Dambreak Study for Apache Junction FRS and Signal Butte FRS

Buckhorn-Mesa Structures

Prepared for:

Flood Control District of Maricopa County (FCD No. 2003C062) and LTM Engineering, Inc.

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DAMBREAK STUDY FOR APACHE JUNCTION FRS AND SIGNAL BUTTE FRS BUCKHORN-MESA STRUCTURES

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY
FCD 2003C062

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DAMBREAK STUDY FOR APACHE JUNCTION FRS AND SIGNAL BUTTE FRS

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1.0 Introduction

The Apache Junction Flood Retarding Structure (FRS) and Signal Butte FRS are located within the cities of Mesa and Apache Junction and in unincorporated Maricopa and Pinal counties, Arizona. The dams lie between the Usery Mountains on the north and the Superstition Freeway on the south. A major water supply canal, the Central Arizona Project (CAP) canal, crosses the downstream inundation study area of the dams. The dams were constructed across the southern alluvial plain of the Usery Mountains. Apache Junction FRS and Signal Butte FRS are operated and maintained by the Flood Control District of Maricopa County (District). **Figure 1** provides a location map of the two dams.

The purpose of Apache Junction FRS and Signal Butte FRS is to provide flood and erosion protection for developments downstream of the dams (agricultural, commercial, and urban) (KHA March 2005). The dams were designed and constructed by the Soil Conservation Service (now the Natural Resources Conservation Service) under the PL-566 Small Watershed Protection Program.

Apache Junction FRS and Signal Butte FRS are homogenous earth embankment dams. Apache Junction FRS was constructed with a central filter as a defensive mechanism for potential transverse cracks. In lieu of a central filter for Signal Butte FRS, the NRCS designed and constructed a central high density polyethylene (HDPE) barrier as a defensive mechanism for potential transverse cracks. Both structures were constructed with reinforced concrete emergency spillways and reinforced concrete pipe principal outlets. The emergency spillways for Apache Junction FRS and Signal Butte FRS are located at near the West abutment and East abutments, respectively. The principal outlets for both structures are located along the right abutment wing of each dam. **Table 1** provides a summary of the physical design characteristics for each structure.

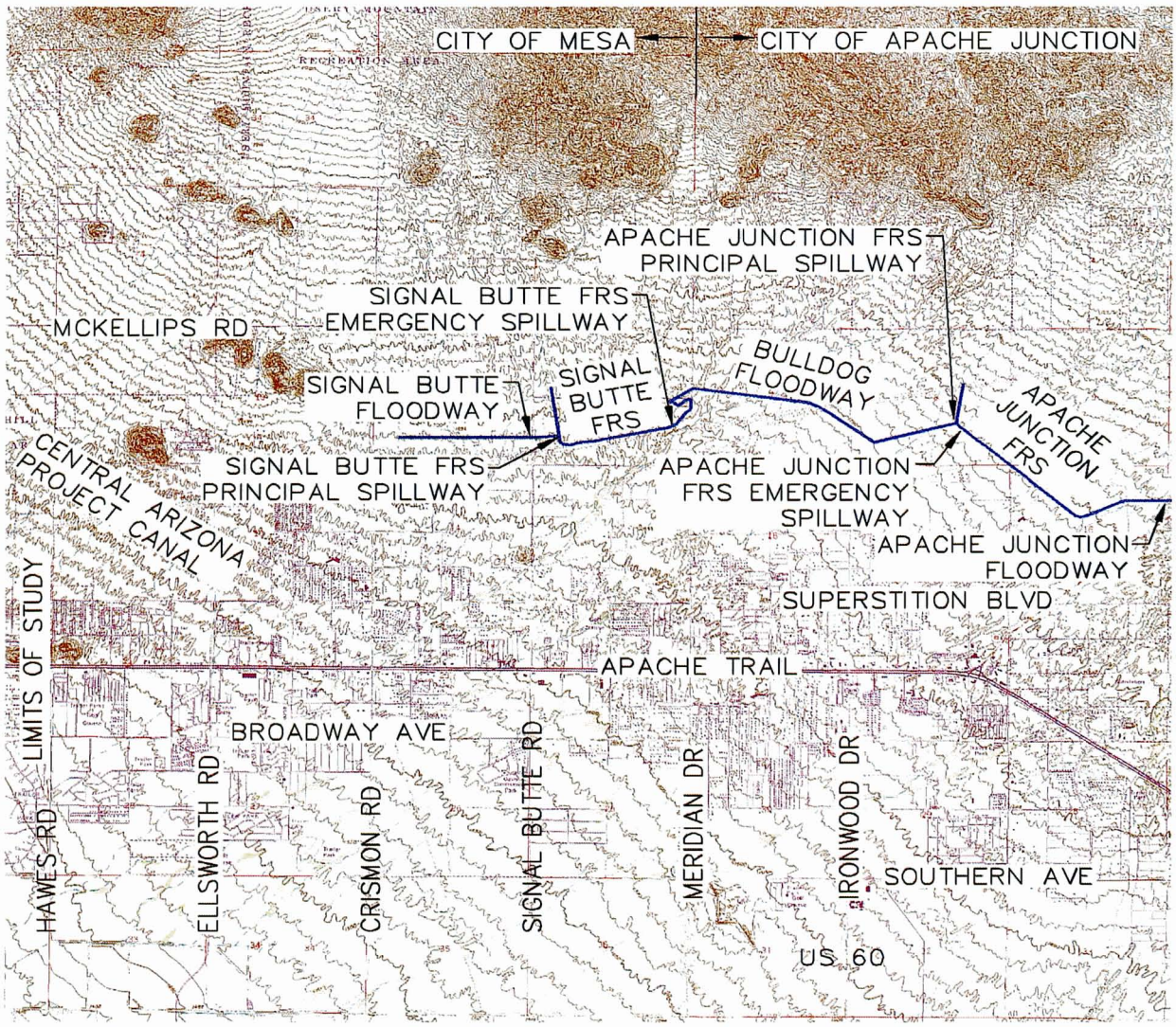
Table 1. Flood Retarding Structure Physical Design Characteristics (NGVD29).

Flood Retarding Structure Parameter	Apache Junction	Signal Butte
Dam Crest Elevation –ft	1810.0	1723.0
Emergency Spillway Crest Elevation – ft	1799.77	1712.4
Sediment Pool Elevation – ft	1793.5	1700.75
Principal Spillway Crest Elevation - ft	1793.5	1701.0
Principal Spillway Outlet Pipe Diameter (in)	30	36
Storage to Emergency Spillway Crest (af)	503.4	1365.3
Storage to Top of Dam Crest (af)	2019.3	2822.1
100-year Sediment Pool Storage (af)	108.7	255.2

Figure 1. Apache Junction FRS and Signal Butte FRS Location Map.

SOURCE:
USGS 7.5 MINUTE SERIES (TOPOGRAPHIC)
APACHE JUNCTION QUADRANGLE

N
N.T.S.



LOCATION MAP

Apache Junction FRS and Signal Butte FRS are classified by the Arizona Department of Water Resources as intermediate size high hazard dams. The inflow design flood for the dams is the probable maximum flood (PMF). The NRCS designed and constructed both structures as Class C dams.

The Flood Control District (District) maintains operational control of Apache Junction FRS and Signal Butte FRS and is responsible for the structural and functional integrity of the dams and appurtenant features.

2.0 Authority and Purpose

The District has retained LTM Engineering, Inc. to develop EAPs for the Buckhorn-Mesa FRSs (Apache Junction, Signal Butte, and Spook Hill). Kimley-Horn and Associates, Inc. (Kimley-Horn) is assisting LTM Engineering by preparing updated dambreak studies and analyses for the Apache Junction FRS and Signal Butte FRS.

The purpose of these studies was to update the dambreak analyses for these two structures. Development downstream of each structure has significantly increased since construction of the dams. The original dambreak analyses for each dam were prepared using simplified technical methods and United States Geological Survey (USGS) 7.5 minute topographic quadrangle mapping. The updated dambreak analyses are based on new two foot contour mapping, new stage-storage-discharge rating curves for each dam, use of the dynamic hydraulic model capability (HEC-RAS Version 3.1.3), and updated Probable Maximum Precipitation (PMP) and Probable Maximum Flood (PMF) for each structure (KHA, September 2005). Kimley-Horn evaluated potential dambreak scenarios for these two structures and developed downstream inundation mapping resulting from the routed dambreak floodwave from each dambreak scenario.

This report documents Kimley-Horn's dambreak analyses for Apache Junction and Signal Butte FRS. This report documents the approach, methodology, assumptions, results, conclusions, and recommendations from the updated dambreak study.

The dambreak study results will provide information that is required for emergency action planning. This data includes information on maximum depths, flow velocities, and travel time for the discharge hydrographs associated with the dam breach and boundary conditions evaluated for Apache Junction FRS and Signal Butte FRS. The data will provide planning information for emergency management purposes, flood warning, and floodplain management.

3.0 Scope of Work

The objective of this study is to provide dam failure analyses and downstream inundation mapping as part of updated emergency action plans for Apache Junction FRS and Signal Butte FRS. The scope of work included these elements and dambreak scenarios:

- Collection of pertinent hydrologic data, as-built plans, topographic mapping for each dam and the downstream inundation area.
- Study analysis flood is the inflow design flood (IDF) which is the Probable Maximum Flood.
- Model Scenario No.1 (Empty Pool): Route the IDF through each dam with initial conditions of an empty pool and breach the dams. This scenario was evaluated according to IDF routing guidelines published by ADWR (ADWR, March 2004). Under these guidelines, routing of the IDF may start with an empty pool provided the dam impoundment is demonstrated to drain within 10 days for a full pool condition (in the case of Apache Junction and Signal Butte FRS full pool corresponds to the 100-year storm event). According to the Apache Junction FRS and Signal Butte FRS Individual Structure Assessment Reports (KHA 2001), the Apache Junction FRS and Signal Butte FRS each drain in less than 10 days, respectively.
- Model Scenario No. 2 (Full Pool): Route the IDF through each dam with initial conditions of a full pool elevation at the emergency spillway crest and breach the dams. This scenario models "back-to-back" storms. The reservoir pool is assumed to be full resulting from approximately the 100-year storm event prior to the IDF event.
- Model Scenario No. 3 (Sunnyday): This scenario does not route the IDF through each dam. Instead the dams are breached with initial pool elevations at the emergency spillway crests (this scenario is referred to as the "Sunnyday failure"). There is no inflow to the dams only static full pools (note that dynamic modeling requires a small amount of inflow to run the models).
- Evaluate the inundation (i.e., flow depths, flow velocity) downstream for each dam from the breaches for each of the three model scenarios.
- Develop flood inundation area maps to aid in development of an emergency action plan.

4.0 Data Collection

Existing studies and reports for each dam was collected by Kimley-Horn in previous works tasks (KHA, March 2005 and April 2005). The data collected from these sources provided the base of information required for conducting this dambreak study. A record of the data collected by Kimley-Horn for this study is provided in **Appendix A**. **Appendix A** also serves as the reference listing. A field reconnaissance visit provided a project site overview of the location of the dams and the downstream inundation area.

Major data sources reviewed as part of this study include:

- Probable Maximum Precipitation/Probable Maximum Flood analysis prepared by Kimley-Horn for Apache Junction FRS and Signal Butte FRS.
- Aerial topographic mapping for the dams (see Section 5.0 below).
- As-built structure plans.
- Apache Junction FRS and Signal Butte FRS Individual Structure Assessment Report prepared by KHA for the District (April 2001).
- Dambreak reports prepared previously by the NRCS.

5.0 Mapping and Aerial Photography

The District provided aerial photography and topographic mapping for this study. The mapping was prepared by others under separate contract. The base mapping was flown in April 2005.

6.0 Inflow Design Flood

The Arizona Department of Water Resources has determined that the inflow design flood for the Apache Junction FRS and Signal Butte FRS is the probable maximum flood (PMF). Kimley-Horn developed updated PMF hydrology for each watershed for both the 6-hour and 72-hour duration events (KHA September 2005). The 6-hour storm was used for these dambreak studies. The peak inflow for the PMF for Apache Junction FRS and Signal Butte FRS was determined to be 23,400 cfs and 26,222 cfs, respectively in the KHA study.

7.0 Description of Downstream Inundation Area

The dambreak study limits are defined as beginning at the dams and traversing downstream to approximately US 60 (Superstition Freeway), a distance of approximately 6.8 miles for Apache Junction FRS and 5.5 miles for Signal Butte FRS . The downstream limits of the study area include the location of the Arizona Department of Transportation's (ADOT) future Red Mountain Freeway (Loop 202). **Figure 1** provided the study limits for the dambreak studies.

The downstream inundation study areas for both dams have the same land use type and characteristics. Within the pool area and immediately downstream of each dam the land use is primarily upland Sonoran desert. In less than ½ mile downstream from each dam the land use changes from desert to rural medium residential. Residential development consists of medium density mobile home trailers, trailer parks, and commercial activities. The density of mobile homes and trailer parks increases moving in the downstream direction. The spillway inundation delineation studies for Apache Junction FRS (July 2000) and Signal Butte FRS (August 1999) provide a discussion of this downstream study area and corresponds Manning's roughness coefficients with land use type. Additional discussion of land use type and Manning's roughness coefficients are provided in Section 8.3 below.

The downstream study area includes local and residential drainage improvements as well as ADOT freeway drainage improvements. The local improvements include trailer park retention/detention basins, roadside drainage channels and minor improved drainage channels. The ADOT freeway drainage facilities includes large regional detention basins located between the Central Arizona Project (CAP) canal and the future Red Mountain Freeway on the north side of US 60 (Superstition Freeway).

8.0 Dambreak/Hydraulic Analysis and Methodology

The U.S. Army Corps of Engineers HEC-RAS model (Version 3.1.3 May 2005) was used to conduct the dambreak and dynamic routing analyses. The HEC-RAS was used for this study to develop one-dimensional, unsteady flow, water surface profile calculations. The HEC-RAS model was used to simulate the passage of the inflow design flood through the dams (for the

Empty and Full Pool scenarios) with a dam breach occurring at approximately the maximum embankment section. The model was also used to simulate the passage of the dam break floodwave through the downstream inundation area.

The HEC-RAS model contains a breach component, which simulates the formation of a dam breach over a designated time period. A second component estimates the reservoir breach outflow hydrograph resulting from the simulated breach. The third component of the model consists of a dynamic routing technique using the unsteady-state flow equations for estimating the dam break flood wave as it advances through the downstream inundation area, and computes resulting water surface elevations at designated locations (or cross sections).

The dynamic routing (unsteady flow) option of HEC-RAS requires similar input data as the steady flow option of HEC-RAS. The model requires geometry data that physically describes the shape of the dam as well as the downstream inundation area, unsteady flow data which in this case consists of upstream inflow hydrographs and upstream and downstream boundary and initial flow conditions. Geometric data for the dam and downstream inundation area is required for both steady and unsteady modeling and may be used for either. One of the major differences is the requirement for flow data in the form of inflow hydrographs and in this study is used as the upstream boundary condition.

8.1 Model Input Requirements

The following is a summary of the required input for the HEC-RAS unsteady dambreak model:

Item	Data Required
Hydrology	Inflow Design Hydrographs (PMF) Upstream boundary condition – inflow hydrographs Base flow (initial conditions)
Breach	Formation time of breach Side Slope of breach Final bottom width and bottom elevation of breach Water surface in dam at initiation of breach Piping failure
Reservoir	Initial water elevations Elevation of water when breach begins Dam Crest Elevation Geometry of channel Manning's roughness coefficients
Emergency Spillway	Cross section at sill Crest elevation
Principal Spillway	Culvert data (physical description)

Downstream Inundation Area	Geometry of channel Manning's roughness coefficients Downstream boundary condition Base Flow (initial condition)

8.2 Cross Section Geometry

Cross section geometry for pool area, dam, and downstream inundation area were developed from aerial topographic mapping provided to Kimley-Horn by the District. The mapping included both dams and pool areas downstream to approximately Hawes Road. The mapping contour interval is two feet. Cross sections of the dam and downstream inundation area were prepared using BOSS RMS (river modeling system) computer program. BOSS RMS prepares cross sections at user specified locations and uses those cross sections to build a HEC-RAS geometry file. Cross section location maps are provided in **Appendix B** for both dams.

Cross sections were then adjusted in HEC-RAS using the graphical editor tool. The graphical editor was used to remove small drainage ditches and roadside channels, as well as local detention basins that do not add to conveyance given the magnitude of the potential routed dambreak flows.

8.3 Manning's Roughness Characteristics

Manning's n-values were obtained from the emergency spillway delineation studies conducted by the District. N-values for the downstream inundation area for Apache Junction FRS were obtained from the report titled "Apache Junction Flood Retarding Structure Spillway Inundation Study" (FCD July 2000) and for Signal Butte FRS from the report titled "Delineation of Spillway Flows for Signal Butte Flood Retarding Structure" (FCD August 1999). Both of these studies identified the downstream inundation area land use types as one of three land used classifications and assigned corresponding roughness coefficients. The three land use types and n-values assigned by these two studies are provided in **Table 2**. This dambreak study used the same land use types and n-values as provided in the spillway delineation studies. The "low-flow" channel modeled for both dambreak studies used an n-value of 0.045 or 0.055.

Table 2. Land Use Types and Manning's Roughness Coefficients.

Land Use Type	Manning's N-Value
Open Desert	0.068
Medium Density Residential (Mobile Homes)	0.12
High Density Residential (Mobile Homes)	0.15
Low Flow Channel	0.045 – 0.055

8.4 Dam Embankment and Lateral Structures

The Apache Junction FRS and Signal Butte FRS embankments are homogeneous earth embankments with flared (or wing) abutments to contain the flood pools. The embankment of the main portion of each dam was modeled using the 'In-Line Structure' option in the Geometry Editor of HEC-RAS. This option requires a station location of the main dam as well as physical parameters that describe the embankment crest profile, crest width, upstream and downstream side slopes, and embankment weir coefficient. This option includes the capability of providing breach parameters for the main dam as well. A discussion of the breach option and parameters are provided in Section 8.5.1 below.

The flared "wing" embankments were modeled as lateral structures using the 'Lateral Structure' option in HEC-RAS from the Geometry Editor. The lateral structure option requires similar physical data as with the 'In-Line Structure" option. The option requires the embankment crest profile, crest width, lateral structure location (left or right overbank), and the cross sections that the lateral structures spans. For both dams, left and right lateral structures were defined in the models to correspond to the left and right abutments/flared wing embankments.

Cross sections were developed for the pool area for each dam. The cross sections spanned beyond the width of the pool area and included the left and right wing abutments. Lateral structures were defined for each cross section that crossed the dam abutments. The crest elevation for each lateral structure was determined using the as-built construction plans (NGVD29) and converting the crest elevations to the datum used for the aerial topographic mapping (NAVD88). The datum conversion (add 2.15 ft to NGVD29 elevations) was taken from the updated stage-storage-discharge rating curves developed by Wood Patel for the Spook Hill Area Drainage Master Plan update (Wood Patel September 2002).

The cross sections of the pool areas along with the in-line structure and lateral structure option allowed KHA to model the dam and reservoir pool. Cross sections were oriented perpendicular to the predominant high flood flows anticipated with the level of a PMF flood. A low-flow channel was defined for the pool area and upstream cross sections for each dam. The cross sections in the pool areas span ephemeral desert washes of limited capacity. For the purposes of model stability, a low flow channel was identified and defined in the cross section geometry for the pool areas.

The emergency spillways for both dams were modeled in HEC-RAS as part of the in-line structure option. The spillway crest elevation and spillway cross section geometry were coded as part of the in-line structure embankment profile.

Both structures were designed and constructed with principal outlet structures. **Table 1** above provided the configuration of the principal outlet conduits. HEC-RAS has the capability of including a low flow outlet through the embankment of a dam. This capability is included in the in-line structure editor. KHA used the 'In-Line Gate Editor' as part of the in-line structure editor to include a principal outlet for each dam. Note that both the Apache Junction FRS outlet and the Signal Butte FRS outlets are reinforced concrete pipes. The geometry for the gate option of HEC-RAS does not include a pipe section or circular gate. Kimley-Horn modeled both outlets as

2-foot tall by 2-foot wide gates with the gates open fully for the entire event simulations. The gate option requires a time series for gate operations during the event simulation. KHA modeled both the Apache Junction FRS outlet and Signal Butte FRS outlet as uncontrolled (no closed or partially closed gates) and thus the time series for both "gates" allowed the gates to be open entirely during model simulations. The Signal Butte FRS also includes one gated irrigation outlet which was not modeled as part of this dambreak study. The discharges from the irrigation gated outlet were considered to be of minor importance and impact when compared to the magnitude of the spillway and breach discharges.

8.5 Model Scenario No. 1 – Empty Pool

The Empty Pool Model Scenario routes the 6-hour PMF through each dam under the conditions of an empty impoundment (no pool) or as close to an empty pool. This scenario follows the guidelines published by ADWR (ADWR, March 2004) which state: "flood routings for single purpose flood control dams may be allowed to begin with the reservoir elevation at the invert of the lowest outlet work if 85 percent of the smaller of either (1) the reservoir volume at spillway crest or (2) the total runoff during the 100-year 24-hour storm can be drained in less than 10 days". The Individual Structure Assessment reports prepared by Kimley-Horn on behalf of the District indicate that the reservoir pools can drain in less than the required 10 day criterion. Therefore, this scenario starts with an empty pool.

8.5.1 Breach Characteristics

A dam breach can be defined as a failure of a reservoir structure that allows for an uncontrolled discharge of water. Typically, a failure results from overtopping of the dam crest or by piping of embankment materials. The Apache Junction FRS and Signal Butte FRS were originally designed and constructed by the NRCS to control the PMF event without an overtopping condition for a Class C dam. Recent evaluations, including Kimley-Horn's PMP/PMF update study (KHA September 2005), have indicated that both dams safely pass the PMF through the emergency spillways without overtopping the dams. The KHA PMP/PMF study indicated that both dams have freeboard from maximum water surface elevations in the pools resulting from the PMFs (for Apache Junction the freeboard is 6.2 feet and for Signal Butte the freeboard is 3.65 feet). Freeboard is measured from maximum water surface elevation to top of dam crest.

The failure mode selected for modeling the dam breach process for both dams is by piping. For a piping failure to occur, a flow path or 'pipe' must occur in the earth embankment. Impounded water seeps through the pipe and due to the high flow velocities within the pipe the water begins to carry away the finer embankment materials. As the fine materials are removed, the size and definition of the pipe are increased. More water flows though the pipe resulting in more erosion of the material around the pipe, expanding the pipe section. Eventually, given the correct conditions, the piping breach expands to a point that the embankment material over the breach collapses into the breach or the breach reaches dam crest elevation, both of which results in an uncontrolled release of the reservoir pool.

Breach parameters for Apache Junction FRS and Signal Butte FRS embankment sections were developed using published parametric equations, historical dam breach data, and engineering

judgment. Parametric data are provided in **Appendix C**. The breach parameters adopted for the three model scenarios for each dam are provided in **Table 3 and Table 4** for Apache Junction FRS and Signal Butte FRS, respectively, below.

Table 3. Dam Breach Parameters for Apache Junction FRS. (NAVD88)

Breach Parameter	Model Scenario		
	Empty Pool	**Full Pool**	**Sunnyday**
Breach formation time (hr)	0.38	0.38	0.38
Breach bottom width (ft)	75	75	75
Base elevation of breach (ft)	1790.15	1790.15	1790.15
Breach side slopes (1H:V)	0.5	0.5	0.5
Breach Station	10000	10000	10000
Initial piping elevation (ft)	1794	1794	1794
Starting water surface elevation for breach (ft)	1810	1812	Set Time
Upstream hydrograph	6-hr PMF	6-hr PMF	500
Initial condition (cfs)	500	500	500

Table 4. Dam Breach Parameters for Signal Butte FRS. (NAVD88)

Breach Parameter	Model Scenario		
	Empty Pool	**Full Pool**	**Sunnyday**
Breach formation time (hr)	0.5	0.5	0.5
Breach bottom width (ft)	130	130	130
Base elevation of breach (ft)	1695	1695	1695
Breach side slopes (1H:V)	0.5	0.5	0.5
Breach Station	10000	10000	10000
Initial piping elevation (ft)	1701	1701	1701
Starting water surface elevation for breach (ft)	1721	1725	~~1714~~ 1716
Upstream hydrograph	6-hr PMF	6-hr PMF	Constant 2000
Initial condition (cfs)	2031	2031	2000

?

8.5.2 Boundary and Initial Conditions

The dynamic routing option of HEC-RAS requires the input of unsteady flow data (inflow hydrographs). The unsteady flow data may be entered as upstream and downstream boundary conditions as well as lateral inflow hydrographs. The model requires boundary conditions at all the external boundaries of the model system, as well as any desired internal locations, and setting the initial flow and storage area conditions at the beginning of simulation.

HEC-RAS has several available types of boundary conditions. A flow hydrograph (to distinguish from a stage hydrograph which is also available) can be used as either an upstream boundary or downstream boundary. A flow hydrograph was selected as the upstream boundary condition for both dams. The upstream hydrograph boundary condition for the dambreak analysis for the empty pool and full pool model scenarios was the 6-hr PMF hydrograph. For the Sunnyday model scenario, it is assumed that no inflow occurs into the reservoir pool; however, the pool is initially full to an elevation of the emergency spillway crest elevation. HEC-RAS requires an upstream boundary condition, thus a small low flow hydrograph was selected for the Sunnyday scenario to satisfy model requirements and model stability. An upstream hydrograph was applied in both models for all three scenarios at the most upstream cross section. **Table 3** and **Table 4** above provided a summary of the upstream boundary conditions and initial conditions for each dam and model scenario. **Appendix D** provides the inflow hydrographs for the 6-hr PMF for each dam.

