Lee Moore Wash
Basin Management Study

Summary Report

September, 2009

Stantec Project No.: 185120071

Stantec

Registered Professional Engineer (Civil)
CERTIFICATE NO.
16738
JOHN S.
WISE
Date Signed 9/14/09
ARIZONA, U.S.A.
Expires 12/31/10

Registered Professional Engineer (Civil)
CERTIFICATE NO.
41207
JOHN B.
PARTRIDGE
Date Signed 9-14-09
ARIZONA, U.S.A.
Expires 9/30/10

ACKNOWLEDGEMENTS

Stantec Consulting Inc. would like to acknowledge and thank the following people instrumental in completing the Lee Moore Wash Basin Management Study (LMWBMS). First and foremost, the Pima County Regional Flood Control District that provided funding for the project, and the key members of the County project team that lent their support and guidance throughout the course of the study. The PCRFCD Project Manager, Mr. Bill Zimmerman, provided countless hours, guidance and invaluable executive-decision making that allowed the project to stay on track and meet key scheduling deadlines. In-depth technical discussions with Mr. Evan Canfield, Chief Hydrologist, and other PCRFCD staff members also provided important insights as the project progressed through the various stages toward completion. In addition, we are indebted to the prime subconsultants involved with the LMWBMS; JE Fuller Hydrology & Geomorphology for their technical expertise, and C.L Williams Consulting, Inc. and Gordley Design Group, Inc. that led the project through the public and private stakeholder scrutiny phases of the LMWBMS; as well as the Development Criteria and Implementation Plan tasks. All provided much-appreciated support needed to meet deadlines, as well as contributions in compiling this Summary Report for the LMWBMS. The completion of the project was truly a joint effort that involved a multi-disciplinary project team including both the public and private sectors.

Lee Moore Wash Basin Management Study

Summary Report

Table of Contents

LIST OF FIGURES AND EXHIBITS

LIST OF TABLES

APPENDIX (CD)

ALTERNATIVE ANALYSIS DOCUMENTS

LIST OF SEPARATE DOCUMENTS

Lee Moore Wash Basin Management Study - Existing Conditions Analysis, *February 8, 2008a*, Stantec Consulting Inc.

Hydrogeologic Evaluation of the Lee Moore Wash Study Area, *July 5, 2007,* GeoSystems Analysis, Inc.

Geomorphic Analysis Report for the Lee Moore Wash Basin Management Study, Pima County, Arizona, *August, 2008a,* JE Fuller Hydrology & Geomorphology, Inc.

Two-Dimensional Flow Analysis Report for the Lee Moore Wash Basin Management Study, Pima County, Arizona, *December, 2008b,* JE Fuller Hydrology & Geomorphology, Inc.,

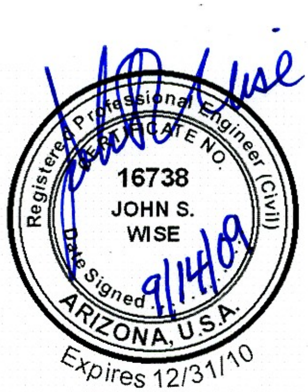
Lee Moore Wash Basin Management Study - Hydrologic and Hydraulic Report, *December, 2008b,* Stantec Consulting Inc.

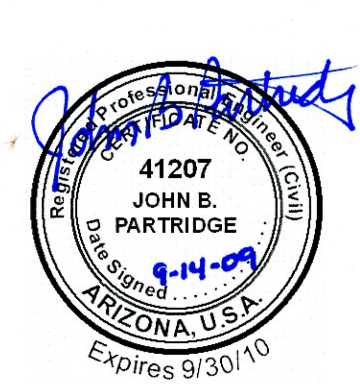
Lee Moore Wash Basin Management Study - Hydrology and Hydraulic Report - Technical Appendices, *December, 2008c,* Stantec Consulting Inc.

Lee Moore Wash Basin Management Study - Public Involvement Report, *June 15, 2009a,* C.L. Williams Consulting, Inc.

Lee Moore Wash Basin Management Study - Development Criteria, *(draft) August 21, 2009b* C.L. Williams Consulting, Inc.

Lee Moore Wash Basin Management Study - Implementation Plan, *2009,* C.L. Williams Consulting, Inc.





1.0 Executive Summary

This report presents a summary of the studies performed by Stantec Consulting, Inc., JE Fuller Hydrology and Geomorphology, Inc., and C.L. Williams Consulting, Inc. for the Lee Moore Wash Basin Management Study (LMWBMS), a 198 square mile watershed situated within southeastern Pima County. The LMWBMS project area extends from the Santa Rita Mountains to the east/southeast to the Lee Moore Wash and Santa Cruz River along the western margin. The watershed consists of eight tributaries, generally known as Gunnery Range Wash, Sycamore Canyon Wash, Fagan Wash, Cuprite Wash, Petty Ranch Wash, Flato Wash, Summit Wash, and Franco Wash (Exhibit A). Headwaters of the larger tributaries are situated within the Santa Rita Mountains and generally drain west-northwest. The Summit Wash and Petty Ranch Wash are situated within valley areas of the northwestern portion of the Lee Moore watershed. All watercourses within the study watershed ultimately discharge to the Lee Moore Wash or Santa Cruz River.

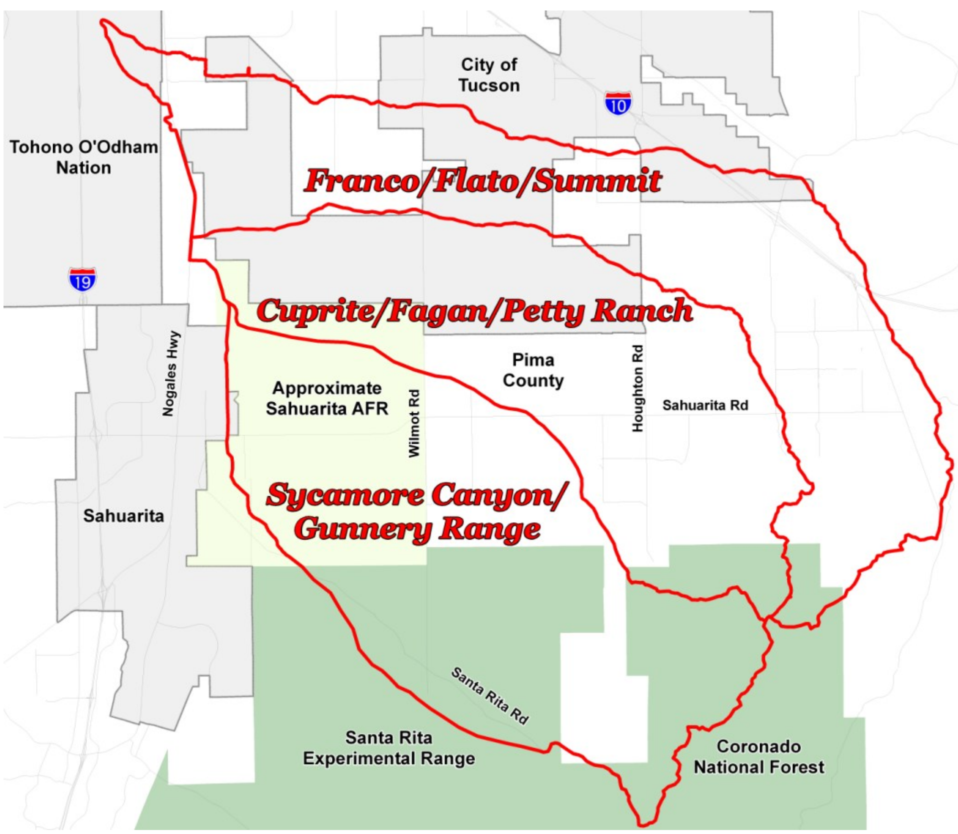


Exhibit A - Location Map and Major Watersheds

The project area is characterized by landscapes typical of the semi-arid areas of the southwest, with the Santa Rita Mountains rising above the valley floor, and alluvial fans situated at the base of the mountains comprising the mountain foothills. Vegetation ranges from limited woodlands in the higher elevations to desert shrub/scrub mix prevalent within the valley floor areas. The full range of ephemeral channels, from steep gradient, mountain washes with coarse sediment loads to sand-bed washes within the lower gradient areas, characterize the drainage area's channel system. The dominant stream channel morphology within the study area is a distributary channel network comprised of numerous, ill-defined channels capable of flowing in multiple directions, and the unpredictable nature of these networks plays a major role in planning efforts for the LMWBMS. An example of this type of drainage network is displayed in Exhibit B.

Exhibit B - Aerial View of Distributary Channel Network

The study area is composed of six different jurisdictional entities, including Pima County, City of Tucson, Town of Sahuarita, Santa Rita Experimental Range, Coronado National Forest, and the Tohono O'Odham Nation (San Xavier District). The unincorporated areas within the Pima County jurisdiction encompass the majority of the study area, and the majority of the land is presently undeveloped and managed by governmental entities. The private land holdings that are developed are typically rural residential and limited areas of suburban residential land uses. Environmentally sensitive lands, including riparian habitat resources, biological corridors, historic and cultural sites within the LMWBMS project area, have been designated for conservation purposes by various jurisdictional plans. The Pima County Sonoran Desert Conservation Plan (SDCP) is a long-range conservation plan that seeks to protect and enhance the natural and cultural environment, with efforts focused on six elements, including Habitat Corridors, Cultural Resources, Mountain Parks, Ranch Conservation and Riparian Protection. The County's plan is structured to reflect the natural system through the conservation of large landscape reserve areas, including parks, preserves and riparian resources in order to provide protection of endangered and vulnerable species.

The purpose of the Lee Moore Wash Basin Management Study (LMWBMS) is to provide a comprehensive flood control protection program and develop floodplain management protocol, while enhancing public safety, fiscal responsibility, and habitat preservation through a balanced multi-objective approach. The study is intended to provide guidance and regulatory authority to discourage development in flood prone areas by minimizing encroachments into regional floodplains, and establishing a watershed-wide "backbone" drainage system, primarily by employing a natural flow corridor concept (Exhibit C). In addition, the study will ensure that the floodplain management regulations/guidelines incorporate a multi-objective approach, which will balance the competing community and private interests. These objectives were met through a systematic and multi-disciplinary process of documenting existing hydrologic, geomorphologic and hydraulic conditions, and evaluating the results of these studies to determine the most effective program to mitigate existing and future drainage issues.

JE Fuller Hydrology and Geomorphology (JEF) prepared a geomorphic assessment of the Lee Moore Wash drainage basin to document existing flow related hazards. Based on this study, recommendations were developed to assist floodplain managers, engineers, and development reviewers in planning for future development of roads, infrastructure, and other amenities within the study area. The assessment was based on review of maps and publications prepared by others, new analysis and field reconnaissance by the Consultant, as well as review of hydraulic modeling prepared by Stantec and JEF as a separate task of this project. Details of this study are presented as a separate volume (JEF, 2008a) of the LMWBMS.

The northernmost watersheds; Franco Wash, Flato Wash, and Summit Wash, represent relatively well-defined drainage areas, and lent themselves to traditional one-dimensional hydrologic and hydraulic modeling techniques. Detailed watershed analysis and modeling associated with these areas was performed by Stantec Consulting. The central portion of Flato Wash, and areas south, display far less watershed definition and channel development, and were analyzed using two-dimensional FLO-2D hydrologic and hydraulic modeling. This area represents approximately 65% of the total Lee Moore watershed, and detailed analysis and modeling for these areas were performed by JEF. Detailed reports associated with these studies are also presented in separate report volumes (Stantec, 2008b, JEF, 2008b). Exhibit C displays the results of the 100-year floodplain modeling associated with the LMWBMS efforts.

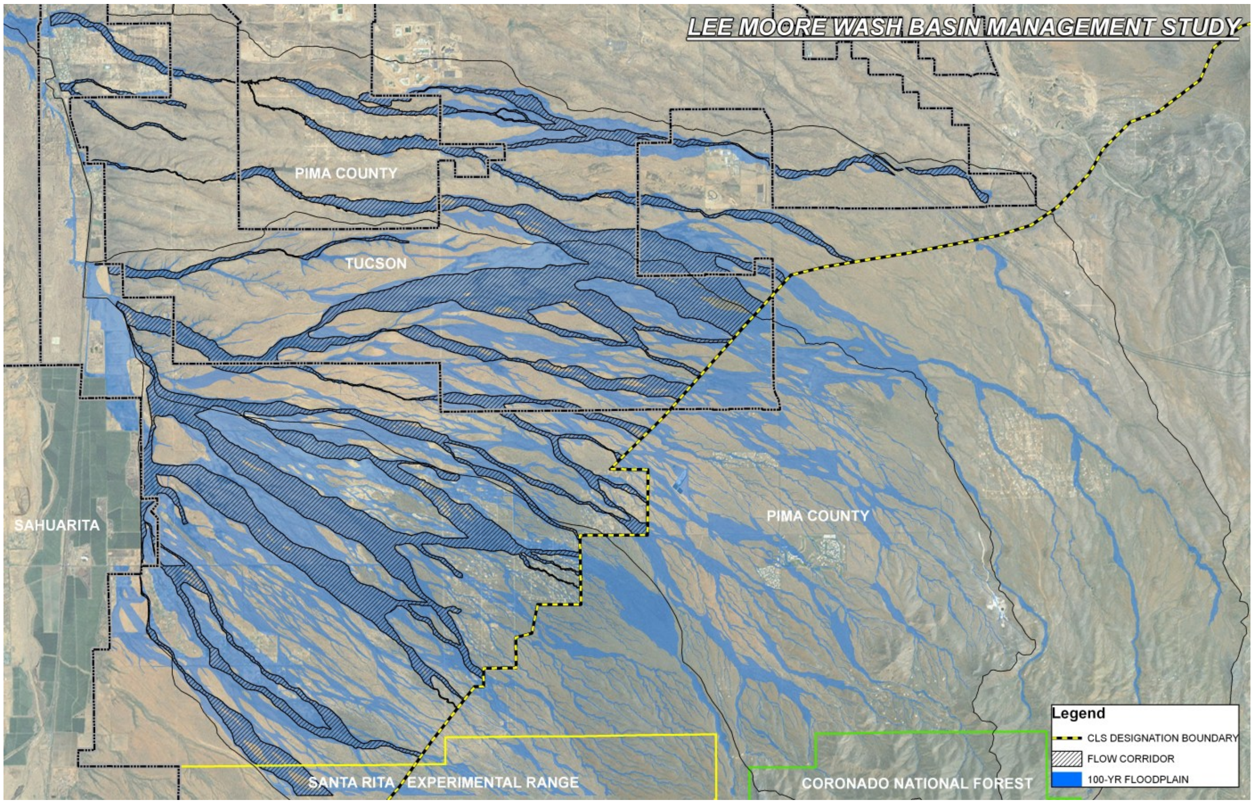


Exhibit C - 100-year Floodplains and Proposed Flow Corridors

While the focus of these studies documented existing drainage conditions, a major component of the LMWBMS was to identify specific alternatives and programs intended to mitigate existing flooding problems identified with these efforts. Planning efforts also focused on minimizing additional concerns associated with proposed future development anticipated within the project area. In order to develop watershed-wide solutions, a comprehensive, systematic approach was employed to evaluate the full range of potential alternatives in an objective manner. Initially, alternatives were analyzed solely on their merits in meeting specific performance criteria; public safety and flood hazard mitigation, implementation, environmental resources, sustainability, and planning and infrastructure needs, with a ranking system developed among the five categories relative to their importance. Workgroups were formed with project team members and stakeholders with expertise in each of the chosen disciplines, and a system of weighting various alternatives was developed. Ultimately, recommended alternatives for the study were chosen on the basis of these criteria through an overall weighting process intended to designate the preferred solutions in the most objective manner as possible.

Sixteen different alternative solutions, focused on mitigating the identified drainage issues, represented the final suite of recommended alternatives for the LMWBMS, with the recommended alternatives including both structural and non-structural solutions. Structural alternatives, which address existing drainage issues, ranged from the installation of new culverts, construction of bank stabilization, floodproofing, to construction of regional detention facilities. Non-structural alternatives will involve public education and outreach, and potential implementation of the FLAP (Floodplain Land Acquisition Program) and/or improvement districts. Future recommended alternatives were much more broad-based in nature, and with the exception of the construction of regional detention facilities, were generally non-structural in nature. The major components of future alternatives involve generating Development Criteria, intended to provide regulations and guidelines for future development within the area, and the delineation of a network of flow corridors throughout the study area. Public education and outreach, as well as recommending modifications or changes to future roadway alignments to avoid floodprone areas, were also recommended alternatives associated with the future analyses.

The Public Involvement Plan for this project was designed to fulfill the promise of “consult” on the International Association for Public Participation (IAP2) Spectrum of Public Participation: to keep the public informed, listen to and acknowledge concerns and aspirations, and provide feedback on how the public input was considered in the decision. The goal of the plan was to bring more information into the study for consideration, provide additional perspectives on alternatives in order to reach the best outcome, and greater public understanding, support and acceptance of the study and its final outcome. The plan outlined 12 stakeholder workgroup meetings, 12 individual stakeholder meetings and six public meetings (three rounds of two meetings).

The actual effort materialized as seven workgroup meetings (three rounds of two meetings - one for public agencies and one for private organizations; the final meeting combined both public and private), seven stakeholder meetings (one each with Diamond Ventures, Pima Association of Governments, Arizona State Land Department, Southern Arizona Home Builders Association and Tucson Water, and two with City of Tucson staff), three rounds of two public meetings (each round included a meeting on both the east and west sides of the study area, for a more inclusive approach), and an additional two (2) public meetings were held in the Summit area to address specific flooding and drainage needs in that area. Additionally, 10 focus group meetings were held with staff from both public agencies and private organizations to collaboratively discuss and edit the Development Criteria for the LMWBMS.

The Development Criteria identified herein are part of the non-structural Recommended Alternative of the LMWBMS. Adherence to these development criteria will lessen the adverse impacts of urbanization and decrease the cost of flooding for the public and private sectors. Over the past few decades that the County has been managing floodplain areas, it has become apparent that there is a lack of tools to adequately manage individual lot development, especially in distributary flow areas. In addition, as part of this basin management study, it was determined that Development Criteria which focused both on single-family development on individual lots, standard subdivisions and/or large master planned developments could reduce flood and related damage within the Lee Moore Wash watershed. As a result, a major component of the study presented herein establishes preferred, natural flow corridors to convey flows within these areas, as illustrated in Exhibit C.

Approximately 48% of the LMWBMS area is owned by the state of Arizona and managed by the Arizona State Land Department (ASLD). ASLD manages lands in compliance with the Enabling Act, the Arizona Constitution, and Arizona Revised Statutes Title 37 which require that State Trust Lands be managed in the best interests of the designated State Trust beneficiaries. As such, certain elements of the Development Criteria may not have the same regulatory compliance authority with regards to State Trust Lands as it does to land owned by others. The principles, policies and practices contained within the Design Criteria provide a useful method for insuring a consistent and comprehensive approach to floodplain management within the Study area; therefore it is in the best interest of all land owners and jurisdictions to comply with these Development Criteria to the fullest extent possible.

The Stakeholder Involvement program for this project was designed by C.L. Williams Consulting, Inc. (CLW), and completed with the goal of maximizing implementation opportunities for the Recommended Alternative of the LMWBMS. The results of the Stakeholder Involvement and Implementation Strategy are summarized in the forthcoming accompanying Implementation Plan (CLW, 2010), which is a separate volume of the LMWBMS. The Implementation Plan details the Recommended Alternative by location, capital improvement costs, potential cost sharing partner, participation interest, potential mechanism for participation and preliminary timeline when ever possible. The Implementation Plan is being developed iteratively and in cooperation with the affected stakeholders. It does not represent a binding legal agreement on any partners, but does provide a solid summary of implementation efforts to date, as well as a roadmap for the Pima County Regional Flood Control District implementation efforts once the LMWBMS is adopted by the Board of Directors, and potentially by the City of Tucson and Town of Sahuarita. Several of the Recommended Alternatives are connected with other agency programs. The result is that often their schedule or funding will drive the implementation timeline. Recognition of this fact by the District and planning for this in future follow through efforts will allow for cost effective and efficient construction completion. If the coordination is not continued after LMWBMS completion, it is possible that other agencies will move ahead with their projects and not include Recommended Alternatives drainage improvements.

The Recommended Alternatives for this project are comprised of structural and non-structural solutions at various locations. These locations are distributed throughout the project area and include construction and non-construction activities that will ultimately be funded in one of three ways:

1) Solely funded by the District.

2) Funded solely or in partnership among private and/or public agencies including the District.

3) Funded solely or in partnership among private and/or public agencies **not** including the District.

