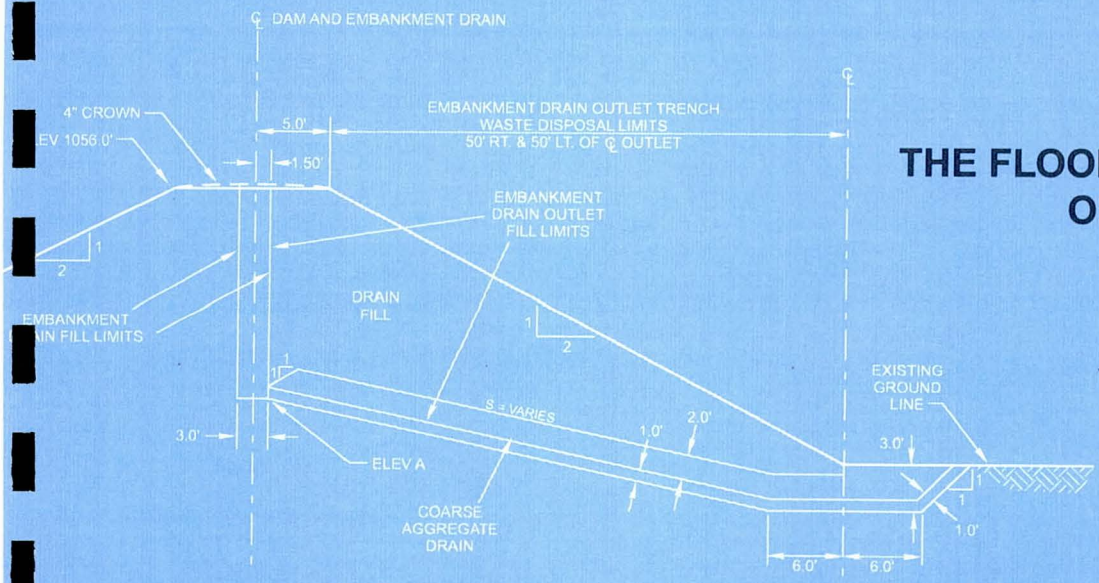
INFLOW DESIGN FLOOD HYDROLOGY
WHITE TANKS FRS No. 4 REHABILITATION PROJECT
BUCKEYE, ARIZONA

FCD CONTRACT No. 2008C002
PROJECT CONTROL No. 201.02.31
LOW ORG No. 6975



PREPARED FOR:

THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

PREPARED BY:

WOOD/PATEL

IN ASSOCIATION WITH

Ninyo & Moore

November, 2010

INFLOW DESIGN FLOOD HYDROLOGY

WHITE TANKS FLOODWATER RETARDING STRUCTURE NO. 4

REHABILITATION PROJECT

FCD CONTRACT NO. 2008C002

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Wood, Patel & Associates, Inc. (Wood/Patel) in association with Ninyo & Moore is pleased to have represented the Flood Control District of Maricopa County (FCDMC) in preparation of this Inflow Design Flood Hydrology report for White Tanks FRS No. 4. This professional assignment presented many interesting and unique challenges requiring creative teamwork solutions.

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WOOD, PATEL & ASSOCIATES, INC.

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Principal/Vice President – Water Resources

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1.0 INTRODUCTION

1.1 Project Location and Features

The White Tanks Floodwater Retarding Structure (FRS) No. 4 is located in central Maricopa County at the southeast end of the White Tank Mountains approximately 20 miles west of Phoenix, Arizona. The FRS structure can be reached by driving west from downtown Phoenix on Interstate 10 (I-10) and exiting south on Jackrabbit Trail (195th Avenue). FRS No.4 is less than one mile south of I-10 and is located between the Tuthill Road alignment on the west, Jackrabbit Trail on the east, and the Van Buren Street alignment on the south. FRS No.4 is generally located in Township 1 North, Range 2 West, Section 5 of the Gila and Salt River Baseline and Meridian. A project location map is provided as Figure 1.

The White Tanks FRS No.4 was constructed in 1954 under the supervision of the Natural Resources Conservation Service (NRCS). The dam is approximately 6,840 feet in length, and is a compacted homogeneous earthen embankment with a maximum height of approximately 20 feet and upstream and downstream slopes of 2:1 (H: V). The embankment top width is typically 10 feet at an elevation of 1,058 feet. The embankment is founded on native soils at approximately existing grades with no key trench or significant foundation treatment. The structure includes two gated corrugated metal pipe (CMP) principal spillways, two auxiliary spillways, and a centerline filter with 33 outlet drains. A central filter was installed along the length of the dam in 1982. The crest elevation of the two auxiliary spillways is about 1,052 feet (NAVD 1988 for all elevations).

The structure is currently classified by Arizona Department of Water Resources (ADWR) criteria as a "small" dam with a "high" downstream hazard, and as a "High Hazard Class" dam according to NRCS. The construction of I-10, Tuthill Dike Wash channel, Jackrabbit Trail Wash channel, and developments in the watershed have resulted in doubling the contributing drainage area of the FRS No.4 – from 10.3 square miles to approximately 20.0 square miles.

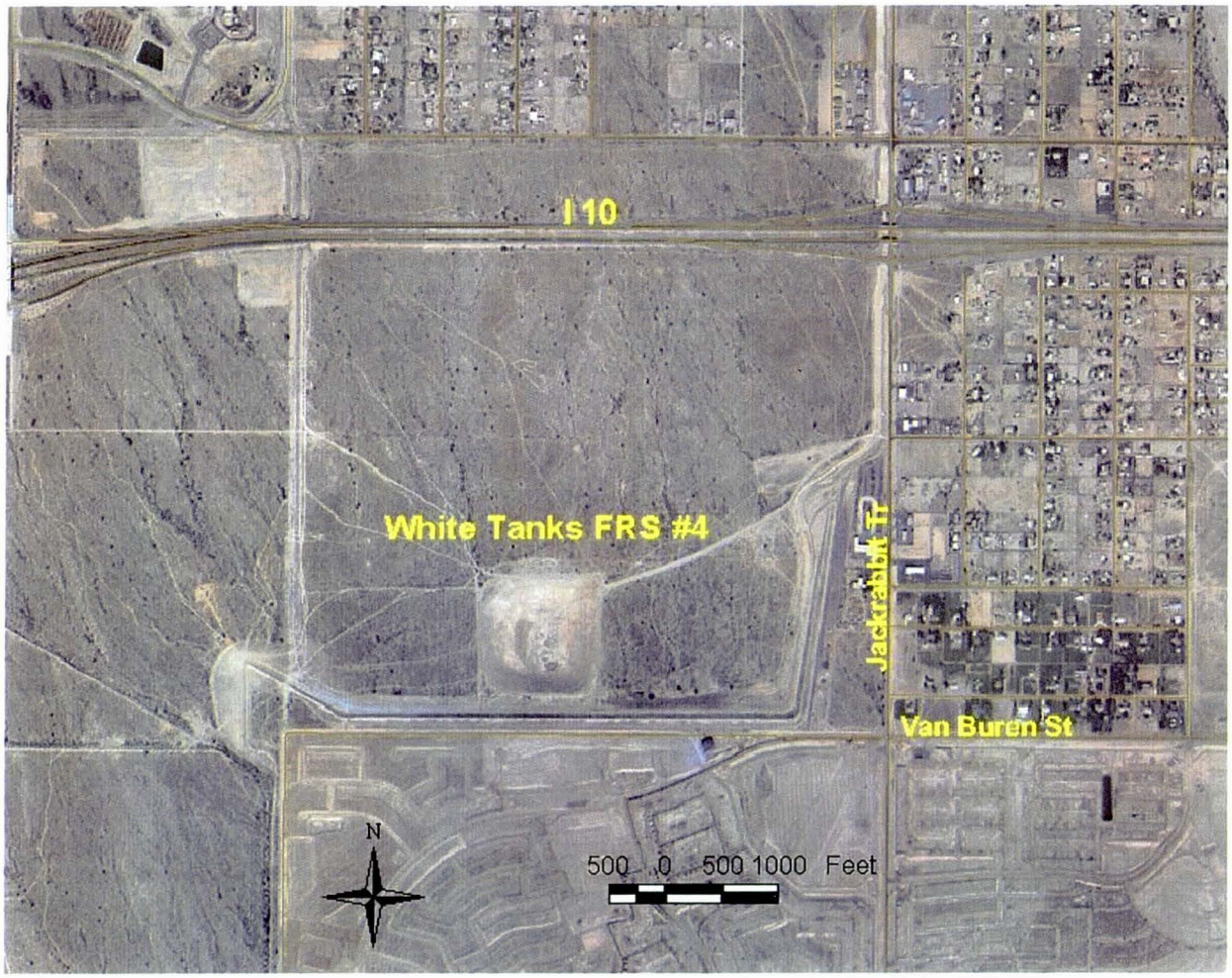


Figure 1 - Location Map

1.2 Authorization

Wood/Patel developed this report for the inflow design flood hydrology of the FRS No.4 in accordance with the FCDMC Contract No. 2008C002, White Tanks Flood Retarding Structure No. 4, Remediation Design and Engineering Support, Work Assignment No. 3: 30% to 100% Design, under contract to Ninyo & Moore. The project manager for the FCDMC is Mr. Dave Degerness, P.E., the project manager for Ninyo & Moore is Mr. Steven Nowaczyk, P.E., and the project manager for Wood/Patel is Mr. Jeff Minch, P.E.

1.3 Purpose

The purpose of this report is to document the assumptions, criteria, and methodologies used for the hydrologic modeling of the inflow design floods as well as the modeling results in support of the remediation design for White Tanks FRS No. 4. To meet the project requirements, hydrologic models were developed for nine (9) different storm events to define the inflow design floods for both existing and future land use conditions:

Hydrologic Model Type	Design Activity	Storm Frequency	Storm Duration	Modeling Condition
1	low flow channel & downstream floodplain	100-year	24-hour	existing
				future
2	additional risk assessment	200-year	24-hour	existing
				future
3	additional risk assessment	500-year	24-hour	existing
				future
4	principal spillway & storage requirements	100-year	10-day	existing
				future
5	stability design hydrograph – auxiliary spillway capacity	$P_{100} + 0.26$ $(PMP - P_{100})$	6-hour	existing
				future
6	integrity hydrograph - freeboard	PMP/PMF	6-hour	existing
				future
7	integrity hydrograph - freeboard	PMP/PMF	24-hour	existing
				future
8	integrity hydrograph - freeboard	PMP/PMF	72-hour	existing
				future
9	ADWR requirement	Half PMF	24-hour	existing
				future

1.4 Report Organization

All of the referenced appendices in this report are provided electronically on the CD in Exhibit F at the end of this report. Printed copies of the referenced material can be provided upon request.

2.0 HYDROLOGIC DESIGN GUIDELINES AND CRITERIA

2.1 General Design Guidelines and Criteria

Wood/Patel utilized the design guidelines published by NRCS, ADWR and the FCDMC to develop the hydrologic studies. Referenced publications include:

- *Earth dams and Reservoirs, TR-60*, United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, July 2005.
- *Arizona Administrative Code, Title 12, Chapter 15, Article 12 – Dam Safety Procedures*, September 2007.
- *PMF Studies for Evaluation of Spillway Adequacy, General Guidelines,* Arizona Department of Water Resources, Revised March 2004.
- *National Engineering Handbook, Section 4 – Hydrology*, United States Department of Agriculture, Soil Conservation Service, 1969.
- *Drainage Design Manual - Hydrology*, Flood Control District of Maricopa County, November 2003.
- *Drainage Design Manual – Hydraulics*, Flood Control District of Maricopa County, September 2003.

2.2 Principal Spillway Design Criteria

Design of the gated outlet structures will be based upon the following NRCS, ADWR and FCDMC criteria:

- Drain the 100-year, 10-day storm volume to 15% within 10 days or less using the gated outlets and infiltration – without passing flow over the auxiliary spillways;
- Drain the 100-year, 10-day storm volume to 15% within 10 days or less using a standard NRCS baffled riser and infiltration – without passing flow over the auxiliary spillways;
- Limit downstream flow rate of 183 cfs through the Blue Horizons Subdivision for the interim condition using the gated outlets;
- Minimize riser height from invert to crest.

2.3 Auxiliary Spillway Design Criteria

Design of the auxiliary spillway outlet structures will be based upon the following NRCS, ADWR and FCDMC criteria:

- Spillway design to prevent dam breach due to head cutting;
- Spillway can pass the PMF hydrographs with adequate residual freeboard.

3.0 HYDROLOGIC MODELING ASSUMPTIONS AND CONSTRAINTS

3.1 General Approach Outline

One of the major goals of the hydrologic analysis is to define the inflow design floods to the White Tanks FRS No. 4 for existing and future conditions. This goal was accomplished by the following tasks:

Task	Description	Design Feature
1	Review previous studies	Identify applicable available data.
2	Principal Spillway Hydrographs	Define principal outlet(s); auxiliary spillway crest elevation, storage requirements; and infiltration.
3	Stability Design (Auxiliary Spillway) Hydrographs	Auxiliary spillway discharge capacity and stability (surface erosion potential).
4	Integrity Design Hydrograph (Freeboard)-PMF Inflow Hydrographs	Auxiliary spillway designs (breaching potential); define top of dam and freeboard requirements.
5	100-year, 24-hour Inflow Hydrograph	FEMA floodplain evaluation; principal outlets for ADWR criteria.
6	Hydrologic Routing Evaluation	Establish principal spillway and auxiliary spillway configurations.
7	200 and 500-year, 24-hour Hydrologic Models	Evaluate system performance for extreme flood events with the goal of increasing the level of downstream flood protection and reducing the risk of auxiliary spillway discharges.

3.2 Existing and Future Conditions

For purposes of the hydrologic modeling effort, existing conditions were defined as existing MAG land use incorporating agency capital improvement projects currently under construction within the contributing watershed. Future conditions were defined as future MAG land use incorporating agency programmed capital improvement projects within the contributing watershed. During the hydrologic model development, the following features were modeled for each inflow design hydrograph (existing and future conditions) for the White Tanks FRS No. 4:

- Levee-like Structures (I-10, Tuthill Dike Wash)
- Detention/Retention Basins

The FCDMC is designing the White Tanks FRS No. 3 outfall channel from the principal outlet (PO) to the Jackrabbit Trail channel. Ultimate conditions for White Tanks FRS

No. 4 will consider one White Tanks FRS No. 3 principal outlet discharging to the improved channel as well as the additional contributing drainage area to the channel. Based on discussions with the FCDMC, it is assumed that the Jackrabbit Trail Channel will be designed to convey the 100-year event; and that the auxiliary spillway discharges from White Tanks FRS No. 3 will bypass the channel through an overchute or the principal outlet discharge will be piped preventing mixing of the flows. Hydrologically, the capacity of the Jackrabbit Trail Channel to convey flow south into White Tanks FRS No. 4 was evaluated based on existing topography. The channel capacity was evaluated using the 60% design hydraulic model for the Jackrabbit Trail Channel for future conditions only since the hydrologic models for the future conditions are in control.

The on-site retention volumes for both existing and future conditions from Verrado development and Loop 303/White Tanks ADMPU models within the watershed were applied to the development of the HEC-1 models for the inflow design flood hydrographs. The on-site retention volume data are summarized in Appendix 1.

3.3 Hydrologic Routing

For existing and future conditions, hydrologic routing of the inflow hydrograph(s) was accomplished using the HEC-1 computer program. The following hydrologic components were modeled for each design scenario (existing and future land use conditions) for the White Tanks FRS No. 4:

- Principal Spillway Outlet Capacity;
- Auxiliary Spillway Design;
- Sediment Considerations;
- Infiltration;
- Reservoir Antecedent Moisture Condition.

Specific elements of the hydrologic routing methods are summarized below:

Channel Routing

For existing and future conditions, Normal depth routing (a hydrologic routing method) was used to route the inflow hydrographs along the Tuthill and Jackrabbit Trail Channels.

Reservoir Routing

The Modified-Puls method, a level-pool reservoir routing procedure, was used to compute the hydrologic outflow hydrograph from the White Tanks FRS No. 4 reservoir. Starting conditions for auxiliary spillway hydrologic routings were performed considering ADWR guidelines for PMF studies. All storage routings presented in this study utilize the existing reservoir configuration (principal spillways, auxiliary spillways, and pool conditions).

Stage-Storage Function

A stage-storage function for existing conditions was developed using recent 1-foot contour interval aerial topographic mapping provided by the FCDMC for the White Tanks FRS No. 4 dam and reservoir. The stage-storage rating curve data for the existing conditions are included in Appendix 2.

Stage-Discharge Function

Principal Spillways

Existing principal spillway rating curves were computed using the Bentley CulvertMaster software. Details for each existing spillway outlet were obtained from the Phase I Inspection Report for the White Tanks FRS No. 4 dated August 1981. The rating curves for existing are included in Appendix 2.

Auxiliary Spillways

HEC-RAS models were used to develop discharge rating curves for the existing auxiliary spillways. The HEC-RAS model geometric data from 15% submittal were updated with the new topographic mapping prepared by the FCDMC. The rating curve data is included in Appendix 2.

Infiltration

The pool infiltration rate was updated from the 30% submittal of 0.7 inches per hour to 1 inch per hour as determined by the recent Ninyo & Moore study (2009). A copy of this analysis is provided in Appendix 15. A previously developed rating curve based on the infiltration at each stage as a function of surface area in the reservoir was revised as necessary using the new FCDMC topographic mapping.