List initial flows?

The unsteady flow option of HEC-RAS requires that initial conditions also be specified. Initial conditions establish the flow and stage at all nodes in the model system at the beginning of the simulation. Initial conditions are used to "warm" up the model and to have the program perform a steady flow backwater run to compute corresponding stages at each cross section.

8.6 Model Scenario No. 2 – Full Pool

The Full Pool Model Scenario routes the 6-hour PMF through both dams under the conditions of an assumed initial conditions of a full impoundment. This scenario simulates "back-to-back" storm events. The full impoundment is assumed to represent a major storm occurring prior to the PMF storm event. This is a conservative scenario which has a very low probability of occurrence. The initial water surface elevations in the reservoirs were set at an elevation corresponding to the crest of the emergency spillways. The same model conditions described for the Empty Pool were applied to the Full Pool Model Scenario except for the condition of an initial full impoundment.

8.7 Model Scenario No. 3 - Sunnyday

In the Sunnyday Model Scenario the initial pool elevation is set at the emergency spillway crest for Signal Butte FRS and Apache Junction FRS. However, the Sunnyday Model scenario does not route the PMF through the dams as in the Full Pool scenario. No PMF inflow hydrograph routing occurs with this scenario except for the upstream hydrograph boundary condition as required by the HEC-RAS model. Breach parameters are the same as in the first two model

scenarios except the water surface elevation at the initiation of breach was set to the emergency spillway elevations. This scenario assumes a full pool resulting from a flood event but no subsequent inflow event. There is no subsequent inflow, only a "static" full pool. This model scenario is known as the Sunnyday failure. This scenario is typically applied to structures that are designed to retain permanent reservoir water for purposes such as water supply, irrigation, and recreational uses. The Sunnyday failure assumes a breach of the dam under non-hydrologic inflow conditions.

9.0 Dambreak Results

The maximum water surface elevation at each cross section in the downstream inundation reach was computed and well as channel velocities section and hydraulic depths of flow in the cross section for each modeling scenario for each dam. Arrival times were derived for the maximum stage based on a time zero of the peak flow through the breach and are included on the inundation exhibit maps in **Appendix E**. The time in hours for the peak of the floodwave to reach the downstream end of the inundation reach for the Apache Junction FRS dambreak is 4.3 hours, 3.9 hours, and 6.3 hours for the Empty Pool, Full Pool, and Sunnyday scenario, respectively. The time in hours for the peak of the floodwave to reach the downstream end of the inundation reach for the Signal Butte FRS dambreak is 3.0 hours, 2.6 hours, and 3.1 hours for the Empty Pool, Full Pool, and Sunnyday scenario, respectively.

The Apache Junction FRS (at maximum water surface elevations) dambreak flood elevations, flow velocities, and depths of channel flow are summarized in **Tables 5, 6,** and **7** for the Empty Pool, Full Pool, and Sunnyday scenario, respectively. The Signal Butte FRS (at maximum water surface elevations) dambreak flood elevations, flow velocities, and depths of channel flow are summarized in **Tables 8, 9,** and **10** for the Empty Pool, Full Pool, and Sunnyday scenario, respectively. Results are not reported in the following tables for interpolated cross sections. Detailed model output is provided as electronic format in the enclosed compact disk as part of this report (see pocket in back of report). A series of dambreak and downstream routing hydrographs are provided in **Figures 2** through **5** for Apache Junction FRS and **Figures 6** through **9** for Signal Butte FRS.

Table 5. Dambreak Summary Table Apache Junction FRS (Empty Pool).

(yellow highlight indicates maximum value for parameter in downstream reach)

HEC-RAS Section No.	Total Flow	Water Surface Elevation	Channel Velocity	Cross Section Velocity	Top Width	Hydraulic Depth
	(cfs)	(ft)	(ft/s)	(ft/s)	(ft)	(ft)
13.580	23,401	1840.77	9.61	3.47	5,171	1.3
13.459	23,381	1830.72	9.71	3.96	4,468	1.3
13.365	23,370	1821.77	6.44	3.39	4,671	1.5
13.286	23,355	1815.66	6.76	3.66	4,713	1.4
13.232	23,343	1810.57	5.32	3.36	6,570	1.1
13.163	8,885	1810.07	0.30	0.22	6,405	6.3
13.123	8,902	1810.07	0.18	0.13	6,402	10.6
13.092	8,877	1810.07	0.14	0.11	6,191	13.4
13.054	8,831	1810.07	0.12	0.09	5,940	16.4
12.998	8,876	1810.07	0.12	0.10	5,275	17.3
12.967	15,560	1790.05	10.69	10.28	1,433	1.1
12.932	21,825	1788.77	5.46	4.05	2,536	2.1
12.904	21,773	1786.83	8.61	4.67	2,386	2.0
12.866	21,706	1783.18	13.03	6.09	2,270	1.8
12.827	21,633	1780.61	5.02	3.34	5,456	1.2
12.743	21,530	1774.86	5.61	3.12	5,892	1.2
12.677	21,432	1769.44	5.49	3.10	4,528	1.5
12.550	21,272	1758.99	3.02	2.61	3,851	2.1
12.406	21,199	1750.82	4.43	2.91	5,199	1.4
12.270	21,122	1741.29	1.90	2.58	4,964	1.7
12.131	21,038	1732.64	4.05	2.91	6,226	1.2
12.019	20,968	1725.40	5.98	2.37	5,791	1.5
11.889	20,879	1718.91	7.43	2.70	5,696	1.4
11.723	20,745	1709.76	5.85	3.16	4,202	1.6
11.600	20,652	1702.30	4.27	3.00	6,072	1.1
11.466	20,541	1695.31	4.93	2.38	5,827	1.5
10.817	20,008	1662.43	7.19	1.75	8,240	1.4
10.569	19,708	1652.30	7.57	1.74	7,391	1.5
10.392	19,432	1645.46	5.17	1.59	8,049	1.5
10.112	19,115	1635.55	7.90	1.89	6,727	1.5
9.944	18,825	1626.72	3.26	1.46	6,672	1.9
9.760	18,580	1618.66	7.07	2.09	5,804	1.5
9.528	18,446	1608.44	3.63	3.09	5,494	1.1
9.313	18,314	1600.88	4.03	3.04	4,234	1.4
8.967	17,841	1591.14	4.67	1.51	9,187	1.3
8.648	17,474	1579.54	7.04	1.45	8,340	1.4
8.391	17,171	1571.21	5.47	1.72	7,362	1.4
8.292	16,688	1566.44	6.18	1.69	6,075	1.7
8.206	15,653	1561.46	6.01	1.45	8,140	2.1
8.072	16,269	1554.61	6.84	1.89	8,532	1.1
7.940	15,762	1548.95	6.41	1.98	7,324	1.1
7.711	14,322	1539.73	3.50	2.00	4,498	1.7
7.431	12,544	1529.26	3.45	1.72	5,886	1.3
7.134	14,686	1521.08	5.20	2.52	4,648	1.3
6.959	14,430	1515.32	5.95	2.44	4,638	1.3
6.684	14,206	1506.89	6.38	2.99	2,927	1.6
6.443	13,986	1499.54	8.29	2.70	3,885	1.3
6.278	13,835	1493.60	5.51	2.52	3,403	1.6
6.121	13,682	1489.15	6.90	2.94	3,670	1.3
5.957	13,508	1483.27	7.59	2.58	4,101	1.3
5.783	13,224	1478.07	3.69	2.04	4,828	1.3
5.642	13,209	1473.96	4.28	1.94	3,540	1.9
5.471	9,463	1469.58	4.43	1.32	4,531	1.6
5.322	12,610	1464.01	7.93	2.23	3,918	1.4
5.000	11,948	1455.03	8.77	2.48	2,649	1.8

Table 6. Dambreak Summary Table for Apache Junction FRS (Full Pool).

(yellow highlight indicates maximum value for parameter in downstream reach)

HEC-RAS Section No.	Total Flow	Water Surface Elevation	Channel Velocity	Cross Section Velocity	Top Width	Hydraulic Depth
	(cfs)	(ft)	(ft/s)	(ft/s)	(ft)	(ft)
13.580	23,400	1840.77	9.61	3.47	5,171	1.3
13.459	23,364	1830.72	9.71	3.96	4,467	1.3
13.365	23,338	1821.76	6.45	3.40	4,669	1.5
13.286	23,308	1815.66	6.76	3.66	4,710	1.4
13.232	12,752	1812.13	1.09	0.72	7,283	2.4
13.163	12,713	1812.12	0.33	0.24	6,674	8.0
13.123	12,681	1812.12	0.21	0.16	6,421	12.6
13.092	12,662	1812.12	0.17	0.13	6,211	15.4
13.054	12,676	1812.12	0.15	0.12	5,978	18.4
12.998	12,538	1812.12	0.15	0.12	5,674	18.0
12.967	15,336	1790.04	10.57	10.25	1,430	1.1
12.932	28,292	1789.15	5.97	4.45	2,590	2.5
12.904	28,244	1787.20	9.15	5.08	2,469	2.3
12.866	28,189	1783.42	14.54	6.97	2,317	2.0
12.827	28,093	1780.86	5.38	3.59	5,596	1.4
12.743	27,901	1775.08	5.92	3.40	5,950	1.4
12.677	27,676	1769.72	5.81	3.37	4,680	1.8
12.550	27,250	1759.34	3.40	2.85	4,088	2.3
12.406	27,065	1751.05	4.77	3.19	5,272	1.6
12.270	26,923	1741.58	2.10	2.78	5,209	1.9
12.131	26,842	1732.88	4.42	3.06	6,549	1.3
12.019	26,752	1725.69	6.33	2.53	6,023	1.8
11.889	26,630	1719.22	7.79	2.81	5,930	1.6
11.723	26,348	1710.13	6.99	3.03	8,474	1.0
11.600	26,247	1702.54	4.60	3.14	6,238	1.3
11.466	26,111	1695.60	5.28	2.52	6,037	1.7
11.406	26,026	1691.82	5.66	2.17	7,211	1.7
11.270	25,887	1681.08	5.17	2.46	5,879	1.9
11.127	25,788	1671.46	5.27	2.55	6,390	1.6
10.817	25,584	1662.68	7.46	1.90	8,338	1.6
10.569	25,324	1652.59	7.87	1.88	7,417	1.8
10.392	25,050	1645.73	5.49	1.73	8,143	1.8
10.112	24,607	1635.84	8.23	2.03	6,962	1.7
9.944	24,341	1627.07	3.62	1.60	6,750	2.3
9.760	24,103	1618.97	7.45	2.24	6,251	1.7
9.528	23,950	1608.70	3.97	3.22	5,763	1.3
9.313	23,776	1601.23	4.40	3.15	4,465	1.7
8.967	23,195	1591.39	5.01	1.64	9,514	1.5
8.648	15,443	1579.97	4.48	0.98	9,025	1.8
8.391	22,455	1571.54	5.83	1.82	7,545	1.6
8.292	21,854	1566.80	6.60	1.82	6,393	2.0
8.206	17,452	1562.16	4.93	1.14	10,369	1.5
8.072	22,102	1555.14	5.87	1.74	8,867	1.6
7.940	21,381	1549.28	6.23	2.05	7,533	1.4
7.711	21,953	1540.47	3.48	1.92	6,668	1.7
7.431	17,672	1529.80	3.12	1.69	5,994	1.8
7.134	19,784	1521.41	5.55	2.68	5,068	1.5
6.959	19,300	1515.61	6.26	2.64	4,864	1.5
6.684	18,910	1507.26	6.80	3.19	3,254	1.8
6.443	18,630	1499.86	8.62	2.87	4,190	1.6
6.278	18,424	1493.97	5.83	2.72	3,542	1.9
6.121	18,237	1489.46	7.41	3.14	3,843	1.5
5.957	18,339	1483.60	8.01	2.76	4,412	1.5
5.783	17,752	1478.41	3.96	2.19	4,860	1.7
5.642	17,762	1474.34	4.92	2.07	4,814	1.8
5.471	12,097	1470.08	4.07	1.28	4,765	2.0
5.322	16,987	1464.39	8.20	2.37	3,958	1.8
5.000	16,171	1455.52	5.96	2.17	2,797	2.7

Table 7. Dambreak Summary Table for Apache Junction (Sunny Day).

(yellow highlight indicates maximum value for parameter in downstream reach)

HEC-RAS Section No.	Total Flow	Water Surface Elevation	Channel Velocity	Cross Section Velocity	Top Width	Hydraulic Depth
	(cfs)	(ft)	(ft/s)	(ft/s)	(ft)	(ft)
13.580	500	1836.94	4.55	2.59	270	0.7
13.459	500	1827.34	4.52	4.52	73	1.5
13.365	500	1819.81	3.73	3.73	177	1.1
13.286	498	1813.53	2.85	2.85	295	0.9
13.232	496	1807.36		15.95	357	0.7
13.163	500	1803.19	0.09	0.14	1,956	2.1
13.123	501	1803.19	0.03	0.02	6,227	3.9
13.092	503	1803.19	0.02	0.01	6,129	6.7
13.054	506	1803.19	0.01	0.01	5,881	9.7
12.998	509	1803.19	0.01	0.01	5,105	10.9
12.967	7,658	1789.42	5.78	5.78	366	6.6
12.932	7,605	1787.55	3.66	2.95	1,896	1.4
12.904	7,580	1785.69	6.75	3.50	1,844	1.2
12.866	7,559	1782.33	9.54	4.02	2,099	1.0
12.827	7,529	1779.46	3.28	3.29	1,657	1.4
12.743	7,378	1774.05	6.35	3.34	5,681	0.4
12.677	7,353	1768.63	4.42	2.15	4,088	0.8
12.550	7,323	1757.77	1.64	1.80	2,548	1.6
12.406	7,274	1749.92	2.79	2.45	2,435	1.2
12.270	7,216	1740.35	1.48	1.86	4,180	0.9
12.131	7,163	1731.75	2.53	2.46	2,688	1.2
12.019	7,124	1724.46	4.74	1.90	5,044	0.7
11.889	7,058	1717.76	5.91	2.92	1,731	1.4
11.723	7,025	1708.70	4.33	2.67	3,144	0.8
11.600	7,001	1701.29	2.98	2.45	2,850	1.0
11.466	6,970	1694.36	3.73	2.03	5,144	0.7
11.406	6,942	1690.68	4.13	1.55	5,985	0.8
11.270	6,893	1679.74	2.87	1.75	3,169	1.3
11.127	6,837	1670.32	3.68	2.18	5,868	0.5
10.817	6,766	1661.29	5.22	1.46	4,232	1.1
10.569	6,686	1651.21	6.20	1.31	4,687	1.1
10.392	5,906	1644.78	3.07	0.86	7,819	0.9
10.112	6,321	1634.60	6.81	1.54	5,982	0.7
9.944	6,075	1625.54	2.04	1.01	4,451	1.4
9.760	5,943	1617.32	5.17	1.77	2,775	1.2
9.528	5,902	1607.51	2.55	2.53	2,403	1.0
9.313	5,875	1599.73	2.76	2.76	1,684	1.3
8.967	5,672	1590.38	3.55	1.08	8,187	0.6
8.648	5,500	1578.70	5.87	0.98	7,151	0.8
8.391	5,239	1570.06	3.85	2.85	6,704	0.3
8.292	5,121	1565.11	4.40	1.28	3,629	1.2
8.206	4,958	1559.87	4.79	1.37	4,875	1.8
8.072	4,702	1553.36	5.10	1.94	3,247	1.1
7.940	4,561	1548.14	6.10	2.06	6,810	0.3
7.711	4,542	1538.64	4.02	1.61	4,153	0.7
7.431	4,487	1528.54	3.59	1.41	5,734	0.6
7.134	4,363	1519.98	4.01	2.84	1,365	1.4
6.959	4,287	1514.44	5.08	1.97	3,833	0.6
6.684	4,247	1505.38	4.74	2.43	1,195	1.5
6.443	4,188	1498.56	7.12	2.31	2,979	0.6
6.278	4,140	1492.52	4.45	2.05	2,998	0.7
6.121	4,039	1488.23	4.81	2.64	3,152	0.5
5.957	3,748	1482.09	5.94	3.59	2,997	0.4
5.783	3,729	1476.96	2.59	1.32	3,014	0.9
5.642	3,714	1472.62	3.53	1.38	2,671	1.0
5.471	3,682	1468.63	5.10	1.25	4,378	0.7
5.322	3,676	1462.57	6.06	2.27	2,332	0.7
5.000	3,562	1452.46	7.00	4.33	648	1.8

Table 8. Dambreak Summary Table Signal Butte FRS (Empty Pool).

(yellow highlight indicates maximum value for parameter in downstream reach)

HEC-RAS Section No.	Total Flow	Water Surface Elevation	Channel Velocity	Cross Section Velocity	Top Width	Hydraulic Depth
	(cfs)	(ft)	(ft/s)	(ft/s)	(ft)	(ft)
11.804	9,474	1721.10	1.76	0.83	2,945	3.9
11.803	9,454	1721.10	1.76	0.82	2,945	3.9
11.753	9,459	1721.10	0.85	0.39	3,687	6.5
11.693	9,416	1721.10	0.50	0.25	4,573	8.4
11.653	9,360	1721.10	0.32	0.18	4,363	12.0
11.585	9,326	1721.10	0.22	0.13	4,724	15.8
11.561	9,316	1721.10	0.19	0.11	4,719	17.2
11.506	9,301	1721.10	0.15	0.09	4,811	21.3
11.417	9,293	1721.09	0.14	0.09	4,843	21.4
11.401	9,168	1721.09	0.16	0.09	4,855	20.8
11.353	43,359	1692.74	9.15	5.50	3,283	2.4
11.332	42,952	1691.20	8.32	4.81	3,373	2.7
11.313	42,723	1689.87	8.65	5.24	2,830	2.9
11.265	42,276	1687.12	7.48	4.90	3,073	2.8
11.231	41,918	1685.26	7.27	4.70	3,210	2.8
11.178	41,024	1682.44	7.14	4.11	3,784	2.6
11.048	39,749	1676.40	6.75	4.89	2,834	2.9
10.966	38,578	1672.55	9.15	4.95	4,690	1.7
10.821	37,412	1663.43	5.67	3.22	5,683	2.0
10.708	36,864	1657.50	6.12	3.51	4,813	2.2
10.629	36,392	1653.33	4.06	2.60	5,233	2.7
10.483	36,278	1647.13	6.14	2.32	7,468	2.1
10.360	36,248	1642.70	8.56	2.77	6,382	2.1
10.170	36,170	1634.68	5.21	2.65	5,427	2.5
10.083	36,134	1631.07	4.83	2.48	6,510	2.2
9.983	36,033	1626.68	4.88	2.21	6,222	2.6
9.901	35,910	1623.36	6.09	2.11	6,403	2.7
9.810	35,807	1619.12	7.69	2.25	6,418	2.5
9.659	35,672	1612.00	6.19	2.61	5,345	2.6
9.599	35,535	1607.81	6.64	1.93	7,042	2.6
9.466	35,097	1602.24	6.28	1.95	7,997	2.3
9.280	34,809	1592.58	7.69	1.95	8,505	2.1
9.154	34,631	1585.34	5.75	2.31	8,647	1.7
9.076	34,331	1579.54	5.83	2.60	5,910	2.2
8.996	34,198	1575.90	6.44	2.91	4,323	2.7
8.965	34,005	1567.44	6.23	6.06	2,769	2.8
8.900	33,809	1565.26	4.58	4.46	3,333	3.7
8.612	33,524	1559.72	5.53	2.07	8,408	1.9
8.417	33,129	1551.32	5.78	1.93	9,103	1.9
8.201	32,675	1540.63	4.89	1.98	10,476	1.6
8.069	31,918	1534.17	6.60	2.55	9,123	1.4
7.983	31,816	1529.50	5.65	2.41	7,829	1.7
7.811	31,613	1520.73	5.23	2.29	10,827	1.3
7.602	31,398	1510.84	5.36	2.45	8,586	1.5
7.223	31,122	1501.96	5.88	2.39	8,105	1.6
6.847	30,679	1490.15	4.84	2.18	8,148	1.7
6.715	30,501	1482.55	3.76	2.72	6,859	1.6
6.586	30,228	1477.14	3.81	2.14	6,736	2.1
6.391	30,037	1472.77	6.05	2.23	6,041	2.2
6.276	29,870	1468.39	7.90	2.33	5,791	2.2
6.168	29,717	1463.44	6.05	2.30	5,612	2.3
6.064	29,567	1458.39	2.72	3.68	4,900	1.6
5.954	29,293	1455.25	5.24	2.23	5,243	2.5
5.836	29,104	1451.79	7.22	2.78	4,738	2.2
5.716	28,857	1446.10	7.60	2.86	5,011	2.0
5.505	27,748	1442.64	5.22	1.82	5,261	2.9
5.291	26,910	1436.41	9.45	1.95	4,751	2.9
5.205	26,502	1432.89	8.88	2.22	4,374	2.7
5.072	26,129	1428.44	10.46	2.79	3,663	2.6
5.000	26,007	1425.88	8.08	2.49	3,623	2.9

Table 9. Dambreak Summary Table Signal Butte FRS (Full Pool)

(yellow highlight indicates maximum value for parameter in downstream reach)

HEC-RAS Section No.	Total Flow	Water Surface Elevation	Channel Velocity	Cross Section Velocity	Top Width	Hydraulic Depth
	(cfs)	(ft)	(ft/s)	(ft/s)	(ft)	(ft)
11.804	15,955	1725.09	1.40	0.65	3,728	6.69
11.803	15,952	1725.09	1.40	0.65	3,728	6.69
11.753	15,931	1725.09	0.88	0.40	4,535	8.84
11.693	15,884	1725.09	0.55	0.28	4,935	11.56
11.653	15,824	1725.09	0.41	0.22	4,888	14.57
11.585	15,786	1725.09	0.30	0.17	4,887	19.16
11.561	15,776	1725.09	0.26	0.16	4,801	20.87
11.506	15,757	1725.09	0.21	0.13	4,911	24.84
11.417	15,642	1725.08	0.21	0.13	5,049	24.42
11.401	15,634	1725.08	0.23	0.13	5,252	23.03
11.353	62,272	1693.41	9.97	6.15	3,402	2.97
11.332	61,843	1691.94	9.09	5.36	3,661	3.15
11.313	61,653	1690.57	10.17	5.90	3,480	3.01
11.265	61,012	1687.93	8.37	5.44	3,332	3.36
11.231	60,511	1686.14	8.47	5.08	3,794	3.14
11.178	60,027	1683.21	7.69	4.65	3,849	3.35
11.048	58,368	1677.41	7.42	5.28	3,001	3.69
10.966	56,921	1673.25	9.74	5.07	5,009	2.24
10.821	55,515	1664.07	6.72	3.61	6,731	2.29
10.708	54,749	1658.24	7.09	3.83	5,678	2.52
10.629	54,023	1654.11	5.35	2.94	6,402	2.87
10.483	53,157	1647.68	6.97	2.69	7,604	2.60
10.360	52,932	1643.33	9.20	3.08	6,574	2.62
10.170	52,340	1635.35	6.06	3.01	5,717	3.04
10.083	52,094	1631.67	5.56	2.82	6,674	2.77
9.983	51,578	1627.40	5.69	2.48	6,486	3.21
9.901	51,150	1624.07	7.13	2.35	7,307	2.98
9.810	50,903	1619.74	8.32	2.55	6,555	3.05
9.659	50,648	1612.52	6.91	2.74	6,613	2.80
9.599	50,371	1608.45	7.36	2.18	7,584	3.05
9.466	49,961	1602.79	6.90	2.22	8,066	2.79
9.280	49,438	1593.10	8.33	2.22	8,709	2.56
9.154	49,171	1585.81	6.41	2.56	8,954	2.14
9.076	48,701	1580.26	6.41	2.69	8,261	2.19
8.996	48,508	1576.52	7.72	3.23	5,580	2.69
8.965	48,163	1568.24	6.79	6.11	4,701	1.68
8.900	47,849	1565.96	5.48	5.30	3,942	4.30
8.612	47,451	1560.27	6.27	2.23	10,441	2.04
8.417	46,605	1551.81	6.33	2.15	9,354	2.32
8.201	46,285	1541.06	5.49	2.21	10,577	1.98
8.069	46,003	1534.71	6.94	2.62	9,626	1.82
7.983	45,826	1529.98	6.21	2.69	8,276	2.06
7.811	45,520	1521.21	5.33	2.39	11,004	1.73
7.602	45,075	1511.30	5.84	2.66	9,180	1.84
7.223	44,660	1502.39	6.47	2.51	11,366	1.56
6.847	44,059	1490.63	5.28	2.44	8,440	2.14
6.715	43,679	1483.06	4.32	2.96	7,151	2.07
6.586	43,187	1477.69	4.41	2.42	7,099	2.52
6.391	42,847	1473.36	6.60	2.50	6,354	2.69
6.276	42,635	1468.95	8.49	2.66	5,921	2.71
6.168	42,435	1463.97	6.94	2.66	5,675	2.81
6.064	42,209	1458.95	3.00	3.91	5,087	2.12
5.954	41,950	1455.90	6.23	2.53	5,287	3.13
5.836	41,769	1452.37	7.92	3.09	5,472	2.47
5.716	41,308	1446.71	7.81	3.13	5,206	2.54
5.505	40,143	1443.41	5.82	2.08	5,261	3.67
5.291	39,291	1437.28	9.91	2.19	4,751	3.77
5.205	38,759	1433.76	9.42	2.46	4,401	3.58
5.072	38,300	1429.45	11.05	2.90	3,955	3.34
5.000	38,200	1426.90	8.73	2.69	3,695	3.84

Table 10. Dambreak Summary Table Signal Butte FRS (Sunnyday).