The Recommended Alternatives were developed after extensive technical review of the drainage, infrastructure and land use conditions in the project area. Significant effort was also put forth by the project team to involve the general public, as well as public and private sector stakeholders, in development of the Recommended Alternatives. Included within the LMWBMS report is documentation of the public and stakeholder activities and responses.

2.0 Introduction

This document presents a summary of multi-faceted studies (performed primarily by Stantec Consulting, Inc., JE Fuller Hydrology and Geomorphology, Inc., and C.L. Williams Consulting, Inc., and other specific specialty subconsultants) for the Lee Moore Wash Basin Management Study (LMWBMS), a 198 square mile watershed situated within southeastern Pima County. The Lee Moore watershed has been the subject of study in previous efforts performed by the County in 1988 (PCDTFCD, 1988). The current study documents existing physiographic conditions within the watershed, including geomorphology, hydrology, and floodplain characteristics, as well as land use, infrastructure and flood incident areas. Future infrastructure needs and anticipated areas of development were also identified. Based on constraints and issues identified with these studies, a multitude of alternative solutions and programs were developed in a workgroup environment, and a systematic, objective weighting approach was applied to determine a suite of recommended alternatives. These alternatives were further evaluated from a feasibility perspective, and a proposed set of solutions was developed intended to address both existing issues and future planning concerns. In conjunction with these efforts, specific development criteria were developed, along with a comprehensive implementation plan to address both funding sources and schedule.

The following sections provide a brief description of the study area, project scope, and objectives of the Lee Moore Wash Basin Management Study. Summary descriptions of specific procedures and results comprise the subsequent sections of this report.

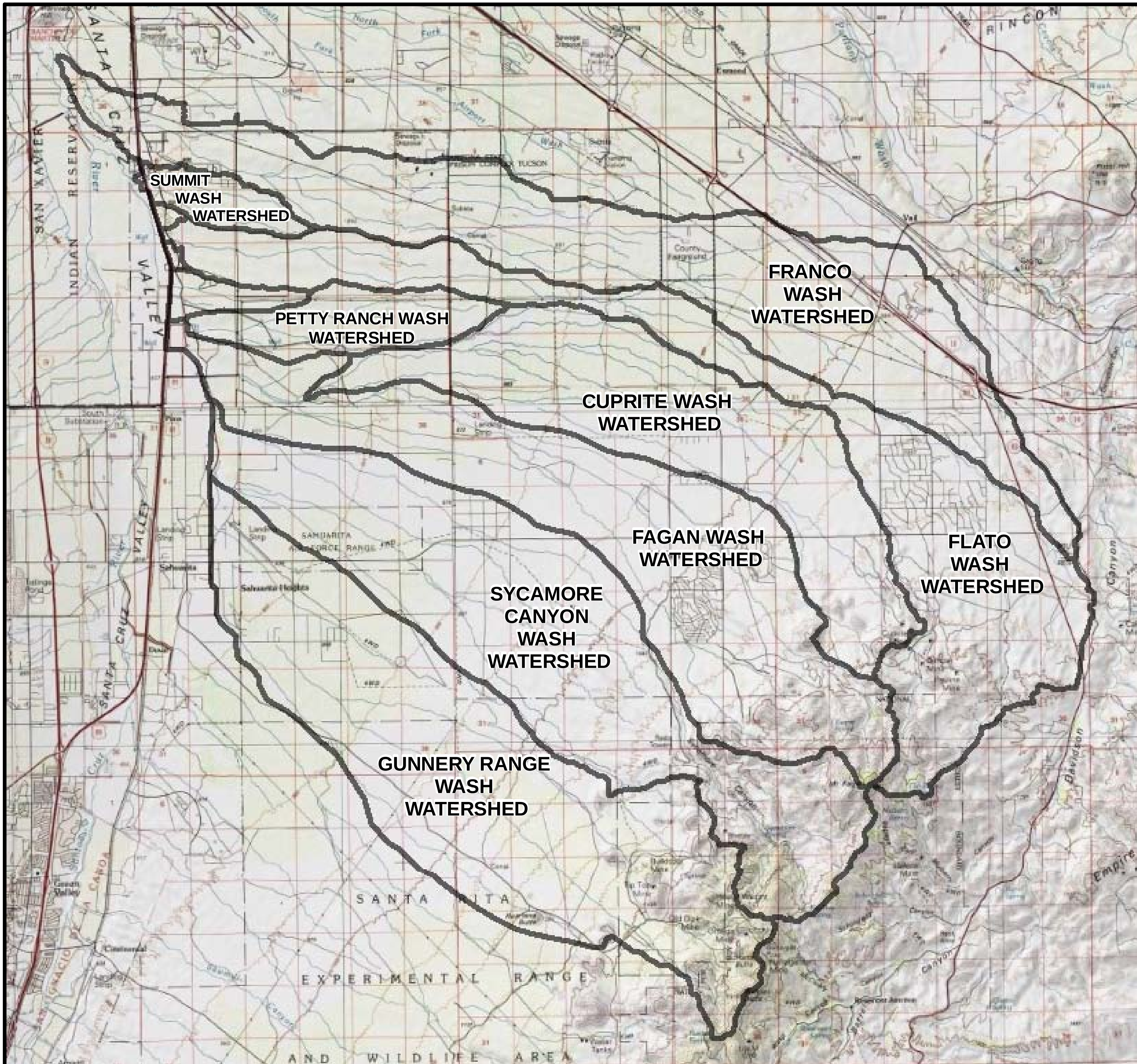
2.1 DESCRIPTION OF PROJECT AREA

The Lee Moore project area extends from the Santa Rita Mountains in the east/southeast portion of the study area to the Lee Moore Wash and/or Santa Cruz River along the western margin, with the studied watershed area comprising about 198 square miles. The watershed east of the Lee Moore channel primarily consists of eight tributaries, with these watercourses designated as Gunnery Range Wash, Sycamore Canyon Wash, Fagan Wash, Cuprite Wash, Petty Ranch Wash, Flato Wash, Summit Wash, and Franco Wash. Headwaters of the larger tributaries are situated to the southeast within the Santa Rita Mountains and/or associated foothill areas, and watercourses generally drain west-northwest to the Lee Moore Wash. The

Summit Wash and Petty Ranch Wash are smaller tributaries situated within valley areas of the northwestern portion of the Lee Moore watershed. The Lee Moore Wash channel discharges to the Santa Cruz River just north of it's confluence with Summit Wash. The northernmost watercourse, Franco Wash, discharges directly to the Santa Cruz River north of the Lee Moore Wash confluence. The referenced major watersheds and overall study area are displayed in Figure 1.

The project area is characterized by a variety of landscapes common to the semi-arid areas of the southwest, with the Santa Rita Mountains rising 3600 feet above the valley floor, and alluvial fans situated along the base of the mountains that comprise the mountain foothills. Vegetation consists of the typical array of southwest desert plant species, ranging from limited woodlands in the higher elevations to desert shrub/scrub mix prevalent within the valley floor areas. The full range of ephemeral stream types are exhibited within the drainage area's channel system, from steep gradient mountain streams characterized by coarse sediment loads to sand-bed washes displaying a much less coarse sediment distribution within the lower gradient areas. The dominant stream channel morphology within the study area, however, is a distributary channel network comprised of numerous, ill-defined channels capable of flowing in multiple directions during a given storm event. The unpredictable nature of these systems plays a major role in both existing and future planning efforts for the Lee Moore study area.

The Lee Moore Wash Basin Management Study area is composed of six different jurisdictional entities, including Pima County, City of Tucson, Town of Sahuarita, Santa Rita Experimental Range, Coronado National Forest, and the Tohono O'Odham Nation (San Xavier District). The unincorporated areas within the Pima County jurisdiction encompass the majority of the study area. The majority of the land within the Lee Moore Wash Basin Management Study area is managed by governmental entities and is presently undeveloped. The private land holdings that are developed are typically rural residential, with limited areas of suburban residential land uses. The suburban residential developments are concentrated near the intersection of Sahuarita Road and Houghton Road.



File: W:\active\185120071\GIS(directory)\alternatives\WATERSHED_MAP.mxd 1/21/2009

Lee Moore Wash
Basin Management Study

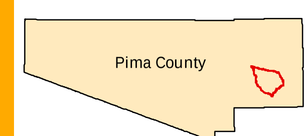
Figure 1
Project Area

Legend

Watershed Boundaries

N

Miles
0 0.5 1 2 3



Stantec Consulting, Inc
201 North Bonita Avenue Ste. 101
Tucson, AZ 85745-2999

2.2 DESCRIPTION OF PROJECT

2.2.1 Project Objective

The purpose of the Lee Moore Wash Basin Management Study is to provide a comprehensive flood control protection program and develop floodplain management protocol, while enhancing public safety, fiscal responsibility, and habitat preservation through a balanced multi-objective approach in managing the watersheds, floodplains and resources in the study area. The study is intended to provide guidance and regulatory authority to manage development in flood prone areas by minimizing encroachments into regional floodplains, while relying on interagency coordination to preserve the hydrologic integrity and stormwater conveyance characteristics of the regional watersheds. In addition, the study will ensure that the floodplain management regulations/guidelines incorporate a multi-objective approach, which will balance the competing community and private interests.

2.2.2 Project Scope

The general scope of work for the Lee Moore Wash Basin Management Study (LMWBMS) is to identify flood and erosion hazard areas, drainage problems, and cost-effective solutions to manage floodwaters in the Lee Moore study area. The study focus for the LMWBMS included the following tasks: identification of drainage problems and the impact of development in the area; hydrology; hydraulics; identification of flood and erosion hazard remediation solutions; identification of preservation corridors; alternative development; development criteria; implementation plan; stakeholder involvement; and public involvement and coordination. The original scope for the LMWBMS was developed in conjunction with the staff at the PCRFCD, and specific efforts have evolved over the span of the project that has encompassed more than two years. These efforts included multi-duration storm distribution evaluations and expanded two-dimensional modeling analyses (performed by subconsultant JE Fuller Hydrology & Geomorphology, Inc.) that are incorporated in the study results presented in this report.

2.2.3 Project Participation

Development of the Lee Moore Wash Basin Management Study focus and direction involved the participation of numerous agencies and entities from the project's initiation. Monthly project update meetings were held that included representatives of various staff from the Pima County Regional Flood Control District (PCRFCD), Pima County Department of Transportation, City of

Tucson, Town of Sahuarita, Tucson Water, as well as the Arizona State Land Department. Public and private stakeholder meetings were held at specific stages of the project intended to update interested parties, as well as gather insight on the project from the attendees. Meetings were also scheduled with the general public. Many of the representatives at the stakeholder and project update meetings were also involved in workgroup and focus group sessions to develop concepts and alternatives that ultimately served as recommended alternatives for the LMWBMS. In this manner, the proposed direction of the study represents the result of a collaborative effort of all stakeholder interests within the project area.

3.0 Existing Conditions

3.1 STUDY AREA (summarized from Stantec, 2008a)

The Lee Moore Wash watershed is situated within southeastern Pima County, with the watershed headwaters lying within the upper elevations of the Santa Rita Mountains. The Santa Cruz River runs along the western margin of the study area, and ultimately collects runoff from all drainage areas within the Lee Moore Wash basin. The study area is generally composed of six jurisdictional entities, with the unincorporated areas of Pima County encompassing the majority of the area. The City of Tucson has annexed the northern portion of the study area, while the Town of Sahuarita (currently occupying a limited area along the southwest margin of the study area) plans to eventually expand easterly beyond current corporate limits. The southern portions of the study are located within the Coronado National Forest and the Santa Rita Experimental Range (SRER). A brief description of existing conditions documented with the study is presented below. A more detailed discussion is provided in the Existing Conditions Analysis Report (Stantec, 2008a), submitted as a separate document.

3.1.1 <u>Land Development</u>

The majority of the land within the Lee Moore Wash Basin Management Study area is managed by governmental entities and is presently undeveloped. The U.S. government holds title to the Coronado National Forest, while the U.S. Bureau of Land Management (BLM) ownership includes about 2500 acres. About 900 acres of the area is comprised of the Tohono O'Odham Nation lands (San Xavier District). The State of Arizona ownership includes about 62,000 acres of state trust land, as well as the Santa Rita Experimental Range. The Arizona State Land Department plans and manages the state trust lands, which over the long-term are sold at public auction for residentially zoned properties, or leased for commercial parcels with proceeds benefiting the public school system.

The private land holdings have developed as rural residential, with limited areas of suburban residential land uses. The rural residential land uses typically consist of four acre-sized lots within unrecorded 'wildcat' subdivisions dispersed throughout the study area. Suburban residential land uses are concentrated near the intersection of Sahuarita Road and Houghton

Road in Corona de Tucson, as well as the New Tucson area situated to the east. Master planned communities in the region include Santa Rita Ranch located southeast of the Sahuarita/Houghton intersection, and Rancho Sahuarita situated immediately west of the study area. Both master planned communities include various sized single-family detached residential lots. One of the more intensely developed areas is located within the northwest portion of the project area along the Nogales Highway corridor, and is generally known as the Summit area. Many of the existing drainage problems within the project area are located within unrecorded subdivisions, such as in the Summit area, as well as older recorded subdivisions within the New Tucson and Corona de Tucson areas. Older unrecorded developments within the Sahuarita area in the southwest portion of the watershed also experience existing flood-related issues.

3.1.2 Environmental Setting

Environmentally sensitive lands, including riparian habitat resources, biological corridors, historic and cultural sites within the Lee Moore Wash Basin Management Study area have been designated for conservation purposes by various jurisdictional plans. The Pima County Sonoran Desert Conservation Plan (SDCP) is a long-range conservation plan that seeks to protect and enhance the natural and cultural environment. The planning efforts of the SDCP focused on six elements, including Habitat Corridors, Cultural Resources, Mountain Parks, Ranch Conservation and Riparian Protection. The County's plan is structured to reflect the natural system through the conservation of large landscape reserve areas, including parks, preserves and riparian resources in order to provide protection of endangered and vulnerable species.

The Pima County Conservation Land System and Riparian Resources elements of the SDCP identified biological resource areas and corridors throughout the Lee Moore Wash Basin Study area. According to the Conservation Land System policies, Important Riparian Areas have the highest level of biological resources and should retain 95% of their existing resources, while the Biological Core Management Areas located primarily in the southeast portion of the study area should retain 80% of their biological resources. Pima County's Watercourse and Riparian Habitat Protection ordinance has also designated and mapped 'regulated riparian habitat' including Important Riparian Areas and Xeroriparian habitats within the study area. Important Riparian Areas are valued for their higher water availability, vegetation density and biological corridors, whereas Xeroriparian habitats are generally associated with an ephemeral water supply.

The City of Tucson in 2006 prepared the Preliminary Draft Habitat Conservation Plan (HCP) that includes the Southlands sub-area, which represents 25,620 acres of city annexed land that is situated within the Lee Moore Wash Basin Management Plan area. The City's HCP is intended to promote conservation of natural resources while providing for future growth, as well as complement other regional conservation planning efforts such as Pima County's SDCP. The primary component of the HCP Southlands conservation program is the protection of habitat within the Petty Ranch and Fagan watersheds.

3.1.3 Hydrogeology (summarized from GSA, 2007)

The Lee Moore Wash study area is located in the southern portion of the Tucson Basin, which is a sub-basin of the Upper Santa Cruz River Basin within the southern Basin and Range physiographic province. The study area lies across a deep sedimentary basin, with depths to bedrock ranging from less than 400 ft below ground surface (bgs) at the base of the Santa Rita Mountains up to in excess of 11,000 ft bgs in the north-central portion of the area. The upper basin fill material contains the primary aquifer and is comprised of surficial alluvial deposits overlying the Fort Lowell Formation, which in turn overlie the Tinaja Beds. These latter two units overlie the lower basin fill associated with the Pantano Formation.

Present-day stream channels contain the youngest surficial deposits, which were laid down by a north-northwest-flowing stream system; deeper, older stratigraphic units were deposited primarily in closed basin environments and, hence, may contain more fine-grained materials. Surficial deposits along streams are 40 to 100 ft thick, and on the average contain approximately 50 ft of coarse material. The older terrace deposits are more compacted and cemented than the younger stream deposits, and are therefore not favorable for groundwater recharge.

Groundwater flow is toward the northwest, except near the Santa Cruz River where groundwater levels have been elevated by the implementation of the Pima Mine Road Recharge Project (PMRRP) located just west of the study area. Based on data from 63 wells having water level measurements in both 1995-6 and 2005-6, 3 wells showed no change, 27 wells showed declines between 1 and 25 feet and 33 showed recoveries between 3 and 76 ft (mean recovery of 38 ft) near the PMRRP. Water levels in wells located east of that area range in depth from 42 to 555 ft bgs and have declined an average of 12 feet in the 10-year period.

Regional groundwater levels below riparian habitat corridors identified by Pima County within the study area are well below the maximum depth (10-30 feet bgs) typically used by facultative phreatophytes, such as mesquite, which inhabit these zones. Although the groundwater elevation data in some areas are sparse, these data indicate that the riparian species in these areas are most likely supported by seasonal precipitation stored within the vadose zone (i.e. perched water), and are not connected to the regional aquifer system.

3.1.4 <u>Drainage</u>

Existing drainage infrastructure within the area is limited, and was documented using a variety of available sources, including locations identified from field survey. In addition to the existing drainage infrastructure, over 100 locations of existing stock ponds and historic flow diversions were identified by review of available existing aerial photography. Locations of all drainage structures and stock ponds were located through the use of a GIS database, and base maps developed for the project area.

Extensive drainage complaints within the Lee Moore Wash watershed have been recorded over the last 10 years by Pima County. These complaints were sorted into three general categories on the basis of each complaint's primary drainage emphasis; flooding issues, roadway or access issues, and conveyance or ponding issues. The locations of each complaint within the Lee Moore watershed are also mapped through the use of a GIS database. In general, the complaints relate flooding issues within the Lee Moore watershed predominantly to undersized culvert crossings, limited access due to roadway flooding and shallow sheetflow flooding.

Newspaper articles from 2005-2006 document that monsoon rains had caused several flooding incidents within the Lee Moore Wash watershed area, predominantly along Franco Wash and associated areas near Old Nogales Highway and Old Vail Connection. This area, known as the Summit area, has experienced significant population growth in recent years, and much of the growth has occurred within 'wildcat" development. These areas typically require little regulation relative to permitting along floodprone areas. This circumstance combined with heavy rainfall events in August of 2005 and 2006 led to flooding of mobile homes, along with access problems along private and public roadways. Due to these issues, a more in-depth study was performed in this area, and mitigation measures were evaluated in order to determine the feasibility of providing flood relief to these areas as a joint effort between Pima County and existing residents in the area. A summary of these efforts is presented in Section 3.3 of this report.

3.2 GEOMORPHIC ASSESSMENT (summarized from JEF, 2008a)

JE Fuller Hydrology and Geomorphology (JEF) prepared a geomorphic assessment of the Lee Moore Wash drainage basin to document flow related hazards. JEF provided recommendations to assist floodplain managers, engineers, and development reviewers in planning for future development of roads, infrastructure, and other amenities within the study area. The assessment was based on review of maps and publications prepared by others, new analysis and field reconnaissance by JEF, and review of the hydraulic modeling prepared by Stantec and JEF as a part of this project. Details of this study are presented as a separate volume of the Lee Moore Wash Basin Management Study (JEF, 2008a).

3.2.1 Summary of Review and Field Work

The studies, maps, and reports reviewed included some specific to the study area, and several specific to the broader Southwest United States region. The studies included climate studies, flood hazard studies, flow path stability assessments, and policies and guidelines prepared for other similar studies. The maps reviewed included USGS 7.5 minute quadrangle maps, AZGS Surficial geology maps, PAG topographic maps and aerial maps, NRCS soil studies and maps, and historic aerial and repeat ground photographs. Field visits were conducted throughout the project area. Approximately 200 locations were cataloged to document sedimentation, erosion, structural failure, headcutting, stable locations, and other areas of interest.

3.2.2 Physiography

The Lee Moore Wash catchment is an alluvial basin situated on the western piedmont of the Santa Rita Mountains and east of the Santa Cruz River, within the Sonoran Desert subprovince of the Basin and Range physiographic province. This province was generally formed by tectonic activity with north-south trending normal faults formed by the extension and stretching of the continental crust. The tectonic activity which constructed this province has been followed by exposed bedrock weathering, subsequent alluvial fan formation, and filling of the intermontane basins.

The study area piedmont is linked to the Santa Cruz River by flow paths which drain directly to this axial stream. The Santa Cruz River has experienced substantial downcutting, both recently and historically, which has subsequently caused downcutting of tributaries and adjacent piedmonts. Fan surfaces which were once active and aggrading became isolated, and are currently experiencing degradation.