The three rating curves (principal spillways, auxiliary spillways and infiltration) were combined (summed) to obtain a single complete stage-discharge rating curve of the existing and interim pool conditions for NRCS inflow design hydrographs (Principal Spillway and Stability) without outfall in place. The combined rating curve without the infiltration component was applied to other inflow design hydrographs (100-, 200-, and 500-year, 24-hour, and PMF) flood routing scenarios and will be used for design pool conditions for NRCS inflow design hydrographs (Principal Spillway and Stability) with new outfall in place. These rating curves are provided in Appendix 2.

3.4 Sediment Considerations

The sediment yield estimation methods used in the study were documented in the FCDMC's River Mechanics Manual for DDMSW, September 2009. The sediment yield consists of two parts and is defined as the sum of the wash load and the total bed material load delivered to a point of interest. The *wash load* is calculated with the MUSLE method, and the *total bed material load* is calculated with the Zeller-Fullerton equation (Zeller and Fullerton, 1983). The design 100-year sediment inflow (193 Ac-Ft) was updated by Wood/Patel. Detailed sediment analysis and supporting data are included in Appendix 3. The storage routing of the hydrologic models assumes a reduction of flood storage volume associated with the design 100-year sediment inflow. This assumption fills in a significant portion of the existing borrow pit.

3.5 Principal Outlet Hydrographs from FRS No. 3

The FCDMC is designing an outfall channel from the White Tanks FRS No. 3 PO to the Jackrabbit Trail Channel. Hydrologic models for principal outlet conditions for White Tanks FRS No. 4 account for one White Tanks FRS No. 3 principal outlet (NRCS Riser) discharging to the channel as well as the additional contributing drainage area to the channel. The original FRS No. 3 TR-20 models were documented in Appendices C, D, and E of the URS Design Report for White Thanks Flood Retarding Structure No.3 Remediation Project – Phase 1, March 2005. The TR-20 models for the inflow design floods were reviewed and revised for new computational time steps and stage-storage relationships to account for sediment pool volume. The TR-20 models with revised stage-storage-discharge relationships and the updated principal spillway hydrographs from FRS No. 3 for the inflow design flood hydrographs for FRS No. 4 are provided in Appendix 4.

HEC-1 models with and without a connection to the FRS No.3 PO hydrographs were developed. These hydrographs were incorporated into the inflow design flood models.

3.6 Hydrologic Modeling Components and Naming Conventions

The major hydrologic modeling components include design storm, inflow design flood assumptions, and FRS No.4 storage routing variables. Table 1 lists all of the hydrologic modeling components. For the inflow design flood models the FRS No.4 storage routing variables are existing conditions for all of the models, i.e., the PO and auxiliary spillway (AS), infiltration, and stage-storage for the pool configuration are modeled with sediment volume (193 ac-ft) excluded to account for the anticipated sediment delivered to the reservoir over the design life of the structure. This approach reflects the active storage available for hydrologic routing. Therefore, the FRS No.4 storage routing variables were not shown in Table 1.

The design storms are divided into three major classes based on the sources of the design storms: NOAA2, Technical Paper 49 (TP 49), and Site-Specific PMP (AWA, 2009). Each class is further divided based on design storm frequency, duration, storm type, and rainfall distribution. Table 1 shows the details of the design storm classifications from column 3 to column 10.

The inflow design flood assumptions include land use condition, rainfall loss method, unit hydrograph method, and the connection with FRS No.3 PO hydrographs. Table 1 shows the details of the inflow design flood assumptions from column 11 to column 20.

The number of design storms is nine (9) as described in Section 1.3, and the total number of inflow design flood hydrologic models is seventeen (17) with multiple storm types and rainfall distributions for site-specific PMP for a single land use conditions. The total number of inflow design flood hydrologic models is fifty one (51) with the combination of land use conditions (existing and future conditions) and FRS No.3 PO flow connection with future land use models. Column 1 of Table 1 shows the names of all HEC-1 models. Four (4) additional models were developed at the request of NRCS to illustrate Principal Spillway and Stability Design Hydrographs without infiltration for design pool conditions for a total of fifty five (55) hydrologic models.

A HEC-1 model naming convention was developed in order to organize the large number of HEC-1 models. A HEC-1 model name is limited to eight characters (combination of letters and numbers) long. The file name extension of DAT is for input data files and OUT for output files. Generally, the HEC-1 name consists of five (5) parts: the first letter represents the land use conditions (E for existing and F for future), the second letter or second to fourth letters represent storm frequency (C for 100-year, 200 for 200-year, 500 for 500-year, PMF for PMP, etc.), the third part of the name defines the storm duration (24 for 24-hour, 10 for 10-day, 6 for 6-hour, 72 for 72-hour, etc.), the fourth part of the name defines the FRS No.4 storage routing condition (B for existing base condition), and the last part represents the FRS No.3 PO hydrograph connection (A for flow connection). Column 1 of Table 1 shows the names of all HEC-1 models. Note that there are some exceptions to the naming conventions.

4.0 PERTINENT STUDIES

4.1 The Plan/EA 15% Design for FRS No.4

Many HEC-1 models for the FRS No. 4 Plan/EA 15% design were developed by Kimley Horn and Associates including models for inflow design flood hydrographs as well as outflow routing alternatives. Five models for the inflow design flood hydrographs and two models for the 200-year and 500-year, 24-hour storms were reviewed. The 100-year, 24-hour HEC-1 model was the base model for the 200-year model with point rainfall depth of 4.55 inches. All JD records were replaced with a PB record. One rainfall value for the 24-hour storm was used with an areal reduction of 20.2 square miles. The area-adjusted rainfall depths were 4.07 inches for the 200-year storm and 4.63 inches for the 500-year and these values were applied for the two models.

4.2 Loop 303-White Tanks Area Drainage Master Study Update

The HEC-1 models for Loop 303 – White Tanks Area Drainage Master Study Update by URS (January 2004) cover contributing watersheds of both FRS No. 3 and FRS No. 4. Two HEC-1 models for existing and future conditions were reviewed. The on-site retention volumes for both existing and future conditions outside Verrado were evaluated and were applied to the development of the HEC-1 models for the inflow design flood hydrographs. The on-site retention data are summarized in Appendix 1.

The preliminary HEC-1 models (future land uses) for Loop 303 – White Tanks Area Drainage Master Study Update by HDR (July 2009) were reviewed. The land use default databases from these models were applied to the hydrologic models for this project per discussions with the FCDMC.

4.3 Verrado Area Drainage Master Study

The Verrado Master Planned Community is the major sub-watershed within the contributing FRS No. 4 watershed. Wood/Patel updated the HEC-1 models for this area for both existing and future conditions in September 2007. The on-site retention volumes for both existing and future conditions were evaluated and were applied to the development of the HEC-1 models for the inflow design flood hydrographs. The on-site retention volume data are presented in Appendix 1.

5.0 FEMA HYDROLOGY

The 100-year, 24-hour HEC-1 models approved by the FCDMC and FEMA for the Loop 303 – White Tanks Area Drainage Master Plan Update by URS (ADMPU, 2004) was reviewed and revised for the application of the FRS No.4 project using data from the existing available Verrado Master Drainage Study by Wood/Patel (September 2007), and the preliminary ADMPU models by HDR (2009). The purpose of the 100-year, 24-hour hydrologic models is to design the low-flow channel, evaluate downstream floodplain impacts, and define the water-surface elevations in the pool for both the existing and the proposed design conditions.

5.1 Drainage Area Boundaries

The sub-basin boundary map from the White Tanks ADMPU (2004) was reviewed and slightly modified. The sub-basin boundaries and the HEC-1 schematic are presented in Exhibit C.

5.2 Sub-basin Physical Parameters

The sub-basin physical parameters have been reviewed and approved by both the FCDMC and FEMA. Sub-basin physical parameters are included in Appendix 8.

5.3 Rainfall Parameters

The rainfall parameters (NOAA 2) have been reviewed and approved by both the FCDMC and FEMA. Rainfall parameters are the same as the ADMPU (2004) model.

5.4 Soils

The hydrologic variables related to soil types have been reviewed and approved by both the FCDMC and FEMA. These parameters are the same as the ADMPU (2004) models. Soil data is summarized in Appendix 5 and soil maps are provided in Exhibit A.

5.5 Land Uses

The existing land uses were reviewed and updated for recent development within the watershed including the Verrado development. Some of these parameters were modified (i.e. RTIMP and retention volumes) for recent development. Future land uses were updated (i.e. RTIMP and retention volumes) for the ultimate approved master planned development within the watershed. Land use data is included in Appendix 6 and land use maps are presented in Exhibit B.

5.6 Rainfall Loss Parameters

Rainfall infiltration losses were computed using the Green and Ampt methodology. These calculations have been reviewed and approved by both the FCDMC and FEMA. These parameters were updated based on the ADMPU (2009) default databases using DDMSW version 2.1.0.

5.7 Rainfall Excess to Runoff Transformation

Precipitation excess is transformed to direct runoff using S-Graph methodology. These calculations have been reviewed and approved by both the FCDMC and FEMA. These parameters were updated using the DDMSW version 2.1.0.

5.8 Flow Diversions

Flow diversion data was reviewed and approved by both the FCDMC and FEMA. These parameters are the same as the ADMPU models with the exception of flow diversions at I-10 and Jackrabbit Trail channel for future conditions (both north and south of I-10). The revised diversion rating curves and supporting calculations including the HEC-RAS models are included in Appendix 7.

5.9 Hydrologic Routing

Hydrologic routing including channel and storage routing was performed using several methods. These calculations have been reviewed and approved by both the FCDMC and FEMA. These parameters are the same as the ADMPU models with the exception of White Tanks No. 4 stage-storage-discharge rating curves. The stage-storage-discharge data is provided in Appendix 2.

5.10 Modeling Results

The HEC-1 models for both existing and future land use conditions were revised to include the updated on-site retention volumes and impervious area percentages. The updated HEC-1 models without FRS No.3 PO flows are EC24BASE.DAT for the existing conditions and FC24BASE.DAT for the future conditions. The HEC-1 model with FRS No.3 PO flow is FC24BASA.DAT for the future conditions. The hydrologic components incorporated into the HEC-1 models are defined in Table 1 and the modeling

results are summarized in Table 2. Table 2 identifies that the future land use conditions with the FRS No.3 flow connection is the controlling inflow hydrograph for the 100-year, 24-hour storm, and the peak stage in the pool is 1,052.1 ft.

5.11 Additional Risk Assessment Models

In order to minimize the potential for downstream impacts associated with auxiliary spillway discharges, one of the project goals is to evaluate flood protection (no auxiliary spillway discharges) for the 200-year and 500-year, 24-hour flood events if feasible to do so. Therefore, the 100-year, 24-hour models were used to develop the 200-year and 500-year, 24-hour models by replacing the rainfall data (JD records) of the 100-year, 24-hour models with the 200-year and 500-year, 24-hour rainfall depths for the existing and future conditions since the S-graph unit hydrograph method used in the HEC-1 models is relatively independent of the precipitation depth. The 200-year and 500-year HEC-1 models for the existing conditions without FRS No.3 connection are E200BASE.DAT and E500BASE.DAT, respectively. The 200-year and 500-year HEC-1 models for the future conditions without FRS No.3 connection are F200BASE.DAT and F500BASE.DAT, respectively. The 200-year and 500-year HEC-1 models for the future conditions with FRS No.3 connection are F200BASA.DAT and F500BASA.DAT, respectively. The hydrologic assumptions incorporated into the HEC-1 models are defined in Table 1 and the modeling results are summarized in Table 2. Table 2 shows that the controlling inflow hydrograph for the 200-year, 24-hour storm is the future land use conditions with FRS No.3 connection and the peak stage in the pool is 1,052.2 ft. The controlling inflow hydrograph for the 500-year, 24-hour storm is the future land use conditions with FRS No.3 connection and the peak stage in the pool is 1,052.3 ft.

6.0 PRINCIPAL SPILLWAY HYDROGRAPH

The purpose of developing the Principal Spillway Hydrograph (PSH, 100-year, 10-day) is to establish the auxiliary spillway crest elevation and the flood storage volume required, and to design the principal spillway(s) including size(s) and invert elevation(s) to meet the design criteria as described in Section 2.

6.1 Sub-Basin Boundary Delineation and Parameter Estimation

FCDMC provided digital topographic mapping and aerial photograph were used as the basis to delineate the sub-basin boundaries in the natural mountain and foothill areas. In the urbanized areas, major structures such as I-10, Tuthill Dike Wash, and Jackrabbit Trail Channel, was used as the sub-basin boundaries. AutoCAD was used to delineate sub-basin boundaries and estimate sub-basin parameters including sub-basin area, flow path length, and slopes. The sub-basin boundaries and HEC-1 schematic are presented in Exhibit D, and the sub-basin parameters are summarized in Appendix 9.

6.2 Rainfall Parameters

Rainfall data from Technical Paper No. 49 were used for the 100-year, 10-day rainfall depth and NOAA 2 were used to estimate the 100-year, 1-day (24-hour) design rainfall depth for this hydrograph. The rainfall data is documented in Appendix 9.

6.3 Soils

The FCDMC provided GIS coverage of the soils data developed by the Soil Conservation Service (now NRCS) which was used to define the soil hydrologic characteristics within the study area. The watershed is covered by both Aguila-Carefree and Maricopa Central Part surveys. The soil data is summarized in Appendix 5, and the soil map is presented in Exhibit A.

6.4 Land Uses

The most current Maricopa Association of Governments (MAG) land use data for both existing and future conditions provided by the FCDMC were applied for this study. Minor revisions to the MAG land use coverage for existing conditions were performed based on recent aerial photography and master drainage study reports. The land use summary data is listed in Appendix 6, and the land use maps are presented in Exhibit B.

6.5 Rainfall Loss Parameters

ArcGIS was used to estimate rainfall loss parameters from sub-basin data, soils and land use data, specifically, the Curve Number (CN) for this hydrograph. Supporting data for the Curve Number calculations is provided in Appendix 9.

6.6 Rainfall Excess to Runoff Transformation

The procedures in Chapters 15, 16, and 21 of NEH-4 were used to develop the PSH using rainfall and runoff amounts as described in the preceding sections. Supporting data for the Principal Spillway Hydrographs are included in Appendix 9.

6.7 Transmission Losses

Transmission (channel) losses were considered since the climatic index, as defined in Chapter 21 of NEH-4, is less than one. See Appendix 9 for supporting calculations.

6.8 Flow Diversions and Hydrologic Routing

Flow diversions are for on-site storage only for the PSH models since the peak flows are low. Hydrologic routing was performed using several methods. These parameters are the same as the 100-year, 24-hour models with the exception of White Tanks No. 4 stage-discharge rating curves includes infiltration. The stage-storage-discharge data is tabulated in Appendix 2.

6.9 Modeling Results

The HEC-1 models without FRS No.3 flow connection are EC10BASE.DAT for the existing conditions and FC10BASE.DAT for the future conditions with infiltration. The HEC-1 model with FRS No.3 connection for the future conditions is FC10BASA.DAT with infiltration. The HEC-1 model without infiltration is FC10BSNI.DAT with FRS No.3 connection and FC10BNI3 without FRS No.3 connection. The hydrologic assumptions incorporated into the HEC-1 models are defined in Table 1 and the modeling results are summarized in Table 2. Table 2 shows that the controlling inflow hydrograph for the 100-year, 10-day storm is the future land use conditions with FRS No.3 connection, and the peak stage in the pool is 1,052.2 ft (without infiltration).

7.0 PROBABLE MAXIMUM FLOOD

The purpose of the Probable Maximum Flood (PMF) hydrologic analysis is to define the top of the dam (freeboard) and evaluate the integrity of the auxiliary spillways. The site-specific PMF precipitation data and their distributions for the FRS No. 4 project were provided by Applied Weather Associates, LLC. (AWA, December 2009). This report is included in Appendix 15. The analytical approach presented below for the hydrologic modeling of the PMF is nearly identical to the methods used and approved by NRCS, ADWR, and FCDMC on the Spook Hill FRS in northeast Mesa (Tuncok and Minch, 2003, included in Appendix 15). Hydrologic models for PMF 6-hour, 24-hour, 72-hour, and half PMF (using the critical 24-hour storm) with numerous temporal distributions were developed for this project. A total of 36 hydrologic models were developed for the PMF for both existing and future land use conditions in combination of with and without the FRS No.3 connection.

7.1 Drainage Area Boundaries

Sub-basin boundaries were defined using existing general topographic features in the study watershed. Due to the magnitude of the peak flows for the PMF event, diversion impacts associated with existing structural features including I-10, detention/retention facilities and conveyance channels (Tuthill Dike and Jackrabbit Trail) were considered when defining sub-basin boundaries.

The entire uncontrolled drainage area contributing to the FRS No. 4 and the Jackrabbit Trail Channel from White Tanks FRS No. 3 was considered when defining the inflow design flood hydrograph from the contributing watershed. The sub-basin boundaries and HEC-1 schematic are presented as Exhibit E for all PMF hydrologic models.

7.2 Sub-basin Physical Parameters

The sub-basin physical parameters were computed using the topographic mapping developed for the Loop 303 Corridor/White Tanks Area Drainage Master Plan Update (i.e. area, drainage flow path length, and slope). AutoCAD was used to estimate the sub-basin parameters and are presented in Appendix 10 for all PMF HEC-1 models.