(yellow highlight indicates maximum value for parameter in downstream reach)

HEC-RAS Section No.	Total Flow	Water Surface Elevation	Channel Velocity	Cross Section Velocity	Top Width	Hydraulic Depth
	(cfs)	(ft)	(ft/s)	(ft/s)	(ft)	(ft)
11.804	2,000	1717.63	0.71	0.53	869	4.33
11.803	2,001	1717.62	0.72	0.53	866	4.34
11.753	2,084	1717.60	0.34	0.17	2,838	4.45
11.693	2,057	1717.59	0.18	0.09	3,788	6.19
11.653	2,116	1717.59	0.10	0.06	3,900	9.72
11.585	2,031	1717.59	0.06	0.03	4,237	13.77
11.561	2,031	1717.59	0.05	0.03	4,481	14.46
11.506	2,031	1717.59	0.04	0.02	4,630	18.56
11.417	2,031	1717.59	0.04	0.02	4,698	18.47
11.401	2,030	1717.59	0.04	0.02	4,659	18.08
11.353	28,448	1691.99	7.90	5.20	2,230	2.45
11.332	28,232	1690.47	7.67	4.30	3,093	2.12
11.313	28,014	1689.01	8.08	4.80	2,537	2.30
11.265	27,792	1686.36	6.59	4.37	2,826	2.25
11.231	27,714	1684.55	6.47	4.13	2,980	2.25
11.178	27,606	1681.62	6.19	3.84	2,952	2.44
11.048	27,330	1675.55	6.14	4.59	2,307	2.58
10.966	27,003	1671.88	7.85	5.32	1,848	2.75
10.821	26,740	1662.99	5.13	2.93	5,520	1.65
10.708	26,620	1657.02	5.60	3.23	4,664	1.77
10.629	26,504	1652.79	3.43	2.35	4,927	2.28
10.483	26,305	1646.75	5.53	2.05	7,375	1.74
10.360	26,222	1642.18	8.34	2.67	6,226	1.58
10.170	25,969	1634.12	4.53	2.43	5,187	2.06
10.083	25,896	1630.61	4.23	2.24	6,384	1.81
9.983	25,766	1626.09	4.20	2.04	6,047	2.09
9.901	25,656	1622.77	5.52	1.92	6,077	2.20
9.810	25,549	1618.62	7.21	2.00	6,310	2.02
9.659	25,417	1611.52	5.45	2.29	5,269	2.10
9.599	25,342	1607.29	6.13	1.72	6,895	2.14
9.466	25,038	1601.64	5.49	1.82	6,487	2.12
9.280	24,739	1592.14	7.30	1.76	8,329	1.69
9.154	24,576	1584.89	5.43	2.20	8,325	1.34
9.076	24,361	1578.89	5.58	2.57	5,481	1.73
8.996	24,268	1575.34	5.71	2.59	4,084	2.30
8.965	24,141	1566.77	5.65	5.54	2,446	2.56
8.900	23,985	1564.59	3.90	3.85	2,755	3.16
8.612	23,768	1559.26	5.10	1.91	8,032	1.55
8.417	23,413	1550.91	5.28	1.74	8,897	1.52
8.201	22,540	1540.19	4.50	1.89	10,374	1.15
8.069	22,403	1533.59	5.02	2.47	4,445	2.04
7.983	22,346	1529.12	5.18	2.17	7,473	1.38
7.811	22,246	1520.15	6.67	2.94	10,615	0.71
7.602	22,095	1510.46	4.96	2.28	8,102	1.20
7.223	21,875	1501.60	5.39	2.14	7,547	1.36
6.847	21,616	1489.72	4.00	1.94	6,207	1.79
6.715	21,427	1482.12	3.27	2.58	6,612	1.25
6.586	21,229	1476.69	3.29	1.90	6,381	1.75
6.391	21,082	1472.28	5.58	1.99	5,783	1.83
6.276	20,953	1467.93	7.29	2.06	5,325	1.91
6.168	20,835	1462.99	5.28	1.99	5,561	1.88
6.064	20,745	1457.95	2.45	3.49	3,807	1.56
5.954	20,522	1454.71	4.37	1.99	5,136	2.01
5.836	20,388	1451.29	6.75	2.50	4,642	1.76
5.716	20,267	1445.64	7.37	2.59	4,851	1.61
5.505	19,533	1442.04	4.70	1.61	5,261	2.30
5.291	18,936	1435.65	8.38	1.81	3,969	2.63
5.205	18,632	1432.23	8.47	2.06	4,353	2.08
5.072	18,391	1427.66	9.94	2.79	3,459	1.91
5.000	18,259	1425.04	7.51	2.43	3,332	2.26

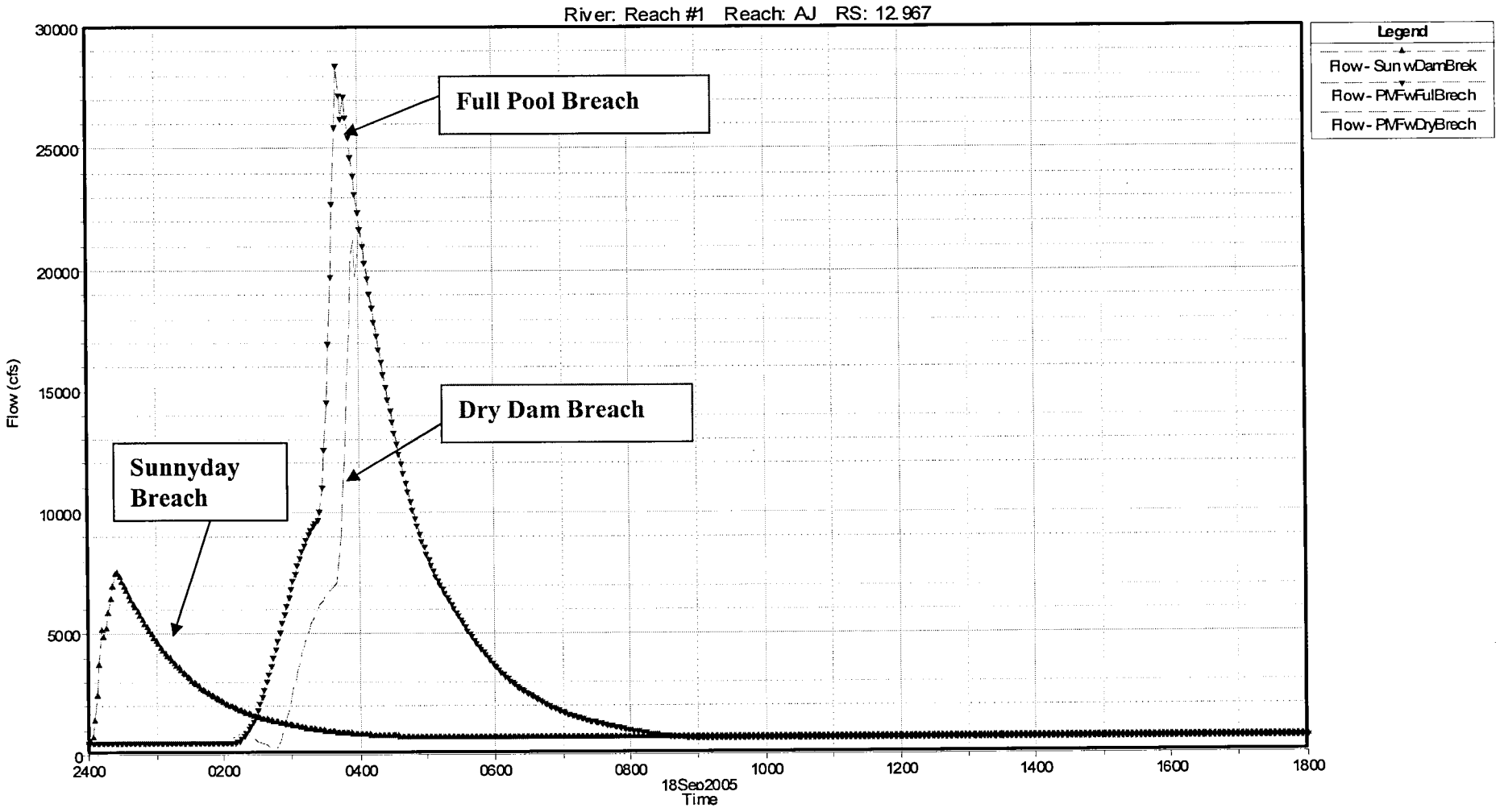


Figure 2. Breach Hydrographs At First Downstream Cross Section (12.976) From Apache Junction FRS (Breach For All Three Scenarios).

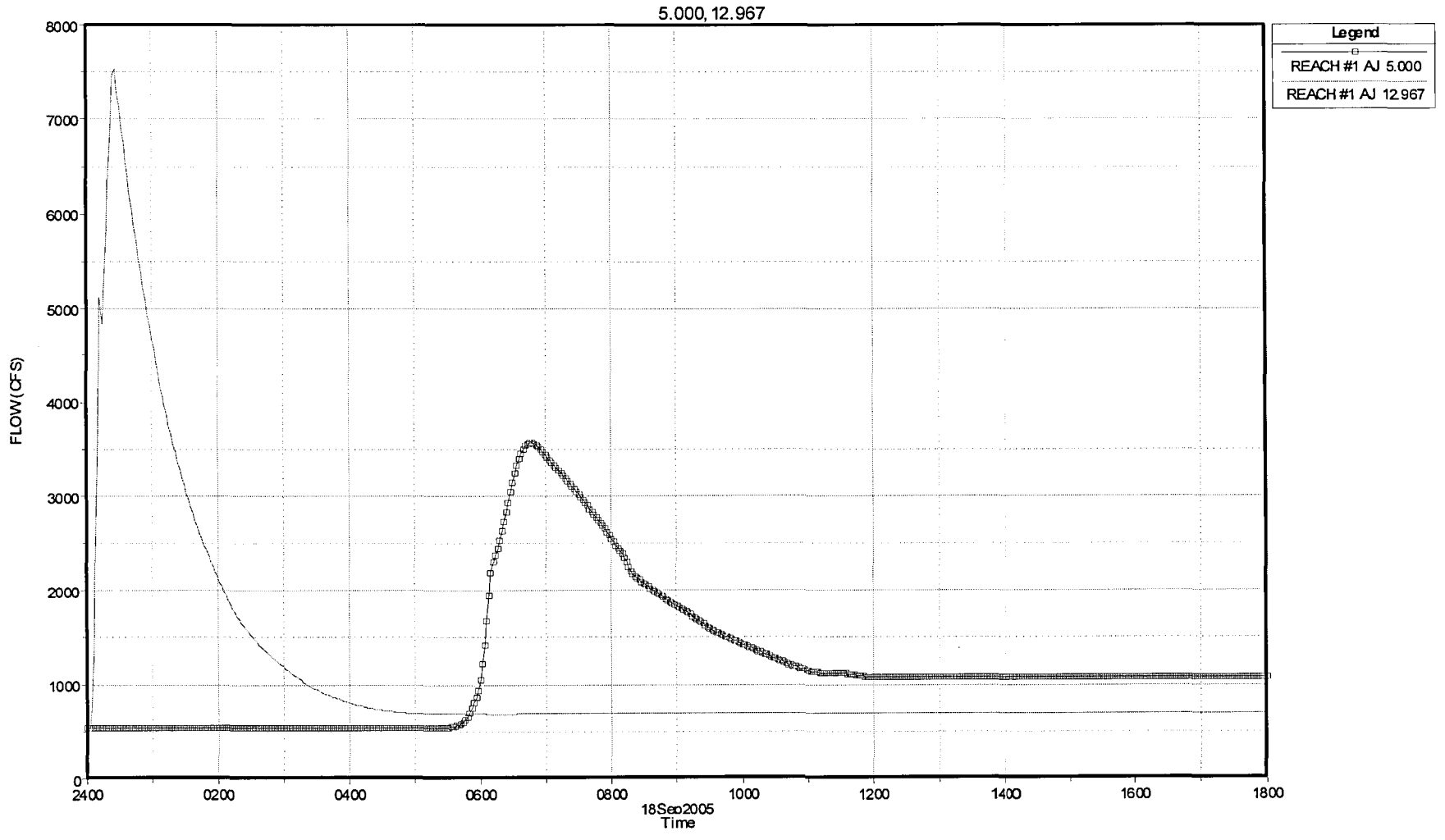


Figure 3. Flow Hydrographs At First Downstream Cross Section (12.967) From Apache Junction FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Sunnyday). Travel Time For Floodwave Peak Is Approximately 6.3 Hours.

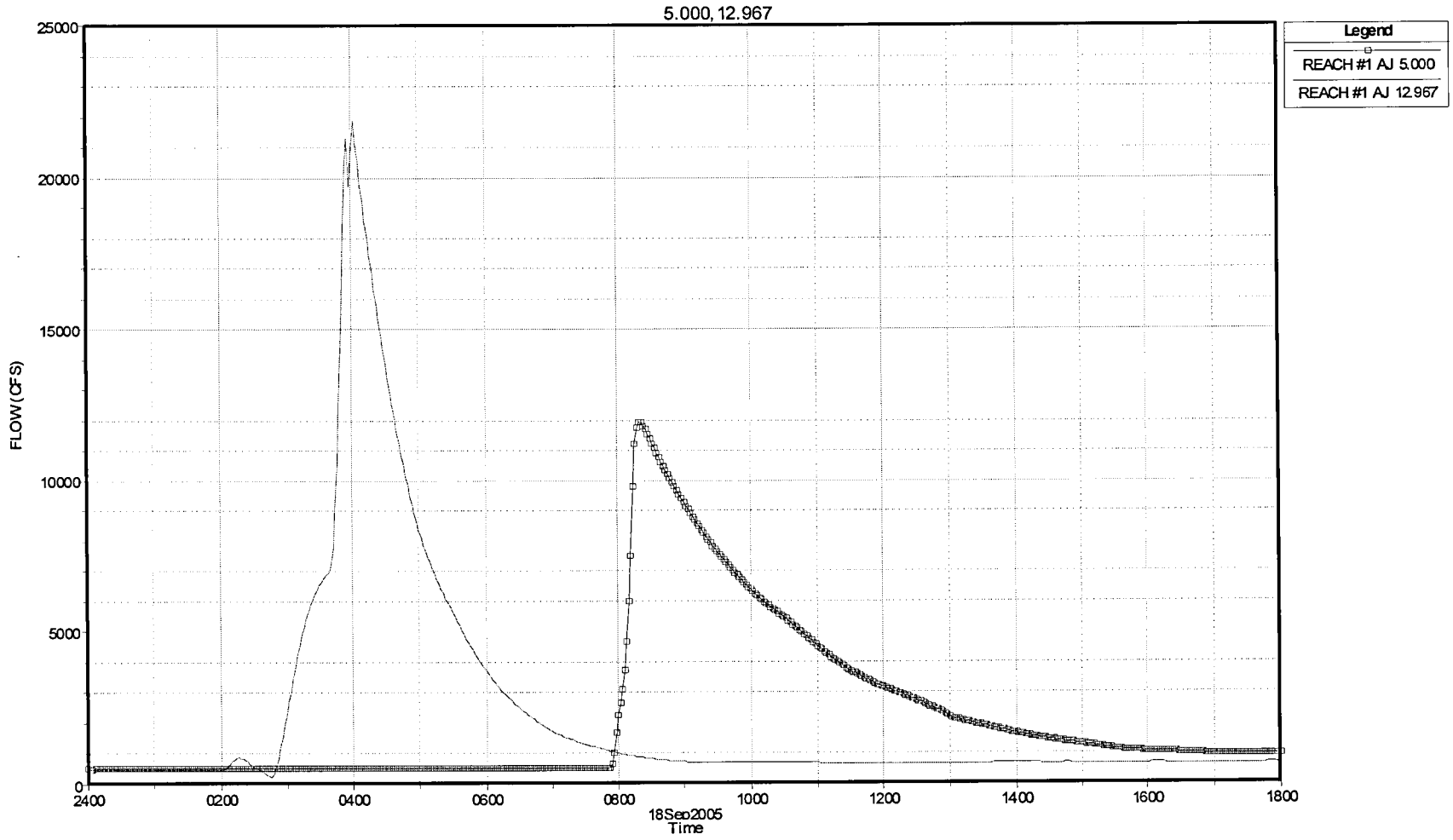


Figure 4. Flow Hydrographs At First Downstream Cross Section (12.967) From Apache Junction FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Empty Pool). Travel Time For Floodwave Peak Is Approximately 4.3 Hours.

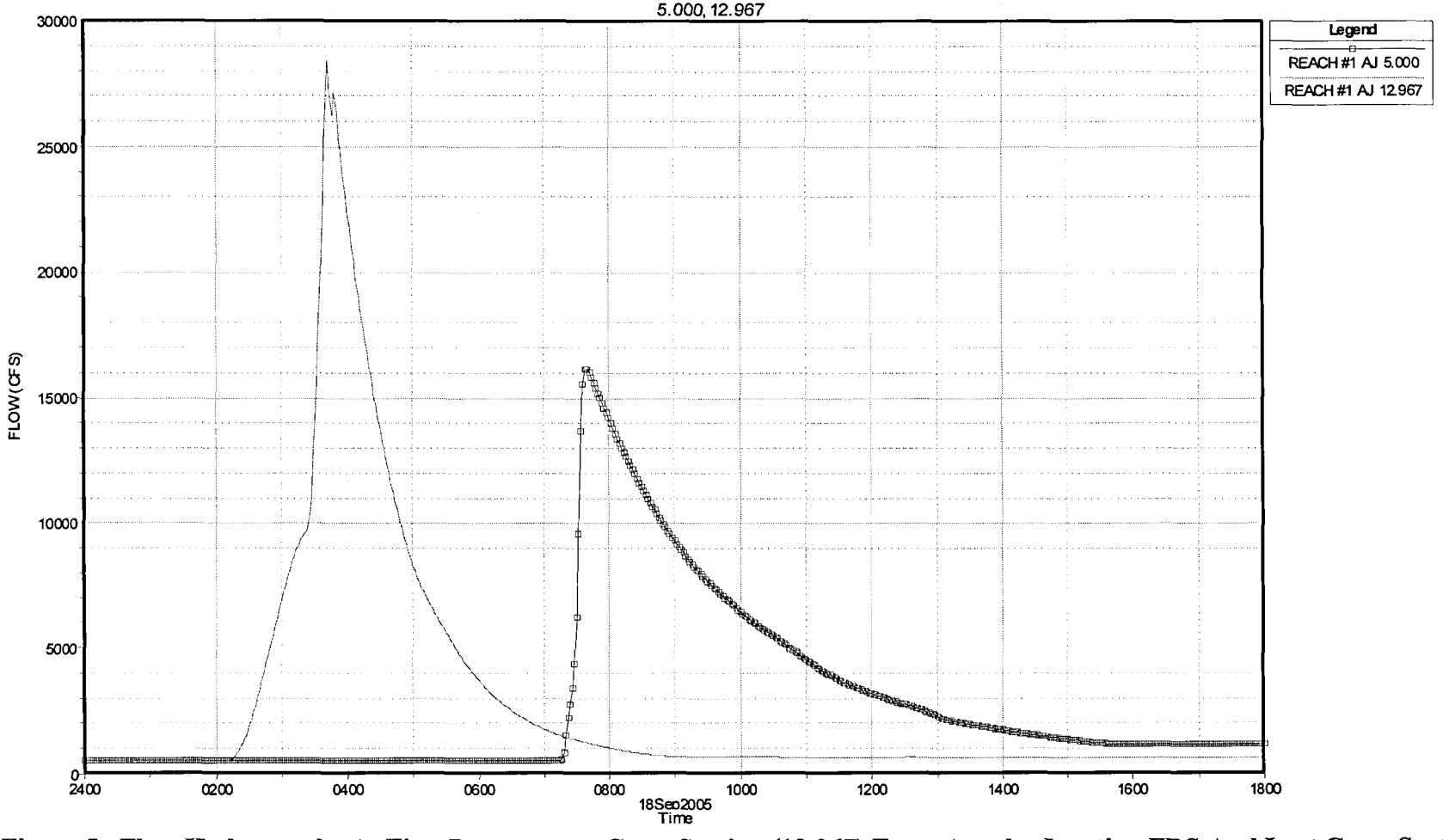


Figure 5. Flow Hydrographs At First Downstream Cross Section (12.967) From Apache Junction FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Full Pool). Travel Time For Floodwave Peak Is Approximately 3.9 Hours.

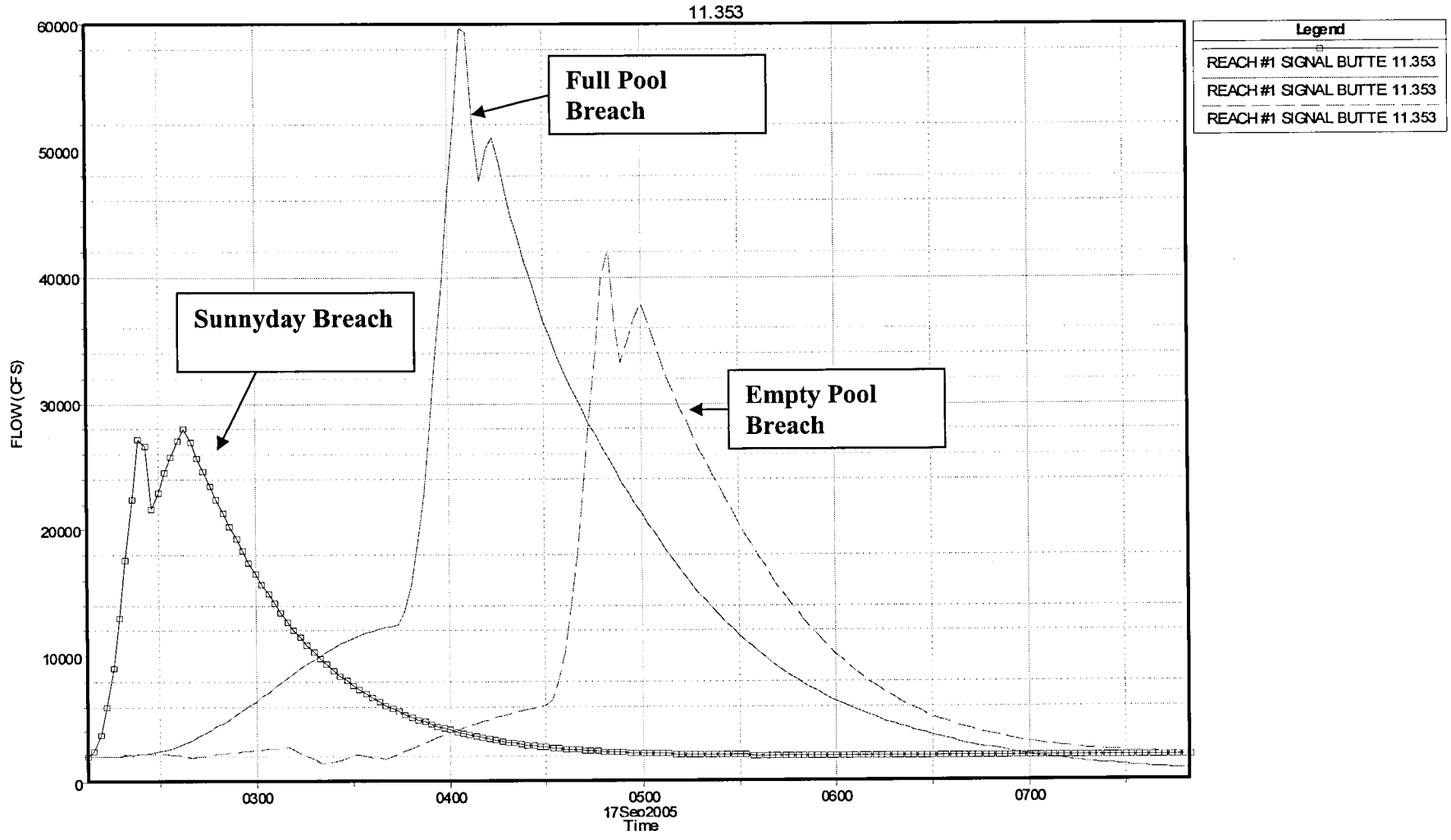


Figure 6. Breach Hydrographs At First Downstream Cross Section (11.353) From Signal Butte FRS (Breach For All Three Scenarios).