Annual runoff within the study area is relatively low, less than 13 inches, and typical of the southwest United States. A hydrologic year will usually have two peaks in precipitation, with one in the winter and one in the summer. On average, July and August have the greatest total rainfall depths of the year, and this combined volume can accumulate as much runoff as the rest of the year. While rainfall is relatively rare throughout the year, intense rainfall can cause important flash flood responses within the basin.

Drainage within the basin is towards the west and northwest, ultimately discharging to the Santa Cruz River. The flow patterns vary within the basin; tributary flow occurs in the upper basin, distributary flow within the lower to middle portion of the piedmont plain, and incised tributary flow near the Santa Cruz River. The vegetation within the majority of the basin is Sonoran Desert Scrub, however grassland areas are found within the higher elevations. Vegetation within the basin is currently in good condition in most of the undeveloped areas.

3.2.3 One and Two Dimensional Flow Areas

JEF delineated a boundary between one-dimensional and two-dimensional flow modeling based on field reconnaissance and review of topographic maps and aerial maps which determined locations of flow divergences and confluences. Topography was analyzed for slope and contour shape, namely crenulation indicating containment of flows. This boundary was used to support the delineation of those areas which could be modeled with HEC-HMS and HEC-RAS versus those which should be modeled with FLO-2D.

3.2.4 Flow Related Hazards

Flow related hazards include distributary flow, headcutting, lateral erosion and migration, sedimentation, and localized scour. Headcutting and lateral erosion risks are greatest in the northwest and furthest down-gradient parts of the basin. Locally induced headcutting occurs basin wide and may be a result of upstream influences and human activity (discharge concentration and/or sediment reduction). Lateral migration and distributary flow are found throughout the lower piedmont. Sedimentation is limited to flow corridors, and primarily within distributary flow areas.

3.2.5 Geomorphic Study Zones

The study area was divided into four broad geomorphic zones based upon similar land forms, flow related hazards, and drainage characteristics. The purpose of delineating these zones was to simplify the study and identify broad areas with similar geomorphic features and hazards. The soils and surficial geologic units characterizing each zone were identified along with their important characteristics. In addition, the lateral (flow containing) and longitudinal slopes were evaluated along with their relation to flow patterns, and field reconnaissance within each zone was performed. Zone-representative ground and aerial photographs, in addition to many location specific photographs, document certain risks of flooding, erosion, sedimentation, lateral migration, headward erosion, and notable drainage crossings.

Beginning up-gradient, the zones include the Pediment Zone and three piedmont plane subdivisions: the Tributary Piedmont Zone, the Distributary Piedmont Zone, and the Incised Zone. A brief description of each zone is provided below, and Figures 2 and 3 illustrate these zones in profile and plan view as they pertain to the Lee Moore Wash drainage basin.

3.2.5.1 Pediment Zone

Sediment production occurs within this zone that is predominantly composed of weathered bedrock and weathered bedrock covered with a relatively thin alluvium veneer. Drainage within the Pediment Zone is contained within well-defined corridors with significant lateral relief. Erosion is limited, confined between bedrock canyon walls and within floodplain corridors. Sedimentation and headcutting are basically nonexistent in this zone.

3.2.5.2 Tributary Piedmont Zone

This zone represents a transition from sediment production to sediment transport. The drainage, along with active erosion and sedimentation, are predominantly contained in well-defined wash corridors. Erosion occurs on the isolated, relict alluvial fan surfaces, and lateral migration is minimal due to the substantial lateral relief and vegetated bank lines. Headcutting occurs in this zone, but at a reduced scale compared to the remaining piedmont plane zones.

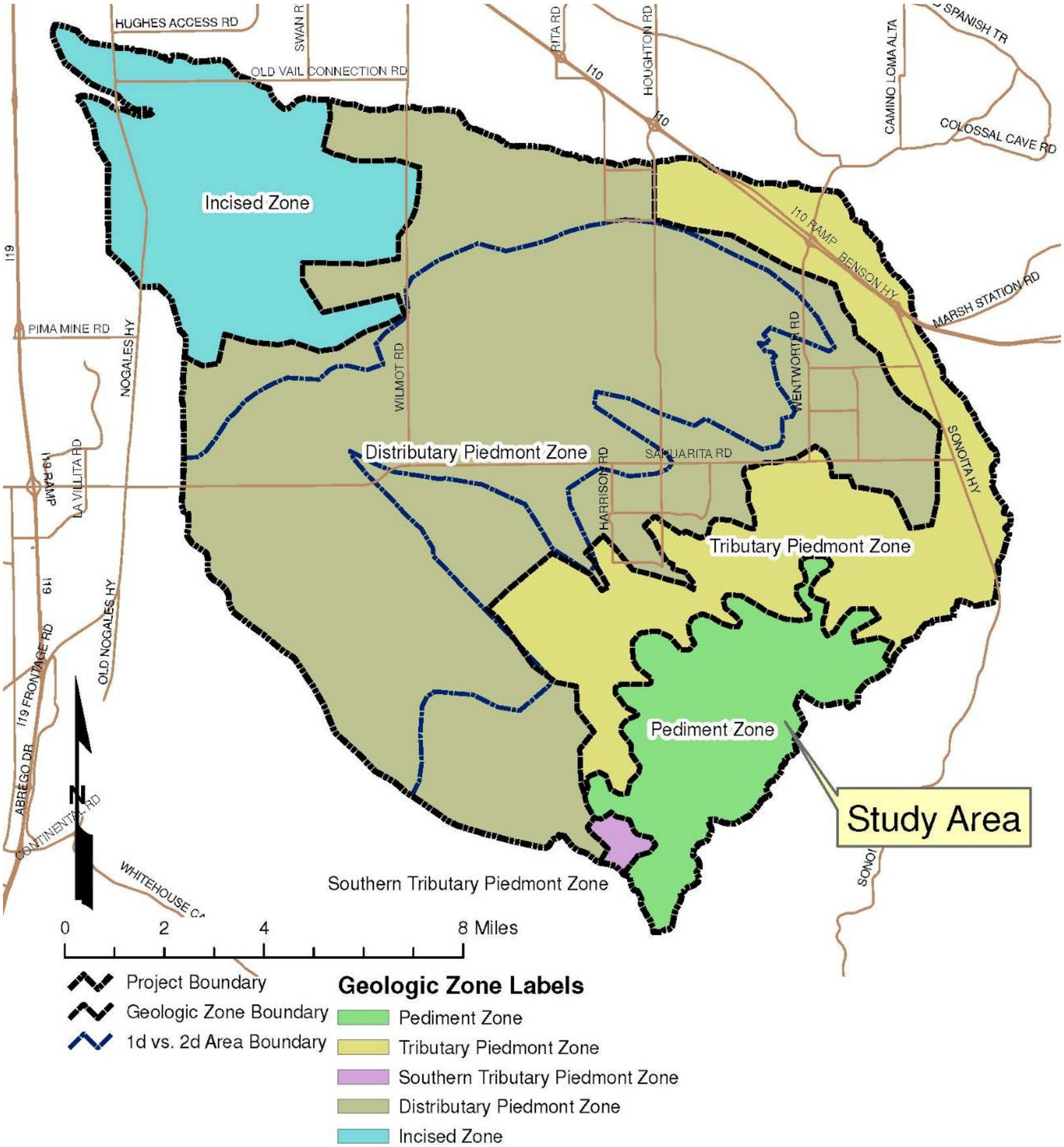


Figure 2 - Geomorphic Zones Location Map

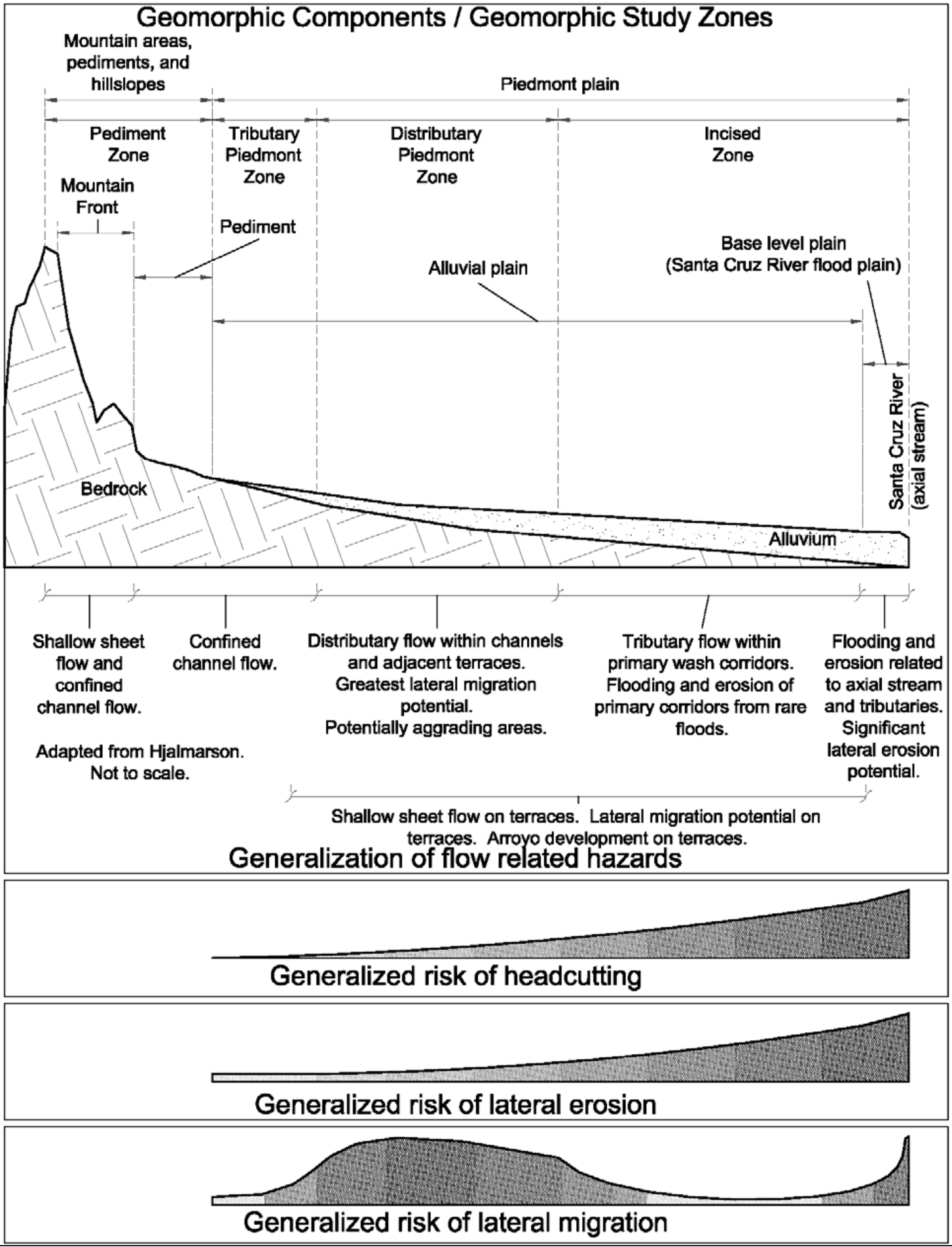


Figure 3 - General profile of study area with flow related hazards and geomorphic components

3.2.5.3 Distributary Piedmont Zone

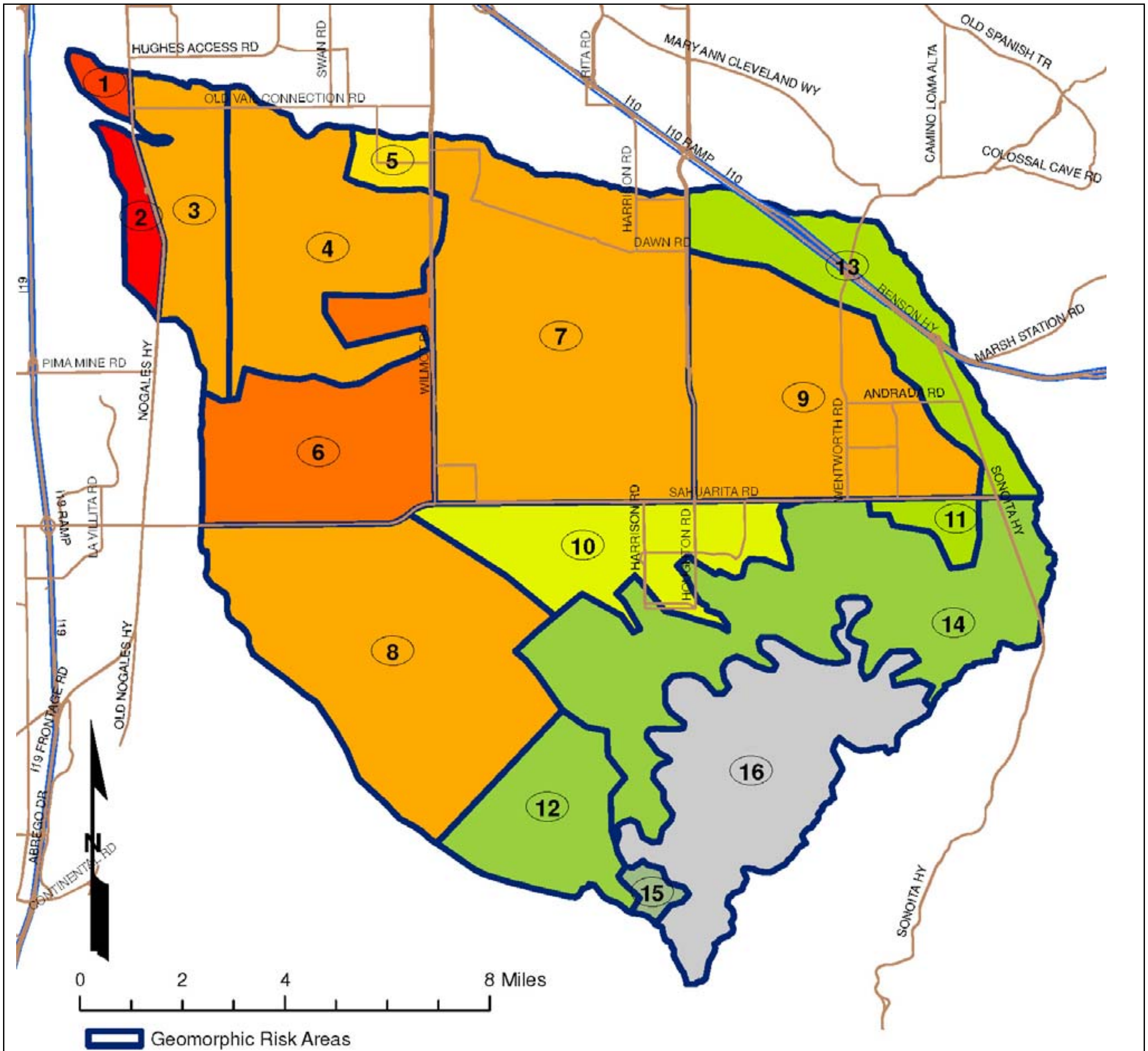
Flow is not only contained in large wash corridors within this zone, but is also prevalent in the smaller swales on the terraces along with uncontained flow on the terraces and floodplains. Large washes and flow corridors provide sediment transport, while the adjacent distributary areas provide transport accompanied by sedimentation. Active erosion, sedimentation, and avulsion are found throughout the zone and are accelerated by human activity. There is a significant potential for lateral migration and stream piracy within this zone. Headcutting extends upstream from the Incised Zone into this zone, and may be the greatest hazard along many flow paths. The Distributary Piedmont Zone includes large areas of isolated relict fan surfaces which are developing internal drainage networks subject to erosive activity and headcutting.

3.2.5.4 Incised Zone

This is a sediment transport zone significantly impacted and formed by system-wide headcutting, driven in great part by the headward erosion emanating from the lowering of the base level of the Santa Cruz River. The washes within this zone have developed into significant flow corridors that typically contain flows. Sedimentation and lateral migration are limited predominantly to the major wash corridors. The risk of these processes may be greatest at stream confluences, with additional erosion and sedimentation risks present on the older terraces.

3.2.6 Geomorphic Risk Areas

The four geomorphic study zones were further divided into areas with more homogenous flow related hazards. Along with position within the watershed, the dominant characteristics used to delineate the geomorphic risk areas were distributary versus tributary flow patterns, risk of headcutting, and lateral erosion and migration hazards. Each zone was assigned a risk label for headcutting, lateral erosion, and lateral migration. Other factors were documented individually for each zone. Figure 4 illustrates the results of this analysis.



Risk Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Headcutting Risk	5	5	4	4	3	4	3	3	3	2	2	1	2	2	1	0
Lateral Erosion Risk	4	5	4	4	3	4	3	3	3	2	2	1	2	1	1	0
Lateral Migration Risk	4	4	2	2	3	4	4	4	4	4	2	2	2	1	1	0

Code	0	1	2	3	4	5
Explanation	Negligible	Low	Moderate	High	Very High	Extreme

Figure 4 - Geomorphic risk areas

3.2.7 Significant Distributary Flow Corridors

Distributary flow corridors were delineated within the Distributary Piedmont Zone. These corridors represent the portion of the flow area which is most important to maintain in order to minimize disruption of fluvial geomorphic processes. The flood maps prepared by JEF and Stantec were superimposed over the surficial geology maps, and corridors were drawn where recent (Holocene) surficial geology units are within the delineated floodplains.

3.3 HYDROLOGIC AND HYDRAULIC ANALYSES

The Lee Moore drainage basin extends from the Santa Rita Mountains in the east/ southeast portion of the project area to the Lee Moore Wash and Santa Cruz River along the western margin of the watershed. The northernmost watersheds; Franco Wash, Flato Wash, and Summit Wash, represent relatively well-defined drainage areas, and with the exception of specific watercourse reaches, lent themselves to traditional one-dimensional hydrologic and hydraulic modeling techniques. Hydrologic and hydraulic modeling associated with these areas was performed by Stantec Consulting. The central portion of Flato Wash and areas south display far less watershed definition and channel development, and were analyzed using two-dimensional FLO-2D hydrologic and hydraulic modeling. The area modeled employing these modeling efforts represents approximately 65% of the total Lee Moore watershed, and includes the Cuprite Wash, Fagan Wash, Sycamore Canyon Wash and Gunnery Range Wash. The two-dimensional modeling was performed by JE Fuller Hydrology & Geomorphology, Inc. The following sections present summaries of the two modeling techniques and associated results as they pertain to the Lee Moore Wash Basin Management Study. Detailed reports associated with these studies are presented in separate report volumes (Stantec, 2008b; JEF, 2008b)

3.3.1 One-Dimensional Modeling Analyses (summarized from Stantec, 2008b)

Since a significant portion of existing development along with future planned development are situated within the northern portion of the Lee Moore watershed, these areas were the initial focus of study for the project. It was during these early efforts that it was identified that only a limited portion of the Lee Moore watershed effectively lent itself to standard one-dimensional hydrologic and hydraulic methodologies. Whereas watershed delineation and flow corridor definition within the Franco Wash was relatively straightforward, watershed definition and channel confinement becomes increasingly diminished to the south. Thus, it was evident upon completion of watershed delineations within the Franco and Flato watersheds that it would be inappropriate to apply one-dimensional modeling techniques in watershed areas further south. In fact, as the project proceeded, a relatively significant portion of the Franco and Flato Wash watershed areas were ultimately modeled utilizing the two-dimensional procedures, with the results manually incorporated into the final one-dimensional models.

3.3.1.1 Hydrologic Modeling

The drainage areas associated with the Franco Wash, Flato Wash, and Summit Wash comprise the northernmost watersheds of the Lee Moore project area, and represent the areas studied using standard one-dimensional hydrologic modeling techniques. These modeling efforts employed the U.S. Army Corps of Engineers Hydrologic Modeling System (HEC-HMS), and parameter estimation routines employed for the study were all developed in collaboration with staff from the Pima County Regional Flood Control District (PCRFCD). A total of fifty-six individual subareas were delineated within these watersheds based on a variety of specific criteria, including watershed shape, location and proximity to major transportation corridors. Each subarea was characterized with a distinct set of watershed parameters consisting of the drainage area, runoff curve number, time of concentration and estimated impervious percentage. GIS analysis was used to generate watershed data through the use of available topographic databases and associated mapping, and procedures consistent with the USDA Soil Conservation Service (SCS, 1986) hydrologic methodologies were employed to develop these parameters. The Modified Puls channel routing routine was employed to rout hydrographs through the watershed network, with storage-discharge relationships generated using HEC-RAS modeling techniques.