7.3 Rainfall Parameters

The site-specific PMF precipitation data and temporal distributions for the FRS No. 4 project were provided by AWA. There are two (2) temporal distributions for the local PMF 6-hour storm (front loaded and Queen Creek), three (3) distributions for the tropical PMF 24-hour storm (front loaded, middle loaded, and back loaded), two (2) distributions for the general PMF 24-hour storm (middle loaded and constant), two (2) distributions for the tropical PMF 72-hour storm (linear and back loaded), and two (2) distributions for the general PMF 72-hour storm (front loaded and middle loaded). The precipitation data and their distributions were documented in Appendices 10, 11 and 12 for the 6-hour, 24-hour, and 72-hour storms, respectively. The precipitation data for the half PMF 24-hour storms are identical to the PMF 24-hour storm. The temporal distributions for the half PMF 24-hour storm were identical to the PMF 24-hour storm providing the greatest peak inflow to the reservoir.

7.4 Soils

A soils map was developed from the GIS coverage of the soils data which was produced by the Soil Conservation Service (now NRCS) and provided by the FCDMC. This GIS coverage was used to quantify the areal distribution of the soil types within each sub-basin. The soil properties were defined based on TR-55 and the FCDMC's Hydrology Manual to determine the rainfall loss parameters. The watershed is covered by both Aguila-Carefree and Maricopa Central Part surveys. A soil map for the curve number method is provided in Exhibit A.

7.5 Land Uses

Maricopa Association of Governments (MAG) land use GIS coverage provided by the FCDMC was used to define the areal distribution of land use within each sub-basin. The land use hydrologic variables for each sub-basin were developed using TR-55 and the FCDMC's Hydrology Manual. The land use maps are provided in Exhibit B.

7.6 Rainfall Loss Parameters

ArcGIS was used to estimate rainfall loss parameters from sub-basin, soils and land use data, specifically, the Curve Number (CN) for these inflow design hydrographs. This method was used due to the relative shallow soil horizons within the study watershed.

Supporting data for the Curve Number calculations were included in Appendix 10 for all PMF and SDH HEC-1 models.

7.7 Rainfall Excess to Runoff Transformation

Precipitation excess is transformed to direct runoff using the Clark unit hydrograph. The Clark unit hydrograph method requires the use of three parameters: time of concentration (Tc), storage coefficient (R), and a time area relationship curve.

Time of Concentration

A relatively new computational procedure for the time of concentration variable was previously developed and approved by the review agencies (NRCS, ADWR, FCDMC) for the Spook Hill FRS study. This methodology combines the procedures and guidelines presented in the Soil Conservation Service (now the Natural Resources Conservation Service, NRCS) Technical Release 55 (TR-55) with a computational algorithm. Using a unit width approach, the algorithm iteratively defines the average channel flow parameters to determine the channel element travel time and ultimately the time of concentration for the contributing watershed or sub-basin. The details of the computational algorithm can be found in the proceedings of the Association of State Dam Safety Officials (ASDSO) Western Regional Conference. A copy of this paper is provided in Appendix 15.

For composite urban and rural subbasins, an arithmetic average of the Manning's "n" for each land use was applied. The iterative solution for the final time of concentration was assumed to converge within 0.1 hours tolerance.

Storage Coefficient

The storage coefficient (R) was computed using procedures in the FCDMC Hydrology Manual which is a function of the time of concentration, drainage area and length of the flow path.

Time Area Relation

The dimensionless time area relation, presented in the FCDMC Hydrology Manual, reflects natural and urban watersheds. The predominant land use was used to define the

applicable time area relation for each sub-basin. Where mixed urban/natural land uses occur within a specific sub-basin, the HEC-1 default time area relation was applied.

Supporting calculations for the Time of Concentration and Storage Coefficient are included in Appendices 10, 11, and 12 for the 6-hour, 24-hour, and 72-hour PMF storms, respectively.

7.8 Flow Diversions

When the PMF storm event occurs within the study watershed, conveyance structures such as Tuthill Dike Wash and Jackrabbit Trail Channel will be overwhelmed and have limited impact on the general drainage flow pattern. Locally, along these conveyance facilities, runoff in excess of the channel capacity will continue southeast following the general topography.

The Jackrabbit Trail Channel and Tuthill Dike Wash inflow hydrographs were developed as part of the total inflow design flood for White Tanks FRS No. 4. The inflow hydrographs are required to model the contribution of the upper watershed, in terms of the peak discharges and volumes, into the White Tanks FRS No. 4. In general, the peak inflow hydrographs from the existing and future Tuthill Dike Wash (below natural grade) and Jackrabbit Trail Channel (as designed by others for FRS No.3 outfall channel project) are truncated at the channel capacity (flow exceeding the channel capacity is diverted east).

The diversion of floodwater concentrating at I-10 was evaluated using the results of a two dimensional hydraulic analysis performed by a previous consultant (TUFLOW, Kimley-Horn and Associates, Inc, June 2008). Flow diversions were incorporated into the hydrologic models to simulate the I-10 embankment.

Two flow diversions along Jackrabbit Trail Channel near I-10 (north and south of I-10) were modeled for the 100-year, 24-hour storm future land use conditions. Flow diversions to the east along Tuthill Dike Wash and Jackrabbit Trail Channel have a significant impact on the total inflow to the FRS No. 4 for the PMF storms (about 40% of the total storm flow overtops the Jackrabbit Trail Channel and continues east). Along Tuthill Dike Wash these diversions include areas between Camelback Road and Indian

School Road, Indian School Road and Thomas Road, and Thomas Road and I-10. Along Jackrabbit Trail Channel diversions are possible between FRS No. 3 and Camelback Road, Camelback Road and Indian School Road, Indian School Road and I-10, and south of I-10.

Some of the diversion data from previous studies was updated and additional diversions were incorporated into the hydrologic models. Recent Jackrabbit Trail Channel design plans (60% submittal) show that the updated channel design has minimum impact on the flow diversions, and there are no current known future projects/plans that would significantly impact the study diversions. All supporting data for flow diversions are included in Appendix 7.

7.9 Hydrologic Routing

Hydrologic routing including channel and storage routing was performed using several methods. On-site storage data and the FRS No. 4 stage-storage-discharge rating curves are the same as the 100-year, 24-hour models. The on-site retention volume data are included in Appendix 1 and the stage-storage-discharge data are provided in Appendix 2.

7.10 Modeling Results

A total of 38 hydrologic models were developed for the PMF 6-hour, 24-hour, 72-hour, and half PMF 24-hour design storms for both existing and future land use conditions in combination of with FRS No.3 flow connection for future land use conditions. The hydrologic components and assumptions incorporated into the HEC-1 models are included in Table 1 and the modeling results are summarized in Table 2. Table 2 documents that the reservoir peak stage, principal outlet and auxiliary spillway discharges resulting from the inflow design flood hydrographs are higher from the future land use models than those from the corresponding existing condition models. The largest inflow is the 24-hour tropical storm with the front loaded rainfall distribution resulting in an estimated peak discharge of 17,526 cfs for both with and without the FRS No.3 connection. The 24-hour tropical storm with front loaded rainfall distribution; 6-hour local storm with the Queen Creek rainfall distribution; and the 6-hour local storm with front loaded rainfall distribution all result in an estimated peak stage of 1,055.9 ft for future land use conditions (both with and without FRS No.3 flow connection). Therefore,

the half PMF design storm evaluated was the 24-hour tropical storm with the front loaded rainfall distribution.

7.11 Sensitivity Analysis

At the request of ADWR, a sensitivity analysis of the curve number (CN) hydrologic variable was conducted and the modeling results show that the CN sensitivity is almost a direct relationship to the peak flow. By increasing or decreasing the CN 10% the resulting peak flows increase/decrease by ±6%. The impact of varying the CN by 10% results in variations in the reservoir maximum water-surface elevation by ±0.2 ft. The results illustrate that the sensitivity of the CN variable on the hydrologic analysis is not as significant as the rainfall data.

A quick model verification was also performed regarding the PMF HEC-1 models by inserting the 100-year precipitation into the 24-hour PMF HEC-1 model. The modeling results are summarized in Table 3.

Table 3 PMF Model Sensitivity Evaluation

HEC-1 Model	Peak Inflow (cfs)	Reservoir Discharge (cfs)	Reservoir Stage (ft)	Reservoir Volume (ac-ft)
100-year	6494	132.0	1049.7	828
PMF (with 100-year rainfall)	3633	267.0	1052.1	1106

It is difficult to compare the results of these two models. The 100-year model uses Green-Ampt methodology while the PMF model uses Curve Number methodology to account for rainfall losses. This was a conscious choice on behalf of the District because of the shallow soil horizon in the watershed. As anticipated, the 100-year model results in greater peak discharges and lower runoff volumes. The PMF model results in lower peak discharges but greater runoff volumes. It should be note that there are other variables that are different between the HEC-1 models that impact these design hydrologic variables.

7.12 Peak Flow Comparison of Previous PMF Models

The peak flow estimates for the PMF inflow hydrograph models by current study are significantly lower than the peak flow estimates developed for the Plan EA. The main reasons for these differences are as follows (for discussion purposes, the 6-hour PMF model is used as a specific example):

1) Rainfall depth – Plan EA model uses HMR No. 49 rainfall depth of 12.5 inches while the current study model used a site-specific PMP rainfall depth of 10.3 inches. The difference in rainfall depth results in more than 20% of the peak flow and volume differences.
2) Rainfall distribution – Plan EA model uses HMR No. 49 rainfall distribution while the current study model used site-specific Queen Creek rainfall distribution. The HMR No. 49 rainfall distribution has more than 40% of the total rainfall within 15 minutes of the third hour which produces significantly high peak flows.
3) Rainfall loss method – Plan EA model had Green-Ampt method while the current study model used SCS (now NRCS) curve number method. These two methods may have some minor impact to the peak flows.
4) Unit hydrograph method – Plan EA model used S-Graph method while the current study model used modified Clark (TR55 method to estimate Tc and corresponding storage coefficient). The S-graph method can generate higher peak flows than the Clark method since the modified TR55 method typically estimates a more reasonable Tc and storage coefficient when evaluating the results based on velocity.
5) Sub-basin delineation – Plan EA model used the Loop 303 ADMS model (100-year model) as the base model while the current study developed new delineations with larger sub-basin areas following the general slope of the land from northwest to southeast. Smaller sub-basin areas generally produce higher peak flows using HEC-1. The Plan EA sub-basin boundaries and hydrologic routing are not accurate for PMF events since the manmade channels would be overwhelmed by flows of this magnitude. This issue can result in significant differences in peak flow distribution and volumes.
6) Flow diversion locations and rating curves – Plan EA model had two diversions to the east of Jackrabbit Trail Alignment since the base model is the 100-year Loop 303 ADMS model. One diversion is along Jackrabbit Trail Wash north of I-10 and the

second one is south of I-10. The current study model evaluated the diversion potential in more detail and included additional flow diversions along the Tuthill Dike Wash and to the east of Jackrabbit Trail Wash at Indian School Road and near Missouri Avenue. The Plan EA model assumed that all of the flows at these locations are routed south even though the washes do not have the conveyance capacity.

It should be noted that the current study recognizes that the Plan EA models were developed in support of the 15% design based on scope limitations. The current study hydrologic models are now developed to a level commensurate with the design of the White Tanks FRS No. 4 rehabilitation project.

8.0 STABILITY DESIGN HYDROGRAPH

The purpose of developing the Stability Design Hydrograph (SDH, auxiliary spillway) is to evaluate the adequacy of the auxiliary spillway capacity and stability or surface erosion of the spillways.

8.1 Sub-Basin Boundary Delineation and Parameter Estimation

Since the magnitude of the SDH is on the order of the 500-year event, the sub-basin boundaries used to define the PMF were used to develop this design hydrograph. The sub-basin boundaries and HEC-1 schematic are the same as those of the PMF and are presented in Exhibit E. The sub-basin parameters are provided in Appendix 13.

8.2 Rainfall Parameters

Rainfall data from NOAA 2 for the 100-year, 6-hour and site-specific, 6-hour local storm were used to estimate the SDH design rainfall depth for this hydrograph. As defined in TR-60, the SDH design precipitation depth is $P_{100} + 0.26(PMP - P_{100})$ for high hazard dams. The rainfall data is provided in Appendix 13.

8.3 Soils

The FCDMC provided GIS coverage of the soils data developed by the Soil Conservation Service (now NRCS) was used to define the soil hydrologic characteristics within the study area. The soil data is summarized in Appendix 5, and a soil map for the curve number method is provided in Exhibit A

8.4 Land Uses

Maricopa Association of Governments (MAG) land use data for both existing and future conditions provided by the FCDMC was applied in this analysis. Minor revisions for existing conditions were required based on recent aerial photography. The land use maps are provided in Exhibit B.

8.5 Rainfall Loss Parameters

ArcGIS was used to estimate rainfall loss parameters from sub-basin data, soils and land use data, specifically, the Curve Number (CN) for this hydrograph. Supporting data for the Curve Number calculations are included in Appendix 13.

8.6 Rainfall Excess to Runoff Transformation

The procedures in Chapters 15, 16, and 21, NEH-4 were used to develop the SDH using rainfall and runoff amounts as described in the preceding sections. Supporting data for the Stability Design Hydrographs are included in Appendix 13.

8.7 Flow Diversions and Hydrologic Routing

The flow diversion and hydrologic routing data are the same as those for the PMF models except that the infiltration component is included for the FRS No. 4 stage-discharge rating curve.

8.8 Modeling Results

The HEC-1 models without FRS No.3 flow connection are ESDHBASE.DAT for the existing conditions and FSDHBASE.DAT for the future conditions with infiltration. The HEC-1 model with FRS No.3 connection is FSDHBASA.DAT for the future conditions with infiltration. The HEC-1 model without infiltration is FSDHBSNI.DAT with FRS No.3 connection and FSDHBNI3 without FRS No.3 connection. The hydrologic assumptions incorporated into the HEC-1 models are defined in Table 1 and the modeling results are summarized in Table 2. Table 2 documents that the controlling inflow hydrograph for the SDH storm is the future land use conditions with FRS No.3 connection and without infiltration. The peak flow is 5,499 cfs and the peak stage in the pool is 1,054.1 ft.

9.0 SUMMARY

This report documents the assumptions, criteria, and methodologies used for the inflow design flood modeling and results in support of the remediation design for FRS No. 4. The hydrologic components and assumptions for the 55 HEC-1 models are included in Table 1. The modeling results including inflow hydrograph peak flows, volumes, and the routing responses of the existing FRS No. 4 reservoir are summarized in Table 2. The HEC-1 input and output files are provided in Appendix 14. The HEC-1 input and output electronic files and supporting data are provided as Exhibit F (CD).

The important conclusions and recommendations from the hydrologic modeling process and modeling results are summarized as follows:

- In general, hydrologic models with future land use conditions generate higher peak inflow design floods for the FRS No.4 than the existing land use condition models;
- The FRS No.3 inflow impacts the FRS No.4 flood pool storage routing including principal outlet design, pool storage volume, and auxiliary spillway crest elevations;
- The existing pool, principal outlets, and auxiliary spillway crest elevation of approximately 1,052.0 ft provides downstream protection for the 100-year inflow design flood without FRS No.3 inflow;
- The estimated maximum water-surface elevation is approximately 1,056.0 ft for the site-specific PMF storms with the existing pool, principal outlets, and auxiliary spillways;
- The 100-year 24-hour storm generates higher peak inflow while the 100-year 10-day storm produces higher flood volume. The pool storage routing variables will determine the controlling inflow design hydrograph for the principal outlet design;
- The inflow design hydrographs for the FRS No.4 from the five (5) key storms (100-year 24-hour, 100-year 10-day, SDH, PMF 6-hour, and PMF 24-hour) are plotted in Figures 2 through 6 for the existing land use conditions without FRS No.3 inflow, the future land use conditions without FRS No.3 inflow, and the future land use conditions with FRS No.3 inflow. The peak flow into WT4 from the contributing watershed is estimated to vary from 2,202 cfs to 17,526 cfs. The corresponding maximum reservoir water-surface elevation is predicted to vary between 1048.6 and 1055.9 ft.
- The controlling inflow design hydrographs for the site-specific PMF storms are: 1) 24-hour tropical storm with front loaded rainfall distribution; 2) 6-hour local storm with

Queen Creek rainfall distribution; and 3) 6-hour local storm with front loaded rainfall distribution.

- The CN sensitivity analysis for the PMF model showed that it is almost a direct relationship to peak flow. By increasing or decreasing the CN 10% the resulting peak flows increase/decrease by ±6%. The impact of varying the CN by 10% results in variations in the reservoir maximum water-surface elevation by ±0.2 feet for the existing pool storage routing.

This study documents the anticipated inflow design flood hydrographs for the remediation design of FRS No.4. These inflow design floods will be used to design modifications to the principal spillway(s), auxiliary spillway(s), the pool, and the top of dam as required.