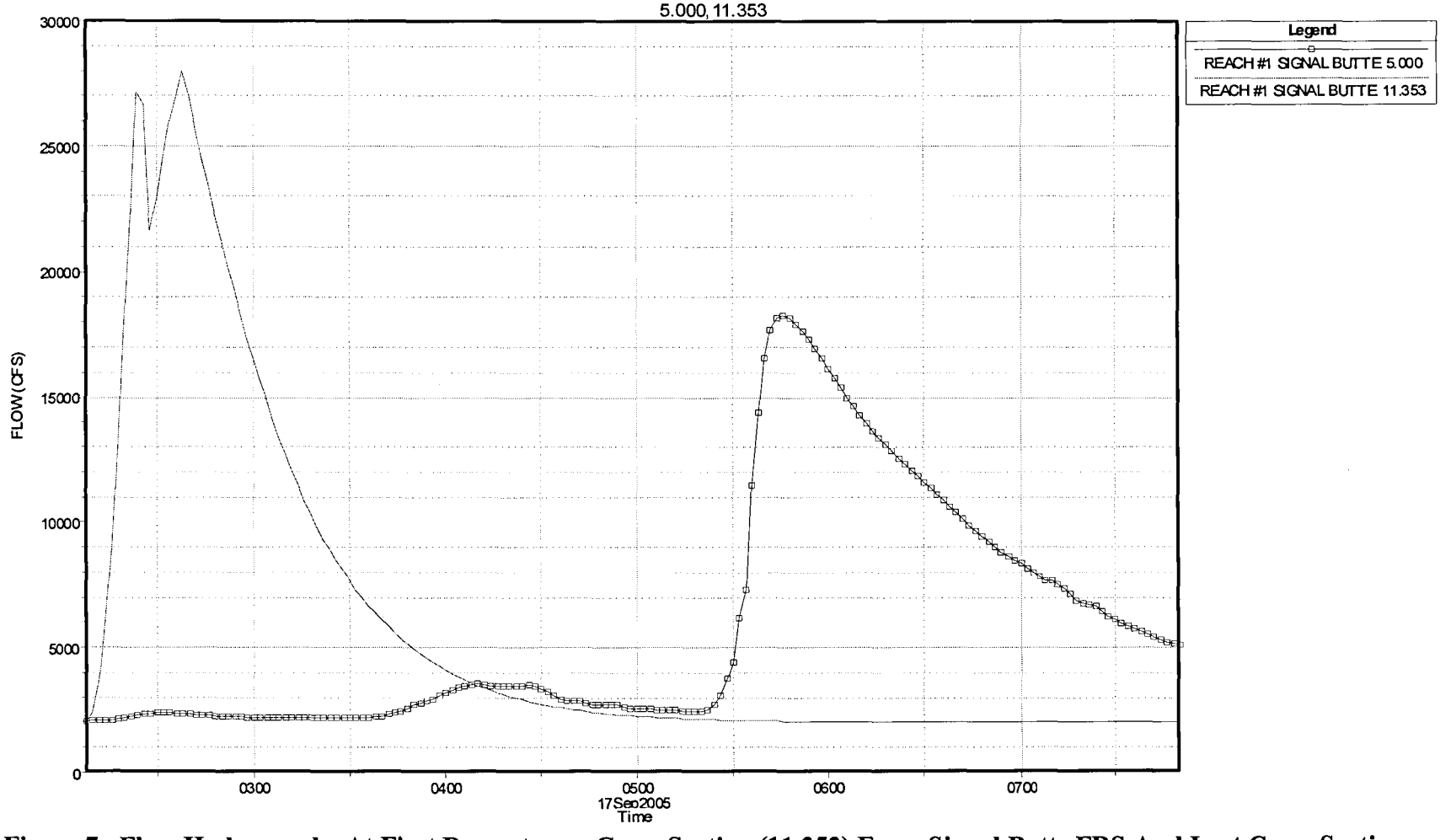


Figure 7. Flow Hydrographs At First Downstream Cross Section (11.353) From Signal Butte FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Sunnyday). Travel Time For Floodwave Peak Is Approximately 3.1 Hours.

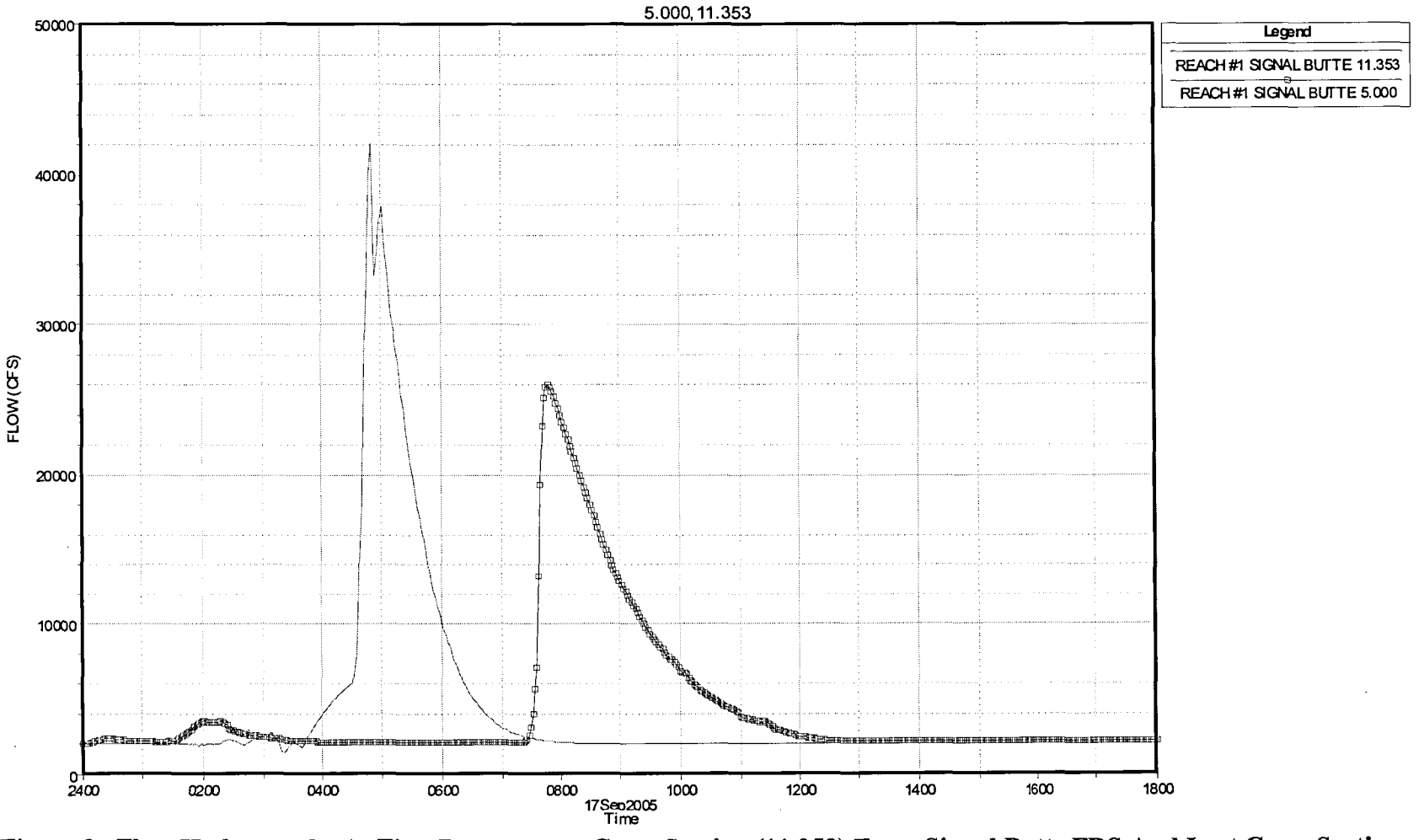


Figure 8. Flow Hydrographs At First Downstream Cross Section (11.353) From Signal Butte FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Empty Pool). Travel Time For Floodwave Peak Is Approximately 3.0 Hours.

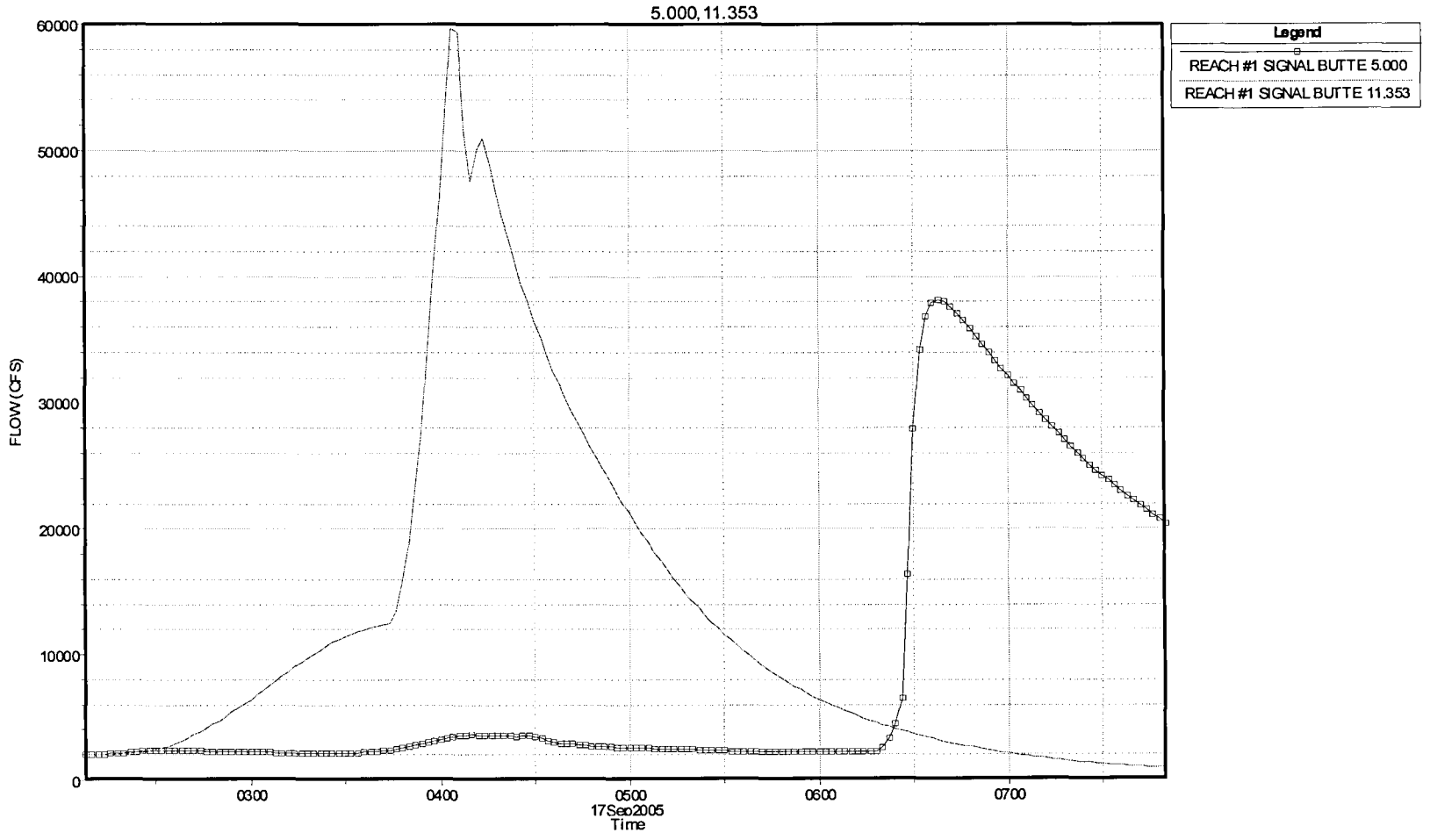


Figure 9. Flow Hydrographs At First Downstream Cross Section (11.353) From Signal Butte FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Full Pool). Travel Time For Floodwave Peak Is Approximately 2.6 Hours.

10.0 Discussion of Assumptions

This section of the report presents a discussion of the study assumptions and an interpretation of the dambreak results.

10.1 Selection of Breach Parameters

The NRCS conducted the original dambreak studies for Apache Junction FRS and Signal Butte FRS in 1986 and 1984, respectively. Kimley-Horn reviewed the available documentation for these dambreak studies and summarized our review in a technical memorandum titled "Technical Memorandum Dambreak Review Buckhorn-Mesa Structures" (KHA May 2005). In summary, the NRCS used the simplified routing method provided by TR-66 (Simplified Dam Breach Routing Procedure) for Signal Butte FRS. This approach does not require development of dambreach parameters. For the Apache Junction FRS, the NRCS used a combination of HEC-1, DAMBRK, and TR-66 to develop the dambreak inundation mapping. A review of the NRCS Apache Junction FRS dambreak indicated that the dambreak parameters used were:

- Time to failure – 5 minutes
- Breach bottom width – three times the height of the dam (which could range from (60 to 93 feet)
- Failure mode - piping

The NRCS time to failure or development of the full breach for Apache Junction FRS is not reasonable. This rapid time to failure is not consistent with current predictive equations and case history. The breach bottom width and failure mode by piping are consistent with predictive equations and case history for an earth embankment dam of this height and reservoir volume.

As stated above the breach parameters for this dambreak study were developed using published predictive equations. The breach parameter calculations are provided in **Appendix C**.

10.2 Failure Mode

The failure mode selected for the dambreak study for both dams was due to piping failure of the earth embankment section. The potential failure mode process of piping would require partial to full erosion of the earth embankment at the breach location. The breach location was selected base on maximum dam height/section above the cut-off trench.

The HEC-RAS unsteady flow model results for the Full Pool scenario (routing of the 6-hr PMF and dambreach) for both dams indicate that the dams have essentially zero freeboard. The maximum water surface elevations for Apache Junction FRS and Signal Butte FRS provide less than 0.2 foot of freeboard.

10.3 Downstream Flood Inundation Limits

The delineation of the flooding limits in the downstream inundation areas as a result of the dambreak discharge hydrographs from the Empty Pool, Full Pool, and Sunnyday scenarios for both dams are provided in **Appendix E** (as **Exhibit E-1, E-2**, and **E-3**, for Apache Junction FRS and **Exhibit E-4**, **E-5**, and **E-6** for Signal Butte FRS). The inundation exhibits include a portion of the hydraulic summary tables provided in Section 9.0 of this report.

The downstream inundation limits and hydraulic models were terminated at the most downstream channel cross section. The downstream inundation limits for both dams is approximately the location of the Red Mountain Freeway (Loop 202 currently under construction). From review of the dambreach hydrograph at this location for both dams under all three scenarios indicates that the floodwave could extend further downstream. The inundation mapping in **Appendix E** provides a note indicating that the potential for the dambreak floodwave to continue downstream beyond the current mapping limits may occur.

10.4 Cross Section N-Values

The Manning's roughness n-values used in this dambreak analysis were based upon previous studies conducted by the District in association with discharges from the emergency spillways. These studies correlated land use types with roughness coefficients. No changes in Manning's n-values were made under this dambreak analysis. Channel n-values were set at 0.045 or 0.055 for model stability at low flows. These channel n-values are reasonable given the high degree of development (density of mobile homes) and lack of defined low flow channels.

10.5 Ineffective Permanent Areas

The downstream inundation areas from both dams include local drainage channels, roadside channels, trailer park detention/retention basins, and ADOT detention basins located on the north side of US 60. Kimley-Horn used the permanent ineffective area option of the geometric editor to model these basins as storage areas and minor channels permanently ineffective for conveying stormwater for low flows. The purpose of this approach was to stabilize the unsteady flow models for low flows during the passage of the breach floodwave. HEC-RAS reviews each cross section for potential areas conducive to actively conveying floodwaters. The permanent ineffective area option was used to code out storage areas and local minor drainage channels that do not convey flow as these features are of minor impact to the large flows of a dambreach floodwave but cause model instabilities for lower flows. Under the model assumption that the Apache Junction FRS and Signal Butte FRS watersheds are experiencing the probable maximum precipitation, it is reasonable to assume that the downstream inundation areas are also concurrently experiencing a rainfall event. As such, it is reasonable to assume that these detention basins, stormwater storage areas, and low flow channels are unavailable for

conveying or storing stormwater under a dambreach floodwave. This provides a conservative approach to the hydraulic results for cross section maximum flow depths, velocities, water surface elevations, and hydrograph peak discharge.

10.6 Pilot Channels

The downstream areas from both dams are located on inactive alluvial fans that characteristically have steep slopes compared to areas located further downslope the mountain front. The inundation areas are located on the alluvial slopes of the Usery Mountains the gradient of the slopes range from 0.01 feet/foot to 0.006 feet/foot. These steep slopes impact the stability of the unsteady flow models such that initial unsteady flow computation results indicated that many cross sections were operating under a critical to supercritical flow regime. One method to bring the hydraulic regime to subcritical is to reduce the slope of the cross section low flow channels. This may be accomplished by the use of the HEC-RAS pilot channel option in the geometric editor. The pilot channel options allows the establishment of a narrow pilot channel between a span of cross sections in order to reduce (flatten) the slope of the cross section channel to convey low flows under subcritical flow regime. Kimley-Horn added pilot channels with a width of 2 ft in both dambreak geometry models. The narrow width of the pilot channels adds flow area and wetted perimeter for low flows to flow under subcritical conditions, but has very minor impact the larger dambreach floodwave discharges through the cross sections.

10.7 In-Line Gates

As discussed previously, in-line gates were provided as part of the geometric description and modeling operations of each dam. The in-line gates were included to provide an outflow for each principal spillway. It should be noted that the principal spillway discharges from Apache Junction FRS were modeled to discharge into the downstream inundation area. In reality, the principal spillway discharges to the Bulldog Floodway which conveys those flows to the Signal Butte FRS. The same model approach was taken for Signal Butte FRS principal spillway. The spillway discharges into the Signal Butte Floodway which conveys those flows to the Spook Hill FRS. The impact of the principal spillway discharges upon the downstream inundation study area ~~in~~ minor compared to the breach peak discharges and initial flow conditions. is

One additional in-line gate was added for the Empty Pool scenario for both the Apache Junction FRS and Signal Butte FRS HEC-RAS models. The purpose of the additional gate was to pass the initial flow condition for each dam. Recall that the condition of the Empty Pool scenario was to model the reservoir pool with an initial condition of an empty pool prior to the inflow of the 6-hr PMF. In the development of the steady and unsteady flow models which included the dams, ~~is~~ it became apparent that HEC-RAS was creating a backwater in the pool area. For the initial unsteady flow models, HEC-RAS was computing a backwater sufficient to begin spills in the emergency spillway prior to the inflow of the 6-hr PMF. In order to alleviate this condition for both dams, KHA added one additional gate of sufficient size and developed a gate operating time series ?

(gate closing) to allow the initial flow conditions to pass through the reservoir and embankment without causing a backwater in the pool. The gates were slowly closed just prior to the arrival of the 6-hr PMF. This approach allowed the pools to be empty (or near empty) upon inflow of the PMF hydrograph.

10.8 Central Arizona Project Canal

The CAP canal traverses through the downstream inundation areas of both dams. The CAP canal location is shown on the map exhibits in **Appendix E**. The CAP canal has low height earthen berms on both the east and west banks of the canal. Kimley-Horn plotted the east berm canal bank profile and determined that the height of the canal berm provided minor storage on the east side of the canal. The canal has a number of drainage structure overshoots that convey low flows to 100-year stormwater flows from the east side of the canal and discharges into facilities on the west side of the canal. For the purposes of this dambreak study the CAP canal banks and drainage overshoots were not considered due to the small amount of storage on the upstream side and small conveyance for flood magnitudes associated with a dambreak floodwave. However, a case may occur such that the CAP embankment may fail, and may fail at any location due to the overtopping of the dambreak floodwave. It is in this instance that a study of the CAP embankment would be warranted.

10.9 Apache Junction Floodway and Bulldog Floodway

The NRCS Buckhorn-Mesa Watershed Workplan designed and constructed several earth embankment dams (Spook Hill FRS, Signal Butte FRS, and Apache Junction FRS) as well as a number of floodways (Spook Hill, Signal Butte, Bulldog, and Apache Junction). The Apache Junction floodway captures flows for the 100-year event from its contributing watershed and directs those flows into the Apache Junction FRS. Under normal operating conditions, the Apache Junction FRS discharges impounded floodwaters into the Bulldog Floodway. The Bulldog Floodway conveys the stormwater from Apache Junction FRS as well as stormwater intercepted from the floodway's own contributing watershed. The flows in Bulldog Floodway discharge into the Signal Butte FRS. It should be noted that the floodways designed under the Watershed Workplan were designed with a capacity for conveying the 100-year storm event and not the PMF event. If such a PMF event were to occur on the Buckhorn-Mesa watershed the potential exists for the floodways to overtopped and damaged prior to any potential breach of either the Apache Junction FRS or Signal Butte FRS.

11.0 Discussion of Results

A summary of the hydraulic results of the unsteady flow dambreak models was provided in tabular form in **Tables 5** through **10** and in graphical form in **Figures 2** through **9** in Section 9. The hydraulic summary tables have been highlighted to indicate maximum values for hydraulic parameters. Maximum velocities and peak discharges are generally located just downstream of each dam for each scenario. Maximum flood widths are on the order of 11,000 feet wide for Signal Butte FRS and 10,300 feet wide for Apache

Junction FRS. **Figure 2** and **Figure 6** provide the breach hydrographs at the downstream cross section at each dam for Apache Junction FRS and Signal Butte FRS, respectively.

The flood inundation limits have been provided on the exhibits in **Appendix E**. The exhibits include an abbreviated hydraulic summary table that includes the arrival times for the floodwave at various downstream locations.

12.0 Recommendations for Further Investigations and Future Updates

This dambreak study developed dynamic routing models for both the Apache Junction FRS and Signal Butte FRS, developed dambreak outflow hydrographs for three dambreak modeling scenarios, and routed the dambreach hydrographs downstream from the breach at the dam embankment. The following discussion provides recommendations for further investigations and actions that are beyond the current scope of work for this study.

- Confirm the locations and capacity of the side inlets to the Bulldog floodway and the capacity of the Apache Junction and Bulldog floodways. Confirm and quantify the potential overtopping of the floodways under a PMF event.
- At a future time include the CAP canal embankments in the unsteady flow dambreak models. The updated model may include a breach of the CAP embankment to examine the impacts on the downstream inundation areas.
- Additionally, development downstream of each dam is increasing, resulting in changing conditions drainage patterns downstream of each structure. As a result, the extent of the inundated areas and the consequences of dambreaks limits may change in the future. Therefore, it is recommended that such a study be revisited periodically to evaluate the impacts of the potential flooding as a result of new development or new analytical techniques.

12.0 Conclusions

The objective of this dambreak study was to provide a dam failure and inundation analysis as part of an updated emergency action plan for the Buckhorn-Mesa structures. For the purposes of this dambreak analysis, three model scenarios were evaluated to simulate the flood wave progression as a result of a dam failure (piping failure) condition. The limits of the study extended from the dams downstream to approximately the alignment of the Red Mountain Freeway. The results from the unsteady/dynamic models are reasonable for the downstream inundation reach/mapping and the limits of mapping/inundation verified by steady flow analysis.

APPENDIX A

Dambreak Study for
Apache Junction FRS and Signal Butte FRS

Appendix A: Data Collection and References

Arizona Department of Water Resources. "PMF Studies for Evaluation of Spillway Adequacy – General Guidelines". Office of Water Engineering. Dam Safety and Flood Mitigation. Revised March 2004.

Daniel, Mann, Johnson, and Mendenhall. "Spook Hill FRS Existing Conditions Analysis". Prepared for Arizona Department of Transportation. 2002

Federal Emergency Management Agency. "Federal Guidelines for Dam Safety: Emergency Action Planning for Dam Owners". FEMA 64. October 1998.

Kimley-Horn and Associates, Inc. "Individual Structures Assessment Report: Spook Hill FRS, Signal Butte FRS, and Apache Junction FRS". Prepared for Flood Control District of Maricopa County. FCD Contract 98-41. KHA Project No. 091131005. April, 2001.

Kimley-Horn and Associates, Inc. "Technical Memorandum Hydrology Review". Buckhorn-Mesa Structures. Prepared for Flood Control District of Maricopa County and LTM Engineering, Inc. March, 2005.

Kimley-Horn and Associates, Inc. "Technical Memorandum – Dambreak Review, Buckhorn-Mesa Structures". Prepared for Flood Control District of Maricopa County. FCD Contract 2003C062. and LTM Engineering, Inc. KHA Project No. 091725005. May, 2005.

Kimley-Horn and Associates, Inc. "Technical Memorandum – Probable Maximum Precipitation/Probable Maximum Flood Analysis, Buckhorn-Mesa Structures". Prepared for Flood Control District of Maricopa County. FCD Contract 2003C062. and LTM Engineering, Inc. KHA Project No. 091725005. September, 2005.

Natural Resources Conservation Service. "Hydrologic Investigation – Emergency Action Plan – Signal Butte FRS, Buckhorn-Mesa Watershed". August, 1984.

Natural Resources Conservation Service. "Technical Release No. 66 – Simplified Dam-Breach Routing Procedure". Revised December, 1981.

Natural Resources Conservation Service. "Technical Release No. 66 – Simplified Dam-Breach Routing Procedure". Third Edition. September, 1985.

Natural Resources Conservation Service. "Apache Junction Flood Retention Structure Downstream Inundation Study". Prepared for USDA Soil Conservation Service. Ebasco Services Incorporated. February, 1986. Located in Phase IV.2 – Final Design Report. "Apache Junction Floodwater Retarding Structure & Floodway". Buckhorn-Mesa Watershed Protection and Flood Prevention Project. Volume II. Ebasco Services Incorporated. October, 1986.

Natural Resources Conservation Service. "Spook Hill FRS and Floodway Design". 1976

Natural Resources Conservation Service. "Signal Butte FRS, Floodway, and Pass Mountain Diversion Design Report". 1985.

Natural Resources Conservation Service. "Apache Junction FRS and Floodway and Bulldog Floodway Design". Ebasco, 1985.

Von Thun, J. L., and David R. Gillette. "Guidance on Breach Parameters". March, 1990. Unpublished document United States Bureau of Reclamation.

Wahl, Tony. "The Uncertainty of Embankment Dam Breach Parameter Prediction Based on Dam Failure Case Studies". June, 1995. United States Bureau of Reclamation

Wood Patel and Associates, Inc. Spook Hill Area Drainage Master Plan". Prepared for the Flood Control District of Maricopa County. 1999 - 2001.

Wood Patel and Associates, Inc. Spook Hill Area Drainage Master Plan Update". Prepared for the Flood Control District of Maricopa County. Appendix A Volume 1 HEC-1 Modeling Input Data and Output Files Level III. September, 2002.

Wood Patel and Associates, Inc. Spook Hill Area Drainage Master Plan Update". Prepared for the Flood Control District of Maricopa County. Appendix A Volume 2 SCS TR-20 Hydrology Analysis. September, 2002.

Wood Patel and Associates, Inc. Spook Hill Area Drainage Master Plan Update". Prepared for the Flood Control District of Maricopa County. Appendix A Volume 3 TR-20 Hydrology Analysis. September, 2002.