Based on the specific watershed parameters developed for individual subareas, separate hydrologic models were developed for each of the referenced watersheds Franco, Flato and Summit. All models were evaluated for two storm events, with the 24-hour, SCS Type I rainfall distribution selected to characterize precipitation during the 100-year storm event for the larger watershed areas in the range of 10 square miles. The 3-hour storm was evaluated for the same recurrence interval with the intent to document peak flows within the smaller watersheds. A modified SCS Type II precipitation distribution developed by the PCRFCD was employed for this rainfall event. Three areas within the central portion of the Franco and Flato watersheds where topography exhibited little watershed definition were evaluated with two-dimensional modeling. These areas were analyzed by routing upstream HEC-HMS generated hydrographs through watershed areas using the FLO-2D modeling procedures, and combining the resultant FLO-2D hydrographs with the HEC-HMS model in downstream areas. Through the use of these combined modeling techniques, existing 100-year peak flow estimates for each watershed were generated at specific locations for planning purposes associated with the Lee Moore Wash Basin Management Study.

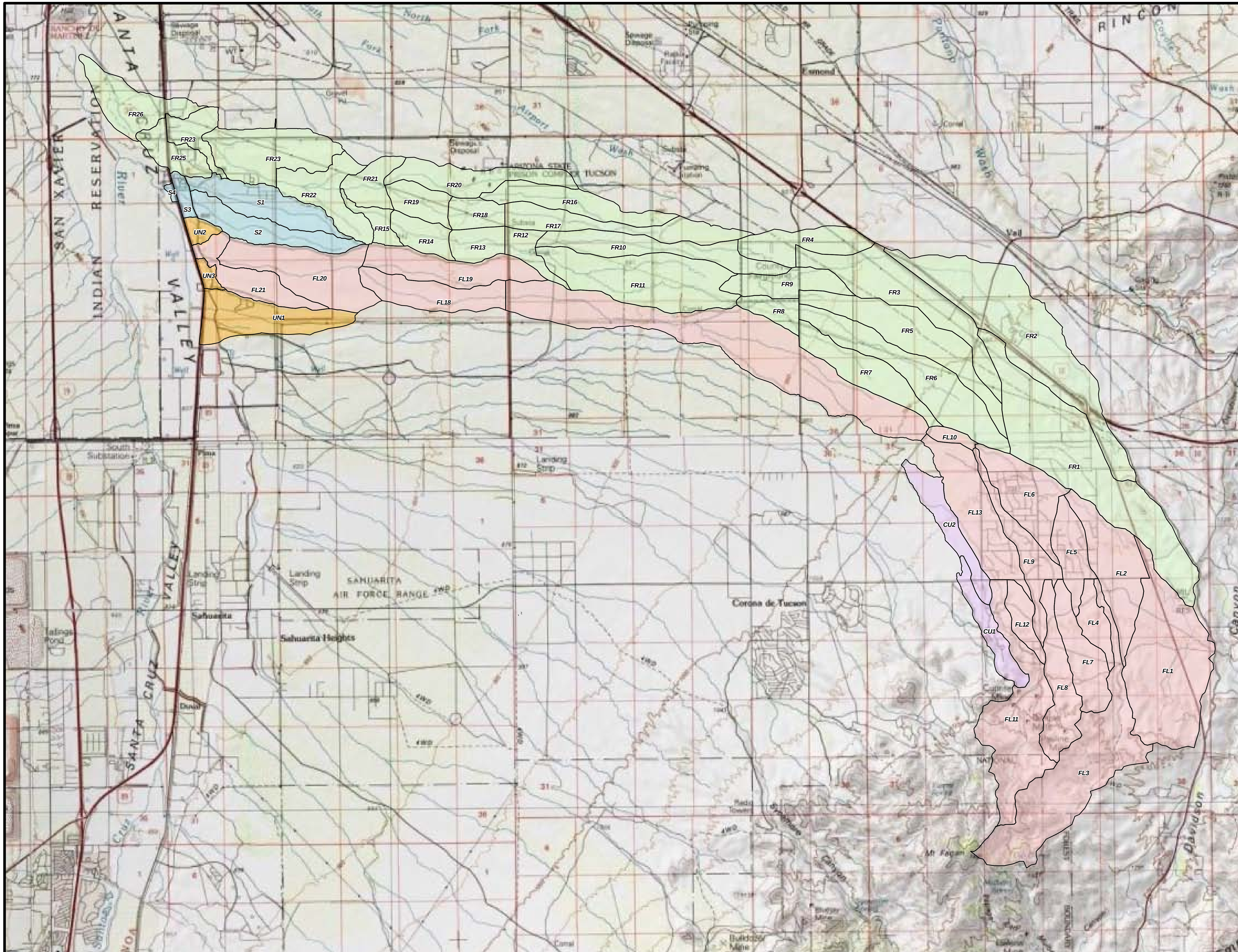
3.3.1.2 Hydrologic Modeling Results

Figure 5 displays the three major watershed areas and the individual subarea delineations employed in the one-dimensional hydrologic modeling analysis, and Table 1 presents a summary of 100-year peak flows and drainage areas at key locations along the Franco Wash,

Table 1 Summary of 100-year Peak Discharges – One-Dimensional Modeling

Watershed	General Location	Drainage Area (square mi.)	100-year Peak Discharge (cfs)
Franco	Wentworth Road	4.2	2188*
Franco	Houghton Road - Fairgrounds	10.1	2586
Franco	Wilmot Road	21.7	2782
Franco	Swan Road.	22.7	2755
Franco	Old Vail Connection	30.8	4449
Franco	Nogales Highway	31.3	4394
Flato	Sonoita Highway	3.4	2982*
Flato	Wentworth road	14.2	5798
Flato	Near Houghton Road	20	5694
Flato	Wilmot Road	23.8	2106
Flato	Near Swan Road	26.3	1979
Flato	Nogales Highway	29.1	2193
Summit	Old Nogales Highway	1.2	603*
Summit (tributary)	Old Nogales Highway	1.1	470*
Summit	Nogales Highway	2.4	1087*
Lee Moore	Nogales Highway	142	20210
Lee Moore	Santa Cruz River	178	21822

* Peak flow is based on the 3-hour storm. All others are based on the 24-hour



Lee Moore Wash Basin Management Study

Figure 5

Watershed Map Displaying HEC-HMS Subareas

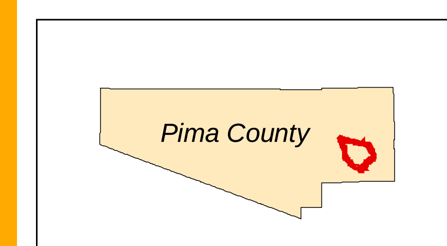
Legend

- Location of FLO-2d Hydrograph/Cross-section
- Junction Point of Combined Hydrographs
- Subarea Concentration Point
- Watershed Boundary
- Cuprite Watershed
- Flato Watershed
- Franco Watershed
- Summit Watershed
- Unnamed Watershed

N

0 1 2 3

Miles



Vicinity Map

Stantec

Stantec Consulting, Inc
201 North Bonita Avenue Ste. 101
Tucson, AZ 85745-2999

Flato Wash and Summit Wash. Peak flows for areas along the main flow corridors of Flato and Franco typically represent values associated with the 24-hour storm, whereas peak flows for the smaller watersheds are those estimated associated with the 3-hour storm event.

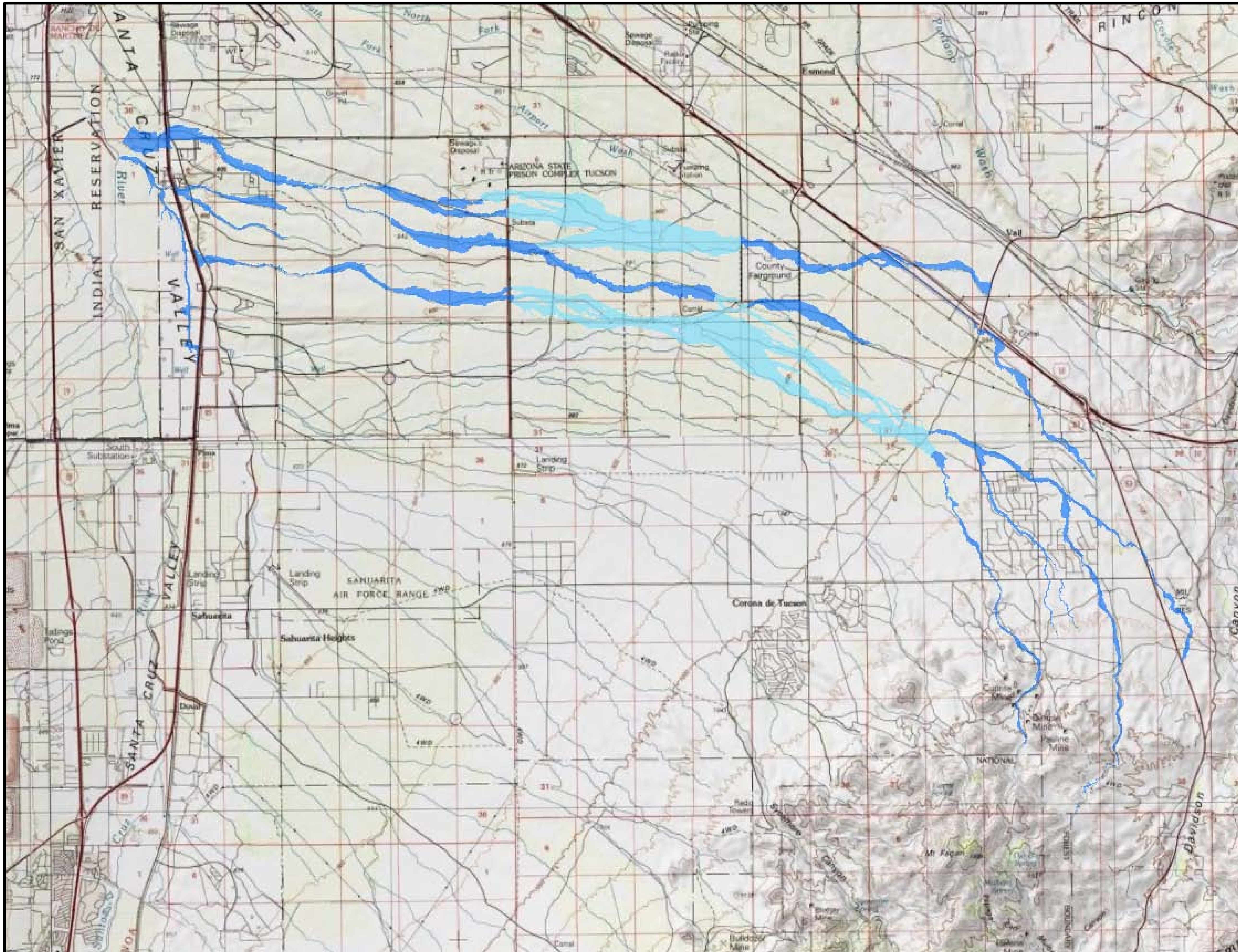
3.3.1.3 Hydraulic Modeling

Approximately 66 miles of 100-year floodplains were delineated through the use of the one-dimensional U.S. Army Corps of Engineers River Analysis System (HEC-RAS) hydraulic modeling routine. An additional 12-13 miles were mapped using two-dimensional FLO-2D modeling in the areas previously noted. Generally, the threshold employed for these efforts were watercourses experiencing a 100-year peak discharge of 1000 cfs or greater. However, several channel reaches were mapped with peak flows less than this criterion, notably within the Summit watershed and FLO-2D areas. For the one-dimensional HEC-RAS modeling, three-dimensional surfaces were developed along designated flow corridors using available topographic data and application of GEO HEC-RAS computer software. River cross-sections were typically spaced at 500-foot intervals, however, cross-sections at 200-foot intervals were evaluated along watercourses within the Summit area in order to evaluate potential flood hazards in more detail. This area represents one of the more intensely developed areas within the Lee Moore watershed, situated downstream of the Country Club Road alignment, and has experienced significant flooding in recent years. Cross-sections were drawn along the channel corridors developed with the GEO HEC-RAS software, and HEC-RAS hydraulic models were developed from these data.

Since only the 100-year floodplains were evaluated, channel banks and roughness coefficients were characterized assuming full-flow corridors, contrary to identifying low-flow channels that play a larger role in characterizing floodplain areas of lesser storm events. Roughness coefficients employed with the analyses are representative of typical values used in channel investigations in other areas of Arizona, and were corroborated by literature references. Several stock ponds and diversion berms were identified along many of the existing main channel washes and tributaries evaluated, however, they were ignored in the modeling and mapping efforts due to the potential failure of the structures. Therefore, floodplain limits developed within the three-dimensional surfaces developed by GEO HEC-RAS software required editing to eliminate potential model-interpreted effects associated with these structures, as well as extraneous low-lying areas outside the potential flooding influence. Thus, the final mapping efforts for the study represent a combination of the hydraulic modeling results, as well as intuition and experience to assess situations outside the one-dimensional capabilities of the

HEC-RAS model. Generally speaking, the floodplain limits defined with the current study are considered conservative, and intended for future planning efforts.

The 100-year peak flows generated for the major watersheds ranged from about 1100 cfs at the mouth of the Summit watershed (3-hour storm) to an estimated 7500 cfs (24-hour storm) within the Flato watershed along the main channel at the location that FLO-2D modeling was initiated. The peak flow at the mouth of Flato Wash at Lee Moore Wash is estimated as approximately 2200 cfs, while the 100-year peak flow for Franco Wash at the Santa Cruz River is about 4300 cfs. Based on these flows, contiguous flood hazard areas were delineated from areas east of Sonoita Highway within the Flato watershed to the Lee Moore Wash and Santa Cruz River. Peak flows developed for the 24-hour storm event were employed for the floodplain mapping along the main channel reaches where contributing watershed areas were in excess of 8-10 square miles, while peak flows generated from the 3-hour storm analyses were used to map floodplains associated with smaller watershed areas. Floodplains ranged from fully-contained channel flows to areas inundating several thousand feet in width within shallow sheetflow areas. Figure 6 represents a composite map displaying the floodplains delineated with the HEC-RAS modeling efforts, combined with the previously referenced three FLO-2D areas situated within the central portion of the Franco and Flato watersheds. Several existing drainage structures were evaluated with the HEC-RAS modeling, and results indicate that most major existing culvert and bridge structures along the primary flow corridors have capacity to convey the 100-year storm peak flows with nominal flooding impacts. A 100-year peak flow of 20,210 cfs is estimated from the FLO-2D hydrologic modeling efforts for the Lee Moore watershed area, representing cumulative runoff generated within areas south of the one-dimensional study area. The specific concentration point of this peak flow is situated at the USPS railroad bridge located north of Pima Mines Road in the western extent of the study area. A HEC-RAS model was developed along the downstream channel of the Lee Moore channel, and indicates the existing channel has marginal capacity to convey the 100-year peak flow within existing channel banks. As displayed in Table 1, the estimated 100-year discharge of the Lee Moore Wash at the Santa Cruz River for the 24-hour storm event is about 22,000 cfs, when combined with additional tributary flows from the Flato watershed and Summit areas.



Lee Moore Wash Basin Management Study

Figure 6

100-yr Floodplains Within One-Dimensional Modeling Area

Legend

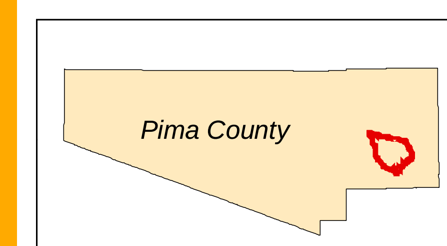
HEC-RAS Floodplain

FLO-2D Floodplain

N

0 1 2 3

Miles



Vicinity Map

Stantec

Stantec Consulting, Inc
201 North Bonita Avenue Ste. 101
Tucson, AZ 85745-2999

3.3.2 Two-Dimensional FLO2D Modeling Analyses (summarized from JEF, 2008b)

As previously noted, during the hydrologic and geomorphic analyses, it was determined that a relatively large portion of the study area is characterized by distributary flow to the extent that standard watershed delineation and one-dimensional hydraulic modeling were deemed ineffective. Therefore, a two-dimensional analysis of rainfall-runoff relationships within the distributary flow areas of the Lee Moore Wash drainage basin was conducted by JE Fuller Hydrology and Geomorphology (JEF) using the FLO-2D flood routing model (FLO-2D FRM). The study area associated with these modeling efforts is shown in Figure 7.

3.3.2.1 Preliminary Modeling

In order to assure that the FLO-2D results are compatible with accepted Pima County hydrology procedures, the SCS Curve Number (CN) procedure was incorporated into the FLO-2D FRM by the authors of the FLO-2D program specifically for this project, based on the Pima County Regional Flood Control District methodology for computing runoff. JEF verified that the FLO-2D FRM generated acceptable and predictable results through a series of comparison tests, and then proceeded with modeling approximately 136 square miles of the study area.

Given that the HEC-HMS model was employed for the remainder of the study area and hydrographs would be shared between the models, JEF calibrated FLO-2D models to HEC-HMS models by varying input and modeling parameters (within reasonable ranges), including grid size, roughness coefficients, and roughness adjustment equation options. Following this, JEF modeled the study area with 400-foot and 200-foot grid models to determine dominant flow paths. Detailed modeling of the study area with 100-foot grid resolution was subsequently performed, coupled with modeling of significant channels and berms within the FLO-2D model.

3.3.2.2 Detailed Models

The study area was sub-divided into seven sub-models to reduce individual model size and runtime, and to allow for the use of two sources of elevation data. The elevation data utilized were Digital Elevation Model (DEM) coverage and Digital Terrain Model (DTM) data from Pima Association of Governments (PAG), in addition to USGS DEM data. The PAG coverage includes most of the study area, from approximately 4 miles south of Sahuarita Road to beyond

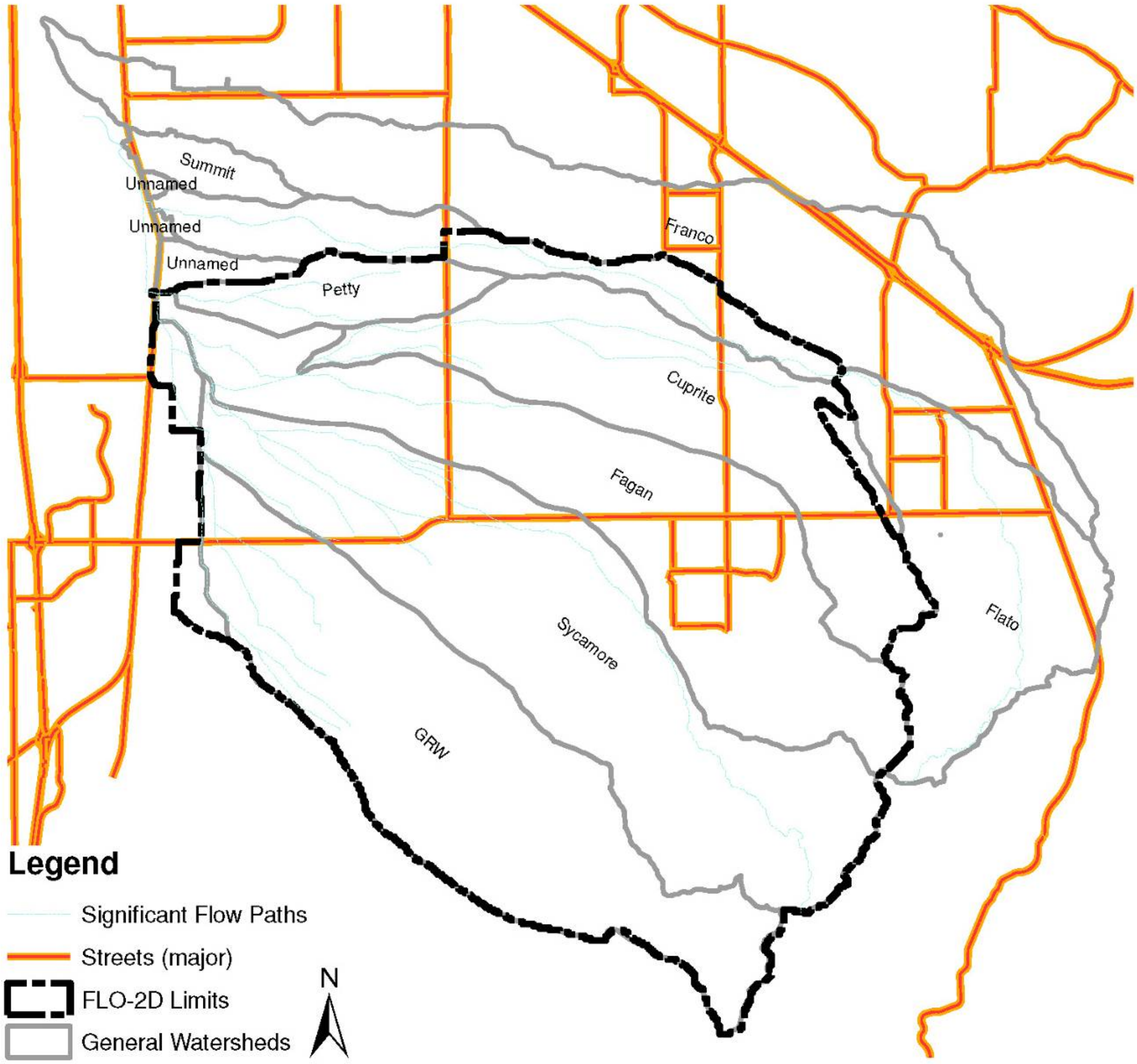


Figure 7 - FLO-2D Modeling Area

the northern limits of the study area. To the south of the PAG coverage, USGS DEM data were used. The USGS coverage is 10 meter resolution (compared to 8 foot for PAG). One 200-foot grid model was prepared for the USGS DEM area, with output hydrographs input into the downstream models as inflow. The areas with PAG coverage were modeled with six 100-foot grid models. The previously prepared 200-foot grid model was used to determine major watershed divide lines, which were then used to subdivide the model area. The model required a total of 311,000 FLO-2D grid elements, including 650 with detailed channel sections and over 30 with levees.