10.0 REFERENCES

1. Arizona Department of Transportation, *Highway Drainage Design Manual, Hydrology,* March 1993.
2. Arizona Department of Water Resources, Surface Water Management Division, *Rules and Regulations Pertaining to Dam Safety Procedures,* June 2000.
3. Arizona Administrative Code, Title 12, Chapter 15, Article 12 – *Dam Safety Procedures*, September 2007.
4. Arizona Department of Water Resources, *PMF Studies for Evaluation of Spillway Adequacy, General Guidelines,* Revised March 2004.
5. Flood Control District of Maricopa County, *Drainage Design Manual for Maricopa County, Arizona, Volume I, Hydrology*, 1995.
6. Flood Control District of Maricopa County, *Drainage Design Manual for Maricopa County, Arizona, Volume II, Hydraulic*s, 1995.
7. Gannett Fleming, *White Tanks FRS No. 4 Rehabilitation Project – Preliminary Design Report,* June 2008.
8. Kimley-Horn and Associates, Inc., *Final Hydrology/Hydraulics Technical Memorandum – Work Assignment No. 5, White Tanks Flood Retarding Structure No. 4*, June 2008.
9. Soil Conservation Service, *National Engineering Handbook, Section 4, Hydrology,* August 1972.
10. Soil Conservation Service, *TR-20 Computer Program for Project Formulation Hydrology,* February 1992.
11. U.S. Army Corps of Engineers & NOAA, *Hydrometeorological Report No. 49,* September 1977.
12. U.S. Army Corps of Engineers, *HEC-1 Flood Hydrograph Package User's Manual,* Hydrologic Engineering Center, 1990.
13. United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, *Earth Dams and Reservoirs, TR-60,* July 2005.
14. Applied Weather Associates, LLC, *Site-Specific Probable Maximum Precipitation Study for the White Tanks #4 Drainage Basin*, December 2009.
15. HDR, *Final Hydrology Report for Loop 303/White Tanks ADMPU Area Hydrologic Analysis in Maricopa County, AZ, for FCDMC*, July 2009.
16. Tuncok, I. Kaan, and Minch, Jeffrey R., *Time of Concentration: A Modification of the TR-55 Methodology, Proceedings of the Association of State Dam Safety Officials (ASDSO) Western Regional Conference,* 2003.

17. Hoskin Ryan, *60% Design HEC-RAS Model for WT FRS No.3 Outfall Channel, for FCDMC*, July 2010.
18. URS, *Design Report for White Thanks Flood Retarding Structure No.3 Remediation Project – Phase 1,* March 2005.
19. Bentley CulvertMaster software.

TABLES

TABLE 1 HEC-1 Models Summary

TABLE 2 Hydrologic Modeling Results Summary

TABLE 3 PMF Model Sensitivity Evaluation

TABLE 1

HEC-1 Models Summary

Table 1 HEC-1 Models Summary for Inflow Design Floods

HEC-1 Model		Design Storm								Inflow Design Flood (IDF) Assumptions									
		NOAA2				TP No.49	Site-Specific PMP			Landuse			Rainfall Loss		Unit Hydrograph			FRS#3 Inflow	
Name	No.	100-Yr 24-Hr	100-Yr 6-Hr	200-Yr 24-Hr	500-Yr 24-hr	100-Yr 10-Day	Rainfall Distr.	Storm Duration	Storm Type & Depth	Existing Landuse	Updated Existing	Future Landuse	Green-Ampt	SCS Curve	S-Graph	NEH-4	Clark+T R55(Tc)	Yes	No
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
EC10BASE.DAT	BE1					X					X			X		X			X
EC24BASE.DAT	BE2	X									X		X		X				X
E200BASE.DAT	BE3			X							X		X		X				X
E500BASE.DAT	BE4				X						X		X		X				X
ESDHBASE.DAT	BE5						NEH630 HG	6-Hour SDH	Area Rainfall = 4.8		X			X		X			X
EPMF6BS1.DAT	BE6						Front Loaded	6-Hour Storm	Local Storm = 10.3		X			X			X		X
EPMF6BS2.DAT	BE7						Queen Creek				X			X			X		X
EPMF24B1.DAT	BE8						Front Loaded	24-Hour Storm	Tropical Storm = 13.0		X			X			X		X
EPMF24B2.DAT	BE9						Middle Loaded				X			X			X		X
EPMF24B3.DAT	BE10						Back Loaded				X			X			X		X
EPMF24B4.DAT	BE11						Middle Loaded		General Storm = 6.3		X			X			X		X
EPMF24B5.DAT	BE12						Constant				X			X			X		X
EPMF72B1.DAT	BE13						Linear	72-Hour Storm	Tropical Storm = 13.5		X			X			X		X
EPMF72B2.DAT	BE14						Back Loaded				X			X			X		X
EPMF72B3.DAT	BE15						Front Loaded		General Storm = 10.8		X			X			X		X
EPMF72B4.DAT	BE16						Middle Loaded				X			X			X		X
EPMF_H24.DAT	BE17						Front Loaded	24-Hour Storm	Half PMF (Q)		X			X			X		X
FC10BASE.DAT	BF1					X						X		X		X			X
FC10BNI3.DAT	BF1-I					X						X		X		X			X
FC24BASE.DAT	BF2	X										X	X		X				X
F200BASE.DAT	BF3			X								X	X		X				X
F500BASE.DAT	BF4				X							X	X		X				X
FSDHBASE.DAT	BF5						NEH630 HG	6-Hour SDH	Area Rainfall = 4.8			X		X		X			X
FSDHBNI3.DAT	BF5-I						NEH630 HG	6-Hour SDH	Area Rainfall = 4.8			X		X		X			X
FPMF6BS1.DAT	BF6						Front Loaded	6-Hour Storm	Local Storm = 10.3			X		X			X		X
FPMF6BS2.DAT	BF7						Queen Creek					X		X			X		X
FPMF24B1.DAT	BF8						Front Loaded	24-Hour Storm	Tropical Storm = 13.0			X		X			X		X
FPMF24B2.DAT	BF9						Middle Loaded					X		X			X		X
FPMF24B3.DAT	BF10						Back Loaded					X		X			X		X
FPMF24B4.DAT	BF11						Middle Loaded		General Storm = 6.3			X		X			X		X
FPMF24B5.DAT	BF12						Constant					X		X			X		X
FPMF72B1.DAT	BF13						Linear	72-Hour Storm	Tropical Storm = 13.5			X		X			X		X
FPMF72B2.DAT	BF14						Back Loaded					X		X			X		X
FPMF72B3.DAT	BF15						Front Loaded		General Storm = 10.8			X		X			X		X
FPMF72B4.DAT	BF16						Middle Loaded					X		X			X		X
FPMF_H24.DAT	BF17						Front Loaded	24-Hour Storm	Half PMF (Q)			X		X			X		X

Table 1 HEC-1 Models Summary for Inflow Design Floods

HEC-1 Model		Design Storm								Inflow Design Flood (IDF) Assumptions									
		NOAA2				TP No.49	Site-Specific PMP			Landuse			Rainfall Loss		Unit Hydrograph			FRS#3 Inflow	
Name	No.	100-Yr 24-Hr	100-Yr 6-Hr	200-Yr 24-Hr	500-Yr 24-hr	100-Yr 10-Day	Rainfall Distr.	Storm Duration	Storm Type & Depth	Existing Landuse	Updated Existing	Future Landuse	Green-Ampt	SCS Curve	S-Graph	NEH-4	Clark+T R55(Tc)	Yes	No
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
FC10BASA.DAT	BF1a					X						X		X		X		X	
FC10BSNI.DAT	BF1a-I					X						X		X		X		X	
FC24BASA.DAT	BF2a	X										X	X		X			X	
F200BASA.DAT	BF3a			X								X	X		X			X	
F500BASA.DAT	BF4a				X							X	X		X			X	
FSDHBASA.DAT	BF5a						NEH630 HG	6-Hour SDH	Area Rainfall = 4.8			X		X		X		X	
FSDHBSNI.DAT	BF5a-I						NEH630 HG	6-Hour SDH	Area Rainfall = 4.8			X		X		X		X	
FPM6BS1A.DAT	BF6a						Front Loaded	6-Hour Storm	Local Storm = 10.3			X		X			X	X	
FPM6BS2A.DAT	BF7a						Queen Creek					X		X			X	X	
FPM24B1A.DAT	BF8a						Front Loaded	24-Hour Storm	Tropical Storm = 13.0			X		X			X	X	
FPM24B2A.DAT	BF9a						Middle Loaded					X		X			X	X	
FPM24B3A.DAT	BF10a						Back Loaded					X		X			X	X	
FPM24B4A.DAT	BF11a						Middle Loaded		General Storm = 6.3			X		X			X	X	
FPM24B5A.DAT	BF12a						Constant					X		X			X	X	
FPM72B1A.DAT	BF13a						Linear	72-Hour Storm	Tropical Storm = 13.5			X		X			X	X	
FPM72B2A.DAT	BF14a						Back Loaded					X		X			X	X	
FPM72B3A.DAT	BF15a						Front Loaded		General Storm = 10.8			X		X			X	X	
FPM72B4A.DAT	BF16a						Middle Loaded					X		X			X	X	
FPM_H24A.DAT	BF17a						Front Loaded	24-Hour Storm	Half PMF (Q)			X		X			X	X	

TABLE 2

Hydrologic Modeling Results Summary

Table 2 HEC-1 Modeling Results for Inflow Design Floods

Hydrologic Model Description Summary				HEC-1 Model Name and No.		FRS#3 Flow			Total FRS#4 Inflow						FRS#4 Storage Routing				
						Hydrograph Name	Peak Flow (cfs)	Volume (Ac-Ft)	Hydrograph Name	Peak Flow (cfs)	HEC1 Vol (cfs)	Residual Q (cfs)	FRS3 Residual Vol (Ac-Ft)	Total Volume (Ac-Ft)	Peak Flow PO (cfs)	Peak Flow Infiltration (cfs)	Peak Flow Total (cfs)	Peak Storage (Ac-Ft)	Peak Stage (NAVD88,ft)
				Name	No.														
Existing Land Uses	Without FRS#3 PO Flow Connection	100-Year 10-Day Model		EC10BASE.DAT	BE1	N/A	N/A	N/A	FRS4	2251	1654	1	N/A	1654	133	102	235	835	1049.8
		100-Year 24-Hour Model		EC24BASE.DAT	BE2	N/A	N/A	N/A	CPWT4	6721	818	0	N/A	818	118	0	118	717	1048.6
		200-Year 24-Hour Model		E200BASE.DAT	BE3	N/A	N/A	N/A	CPWT4	7986	1031	0	N/A	1031	141	0	141	924	1050.6
		500-Year 24-Hour Model		E500BASE.DAT	BE4	N/A	N/A	N/A	CPWT4	9140	1247	0	N/A	1247	154	0	318	1110	1052.1
		Site-specific PMP 6-Hour SDH Model	Area Rainfall = 4.8	ESDHBASE.DAT	BE5	N/A	N/A	N/A	CFRS4	8749	2264	0	N/A	2264	170	149	4974	1372	1053.9
		Site-specific PMP 6-Hour Storm Models	Local Storm = 10.3	EPMF6BS1.DAT	BE6	N/A	N/A	N/A	CFRS4	15561	5591	0	N/A	5591	183	0	15204	1683	1055.8
				EPMF6BS2.DAT	BE7	N/A	N/A	N/A	CFRS4	15652	5474	0	N/A	5474	184	0	15286	1685	1055.8
		Site-specific PMP 24-Hour Storm Models	Tropical Storm = 13.0	EPMF24B1.DAT	BE8	N/A	N/A	N/A	CFRS4	16809	8076	0	N/A	8076	184	0	15327	1686	1055.8
				EPMF24B2.DAT	BE9	N/A	N/A	N/A	CFRS4	11069	9219	0	N/A	9219	178	0	10841	1565	1055.1
				EPMF24B3.DAT	BE10	N/A	N/A	N/A	CFRS4	14829	7954	0	N/A	7954	182	0	13919	1648	1055.6
			General Storm = 6.3	EPMF24B4.DAT	BE11	N/A	N/A	N/A	CFRS4	7050	3530	0	N/A	3530	171	0	5938	1411	1054.2
				EPMF24B5.DAT	BE12	N/A	N/A	N/A	CFRS4	6990	3530	0	N/A	3530	171	0	5922	1411	1054.2
		Site-specific PMP 72-Hour Storm Models	Tropical Storm = 13.5	EPMF72B1.DAT	BE13	N/A	N/A	N/A	CFRS4	7263	10346	0	N/A	10346	173	0	7136	1450	1054.4
				EPMF72B2.DAT	BE14	N/A	N/A	N/A	CFRS4	10759	9647	0	N/A	9647	178	0	10686	1561	1055.1
			General Storm = 10.8	EPMF72B3.DAT	BE15	N/A	N/A	N/A	CFRS4	7057	7738	0	N/A	7738	173	0	7017	1446	1054.4
				EPMF72B4.DAT	BE16	N/A	N/A	N/A	CFRS4	6730	7739	0	N/A	7739	172	0	6581	1432	1054.3
		Half PMF 24-hour Model	Half Flows	EPMF_H24.DAT	BE17	N/A	N/A	N/A	CFRS4	11391	4451	0	N/A	4451	175	0	8653	1499	1054.7
Future Land Uses	Without FRS#3 PO Flow Connection	100-Year 10-Day Model		FC10BASE.DAT	BF1	N/A	N/A	N/A	FRS4	2202	1666	0	N/A	1666	129	100	229	804	1049.5
		100-Year 10-Day Model w/o Infiltration		FC10BNI3.DAT	BF1-I	N/A	N/A	N/A	FRS4	2202	1666	0	N/A	1666	142		142	938	1050.7
		100-Year 24-Hour Model		FC24BASE.DAT	BF2	N/A	N/A	N/A	CPWT4	6599	967	0	N/A	967	132	0	132	828	1049.7
		200-Year 24-Hour Model		F200BASE.DAT	BF3	N/A	N/A	N/A	CPWT4	8594	1177	0	N/A	1177	148	0	148	1013	1051.3
		500-Year 24-Hour Model		F500BASE.DAT	BF4	N/A	N/A	N/A	CPWT4	9841	1360	0	N/A	1360	154	0	382	1115	1052.1
		Site-specific PMP 6-Hour SDH Model	Area Rainfall = 4.8	FSDHBASE.DAT	BF5	N/A	N/A	N/A	CFRS4	9087	2351	0	N/A	2351	170	150	5181	1382	1054.0
		PMP 6-Hr SDH Model w/o Infiltration	Area Rainfall = 4.8	FSDHBNI3.DAT	BF5-I	N/A	N/A	N/A	CFRS4	9087	2351	0	N/A	2351	170	0	5246	1389	1054.0
		Site-specific PMP 6-Hour Storm Models	Local Storm = 10.3	FPMF6BS1.DAT	BF6	N/A	N/A	N/A	CFRS4	16117	5729	0	N/A	5729	184	0	15729	1697	1055.9
				FPMF6BS2.DAT	BF7	N/A	N/A	N/A	CFRS4	16268	5617	0	N/A	5617	184	0	15804	1699	1055.9
		Site-specific PMP 24-Hour Storm Models	Tropical Storm = 13.0	FPMF24B1.DAT	BF8	N/A	N/A	N/A	CFRS4	17526	8353	0	N/A	8353	184	0	15898	1701	1055.9
				FPMF24B2.DAT	BF9	N/A	N/A	N/A	CFRS4	11534	9535	0	N/A	9535	179	0	11277	1577	1055.2
				FPMF24B3.DAT	BF10	N/A	N/A	N/A	CFRS4	15486	8165	0	N/A	8165	182	0	14252	1657	1055.7
			General Storm = 6.3	FPMF24B4.DAT	BF11	N/A	N/A	N/A	CFRS4	7584	3664	0	N/A	3664	172	0	6363	1425	1054.3
				FPMF24B5.DAT	BF12	N/A	N/A	N/A	CFRS4	7535	3665	0	N/A	3665	172	0	6339	1424	1054.3
		Site-specific PMP 72-Hour Storm Models	Tropical Storm = 13.5	FPMF72B1.DAT	BF13	N/A	N/A	N/A	CFRS4	7703	10833	0	N/A	10833	174	0	7564	1464	1054.5
				FPMF72B2.DAT	BF14	N/A	N/A	N/A	CFRS4	11053	9950	0	N/A	9950	179	0	10975	1568	1055.2
			General Storm = 10.8	FPMF72B3.DAT	BF15	N/A	N/A	N/A	CFRS4	7493	8100	0	N/A	8100	174	0	7437	1460	1054.5
				FPMF72B4.DAT	BF16	N/A	N/A	N/A	CFRS4	7280	8101	0	N/A	8101	173	0	7080	1448	1054.4
		Half PMF 24-hour Model	Half Flows	FPMF_H24.DAT	BF17	N/A	N/A	N/A	CFRS4	11667	4537	0	N/A	4537	176	0	8764	1502	1054.7
	With FRS#3 PO Flow Connection	100-Year 10-Day Model		FC10BASA.DAT	BF1a	FRS3	210	1516	FRS4	2290	3182	1	0	3182	154	127	313	1100	1052.0
		100-Year 10-Day Model w/o Infiltration		FC10BASA.DAT	BF1a-I	FRS3	210	1516	FRS4	2290	3182	1	0	3182	154	0	499	1125	1052.2
		100-Year 24-Hour Model		FC24BASA.DAT	BF2a	FRS3	243	2337	CPWT4	7034	3268	22	28	3296	154	0	290	1108	1052.1
		200-Year 24-Hour Model		F200BASA.DAT	BF3a	FRS3	253	2337	CPWT4	8622	3802	73	109	3911	154	0	405	1117	1052.2
		500-Year 24-Hour Model		F500BASA.DAT	BF4a	FRS3	259	2337	CPWT4	9859	4119	120	183	4302	156	0	620	1134	1052.3
		Site-specific PMP 6-Hour SDH Model	Area Rainfall = 4.8	FSDHBASA.DAT	BF5a	FRS3	265	2365	CFRS4	9135	4704	12	9	4713	171	151	5453	1391	1054.1
		PMP 6-Hr SDH Model w/o Infiltration	Area Rainfall = 4.8	FSDHBSNI.DAT	BF5a-I	FRS3	265	2365	CFRS4	9135	4704	12	9	4713	171	0	5499	1397	1054.1
		Site-specific PMP 6-Hour Storm Models	Local Storm = 10.3	FPM6BS1A.DAT	BF6a	FRS3	287	2848	CFRS4	16118	8434	48	70	8504	184	0	15730	1697	1055.9
				FPM6BS2A.DAT	BF7a	FRS3	287	2848	CFRS4	16269	8297	48	70	8367	184	0	15805	1699	1055.9
		Site-specific PMP 24-Hour Storm Models	Tropical Storm = 13.0	FPM24B1A.DAT	BF8a	FRS3	281	3127	CFRS4	17526	11183	126	194	11377	184	0	15946	1703	1055.9
				FPM24B2A.DAT	BF9a	FRS3	281	3127	CFRS4	11541	12303	126	194	12497	179	0	11325	1578	1055.2
				FPM24B3A.DAT	BF10a	FRS3	281	3127	CFRS4	15491	10948	126	194	11142	182	0	14255	1657	1055.7
			General Storm = 6.3	FPM24B4A.DAT	BF11a	FRS3	281	3127	CFRS4	7855	6592	126	194	6786	173	0	6729	1437	1054.3
				FPM24B5A.DAT	BF12a	FRS3	281	3127	CFRS4	7808	6592	126	194	6786	173	0	6703	1436	1054.3
		Site-specific PMP 72-Hour Storm Models	Tropical Storm = 13.5	FPM72B1A.DAT	BF13a	FRS3	284	3794	CFRS4	7840	13747	203	847	14594	174	0	7715	1468	1054.5
				FPM72B2A.DAT	BF14a	FRS3	284	3794	CFRS4	11061	12720	203	847	13567	179	0	10983	1569	1055.2
			General Storm = 10.8	FPM72B3A.DAT	BF15a	FRS3	284	3794	CFRS4	7684	11016	203	847	11863	174	0	7636	1466	1054.5
				FPM72B4A.DAT	BF16a	FRS3	284	3794	CFRS4	7546	11029	203	847	11876	174	0	7434	1459	1054.5
		Half PMF 24-hour Model	Half Flows	FPM_H24A.DAT	BF17a	FRS3	281	3127	CFRS4	11676	5973	65	103	6076	176	0	8821	1504	1054.8

