protection and Mitigation Requirements riparian habitat maps (Chapter 16.54 Pima County Floodplain and Erosion Hazard Ordinance). Permitting, and possibly mitigation, shall be required if these riparian areas are altered.

5.4 Arizona Department of Environmental Quality

In addition to 401-certification previously mentioned in the Section 404 permits, ADEQ oversees compliance with the Arizona Pollutant Discharge Elimination System (AZPDES) permit program for storm water quality. Any construction project that disturbs an area of 1 acre or more is required to obtain permit coverage under the AZPDES program. To obtain an AZPDES permit, a Notice of Intent (NOI) must be submitted to ADEQ and a Stormwater Pollution Prevention Plan must be prepared and retained onsite.

5.5 Federal Emergency Management Agency (FEMA)

The Airport Wash and portions of Franco Wash are mapped as Special Flood Hazard Areas (Zone A) on the currently effective FEMA Flood Insurance Rate Map for Pima County Arizona. (February 8, 1999). Federal flood insurance is required for habitable structures which are constructed in these areas. Zone A is an approximate mapping method for determination of the limits of the 100-year floodplain. Based upon TSMS modeling, the FEMA peak discharge values for the Airport Wash were revised in October of 1997 (see FEMA letter in Appendix H). The corresponding TSMS 100-year peak discharge for the Airport Wash at Valencia Rd is 4957 cfs (N0620). Based upon recent (2001) HEC-RAS modeling of the Airport Wash downstream of Plumer Ave., which utilized a 100-year peak discharge of 6978 cfs, the FEMA 100-year floodplain for the Airport Wash may be reduced in the General Aviation (GA) area upstream of Taxiway D (see exhibit in Appendix H). Preliminary analyses utilizing a 100-year peak discharge of 4957 cfs indicates that the 100-year water-surface for the Airport Wash may be further reduced, on average, an additional 1 ft in depth. Mannings ratings of the Airport Wash utilizing 1998, 2 ft. contour interval topography and a 100-year peak discharge of 4957 cfs indicates a change in the Zone A delineation of the Airport Wash floodplain between Tucson Blvd. and Plumer Ave. Processing of a Letter of Map Revision (LOMR) for the Airport Wash is recommended. The LOMR process includes submittal of hydrologic and hydraulic modeling data to FEMA along with completed FEMA forms. A review fee of approximately $4200.00 is also required.

6 RECOMMENDATIONS

Two subregional detention basins and one retention basin will be utilized to control flows in the three major watersheds. Detention basins will be implemented in the Airport and Airfield watersheds and a retention basin will be implemented in the Hughes watershed. Figure 10 shows approximate location of the basins. The basin locations are general and may be varied as to size and number. Basin construction will be phased based upon future development threshold within the airport per Section 4.2. Based upon the Master Plan planned development levels, PDLs, the Airfield basin will be required in conjunction with construction of Runway 11R/29L in PDL 1, 2004 -2008. The Airport Wash basin will be required in PDL 4, 2018-2023. The Hughes wash retention basin is not foreseen in the 20-year planning period and beyond.

The basins should comply with the PCDOT&FCD/Cot “Stormwater Detention/Retention Manual” and the other design considerations presented in this report. The operation and maintenance of the detention basins is the responsibility of the TAA. A comprehensive maintenance program must be established for the detention/retention basins. The TAA must establish a program that ensures the basins are operating properly and the basin capacities are not compromised due to vegetation and silting.

Several facilities are proposed adjacent to the Airport Wash in PDL 1. A detail study of the Airport Wash from Country Club to Taxiway D is recommended prior to concept development of these facilities to address floodplain design, permitting and FEMA issues.

REFERENCES

City of Tucson "Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona", December 1989

Federal Aviation Authority AC150/5320-5B "Airport Drainage", July 1970

Federal Highway Administration, HEC-5, "Hydraulic Design of Highway Culverts"

Pima County Department of Transportation and Flood Control District letter date March 20, 1990, Re: Tucson Airport Authority Drainage

Pima County Department of Transportation and Flood Control District and City of Tucson, "Stormwater Detention/Retention Manual"

Pima County Department of Transportation and Flood Control District, "Hydrology Manual for Engineering Design and Floodplain Management Within Pima County, Arizona," September 1979

Stantec, "Airport Wash Hydraulic Study, Plumer Ave. to Taxiway D"   May 2001.

U.S. Army Corps of Engineers, "HEC-1 Flood Hydrograph Package Users Manual", September 1981, Revised March 1987