Outflow was modeled at four locations:

1. Where the Lee Moore Wash channel crosses the Union Pacific Railroad Bridge.
2. The Flato Wash corridor at Wilmot Road.
3. In the Gunnery Range Wash area, north across Sahuarita Road.
4. The Gunnery Range Wash area, flowing west and about one mile south of Sahuarita Rd.

Stantec incorporated Outflow Locations 1 and 2 into their HEC-HMS models, while locations 3 and 4 are considered breakout flow from the Lee Moore Wash watershed to the Santa Cruz River. Inflow from the well-defined, upper reaches of the Flato and Cuprite watersheds was modeled with hydrographs provided by Stantec that were generated with HEC-HMS models. Flow paths break down between Wentworth Road and Houghton Road, therefore the HEC-HMS modeling terminates and FLO-2D was used within the distributary areas of these watersheds.

3.3.2.3 Modeled Storm Events

Four storms were modeled, with the 100-year, 24-hour storm based on the SCS Type I rainfall distribution modeled in the initial project phase. This model gave a satisfactory picture of the overall basin response, including peak discharges in the significant flow corridors. However, it was observed that discharges predicted in many of the smaller drainage paths were lower than expected. Therefore, the model was rerun with the 100-year, 3-hour storm with a modified SCS Type II rainfall distribution. This gave more appropriate discharges for the smaller drainage areas, while over-predicting discharges in the primary flow corridors, especially the Flato and Cuprite Wash corridors.

Since floodmaps were prepared documenting a single 100-year discharge and floodplain, it was decided to report and delineate to the greater of the 3-hour and 24-hour storms up to a certain threshold. Ten square miles of drainage area was determined to be a reasonable cutoff, as it is unlikely that the 3-hour storm will be the dominant storm in watershed areas greater than this.

This approach provided a relatively clean delineation which includes the Flato Wash and the Cuprite Wash, as well as the incised portions of the Gunnery Range Wash and Lee Moore Wash. Thus, all reported peak discharges within these areas are based upon the 24-hour model. Outside of these areas, the greater of the 3-hour or 24-hour discharges is reported.

A further goal of the project was to determine and delineate primary flow corridors. An initial attempt was made by JEF to do this as a part of the geomorphic assessment by mapping the youngest alluvial deposits. This generated flow corridors which were larger than what could be reasonably regulated, and a more technical approach was desired. JEF therefore modeled the 10- and 25-year, 3-hour storms with the SCS Type II rainfall distribution. A small area was mapped with both floodplains, and it was decided that the 10-year floodplain provides a representative baseline for determining flow corridors.

3.3.2.4 Floodplain Mapping

Detailed flood mapping was conducted only within areas covered by PAG coverage. The flood inundation maps were delineated by hand based upon the peak discharges predicted by the FLO-2D model, and supported by normal depth modeling. Typically, floodplains were delineated in areas where peak discharges in excess of 100 cfs were recorded, unless judgment indicated either the FLO-2D runoff estimate may be low or no cross section was present, but runoff may be over 100 cfs.

3.3.2.5 Summary Results

The final mapping indicates that approximately 48 square miles within areas with PAG coverage (47 percent of said area) are prone to 100-year flood inundation of 100 cfs or more. The predicted 100-year discharge within the Lee Moore Wash at the USPS (Union Pacific/Southern Pacific) railroad crossing is 20,210 cfs. Peak discharges were recorded elsewhere at approximately 1,900 other locations within distributary flow areas and along watercourses such as the Gunnery Range Wash, Sycamore Wash, Fagan Wash, Cuprite Wash, Flato Wash, and Petty Ranch Wash. Figures 8a through 8d show the locations of key concentration points within the FLO-2D study area, and Table 2 provides their associated 100-year peak discharge.

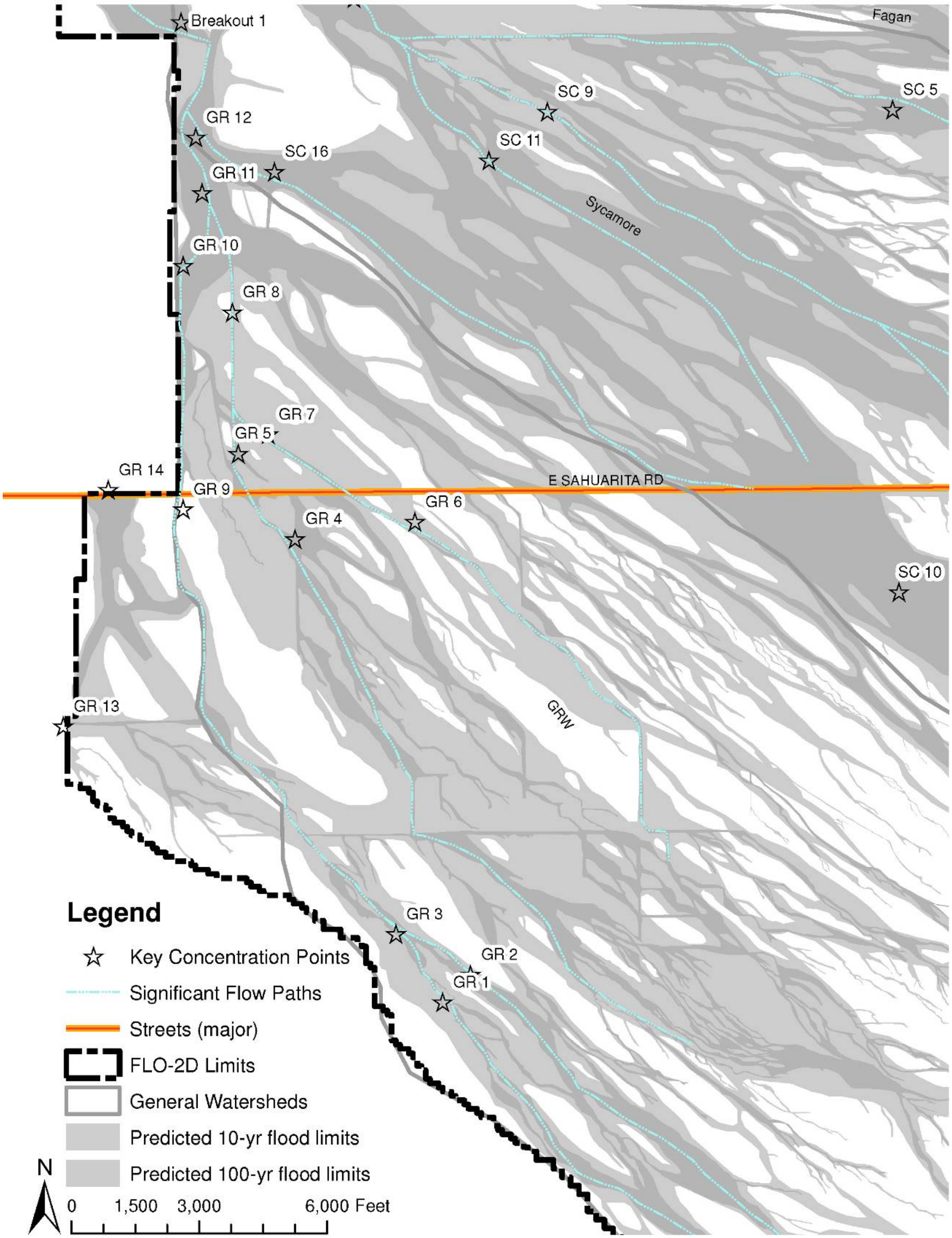


Figure 8a – FLO-2D Area Key concentration points

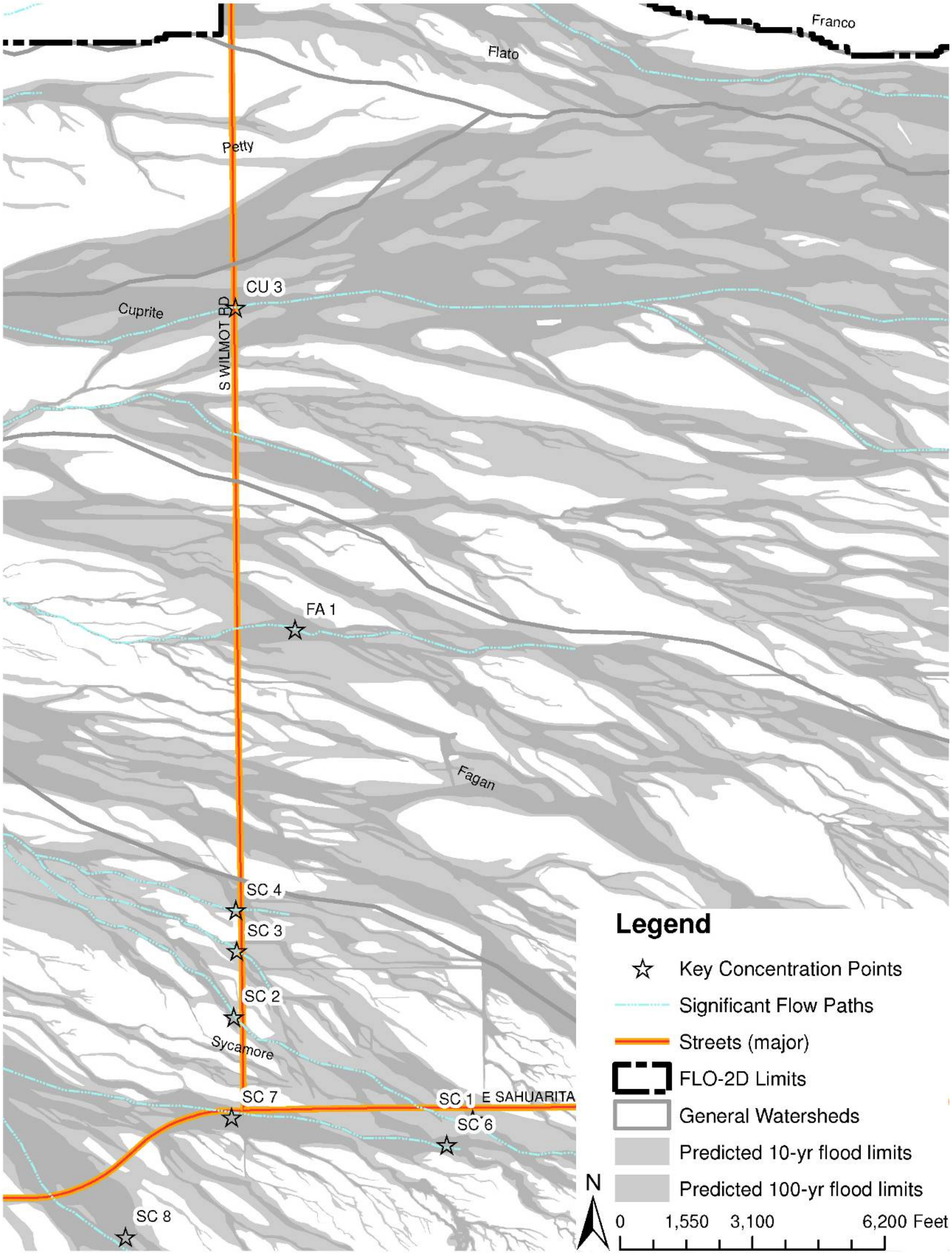


Figure 8b – FLO-2D Area Key concentration points

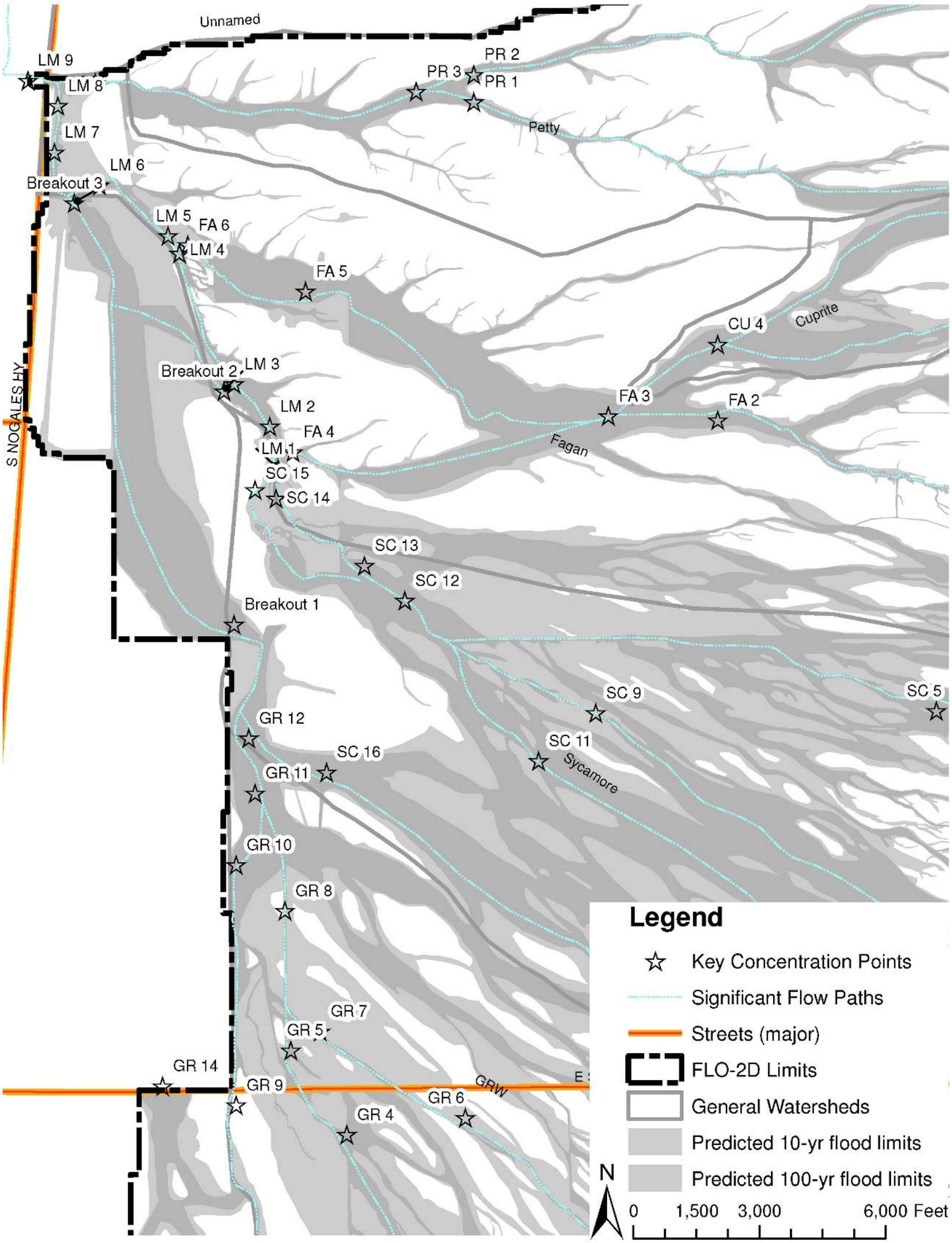


Figure 8c – FLO-2D Area Key concentration points

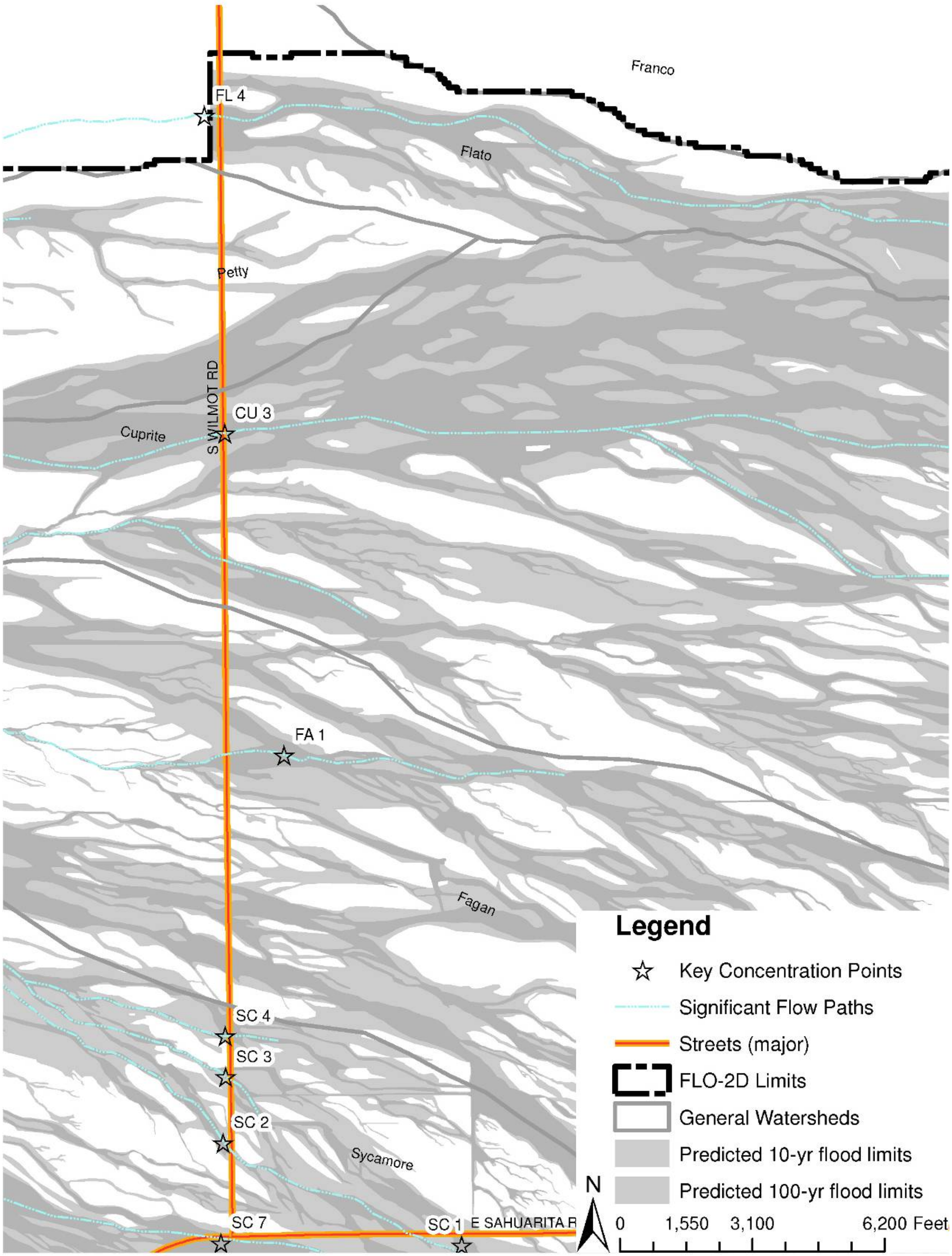


Figure 8d – FLO-2D Area Key concentration points

Table 2 - Summary of FLO-2D 100-year Peak Discharges

Concentration Point		Reported Q-100 (cfs)	Concentration Point		Reported Q-100 (cfs)
Breakout	1	4,480	GR	14	1,450
Breakout	2	4,020	LM	1	6,150
Breakout	3	10,420	LM	2	9,160
CU	1	1,240	LM	3	4,870
CU	2	4,260	LM	4	4,130
CU	3	2,290	LM	5	10,850
CU	4	6,750	LM	6	11,280
FA	1	2,560	LM	7	19,210
FA	2	3,100	LM	8	18,980
FA	3	9,810	LM	9	20,210
FA	4	2,760	PR	1	690
FA	5	7,390	PR	2	870
FA	6	6,760	PR	3	1,150
FL	1	5,780	PR	4	1,780
FL	2	1,840	SC	1	1,520
FL	3	5,690	SC	2	950
FL	4	2,120	SC	3	1,490
GR	1	1,560	SC	4	1,010
GR	2	400	SC	5	2,440
GR	3	1,930	SC	6	2,390
GR	4	1,290	SC	7	930
GR	5	1,070	SC	8	1,480
GR	6	140	SC	9	1,440
GR	7	400	SC	10	2,570
GR	8	470	SC	11	2,150
GR	9	420	SC	12	3,190
GR	10	1,200	SC	13	6,220
GR	11	2,860	SC	14	4,280
GR	12	4,480	SC	15	1,380
GR	13	430	SC	16	1,860

3.3.3 Summit Area Study

As previously noted, one of the more intensely developed areas is located within the northwest portion of the Lee Moore Wash Basin Management Study project area along the Nogales Highway corridor, and is generally known as the Summit area. This area is situated within the downstream reach of the Franco Wash, and represents about a two-square mile residential area bounded by Old Vail Connection Road and the Singing Cactus Lane alignment along the north and south, respectively, and the Country Club Road alignment and Nogales Highway along the east and west. The Summit Wash impacts the southern portion of the area. There are a few small platted subdivisions within the area along with a limited number of County-maintained roads, however, the vast majority of the development within the area are unplatted subdivisions and lots. Many of the existing drainage problems reported within the LMWBMS project area are experienced within the above-referenced unrecorded subdivisions. Given the nature of flooding issues within the area, a more detailed study of the hydrology and hydraulics was authorized by the PCRFCD as part of the Lee Moore Wash Basin Management Study in order to evaluate the potential of developing site-specific drainage solutions. A summary of these efforts is presented in the following discussion.