TABLE 3

PMF Model Sensitivity Evaluation
(See page 22)

LIST OF FIGURES

Figure 1 Project Location Map

Figure 2 FRS No.4 Inflow Hydrographs-100 Year, 24 -Hour Storm

Figure 3 FRS No.4 Inflow Hydrographs-100 Year, 10 -Day Storm

Figure 4 FRS No.4 Inflow Hydrographs-SDH Storm

Figure 5 FRS No.4 Inflow Hydrographs-PMF 6 - Hour Storm

Figure 6 FRS No.4 Inflow Hydrographs-PMF 24 - Hour Storm

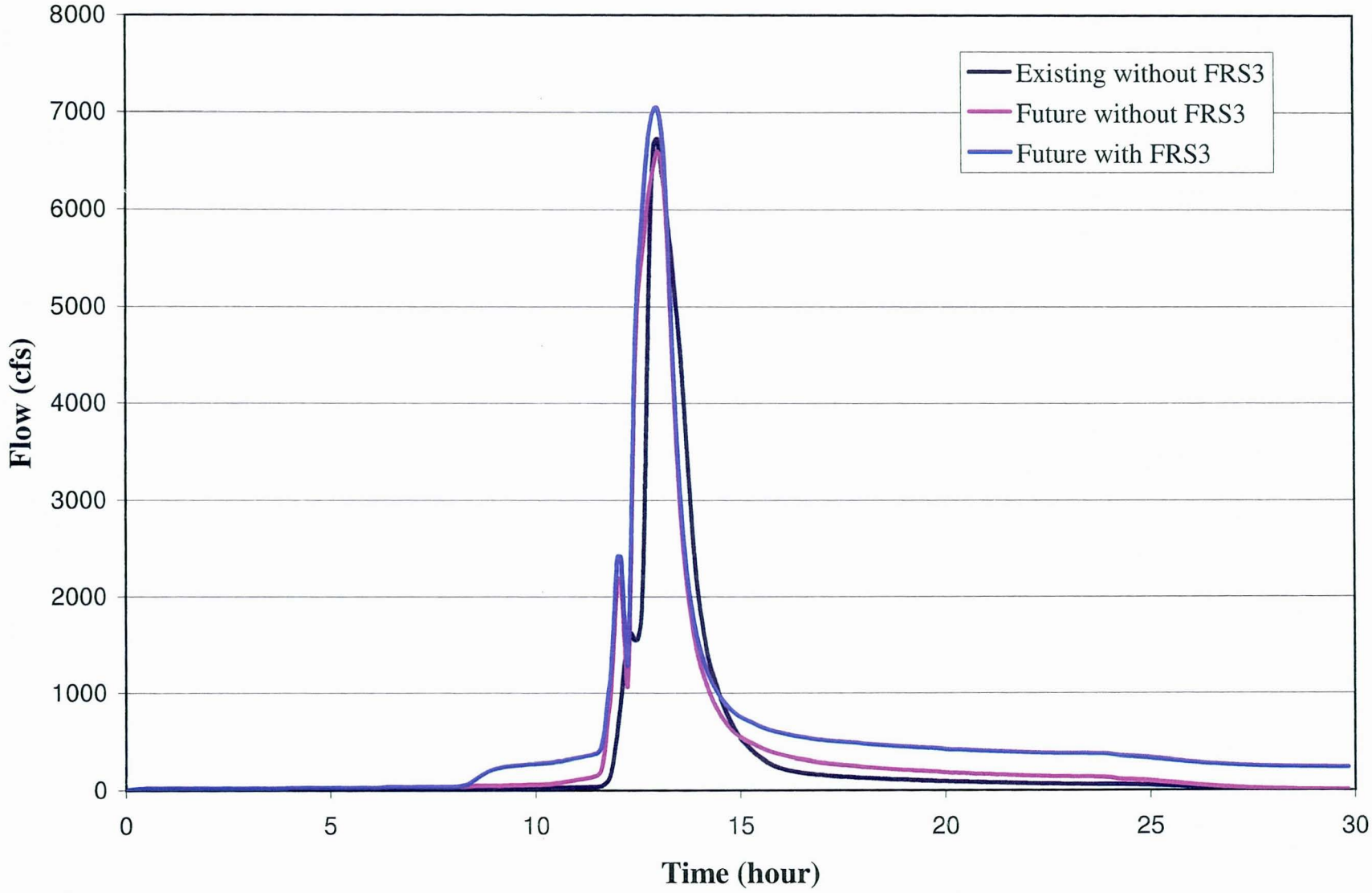
FIGURE 1

Project Location Map
(See Page 2)

FIGURE 2

FRS No.4 Inflow Hydrographs-100 Year, 24 -Hour Storm

Figure 2 FRS No.4 Inflow Hydrographs - 100-Year 24-Hour Storm



11/17/2010

FIGURE 3

FRS No.4 Inflow Hydrographs-100 Year, 10 -Day Storm

FIGURE 4

FRS No.4 Inflow Hydrographs-SDH Storm

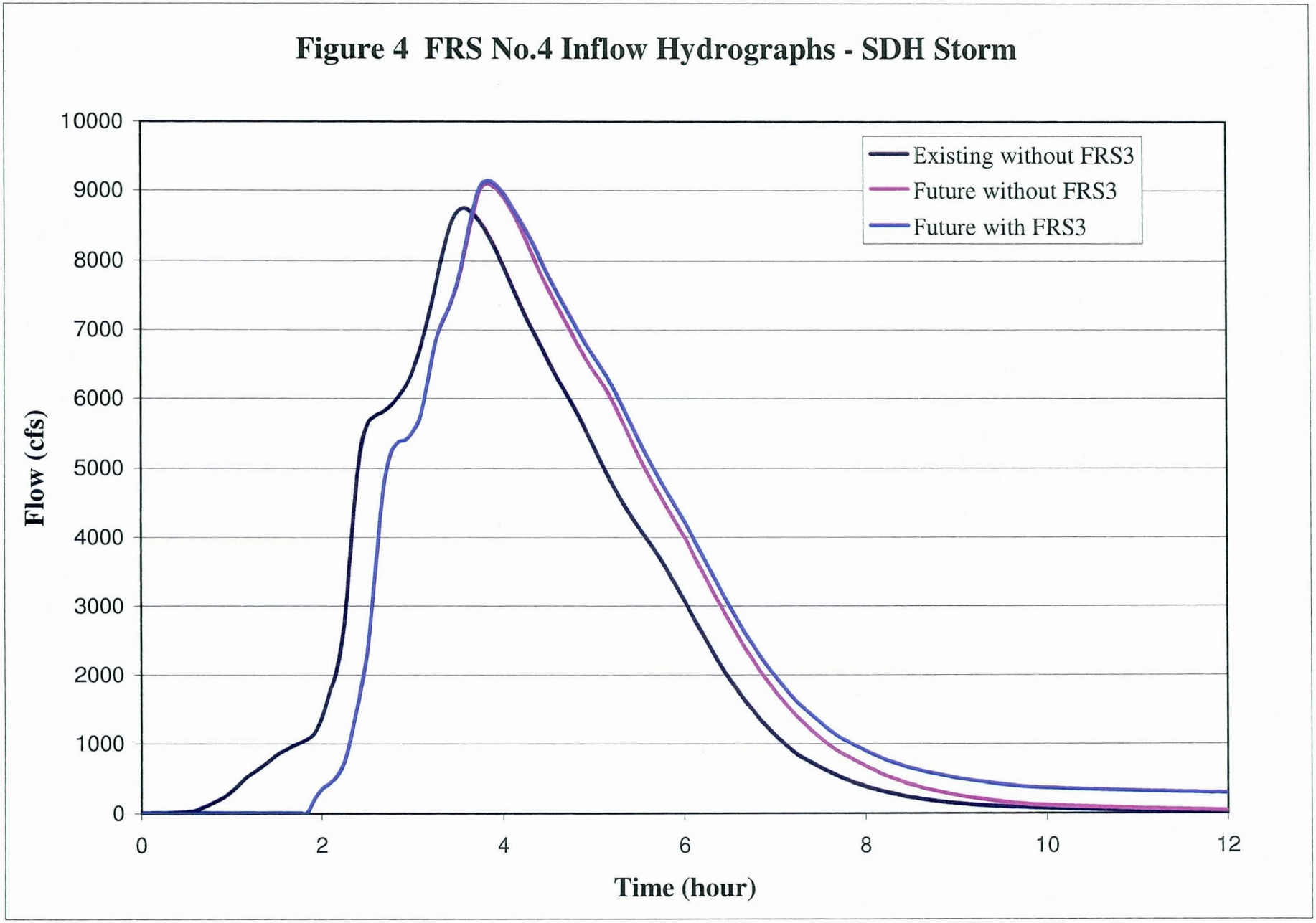


Figure 4 FRS No.4 Inflow Hydrographs - SDH Storm
Existing without FRS3
Future without FRS3
Future with FRS3
Flow (cfs)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2
4
6
8
10
12
Time (hour)

11/17/2010

FIGURE 5

FRS No.4 Inflow Hydrographs-PMF 6 - Hour Storm

Figure 5 FRS No.4 Inflow Hydrographs - PMF 6-Hour Storm

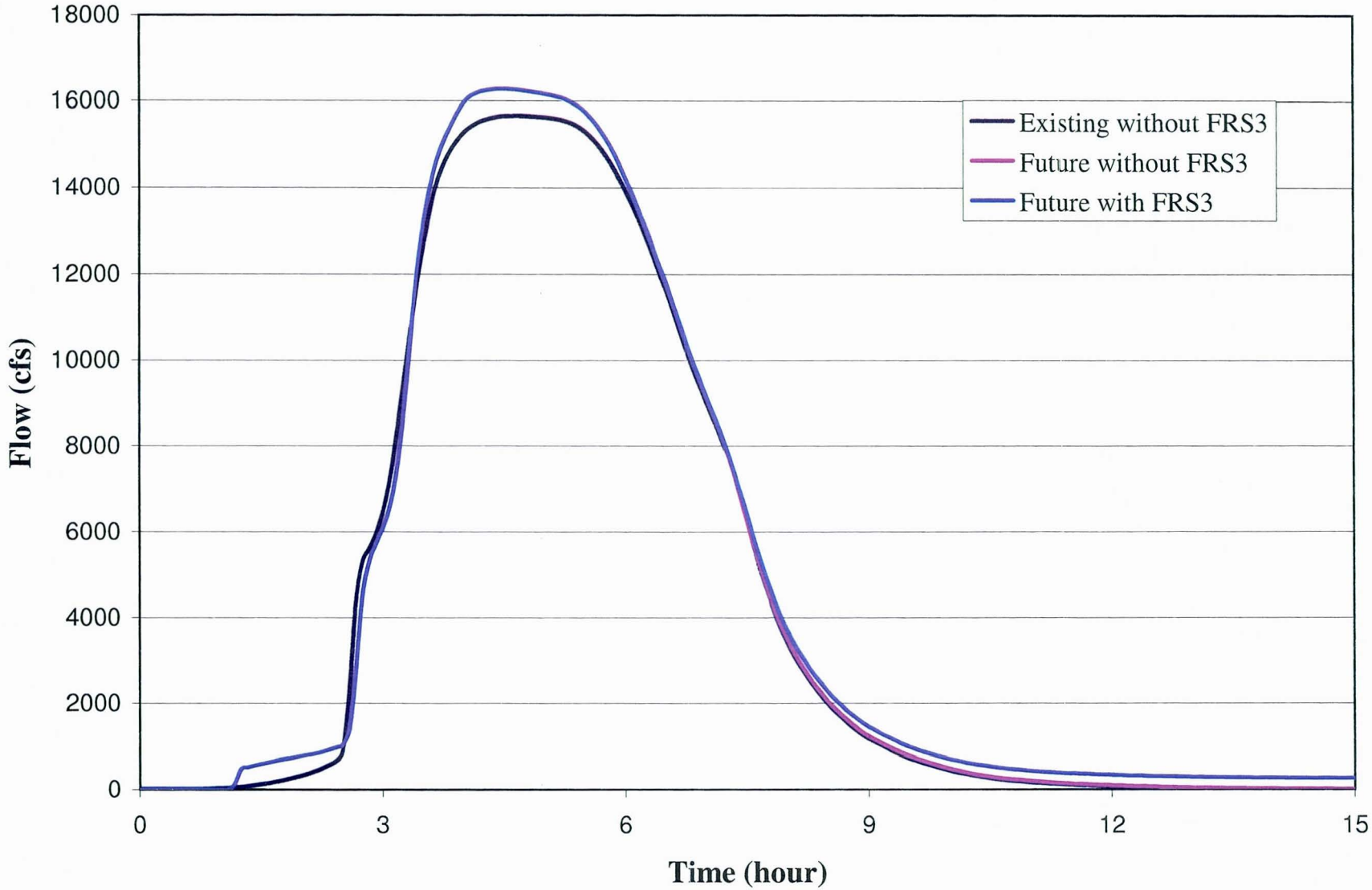
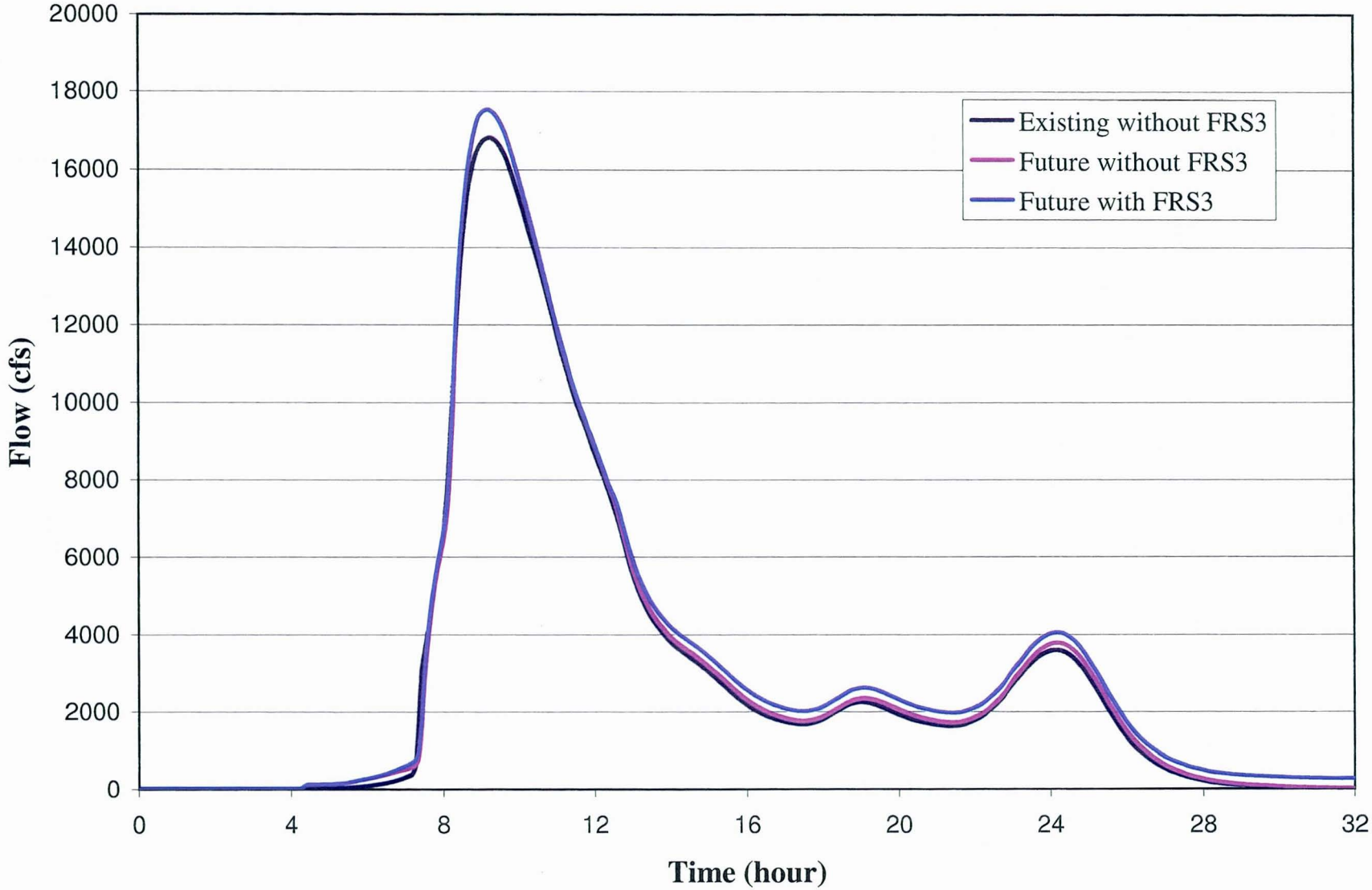