APPENDIX B

Dambreak Study for
Apache Junction FRS and Signal Butte FRS

NOTES:

1. INTERPOLATED CROSS SECTIONS DEPICTED IN HYDRAULIC MODEL NOT SHOWN ON THIS EXHIBIT.
2. SEE HEC-RAS MODEL FOR APACHE JUNCTION FLOOD RETARDING STRUCTURE INTERPOLATED CROSS SECTIONS.
3. HYDRAULIC BASELINE SET TO STATION 10,000.
4. TOPOGRAPHIC MAPPING PROVIDED TO KIMLEY-HORN BY FLOOD CONTROL DISTRICT.

BASE MAPPING SOURCE:

BASE MAPPING FROM FCD CONTRACT NUMBER FCD 03-49

MAPPING BASED ON NORTH AMERICAN VERTICAL DATUM 1988.

LEGEND

HEC-RAS CROSS SECTION LABEL — 11.995

CROSS SECTION

HYDRAULIC BASELINE (RIVER MILES) — 9.0 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 10.0

GRAPHIC SCALE
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(IN FEET)

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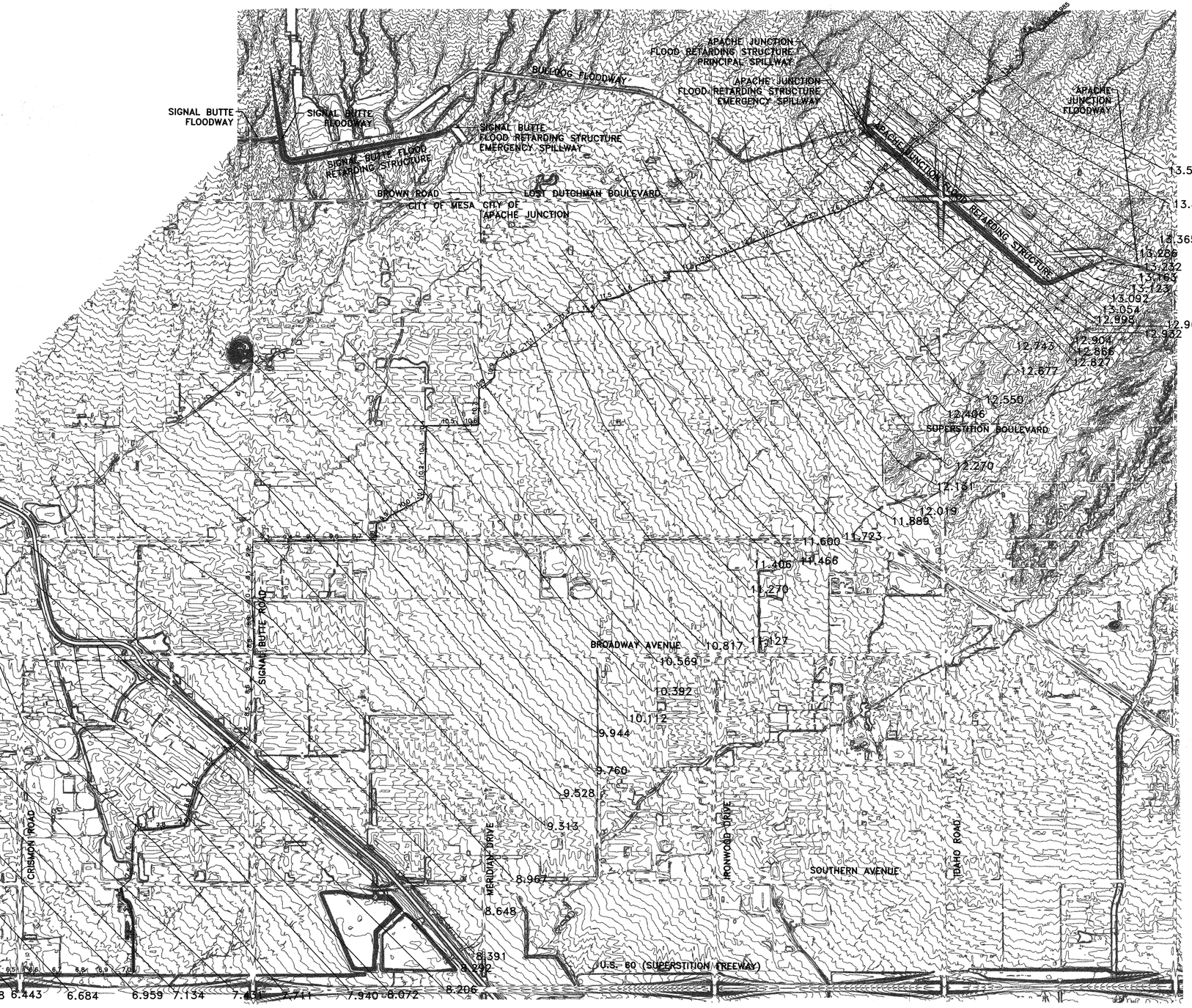

NO.	REVISION	BY	DATE	APPR.

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Phoenix, Arizona 85020 (602) 944-5500

SCALE (H): 1"=1200'
SCALE (V): NONE
DESIGNED BY: PAC
DRAWN BY: PAC
CHECKED BY: RAE
DATE: 10/21/05

EXHIBIT B-1. BUCKHORN MESA STRUCTURES DAMBREAK HEC-RAS CROSS SECTION LOCATION MAP

APACHE JUNCTION FLOOD RETARDING STRUCTURE

PROJECT NO. 091725005

DRAWING NAME XSECLM-AJ

K:\WaterResources\091725005\CADD\Exhibits\XSECLM-AJ.dwg Oct 26, 2005 Pat.Crawford
THIS DOCUMENT, TOGETHER WITH THE CONCEPTS AND DESIGNS PRESENTED HEREIN, AS AN INSTRUMENT OF SERVICE, IS INTENDED ONLY FOR THE SPECIFIC PURPOSE AND CLIENT FOR WHICH IT WAS PREPARED. REUSE OF AND IMPROPER RELIANCE ON THIS DOCUMENT WITHOUT WRITTEN AUTHORIZATION AND ADAPTATION BY KIMLEY-HORN AND ASSOCIATES, INC. SHALL BE WITHOUT LIABILITY TO KIMLEY-HORN AND ASSOCIATES, INC.

NOTES:

1. INTERPOLATED CROSS SECTIONS DEPICTED IN HYDRAULIC MODEL NOT SHOWN ON THIS EXHIBIT.
2. SEE HEC-RAS MODEL FOR SIGNAL BUTTE FLOOD RETARDING STRUCTURE INTERPOLATED CROSS SECTIONS.
3. HYDRAULIC BASELINE SET TO STATION 10,000.
4. TOPOGRAPHIC MAPPING PROVIDED TO KIMLEY-HORN BY FLOOD CONTROL DISTRICT.

BASE MAPPING SOURCE:

BASE MAPPING FROM FCD CONTRACT NUMBER FCD 03-49

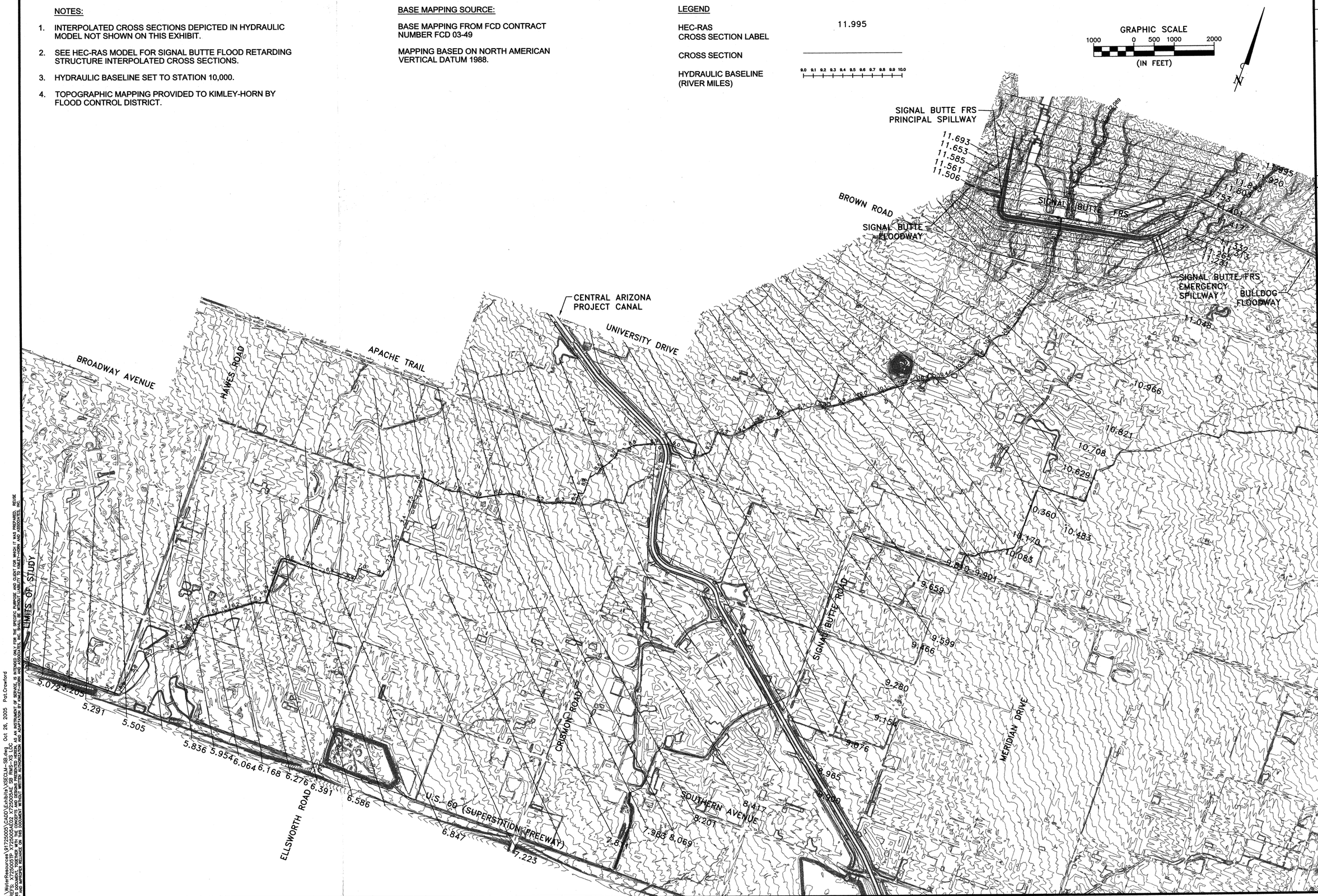
MAPPING BASED ON NORTH AMERICAN VERTICAL DATUM 1988.

LEGEND

HEC-RAS CROSS SECTION LABEL — 11.995

CROSS SECTION

HYDRAULIC BASELINE (RIVER MILES) — 8.0 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 10.0



NO.	REVISION	BY	DATE	APPR.

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Phoenix, Arizona 85020 (602) 944-5500

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SCALE (V): NONE
DESIGNED BY: PAC
DRAWN BY: PAC
CHECKED BY: RAE
DATE: 10/21/05

EXHIBIT B-2. BUCKHORN MESA STRUCTURES DAMBREAK HEC-RAS CROSS SECTION LOCATION MAP

SIGNAL BUTTE FLOOD RETARDING STRUCTURE

PROJECT NO. 091725005

DRAWING NAME XSECLM-SB

1 OF 1

K:\WaterResources\091725005\CADD\Exhibits\XSECLM-SB.dwg Oct 26, 2005 Pat.Crawford
XREFS: X725005TP X725005-ALO2 X725005AE SB RMS-XS LOC
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APPENDIX C

Dambreak Study for
Apache Junction FRS and Signal Butte FRS

Kimley-Horn and Associates, Inc.

Ref: **Guidance on Breach Parameters**
J. Lawrence Von Thun and David R. Gillette
13-Mar-90

Recommended Parameter Values

Notes
English Units
for all breach types
Hw varies with breach type

Side Slopes:

	Horizontal	Vertical
Non-Cohesive Shell Material	1	1
Cohesive Shell Material	1	3

Varies from 1:1 to 1:3 H:V

Breach Width

W = 2.5 * Hw + B

B varies according to Reservoir size

Reservoir Size (acre feet)				B (ft)
<	1000			20
	1000	to	5000	60
	5000	to	10000	140
		>	10000	180

Breach Formation Time (hrs.)

T =	0.0046Hw	easily eroded
T=	0.0061Hw + 0.25	erosion resistant
	or	
T =	W/(4Hw + 200)	easily eroded
T=	W/(4Hw)	erosion resistant

Apache Junction FRS

Breach Width
AJ Max depth/section
Station Sta xx+xx
AJ Reservoir Size
at Emergency Spillway
<1000af B = 20 ft

Hw	B	W (ft)
22	20	75

Breach Formation Time

Hw	Tw (hrs)	
		erosion resistant
22	0.3842	Hrs
	23.052	mins

Signal Butte FRS

Breach Width
AJ Max depth/section
Station Sta xx+xx
AJ Reservoir Size
at Emergency Spillway
1000af - 5000af B = 60 ft

Hw	B	W (ft)
38.5	38.5	134.75

Breach Formation Time

Hw	Tw (hrs)	
38.5	0.48485	Hrs
	29.091	mins

Kimley-Horn and Associates, Inc.

Estimation of Dam Breach Characteristics for earthfill dams
Reference: Technical Note 1, pages 3 to 11
Bob Eichinger; Sept 15, 2005

Key equations:

Breach Formation Factor	$BFF = V_w * H_w$
Volume of material eroded	
Cohesionless/erodible materials	$V_m = 3.75\ BFF^{0.77}$
Erosion resistant materials	$V_m = 2.50\ BFF^{0.77}$
Breach geometry	
Base width (of breach and flow)	$W_b = [27\ V_m - K_2] / [K_1]$
	$K_1 = H_b\ [C + (H_b\ Z_3 / 2)]$
	$K_2 = (H_b^2)\ [(C\ Z_b) + (H_b\ Z_b\ Z_3 / 3)]$
Average width of flow	$W_{avg} = W_b + Z_b\ H_w$
Top width of flow	$W_{top} = W_b + 2\ Z_b\ H_w$
Time for breach development	
Cohesionless/erodible materials	$t = 0.028\ V_m^{0.36}$
Erosion resistant materials	$t = 0.042\ V_m^{0.36}$
Dam breach peak discharge	$Q_p = 3.1\ W_{avg}\ H_w^{1.5}\ [K_3^3]$
	$K_3 = [A / (A + (t * H_w^{0.5}))]$
	$A = 23.4\ S_a / W_{avg}$

Project-specific data : Apache Junction FRS

Reference : (report title & page; drawing no.)

Elevations :

Dam crest elevation (ft.) =	1810
Base elevation of breach (ft.) =	1788
Height (depth) of breach, H_b =	22
At normal pool / 100-year storm :	
Water surface elevation (ft.) =	1799.77
Height over breach elev, H_w =	11.77
Volume of water, V_w (ac-ft) =	550
Surface area, S_a (acres) =	98
Inflow during breach (cfs) =	23400
At maximum pool (dam crest) :	
Water surface elevation (ft.) =	1810
Height over breach elev, H_w =	22
Volume of water, V_w (ac-ft) =	2000
Surface area, S_a (acres) =	1200
Inflow during breach (cfs) =	23400

Erosion resistance of dam materials:		Typical range : cohesionless	resistant
factor for volume (V_m) =	2.5	3.75	2.50
factor for breach time (t) =	0.042	0.028	0.042

Project-specific data : Signal Butte FRS

Reference : (report title & page; drawing no.)

Elevations :

Dam crest elevation (ft.) =	1721
Base elevation of breach (ft.) =	1682.5
Height (depth) of breach, H_b =	38.5
At normal pool / 100-year storm :	
Water surface elevation (ft.) =	1712.4
Height over breach elev, H_w =	29.9
Volume of water, V_w (ac-ft) =	1430
Surface area, S_a (acres) =	140
Inflow during breach (cfs) =	24000
At maximum pool (dam crest) :	
Water surface elevation (ft.) =	1721
Height over breach elev, H_w =	38.5
Volume of water, V_w (ac-ft) =	2800
Surface area, S_a (acres) =	210
Inflow during breach (cfs) =	24000

Erosion resistance of dam materials:		Typical range : cohesionless	resistant
factor for volume (V_m) =	2.5	3.75	2.50
factor for breach time (t) =	0.042	0.028	0.042

Flood Control District of Maricopa County - Apache Junction FRS and Signal Butte FRS

Estimation of Dam Breach Characteristics for earthfill dams

0 0
0

Reference: Technical Note 1, pages 3 to 11
Bob Eichinger; Sept 15, 2005

Project-specific data (cont.) :

Reference : (report title & page; drawing no.)

Geometry :

Crest width, C (ft.) =	14
Crest length (ft.) =	8765
Slope of upstream face, Z_1 =	3
Slope of downstream face, Z_2 =	1
$Z_1 + Z_2 = Z_3$ =	4

Est. sideslope of breach, Z_b :		Suggested range : cohesionless	resistant
normal pool, Z_b =	0.5	1.0	0.5
max. pool, Z_b =	0.5	1.0	0.5

Failure due to **piping** (WL at normal pool / 100-year storm) :

Breach Formation Factor, BFF (--) =	6473.5
Volume of material eroded, V_m (cu.yds.) =	2150.4
Breach geometry: K_1 =	1276
K_2 =	10486.667
Base width, W_b (ft.) =	37.3
Average width, W_{avg} (ft.) =	43.2
Top width (flow), W_{top} (ft.) =	49.1
Top width (crest), W_{cr} (ft.) =	59.3
Breach % of crest length =	1 %
Time for breach development, t (hrs.) =	0.67
t (min.) =	39.9
Dam breach peak discharge	
A =	53.121965
K_3 =	0.9588091
Peak discharge, Q_p (cfs) =	4763
Inflow during breach (cfs) =	23400
Combined peak discharge =	28163

Comparisons:	This project	Typical range	
Breach width/height	1.96	0.5 to 3.0	
Failure time (hrs.)	0.67	0.2 to 4.0	
Peak discharge (cfs)	4763		from Table 4A (cohesionless)
			from Table 4B (resistant)

Project-specific data (cont.) :

Reference : (report title & page; drawing no.)

Geometry :

Crest width, C (ft.) =	14
Crest length (ft.) =	7022
Slope of upstream face, Z_1 =	3
Slope of downstream face, Z_2 =	2
$Z_1 + Z_2 = Z_3$ =	5

Est. sideslope of breach, Z_b :		Suggested range : cohesionless	resistant
normal pool, Z_b =	0.5	1.0	0.5
max. pool, Z_b =	0.5	1.0	0.5

Failure due to **piping** (WL at normal pool / 100-year storm) :

Breach Formation Factor, BFF (--) =	42757.0
Volume of material eroded, V_m (cu.yds.) =	9200.6
Breach geometry: K_1 =	4244.625
K_2 =	57931.27
Base width, W_b (ft.) =	44.9
Average width, W_{avg} (ft.) =	59.8
Top width (flow), W_{top} (ft.) =	74.8
Top width (crest), W_{cr} (ft.) =	83.4
Breach % of crest length =	1 %
Time for breach development, t (hrs.) =	1.12
t (min.) =	67.4
Dam breach peak discharge	
A =	54.7582
K_3 =	0.899199
Peak discharge, Q_p (cfs) =	22046
Inflow during breach (cfs) =	24000
Combined peak discharge =	46046

Comparisons:	This project	Typical range	
Breach width/height	1.55	0.5 to 3.0	
Failure time (hrs.)	1.12	0.2 to 4.0	
Peak discharge (cfs)	22046		from Table 4A (cohesionless)
			from Table 4B (resistant)

Flood Control District of Maricopa County - Apache Junction FRS and Signal Butte FRS

Estimation of Dam Breach Characteristics for earthfill dams
Reference: Technical Note 1, pages 3 to 11
Bob Eichinger; Sept 15, 2005

APPENDIX D

Dambreak Study for
Apache Junction FRS and Signal Butte FRS

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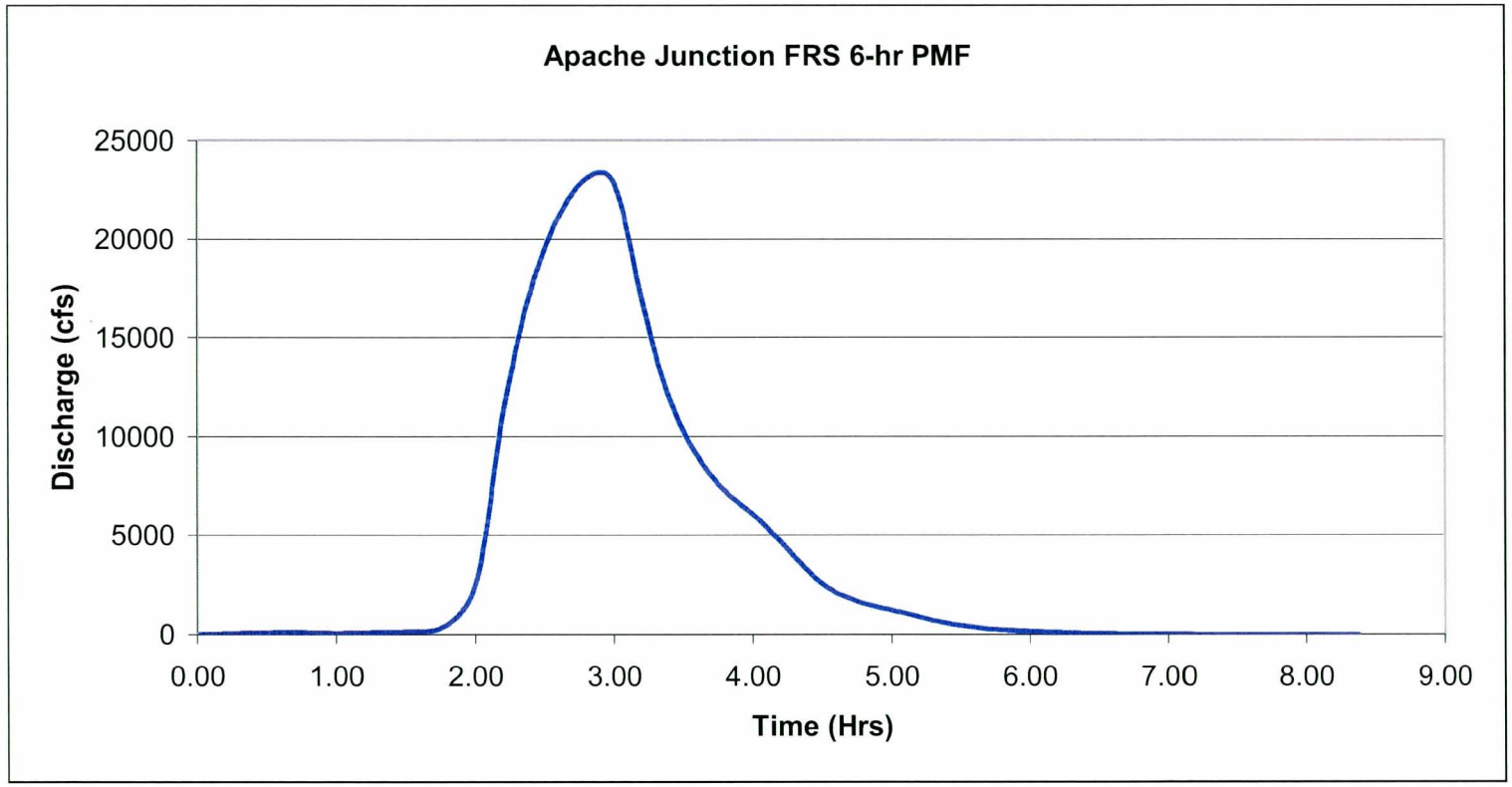
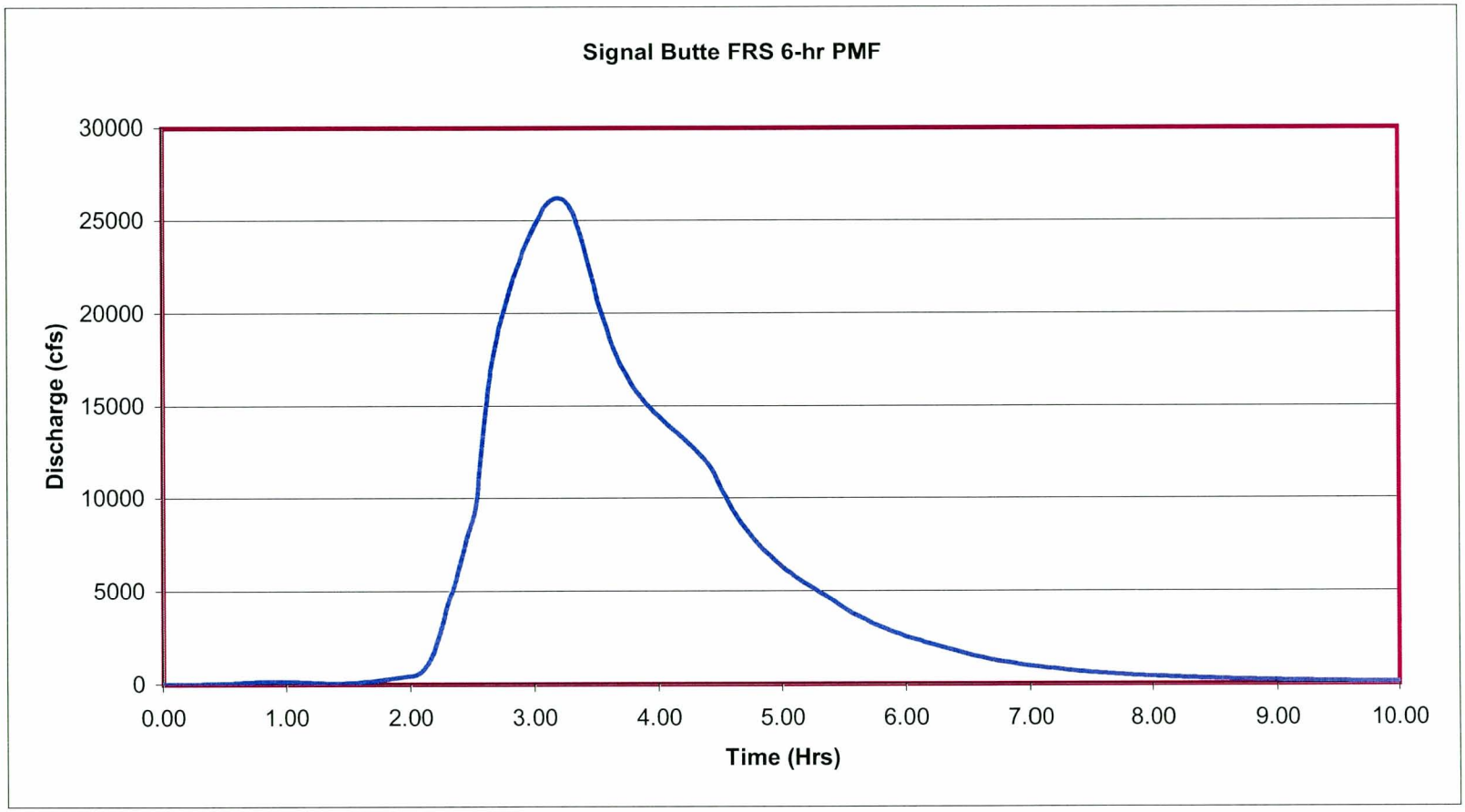


Kimley-Horn
and Associates, Inc.