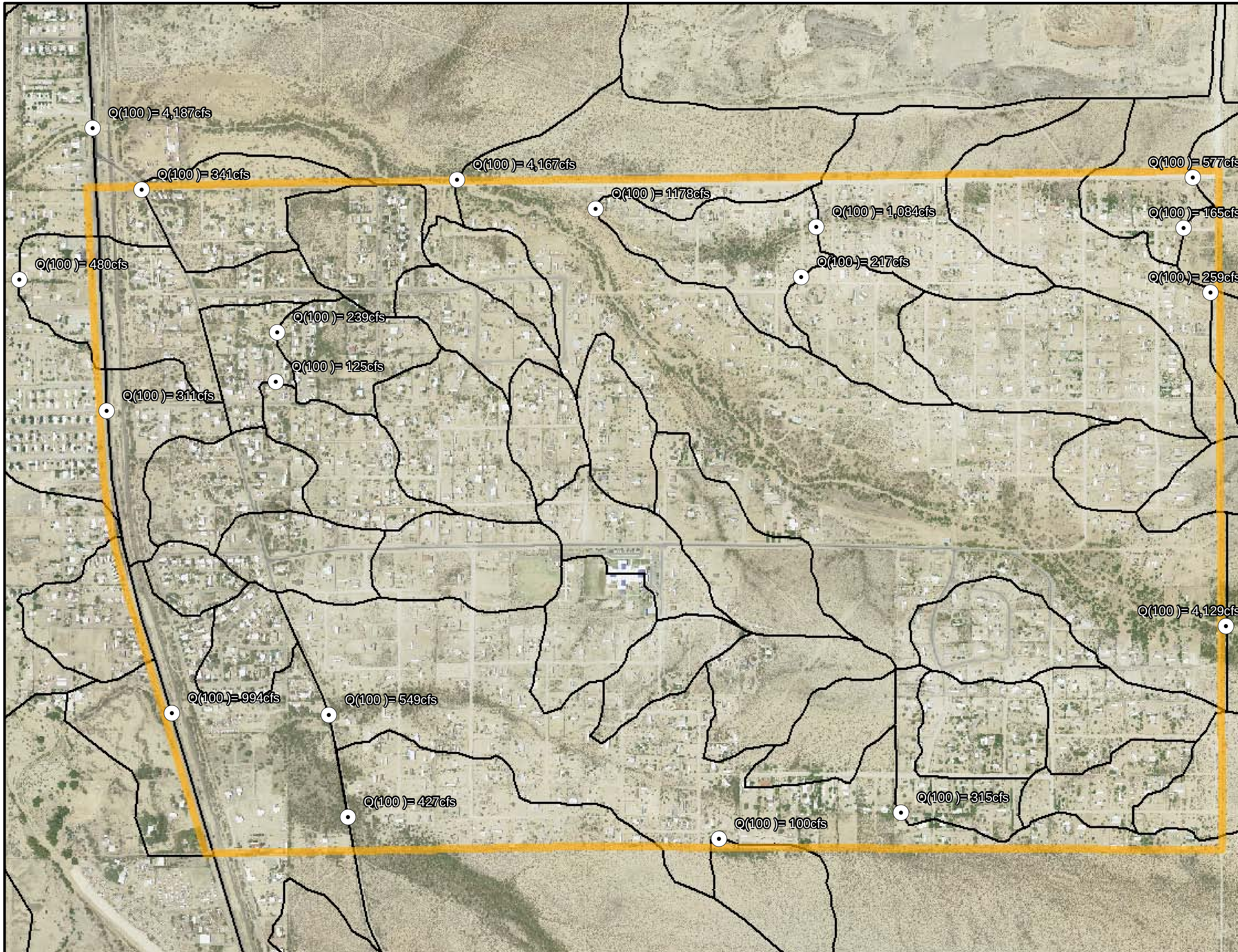
The intent of the study was to identify local watersheds that generate peak flows in excess of 100 cfs, the threshold defined by Pima County ordinance for regulatory 100-year floodplains. Based on these criteria, each watershed within the Summit area in the range of 20 acres was delineated, and 100-year peak flows were computed. The most recent version of the Pima County Hydrology procedures, PC-Hydro Version 5 (PCRFCD, 2007), was utilized for these calculations as per current Pima County ordinance. Since the Summit area is generally bisected by the Franco Wash from southeast to northwest and the Summit Wash flows along the southern section, many of the subareas identified with these efforts were generally small tributary drainage areas flanking either side of these main washes. Additional areas that discharge east toward Nogales Highway, as well as a larger tributary to Franco Wash (north of the main Franco flow corridor) comprise the remainder of the watershed area impacting the Summit residential areas. Figure 9 represents the watershed map generated with this study along with 100-year peak flows at key locations. Peak discharge data sheets are provided within the technical appendices for the LMWBMS Hydrology and Hydraulic Report.

Upon identification of watershed areas that generate peak flows meeting the regulatory threshold, hydraulic models were developed using the USACE HEC-RAS computer model to determine local regulatory 100-year floodplains within the Summit area. A map was generated displaying these floodplain areas, as well as the regional floodplains for Franco Wash and Summit Wash developed with the LMWBMS. The results of these efforts are presented in Figure 10. Based on the data developed with this study, along with review of drainage complaints and information gathered from meetings with residents, potential drainage solutions to specific localized flooding areas were developed. The primary recommended alternatives involved grading and/or clearing specific drainage paths in order to provide positive drainage through the identified areas, as well as maintenance or upgrading of existing drainage culverts

Lee Moore Wash Basin Management Study

Figure 9

Summit Area Watershed Map



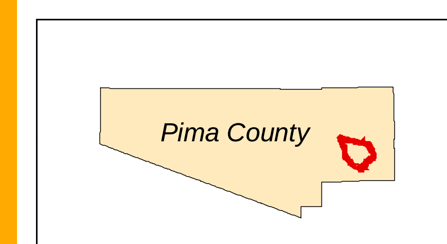
Legend

- Concentration Point
- Project Area
- Watershed Delineation

N

0 500 1,000 1,500

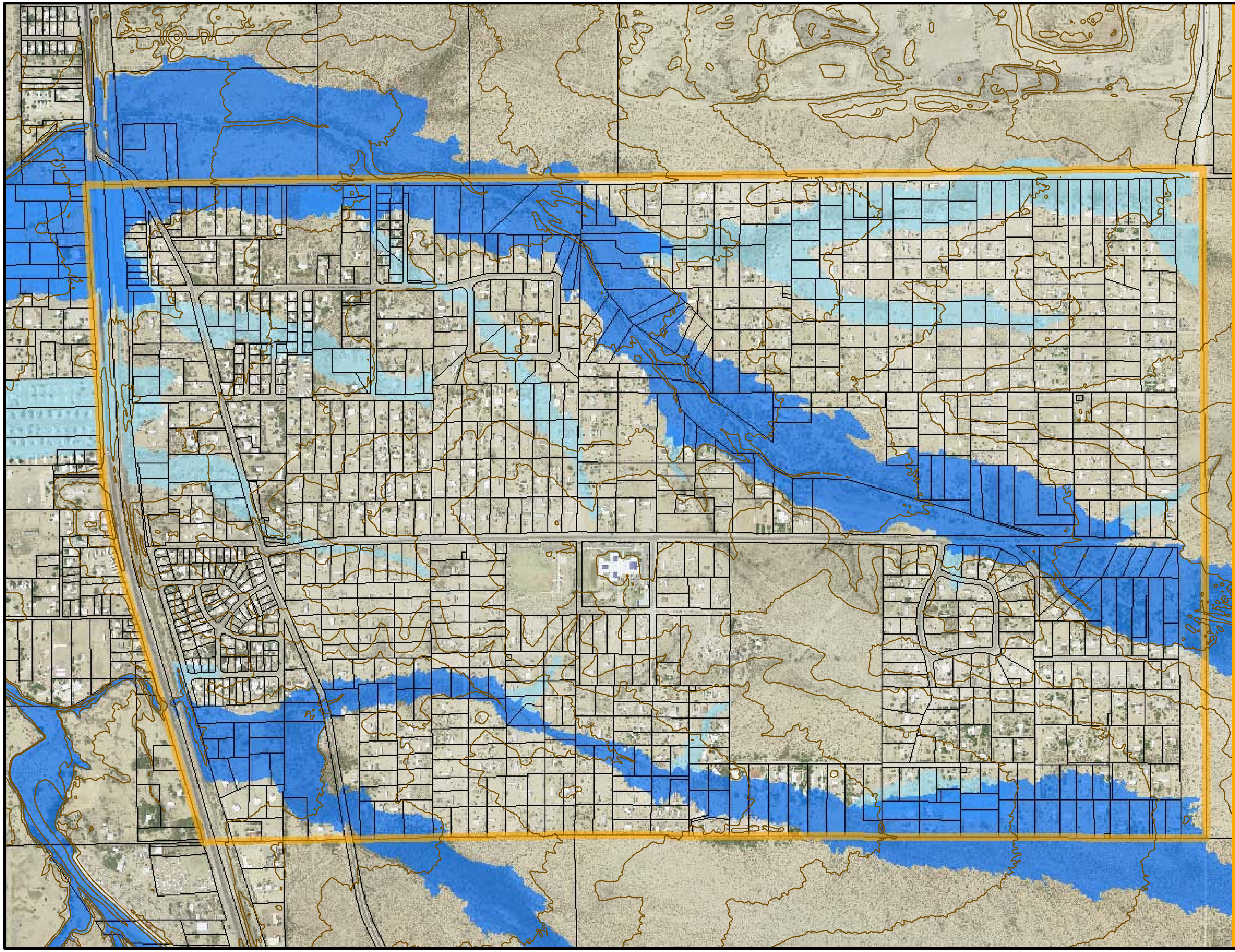
Feet



Vicinity Map

Stantec

Stantec Consulting, Inc
201 North Bonita Avenue Ste. 101
Tucson, AZ 85745-2999



Lee Moore Wash Basin Management Study

Figure 10

Summit Area
Local Floodplain Map

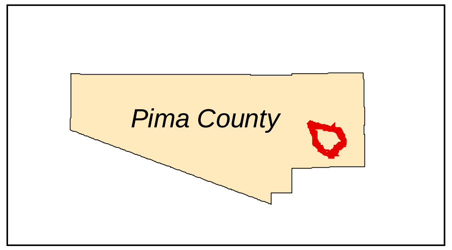
Legend

index

- 10' Contour Line
- Project Area
- Parcel Boundary
- Regional Floodplain
- Local Floodplain

N

0 500 1,000 1,500
Feet



Vicinity Map

Stantec

Stantec Consulting, Inc
201 North Bonita Avenue Ste. 101
Tucson, AZ 85745-2999

The proposed conveyance swales would typically be 10-20 feet wide with a depth of about one foot, and would convey flows associated with the smaller, frequent storms in a westerly, northwesterly direction through the developed areas. Maps of the proposed location and alignments of the conceptual improvements were generated, and are included in the Technical Appendices (Stantec, 2008c) associated with the LMWBMS Hydrologic and Hydraulic Report. The results of these efforts were presented to residents of the Summit area at public meetings. However, due to private ownership conflicts, it was determined that implementation of the proposed alternatives was not feasible at this time.

3.3.4 Santa Cruz River Study

The Santa Cruz River floodplain north of Pima Mine Road, an area that is adjacent to the western margin of the LMWBMS study area and ultimately impacted to the north where the Lee Moore channel discharges west underneath Nogales Highway, was investigated with the study. The Santa Cruz River south of Pima Mine Road has been previously mapped in the FEMA FIS study dated February 1999, however only a portion of the subject area north was mapped by approximate methods, precluded because the area is situated predominantly within the Tohono O'Odham reservation.

In the event that breakout flow from the Santa Cruz River would occur upstream of Pima Mine Road as identified in a preliminary upstream study, it is apparent that flow from the south may overflow both the Nogales Highway to the east and Pima Mine Road to the north. Review of available aerial photography from the 1983 event indicates a situation similar to these circumstances did occur during this flood event. The existing topography to the north of Pima Mine Road and east presents several flow obstructions, and the flow distribution within the eastern overbank of the Santa Cruz River under the given situation is complex, with several areas of divided flow paths. These encroachments include an existing gravel pit northeast of the Pima Mine Road and Nogales Highway intersection, and the Tucson Water recharge ponds to the north and west of Nogales Highway. Thus, in order to estimate existing flood limits, several different models were developed to evaluate hydraulic conditions surrounding these structures. These models were all generated from identical cross-sections developed to characterize the floodplain topography within these areas, with separate topographic constraints employed to isolate specific areas and estimate flooding conditions. The following discussion provides a brief description of the methods employed to separate each model and their base conditions. The results are presented on a map in the Technical Appendices (Stantec, 2008c) of the LMWBMS

Hydrology and Hydraulic Report that displays the approximate flood limits associated with this study, along with a more detailed discussion of the modeling efforts.

A three-dimensional surface and topography was generated for the study reach north of Pima Mine Road using GEO HEC-RAS computer software, and strategic cross-sections identified and employed with HEC-RAS modeling. Initial HEC-RAS modeling indicated five distinct areas of divided flow, and separate models were developed for each specific reach. These reaches are generally characterized as follows: the Santa Cruz River channel (Model 1), the ROB (right overbank) between the river and Nogales Highway (Models 2 and 3), and the area east of Nogales Highway (Models 4 and 5). In this manner, several different hydraulic conditions could be efficiently evaluated, while providing reasonable estimates of potential flooding. The initial modeling efforts also identified that each area of divided flow would have a distinct discharge, predominantly dependent on the flow distribution upstream of Pima Mine Road. Since detailed upstream modeling was not available, a simplified approach, along with an iterative process, was utilized to determine the range of these potential discharges. On the basis of these analyses and an estimated breakout flow of 36,000 cfs upstream of Pima Mine Road, it was estimated that approximately 11,000 cfs would impact Pima Mine Road between the river and Nogales Highway (Models 2 and 3), while a flow of 25,000 cfs flow is estimated to discharge to the area east of Nogales Highway (Models 4 and 5). The Santa Cruz River channel flow was estimated as 8800 cfs by the previously referenced study, and was employed along the main river channel reach north of Pima Mine Road.

Flood limits along each reach associated with Models 1 to 5 were delineated, and are displayed on the map previously referenced, along with the estimated discharges used with the modeling. These results indicate that the majority of the area east of Nogales Highway and north of Pima Mine Road may experience shallow flooding, as well as the areas west of the highway to the Santa Cruz River. It is also worthy to note that the Lee Moore channel as studied in the overall LMWBMS hydraulic analysis has marginal capacity for the estimated 100-year flow of 22,000 cfs generated by the Lee Moore Wash, however, the estimated 32,500 cfs associated with this analysis may induce flooding within residential areas located along the Lee Moore overbank areas to the north.

4.0 Public Involvement (summarized from CLW, 2009a)

The Public Involvement Plan for this project was designed to fulfill the promise of “consult” on the International Association for Public Participation (IAP2) Spectrum of Public Participation: to keep the public informed, listen to and acknowledge concerns and aspirations, and provide feedback on how the public input was considered in the decision. The goal of the plan was to bring more information into the study for consideration, along with providing additional perspectives on alternatives in order to reach the best outcome, greater public understanding, support and acceptance of the study and its final outcomes. The plan outlined 12 workgroup meetings, 12 stakeholder meetings and six public meetings (three rounds of two meetings each).

The actual effort materialized as seven workgroup meetings (three rounds of two meetings - one for public agencies and one for private organizations; the final meeting combined both public and private), seven stakeholder meetings (one each with Diamond Ventures, Pima Association of Governments, Arizona State Land Department, Southern Arizona Home Builders Association and Tucson Water, and two with City of Tucson staff), three rounds of two public meetings (each round included a meeting on both the east and west sides of the study area, for a more inclusive approach), and an additional public meeting was held in the Summit area to address specific flooding and drainage needs in that area. Additionally, 10 focus group meetings were held with staff from both public agencies and private organizations to collaboratively discuss and edit the development criteria for the entire Lee Moore Wash Basin.

5.0 Alternative Identification Analysis

5.1 ALTERNATIVE DEVELOPMENT

One of the major components of the study, in conjunction with documenting existing drainage conditions, was to identify specific alternatives and programs intended to mitigate existing flooding problems. Additionally, these efforts also focused on preventing additional concerns associated with future development anticipated within the project area. In order to develop watershed-wide solutions, a comprehensive, systematic approach was employed intended to evaluate the full range of potential alternatives in an objective manner, initially unrelated to cost and viability. Rather, the alternatives were analyzed more on their merits in meeting performance criteria identified by the project team. The five performance criteria are:

1. Public safety and flood hazard mitigation,
2. Implementation,
3. Environmental resources,
4. Sustainability, and
5. Planning and infrastructure

A weighted ranking hierarchy was developed among the five categories relative to their importance when compared to each other. The weighting process was conducted using a matched pair matrix with an interdisciplinary group of stakeholders. Workgroups for each of the performance criteria were formed with project team members and stakeholders that were knowledgable in each chosen discipline. These workgroups then developed a system of specific criteria along with assigned weighting values for evaluation of the various alternatives. Ultimately, recommended alternatives for the study were chosen on the basis of these performance and specific criteria in the most objective manner as possible. The following section provides a summary of the step-by-step process employed with this task.

5.1.1 Planning Areas

In order to effectively develop a program of recommended alternatives for the LMWBMS, it was decided that the watershed area should be subdivided into smaller areas with similar hydrologic and hydraulic characteristics, thus comparable issues. Additional watershed attributes such as existing land use, future anticipated development and political jurisdiction were also taken into consideration. Ultimately, the following four individual planning areas were identified;

1. Franco/Flato/Summit Wash watershed areas,
2. Cuprite/Fagan Wash watershed areas,
3. Sycamore Canyon/Gunnery Range Wash watershed areas, and
4. Area-Wide watershed.

The Franco, Flato and Summit watersheds were grouped into a single planning area since they have the most defined riverine watercourses within their watersheds (see Section 3.1) and display more existing development than areas to the south, thus presenting a distinct set of flooding issues and existing problems.