FIGURE 6

FRS No.4 Inflow Hydrographs-PMF 24 - Hour Storm

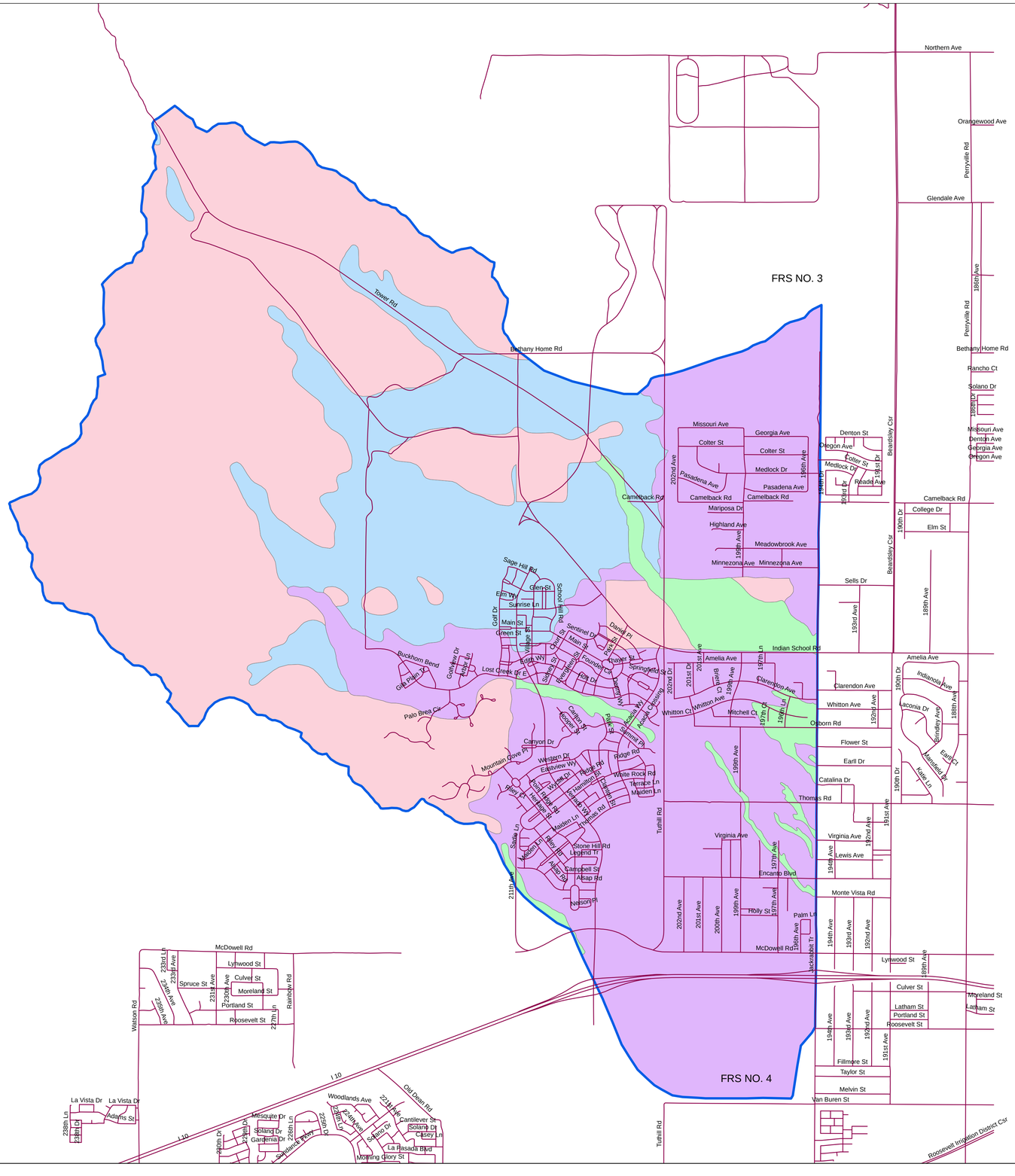
Figure 6 FRS No.4 Inflow Hydrographs - PMF 24-Hour Storm



EXHIBITS

EXHIBIT A	Watershed Soil Maps
EXHIBIT B	Watershed Land Use Maps
EXHIBIT C	Subbasin Boundary and HEC-1 Schematic for 100-Year, 24-Hour Storms
EXHIBIT D	Subbasin Boundary and HEC-1 Schematic for 100-Year, 10-Day Storms
EXHIBIT E	Subbasin Boundary and HEC-1 Schematic for PMF and SDH Storms
EXHIBIT F	CD Containing Electronic Files

EXHIBIT A
Watershed Soil Maps



WHITE TANKS FRS NO. 4
REMEDIATION AND ENGINEERING SUPPORT
EXHIBIT A
SOIL COVERAGE FOR CURVE NUMBER METHOD

FCD 2008C002
NOVEMBER 2010

LEGEND

Hydrologic Soil Group

- A
- B
- C
- D

- Roads
- Watershed Boundary_Future

Hydrologic Soil Groups are from Soil Surveys:
Aguila-Carefree Area, Parts of Maricopa and Pinal Counties and Maricopa County, AZ, Central Part.

The soil shape file was provided by the FCDMC.

N

0 2,000 4,000 6,000 Feet

SCALE: 1" = 2000'

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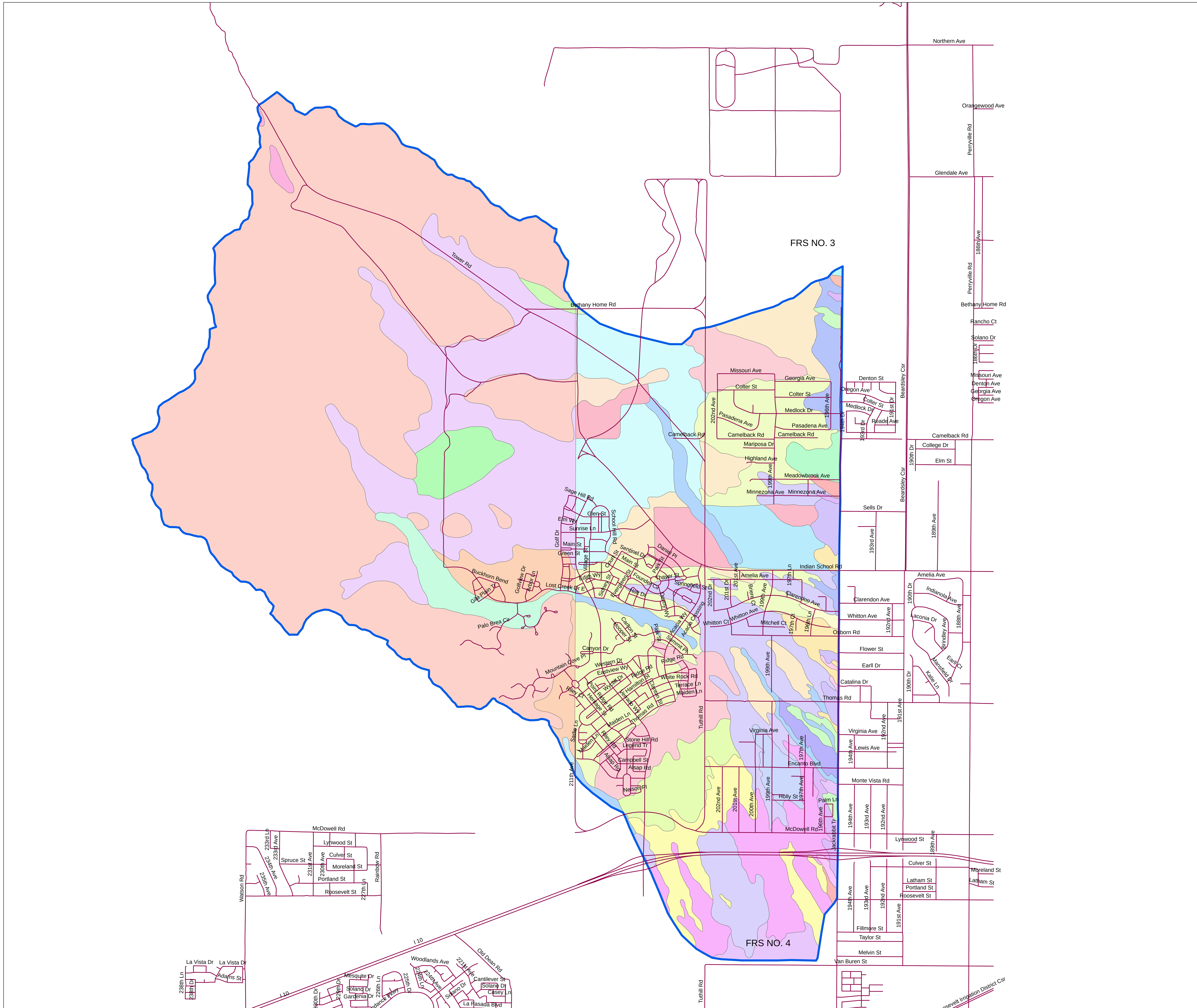

WHITE TANKS FRS NO. 4
REMEDIATION AND ENGINEERING SUPPORT
EXHIBIT A
SOIL COVERAGE FOR GREEN-AMPT METHOD

FCD 2008C002
NOVEMBER 2010

LEGEND

SOIL_LID, AREA (acres)

- 6453, 179
- 64510, 7
- 64518, 24
- 64529, 266
- 64544, 172
- 64548, 1350
- 64549, 23
- 645100, 4866
- 6512029, 3
- 6512042, 731
- 6512044, 81
- 6512257, 85
- 6512423, 15
- 6512448, 2
- 6512451, 85
- 6512462, 425
- 6514223, 46
- 6514421, 65
- 6514449, 4
- 6515456, 55
- 6515822, 195
- 6515825, 183
- 6516221, 46
- 651202320, 19
- 651202720, 5
- 651202722, 63
- 651203222, 1143
- 651203424, 401
- 651204122, 128
- 651225036, 236
- 651285026, 681
- 651323320, 46
- 651502920, 8
- 651505422, 303
- 651506826, 478
- 651585624, 222

Roads

Watershed Boundary_Future

Soil Survey as shown by soil prefix:
645xxx - Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona
651xxx - Maricopa County, AZ, Central Part

The soil shape file was provided by the FCDMC.

N

0 2,000 4,000 6,000 Feet

SCALE: 1" = 2000'

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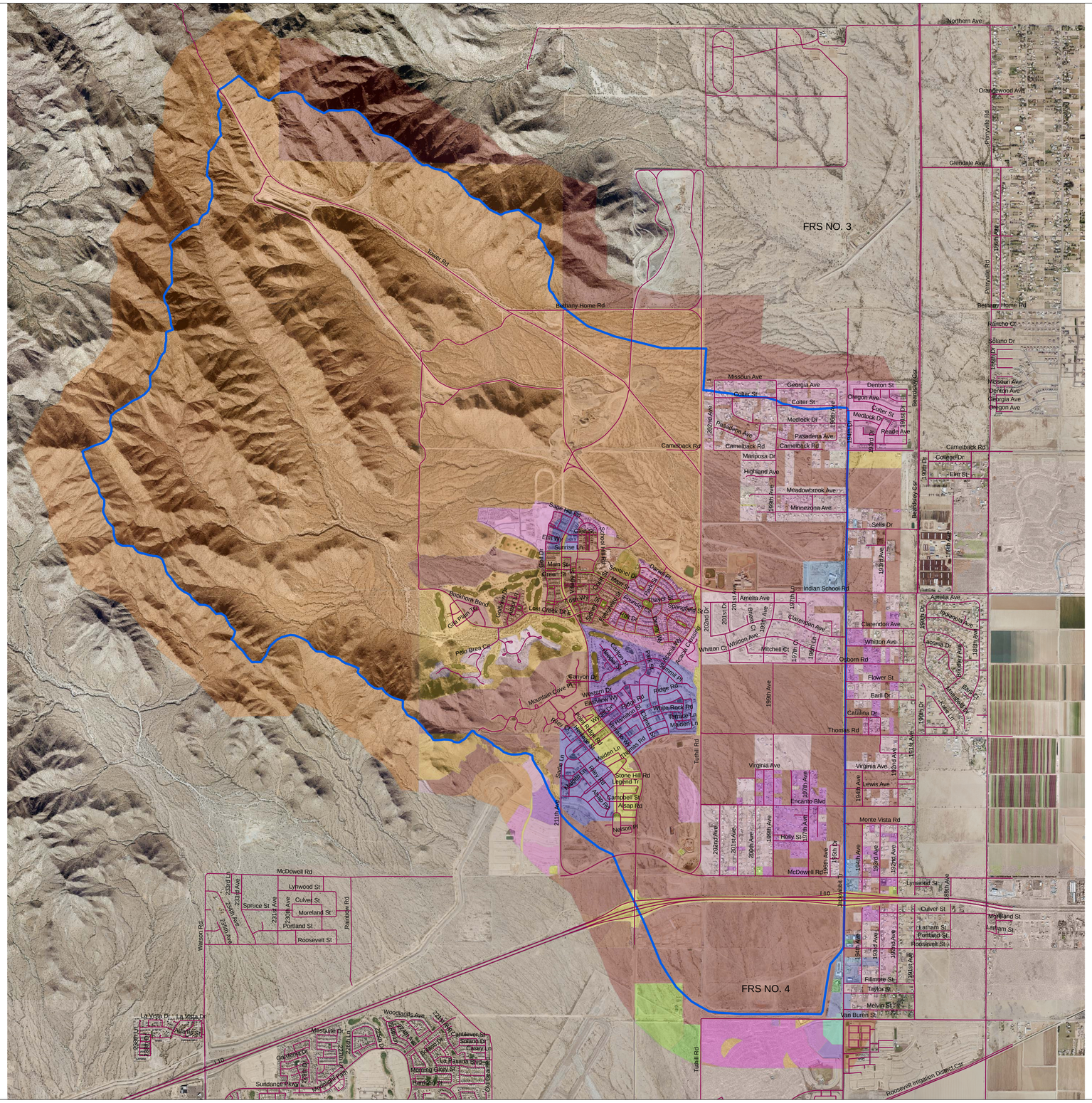
EXHIBIT B
Watershed Land Use Maps



WHITE TANKS FRS NO. 4
REMEDIATION AND ENGINEERING SUPPORT
EXHIBIT B
LAND USE - EXISTING CONDITIONS

FCD 2008C002
NOVEMBER 2010

LEGEND

Roads

Watershed Boundary

LAND USE

LUCODE

- 110, Rural Residential (<= 1/5 du per acre)
- 120, Estate Residential (1/5 du per acre to 1 du per acre)
- 130, Large Lot Residential - Single Family (1-2 du per acre)
- 140, Medium Lot Residential - Single Family (2-4 du per acre)
- 150, Small Lot Residential - Single Family (4-6 du per acre)
- 160, Very Small Lot Residential - Single Family (>6 du per acre)
- 170, Medium Density Residential - Muli Family (5-10 du per acre)
- 180, High Density Residential - Multi Family (10-15 du per acre)
- 190, Very High Density Residential - Multi Family (>15 du per ac)
- 200, General Commercial (Commercial where no detail available)
- 210, Specialty Commercial (<=50,000 sq. ft.)
- 220, Neighborhood Commercial (50,000 to 100,000 sq. ft.)
- 230, Community Commercial (100,000 to 500,000 sq. ft.)
- 240, Regional Commercial (500,000 to 1,000,000 sq. ft.)
- 310, Warehouse/Distribution Centers
- 320, Industrial
- 410, Office Low Rise (1-4 stories)
- 520, Educational (Schools and universities)
- 530, Institutional (Includes hospitals and churches)
- 550, Public Facilities (comm centers, libraries, sub-stations)
- 610, Transportation (railways, transit centers, freeways)
- 620, Airports (Includes public use airports)
- 710, Active Open Space (Includes parks)
- 720, Golf courses
- 730, Passive Open Space (Includes mountain preserves and washes)
- 750, Agriculture
- 810, Business Park (enclosed industrial, office or retail)
- 900, Vacant (Existing land use database only)