APPENDIX E

Dambreak Study for
Apache Junction FRS and Signal Butte FRS

NOTES

1. TIME ZERO IS TAKEN AT THE TIME OF MAXIMUM FLOW THROUGH THE DAM BREACH.
2. MAPPED INUNDATION LIMITS AT CROSS SECTIONS CORRESPOND TO MAXIMUM STAGE ELEVATION.
3. INFLOW DESIGN FLOOD = 6-HR PROBABLE MAXIMUM FLOOD. DEVELOPED IN PMP/PMF STUDY CONDUCTED UNDER FCD CONTRACT 2003C052.
4. THE STRUCTURAL INTEGRITY AND HYDRAULIC INTEGRITY OF ANY LEVEES, BERMS, CANAL EMBANKMENTS, DETENTION/RETENTION BASINS, OR FILL TO WITHSTAND EROSION (OR FAILURE) DURING FLOODING WAS NOT EVALUATED AS PART OF THIS STUDY.
5. THIS EXHIBIT SHOWS INUNDATION LIMITS FOR POTENTIAL PIPING FAILURE.
6. MAPPING/INUNDATION LIMITS FOR POTENTIAL OVERTOPPING OF BULLDOG FLOODWAY OR SIGNAL BUTTE FLOODWAY NOT INCLUDED IN SCOPE OF WORK.
7. MODEL SCENARIO NO. 2. ASSUMES APACHE JUNCTION FRS HAS EMPTY POOL AT BEGINNING OF SIMULATION. DAM BREACH INITIATION STARTS AT ELEVATION OF 1812.0 FT.
8. CREST ELEVATION OF SIGNAL BUTTE FRS 1810.0 FT. PER AS-BUILT CONSTRUCTION PLANS. (NAVD 29)
9. DAM BREAK FLOOD WAVE POTENTIALLY EXTENDS PAST (WEST) OF CROSS SECTION 9, AS INDICATED BY FLOW ARROWS.
10. DAM BREACH LOCATION AT MAXIMUM DAM STATION.
11. HYDRAULIC BASELINE SET TO STATION 10,000.

BASE MAPPING SOURCE:

BASE MAPPING FROM FCD CONTRACT NUMBER FCD 03-49

MAPPING BASED ON NORTH AMERICAN VERTICAL DATUM 1988.

Cross Section ID	HEC-RAS Cross Section Location (mi)	Maximum Channel Depth (ft)	Maximum Flow (cfs)	Time To Peak (hr)	Average Cross Section Velocity (ft/sec)	Channel Velocity (ft/sec)	Hydraulic Depth (ft)	Maximum Stage Elevation (ft)	Cross Section Reference
0	0.00	9.1	28292	0.0	4.45	5.97	2.45	1789.14	APACHE JUNCTION FRS
1	0.56	3.1	27065	0.2	3.19	4.77	1.61	1751.04	LOST DUTCHMAN BOULEVARD
2	1.37	2.5	26247	0.6	3.14	4.60	1.34	1702.54	SUPERSTITION BOULEVARD
3	2.15	4.7	25584	0.9	1.90	7.46	1.62	1662.68	APACHE TRAIL
4	3.21	5.0	24103	1.4	2.24	7.46	1.72	1618.97	BROADWAY ROAD
5	4.58	9.5	22455	2.1	1.82	5.83	1.64	1571.53	SOUTHERN AVENUE
6	4.76	20.2	17452	2.2	1.14	4.93	1.47	1562.02	SIGNAL BUTTE ROAD
7	6.01	9.6	19300	3.0	2.64	6.26	1.51	1515.61	CRISMON ROAD
8	7.01	23.6	18339	3.4	2.76	8.01	1.51	1483.60	ELLSWORTH ROAD
9	7.97	13.5	16171	4.0	2.17	5.96	2.66	1455.52	RED MOUNTAIN FREEWAY

N

GRAPHIC SCALE
1500 0 750 1500 3000
(IN FEET)

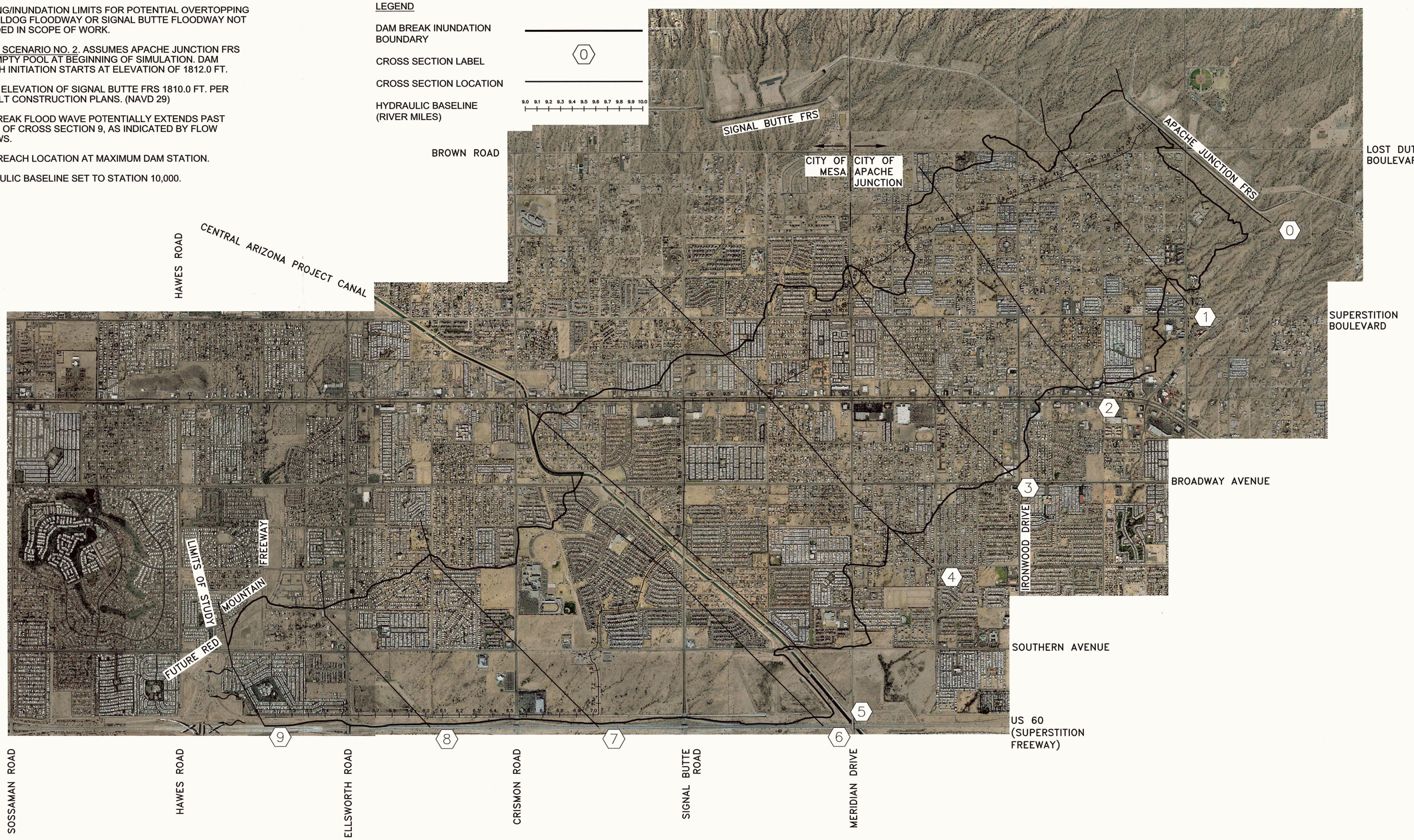
LEGEND

DAM BREAK INUNDATION BOUNDARY

CROSS SECTION LABEL

CROSS SECTION LOCATION

HYDRAULIC BASELINE (RIVER MILES)



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SCALE (V): NONE
DESIGNED BY: PAC
DRAWN BY: PAC
CHECKED BY: RAE
DATE: 10/21/05

EXHIBIT E-2. BUCKHORN MESA STRUCTURES DAMBREAK MODEL SCENARIO NO. 2 FULL POOL

APACHE JUNCTION FLOOD RETARDING STRUCTURE

PROJECT NO. 091725005

DRAWING NAME MODEL-AJ2

K:\WaterResources\091725005\CADD\Exhibits\MODEL-AJ2.dwg Oct 26, 2005 Pat.Crawford
XREFS: X725005TP AJ RMS-XS LOC X725005AE AJ RMS-XS LOC-FULL AJSTA X725005AE02 X725005AE AJ RMS-XS LOC-FULL AJSTA
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NOTES

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3. INFLOW DESIGN FLOOD = 6-HR PROBABLE MAXIMUM FLOOD. DEVELOPED IN PMP/PMF STUDY CONDUCTED UNDER FCD CONTRACT 200XXXX.
4. THE STRUCTURAL INTEGRITY AND HYDRAULIC INTEGRITY OF ANY LEVEES, BERMS, CANAL EMBANKMENTS, DETENTION/RETENTION BASINS, OR FILL TO WITHSTAND EROSION (OR FAILURE) DURING FLOODING WAS NOT EVALUATED AS PART OF THIS STUDY.
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BASE MAPPING SOURCE:

BASE MAPPING FROM FCD CONTRACT NUMBER FCD 03-49

MAPPING BASED ON NORTH AMERICAN VERTICAL DATUM 1988.

LEGEND

DAMBREAK INUNDATION BOUNDARY

CROSS SECTION LABEL

CROSS SECTION LOCATION

HYDRAULIC BASELINE (RIVER MILES)

9.0 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 10.0

Cross Section ID	HEC-RAS Cross Section Location (mi)	Maximum Channel Depth (ft)	Maximum Flow (cfs)	Time To Peak (hr)	Average Cross Section Velocity (ft/sec)	Channel Velocity (ft/sec)	Hydraulic Depth (ft)	Maximum Stage Elevation (ft)	Cross Section Reference
0	0.00	7.5	7605	0.0	2.95	3.66	1.36	1787.54	APACHE JUNCTION FRS
1	0.56	1.9	7274	0.3	2.45	2.79	1.22	1749.92	LOST DUTCHMAN BOULEVARD
2	1.37	1.3	7001	0.8	2.45	2.98	1.00	1701.29	SUPERSTITION BOULEVARD
3	2.15	3.3	6766	1.3	1.46	5.22	1.10	1661.29	APACHE TRAIL
4	3.21	3.3	5943	2.2	1.77	5.17	1.12	1617.32	BROADWAY ROAD
5	4.58	8.1	5239	3.2	2.85	3.85	0.27	1570.06	SOUTHERN AVENUE
6	4.76	17.9	4958	3.4	1.37	4.79	1.76	1559.86	SIGNAL BUTTE ROAD
7	6.01	8.4	4287	4.7	1.97	5.08	0.57	1514.44	CRISMON ROAD
8	7.01	22.1	3748	5.6	3.59	5.94	0.35	1482.09	ELLSWORTH ROAD
9	7.97	10.5	3562	6.3	4.33	7.00	1.76	1452.46	RED MOUNTAIN FREEWAY

N

GRAPHIC SCALE
1500 0 750 1500 3000
(IN FEET)

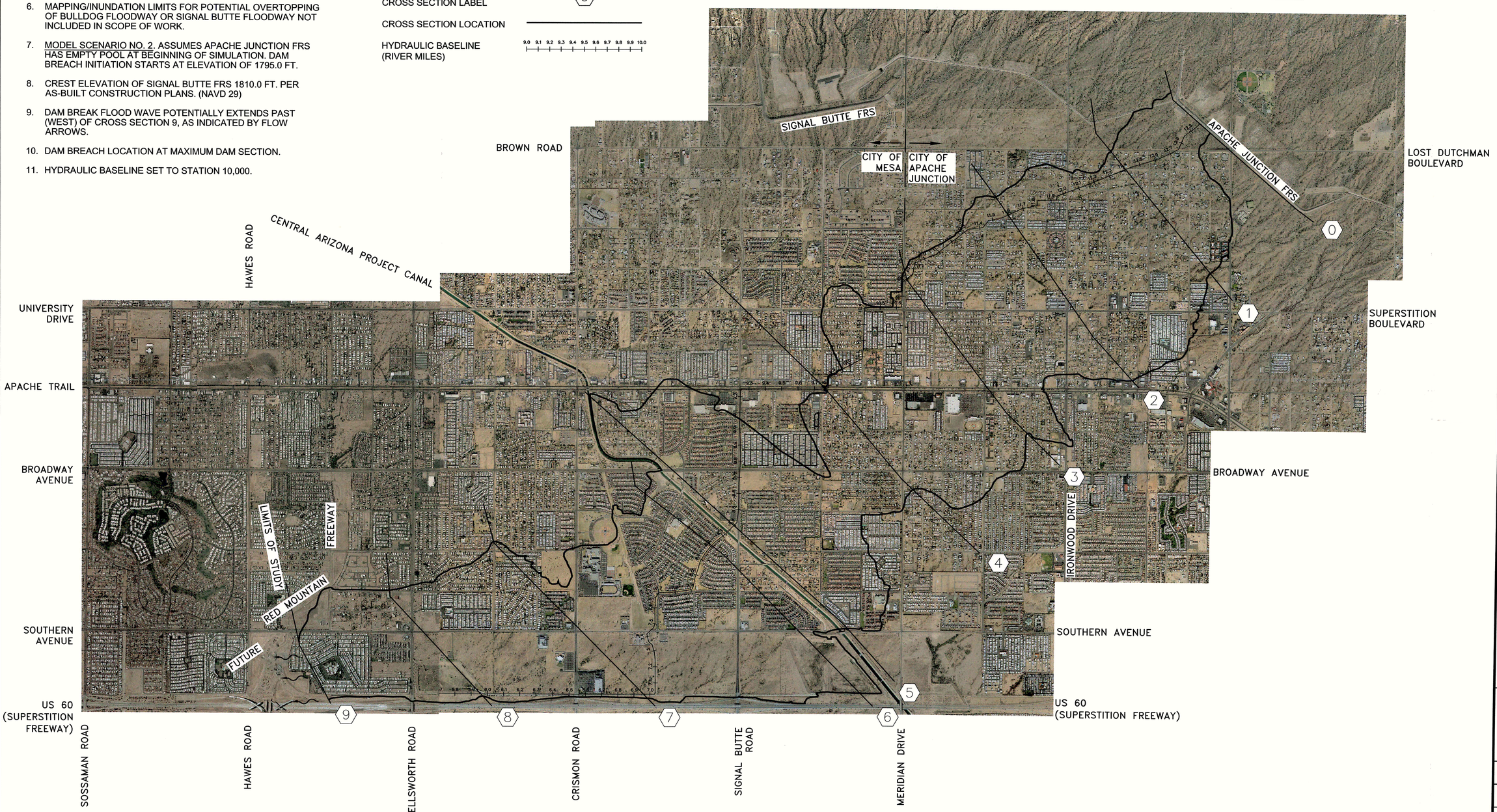

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EXHIBIT E-3. BUCKHORN MESA STRUCTURES
DAMBREAK MODEL SCENARIO NO. 3
SUNNY DAY
APACHE JUNCTION FLOOD RETARDING STRUCTURE

PROJECT NO. 091725005

DRAWING NAME MODEL-AJ3

K:\WaterResources\091725005\CADD\Exhibits\MODEL-AJ3.dwg Oct 26, 2005 Pat.Crawford
XREFS: X725005TP X725005AE02 X725005AE AJ RUS-XS LOC AJSTA
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NOTES

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2. MAPPED INUNDATION LIMITS AT CROSS SECTIONS CORRESPOND TO MAXIMUM STAGE ELEVATION.
3. INFLOW DESIGN FLOOD = 6-HR PROBABLE MAXIMUM FLOOD. DEVELOPED IN PMP/PMF STUDY CONDUCTED UNDER FCD CONTRACT 2003C062
4. THE STRUCTURAL INTEGRITY AND HYDRAULIC INTEGRITY OF ANY LEVEES, BERMS, CANAL EMBANKMENTS, DETENTION/RETENTION BASINS, OR FILL TO WITHSTAND EROSION (OR FAILURE) DURING FLOODING WAS NOT EVALUATED AS PART OF THIS STUDY.
5. THIS EXHIBIT SHOWS INUNDATION LIMITS FOR POTENTIAL PIPING FAILURE.
6. MAPPING/INUNDATION LIMITS FOR POTENTIAL OVERTOPPING OF BULLDOG FLOODWAY OR SIGNAL BUTTE FLOODWAY NOT INCLUDED IN SCOPE OF WORK.
7. MODEL SCENARIO NO. 1. ASSUMES SIGNAL BUTTE FRS HAS EMPTY POOL AT BEGINNING OF SIMULATION. DAM BREACH INITIATION STARTS AT ELEVATION OF 1721.0 FT. (NAVD88)
8. CREST ELEVATION OF SIGNAL BUTTE FRS 1723.0 FT. PER AS-BUILT CONSTRUCTION PLANS. (NGVD 29)
9. DAMB REAK FLOODING POTENTIALLY EXTENDS PAST (WEST) OF CROSS SECTION 8 AS INDICATED BY FLOW ARROWS.
10. DAM BREACH LOCATION AT MAXIMUM DAM SECTION.
11. HYDRAULIC BASELINE SET TO STATION 10,000.

BASE MAPPING SOURCE:

BASE MAPPING FROM FCD CONTRACT NUMBER FCD 03-49

MAPPING BASED ON NORTH AMERICAN VERTICAL DATUM 1988.

Cross Section ID	HEC-RAS Cross Section Location (mi)	Maximum Channel Depth (ft)	Maximum Flow (cfs)	Time To Peak (hr)	Average Cross Section Velocity (ft/sec)	Channel Velocity (ft/sec)	Hydraulic Depth (ft)	Maximum Stage Elevation (ft)	Cross Section Reference
0	0	9.4	62,289	0.0	6.15	9.97	2.98	1693.34	SIGNAL BUTTE FRS
1	0.18	9.2	59,990	0.2	4.65	7.69	3.35	1683.17	LOST DUTCHMAN BOULEVARD
2	1.37	5.4	51,544	0.4	2.48	5.69	3.21	1627.40	SUPERSTITION BOULEVARD
3	2.36	10.5	48,462	0.9	3.23	7.72	2.69	1576.52	APACHE TRAIL/CAP CANAL
4	2.74	10.1	47,396	1.0	2.22	6.27	2.04	1560.26	BROADWAY ROAD/CRISMON ROAD
5	3.74	7.3	45,016	1.5	2.66	5.83	1.84	1511.30	ELLSWORTH ROAD
6	4.65	27.1	43,626	1.8	2.96	4.32	2.06	1483.06	RED MOUNTAIN FREEWAY
7	5.64	16.7	41,294	2.2	3.13	7.81	2.53	1446.71	HAWES ROAD
8	6.36	13.0	38,187	2.6	2.69	8.73	3.84	1426.90	80TH STREET

N

GRAPHIC SCALE
1500 0 750 1500 3000
(IN FEET)

LEGEND

DAMBREAK INUNDATION BOUNDARY

CROSS SECTION LABEL (0)

CROSS SECTION LOCATION

HYDRAULIC BASELINE (RIVER MILES) 9.0 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 10.0

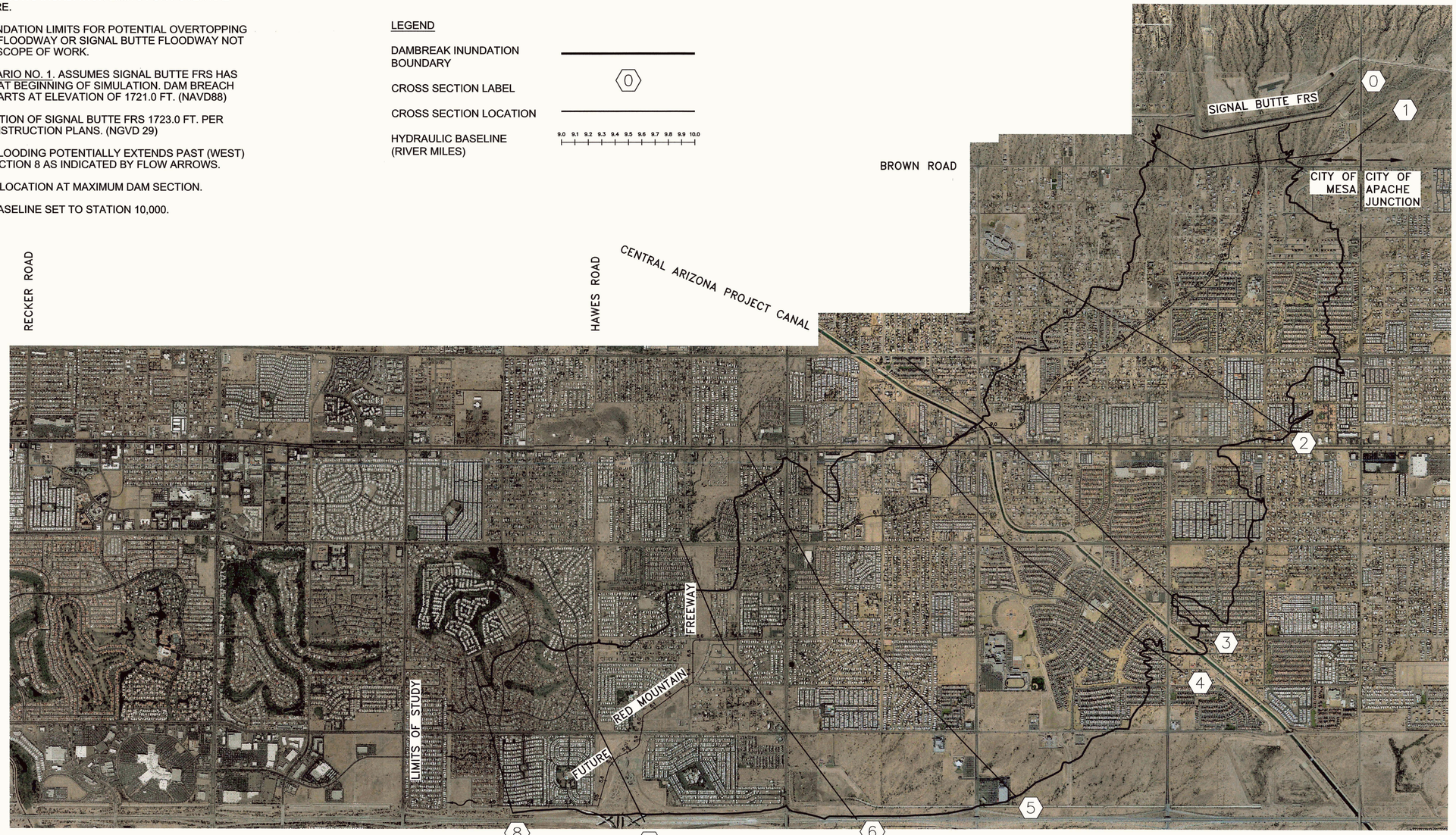

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EXHIBIT E-4. BUCKHORN MESA STRUCTURES DAMBREAK MODEL SCENARIO NO. 1 EMPTY POOL

SIGNAL BUTTE FLOOD RETARDING STRUCTURE

PROJECT NO. 091725005

DRAWING NAME MODEL-SB1

K:\WaterResources\091725005\CADD\Exhibits\MODEL-SB1.dwg Oct 26, 2005 Pat.Crawford
XREFS: X725005TP X725005AE02 X725005AE SB RMS-XS LOG SBSTR
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NOTES

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3. INFLOW DESIGN FLOOD = 6-HR PROBABLE MAXIMUM FLOOD. DEVELOPED IN PMP/PMF STUDY CONDUCTED UNDER FCD CONTRACT 2003C062.
4. THE STRUCTURAL INTEGRITY AND HYDRAULIC INTEGRITY OF ANY LEVEES, BERMS, CANAL EMBANKMENTS, DETENTION/RETENTION BASINS, OR FILL TO WITHSTAND EROSION (OR FAILURE) DURING FLOODING WAS NOT EVALUATED AS PART OF THIS STUDY.
5. THIS EXHIBIT SHOWS INUNDATION LIMITS FOR POTENTIAL PIPING FAILURE.
6. MAPPING/INUNDATION LIMITS FOR POTENTIAL OVERTOPPING OF BULLDOG FLOODWAY OR SIGNAL BUTTE FLOODWAY NOT INCLUDED IN SCOPE OF WORK.
7. MODEL SCENARIO NO. 2. ASSUMES SIGNAL BUTTE FRS HAS EMPTY POOL AT BEGINNING OF SIMULATION. DAM BREACH INITIATION STARTS AT ELEVATION OF 1725.0 FT. (NAVD88)
8. CREST ELEVATION OF SIGNAL BUTTE FRS 1723.0 FT. PER AS-BUILT CONSTRUCTION PLANS. (NGVD 29)
9. DAM BREAK FLOODING POTENTIALLY EXTENDS PAST (WEST) OF CROSS SECTION 8 AS INDICATED BY FLOW ARROWS.
10. DAM BREACH LOCATION AT MAXIMUM DAM SECTION.
11. HYDRAULIC BASELINE SET TO STATION 10,000.