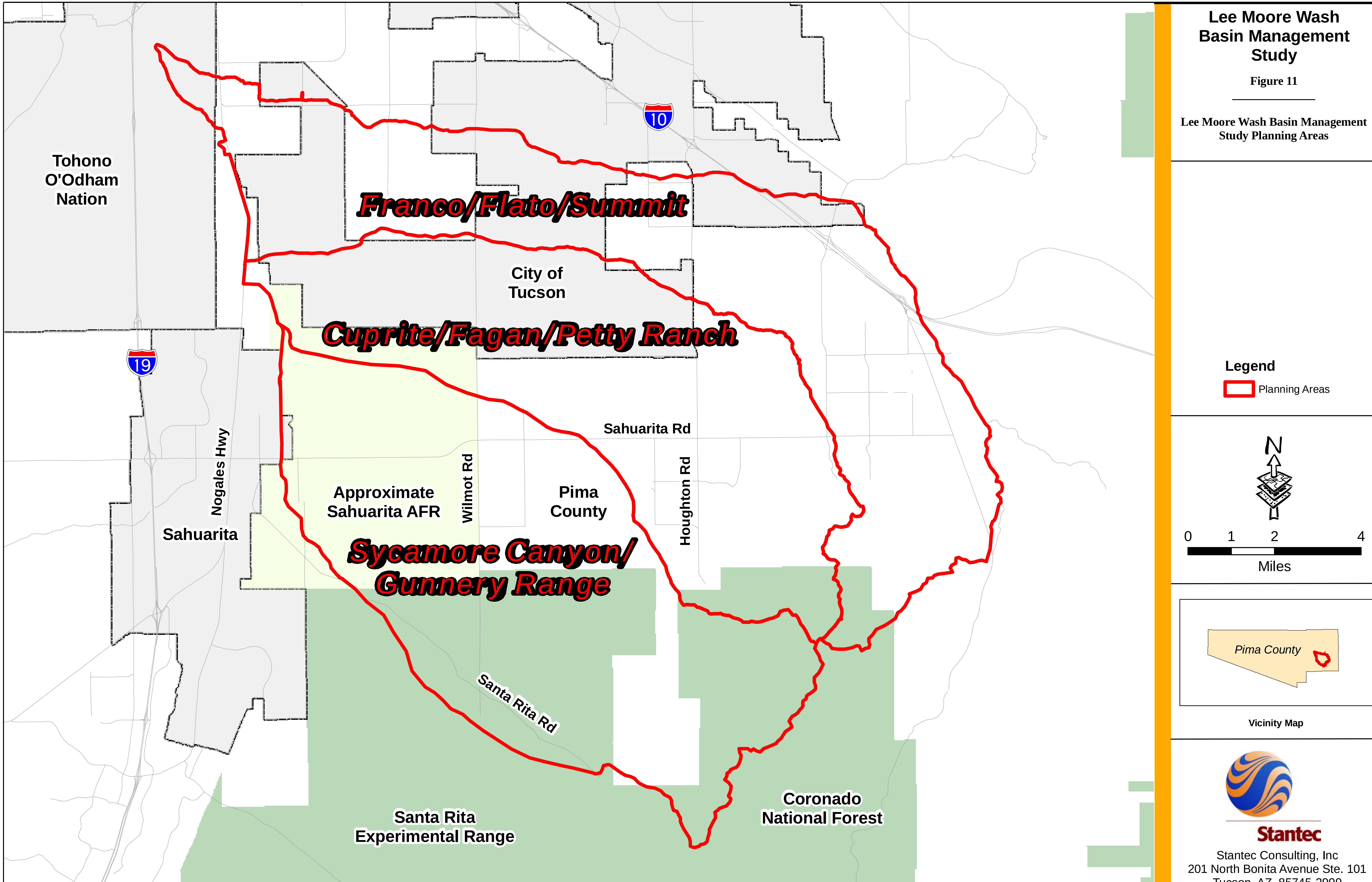
The Cuprite and Fagan watersheds were identified as areas dominated by shallow, distributary flow type watercourses, as were the Sycamore Canyon and Gunnery Range watersheds. These planning areas were separated on the premise that the latter watersheds display less existing development, and the southernmost portions of their drainage areas are comprised of undevelopable government land associated with the Santa Rita Experimental Range and Coronado National Forest.

The Area-Wide planning area was employed to assess problems generally consistent in all areas associated with the LMWBMS. Figure 11 presents the watershed delineations of the three major planning areas within the Lee Moore watershed. Based on the division of the watersheds into separate planning areas, a comprehensive list of existing problem areas and associated issues, both documented and/or evident from hydrologic and hydraulic analyses was compiled. A similar list was developed for future issues within each planning area. This information was combined into a single document (see Appendix) that ultimately served as the basis to develop alternative solutions to address the concerns.

Lee Moore Wash Basin Management Study

Figure 11

Lee Moore Wash Basin Management Study Planning Areas



Stantec Consulting, Inc
201 North Bonita Avenue Ste. 101
Tucson, AZ 85745-2999

5.1.2 Specific Criteria

As noted, the framework of the alternative analysis was based on the five performance criteria. Stakeholder Workgroups were held to evaluate proposed alternatives within each of these five performance criteria areas. The members of each workgroup were chosen on the basis of their technical background, along with the intent to provide a representative cross-section of project area stakeholders and team members. Workgroup meetings were scheduled, and specific performance criteria were developed by group members. These specific criteria were acknowledged as important indicators of how well an alternative achieved the given specific criteria. These criteria were each assigned a value, or weighting factor, relative to their importance on the basis of a total of 10, i.e. designating higher values associated with a higher degree of importance. Finally, specific guidelines were developed in order to evaluate a potential alternative's success or failure to meet each of these performance criteria. These criteria were also assigned numeric values in the range of 1 to 10, with a higher value indicating the relative success of an alternative's capacity to meet the functions defined by the performance criteria. Ultimately, each alternative was judged using this process by the workgroups, and assigned a total numeric value based on the product of the specific criteria value and the specific performance criteria relative weighting, with a score of 100 representing the highest score any alternative can attain within each workgroup.

5.1.3 Alternative Identification

Potential alternative solutions for the Lee Moore Wash Basin Management Study were developed in a brainstorming session attended by members of the five performance criteria workgroups. A GIS database was developed that included all existing data compiled to date, including but not limited to mapped floodplains, riparian areas, infrastructure, jurisdictional boundaries and future roadway alignments. The list of existing problem areas and future issues were individually identified in each planning area, and a list of potential solutions was elicited from workgroup members. Alternatives were developed from seed lists generated by the project team, and generally were categorized as structural or non-structural options. As a part of the brainstorming session, ideas were not evaluated on the basis of cost, feasibility or merit, rather, all ideas were considered valid in order to develop a comprehensive suite of potential solutions. A fatal flaw analysis was performed at a later date by members of the project team to eliminate alternatives that were determined to be impractical or inappropriate for consideration, with the final list (see Appendix) representing the alternatives chosen to be evaluated by the five workgroups representing the major performance criteria.

5.1.4 Alternative Scoring

Each of the five workgroups; Public Safety, Implementation, Environmental Resources, Sustainability and Planning/Infrastructure, were again assembled to evaluate each individual alternative relative to the specific criteria previously determined by them. Maps were generated that conceptually displayed the chosen alternatives, divided up into eight panels representing the project area within the three different planning areas. These alternative exhibits were also incorporated into the GIS database in order that alternatives could be spatially viewed, on an as-needed basis, with respect to the variety of resources assembled on different map layers. Workgroup members then evaluated each alternative on a case-by-case basis, assessing the capacity of the proposed solution to meet the objectives of the performance requirements that each workgroup had developed at their previous individual workgroup sessions, as outlined in Section 4.1.2. Numeric values were assigned to each alternative on the basis of this analysis, and were weighted per the performance criteria relative scale. A total score was then developed by each workgroup leader for each alternative.

5.2 RECOMMENDED ALTERNATIVE ANALYSIS

5.2.1 Alternative Weighting

The total scores for each alternative developed by the five workgroups were employed in the alternative weighting procedure to rank and compare each alternative on an objective basis. As noted in Section 4.1, a ranking hierarchy for the five performance criteria was developed to rank their relative importance in meeting the goals of the Lee Moore Wash Basin Management Study. Similar to the specific performance criteria ranking within each workgroup, the weighting factor was also based on a total value of ten, with the higher values representing increased importance. These values were generated using a matrix analysis by comparing the relative importance of each performance criteria to each other. The results of this analysis are summarized in Table 3. These weighting factors were then applied to the total score for each alternative from the individual workgroups, and a total score for all alternatives for each given issue was computed. These scores were then tabulated relative to each other, and the top-ranking scores were chosen for further evaluation.

Table 3 – Performance Criteria Weighting Factor Score

Performance Criteria	Weighting Factor
Public Safety and Flood Hazard Mitigation	3.5
Implementation	1.5
Environmental Resources	1.5
Sustainability	1.0
Planning/Infrastructure	2.5

5.2.2 Ranked Alternative Analyses

In order to determine the recommended alternatives, additional information was required to determine the impacts of specific alternatives. Requisite data for structural solutions generally consisted of documenting the overall magnitude and extent, i.e. size, length, quantity, etc., in order that an estimated cost could be determined. Depending on specific non-structural options, data required for these alternatives generally consisted of quantifying items to develop a total unit cost associated with the solution, i.e. total area, number of structures, etc. Certain non-structural solutions have no estimated cost associated with the alternative. The following sections provide a summary of the additional analyses performed that cover the majority of the alternatives that were ultimately evaluated.

5.2.2.1 Regional Detention Basins

A total of 25 potential locations for regional detention facilities were initially sited by the PCRFCD, and the estimated volume requirements of each facility were evaluated. These analyses were performed as a combined effort between Stantec and JE Fuller, with Stantec analyzing facilities within the watershed areas where one-dimensional modeling was performed, and JEF evaluating those in areas where the two-dimensional models were developed. The analyses consisted of employing HEC-HMS (HEC-1 by JEF) watershed models to rout 100-year hydrographs through potential facilities, with facilities designed to reduce flows to a level comparable to the 10-year storm event, approximated as 50% of the 100-year peak flow. Facilities were designed on a very conceptual basis, assumed as square facilities with estimated depths of 6 to 10 feet deep (the lesser depth for two smaller facilities). Sixteen facilities were evaluated assuming they would be constructed to mitigate existing flooding issues in downstream locations, while nine facilities were evaluated assuming they might be installed as future regional facilities to serve as part of a backbone drainage infrastructure for the Lee Moore Wash Basin Management Study. The future condition facilities were evaluated based on estimated hydrologic conditions assuming watershed areas were fully developed.

While regional detention facilities were a preferred alternative for many of the issue areas identified within the planning areas, only four existing facilities ultimately were selected as ranked alternatives. All of the future facilities were selected, as they were ranked together as an individual alternative associated with developing drainage infrastructure for the Area-Wide planning area. Based on these results, estimated costs associated with the construction of these facilities were developed, with the basic criteria summarized in Section 4.2.2.3. All facilities were assumed to provide multi-use benefits, such as recreational facilities and walking trails, and facility sizes were consequently increased to account for these additional amenities.

5.2.2.2 Flow Corridors

The delineation and preservation of flow corridors throughout the Lee Moore Wash watershed was also a preferred alternative to the majority of workgroups, thus resulting in the need to quantify their impact. Since reduction of 100-year peaks to a 10-year discharge level was the goal associated with the design of regional detention facilities, it was deemed appropriate to consider the 10-year floodprone areas along significant watercourses as a zone to preserve as a flow corridor. In this manner, frequent storms up to and including the 10-year event would flow through the existing Lee Moore drainage network unimpeded, providing requisite water supply to maintain riparian areas along with a balanced sediment transport regime. Thus, hydraulic analyses were employed to delineate the 10-year floodplains, utilizing the HEC-RAS and FLO-2D models within the representative areas associated with these modeling techniques. Since it is proposed that the designated flow corridors be left natural and undisturbed for flow conveyance, encroachment up to these limits may be allowed providing ordinance requirements are met. Thus, the impact of this alternative was quantified by determining the total area to be preserved, versus the total floodplain area, and assuming that the latter may serve as reclaimed land potentially suitable for development. Thus, the estimated cost associated with this alternative may be a resultant benefit to the private land owner.

5.2.2.3 Cost Estimates

An estimated cost was applied to all ranked alternatives where practical. Certain alternatives represent solutions that would ultimately serve as guidelines and regulations, and thus have no associated direct cost. The estimated costs were based on recent construction cost data provided by the PCRFCD, while other costs were developed on the basis of past experience of project team members with recent projects that were similar in nature. Additional cost data were determined by review of internet databases as appropriate. These costs were utilized as a final screening measure from which recommended alternatives were determined for the Lee Moore Wash Basin Management Study.

5.3 RECOMMENDED ALTERNATIVES

5.3.1 Cost/Benefit Analysis

The final analysis employed to determine the recommended alternatives for the Lee Moore Wash Basin Management Study involved developing a weighted score to compare alternatives based upon their preference from the workgroups combined with their associated cost, similar to a cost/benefit ratio analysis. This was performed by dividing the total score of each top-ranked alternative by the estimated cost, thus providing the basis to compare each proposed solution using all the data developed with these analyses. A final fatal flaw analysis was performed on these data to eliminate alternatives that were outside the realm of practicality, as determined by County staff and the project team. The remaining options were selected for further consideration as the recommended alternatives for the study.

5.3.2 Summary of Recommended Alternatives

A total of sixteen different alternative solutions to the various identified drainage issues became the final suite of recommended alternatives for the LMWBMS. The recommended alternatives represent both structural and non-structural solutions, and several of the solutions are proposed to mitigate issues in multiple locations. Sets of recommended alternatives were developed separately to address problems identified within each planning area, as well distinct arrays of alternatives for existing and future conditions. The detailed list of all the specific recommended alternatives were tabulated in a final worksheet, and are presented in Tables 4 through 11 at the end of this section. A brief summary of the chosen alternatives are discussed in the following paragraphs.

Existing condition alternatives were generally specific in nature, as they were developed to address distinct flooding-related circumstances. Structural alternatives intended to address existing drainage issues ranged from the installation of new culverts, construction of channels and/or bank stabilization and floodproofing of existing structures. Four locations were identified where regional detention facilities may be considered to mitigate downstream flooding problems. Non-structural alternatives would involve public education and outreach, roadway access improvements, and potential implementation of the FLAP (Floodplain Land Acquisition Program) and/or improvement districts. A program to evaluate and maintain issues associated with the numerous stock ponds within the LMWBMS area is also a recommended alternative related to the existing conditions analyses, but will be addressed with the adoption of the Development Criteria generated with the future conditions alternatives discussed below.

Future recommended alternatives were much more broad-based in nature and, with the exception of the construction of regional detention facilities aimed to serve as a backbone drainage infrastructure, are generally non-structural in nature. In addition to generating the above-noted Development Criteria, devoted toward providing regulations and guidelines for future development within the area, the delineation of a network of flow corridors throughout the study area was also a well-received recommended alternative to be implemented with future growth. Public education and outreach, potential delineation of floodplains regulated by FEMA, as well as recommended modifications and/or changes to future roadway alignments to avoid floodprone areas were additional alternatives chosen with the future analyses. In addition to the above-noted spreadsheet, the final recommended alternatives are also displayed spatially on two sets of maps (existing and future) that accompany this report. A more detailed description of the efforts associated with generating the Development Criteria for the LMWBMS is provided in the following section of this report (Section 7.0)

Stantec

Table 4
Area-Wide Recommended Alternatives
Existing Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Area Wide Alternatives	EXISTING PROBLEM AREAS									
	Existing Problem Statement:	25 drainage complaints within unplatted areas north of Sahuarita Rd; 60% related to access and flooding issues								
	Floodproofing	97	90	70	52	125	434	$180,000	0.002412	24.1
		20 drainage complaints along Wilmot corridor unplatted areas; 35% related to access and flooding issues								
	Floodproofing	97	90	70	52	125	434	$510,000	0.000851	8.5
		35 drainage complaints within unplatted areas east of Wilmot Rd; 40% related to access issues								
	Floodproofing	97	90	70	52	125	434	$240,000	0.001808	18.1
		Existing Stock Pond/Diversion Structures								
	Ensure maint & operation of stock ponds/diversion structures; study & analysis with future development	51	79	73	68	158	428	$2,625,000	0.000163	1.6
	No Action	74	68	70	46	125	383			
		Enhance Public Education and Outreach								
	Public Education and Outreach	83	112	70	54	119	438	$30,000	0.014600	146.0
		Flooding within unplatted residential areas								
	Improvement District	113	89	75	50	143	470			

Stantec

Table 5
Franco/Flato/Summit Area Recommended Alternatives
Existing Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Franco/Flato/Summit Area Alternatives	EXISTING PROBLEM AREAS									
	Existing Problem Statement:	Old Vail Road -- Franco Wash 100-yr flow depth 7-8 feet								
	Automatic Barricade Control	84	101	70	54	119	427	$300,000	0.001422	14.2
	Culvert	83	98	41	42	150	414	$1,718,750	0.000241	2.4
	INSTALL BARRICADES AS INTERIM SOLUTION - CULVERT POTENTIAL PERMANENT LONG-TERM STRATEGY FOR ALL-WEATHER ACCESS									
		Summit Street -- Franco Wash 100-yr flow depth 3-4 ft								
	Automatic Barricade Control	84	101	70	54	119	427	$300,000	0.001422	14.2
		Flooding along Franco Wash--potential flooding of 45-50 structures within Summit Area								
	Public Education and Outreach	83	112	70	54	119	438	$30,000	0.014600	146.0
	DEVELOP PROGRAM TO INFORM & EDUCATE RESIDENTS SITUATED WITHIN IDENTIFIED LOCAL FLOODPLAINS									
		Flooding along Summit Wash--potential flooding of 30-35 structures from County Club to Nogales Hwy								
	Public Education and Outreach	83	112	70	54	119	438	$30,000	0.014600	146.0
	DEVELOP PROGRAM TO INFORM & EDUCATE RESIDENTS SITUATED WITHIN IDENTIFIED LOCAL FLOODPLAINS									
	Regional detention basin	118	85	92	60	98	452	$513,110	0.000881	8.8
		Additional flooding along Franco Tributary south of Old Vail Rd								
	Public Education and Outreach	83	112	70	54	119	438	$30,000	0.014600	146.0
	DEVELOP PROGRAM TO INFORM & EDUCATE RESIDENTS SITUATED WITHIN IDENTIFIED LOCAL FLOODPLAINS									
	Regional detention basin	118	85	92	60	98	452	$578,920	0.000781	7.8
		Flooding along Flato at Old Nogales Hwy								
	Public Education and Outreach	83	112	70	54	119	438	$30,000	0.014600	146.0
	FLAP	256	67	98	57	145	623	$1,482,000	0.000421	4.2
		Maintenance of Lee Moore Channel Bank Protection/Bank Erosion								
	Bank Stablization	132	94	82	46	170	524	$3,445,200	0.000152	1.5
	COST TO BE RE-EVALUATED TO DETERMINE IF ESTIMATE MAY BE LOW									

Stantec

Table 5A
Franco/Flato/Summit Area Recommended Alternatives
Existing Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Franco/Flato/Summit Area Alternatives	EXISTING PROBLEM AREAS									
	Franco Wash at Houghton Rd: +/-1000 ft, depth >1ft									
	Automatic Barricade Control	84	101	70	54	119	427	$300,000	0.001422	14.2
	Culvert	71	115	41	42	150	420	$1,093,750	0.000384	3.8
	INSTALL BARRICADES AS INTERIM SOLUTION - CULVERT AT FRANCO POTENTIALLY PART OF LONG-TERM STRATEGY FOR ALL-WEATHER ACCESS									
	Flato Wash at Houghton Rd--depth>1ft									
	Automatic Barricade Control	84	101	70	54	119	427	$300,000	0.001422	14.2
	Culverts	71	115	41	42	150	420	$3,125,000	0.000134	1.3
	INSTALL BARRICADES AS INTERIM SOLUTION - CULVERTS AT FLATO PART OF LONG-TERM STRATEGY FOR ALL-WEATHER ACCESS									
	Stock ponds upstream of Wentworth/I-10 interchange--potential flooding at interchange with failure									
	stock ponds/diversion structures; study & analysis with future development	51	79	73	68	158	428	$200,000	0.002141	21.4
	Utilize as regional detention basins	94	59	92	60	175	481	$2,611,000	0.000184	1.8
	INSPECTION AND MAINTENANCE MAY BE AN INITIAL STRATEGY - ADDITIONAL ANALYSIS AND STUDY REQUIRED TO DETERMINE STRUCTURES THAT MAY BEST SERVE AS									
	Stock Ponds/diversions along Flato main corridor--potential diversion of flow north into Franco watershed									
	stock ponds/diversion structures; study & analysis with future development	51	79	73	68	158	428	$75,000	0.005710	57.1
	Utilize as regional detention basins	94	59	92	60	175	481	$979,125	0.000491	4.9
	INSPECTION AND MAINTENANCE MAY BE AN INITIAL STRATEGY - ADDITIONAL ANALYSIS AND STUDY REQUIRED TO DETERMINE STRUCTURES THAT MAY BEST SERVE AS									
	New Tucson all-weather access issues at several crossings; undersized culverts at several crossings									
	Maintain culverts, upgrade culvert size	57	108	86	50	125	426	$2,415,750	0.000176	1.8
	Remove access points	109	88	92	50	125	464	$545,600	0.000850	8.5
	Impacts of stock ponds/diversion structures south of Sahuarita Rd and New Tucson area									
	stock ponds/diversion structures; study & analysis with future development	51	79	73	68	189	460	$250,000	0.001838	18.4
	Utilize as regional detention basins	74	55	92	56	194	471	$3,263,750	0.000144	1.4
	INSPECTION AND MAINTENANCE MAY BE AN INITIAL STRATEGY - ADDITIONAL ANALYSIS AND STUDY REQUIRED TO DETERMINE STRUCTURES THAT MAY BEST SERVE AS									