N

0 2,000 4,000 6,000 Feet

SCALE: 1" = 2000'

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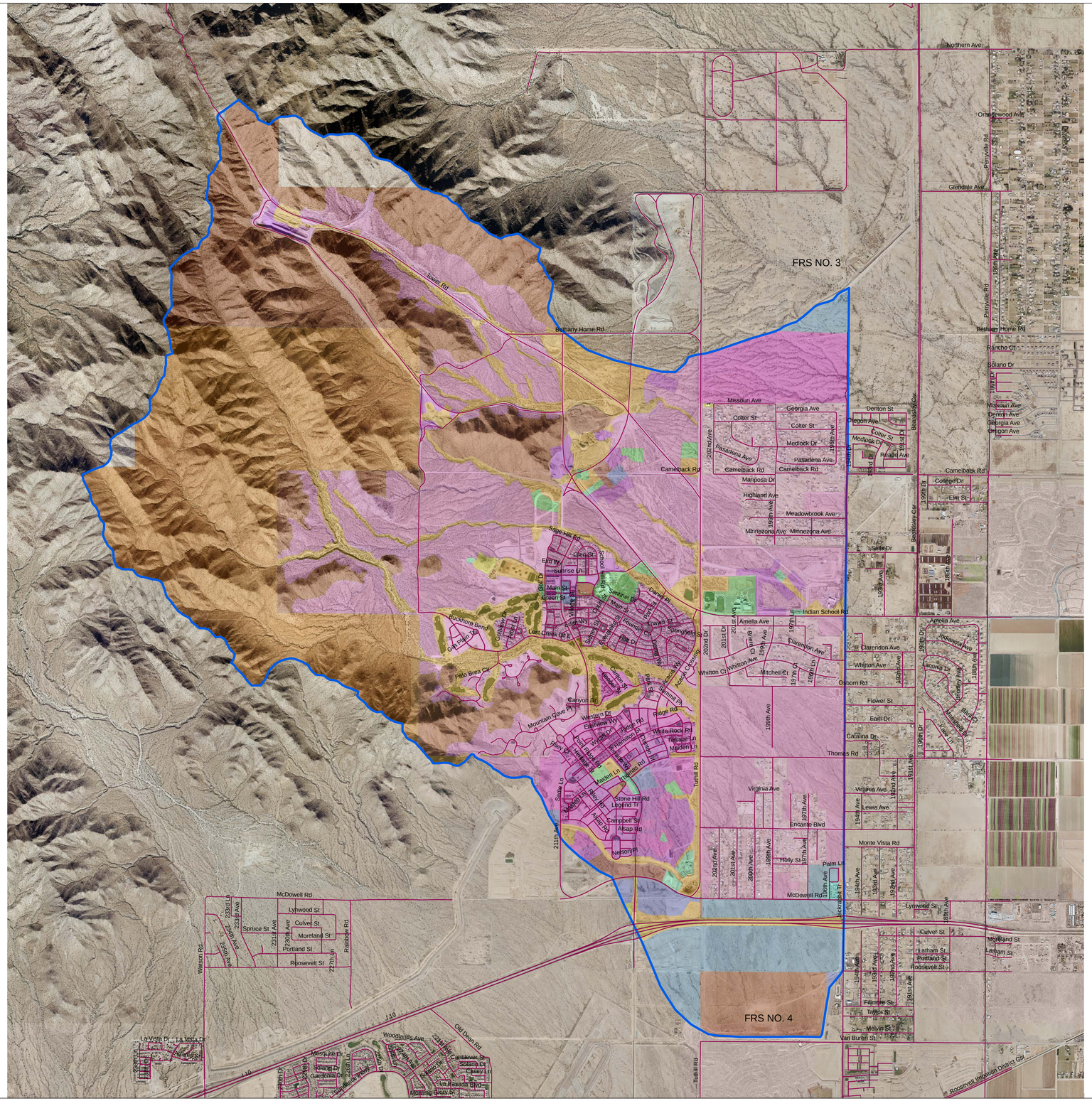

WHITE TANKS FRS NO. 4
REMEDIATION AND ENGINEERING SUPPORT
EXHIBIT B
LAND USE - FUTURE CONDITIONS

FCD 2008C002
NOVEMBER 2010

LEGEND

Roads

Watershed Boundary_Future

FutureLandUse_CIP_Dis1_PA

LUCODE

- 110, Rural Residential (<= 1/5 du per acre)
- 120, Estate Residential (1/5 du per acre to 1 du per acre)
- 130, Large Lot Residential - Single Family (1-2 du per acre)
- 140, Medium Lot Residential - Single Family (2-4 du per acre)
- 150, Small Lot Residential - Single Family (4-6 du per acre)
- 160, Very Small Lot Residential - Single Family (>6 du per acre)
- 210, Specialty Commercial (<=50,000 sq. ft.)
- 230, Community Commercial (100,000 to 500,000 sq. ft.)
- 240, Regional Commercial (500,000 to 1,000,000 sq. ft.)
- 310, Warehouse/Distribution Centers
- 320, Industrial
- 400, Office General (Office where no detail available)
- 510, Tourist and Visitor Accommodations (Hotels, motels, resorts)
- 520, Educational (Schools and universities)
- 531, Hospitals/Medical Centers
- 550, Public Facilities (comm centers, libraries, sub-stations)
- 610, Transportation (railways, transit centers, freeways)
- 700, General Open Space (Open space where no detail available)
- 730, Passive Open Space (Includes mountain preserves and washes)
- 740, Water
- 810, Business Park (enclosed industrial, office or retail)
- 820, Jurisdictional Defined

N

0 2,000 4,000 6,000 Feet

SCALE: 1" = 2000'

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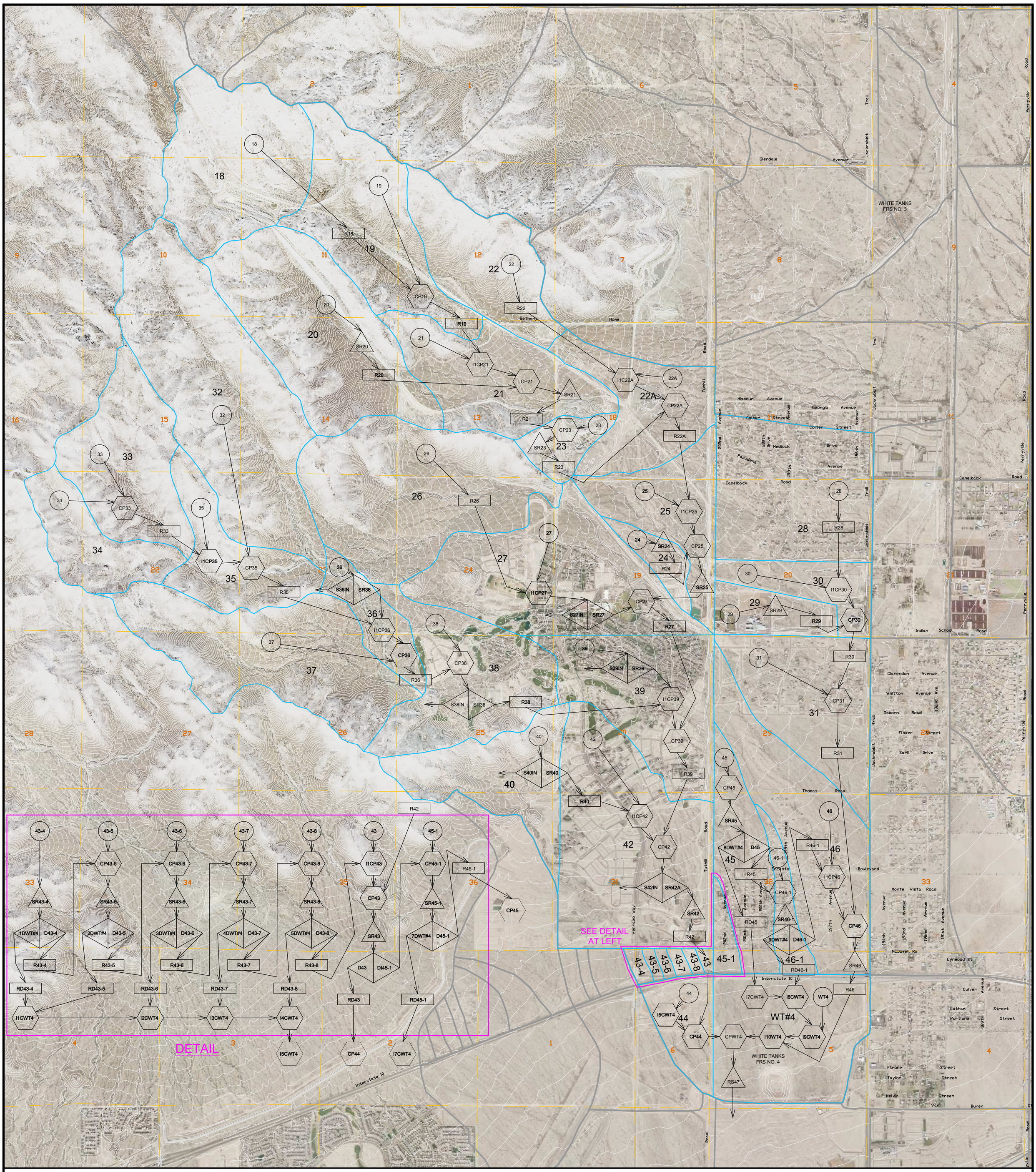
EXHIBIT C
Subbasin Boundary and HEC-1
Schematic for 100-Year, 24-Hour Storms



LEGEND

Sub-basin Boundary	
37	Sub-basin Name
ADMPU Sub-basin Boundary	
Section Boundary	
14	Section Number
SUB4	Subbasin Hydrograph
RSUB2S	Surface Routing
CSUB1	Flow Combine
DSUB2S / DSUB2E	Flow Diversion
FRS4	Storage Routing
	General Flow Direction

1500' 0' 1500' 3000'

SCALE: 1"= 1500' FEET
CONTOUR INTERVAL = 10 FEET

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANKS FRS NO. 4 REMEDIATION

EXHIBIT C
SUB-BASIN BOUNDARIES AND HEC-1 SCHEMATIC
For 100 Year - 24 Hour Storm, Existing Conditions
FCD 2008C002
NOVEMBER 2010

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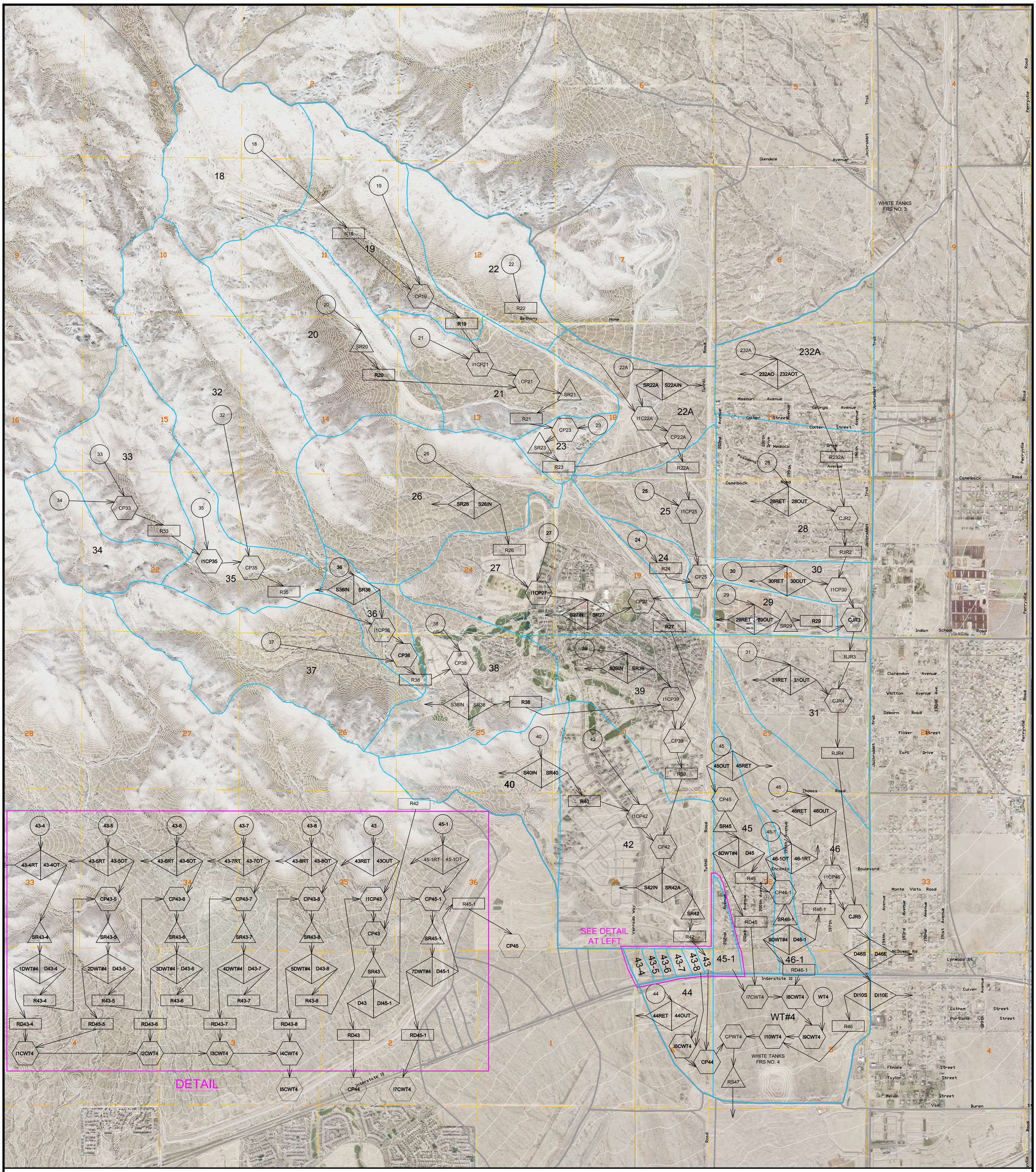

LEGEND

- Sub-basin Boundary
- 37 Sub-basin Name
- ADMPU Sub-basin Boundary
- Section Boundary
- 14 Section Number
- SUB4 Subbasin Hydrograph
- RSUB2S Surface Routing
- CSUB1 Flow Combine
- DSUB2S DSUB2E Flow Diversion
- FRS4 Storage Routing
- General Flow Direction

1500' 0' 1500' 3000'

SCALE: 1"= 1500' FEET
CONTOUR INTERVAL = 10 FEET

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

WHITE TANKS FRS NO. 4 REMEDIATION

EXHIBIT C
SUB-BASIN BOUNDARIES AND HEC-1 SCHEMATIC
For 100 Year - 24 Hour Storm, Future Conditions
FCD 2008C002
NOVEMBER 2010

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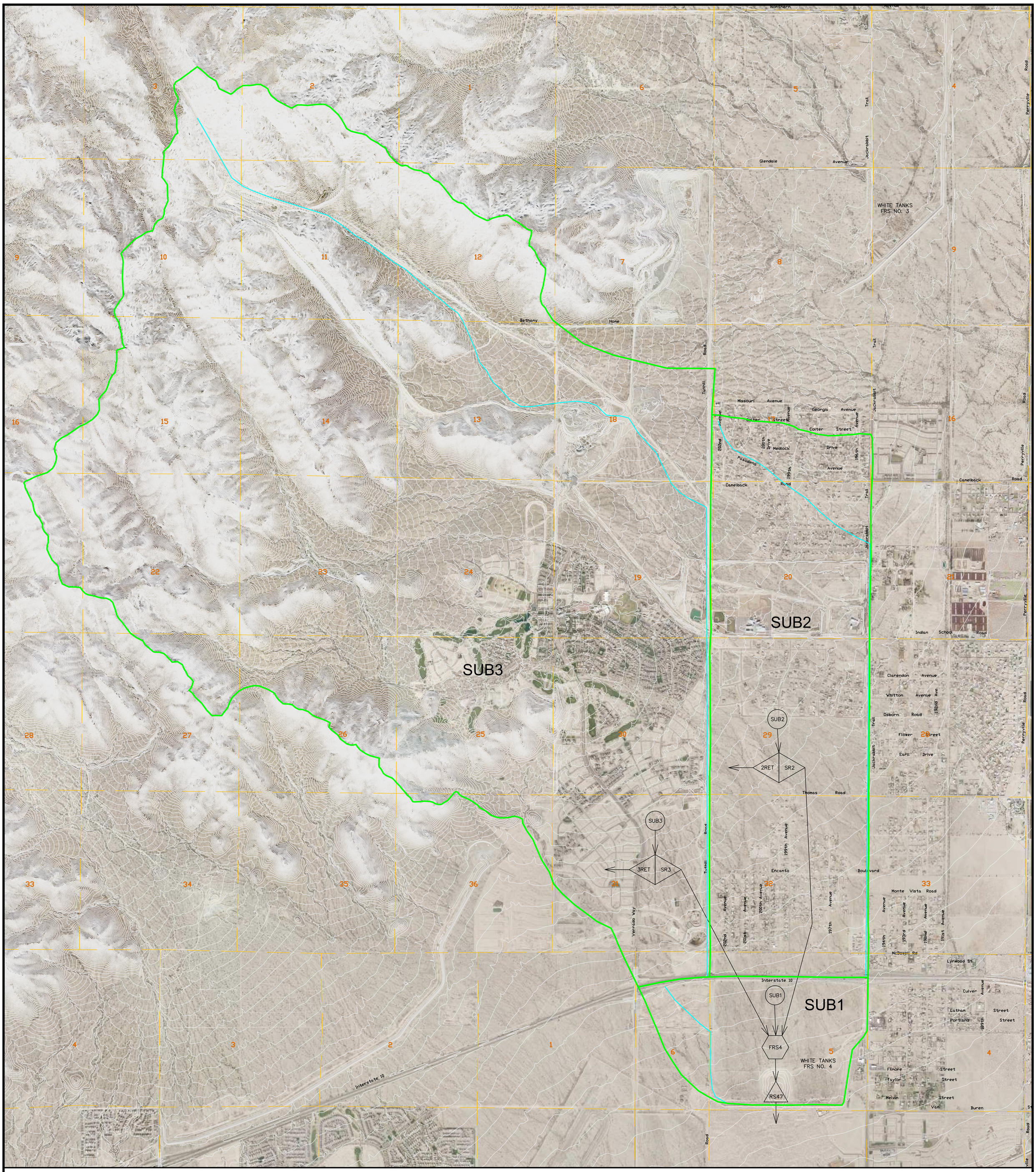
EXHIBIT D
Subbasin Boundary and HEC-1
Schematic for 100-Year, 10-Day Storms