BASE MAPPING SOURCE:

BASE MAPPING FROM FCD CONTRACT NUMBER FCD 03-49

MAPPING BASED ON NORTH AMERICAN VERTICAL DATUM 1988.

Cross Section ID	HEC-RAS Cross Section Location (mi)	Maximum Channel Depth (ft)	Maximum Flow (cfs)	Time To Peak (hr)	Average Cross Section Velocity (ft/sec)	Channel Velocity (ft/sec)	Hydraulic Depth (ft)	Maximum Stage Elevation (ft)	Cross Section Reference
0	0	9.4	62,272	0.0	6.15	9.97	2.97	1693.33	SIGNAL BUTTE FRS
1	0.18	9.2	60,027	0.1	4.65	7.69	3.35	1683.18	LOST DUTCHMAN BOULEVARD
2	1.37	5.4	51,578	0.4	2.48	5.69	3.21	1627.40	SUPERSTITION BOULEVARD
3	2.36	10.5	48,508	0.9	3.23	7.72	2.69	1576.52	APACHE TRAIL/CAP CANAL
4	2.74	10.1	47,451	1.0	2.23	6.27	2.04	1560.26	BROADWAY ROAD/CRISMON ROAD
5	3.74	7.3	45,075	1.5	2.66	5.84	1.84	1511.30	ELLSWORTH ROAD
6	4.65	27.1	43,679	1.8	2.96	4.32	2.07	1483.06	RED MOUNTAIN FREEWAY
7	5.64	16.7	41,308	2.2	3.13	7.81	2.54	1446.71	HAWES ROAD
8	6.36	13.0	38,200	2.6	2.69	8.73	3.84	1426.90	80TH STREET

N

GRAPHIC SCALE
1500 0 750 1500 3000
(IN FEET)

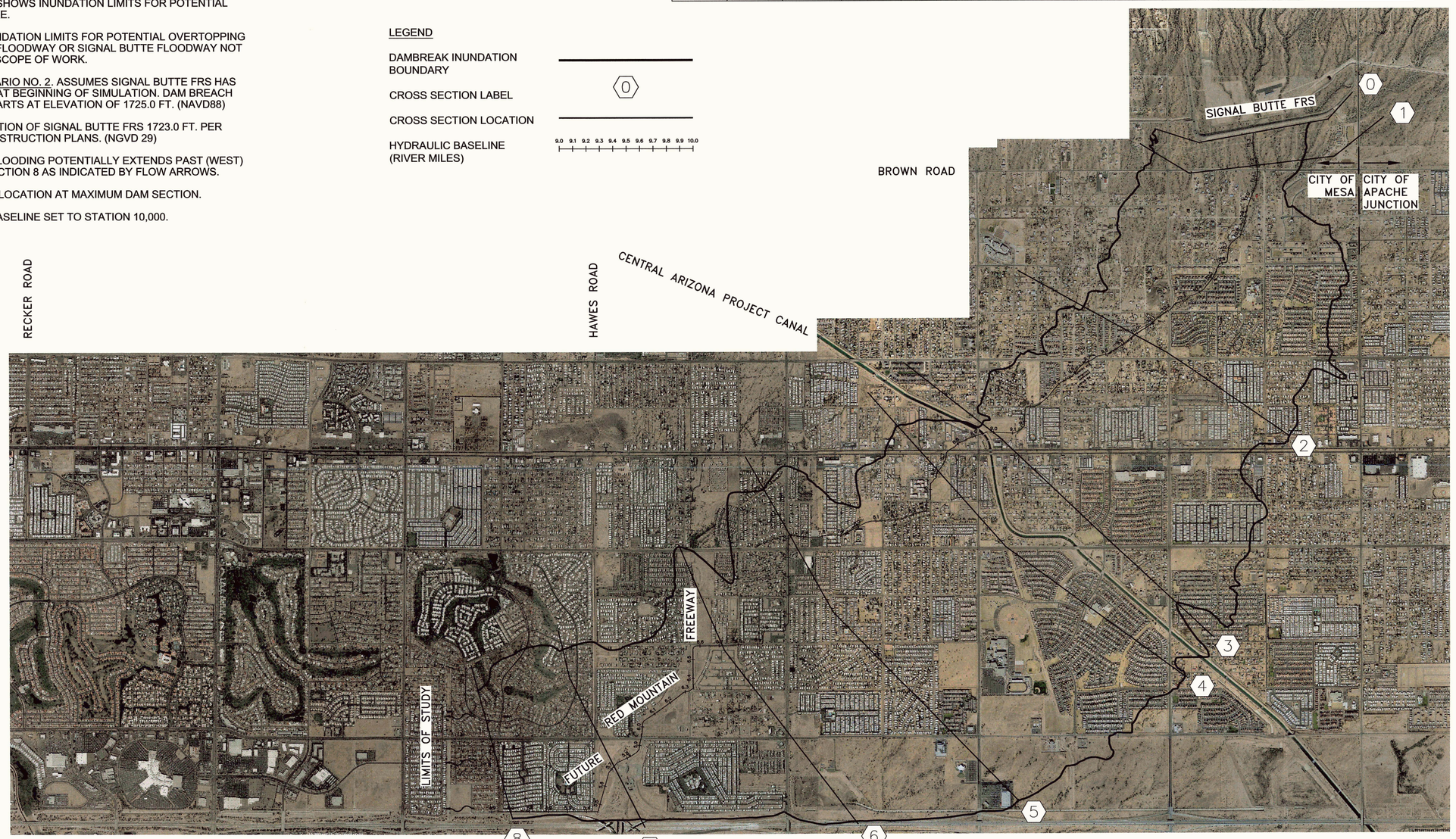
LEGEND

DAMBREAK INUNDATION BOUNDARY

CROSS SECTION LABEL (0)

CROSS SECTION LOCATION

HYDRAULIC BASELINE (RIVER MILES) 9.0 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 10.0



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CHECKED BY: RAE
DATE: 10/21/05

EXHIBIT E-5. BUCKHORN MESA STRUCTURES
DAMBREAK MODEL SCENARIO NO. 2
FULL POOL
SIGNAL BUTTE FLOOD RETARDING STRUCTURE

PROJECT NO. 091725005
DRAWING NAME MODEL-SB2
1 OF 1

K:\WaterResources\091725005\CADD\Exhibits\MODEL-SB2.dwg Oct 26, 2005 Pat.Crawford
XREFS: X725005TP X725005AE X725005AE SB RMS-XS LOC SBSTA
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NOTES

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2. MAPPED INUNDATION LIMITS AT CROSS SECTIONS CORRESPOND TO MAXIMUM STAGE ELEVATION.
3. INFLOW DESIGN FLOOD = 6-HR PROBABLE MAXIMUM FLOOD. DEVELOPED IN PMP/PMF STUDY CONDUCTED UNDER FCD CONTRACT 2003CO62.
4. THE STRUCTURAL INTEGRITY AND HYDRAULIC INTEGRITY OF ANY LEVEES, BERMS, CANAL EMBANKMENTS, DETENTION/RETENTION BASINS, OR FILL TO WITHSTAND EROSION (OR FAILURE) DURING FLOODING WAS NOT EVALUATED AS PART OF THIS STUDY.
5. THIS EXHIBIT SHOWS INUNDATION LIMITS FOR POTENTIAL PIPING FAILURE.
6. MAPPING/INUNDATION LIMITS FOR POTENTIAL OVERTOPPING OF BULLDOG FLOODWAY OR SIGNAL BUTTE FLOODWAY NOT INCLUDED IN SCOPE OF WORK.
7. MODEL SCENARIO NO. 3. ASSUMES SIGNAL BUTTE FRS HAS EMPTY POOL AT BEGINNING OF SIMULATION. DAM BREACH INITIATION STARTS AT ELEVATION OF 1714.0 FT. (NAVD88)
8. CREST ELEVATION OF SIGNAL BUTTE FRS 1723.0 FT. PER AS-BUILT CONSTRUCTION PLANS. (NGVD 29).
9. DAM BREAK FLOODING POTENTIALLY EXTENDS PAST (WEST) OF CROSS SECTION 8 AS INDICATED BY FLOW ARROWS.
10. DAM BREACH LOCATION AT MAXIMUM DAM SECTION.
11. HYDRAULIC BASELINE SET TO STATION 10,000.

BASE MAPPING SOURCE:

BASE MAPPING FROM FCD CONTRACT NUMBER FCD 03-49

MAPPING BASED ON NORTH AMERICAN VERTICAL DATUM 1988.

Cross Section ID	HEC-RAS Cross Section Location (mi)	Maximum Channel Depth (ft)	Maximum Flow (cfs)	Time To Peak (hr)	Average Cross Section Velocity (ft/sec)	Channel Velocity (ft/sec)	Hydraulic Depth (ft)	Maximum Stage Elevation (ft)	Cross Section Reference
0	0	8.0	28,448	0.0	5.2	7.9	2.45	1691.96	SIGNAL BUTTE FRS
1	0.18	7.6	27,606	0.1	3.84	6.19	2.44	1681.62	LOST DUTCHMAN BOULEVARD
2	1.37	4.1	25,766	0.5	2.04	4.2	2.09	1626.09	SUPERSTITION BOULEVARD
3	2.36	9.3	24,268	1.1	2.59	5.71	2.3	1575.34	APACHE TRAIL/CAP CANAL
4	2.74	9.1	23,768	1.2	1.91	5.1	1.55	1599.26	BROADWAY ROAD/CRISMON ROAD
5	3.74	6.5	22,095	1.8	2.28	4.96	1.2	1510.46	ELLSWORTH ROAD
6	4.65	26.1	21,427	2.2	2.58	3.27	1.25	1482.12	RED MOUNTAIN FREEWAY
7	5.64	15.7	20,267	2.7	2.59	7.37	1.61	1445.64	HAWES ROAD
8	6.36	11.0	18,259	3.1	2.43	7.51	2.26	1425.04	80TH STREET

N

GRAPHIC SCALE

1500 0 750 1500 3000

(IN FEET)

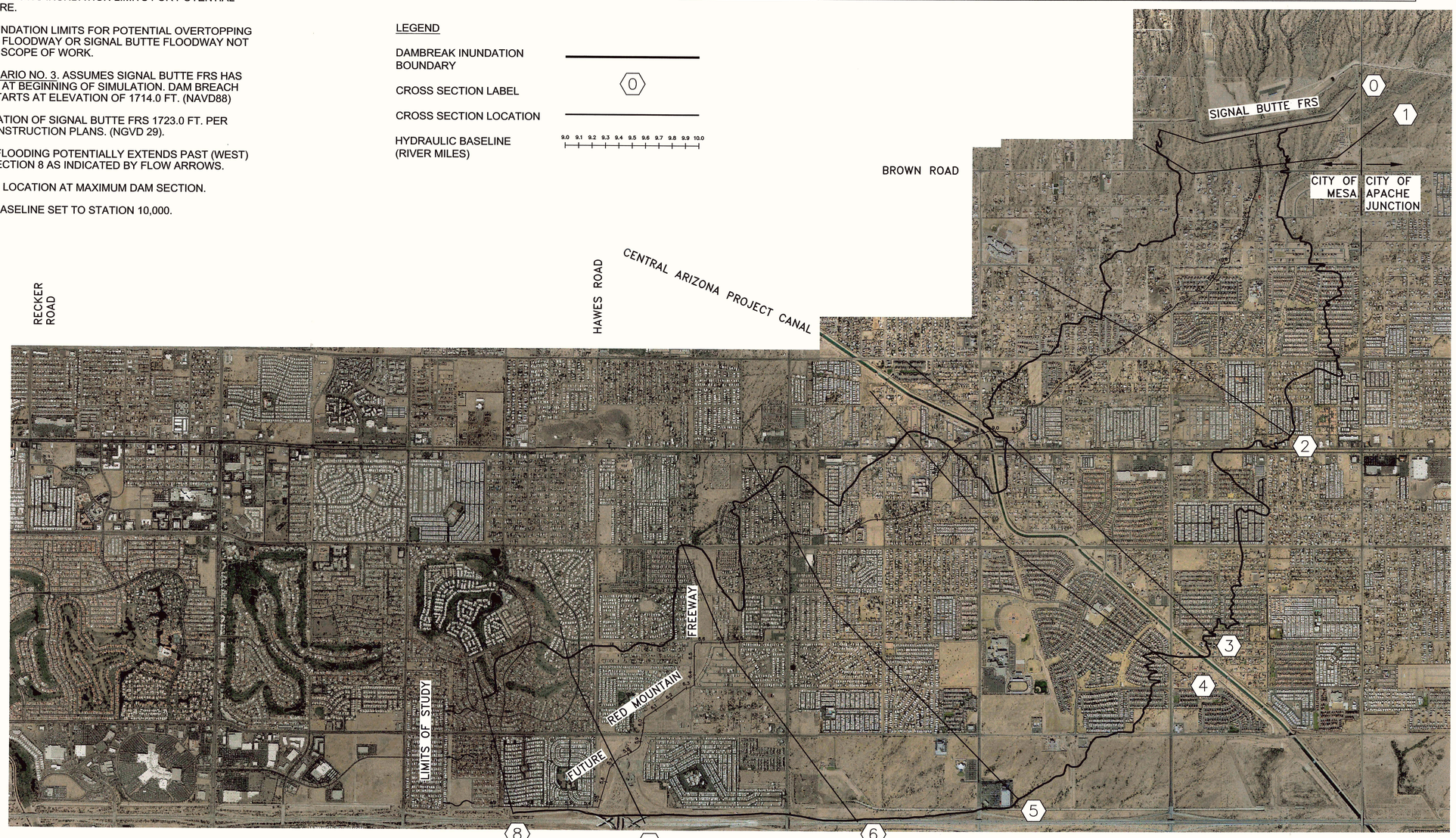
LEGEND

DAMBREAK INUNDATION BOUNDARY

CROSS SECTION LABEL (0)

CROSS SECTION LOCATION

HYDRAULIC BASELINE (RIVER MILES) 9.0 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 10.0



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DRAWN BY: PAC
CHECKED BY: RAE

DATE: 10/21/05

EXHIBIT E-6. BUCKHORN MESA STRUCTURES
DAMBREAK MODEL SCENARIO NO. 3
SUNNY DAY
SIGNAL BUTTE FLOOD RETARDING STRUCTURE

PROJECT NO. 091725005

DRAWING NAME MODEL-SB3

1 OF 1

K:\WaterResources\091725005\CADD\Exhibits\MODEL-SB3.dwg Oct 26, 2005 Pat.Crawford
XREFS: XTOPO01 XTOPO02 XTOPO03 XTOPO04 XTOPO05 XTOPO06 XTOPO07 XTOPO08 XTOPO09 XTOPO10
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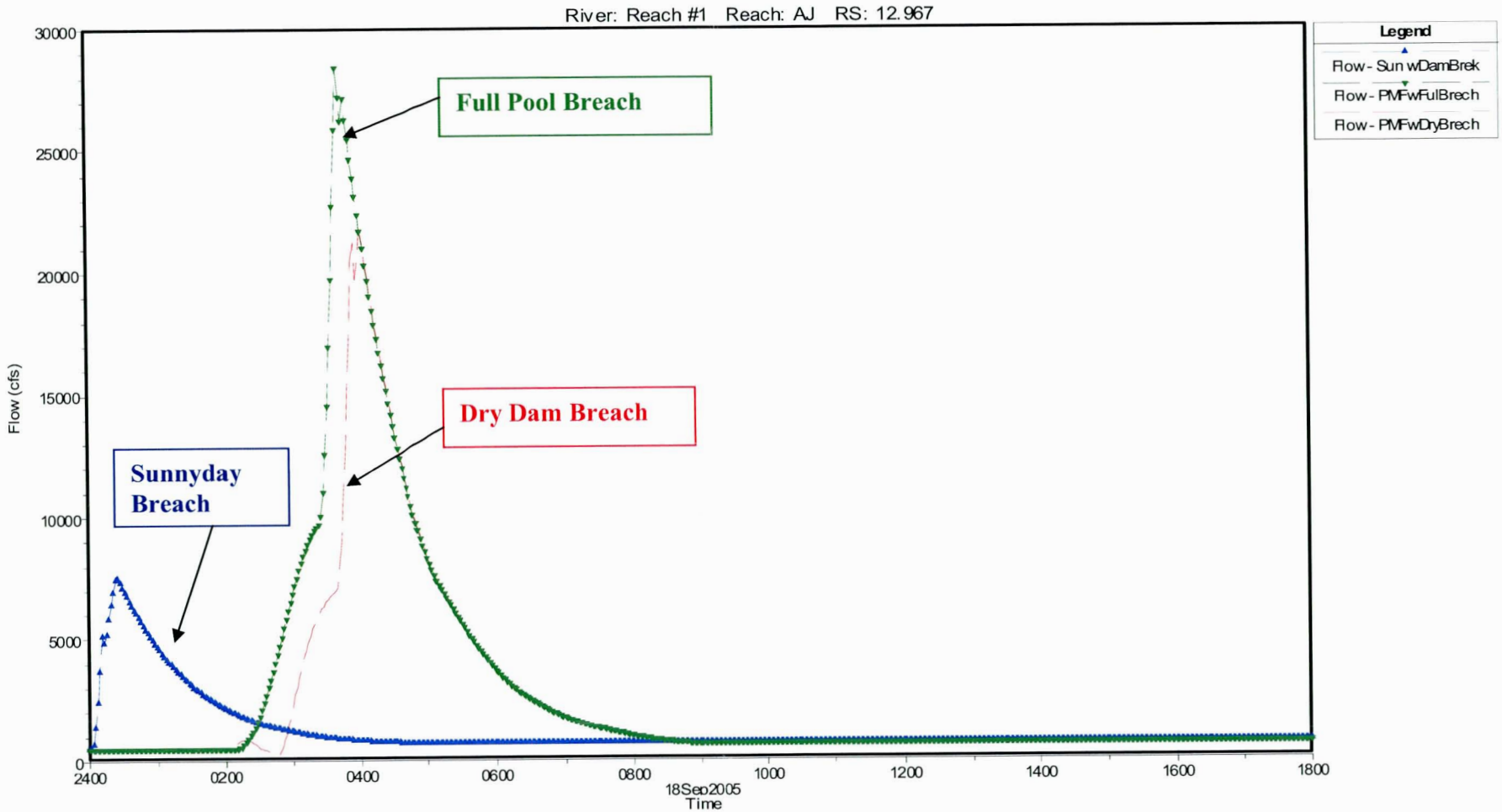

Figure 2. Breach Hydrographs At First Downstream Cross Section (12.976) From Apache Junction FRS (Breach For All Three Scenarios).

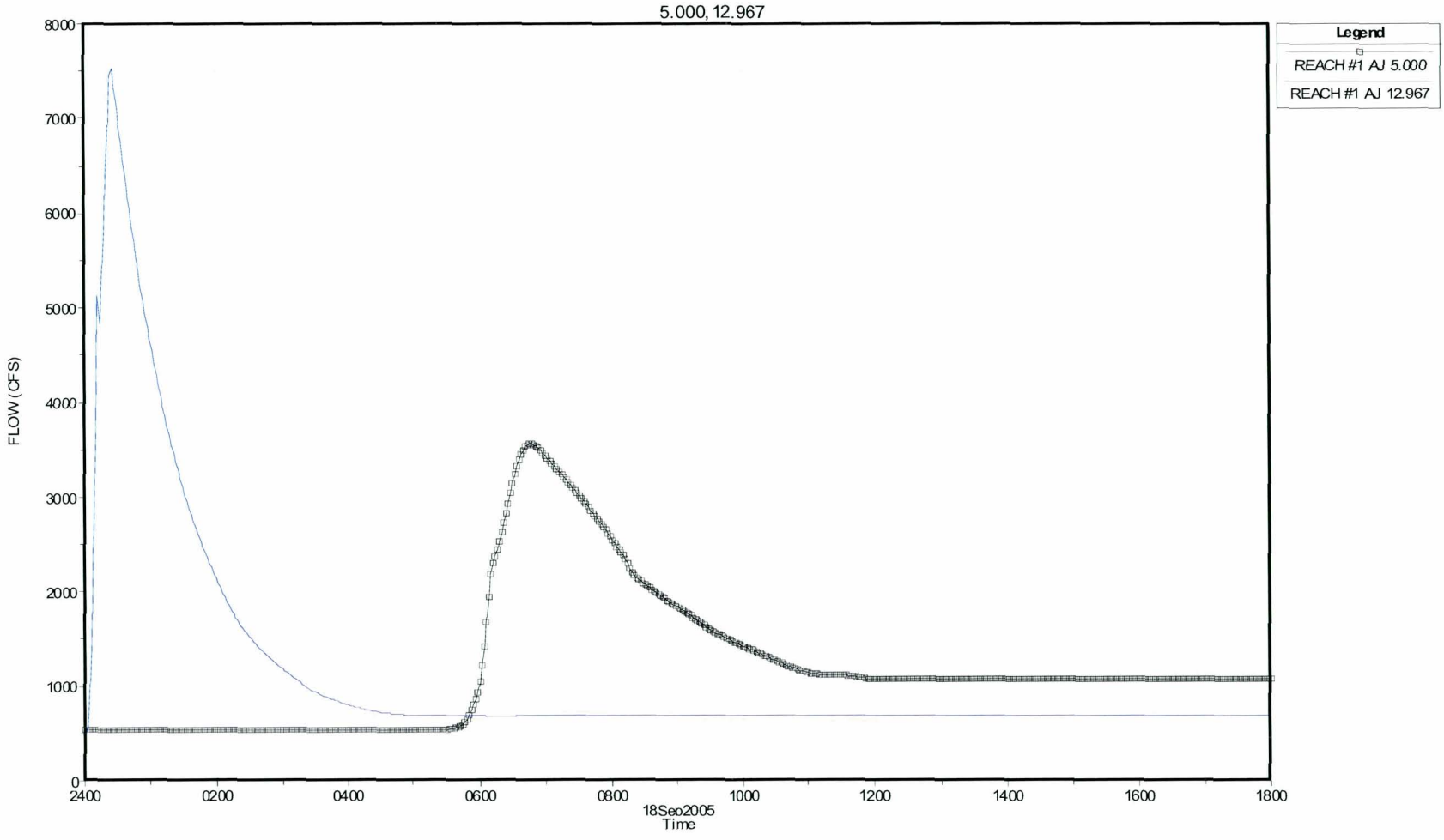

Figure 3. Flow Hydrographs At First Downstream Cross Section (12.967) From Apache Junction FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Sunnyday). Travel Time For Floodwave Peak Is Approximately 6.3 Hours.

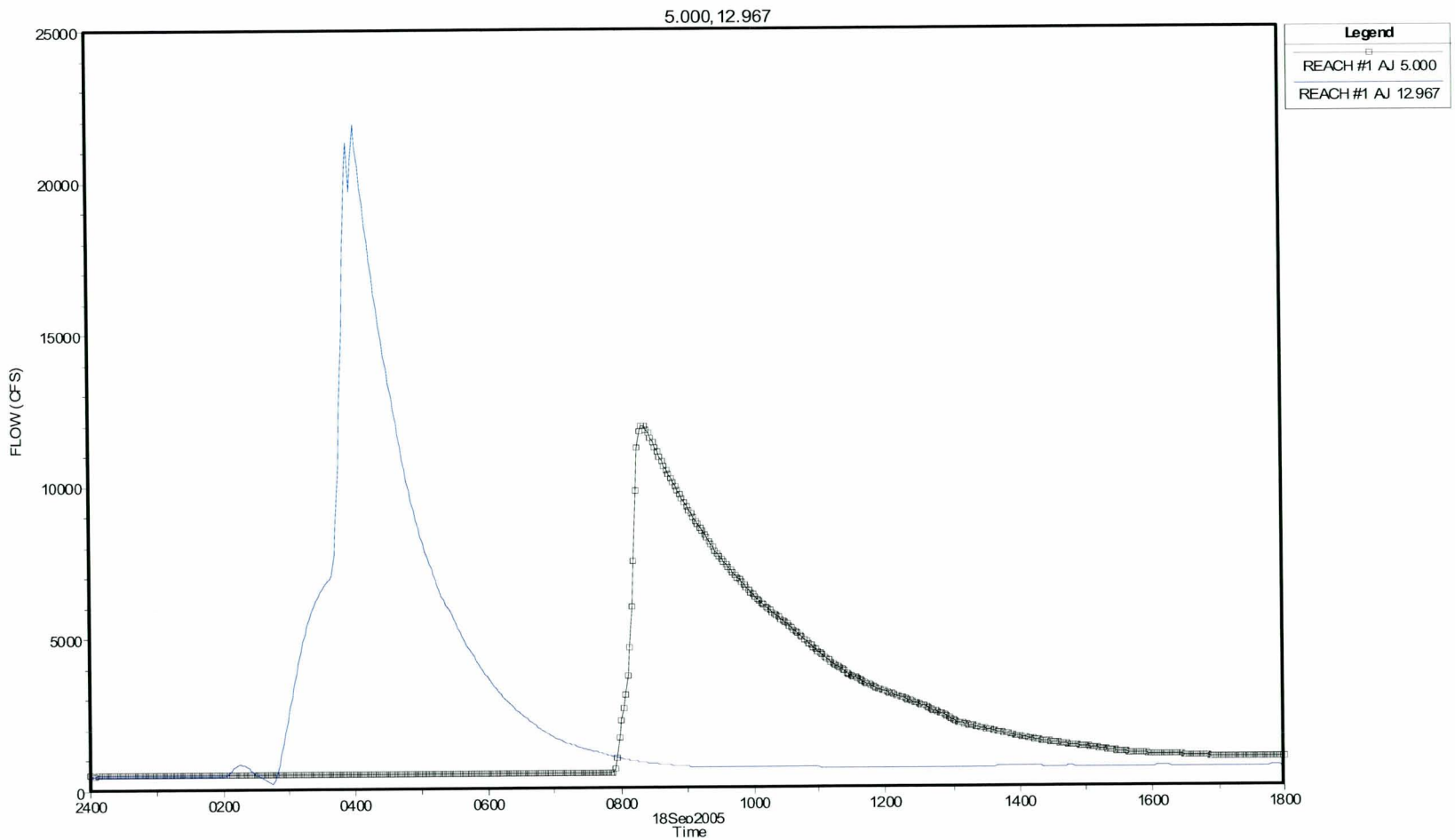

Figure 4. Flow Hydrographs At First Downstream Cross Section (12.967) From Apache Junction FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Empty Pool). Travel Time For Floodwave Peak Is Approximately 4.3 Hours.