Table 6
Cuprite/Fagan/Petty Ranch Area Recommended Alternatives
Existing Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Culprite/Fagan/Petty Ranch Areas Alternatives	EXISTING PROBLEM AREAS									
	Existing Problem Statement:	FICO Channel lacks capacity to convey flow north, breakout/flooding to west								
	No Action	74	68	70	50	125	387			
		Sahuarita Rd-all-weather access limited from east near Wentworth Rd to Houghton								
	Culverts	83	115	41	42	150	431	$1,306,875	0.000330	3.3
	Maintain culverts, upgrade culvert size	57	101	86	50	150	444	$357,000	0.001245	12.4
	MAINTENANCE AND/OR UPGRADE OF EXISTING STRUCTURES INITIAL STRATEGY - ADDITIONAL NEW CULVERTS LONG-TERM STRATEGY FOR ALL WEATHER ACCESS									
		Approx. 2 miles of Sahuarita Rd - Houghton Rd to Rita Rd alignment								
	Culverts	83	115	41	42	150	431	$4,235,000	0.000102	1.0
	Maintain culverts, upgrade culvert size	57	101	86	50	150	444	$15,000	0.029620	296.2
	MAINTENANCE AND/OR UPGRADE OF EXISTING STRUCTURES INITIAL STRATEGY - ADDITIONAL NEW CULVERTS LONG-TERM STRATEGY FOR ALL WEATHER ACCESS									
		Houghton Rd-all-weather access limited from north								
	Automatic Barricade Control	84	101	70	54	119	427	$300,000	0.001422	14.2
	BARRICADE CONTROLS AS AN ITERIM SOLUTION - WOULD REQUIRE MORE THAN TWO LOCATIONS AS REGIONAL ALTERNATIVE									
	Provide all weather access	71	123	38	53	125	410	$6,658,596	0.000062	0.6
	Culverts	83	108	41	42	150	424	$5,326,875	0.000080	0.8
	ALL WEATHER ACCESS ASSUMES COST OF CULVERTS AND INCIDENTAL CROSSINGS/ADDITIONAL COSTS ASSOCIATED WITH TWO LANE ROADWAY - I-10 TO SAHUARITA RD									
		Houghton, Sahuarita Area--flooding/erosion issues								
	No Action	74	68	70	50	125	387			

Stantec

Table 7
Sycamore Canyon Gunnery Range Area Recommended Alternatives
Existing Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Sycamore Canyon & Gunnery Range Areas Alternatives	EXISTING PROBLEM AREAS									
	Sahuarita Rd-Rita Rd alignment to Nogales hwy									
	Culverts	83	115	41	42	150	431	$8,855,625	0.000049	0.5
	Maintain culverts, upgrade culvert size	57	101	86	50	150	444	$967,500	0.000459	4.6
	MAINTENANCE AND/OR UPGRADE OF EXISTING STRUCTURES INITIAL STRATEGY - ADDITIONAL NEW CULVERTS LONG-TERM STRATEGY FOR ALL WEATHER ACCESS									
	Undersized/clogged culverts in Sycamore Canyon Estates south of Sahuarita Rd									
	Maintain culverts, upgrade culvert size	57	101	86	50	125	419	$27,000	0.015530	155.3
	No Action	74	68	70	50	125	387			
	Complaints about integrity of berm along Columbus Blvd, north of Dawson, east of Irving									
	No Action	74	68	70	50	125	387			
	Sahuarita, Delgado, Dawson: FICO channel--lack of capacity/sedimentation causes residential flooding									
	FLAP	256	70	86	57	145	614	$23,062,806	0.000027	0.3
	Regional detention basins	47	85	92	60	175	459	$14,881,300	0.000031	0.3
	COST ASSUMES FACILITIES AT TWO LOCATIONS									
	Construct 100-year channel	59	103	70	38	138	407	$2,541,000	0.000160	1.6

Stantec

Table 8
Area-Wide Recommended Alternatives
Future Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Area Wide Alternatives	FUTURE PROBLEM AREAS									
	Future Problem Statement:	Develop Backbone Drainage Infrastructure								
	Delineate and preserve flow corridors	210	114	82	73	175	654	$504,500,000		
	COST REPRESENTS BENEFIT IN FORM OF RECLAIMED FLOODPLAIN ACRES									
	Regional detention basins	125	85	96	60	175	540	$127,692,675	0.000004	0.04
	COST BASED ON FUTURE FACILITIES AT NINE LOCATIONS									
	Rules of Development	174	101	135	64	125	599			
		Identify and Disclose Flood Hazard Information								
	Delineate additional FEMA floodplains	193	93	92	51	138	566	$1,665,000	0.000340	3.4
	COST COULD BE SUBSTANTIALLY LESS IF ALL AREAS PROCESSED AS APPROXIMATE STUDIES									
	Public Education and Outreach	83	112	70	51	125	441	$30,000	0.014692	146.9

Stantec

Table 9
Franco/Flato/Summit Area Recommended Alternatives
Future Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Franco/Flato/Summit Area Alternatives	FUTURE PROBLEM AREAS									
	Future Problem Statement:	50% of Wilmot Rd & Kolb Rd alignments are impacted by defined floodplain areas								
	Rules of development	174	101	96	64	125	560			
	Realign Wilmot Rd	79	99	96	57	170	501	-$606,061	-0.000827	-8.3
	COST REPRESENTS BENEFIT IN FORM OF REDUCED LENGTH & CONSEQUENT ROADWAY COST									
		Country Club Rd alignment impacted by main flow corridors of Franco Wash and Flato Wash								
	Rules of development	174	101	96	64	125	560			
	Realign Country Club Rd	79	99	96	57	170	501	-$1,060,606	-0.000472	-4.7
	COST REPRESENTS BENEFIT IN FORM OF REDUCED LENGTH & CONSEQUENT ROADWAY COST									
		Access to private parcel near Country Club/Pima Mine Rd								
	Rules of development	174	101	96	64	125	560			
		Intersection at Dawn Rd & I-10 located within floodprone area								
	Relocate intersection	62	99	91	55	158	463	$1,136,364	0.000408	4.1
	COST REPRESENTS INCREASED LENGTH OF ROADWAY TO AVOID FLOD HAZARD AREA - COST COULD BE LESS WHEN OFFSET BY REDUCED DREQUISITE DRAINAGE									

Stantec

Table 10
Cuprite/Fagan/Petty Ranch Area Recommended Alternatives
Future Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Cuprite/Fagan/Petty Ranch Areas Alternatives	FUTURE PROBLEM AREAS									
	Existing Problem Statement:	Proposed Dawn Rd alignment swings south into flood hazard area, +/- 1/3 mile flow depths >0.5ft								
	Rules of development	174	101	96	64	125	560			
	Realign roadway	79	99	101	61	170	510	-$757,576	-0.000673	-6.7
	COST REPRESENTS BENEFIT IN FORM OF REDUCED LENGTH & CONSEQUENT ROADWAY COST									
		60-65% of proposed Wilmot Rd & Rita Rd alignments impacted by defined floodplain areas								
	Rules of development	174	101	96	64	125	560			
	Realign Wilmot Rd	79	99	90	57	170	495	-$3,030,303	-0.000163	-1.6
	COST REPRESENTS BENEFIT IN FORM OF REDUCED LENGTH & CONSEQUENT ROADWAY COST									
		Swan Rd Alignment--situated within sheet flow area north of Sahuarita Rd								
	Remove roadway section	74	53	115	65	63	370	-$10,984,848	-0.000034	-0.3
	COST REPRESENTS BENEFIT IN FORM OF REDUCED LENGTH & CONSEQUENT ROADWAY COST									
		Pima Mine Rd--from Houghton to Wilmot is within shallow sheet flow; divert flow to Cuprite watershed								
	No Action	74	68	61	44	125	371			
	NO ACTION ASSUMES ROADWAY BUILT AS PROPOSED IN SE ARTERIAL STUDY - DRAINAGE MAINTAINED PER EXISTING FLOW PATTERNS									
		Hook M Ranch property--40-50% of property impacted by shallow sheet flow								
	corridors	210	114	82	73	170	649	$28,900,000		
	COST REPRESENTS BENEFIT IN FORM OF RECLAIMED FLOODPLAIN ACRES									
	Rules of development	174	101	96	64	125	560			

Table 11
Sycamore Canyon Gunnery Range Area Recommended Alternatives
Future Conditions

Planning Area	Alternative	Public Safety and Flood Hazard Mitigation	Implementation	Environmental Resources	Sustainability	Planning and Infrastructure	Total Score	Probable Construction Cost ($)	Total Score divided by probable construction cost	Total score x 10000
	Weighted Value	3.5	1.5	1.5	1	2.5	10			
Sycamore Canyon & Gunnery Range Areas Alternatives	FUTURE PROBLEM AREAS									
		Wilmot Rd & Dawson Rd proposed alignments situated in areas dominated by shallow sheet flow								
	No Action	74	68	40	49	125	355			
		Sycamore Canyon Blocks C-G--plan platted, currently undeveloped; flood hazard areas fairly contained								
	Delineate and preserve flow corridors	210	114	82	73	170	649			
		COST REPRESENTS BENEFIT IN FORM OF RECLAIMED FLOODPLAIN ACRES								
	Rules of development	174	101	96	64	125	560			

6.0 Development Criteria (summarized from CLW, 2009b)

Historically, Arizona communities have developed floodplain management measures such as floodplain ordinances, drainage ordinances, and development standards intended to mitigate the flood impacts of urbanization. If these measures are not adequate or are not adequately enforced, the consequences may include flooding of homes and businesses, displacement of existing natural flood flows, increased flood depths, and flooding of lands previously not in a floodplain. The adverse impacts of urbanization on drainage often include the following:

a. More Frequent Flooding. As the land area within a watershed is converted from natural rangeland to rooftops and pavement, less rainfall infiltrates into the ground and more rainfall becomes runoff. This results in more frequent runoff events and increased nuisance flooding.

b. Larger Flood Peaks. The change from natural pervious land surfaces to urbanized impervious surfaces also causes the size of floods to increase, as more runoff leaves the watershed. Urbanized watersheds generate not only larger flood peaks, but also greater flood volumes and floods of longer duration, both of which increase flood damages. As flood peaks increase with urbanization, existing drainage structures become inadequate and have a greater risk of failure.

c. Loss of Natural and Beneficial Floodplain Functions. Natural floodplains provide important sociological, as well environmental and hydrologic benefits. These sociological benefits include continuous linear open space, visual and aesthetic beauty, multi-sensory relief from pervasive constructed hardscapes, and a sense of community character tied to the natural setting.

d. Scour and Erosion. Because more land area is covered by homes, streets and landscaping as a watershed urbanizes, the natural sediment supply to streams is decreased, which causes floods to be more erosive. This erosion leads to loss of homes and land due to riverine bank erosion, scour damage to bridges, and adverse impacts to flood control facilities and natural river habitat.

e. Flow Diversion. Unmanaged development can block natural flow paths, diverting runoff toward areas that were previously not flooded.

f. Flow Concentration. Development in riverine or distributary flow floodplains blocks natural overland flow paths, concentrating runoff through narrower conveyance corridors. Flow concentration leads to higher flood peaks, higher flood velocities, and accelerated scour and erosion.

g. Expanded Floodplains. Increased flood peaks and flow diversion increase flood water elevations and expand floodplain widths, inundating properties previously safe from flooding and expanding the number of homes and business at risk for future flood damage.

h. Reduced Surface Storage. Reducing surface storage areas by grading individual lots to reduce ponding areas or soggy soils or by erecting structures within former ponding and flood-prone areas increases both the peak flow and the volume of runoff generated by a given storm, and may also result in a loss of vegetation that further increases runoff rates.

i. Decreased Ground Water Recharge. Increased impervious surface area in an urbanized watershed inhibits ground water recharge and reduces soil moisture, with adverse consequences to long-term water supply, subsidence, and vegetation.

j. Loss of Riparian Habitat. Increased erosion due to increased flood peaks and reduced sediment supply leads to degraded habitat along river corridors, with adverse impacts to wildlife and public recreation.

In order to protect private and public property, and the health and general welfare of the public, naturally occurring flood hazards and potential flood hazards related to development need to be identified, and appropriate standards applied to safely manage new development. Development Criteria are a work product of a Basin Management Plan (BMP). This plan develops hydrology for a watershed, identifies potential flood prone areas and drainage problems, and identifies alternatives for solving these problems. Adherence to these development criteria will lessen the adverse impacts of urbanization and decrease the cost of flooding for the public. The BMP takes the compiled information and analyzes the alternatives to reach Recommended Alternatives (RA). The RA contains both structural (such as basins, culverts and channels) and non-structural (such as development criteria, flood warning system, and property acquisition) solutions.

The Lee Moore Wash study area is located in the southeast portion of Pima County including a portion of the City of Tucson and Town of Sahuarita. The northern half of the study area lies predominantly within the incorporated limits of the City of Tucson. The Town of Sahuarita covers a small area in the southwestern portion of the study area. The majority of the central portion of the study area is unincorporated Pima County.

Counties lack the regulatory authority to manage lot splits. As a result, these types of land division are exempt from subdivision and/or other improvement requirements. Although impacts from lot split development may appear relatively insignificant when viewed on the individual lot basis, frequently the cumulative impact of such external impacts is much more significant. Counties have greater ability to review residential subdivisions, multi-family, industrial and commercial projects to address potential impacts on adjacent properties. Cities have the authority to review and require compliance with development standards for the above projects, as well as individual lots.

In reviewing these issues, it became apparent that Development Criteria would have a positive effect on single-family development on individual lots within the LMWBMS study area. Therefore, the analysis of the types of potential regulations was done with a focus on the nature of single-family development on individual lots as well as master planned subdivisions.

7.0 Implementation Plan (summarized from CLW, 2010)

7.1 STAKEHOLDER INVOLVEMENT PROGRAM APPROACH

The Stakeholder Involvement program for this project was designed and completed with the goal of maximizing implementation opportunities for the Recommended Alternatives of the LMWBMS. To achieve this end, the "3 I's" method which has been used successfully in other similar projects was utilized. Simply put, the "3 I's" method of Stakeholder Involvement is to utilize a 3-Phase approach as identified in the Stakeholder Flowchart included in the Implementation Plan, and described below in the following sections.

7.1.1 Phase 1

Inform the stakeholders of the project in the early stages to obtain any useful knowledge they may have from a data collection standpoint, as well as to receive any initial input they may have regarding the scope of work or process. This was accomplished through facilitated workgroups of stakeholders with similar mandates, jurisdictions, and interests (i.e. transportation system agencies, unincorporated area, etc.). Several individual meetings were also held for those stakeholders with a unique interest (i.e. Southern Arizona Homebuilders Association, etc.). Stakeholders and their anticipated preliminary concerns/interests were identified and compiled into a spreadsheet, which was used as the baseline database for the rest of the stakeholder involvement program.

7.1.2 Phase 2

Involve the stakeholders throughout the course of the study so that they stay informed and interested in the project. This also allowed them to see the reasons why, or why not, their input would be included in the development of alternatives. This was accomplished through the use of workgroups, as well as individual meetings. An added benefit of maintaining contact through the course of the project is that new staff members from the agencies were educated prior to being shown the end product. Their involvement was documented in the matrices developed for all of the alternatives evaluated at each site.

7.1.3 Phase 3

Include the stakeholders in the process of selection of the Recommended Alternatives. This effort included information exchange and discussion of:

a) costs of capital improvements

b) costs of maintenance

c) conceptual cost sharing agreements for capital improvements

d) conceptual agreements on maintenance responsibilities

e) construction timelines coordinated with other agencies' projects and budgets.

This was accomplished using a combination of workgroups and individual meetings because of the iterative nature of these negotiations.

7.2 IMPLEMENTATION STRATEGY

The results of the Stakeholder Involvement and Implementation Strategy are discussed in more detail in the forthcoming Implementation Plan. The Implementation Plan will detail the Recommended Alternatives by location, capital improvement costs, potential cost sharing partner, identified participation interest, mechanism for participation, method for jurisdictional adoption of the LMWBMS and a preliminary timeline of appropriate activities. The Implementation Plan will continue to be developed iteratively and in cooperation with the affected stakeholders. It will not represent a binding legal agreement on any partners, but will provide a solid summary of implementation strategies to date and a roadmap for the Pima County Regional Flood Control District implementation efforts once the LMWBMS is adopted by the Board of Directors. Many of the Recommended Alternatives are connected with other agency programs. The result is that often their schedule or funding will drive the construction and other non-structural measures timelines. Recognition of this fact by the District, and planning for this in future follow through efforts, will allow for cost effective and efficient Recommended Alternatives completion. If the coordination is not continued after completion of the LMWBMS, it is possible that other agencies will move ahead with their projects and not include the Recommended Alternatives.

The Recommended Alternatives, as described in Section 5.0 of this report, are comprised of structural and non-structural solutions at various locations. These locations are distributed throughout the project area, and include construction and non-construction activities that will ultimately be funded in one of three ways:

1. **Solely** funded by the District.

2. Funded solely or in partnership among private and/or public agencies, **including** the District.

3. Funded solely or in partnership among private and/or public agencies, **not** including the District.

An outline of each of the Recommended Alternatives funding and implementation strategies will be presented in the forthcoming Implementation Plan (CLW, 2010).

8.0 References

C.L. Williams Consulting, Inc., June 15, 2009a, Lee Moore Wash Basin Management Study - Public Involvement Report

C.L. Williams Consulting, Inc., (draft) August 21, 2009b, Lee Moore Wash Basin Management Study – Development Criteria

C.L. Williams Consulting, Inc., 2010, Lee Moore Wash Basin Management Study - Implementation Plan (in process)

Hydrogeologic Evaluation of the Lee Moore Wash Study Area, *July 5, 2007,* GeoSystems Analysis, Inc.

JE Fuller Hydrology & Geomorphology, Inc., August 2008a, Geomorphic Analysis Report for the Lee Moore Wash Basin Management Study, Pima County, Arizona

JE Fuller Hydrology & Geomorphology, Inc., December 2008b, Two-Dimensional Flow Analysis Report for the Lee Moore Wash Basin Management Study, Pima County, Arizona

Pima County Department of Transportation and Flood Control District, Planning Division, 1988, Hydrologic Investigation for the Lee Moore Wash Watershed, Pima County, Arizona

Pima County Regional Flood Control District, March 2007, PC-Hydro V.5, Pima County Hydrology Procedures - PC-Hydro User Guide

Soil Conservation Service (SCS), 1986, Urban Hydrology for Small Watersheds, Technical Release No. 55

Stantec Consulting Inc., February 2008a, Lee Moore Wash Basin Management Study - Existing Conditions Analysis

Stantec Consulting Inc., December 2008b, Lee Moore Wash Basin Management Study - Hydrologic and Hydraulic Analysis

U. S. Army Corps of Engineers, Hydrologic Engineering Center, July 1999, HEC-HMS Hydrologic Modeling System, Technical Reference Manual

U. S. Army Corps of Engineers, Hydrologic Engineering Center, Version 3.1, 2002, HEC-RAS User's Manual

U. S. Army Corps of Engineers, Hydrologic Engineering Center, September 2005, HEC-GeoRAS User's Manual

U. S. Army Corps of Engineers, Hydrologic Engineering Center, Version 3.0.1, April 2006, HEC-HMS User's Manual

Appendix (CD)

ALTERNATIVES ANALYSIS DOCUMENTS

Alternative Development Process

Planning Area Problem ID Document

Specific Criteria Weighting Evaluation Spreadsheet

Performance Criteria Weighting Matrix

Alternatives Development Table

Final Alternative Weighting Score Sheet

Cost Estimate Assumptions

Cost Estimate Spreadsheet

Weighted Recommended Alternative Spreadsheet

Project Base Maps

Environmental Opportunities and Constraints Map

Riparian Habitat Map

Proposed Landuse Map

Physical Setting Map

Floodplains & Drainage Complaints Map

Recommended Alternatives Exhibits

Existing Conditions - Plates 1 to 8

Future Conditions - Plates 1 to 8

Recommended Alternative Concept Drawings

Flow Corridor Schematic for Riverine Areas

Flow Corridor Schematic for Distributary Flow Areas

Multi-Use Regional Detention Basin Concept - Plan View

Multi-Use Regional Detention Basin Concept - Section