LEGEND

Sub-basin Boundary	Subbasin Hydrograph
SUB1 Sub-basin Name	Surface Routing
Section Boundary	Flow Combine
14 Section Number	Flow Diversion
Longest Flow Path	Storage Routing
	General Flow Direction

1500' 0' 1500' 3000'

SCALE: 1"= 1500' FEET
CONTOUR INTERVAL = 10 FEET

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANKS FRS NO. 4 REMEDIATION

EXHIBIT D
SUB-BASIN BOUNDARIES AND HEC-1 SCHEMATIC
For 100 Year - 10 Day Storm, (PSH) - Existing
FCD 2008C002
NOVEMBER 2010

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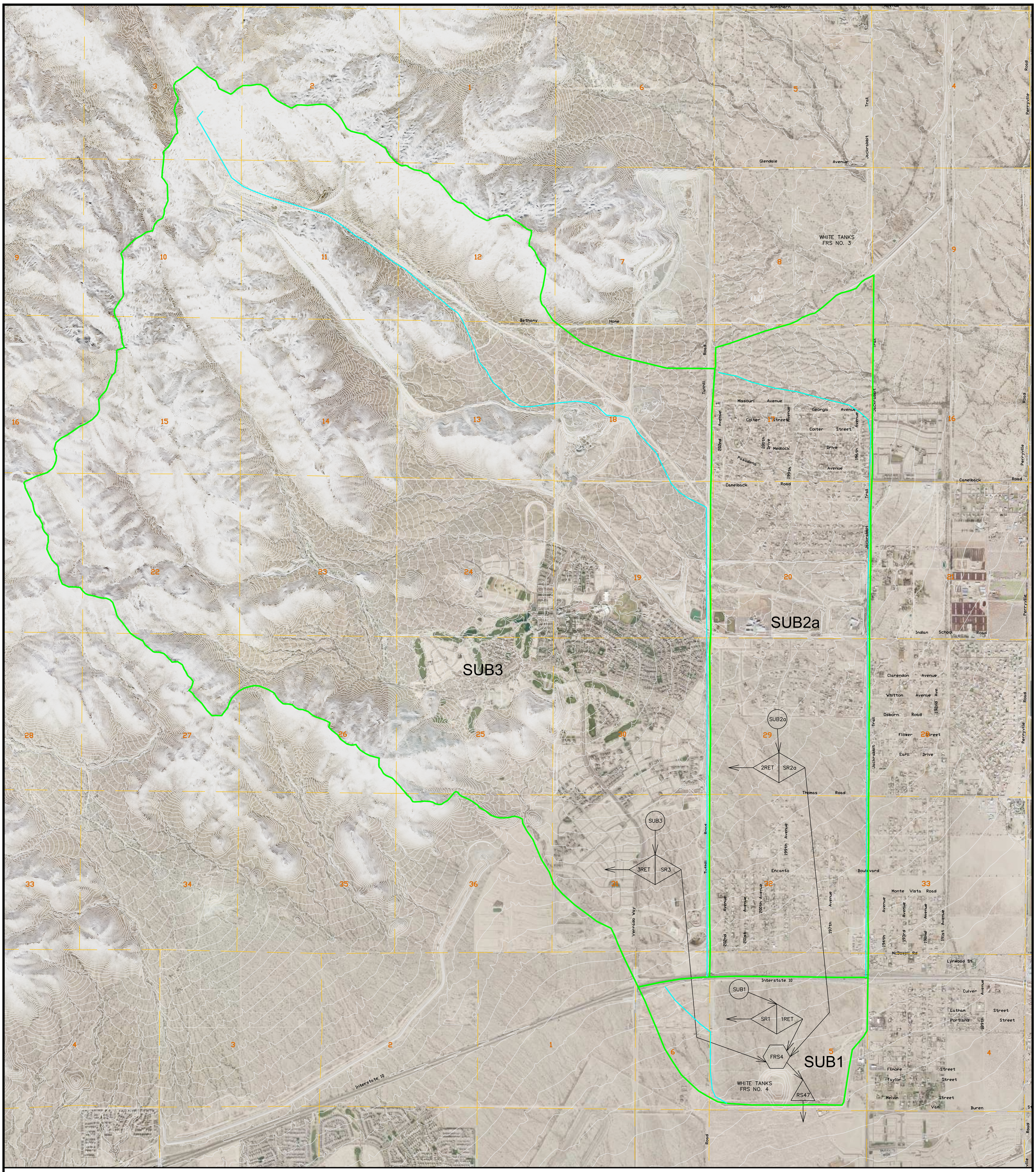

LEGEND

Sub-basin Boundary	Subbasin Hydrograph
SUB1 Sub-basin Name	Surface Routing
Section Boundary	Flow Combine
14 Section Number	Flow Diversion
Longest Flow Path	Storage Routing
	General Flow Direction

1500' 0' 1500' 3000'

SCALE: 1"= 1500' FEET
CONTOUR INTERVAL = 10 FEET

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANKS FRS NO. 4 REMEDIATION

EXHIBIT D
SUB-BASIN BOUNDARIES AND HEC-1 SCHEMATIC
For 100 Year - 10 Day Storm, (PSH) - Future
FCD 2008C002
NOVEMBER 2010

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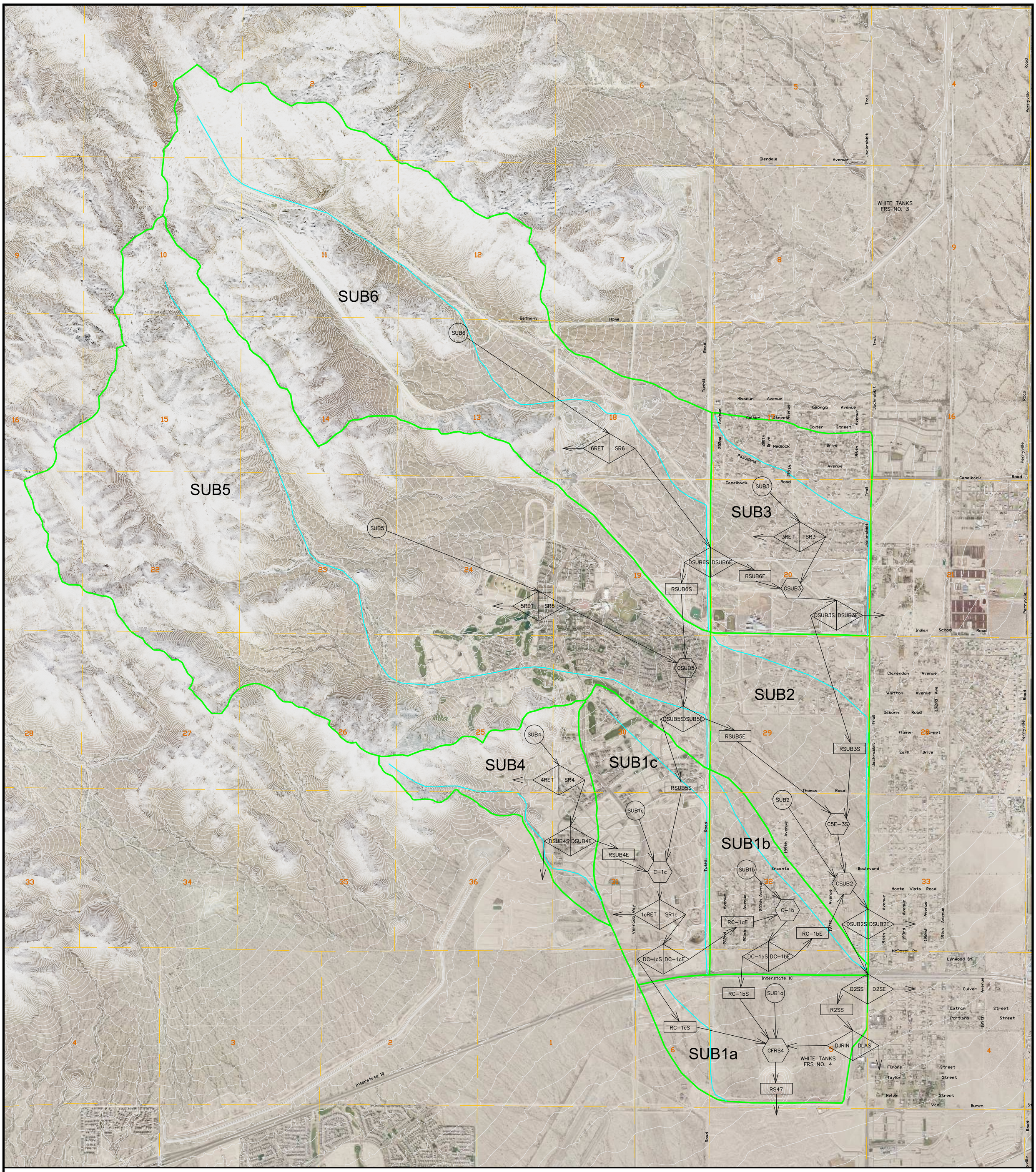
EXHIBIT E
Subbasin Boundary and HEC-1
Schematic for PMF and SDH Storms



LEGEND

	Sub-basin Boundary	SUB4	Subbasin Hydrograph
SUB1	Sub-basin Name	RSUB2S	Surface Routing
	Section Boundary	CSUB1	Flow Combine
14	Section Number	DSUB2S DSUB2E	Flow Diversion
	Longest Flow Path	FRS4	Storage Routing
			General Flow Direction

1500' 0' 1500' 3000'

SCALE: 1"= 1500' FEET
CONTOUR INTERVAL = 10 FEET

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANKS FRS NO. 4 REMEDIATION

EXHIBIT E
SUB-BASIN BOUNDARIES AND HEC-1 SCHEMATIC
For SDH/PMF Storms - Existing
FCD 2008C002
NOVEMBER 2010

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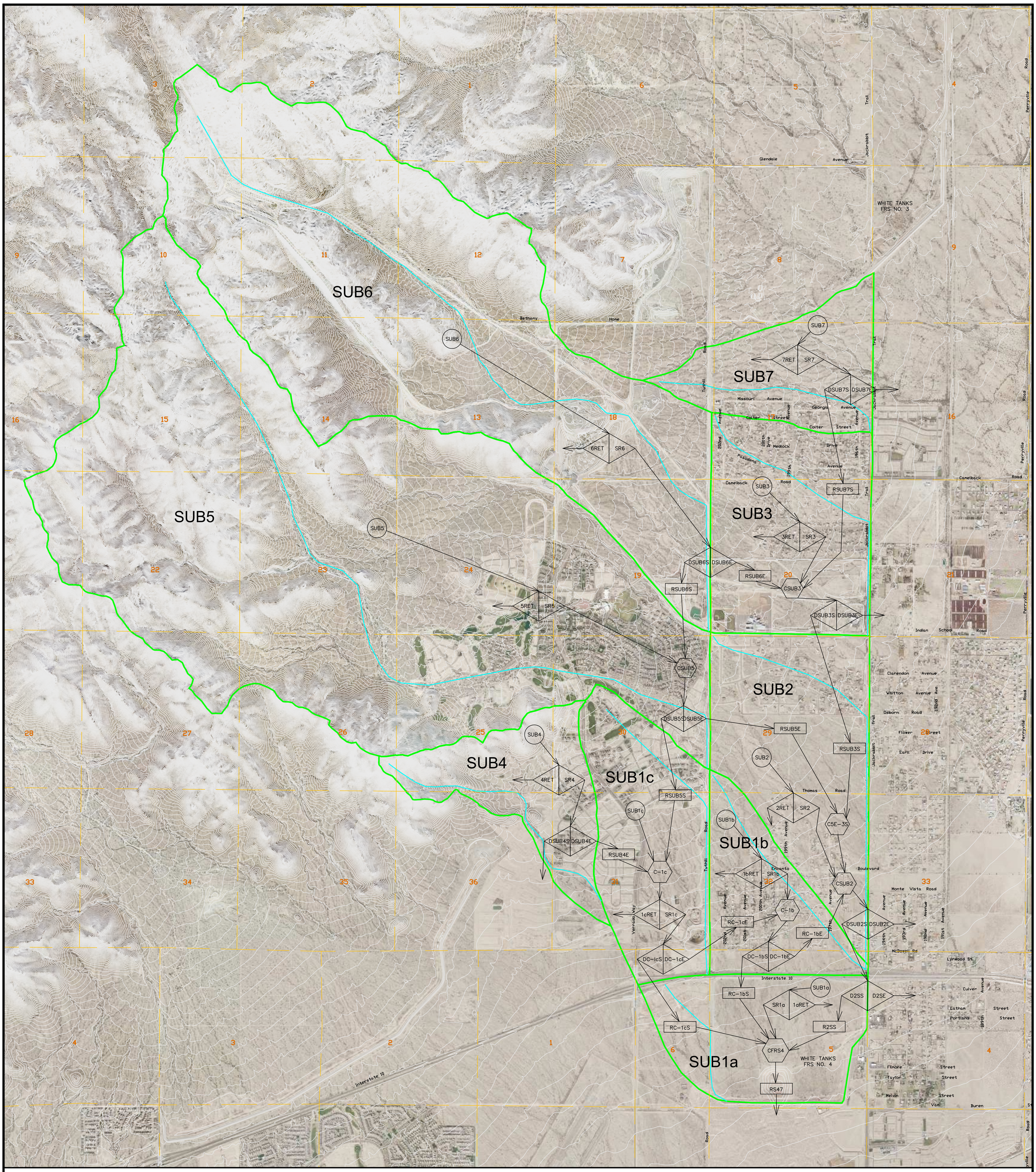

LEGEND

	Sub-basin Boundary	SUB4	Subbasin Hydrograph
SUB1	Sub-basin Name	RSUB2S	Surface Routing
	Section Boundary	CSUB1	Flow Combine
14	Section Number	DSUB2S DSUB2E	Flow Diversion
	Longest Flow Path	FRS4	Storage Routing
			General Flow Direction

1500' 0' 1500' 3000'

SCALE: 1"= 1500' FEET
CONTOUR INTERVAL = 10 FEET

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

WHITE TANKS FRS NO. 4 REMEDIATION

EXHIBIT E
SUB-BASIN BOUNDARIES AND HEC-1 SCHEMATIC
For SDH/PMF Storms - Future
FCD 2008C002
NOVEMBER 2010

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EXHIBIT F
CD Containing Electronic Files

LIST OF APPENDICES ON CD

(Reference Section 1.4)

APPENDIX 1	On-Site Retention Volumes
APPENDIX 2	Storage Routing Data for FRS No. 4
APPENDIX 3	Supporting Data for Sediment Analysis
APPENDIX 4	Principal Outlet Hydrographs from FRS No. 3
APPENDIX 5	Watershed Soil Data
APPENDIX 6	Watershed Land Use Data
APPENDIX 7	Supporting Data for Flow Diversions
APPENDIX 8	Hydrologic Modeling Supporting Data for 100-Year, 24-Hour Storms
APPENDIX 9	Hydrologic Modeling Supporting Data for 100-Year, 10-Day Storms
APPENDIX 10	Hydrologic Modeling Supporting Data for PMF 6-Hour Storms
APPENDIX 11	Hydrologic Modeling Supporting Data for PMF 24-Hour Storms
APPENDIX 12	Hydrologic Modeling Supporting Data for PMF 72-Hour Storms
APPENDIX 13	Hydrologic Modeling Supporting Data for SDH Hydrographs
APPENDIX 14	HEC-1 Output Files
APPENDIX 15	Additional Supporting Documents