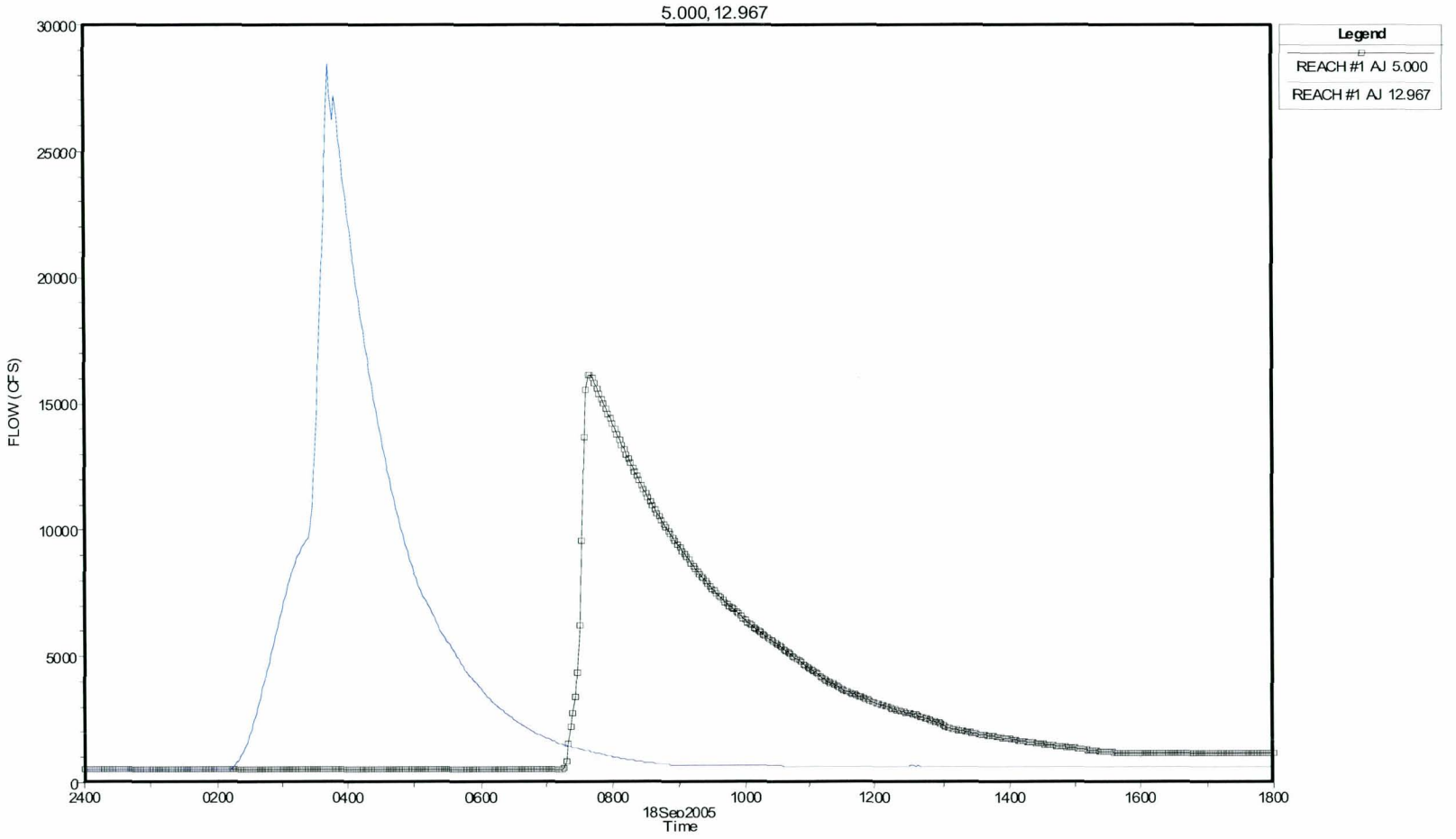

Figure 5. Flow Hydrographs At First Downstream Cross Section (12.967) From Apache Junction FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Full Pool). Travel Time For Floodwave Peak Is Approximately 3.9 Hours.

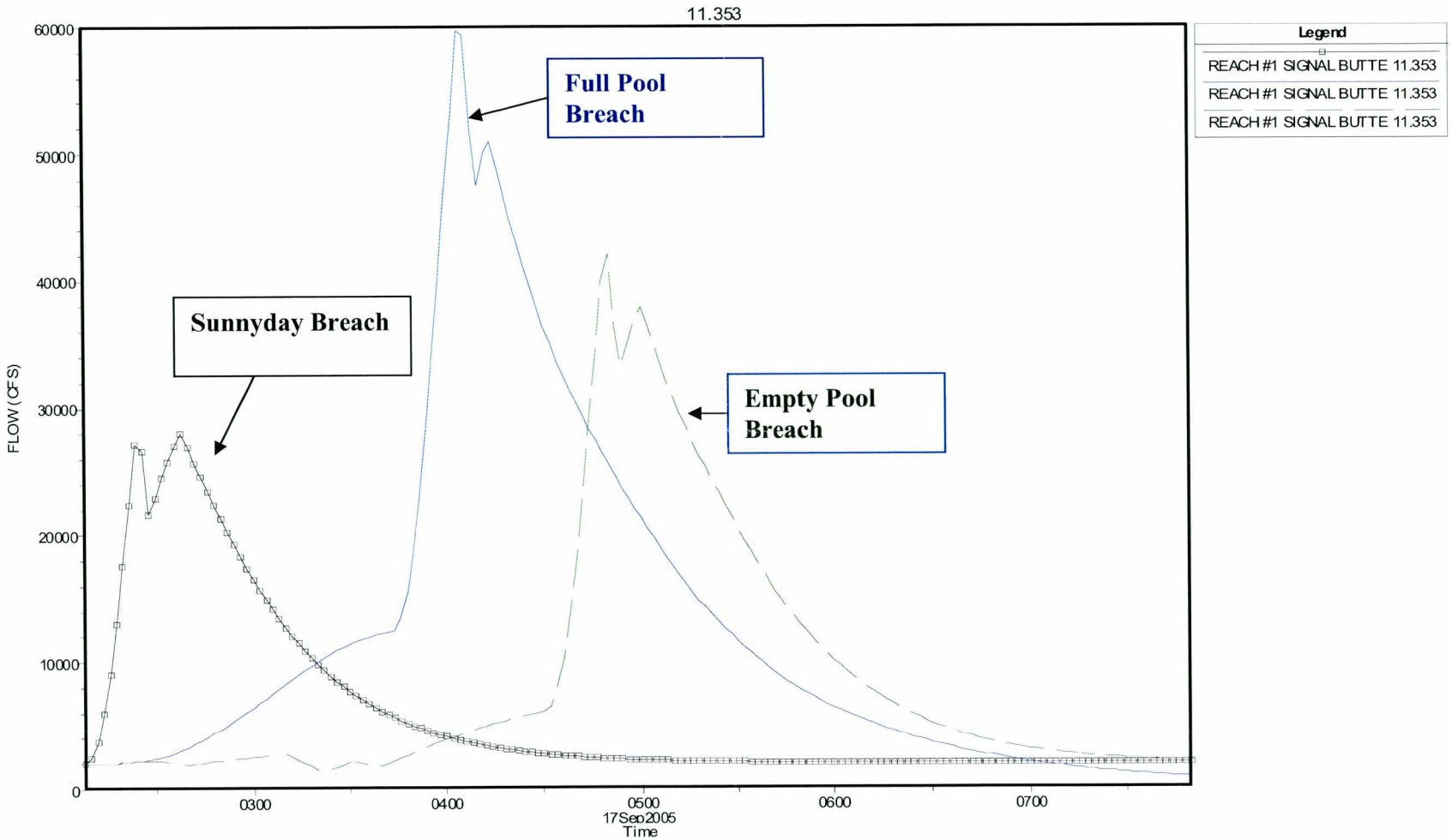

Figure 6. Breach Hydrographs At First Downstream Cross Section (11.353) From Signal Butte FRS (Breach For All Three Scenarios).

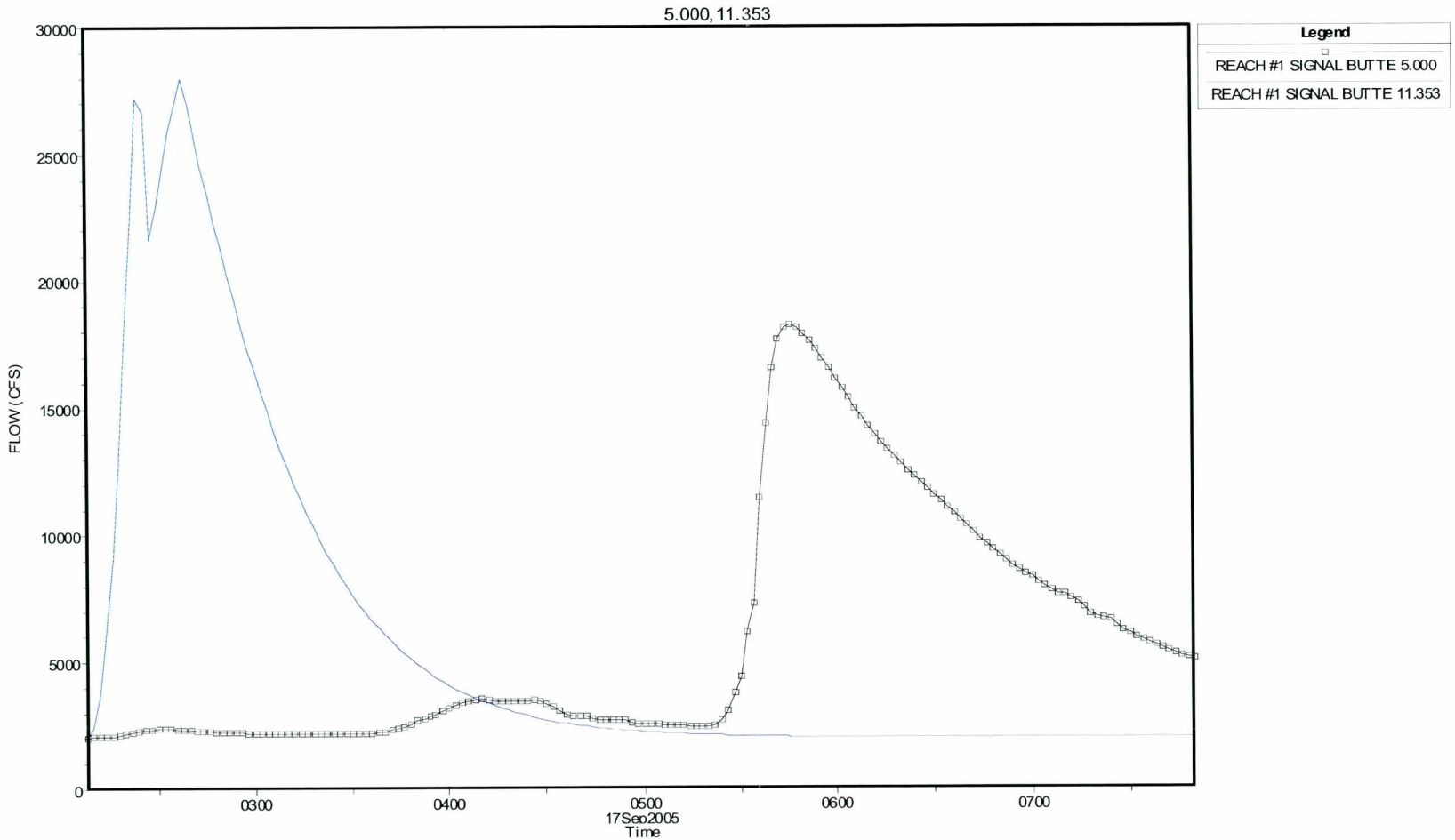

Figure 7. Flow Hydrographs At First Downstream Cross Section (11.353) From Signal Butte FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Sunnyday). Travel Time For Floodwave Peak Is Approximately 3.1 Hours.

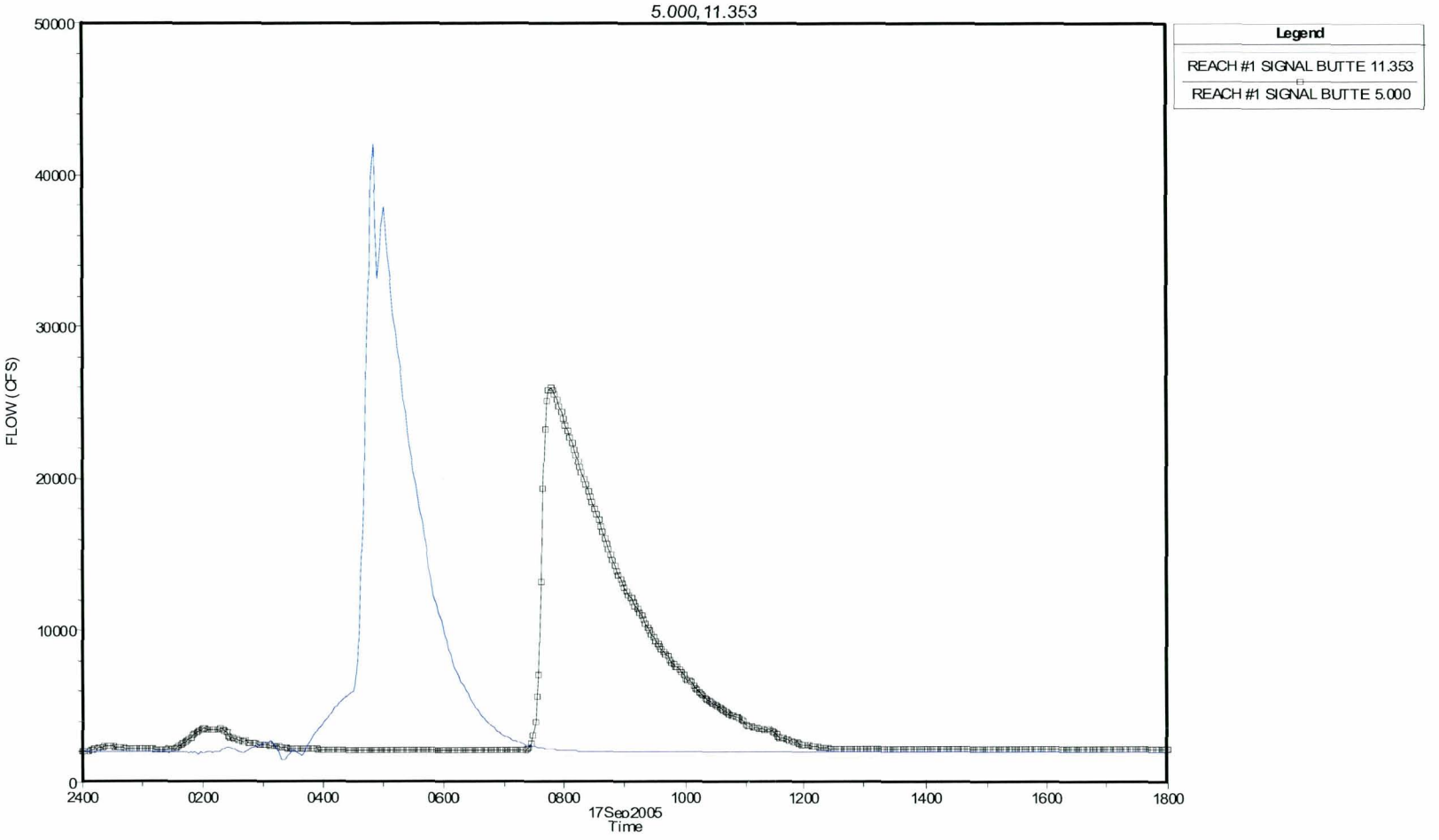

Figure 8. Flow Hydrographs At First Downstream Cross Section (11.353) From Signal Butte FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Empty Pool). Travel Time For Floodwave Peak Is Approximately 3.0 Hours.

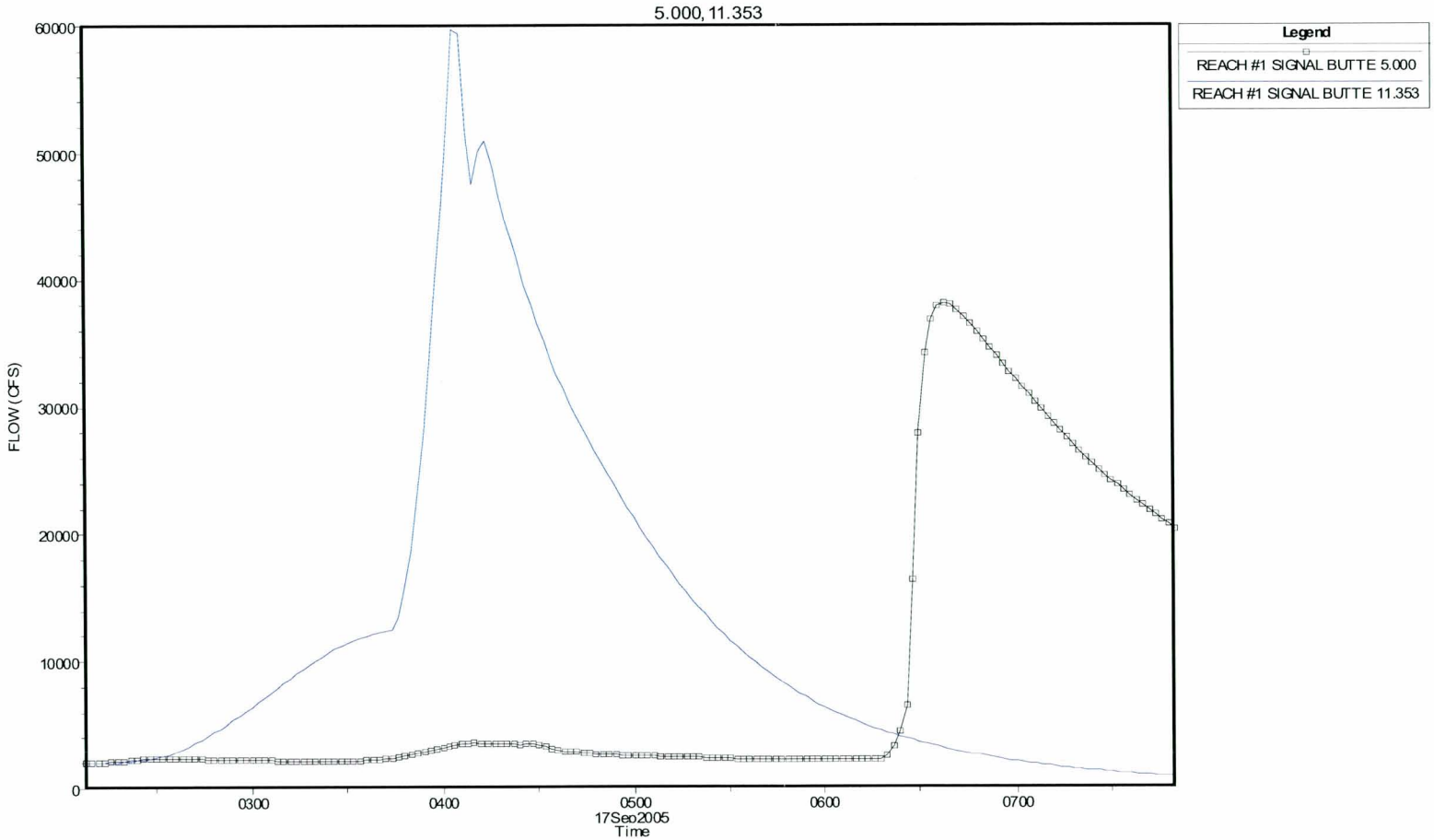

Figure 9. Flow Hydrographs At First Downstream Cross Section (11.353) From Signal Butte FRS And Last Cross Section (5.000) In Downstream Inundation Reach (Breach For Full Pool). Travel Time For Floodwave Peak Is Approximately 2.6 Hours.

Joe Rumann - FCDX

From: Michael Greenslade - FCDX
Sent: Wednesday, November 09, 2005 9:18 AM
To: 'Bob.Eichinger@kimley-horn.com'
Cc: 'Laurie T. Miller'; Joe Rumann - FCDX
Subject: RE: Datum Conversions for AJ and SB FRS - PMP review

Bob,

I understand that you and Joe have scheduled a meeting for November 16th to discuss the dambreak study report for Apache Junction FRs and Signal Butte FRS. Since I cannot attend that meeting I wanted to provide you with my comments as follows prior to the meeting.

- The correct PCN for this project is 300.01.26. The one you are using is for McMicken FRZR. For future reference, the PCN for a specific work assignment is shown on the Notice to Proceed.
- Table 1 provides physical design characteristics using the NGVD29 datum. This should be converted to the NAVD88 datum consistent with the rest of the report so that a comparison with other data presented such as that provided in Tables 3 & 4 can be made without applying the conversion.
- On Table 2 in the Land Use Type column both "Medium Density Residential" and "High Density Residential" include a reference to "MobilHomes". Is this correct?
- On Page 8 of 31 you state that the NGVD29 to NAVD88 datum conversion (+2.15') used was taken from the Spook Hill ADMP. You and I had previously corresponded (see below) on this and I shared that we had established "published" conversions for each of the structures and provided that information which is again attached. Use the published conversions. For Apache Junction use +2.014' and for Signal Butte use +2.016.
- For the Full Pool Scenario is it possible to identify what frequency of storm a full pool is associated with based on the new H&H?
- Table 5 please identify the datum used.
- On all of the drawings in Appendix B & C I suggest you include a note indicating why there is a "Limits of Study" line. In Section 10.3 of the report you indicate that this is due to the proposed Red Mountain Freeway. Does this apply to all the drawings?

Looks like we are getting close to a final product and we may be setting a new standard for this type of study. Keep up the good work.

Thanks

Mike G.

From: Bob.Eichinger@kimley-horn.com [mailto:Bob.Eichinger@kimley-horn.com]
Sent: Monday, August 29, 2005 11:35 AM
To: Michael Greenslade - FCDX
Subject: RE: Datum Conversions for AJ and SB FRS - PMP review

Mike
thanks, muchas gracias
Bob

Bob Eichinger, P.E., CFM
Kimley-Horn and Associates, Inc.
7878 N. 16th Street, Suite 300
Phoenix, Arizona 85020

Work (602) 944-5500
Direct (602) 906-1182
Cell (602) 828-7409
Fax (602) 906-1131
bob.eichinger@kimley-horn.com

From: Michael Greenslade - FCDX [mailto:mdg@mail.maricopa.gov]
Sent: Monday, August 29, 2005 11:18 AM
To: Eichinger, Bob
Cc: John Stock - FCDX
Subject: RE: Datum Conversions for AJ and SB FRS - PMP review

Bob,

My understanding is that all mapping conducted by the District utilizes the NAVD88 datum. If you have any issues or questions related to the survey data provided by the District, please do not hesitate to contact the District's Surveyor, John Stock, at 602-506-5460.

As for the conversion from 29 to 88 datum, we have established "published" conversions for each of the structures which are attached.

Michael D. Greenslade, P.E.
Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009

Phone: (602) 506-5426
Fax: (602) 506-8561
E-mail: mdg@mail.maricopa.gov

From: Bob.Eichinger@kimley-horn.com [mailto:Bob.Eichinger@kimley-horn.com]
Sent: Monday, August 29, 2005 9:30 AM
To: Michael Greenslade - FCDX
Cc: miller@LTMengineering.com
Subject: Datum Conversions for AJ and SB FRS - PMP review

Hi Mike

I wanted to confirm that the mapping we received for the Apache Junction FRS and Signal Butte FRS was flown in NAVD88 datum. The as-builts are NGVD29 datum. I have been checking my references for a conversion from 29 to 88 at each of these structures. Can you get the conversion?

Any update on the review of the PMP analysis?

Bob

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